# The National Atlas as a Metaphor for Improved Use of a National Geospatial Data Infrastructure

Trias Aditya

International Institute for Geo-information Science and Earth Observation,
Enschede, The Netherlands

ITC dissertation number 146
ITC, P.O. Box 6, 7500 AA Enschede, The Netherlands

ISBN 978-90-6164-261-9
Copyright © 2007 Trias Aditya

The National Atlas as a Metaphor for Improved Use of
a National Geospatial Data Infrastructure

De nationale atlas als een metafoor voor beter gebruik van
een nationale geo data infrastructuur
(met een samenvatting in het Nederlands)

Atlas Nasional sebagai sebuah Metafora untuk Meningkatan Pendayagunaan
Infrastruktur Data Geospasial Nasional
(dengan ringkasan dalam Bahasa Indonesia)

Proefschrift
ter verkrijging van de graad van doctor aan de Universiteit Utrecht op gezag van de
rector magnificus, prof.dr. W.H. Gispen, ingevolge het besluit van het college voor
promoties in het openbaar te verdedigen op dinsdag 26 juni 2007 des ochtends
te 10.30 uur

door

Trias Aditya Kurniawan Muhammad

geboren op 22 April 1975
te Yogyakarta, Indonesia

Promotoren: prof. dr. M.J. Kraak
prof. dr. F.J. Ormeling

This thesis was (partly) accomplished with financial support from the International Institute for Geo-Information Science and Earth Observation (ITC) and Utrecht University

Leden promotie commissie:

prof. dr. Lorenz Hurni, Institute of Cartography, Swiss Federal Institute of Technology (ETH)
prof. dr. ir. Peter van Oosterom, GIS Technology, Delft University of Technology
prof. dr. ir. Arnold Bregt, Centre for Geo-Information, Wageningen University
prof. dr. ir. Alfred Stein, Department of Earth Observation System, ITC
dr. Stan Geertman, Faculty of GeoSciences, Utrecht University

# Summary

This study focuses on the development of a web national atlas as an alternative means to geoportals, when accessing a Geospatial Data Infrastructure (GDI). The development of the atlas metaphor was undertaken throughout the problem space, design space, and evaluation space by combining techniques in Human-Computer Interaction and Geovisualization. During the development of the atlas metaphor, in the problem space, design space, and evaluation space, potential users were involved and scenarios were employed in order to guide and validate the design decisions.

***The problem space***: Activities of geoportals' reviews and contextual inquiries into the use of the current Dutch clearinghouse were undertaken in order to develop an understanding of the usability issues in geoportals. From these activities, it was apparent that interaction methods and information presented in many geoportals (to help user review and make sense of the search results) are far from optimal. The virtue of maps and graphics in order to stimulate visual thinking and to provide effective communication before and after "a search" in current geoportals have not yet been considered essential. When thinking of a solution to the usability issues associated with the use of national geoportals or clearinghouses, the recognizable concept of a national atlas is recalled. The decision to select the national atlas as the source of metaphor is based on the similarity of the functional definition of geoportals or clearinghouses and national atlases as search and access tools. Thus, in order to generate design ideas on how the national atlas should be developed to overcome the current usability issues of geoportals, this study adapted the prospective use of the atlas schemata. The prospective use of the atlas schemata includes the prominent role of maps in the atlas and the organizational approach of the atlas. Therefore, as a result of the adaptation of the national atlas schemata, operational functionalities related to searching and browsing information seeking behaviour to help users locating information using the national atlas were envisioned and framed into a rapid prototype.

***The design space***: The specifications of functions generated from the problem space were transformed into a working prototype of the atlas interface metaphor for improved use and accessibility of the GDI, called ***Aim4GDI.*** The Aim4GDI applied the atlas information structure. This structure was built as the basis for implementing the realization of an adaptation of the atlas schemata and designed to organize thematic maps, images, graphics and information resources related to the GDI including metadata summaries. Metadata summaries are aggregated metadata of geospatial resources in the GDI like offline data, Web Map Services (WMS), Web Feature Services (WFS), and other online information resources such as geocoded news. The application framework of the prototype combines the metadata and query language for the Semantic Web with cartographic design templates in aggregating, managing, and visualizing metadata summaries. The Aim4GDI enables users to search and browse geospatial resources through developed visual methods. The table view, thumbnail view, bull's-eye view, and Parallel Coordinate Plots (PCP) view) are as the name suggests, visual methods that can help users indicate, compare, and associate the search results. Meanwhile, in order to help users browse and

make sense of the resources, the topic directory, map view, thumbnail view, PCP view, in-focus view, and the underlying navigation trails as well as several browsing links are offered. A map viewer is used to display thematic layers, WFS, metadata footprints, a map legend, and a metadata legend. This map viewer is essential to represent a synthesis of knowledge of physical and geographic elements that characterize a country as well as a medium to improve the user's understanding on the search or exploration context. In support of browsing interactions, the developed information structure is used as a narrative structure in order to provide users with an interactive storytelling presentation during their browsing session. Such narrative structure is developed in order to provide a trajectory trail enabling users to advance from exploration to other stages of research or problem solving (i.e., synthesis, analysis, and presentation) in an iterative fashion. Also, the trajectory enables users to organise the complexity of the problem solving processes, and to really make sense the geospatial resources in the GDI during their interactions with the Aim4GDI. To further demonstrate the usefulness of this approach, an extension of the atlas metaphor to support collaboration efforts using geospatial resources in the GDI was developed.

***The evaluation space***: The usefulness of the visual methods of the Aim4GDI to facilitate searching, browsing, and collaboration activities were assessed in a series of "use" tests. The results of the use assessments confirmed the usefulness of the developed visual methods to help users understand and make sense the geospatial resources, when looking for required geospatial data either by searching (except the use of bull's-eye and PCP view) or by browsing. The abilities of the prototype to indicate and compare geospatial data were slightly better than today's typical geoportal: GeoNetwork. In addition, the ability to sort results during the search results review, a simple feature that is not currently available in today's geoportals, was indeed considered very useful. Moving on from exploration stage of problem solving, the potential use of the atlas metaphor to assist collaborative analysis and collaborative synthesis was recognized as a possible and useful solution.

Based on the results of this study, the national atlas metaphor can be defined as intentional combinations of specially structured maps, text summaries and visual methods; including graphics and thumbnails organized within the atlas information structure aiming at representing a synthesis of knowledge of physical and geographic elements that characterize a country as well as a synthesis of accessible geospatial resources in that country. It can be concluded that for useful and effective discovery and integration of geospatial resources, a web-based national atlas metaphor can be helpful in providing an alternative means to understand and make use of geospatial resources via a GDI. This study was envisioning the use of the national atlas metaphor in the context of the national Dutch GDI. However, the results of this study are also applicable in order to help other countries advance the role of their national atlases in the world of Geospatial Data Infrastructures.

# Samenvatting

Dit onderzoek richt zich op de ontwikkeling van een nationale webatlas als toegangspoort voor een Geografische Data Infrastructuur (GDI), als alternatief voor een geoportaal. De ontwikkeling van de atlas metafoor werd aangepakt in de probleem-, ontwerp en evaluatieruimte, middels een combinatie van technieken uit de mens-computer-interactie en geovisualisatie. Potentiële gebruikers werden betrokken bij de ontwikkeling van de atlas metafoor en er werden scenario's gehanteerd als uitgangspunt en validatiemiddel voor de ontwerpbeslissingen.

***De probleemruimte:*** om begrip te kweken voor de bruikbaarheidaspecten van geoportalen werden bestaande geoportalen beoordeeld en werd contextueel onderzoek verricht naar het gebruik van het huidige Nederlandse clearinghouse. Uit deze activiteiten bleek dat de interactiemethoden en de informatie die gepresenteerd wordt om de gebruiker te helpen bij het beschouwen en begrijpen van de zoekresultaten in veel geoportalen verre van optimaal zijn. Ondanks hun positieve werking bij het stimuleren van visueel denken en voor een effectieve communicatie voor en na "een zoekopdracht" worden kaarten en grafiek kennelijk nog niet van wezenlijk belang geacht in de huidige geoportalen. Bij het beschouwen van mogelijke oplossingen voor de problemen bij het gebruik van nationale geoportalen of clearinghouses kwam het herkenbare concept van een nationale atlas naar voren. De beslissing om de metafoor van de nationale atlas te kiezen is gebaseerd op overeenkomsten tussen de functionele definities van geoportalen / clearinghouses en nationale atlassen als hulpmiddelen voor het zoeken en toegankelijk maken van geodata. Aldus werd bij het ontwikkelen van ontwerpideeën voor een nationale atlas interface in dit onderzoek gebruik gemaakt van atlas schemata om de huidige bruikbaarheidsproblemen van geoportalen te overwinnen. In deze schemata zijn inbegrepen de prominente rol van kaarten en de organisatorische opzet van een atlas. Bij de aanpassing van de nationale atlas schemata werden een aantal operationele functionaliteiten in beschouwing genomen en samengebracht in een snel prototype. Deze operationele functionaliteiten zijn gerelateerd aan het zoek- en 'browsing' gedrag van gebruikers die met behulp van de nationale atlas informatie willen vinden.

***De ontwerpruimte:*** de specificaties van de functies die voortkwamen uit de probleemruimte werden gebruikt voor het bouwen van een werkend prototype van de atlas interface metafoor voor beter gebruik en toegankelijkheid van de GDI, ***Aim4GDI*** genoemd. Via een aanpassing van de atlas schemata werd in Aim4GDI de atlas informatie structuur toegepast voor de organisatie van thematische kaarten, beelden, grafiek en informatiebronnen gerelateerd aan de GDI, inclusief samenvattingen van metadata. Dit zijn de metadata van de geografische hulpbronnen in de GDI, zoals offline data, Web Map Services (WMS), Web feature Services (WFS), en andere online informatiebronnen, zoals geogecodeerd nieuws. In het aggregeren, beheren en visualiseren van metadata samenvattingen combineert het prototype de metadata en querytaal voor het Semantische Web met cartografische ontwerpsjablonen. Aim4GDI stelt gebruikers in staat om via de ontwikkelde visuele methoden te zoeken en browsen in geografische bronnen. De visuele methoden 'table view', 'thumbnail view', 'bull's-eye view' en 'Parallel Coordinate Plots (PCP) view' kunnen gebruikers helpen bij het indiceren, vergelijken en

associëren van zoekresultaten. Om ze te helpen bij het browsen door en het wijs worden uit de bronnen worden de volgende middelen aangeboden aan de gebruikers: een onderwerpsregister en thematische kaart view, 'thumbnail view, 'PCP view', 'in-focus view' en de onderliggende navigatietrail, alsmede verschillende browsing links. Er wordt een kaartviewer gebruikt voor het weergeven van thematische lagen, WFS, metadata miniatuur, een kaartlegenda en een metadata legenda. Deze kaartviewer is van wezenlijk belang voor de weergave van een synthese van de kennis van de fysieke en geografische elementen die een land kenmerken en is bovendien een middel om het begrip van de gebruiker van de zoek en exploratie context te vergroten. Ter ondersteuning bij het browsen wordt aan de gebruikers een interactieve verhaallijn gepresenteerd. De structuur daarvan is gebaseerd op de ontwikkelde informatiestructuur. Een dergelijke narratieve structuur is ingebouwd om een pad te bieden die gebruikers in staat stelt om op een iteratieve manier voort te gaan van exploratie naar andere stadia van onderzoek of probleemoplossen (d.w.z. synthese, analyse en presentatie). Een trajectorie stelt gebruikers ook in staat om de complexiteit van het proces van het probleemoplossen te organiseren en om werkelijk wijs te worden uit de geografische bronnen in de GDI bij hun interacties met Aim4GDI. Om het nut van deze benadering verder te demonstreren werd ook een uitbreiding van de atlas metafoor ontwikkeld ter ondersteuning van samenwerk ingsinspanningen bij het gebruik van de geografische bronnen in de GDI.

***De evaluatieruimte***: de bruikbaarheid van de visuele methoden in Aim4GDI ter facilitering van het zoeken, browsen en samenwerken werd beoordeeld in een reeks "gebruiks"onderzoeken. De resultaten bevestigen het nut van de visuele methoden om gebruikers te helpen bij het wijs worden uit en het begrijpen van de geografische bronnen via 'browsing'. Als ze gericht zoeken naar gewenste geodata blijkt het gebruik van de 'bull's-eye view' en 'PCP view' niet effectief. Het vermogen van het prototype om geografische data te indiceren en te vergelijken bleek iets beter dan het typische geoportaal van vandaag: GeoNetwork. De mogelijkheid om te sorteren gedurende het beoordelen van de zoekresultaten, iets wat momenteel niet beschikbaar is in de huidige geoportalen, werd inderdaad als zeer bruikbaar beschouwd. Voortgaand vanuit de exploratiefase van het probleemoplossen werd geoordeeld dat het potentiële gebruik van de atlas metafoor ter ondersteuning van samenwerking bij analyse en synthese een nuttige oplossing is.

Op basis van de resultaten van dit onderzoek kan de nationale atlas metafoor worden gedefinieerd als een met een bepaald intentie bij elkaar gebrachte set kaarten, tekstsamenvattingen en visuele representaties, inclusief grafiek en miniatuuren, georganiseerd in een atlas informatie structuur en gericht op het weergeven van een synthese van kennis van fysieke en geografische elementen die een land kenmerken, alsmede een synthese van toegankelijke geografische hulpbronnen in dat land. De conclusie is dat voor het bruikbaar en effectief ontdekken en integreren van geografische bronnen een web nationale atlas metafoor behulpzaam kan zijn door het bieden van een alternatieve manier voor het begrijpen en gebruik maken van geografische bronnen via een GDI. In dit onderzoek werd uit gegaan van het gebruik van de nationale atlas metafoor in de context van de Nederlandse nationale GDI. De resultaten van dit onderzoek kunnen echter ook door andere landen worden gebruikt bij het bevorderen van de rol van hun nationale atlassen in de wereld van de Geografische Data Infrastructuren.

# Ringkasan

Penelitian ini mengkaji pembangunan atlas nasional berbasis internet sebagai alternatif dari geoportal dalam mengakses Infrastruktur Data Geospasial (IDG). Pembangunan atlas sebagai sebuah metafora dilakukan dalam ruang lingkup masalah, ruang lingkup desain, dan ruang lingkup evaluasi, melalui penggabungan teknik-teknik dalam bidang Interaksi Manusia-Komputer (IMK) dan Geovisualisasi dengan melibatkan pengguna potensial dan skenario penggunaan untuk mendapatkan hasil desain yang tepat dan terarah.

***Ruang lingkup masalah***: Kajian terhadap beberapa geoportal dan penyelidikan kontekstual pada penggunaan antarmuka 'clearinghouse' negeri Belanda dilakukan untuk memahami aspek-aspek efektivitas, efisiensi, dan kepuasan dalam menggunakan geoportal-geoportal yang ada. Dari kedua aktivitas tersebut, dapat disimpulkan bahwa metode-metode interaksi berikut informasi yang tersaji di banyak geoportal masih jauh dari optimal. Manfaat peta dan grafik dalam merangsang cara berpikir visual dan dalam mengkomunikasikan informasi secara efektif untuk menunjang aktivitas interaksi sebelum dan sesudah 'sebuah pencarian' pada semua geoportal yang telah ada, masih sangat terbatas. Dalam mencari solusi guna memperbaiki aspek kegunaan geoportal nasional, konsep atlas nasional didayagunakan dalam penelitian ini. Atlas nasional dipilih, karena konsep ini memiliki kemiripan fungsi dengan geoportal atau 'clearinghouse' sebagai alat pencari dan penyedia akses informasi dan data geospasial. Untuk menggali ide desain bagaimana atlas nasional harus dibangun, dilakukan adaptasi terhadap skema-skema atlas yang dianggap menguntungkan dalam membantu memecahkan masalah kegunaan dari geoportal-geoportal yang ada. Skema-skema atlas yang diadaptasi meliputi peran peta dan aspek organisasi data di dalam atlas. Hasil dari proses adaptasi skema-skema atlas nasional adalah fungsi-fungsi operasional untuk mendukung aktivitas penelusuran ("searching") dan penjelajahan ("browsing") yang diperlukan para pengguna untuk menemukan informasi melalui atlas nasional. Fungsi-fungsi tersebut selanjutnya diperinci dan diujicobakan pada sebuah prototipe cepat.

***Ruang lingkup desain***:Spesifikasi fungsi yang dihasilkan dalam ruang lingkup masalah tersebut di atas, selanjutnya diubah menjadi prototipe kerja sebuah metafora berupa antarmuka atlas untuk meningkatkan pendayagunaan dan akses ke IDG, disebut ***Aim4GDI***. Aim4GDI dibangun dengan dukungan struktur informasi atlas. Struktur informasi ini merupakan dasar aplikasi dalam mengadaptasi skema-skema atlas dan berfungsi untuk mengorganisir peta-peta tematik, citra-citra, grafik-grafik, dan berbagai sumber data dan informasi geospasial yang terkait dengan IDG . Dalam hal ini, sumber data dan informasi yang terkait dengan IDG dihubungkan dengan atlas nasional melalui ringkasan metadata. Ringkasan metadata merupakan kumpulan informasi singkat mengenai berbagai metadata tentang data geospasial yang ada di dalam IDG, meliputi data 'offline', *Web Map Services* (WMS), *Web Feature Services* (WFS), dan berbagai sumber informasi 'online' lainnya seperti misalnya ringkasan berita bereferensi spasial. Untuk keperluan perangkuman, pengelolaan, dan penyajian visual ringkasan metadata tersebut, pendekatan yang dipilih dalam membangun prototipe adalah penggabungan metadata dan bahasa kueri untuk teknologi *Semantic Web* dengan pola desain kartografi. Melalui prototipe ini, pengguna mampu menelusuri dan menjelajahi sumber data dan informasi geospasial dengan

bantuan beberapa metode visual yang tersedia. Tampilan tabel, tampilan miniatur citra, tampilan *bull's-eye* atau mata kerbau, dan tampilan plot koordinat paralel (PKP) adalah metode-metode visual yang khusus disediakan untuk membantu para pengguna mengindikasikan, membandingkan, dan menyinambungkan hasil carian. Sementara itu, tampilan peta, tampilan miniatur citra, tampilan PKP, tampilan 'dalam-fokus', lintasan navigasi, dan juga beberapa pranala pendukung penjelajahan, adalah metode-metode visual yang dikhususkan untuk membantu para pengguna menjelajah dan mengambil manfaat dari sumber-sumber data dan informasi geospasial yang tersedia. Tampilan peta dipergunakan untuk menyajikan lapis data tematik, WFS, tapak luasan metadata, legenda peta dan legenda metadata. Tampilan peta berperan penting untuk menyajikan sintesa pengetahuan mengenai elemen fisik dan geografis yang menjadi ciri sebuah negara dan sebagai media untuk menambah pemahaman pengguna pada saat menelusuri data. Struktur informasi yang dibangun juga difungsikan sebagai sebuah kerangka narasi yang mendasari penyajian informasi dengan metode bercerita secara interaktif untuk memudahkan interaksi pengguna pada saat menjelajahi atlas. Dengan kerangka narasi tersebut, kebutuhan pengguna untuk mendapatkan lintasan navigasi yang bermanfaat untuk menunjang interaksi mereka di dalam tahap-tahap penelitian dan pemecahan masalah (tahap eksplorasi, sintesa, analisa, dan penyajian) dapat difasilitasi. Lintasan navigasi ini juga ditujukan untuk memudahkan pengguna mengelola kerumitan selama proses pemecahan masalah dan pemanfaatan sumber data dan informasi geospasial dengan Aim4GDI. Untuk lebih mendayagunakan potensi metode yang telah dibangun tersebut, metafora atlas juga dilengkapi dengan fungsi-fungsi yang memungkinkan beberapa pengguna untuk berkolaborasi dalam memanfaatkan data dan informasi geospasial melalui IDG.

***Ruang lingkup evaluasi***: Penggunaan metode-metode visual yang ada pada Aim4GDI untuk menunjang aktivitas penelusuran, penjelajahan, dan kolaborasi telah diuji melalui berbagai macam test kegunaan. Hasil yang diperoleh menunjukkan bahwa metode-metode visual yang telah dibangun berhasil membantu para pengguna dalam menelusuri data geospasial (terkecuali tampilan mata kerbau dan PKP) dan dalam menjelajahi data dan informasi geospasial. Kemampuan prototipe dalam membantu pengguna mengindikasikan dan membandingkan hasil penelusuran teruji lebih baik sedikit dibandingkan dengan tipikal geoportal saat ini: GeoNetwork. Lebih dari itu, kemampuan dalam menyortir hasil penelusuran, suatu kemampuan sederhana yang tidak tersedia pada geoportal pada umumnya, terbukti sangat bermanfaat. Potensi pendayagunaan metafora atlas untuk berkolaborasi dalam melakukan sintesa dan analisa terbukti layak dan tampak menjanjikan.

Berdasarkan hasil-hasil yang diperoleh dari penelitian ini, metafora atlas nasional dapat didefinisikan sebagai sebuah sistem kombinasi dari bermacam-macam metode visual, peta, grafik, dan ringkasan teks berlandaskan struktur informasi atlas. Sebagai sebuah media penyaji sintesa pengetahuan tentang elemen fisik dan geografis yang menjadi ciri sebuah negara dan penyaji sintesa sumber-sumber informasi dan data geospasial siap akses yang ada, metafora atlas nasional berbasis internet merupakan jawaban alternatif yang tepat dalam usaha pengefektifan dan pendayagunaan akses dan integrasi data geospasial melalui IDG. Meskipun studi ini khusus meneliti penggunaan metafora atlas nasional di dalam lingkup IDG Nasional negeri Belanda, hasil studi ini dapat diterapkan di negara-negara lain untuk memajukan pengembangan atlas nasional mereka di dalam dunia Infrastruktur Data Geospasial.

# Contents

# List of Figures

# List of Tables

# List of Acronyms

| | |
|---|---|
| Aim4GDI | Atlas Interface Metaphor for Improved Use and Accessibility of GDI |
| AJAX | Asynchronous Javascript and XML |
| API | Application Programming Interface |
| CLM | Collection-Level Metadata |
| CSS | Cascading Style Sheets |
| CSCW | Computer Supported Cooperative Work |
| CSW | Catalog Services for the Web |
| FAO | Food and Agriculture Organization (United Nations) |
| FGDC | Federal Geographic Data Comittee |
| GDI | Geospatial Data Infrastructure |
| GeoRSS | Geographically Encoded Objects for RSS Feeds |
| GIS | Geographic Information Systems |
| GIMA | Geographical Information Management and Applications (MSc Programme) |
| GOMS | Goals - Operators - Methods - Selection |
| GOS | U.S. Geospatial One Stop |
| GPS | Global Positioning System |
| HCI | Human-Computer Interaction |
| HTML | Hypertext Markup Language |
| HTA | Hierarchical Task Analysis |
| ICA | International Cartographic Association |
| IGU | International Geographic Union |
| ISO | International Organization for Standardization |
| ITC | International Institute for Geoinformation Science and Earth Observation |
| KMZ | Downloadable zipped Keyhole Markup Language (KML)® |
| LRS | Longest Repeating Subsequences |
| MODIS | Moderate Resolution Imaging Spectroradiometer |
| NASA | National Aeronautics and Space Administration |
| NCGI | Nationale Clearinghouse Geo-Informatie |
| NGDI | National GDI, also known as a National Spatial Data Infrastructure (NSDI) |
| NGII | National Geographic Information Infrastructure |
| NSDI | National Spatial Data Infrastructure, see also NGDI |
| OGC | Open Geospatial Consortium Inc. ® |
| PCP | Parallel Coordinate Plot |
| RAVI | the Dutch Council for Geographic Information |
| RD | *Rijksdriehoeksmeting*, the Dutch coordinate system |
| RDF | Resources Description Framework |
| RDF/XML | RDF encoded as XML |
| RSS | RDF Site Summary also known as Really Simple Syndication |
| SPARQL | the Proposed Standard for RDF Query Language and Access Protocol |
| SVG | Scalable Vector Graphics |
| SWE | Sensor Web Enablement |
| TAF | Task Artefact Framework |

| | |
|---|---|
| UI | User Interfaces |
| USD | US dollars |
| W3C | World Wide Web |
| WFS | Web Feature Services |
| WMS | Web Map Services |
| WPS | Web Processing Services |
| WUFIS | Web User Flow by Information Scent |
| XHTML | a reformulation of HTML 4 as an XML 1.0 application |
| XML | eXtensible Markup Language |
| XPath | a language for addressing parts of an XML document |
| XSLT | eXtensible Stylesheet Language Transformations, a language for transforming XML documents into other XML documents |
| Z39.50 | the search and retrieve protocol, also known as ISO 23950 |

CHAPTER 1

# Introduction

The research presented in this study deals with the development of a web atlas, intended to help users access geospatial resources via the Geospatial Data Infrastructure (GDI). Here, geospatial resources denote maps, offline Geographic Information Systems (GIS) data (e.g., data with a proprietary format) as well as web-accessible geospatial contents, including Web Map Services (WMS) and Web Feature Services (WFS). This chapter will describe the motivation and aim of this study, starting with an overview of the progress of surveying and mapping activities and initiatives to develop an infrastructure to enable geospatial data and information access. Subsequently, it will examine the role of geoportals in GDIs including some usability issues in their applications. This chapter will then go on to discuss the rationale to do research in this field, the research objective, and the organization of this thesis.

## 1.1. Background

### 1.1.1. Geospatial data production and use

Surveying and mapping activities have been developing throughout human history. In the literature, one can observe that mapping and surveying have been practiced for at least 5000 years in parts of Europe, the Mediterranean, the Middle East and Asia (Harley and Woodward 1987; Harley and Woodward 1992; Harley and Woodward 1995; Tufte 2001). The discoveries of the “earliest known maps”, such as a Babylonian river valley map in Iraq (c.2300 BCE) and the Çatalhöyük town map in Turkey (c.6000 BCE) provide a strong indication that people in those periods created and used early picture maps to transmit their ideas and conceptions about location. There is also evidence to suggest that the practice of modern surveying started as early as 2900 BCE to provide the relevant accuracies in the construction of the Great Pyramid of Giza and about 1300 BCE in the earliest boundary surveys in Egypt (Wolf 2002). These records suggest that measurements and graphic representations of location and spatial features are necessary for mankind and have been essential activities to advance human knowledge in many application domains.

Advances in engineering and in computer technology have been influential in the progress of surveying and mapping activities (Beutler 2006; Goodchild 2000; Wolf 2002). As an example, one can take a look at the evolution of map media: early maps were carved on stone or painted on walls, but for the past three centuries, maps have commonly been printed on paper for scientific or industrial purposes. And since the 1980s, modern cartography has recognized electronic resources and especially the web as essential media for disseminating maps (Kraak and Brown 2001; Peng and Tsou 2003). The production of the Electronic Atlas of Arkansas (the first electronic atlas in 1987) and the Xerox PARC Map Viewer (the first known map server made available in 1993) mark the start of this new era.

A similar story also holds for the development of surveying engineering practices. Earlier surveys include the use of graduated ropes, ancient surveying instruments like the *diopter* for measuring angles and *chrobates* for levelling, and the invention of precise theodolite instruments (Wolf 2002). After the 1950s, with the advances of machining techniques, optical systems and computer technology, traditional surveying practices with chains and telescope-mounted theodolites were gradually replaced by the use of optical-reading theodolites, total stations, electronic surveying, and also by analytical and digital photogrammetry (Williamson 1997; Wolf 2002). Subsequently, the advance of space technology (e.g., positioning technology with Global Positioning Systems (GPS), satellite remote sensing) (Beutler 2006) and the latest developments in earth and environmental sensors (due to progress in nanotechnology) (Duckham et al. 2005; Liang et al. 2005) have vastly expanded the options for collecting more geospatially related or geocoded data and for conducting efficient and effective surveying and mapping activities (now commonly termed geomatics).

Today, not only government agencies produce and use various types of geospatial data in support of their monitoring and planning programs, such as land administration, natural resources management, and urban settlements, but private agencies, and even individuals, also collect and use geospatial data for a wide variety of commercial, social, and environmental applications. The ubiquitousness of the use of geospatial data is fuelling geospatial market growth. This can be seen from the projected geospatial software and data revenues as well as from the growing demand for more geospatial professionals. It was reported that worldwide revenues were to reach 3.6 billion US dollars in 2006 (up from USD 2.8 billion in 2004 and USD 1 billion in 2001), in which software was the largest component while data was the second-largest component of core-business revenues (Duffy 2002; Geospatial-Solutions 2006). Another report indicated that the demands for geospatial skills and training is growing very fast worldwide, following the increase in uses of geospatial-enabled technologies (Gewin 2004).

When one considers the progress that geomatics (as well as geographic information – GI) science and technology and specifically the data collection and processing efforts have made so far, together with the applicability of geospatial-enabled technologies for a wide range of domain applications, the challenges associated with the access and discovery of geospatial data soon become clear (*discovery is used here to mean searching and finding, retrieval, being able to locate*). For instance, from the diversity perspective, it is not a straightforward task to select and to have access to specific data of interest covering a particular administrative unit among all the various geospatial data available in a country. Each unit and their aggregated units (e.g., a municipality and province or a county and state) can have basic or fundamental data such as geodetic networks, a topographic template, elevation model, and geographic names as well as framework data that covers certain thematic aspects including transportation, hydrology, land ownership and cadastre, and agriculture.

From the currency perspective, the availability of large volumes of geospatial-related data will produce challenges for data access, and for detecting the expected and discovering the unexpected (Thomas and Cook 2005). For example, the Aqua and Terra satellites generate nearly 2 terabytes of Moderate Resolution Imaging Spectroradiometer (MODIS) data per day (NASA 2006b). A further example is the issue associated with the necessity to manage E-commerce-related geospatial-temporal data. It is reported that, per day, there are 1000 million FedEx and 150 million VISA transactions, 300 million long-distance phone calls through the ATT network, 35 billion e-mails delivered worldwide, and 600 billion IP packets via the German Commercial Internet Exchange (Keim 2006). Disaster-related geospatial-temporal data is also of interest when one considers the growing uses of earth sensors and GIS in comparison to the average numbers of natural phenomena occurring each year: 12 million earthquakes, 100,000 thunderstorms, 10,000 floods, hundreds of landslides and tornadoes, and scores of hurricanes, wild fires, volcanic eruptions, droughts, and tsunamis (USGS 1995). The need to have effective and efficient access and discovery means to various up-to-date geospatial data has long been an issue of interest to the geospatial community.

### 1.1.2. Geospatial Data Infrastructures and geoportals

Access to the wealth of collections of geospatial data is a crucial issue since such data can probably be used for multiple applications and shared among different institutions (Groot 1997; Nebert 2004b). In this way, cooperating agencies and institutions gain maximum savings and reduce unnecessary data redundancy. In relation to this potential, it is estimated that 80 percent of the cost of GIS projects is incurred in acquiring the geospatial data (Thapa and Bossler 1992). In civil projects meanwhile, surveying and mapping costs make up approximately 40 percent of the total budget, whereas half these costs could be saved if GIS was employed to support the planning and design of those projects (Wolf 2002).

The vision of “created once, used many times” started in the late 1970s, when many national mapping agencies recognized the need to develop strategies (and specifically technical standards) for coordinating and standardizing the access to and uses of geospatial data (Groot and McLaughlin 2000b). In the following years, the coordinating efforts and development of standards for sharing geospatial data led to the development of a National Geospatial Data Infrastructure, also known as a National Spatial Data Infrastructure (NSDI). This notion was first raised in the early 1980s in Canada (Groot and McLaughlin 2000b), although in the USA, the federal government started coordinating their surveying and mapping efforts in the 1950s (Koontz 2003). Building on previous coordination and data sharing efforts, the US government established an NSDI program through an Executive Order in 1994. Since then, according to Crompvoets' studies (Crompvoets et al. 2005; Crompvoets et al. 2004), more than 100 countries have developed GDI or GDI-like initiatives. Crompvoets reported that USD 120 million are spent yearly around the world for managing geoportals.

A GDI offers a set of institutional, technical, and economical arrangements for communities at local, national, regional, and global levels to access and use geospatial resources (data, services, sensors, and applications) in support of decision-making processes (Groot and McLaughlin 2000b; Nebert 2004a). From local, national, and global perspectives, this infrastructure is intended to promote sustainable environment, economic development, and better government among other aspects, as well as disaster awareness and provision of emergency aid, and hence it is perfectly suitable for supporting the implementation of the Agenda 21 plan of action (ESCAP 2003; Williamson et al. 2003).

A national GDI seeks to support the coordination and management of geospatial resources in the national context. The practical goal of this program is to realize the effectiveness and efficiency of data collection, sharing, and use (Groot and McLaughlin 2000a; Williamson et al. 2003). Best practices to realize such programs, as implemented in some GDI pioneers such as US GDI and Australian GDI, include adopting metadata standards and profiles, establishing a geoportal, and having framework datasets available. Obviously, in line with these three components, policy and institutional aspects are also important aspects to ensure that collaborative processes of data sharing and access can take place in GDI (Maguire and Longley 2005). Among these components, geoportals have been considered a key feature in promoting national GDIs (Crompvoets et al. 2004; Maguire and Longley 2005; Nebert 2004c).

Such portals often provide access to a collection of geospatial metadata describing the available geospatial resources, based on which the user will decide the fitness for use of the resources for his purpose. Geospatial resources here refer more specifically to offline or proprietary data and to what the Open Geospatial Consortium (OGC) distinguishes as geospatial web contents, including data services, such as Web Map Services (WMS), Web Feature Services (WFS), and Sensor Web Enablement (SWE), as well as processing services (i.e., WPS). Hence, metadata in this respect are data or information summaries describing the substance, quality, currency, and accessibility of offline data, geospatial web contents, and services. In addition, for better access to a large variety of geospatial resources, geoportals can enhance data exchange and sharing between organizations to prevent redundancy and improve the coordination of efforts in collecting data and offering them via the web.

If we consider the variety of the type and scope of the geospatial resources with which geoportals have to deal, they can be classified into two groups: (a) national or regional geoportals, such as the US Geospatial One Stop – GOS (USGS 2006), GeoConnections (NRC 2006b), and Inspire Geoportal (INSPIRE 2006a), and (b) thematic geoportals, such as the Food and Agriculture Organization (FAO) portal (FAO 2006), European Protected Areas portal (Nature GIS) (INSPIRE 2006b), and Earth Science Gateway (NASA 2006a).

Geoportals are concerned primarily with providing catalogue services (Crompvoets et al. 2004; Maguire and Longley 2005). In this regard, geo-information users might have been familiar with the web catalogue, years before the rise of GDI, where they searched for products of earth observations and satellite images through the web site of a specific data provider like SPOT Image (Image 2007) for instance. In GDI context, geoportals publish not only products (i.e., resources) related to one specific provider, but also resources offered by various providers participating in the infrastructure; geoportals facilitate discovery of and access to these resources.

Catalogue services facilitate publication and discovery of collections of geospatial resources, which are mostly offline and online data services. For publishing data, the data providers need to create metadata describing their data and then publish this through the catalogue client. This registering process can be done either by manual inputs or metadata harvesting. The metadata to be published should be encoded as specific standardized metadata (e.g., using ISO 19115 standard). For data discovery, the catalogue services are equipped with tools to query and present metadata records as users initiate searches for data or services they require (see Figure 1.1). The OGC specification for Catalogue Services for the Web (CSW 2.0) defines the framework, interfaces, and protocol bindings required for providing catalogue services to the geospatial community. Currently, several solutions of catalogue services based on CSW 2.0 specifications are available, including Red Spider (Ionic 2006), Terra Catalogue (Conterra 2006), and GeoNetwork (GeoNetwork 2006).

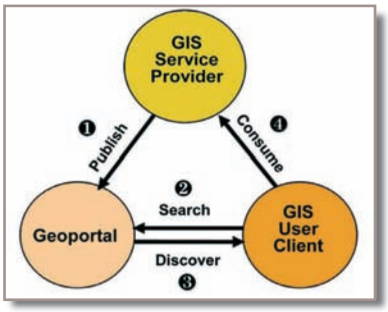



**Figure 1.1.** The role of a geoportal in a Geospatial Data Infrastructure (GDI). Operation 1 refers to the publication of metadata on geospatial resources in a geoportal by providers; Operation 2 indicates search queries sent by users via web; Operation 3 indicates responses offered to help users discover the data requested; and Operation 4 is done when users make use of the resources offered (Maguire and Longley 2005). (Reprinted with permission from Elsevier).

To find and access data or map services via geoportals, users first have to provide at least one of many possible search terms related to location, attribute, or time of the required data. For this, the common strategy is to offer users possibilities to ask “where”, “what”, and “when” regarding the data required. The search terms for “where” can be expressed as latitude-longitude definitions, place names or administrative areas, or by drawing a rectangle specifying the area of interest. The “what” questions refer to search terms related to data attributes, such as format, scale, and the publisher. In addition to “where” and “what”, users can submit “when” questions to limit the search to a specific date or period of publication or creation, as well as to limit the temporal information of the data. A common solution provided to users as a result of their queries is the display of search results in the form of a set of abstracts and thumbnails with links to view the data and to review its full metadata description (Tait 2005) (see Figures 1.2 and 1.3).


**Figure 1.2.** An example of a regional geoportal. Using user interface components that are organized according to where, what, and when questions, users can define search terms related to location, topic and attributes, as well as to time of interest. The display of search results (shown in the right lower corner) is given on a new page after users click on the search button (source: INSPIRE 2006a).

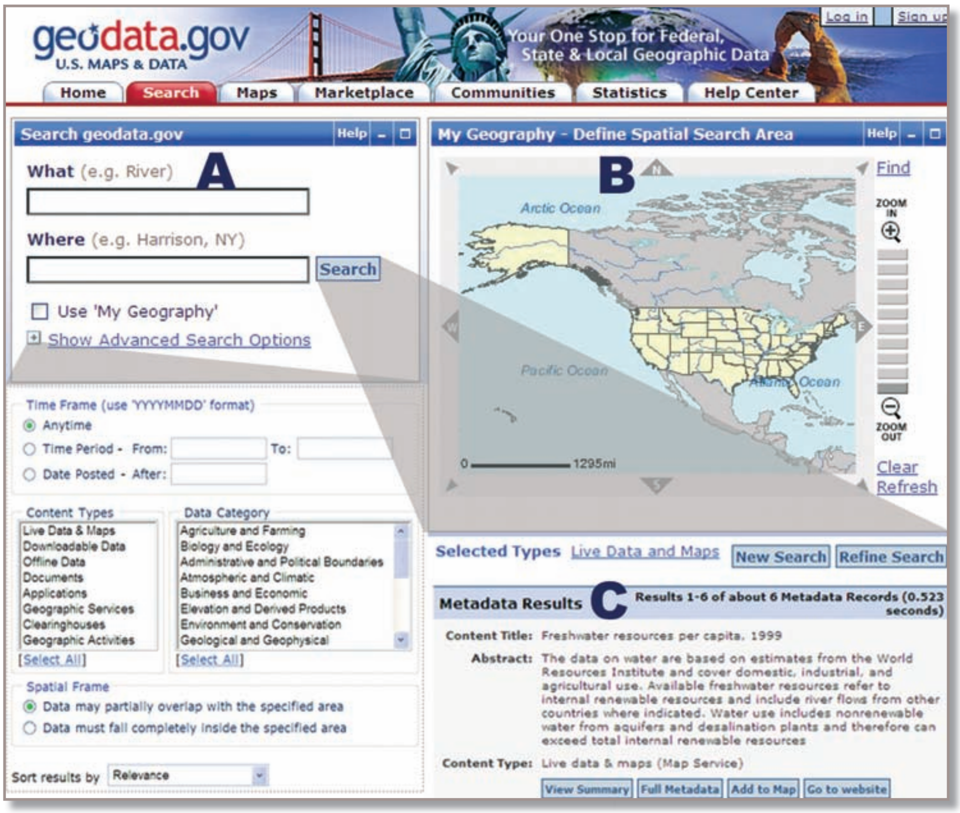



**Figure 1.3.** Another example of a national geoportal. Input widgets (A) can be extended to define more specific search terms and a map (B) is commonly used to define an area related to the search interest. The display of search results (C) is given in the form of a listing of results showing the title, abstract, resource type, and link options (source: USGS 2006).

In addition to catalogue services, geoportals can be used to organize community information and provide direct access to mapping and processing services (Maguire and Longley 2005). Integrating the catalogue service with mapping and processing services is a helpful approach to exploiting GDI's potential in support of the analysis and decision-making processes that users require. As exemplified in the web mapping application for European forest fire detection (Friis-Christensen et al. 2006), the catalogue service can be offered next to the WMS, WFS and WPS, enabling users to directly detect the burned areas in the application. Such applications offer a dynamic approach to integrating distributed computing resources and to sharing information.

The world status of national and regional geoportals is progressing steadily. As of April 2005, according to the study by Crompvoets and Bregt (2006), although the maturity level of implementation of four types of operations described in Figure 1.1 is different from one country to another, as many as 83 countries have developed national web access services (Crompvoets and Bregt 2006) (see Figure 1.4).


**Figure 1.4.** The world status of geoportals as of April 2005 (source: Crompvoets and Bregt 2006).


**Figure 1.5.** The world status of national atlases since 1960. The data was compiled from (Bakker et al. 1987), which is based on (Stams 1978), and the national atlases collection in the Map Libraries of Utrecht University (Oddens 2007) and of the International Institute of Geoinformation Science and Earth Observation (ITC), the Netherlands.

### 1.1.3. National atlases

Long before the first GDI initiatives and geoportals were established, from a modern cartography point of view, some countries had already shown at least one visible initiative towards providing easy access to geospatially related data and knowledge in a national context. That initiative was the development of national atlases, presenting the geographical information of a country in great detail and in a concise manner pertaining to the physical, economy, and political data of a country through maps (Salichtchev 1972). National atlases present a synthesis of the knowledge of physical and geographic elements that characterize a country (Ormeling 1979).

In addition to the focus and the scope of the contents as well as their topical complexities, an important feature of national atlases is the intended objectives that motivate their publication (Freitag 1997). Some of the predetermined functions are to provide a prestige publication to display national pride that covers national unity and identity or the claim to it; maps for physical and economic planning and policy; tools for problem solving (e.g., unemployment problems in the context of the economic development in a country); stimulating interests in both novices and experts; and a sound basis for further cartographic work (Bakker et al. 1987; Freitag 1997; Symons 1979).

The first atlas of this type was the Atlas of Finland, published in 1899. In fact, the idea of producing an atlas combining inter-related maps pertaining to various national topics had been conceived in the seventeenth century, and accelerated after substantive topographic and earth science data became available, as well as after a significant increase in the utilization of Von Humboldt's work on physical geography maps and of Playfair's innovation on statistical charts (Salichtchev 1972; Wainer and Spence 2005). The concept of national atlases was motivated by goals to give a complete picture, based on scientific data, of a variety of national themes and to help the nation's scientific community. Through this type of atlas, a concise presentation of multi-thematic national information was made accessible for practical uses. As mentioned in Ormeling (1979), prerequisites to publish national atlases include: the availability of data, human resources, cartographic skills, financial backing, and an editorial board. As a "national" product, national atlas projects usually compile and make comparable various data sets from several (institutional) domains and have been successful in getting several institutions to work together and participate in the production of national atlases (Bakker et al. 1987).

Atlases, including national atlases, offer an on-demand analysis and interpretation through map comparison. On-demand map comparison and composition include: the comparison of a map with the larger scale map of the user to characterize similarities and differences ("zoom in" tool); the comparison of various maps for detecting the textures and corresponding features ("overlaying" tool); the comparison of various maps to correlate subjects ("spatial synthesis" tool); and the comparison of maps for the same subject in the same region but at different times ("spatio-temporal recognition" tool) (Freitag 1997; Groot 1979; Kraak and Ormeling 2002). In addition to its capability as a spatial comparison machine, an atlas can serve as a spatial data organizer, a visualization device, and an exploration device (Buckley 2001; Ormeling 1997a).

Salichtchev (1972) provided an authorative analysis of the history, contents, and production of national atlases. An original report, called the "IGU – International

Geographic Union report on National Atlases", was regarded as a principal guideline for the development of national atlases. At the time the IGU report was made public (1960), 26 national atlases had been published, but nearly twenty years later, it was estimated that some 50 to 60 national atlases (in book form) had been compiled (Ormeling 1979). Figure 1.5 presents the world status of national atlases (as books) that have been published since 1960.

Since the beginning of the 1990s, national atlases have also become available in electronic form, also known as atlas information systems. The early electronic national atlases were usually published through physical digital media such as CD-ROM, whereas in subsequent years, interactive national atlases have been disseminated via the web. The Atlas of Canada was one of the first examples of a national web atlas, with Sweden and the US as other early examples. Using the web as media, the accessibility of national atlases can be greatly advanced. At the same time, the interactivity and analytical functions of the atlas can be developed in order to maintain or improve their navigation possibilities. Apart from their common goal to disseminate a national atlas through the web, some countries are positioning their national atlases as the node of a national clearinghouse, as can be seen for the US atlas and the Canada Atlas.

## 1.2. Research issues

Making geospatial resources more accessible will bring new business opportunities and stimulate well-informed decision-making by government agencies, private companies, non-government organizations, and individuals (Groot and McLaughlin 2000a; Muntz et al. 2003; Williamson et al. 2003). Present web user interfaces for providing access and use of geospatial resources include: geospatial digital libraries (e.g., Alexandria Digital Library), public or commercial geospatial data catalogues (e.g., SPOT catalogue or IKONOS catalogue), customized web mapping composites (e.g., GoogleEarth and the use of KMZ (downloadable zipped Keyhole Markup Language) for indexing global elevation data and satellite images) and geoportals.

Geoportals are considered vital and of the highest priority for the success of GDI (Crompvoets et al. 2004; Groot and McLaughlin 2000a; Masser 2005a). This study examines the usefulness and usability of geoportals in enabling the discovery and integration of geospatial resources required by users. Here, users are not only understood to be specialists with good geospatial skills, but they may also include any other potential user (with or without any specific geospatial skills) who can actually make use of the data on offer to support research, planning, or other decision-making activities.

Users need effective, efficient, useful and easy means to define search terms and to assess the search results via a user interface. Providing usable and useful user interfaces in support of geospatial data retrieval has been one of the important research challenges in geovisualization (Cartwright et al. 2001; Fuhrmann et al. 2005b; Slocum et al. 2001). As far as the user interface of a geoportal is concerned, within the human-computer interaction domain, a guideline for developing user interfaces in support of information discovery was proposed by Shneiderman, Byrd, and Croft (1997) as a "four-phase framework for search": *formulation, action, review of results*, and *refinement*. For "review of results", most geoportals require users to drill-down and review the search results item-by-item, to judge which data best fit their needs. Such a search process is arguably ineffective and inefficient. For "action" and "refinement", the navigation tools to control the search arguably could be improved. As an example, a functionality to revisit items that have been visited before in an attempt to compare their appropriateness for a specific search interest is not yet available in most of the current geoportals.

Providing usable and useful user interfaces not only refers to the utility of human interaction methods, but also to the information presented. During and after a search, the information presented will be essential in helping users finding the right information. Due to the complexity of information to be accessed and often due to the tight correlation between search terms and geographic location, maps can play a prominent role in helping users discover the geospatial resources requested. To some extent, combining or juxtaposing different maps or graphics can lead to easy access to the information wanted. In some other cases, integrating maps with other resources, such as online WFS or WMS, could help users define search terms and assess the search results. The advantages of maps and graphics to stimulate visual thinking and to provide effective communication before and after a search in current geoportals have not yet been considered extensively. Geoportals often provide a map in their interfaces, but its use thus far is mainly limited to being a medium to define or indicate a search area.

## 1.3. Motivation

As a solution intended to help users discover and integrate geospatial resources, this study considers the national web atlas as a gateway to access and use geospatial resources in a GDI. In this way, the national atlas is used as a metaphor in the access to GDI. A metaphor is defined here as a way to conceive one concept in terms of another and it is applied in order to improve human understanding (Lakoff and Johnson 1980). Metaphors are used in human communication as well as human-computer communication. The concept being described is called a target, and the concept used to provide insights about the target is called a source. An appropriate metaphor should consider that the source domain is understandable and has meaningful functional definitions that support tasks required by potential users in the target domain (Erickson 1990; Kuhn 1995). The decision to select the national atlas as the source is based on the similarity of the functional definition of geoportals or clearinghouses and national atlases as search and access tools. It is also based on a belief that GDI users can benefit in using the national atlas instead of a geoportal.

In this regard, the concept of a national atlas is seen to have a capacity to support users' tasks in accessing GDI because of the prominent role of maps in national atlases, the distinctive role that the concept of an atlas plays, and the organizational approach to their contents. The following paragraphs will elaborate on these three aspects.

With regard to the role of maps, they represent a major part of any national atlas (web-based or book form). Their uses along with the existence of graphics in national atlases can help users find answers to their geographic or thematic inquiries (Kraak 2000; Kraak et al. 2001) and make geospatial information comparable (Ormeling 1995b; Ormeling 1997a).

In relation to their role as a search engine or as a supporting component for a search engine, the map has been utilized in research and industry much more than before thanks to the advance of computer technology. For research, the potential of using maps for effective information discovery has attracted many scientists from cartography and computer science to work on the topic (see e.g., Borner 2002; Chen 2003; Fabrikant 2000a; Kraak 2006; MacEachren et al. 2004; Shiffrin and Borner 2004). For industry, many electronic products including encyclopaedias, guidebooks, and of course, atlases, use maps to support the exploration of geospatial and non-geospatial information (e.g., Britannica 2007; Microsoft 2007b). In the world of web searches, maps and the functions related to location searches are becoming a common tool offered by search engine companies (Google 2007b; Microsoft 2007a; Yahoo! 2007).

This progress, and more specifically the availability of open codes of mapping Application Programming Interfaces (APIs) like Google Maps API, have encouraged many promising grass roots web-mapping applications, known as mapping "mashups", to emerge (Darlin 2005; Lerner 2006; Miller 2006). A mashup is defined as a website or application that is built from two or more different or separate applications. At the start of 2007, there were 1417 mashups: the first top mashup is about mapping (31%), and in total the term "mapping" is used to tag 878 mashups. A similar idea to mashup was exhibited in atlas production long before the emergence of web technology, for example, in the combining of statistical charts from population or economic data and industry sectors with poly-thematic maps from the environment or transportation sectors.

Further, the idea to combine and integrate inter-related thematic maps and statistical information for information access and analysis as currently envisaged through GDI (e.g., Friis-Christensen et al. 2006; Peng 2005) has been practiced since the early development of atlases. Combining more than one thematic dataset has long been common in the production of atlases. They have visualized different but conceivably inter-related themes on one map. For national atlases, syntheses of thematic information was recommended for the physical environment and economic geography after the publication of Salichtchev's report (Ormeling 1979). To date, many book-form national atlases provide synthesis and poly-thematic maps. On demand synthesis of various thematic layers that are useful in supporting national atlas users' inquiries, has also been considered since the emergence of digital cartography (Groot 1979) and the web era (Gosson 2006; Kramers 2005). This feature is extremely relevant and can be offered with current web technologies in order to show interdependencies or relationships between two or more topics of interest.

The concept of national atlases (either as a book or web-based) has evolved for more than a century, with many countries producing atlases as a showcase of their nation (Bakker et al. 1987; Gosson 2006; Groot 1979; Hurni et al. 2001; Kraak 2001; Ormeling 1979; Ormeling 1995b). They present multi-subject maps in a coherent narrative, depicting the potential and resources of a particular country. Such atlases have long been known by the global community to be an information resource for discovering places and thematic information. For many countries, the use of atlases is introduced to their citizens during their secondary school education (Ormeling 1996a; 1996b). In the world of geospatial data infrastructures, many of the users will have learnt to work with such information at a young age and can use it as a means to help structure their view of the world.

In relation to the organizational aspects of the atlas, topics are specified based on the objective and contents to be presented. Each topic is represented by relevant maps to deliver a coherent visualization of one or more specific themes within that topic. This allows users to navigate their focus of interest from one map to another, either via sequential or random access (Kraak and Ormeling 2002). Maps in electronic atlases can be considered as an interface to spatial databases and to obtaining data and links beyond the symbols (Buckley 2001; Frappier and Williams 1999; Neumann and Richard 1999). In such an arrangement, the atlas can provide broad access to a wide range of related information.

## 1.4. Research objectives

Based on the above considerations, this study asserts that: *for useful and effective discovery and integration of geospatial resources, a national web atlas metaphor will be helpful in providing an alternative means of access to support users in searching and browsing geospatial resources via a Geospatial Data Infrastructure*. To demonstrate and assess the approach proposed, this study will specifically aim:

1. To design a new paradigm of interaction methods to facilitate the process of searching and browsing geospatial resources and more specifically geospatial data through the atlas metaphor;
2. To develop a visualization method to produce a uniform design and approach that allows users to easily understand the metadata offered and to assess and indicate the fitness for use of geospatial data;
3. To develop a mechanism for the use of maps as tools for data discovery and for the integration of geospatial resources and non-geospatial resources;

4. To test the applicability of the atlas metaphor through use scenarios in order to assess its feasibility as a metaphor.

## 1.5. Scope of the study and organization of this thesis

The study focuses on the use aspect of the web atlas metaphor. It attempts to combine methods available in Human-Computer Interaction (HCI) and geovisualization in order to reach the desired objective. As a showcase and evaluation for the concept and techniques developed, a prototype of the national web atlas metaphor has been built in this study and called Atlas Interface Metaphor for Improved Use and Accessibility of GDI (Aim4GDI). Aim4GDI is targeted to enable data discovery and integration of geospatial resources in the Netherlands within the framework of the National Geographic Information Infrastructure (NGII).

In the Netherlands, the development of the national GDI was started as early as 1992, when the RAVI (the Dutch Council for Geographic Information) published a policy document concerning a structure plan for land information (Finley et al. 2000; Loenen 2006). The process of developing metadata standards and a national web access (referred to as *Nationaal Clearinghouse Geo-Informatie* (NCGI)) were started in1995. In this study, the clearinghouse or geoportal was observed and used as a test interface in the early development of the prototype.

The data used in the study and especially in the test activities were related to transportation, environment, and agricultural subjects in the Province of Overijssel, the Netherlands, but some agriculture and transportation data with a national scope was used too.

The result of the study is presented in the following six chapters. An overview of the organization of the thesis is given in Figure 1.6 and an outline of the chapters is given in Table 1.1. In summary, the chapters will describe a process of developing a national atlas metaphor using scenario-based design principles. The national atlas metaphor will be envisioned in Chapter 2, developed using an application framework presented in Chapter 3, and put into practice in Chapter 4 and Chapter 5. The principles of scenario-based development are applied throughout the problem, design, and evaluation phases and are described in Chapter 6 (Figure 1.6).

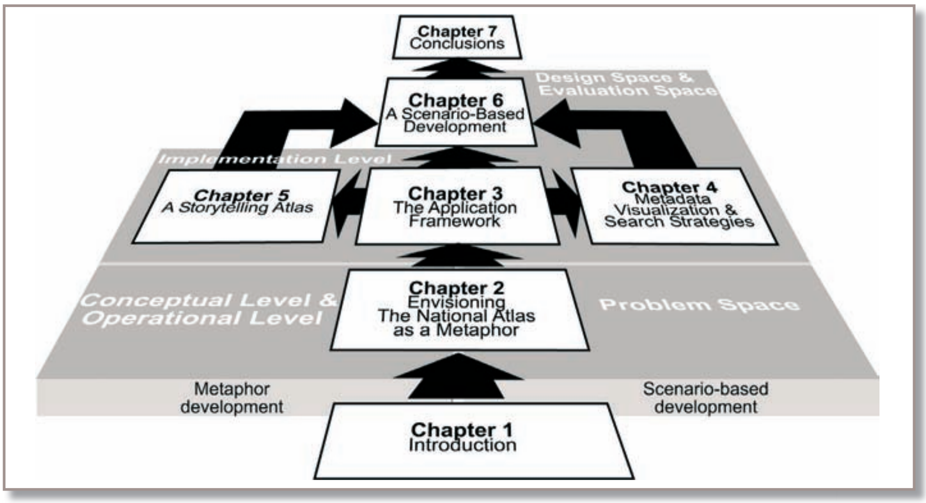



**Figure 1.6.** Representation of the contents of the study

**Chapter 2** presents the general framework of user interaction and interfaces of the national atlas as a metaphor. The questions this chapter will try to resolve are: *What is a national atlas metaphor? How can this be used in the access to a GDI? What strategies should be offered to support user tasks in searching for data via a GDI portal?* **Chapter 3** looks at the application framework of Aim4GDI to enable searching and browsing modes via the atlas. This chapter will answer two essential questions: *How to provide an application framework supporting the concept developed? Which technology components can be of help in enhancing the concept?* **Chapter 4** deals with the search functionality and metadata visualization. It seeks to provide answers to the question: *How effective are the search strategy and interfaces envisaged?* **Chapter 5** focuses on the navigation and interaction aspects of the atlas in support of the browsing mode. In this context, the concept of storytelling has been used. This chapter also discusses the possible use of the national atlas metaphor to support collaboration activities. Like chapter 4, this chapter provides answers to questions related to the effectiveness of the browsing strategy: *How effectively can this be used to support the exploratory and synthesis phases required for both individual use and collaborative use of the national atlas metaphor?* **Chapter 6** discusses the implementation of scenario-based design principles in the development of the national atlas metaphor. By focusing on the design and evaluation stages of the study, this chapter seeks to provide answers as to whether the claim made in the research objective (Section 1.4) is defensible, i.e., *Is the atlas metaphor really feasible and usable?* And finally, conclusions will be drawn in **Chapter 7**.

**Table 1.1.** The chapters and outline of their contents

| Chapters | Description and methods used | Deliverables |
|---|---|---|
| **Chapter 2** Envisioning the National Atlas as a Metaphor | The chapter provides a general framework of interaction and information design in the development of the atlas metaphor through reviews, inquiry, analysis, and rapid prototyping activities | • The analysis of requirements<br>• The information and interaction design framework<br>• The notion of metadata summary and information structure<br>• Prototype I: Flash-ArcIMS version |
| **Chapter 3** The Application Framework | The chapter details the strategies and technical functionalities of the web mapping applications developed of the national atlas metaphor to support exploration and synthesis processes of problem-solving. | • Web application framework<br>• Implementation of metadata summary and information structure with Semantic Web technology<br>• Metadata and thematic mapping<br>• Prototype II: SVG version |
| **Chapter 4** Metadata Visualization & Search Strategies | The chapter describes the strategies to facilitate searching and completing a tightly defined task to discover a specific geospatial resource. The feedback from users testing the search interface is also discussed. | • Search interface<br>• Case study 1: searching<br>• Quantitative evaluation<br>• Qualitative evaluation |
| **Chapter 5** A Storytelling Atlas | The chapter discusses the approaches to enable easy access and understanding of the contents and juxtaposition of the geospatial resources through browsing and storytelling. The collaborative use of the atlas for group work is discussed and, as in chapter 4, there is also a discussion of the feedback from users testing the browsing strategy. | • Browsing interface<br>• Case study 2: individual use<br>• Case study 3: collaborative use<br>• Quantitative evaluation<br>• Qualitative evaluation |
| **Chapter 6** Scenario-Based Development | The chapter presents an organized approach in applying scenario-based development in designing and evaluating the web atlas metaphor. The chapter presents a comparison of searching and browsing via the atlas metaphor and via a typical current geoportal. | • Design and development framework<br>• Quantitative evaluation<br>• Qualitative evaluation<br>• The atlas metaphor feasibility |
| **Chapter 7** Conclusions | The chapter summarizes the findings and outlines possible improvements for the development of the web atlas metaphor | |

# Geoportals: Envisioning the National Atlas as a Metaphor*

This chapter will further elaborate on the research issues and motivation stated in Chapter1. This chapter is aiming at providing a useful basis for the design of information and interaction methods required by users in making use of the web atlas metaphor when looking for geospatial information. For that purpose, this chapter will firstly look at the early stages of the design processes of a national atlas metaphor. These will include the activities to gather the requirements and a literature analysis concerning the suitability of the national atlas concept as a metaphor. Subsequently, it will provide a framework for the use of the metaphor and the tasks that users can complete by virtue of a rapid prototype of a national atlas metaphor.

## 2.1.Introduction

Geoportals are seen as a central component that may be used to facilitate the access to, and use of the proposed GDI initiatives. From a survey conducted by Crompvoets and Bregt (2003), it is suggested that the development of geoportals will increase in the future. They conclude that political and funding support are among the key components that lead to the success of development and continuation of geoportals.

Although political and funding support are essential in sustaining the GDI access means, user perspectives are also crucial in enabling an accessible GDI. Benefits of the GDI will be doubtful when users have difficulties using geoportals to discover any data that may be needed. As mentioned in the research issues (Chapter 1), the GDI users may include people with very few practical skills in GIS and GDI. Thus, users have different backgrounds and skills and this will influence their strategies in searching for any data that may be required. For example, a GIS technician, who requires a specific dataset for a project could start the search process based on format, scale, and area definition. On the other hand, a graduate student who requires data for a research assignment (for instance) might need more information than just simply defining an area of interest, and the format of data. Therefore, along with the political and funding support, the design and implementation of an easy to use, effective, and efficient geoportal are also important factors to the success of the GDI.

*This chapter is based on:
Aditya, T., and Kraak, M.-J. (2006). "Geospatial Data Infrastructure Portals: Using National Atlases as a Metaphor." Cartographica, 41(2), 115-134.

The interdisciplinary field that is aimed to support effective and efficient interactions between humans and computers through user interface design is Human Computer Interaction (HCI) (Preece et al. 2002; Shneiderman 1998). From the HCI point of view, success can be achieved when developed computer tools are suitable for human use (Carroll et al. 1992). The focus is on the design evaluation of users' perception, action, and information processing (John 2003) in dealing with computers. The notion of usability engineering has been a central approach in the development of user-centred systems. Some key features of usability engineering are: iterative development, users' involvement, and cost effectiveness (Carroll 1997a). This approach aims at providing methods to define usability parameters that can be measured (Nielsen and Levy 1994). These usability parameters provide indications about whether the designed software or user interface is easy to learn, efficient to use, easy to remember, preventive of user errors and pleasant to use (Nielsen 1994).

The International Organization for Standardization (ISO) 9241-11 has also defined usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use". *Effectiveness* refers to the accuracy and completeness required to achieve specified goals. *Efficiency* refers to the amount of resources including time, money and mental effort put into achieving the specified goals. *Satisfaction* refers to the users comfort and acceptability (ISO-9241-11 1998).

The literature reveals limited activity when it comes to improving the usability of geoportals. At the conceptual stage, Walsh et al. (2002) reviewed usability aspects of several large clearinghouses in the U.S. In their assessment, they concentrate on predictive evaluation, a user expectations survey, and user testing. From a more technical perspective, Tsou (2002) proposes a framework for managing metadata based on their unique features and functions in order to improve search mechanisms. In addition, methods to improve the recall and precision of the query have also been investigated (Jones et al. 2003; Rodriguez and Egenhofer 2003; Schlieder et al. 2001). Next to providing rigorous search mechanisms to discover geospatial data, presenting effective visualizations is also essential. Multivariate visualizations such as: space-time plots, glyph plots, parallel co-ordinates plots, star plots, and Chernoff-faces have been used to enable users to explore the characteristics of geospatial data during and after the search (Ahonen-Raino and Kraak 2005; Gobel and Jasnoch 2001). Despite these efforts, it remains difficult to assess the data suitability for a specific purpose (e.g., planning) or to study the relationships between the different data sets offered, since the tools that are offered do not necessarily allow users to search effectively for those data that they require.

This chapter seeks a new approach for improving the accessibility of geospatial data within the GDI by proposing the atlas concept as the metaphor. The term accessibility here refers to mechanisms for searching, browsing, and selecting geospatial services through interactions with geoportals. This chapter concentrates on the access to the geospatial data. Questions that will be answered in this chapter are: Can the atlas be used as a metaphor in the access to the GDI? What strategies should be offered to support user tasks in searching for data via a GDI portal? In this chapter, the terms 'geospatial' and 'geographic' are used interchangeably.

## 2.2. The need for a usable geoportal

The main benefit of the GDI is that it offers users access to multiple datasets via a 'one-stop-shop' (geoportals), which they require for their application. It also allows the providers to 'better' disseminate their products (or services) and reach their potential customers (and users). As such, it also stimulates the 'produced one, used often' paradigm. Regarding access via geoportals, the two mechanisms that are offered (referred to as two steps in Figure 2.1):

1. Providing interfaces for defining geographical, topical, and temporal properties of the data needed.
2. Presenting search results, thus allowing users to assess the 'fitness for use' of the data.

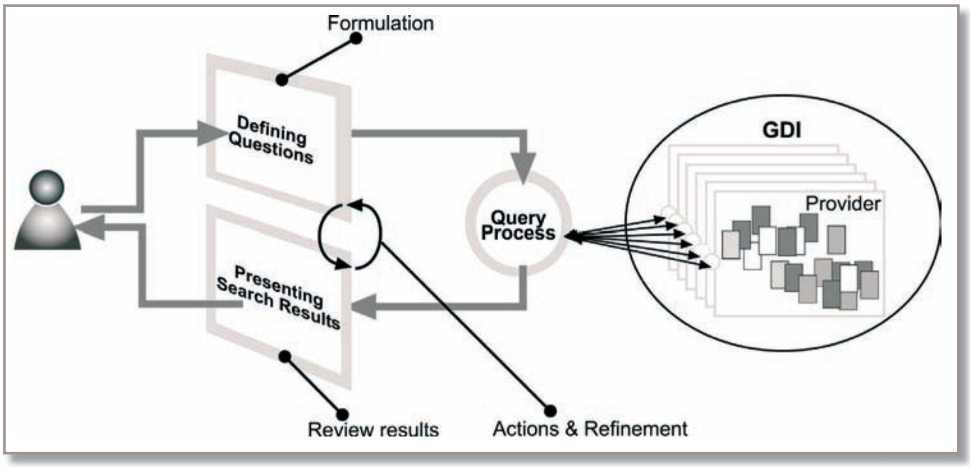



**Figure 2.1.** Separating search mechanisms offered on the available geoportals into two components: defining questions and presenting the search results.

To study these two mechanisms, some national and regional geoportal websites were reviewed, and then contextual inquiries were undertaken. The objective for these activities was to gather data regarding what functionalities and interactions have been offered and are available, in order to support search mechanisms in the GDI context. The findings will be summarized below in Section 2.2.1.

## 2.2.1. Reviews of some geoportals

Some national and regional geoportal websites were reviewed during this study. The focus of this activity was to investigate what functionalities are offered to users for defining the query and for assessing the search results, two activities related to point (1) and (2) respectively. The first reviews were undertaken in June 2003. In July 2004 and February 2005, these websites were revisited in order to check whether there had been any updates to their interaction interfaces. Indeed, some changes had occurred during this period. For example, in June 2003, the observation for the US geoportal was targeted to the national clearinghouse hosted by FGDC (Federal Geographic Data Committee) (FGDC 2004). However, in 2006 the Geospatial One Stop (GOS) (USGS 2006) was officially published. Hence, the US geoportal (herein referred to as GOS) is an intergovernmental project sponsored by the Department of the Interior that built upon its partnership with the FGDC.

The results of the reviews of the question definition are given in Table 2.1, and on the presentation of search results in Table 2.2.

**Table 2.1.** The first component of searching: defining questions. Some mechanisms applied in some national / regional geoportals (see their web addresses at the end of the References).

| | SEARCH DEFINITION | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | The area of interest | | | | | | | The attribute of interest | | | The time of interest | | Data provider |
| COUNTRY/REGION | Maps | Lat-Long | Place name | Admin. Boundary | Bounding Box | Zooming | Pan | Subjects Class. | Format Definition | Keywords | Time stamps | Temporal Changes | |
| *North-America* | | | | | | | | | | | | | |
| Canada Geoportal | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | X |
| Geospatial One Stop (GOS) | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | X |
| ESRI Geography Network | ✓ | X | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | X | X | ✓ |
| *Europe* | | | | | | | | | | | | | |
| Inspire Geoportal | ✓ | X | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Netherlands | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ | X | X | ✓ | X | X | ✓ |
| Germany | ✓ | X | X | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | X | X |
| *Asia & Australia* | | | | | | | | | | | | | |
| The Asia Pacific (APSDI) | X | ✓ | X | X | X | X | X | X | X | ✓ | ✓ | ✓ | ✓ |
| Australia | ✓ | ✓ | X | X | X | X | X | X | X | ✓ | ✓ | X | ✓ |
| Japan | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ | X | X | ✓ | ✓ | ✓ | ✓ |
| Malaysia | ✓ | ✓ | X | ✓ | X | ✓ | ✓ | ✓ | X | ✓ | ✓ | X | ✓ |
| *Africa* | | | | | | | | | | | | | |
| South-Africa | X | ✓ | X | X | X | X | X | X | X | ✓ | ✓ | ✓ | ✓ |

**Table 2.2.** The second component of searching: assessing the results. Presentations of search results offered in some national or regional geoportals (see their web addresses at the end of the References).

| COUNTRY | THE PRESENTATION OF SEARCH RESULTS | | | |
|---|---|---|---|---|
| | Ranking | Abstract | Link to the topic | Link to the web map |
| *North-America* | | | | |
| Canada Geoportal | ✓ | ✓ | x | data coverage on map only |
| Geospatial One Stop (GOS) | x | ✓ | x | ✓ |
| ESRI Geography Network | x | ✓ | x | ✓ |
| *Europe* | | | | |
| Inspire Geoportal | x | ✓ | x | ✓ |
| Netherlands | ✓ | x | x | x |
| Germany | x | ✓ | x | x |
| *Asia & Australia* | | | | |
| The Asia Pacific (APSDI) | x | x | x | x |
| Australia | x | x | x | x |
| Japan | x | x | x | x |
| Malaysia | x | x | x | ✓ |
| *Africa* | | | | |
| South-Africa | x | x | x | x |

As can be seen in Table 2.1, through the user interfaces that are offered, users can define an area of interest by using a map or by defining latitude and longitude or by specifying place names and an administrative boundary. All but two of the geoportals observed in this review offer users with more than one means the possibility to define an area of interest. The other two only provide latitude and longitude inputs for defining an area of interest. A map is commonly available in all geoportals as a medium to define an area of interest. The bounding box and zooming functionalities are common features in these maps. All geoportals include a textbox in their interface to allow users to enter search terms. Lists of topic categories and data formats are not available in all geoportals. Although some interfaces seem to provide options to define a temporal query as a temporal change (with an option to specify the starting date and the ending date of a particular time period), the time of interest is mainly queried based upon the time stamps of the publication date given in the metadata records. In addition, some user interfaces provide an option to search data based on the data provider.

After defining search terms, users can initiate the search. Once users click the search button, and given that the query returns matches, the search results will then be shown on the screen. The results are displayed as a list of metadata titles with additional information such as a ranking measure, an abstract, a linkage to the subject or topic in which the data is grouped, or a link to the (online) map, are added (Table 2.2). As mentioned in Section 1.1.2, today's geoportals present the search results in forms of a set of abstracts and thumbnails with links to view the data and to review its full metadata description. In the case when the item listed in the search results is an online map (i.e., WMS), it can be visualised in a map viewer.

It is worth noting that this kind of display of search results first appeared in the Metadata Explorer application, which has been shipped with the ArcIMS map server of Environmental System Research Institute (ESRI) since 2000 (ESRI 2006a). The Geography Network website (ESRI 2006b) of ESRI can be seen as a first showcase of Metadata Explorer. ESRI was also selected by the US Government to develop the GOS portal (ESRI 2005). This can be the reason why display and interaction methods similar to Geography Network have been implemented in the US GOS.

It is interesting to underline here that a Metadata Explorer-like display is seen as an acceptable approach by many professionals in the GDI organizations and is thus implemented in many national and regional geoportals. A Metadata Explorer-like geoportal offers an interface that allows users to define what-where-when questions and to interact accordingly with the returned results, which are presented as a list of data titles and their corresponding abstracts and thumbnails. Examples of this include: the European Union geoportal (INSPIRE 2006a) and the latest version of Malaysian's geoportal (MacCGDI 2006). This style of display seems also acceptable for other companies that produce web mapping software and catalogues. This can be seen for example in IONIC's Red Spider (Ionic 2006), Conterra's Terracatalog (Conterra 2006), and also in an open source version - geoportal GeoNetwork's geoportal (GeoNetwork 2006). Using these web catalogues, search results are presented in a very similar fashion to the presentation of search results using the GOS interface.

It is also interesting to note that many countries and regional clearinghouses implement the 'old' FGDC clearinghouse-like interface. They include the Australian Spatial Data Directory (ASDD 2007), Germany's Geoportal Bund (Geoportal.Bund 2007), Asia Pacific Initiative (PCGIAP 2007), as well as the recent version of the United Kingdom's Gigateway (Gigateway 2006). With such an interface, the results that are returned are organised according to the publisher to which the matched item belongs to. To assess the matching, users need to peruse the results starting from selecting a specific provider link and subsequently, in order to assess a full-view of metadata descriptions, choosing a title from the metadata list. In this approach, users need to go back to the previous page to assess the other items offered by the same provider. Also, in order to visit items offered by other providers, they need to go at least two pages back. As a result, immediate indications regarding the overview of the results (e.g., ranking, abstract) and the presentation of each item (e.g., linkage with subjects and maps) are not available. The display is merely developed as a simple hypertext application. As clearly seen in Table 2.2, most of the geoportals in Pacific Asia and Africa implement FGDC's clearinghouse style, when cues and navigation tools to support the assessment of data suitability were not available.

In the case of the Netherlands' geoportal, called *Nationaal Clearinghouse Geo-Informatie (NCGI) Geografische Catalogus* (NCGI 2005), the results are displayed as a list of metadata titles with ranking information given for each data listed. It is possible to display the thumbnail of the listed item, but the data listed as well as their footprints cannot be projected onto the map, such that users can define their own area of interest. When the users click one of title links in the search results, a new window showing a more detailed metadata description appears on the screen.

### 2.2.2. Contextual inquiries of the geoportal's use

Contextual inquiry is one of the techniques used in user-centred design for gathering requirements. It can help designers or developers understand "the real environment people live in and work in, and it reveals their needs within that environment" (Beyer and Holtzblatt 1998; Kuniavsky 2003). According to a practical guideline (Kuniavsky 2003), five to eight people should be enough for the first round of inquiries, giving designers a proper idea of how the typical users accomplish their discovery task. Since the objective of the first inquiry is to develop an abstraction of requirements using the participants experiences, seven test participants should suffice. Studying the user experiences in defining questions and reviewing results using the Netherlands's GDI catalogue was the focus of this activity. This activity involved four participants within the International Institute for Geo-Information Science and Earth Observation (ITC) and three participants from other institutions. These participants have been working with geospatial data for their work and research, and are therefore assumed to be potential users for the Netherlands' GDI.

Two different tasks plus their related questions and instructions on how to participate were sent to participants through their personal emails. The first task was to find data with specific attribute values; the second was to find relevant data for planning a traffic survey campaign (see Table 1.3.). Both tasks were to be completed using the existing Netherlands' catalogue or geoportal (NCGI 2005). The participants were required to provide feedback related to functional requirements (e.g.,what functions were available and how did they work?), but not about data requirements (e.g., language, data availability, etc.).

Additional interviews were held for some of the participants in order to clarify and explore the feedback they provided. From feedback and interviews, two important findings can be summarised. The first is related to the user's understanding: users expect more flexibility to define questions and more insightful representation of search results. Secondly, although the portal or clearinghouse provides reasonably accurate results, users require more functions in order to ease the search process (such as the possibility to sort and compare datasets).

**Table 2.3.** Test form used to solicit test participants' experiences to the users interfaces of the Netherlands's clearinghouse.

## Contextual Inquiries

On the use of the Netherlands Clearinghouse (NCGI)

**INTRODUCTION**

The project aims to study the environmental impacts regarding a government plan to extend the road and railway networks in the urban areas in the southern part of Overijssel province. For this activity, set in your mind, that via the Netherlands Clearinghouse you can (probably) get the data you need.

**Task I**

One of your responsibilities is to make a "noise map". This map shows zones depicting the degree of noise "pollution" resulting from the existing road networks. From the term of reference you get a guideline that a noise map you produce should consider transportation, popuation, health indicators, road features, land use, traffic statistics, and population. Focus only to discover the road data. Things you should consider: the project requires you to use coordinate-system: RD, scale 1:100.000 or above.

| Questions related to Task I | The summary of test participants (TP) feedback |
|---|---|
| 1. Can you successfully define questions? How? | 1. Most of TP used keywords to search data |
| 2. What kind of tools would you expect? | 2. A combination of a map and keyword was expected,some TP also expect list of keywords and topics |
| 3. How did you decide the suitability of metadata? | 3. By paging through the results, which was considered time consuming |
| 4. If the portal has tools to allow you sorting and comparing metadata items, would you use them? | 4. Most of TP said "yes". |

**Task II**

Assuming you have successfully completed your job producing the noise map, your next task is to produce a map depicting useful information for the group to conduct a traffic survey. This survey aims at gaining the following information:

- *Measuring traffic noise, with emphasis on the distribution of sound levels over time and over population.*
- *Sampling people's perceptions of their noise environment (this should consider population distributions in terms of gender, type of works, and geographic distribution).*

For this taks, you are free to decide which data are suitable to produce such a planned map (What you need in general are the data about road traffic, road networks, and population distribution).

| Questions related to Task II | The summary of test participants (TP) feedback |
|---|---|
| 1. Suppose next to the online catalogue, there is an atlas, e.g., Bosatlas. Will you use the atlas to help you complete the Task II? | 1. All TP said "yes". |
| 2. If the catalog also contains the thematic map, e.g., population distribution map, and has ability to load particular dataset available in the GDI, will you use this possibility to improve your search efforts? | 2. An atlas would perhaps help TP to assist their search process. |
| 3. If each of item of the search results can be visualised on top of a thematic map, intended to help you discover data, would you use them? | 3. Most of TP would use such a feature. |

### 2.2.3. User requirements

It has been noted in Section 1.2. that Shneiderman, Byrd, and Croft (1997) proposes a 'four-phase' framework for search including *formulation*, *action*, *review of results*, and *refinement*. Based upon reviews and interview activities concerning this framework, two potential setbacks were identified in the current implementation of geoportals if one considers the ’four-phase’ framework. In relation to the ’formulation’ phase, to define questions, only some provide possibilities to express geographic interest in forms of geographic co-ordinates, geocoding, and map in one interface. The map used to define an area of interest has no possibility to be used as a thematic viewer. A map in geoportals is commonly utilized only to locate an area of interest. As such, during the search, no thematic information in relation to the user’s inquiry or search terms can be visualised on top of the map used to define an area of interest.

In relation to the ‘review of results’ phase, most of portals require users to assess the results thoroughly. Some geoportals, like the GOS and the Earth Science Gateway of NASA mentioned in Section 1.1.2, offer the possibility to visualize and cascade the selected item into a map viewer (in case the selected item is a WMS). Unfortunately, none offer the possibility to link results to specific thematic maps or to link to relevant web pages or applications, and only a few of them incorporate additional information that gives an indication of the matching (e.g., ranking, thumbnail or preview graphics). As a consequence, users must review the list item-by-item in order to judge which results best fit their needs. Such an interaction requires larger allocation of the user’s information processing capability than is actually required, and also reduces the user‘s experience with the interface (see Section 5.1 in Chapter 5 for some empirical findings on the general web cases related to this issue).

Subsequently, regarding ’action’ and ‘refinement’ phases of Shneiderman’s framework, they lack navigation tools to control the searching, and as shown in Tables 2.1 and 2.2, they limit the user’s interaction. As an example, a functionality to revisit items that have been visited before in order to compare their characteristic with others is not available. This is an interesting issue, as Metadata Explorer-like displays have a great impact on the design of today’s geoportals, but from an interaction design point of view, their navigation schemes could have been improved. One feature arguably missing in most (if not all) geoportals is the ability to sort the list based on a specific field of interest (e.g., the type of resource, data provider, scale, or topic of interest) during the ’review of results’ phase. In fact, the OGC specification for CSW incorporates the sorting function in its `GetRecords` operation using the `sortBy` keyword (OGC 2005). As a matter of fact, the ability to sort or rearrange the results is still hard to find in geoportals.

Other limitations include the lack of support for users to gain a quick overview of the results as a whole, and as an individual item. Instead of a quick overview, they usually require users to open a new context (e.g., a new pop-up window or a new page) in order to view the listed metadata item in more detail. As such, users may lose the overall context. As addressed in a well-known visual information-seeking principle (Shneiderman 1998): overview, zoom and filter, details-on-demand, relate tasks are among the fundamental tasks that should be facilitated in user interfaces for information search. This principle is useful, especially for the ‘review of results’, ’action’, and ’refinement’ phases as mentioned earlier. Since methods to get a quick overview or indication of the match (e.g., focusing on a specific item of results while preserving the context of the collections) are lacking, it is arguably difficult to compare the suitability of individual items (in the results) to search terms. In so doing, users who interact with the clearinghouse-type visual display (mentioned earlier) get less support to compare items of search results. Thereby, users have to drill down and follow a static trail of links in order to assess a single metadata description and to change the focus of interest. Thus, geoportal interfaces lack appropriate navigation tools and interactions to support data discovery.

From reviews and inquiry activities, it was found that current geoportals, including the Netherlands's geoportal, lack schemes for supporting user understanding and appropriate navigations tools. The lack of support for user understanding might deter potential GDI users. In the field of geoinformation visualization, the necessity to recognize individual and group differences for expert and non-experts in designing interfaces has been identified as one of important research agenda items in geovisualization (Cartwright et al. 2001; Slocum et al. 2001). The aspect of user diversity should be considered since the GDI initiatives will involve institutions and people with different skills and backgrounds (expertise). With more appropriate tools and functionalities in geoportals, users would have a more effective and efficient manner with which to interact with an interface in an attempt to find the data required.

Being successful in these two aspects will arguably increase the use of GDI in practice. For this purpose, the rest of this chapter will discuss the use of the atlas concept for developing a usable geoportal. By 'usable' it is meant that users can make use of the geoportal interface in an efficient, effective and satisfying manner.

## 2.3. The national atlas as a metaphor

To ease user understanding of learning and using the content presented, designers make use of metaphorical references in the designed user interfaces. As stated earlier, in Section 1.3., Erickson (1990) and Kuhn (1995) recommend that a metaphor candidate should have both understandable and meaningful functional definitions in order to support the user's tasks. Similar to these recommendations, as cited in (Howard 1998), Madsen (1994) specifies some strategies to develop a metaphor. These strategies are: listening to how users understand their computer systems, building on already existing metaphors, using predecessor artefacts as metaphors, and using a physical or real-world metaphor.

Those guidelines (Erickson 1990; Kuhn 1995; Madsen 1994) suggest that the familiarity and understandability of a source concept are crucial for selecting a new metaphor. On the familiarity of atlases, as mentioned earlier in Section 1.3., in many countries, users are familiar with atlases since they probably used them during their secondary school education. The use of atlases has been introduced (Ormeling

1996a; Ormeling 1996b). In relation to national atlases, a survey targeted at atlas users in Canada, confirms that an atlas will be the first thing that will be 'picked up' when they have questions about geographic names, economic development, or politics for a certain place (Williams et al. 2003). Groot (1979) concluded that "there are certain classes of planners, administrators, scholars, students and private industry" that depend on the national atlas. A recent study on a regional exploratory studies also indicates that the atlas will be considered as the first choice to complete required tasks (Elzakker 2004).

Basing the feasibility of the atlas as a metaphor merely on its assumed familiarity to users would provide a rather weak foundation. Firstly, as the design and intended use of atlases vary from one product or development to another, the evidence mentioned above is inadequate to help designers select the best of all atlas design choices. Questions regarding users acceptance and satisfaction for the form and concept of atlases remain unknown (Keller 1995). In the development of many atlases, it is difficult to measure whether the atlas has been interpreted and used as the authors intended. Secondly, the ways in which users make sense of, or really interact with national atlases (and other atlases) depend on many aspects, including users' topics of interest, experiences, and information processing skills. Rather than based on user familiarity with atlas displays, user understanding is more likely based on resemblances between atlases and familiar artefacts including maps, graphics, and books that they have used before. For further discussion on the concept of family resemblances or likeness for geovisualization, see (MacEachren 1995, p. 150 - 193).

It is therefore regarded more meaningful to consider the feasibility of an atlas to be a metaphor based on the atlas's ability to provide appropriate aids to the user's understanding. For this reason, the investigation is focused on the common structures (schemata) grounded in the concept of national atlases. As discussed in Section 1.3 (Chapter 1), they can be summarised as three important 'standard' schemata. Firstly, maps play an important role in displaying information. Secondly, atlases can carry out a specific role or an intended function. Thirdly, atlases have specific approaches of organizing the content (Bakker et al. 1987; Freitag 1997; Ormeling 1979; Ormeling 1995b; Salichtchev 1972; Symons 1979).

Howard (1998) sees the linkage between the schemata adaptation and the metaphors generation. Both schemata and metaphors are aimed at aiding user understanding. When there is no schema available to view a new type of graph, an existing schema for another type of graph is used first, until more appropriate schemas have either been created or updated (MacEachren 1995). Through a metaphor, users interact with an object using a special concept to successfully complete the task (Shneiderman 1998).

In an attempt to assess how the concept of national atlas can provide the required schemata for the target domain (i.e., a geoportal in the GDI context), the discussion will be as follows. Firstly, it will describe the map metaphor and its extension towards the atlas metaphor. This issue is related to the first schemata, as mentioned above: the role of maps to convey information. Subsequently, the organization of the atlas and its objective, referred to as the atlas information structure, is elaborated on a GDI context. This issue relates to the last two schemata of the atlas concept: the organization and objective of the atlas. The proposed strategies to link metadata and to represent data suitability in the atlas will be discussed afterwards.

### 2.3.1. From a map metaphor towards an atlas metaphor

What can be the best definition of map? A lexicographical record published in 1996 shows that 321 definitions of the word 'map' were found from samples of dictionaries, glossaries, encyclopaedias, textbooks, monographs, and learned journals of the period 1649 – 1996 (Andrews 1996). From those many definitions, the most common lexicographical approach is to consider '*maps as representations of the surface of the earth*'. In the strategic plan for the International Cartography Association 2003-2011, a map has been defined as:

> *"A symbolised representation of a geographical reality, representing selected features and characteristics, resulting from the creative effort of its author's execution of choices, that is designed for use when spatial relationships are of primary relevance"* (ICA 2003).

This definition can be an authoritative view for many cartographers. However, as use and practices of mapping (i.e. location or spatial depictions) using computer technology of new frontiers in many domain applications including medicine, biology, physics, mathematics, and astronomy are growing, an expansion of the map definition, for instance regarding the emphasis on the word "use" (Kraak 2006), is to be foreseen (Chen 2003; MacEachren 1995). When the emphasis is more on the word 'use', before a reader or a user can use the map, typically he or she needs to get to know first what kind of map or object it is.

In this regard, based on a radial category concept (Lakoff 1980), MacEachren sees 'map' as a case of a radial category (MacEachren 1995). A radial category has a clearly defined centre or prototype. Two orthogonal axes define its category space, one leading from image to diagram (related to map abstractness), the other from universe to atom (related to prototype scale) (Figure 2.2). Typical maps, termed as prototypic maps (most probably including maps envisaged in the definition of map from ICA), inhabit the middle ground of the space. In such a pattern, the 'map is seen as a fuzzy radial category. Being fuzzy, the prototypic map involves "some processing, and therefore some potential for bias (but also becomes functional due to this processing)" (MacEachren 1995). In this sense, MacEachren suggests that a depiction may be considered to be a map if it can function like one, e.g., to plan a trip.

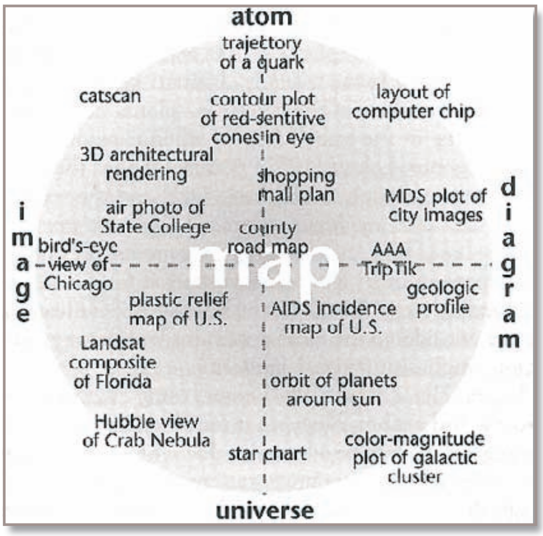



**Figure 2.2.** A map as seen as a radial category (MacEachren 1995) (reprinted with a permission of Guifold Press).

As such, a map is a metaphor in its own right (Muehrcke 1992). As Muehrcke (1992) illustrated that through a map, cartographers ask the map readers to think that points, lines and areas arranged on a paper (or on a screen) are equivalent to a multi-dimensional world in space and time. However, for its full meaning, the map readers must go directly to the real-world depicted. Maps can be used to generate visualization tools to support representations of data (either these data are geospatial or non-geospatial in their nature) according to a specific location reference. An example on how a map can be used to present information related to geographic location includes a process of assigning geospatial position (in forms of geographic or map co-ordinates) to any object that has a geo component (e.g., street address, news, IP address), termed 'geocoding'. Today, many examples of geocoding can be found thanks to the rise of mapping mashups (see Section 1.3.), projecting anything with a geo component into a web map (see Figure 2.3 for an example).

When the location reference or the emphasis of visualization is related to information space (instead of geographical space), data representations can involve **spatialization** efforts. Spatialization refers to an effort to make high-dimensional information spaces more accessible to human cognition by presenting them in a low-dimensional, representational space (Fabrikant 2000b; Skupin and Fabrikant 2003). It includes, for example, the use of an earth landscape (i.e., involving the surface elevation and distances between peaks) to provide insights regarding the keyword's match in support of users' interaction with a library collection (Fabrikant and Buttenfield 2001; Skupin and Fabrikant 2003)(Figure 2.4). Clearly, maps pose many potentials as metaphors in order to ease user understanding and to imply the predetermined meaning for geospatial and non-geospatial information access and retrieval purposes (see also e.g., Aufare and Trepied 2001; Cartwright 1999; Chen 2003; Gould and McGranaghan 1990).

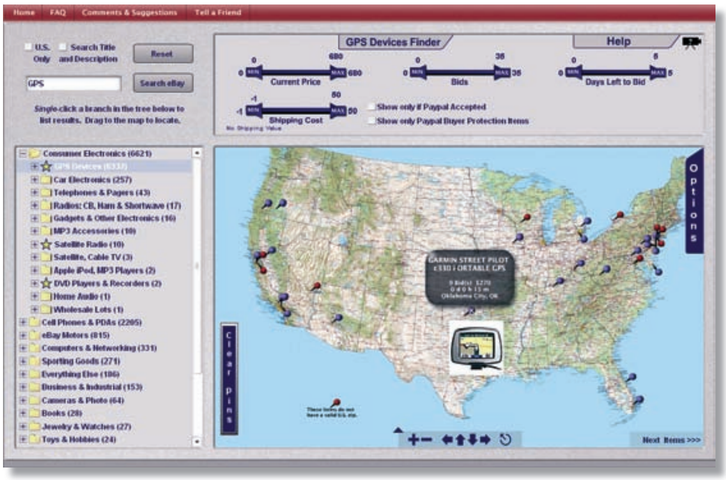



**Figure 2.3.** An example of a geocoding mashup: The items auctioned in a commercial web auction system can be plotted onto the map, providing an overview of the locations of the item wanted, including their thumbnails and short descriptions. The categories that reside in the left window can be projected onto the map by dragging them on top of the map (source: www.auctionmapper.com).

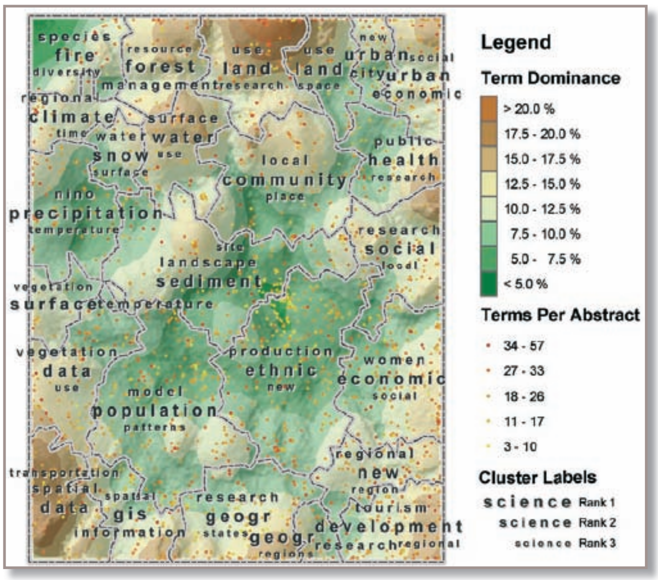



**Figure 2.4.** Spatialization: visualizing document clustering of several thousands of American Association for Geographers (AAG) conference abstracts. It shows the distribution of individual term used in the abstract and the dominance of the terms across 25 ranked clusters. It also indicates how much the highest ranked terms dominate particular regions (source: Skupin and Fabrikant 2003).

Ever since ancient times, maps have been used as cognitive artefacts to extend memory and ease information processing (Tversky 2000). As cited in MacEachren (1995), Wood (1992) argues that even in cultures that do not make any tangible maps, active mapping activities were practiced. In addition, spatial concepts, concepts that emerge from constant human spatial experience, i.e., human interaction with the physical environment, are concepts that humans "live by in the most fundamental way" (Lakoff and Johnson 1980).

With regard to human interactions with maps, which always involve the human understanding of spatial concepts, MacEachren (1995) states that humans do indeed have knowledge of a general map schema. Here, the schema can be seen as a "plug-and-play cognitive structure" for representing and organizing knowledge (MacEachren 1995). A **general map schema** includes the following (MacEachren 1995, p.184): "1. A theme is linked to geographic position via geographic co-ordinates; 2. Objects and parts are described in terms of visual variables; 3. Symbol referents specified in terms of explicit or implicit assignment in a legend; 4. Text grouped with object labels or the specific absolute value of an object; 5. Relative position of objects specifies relative position in geographic space". It can be seen then that a map involves *structure*, "an assemblage of symbols of prescribed meaning ordered according to a system of positional rules of interrelationships", and *visual images* to portray phenomena or topics of interest (Peuquet and Kraak 2002).

Information displays will be used effectively, when the designed display employs an identical schema to the schema used by potential viewers, or when the display provides an adaptation of the general schema that potential viewers utilize (MacEachren 1995). In many cases, the use of maps can successfully facilitate, among others, visual thinking and visual communication on a specific topic or theme of interest (Kraak 2006; Peuquet and Kraak 2002). Considering the strength that a map can provide to help viewers explore, navigate, and make sense of information presented, the map metaphor can be of help to GDI users, not only to define an area of interest, but also to ease the search process and to provide an easy access. As a GDI initiative often deals with a multitude of topics of interest, an adaptation to map schemata suited to a national GDI initiative is needed. In order to achieve this, a collection of multi-thematic maps of a country is considered as a possible candidate. As mentioned in Section 1.1.3, a collection of maps including thematic maps of representing syntheses is usually regarded as atlas.

The next section will deal with the structure that organizes the map schemata and their relationships with related images and graphics.

### 2.3.2. Atlas information structure

When one observes the notion of atlases, it can be seen that there are three possibilities to look at atlases. By their formats, atlases can be divided into paper atlases and electronic atlases that can be view-only, interactive, or analytical electronic atlases (Kraak and Ormeling 2002). In both paper and electronic atlases, the scope of atlas use is very broad. By their content, atlases are used for organizing assorted geospatial information in which the extent of data compiled is tailored either to the geographic region the atlas deals with, for example, a world atlas, national atlas, urban atlas, or to the theme of the atlas, such as a road atlas, climate atlas, maritime atlas, physical geographical atlas, or even an atlas of the human body, or a cyberspace atlas. However, when looking at the structures and objectives of atlases, they can be seen as intentional combinations of specially structured maps compiled from geospatial data sets and based upon specific objectives (Kraak and Ormeling 2002). The objective or function of the atlas is determined depending on the need. It might be, for example, to provide a solid tool for environment analysis, or even just to communicate the management of natural resources of a specific region.

Of those three possibilities to look at atlases, this section will concentrate on the structural definition of the atlas. In relation to this, topics are specified (in the atlas) based on the objective and contents to be presented. Each topic is represented by relevant maps to deliver a coherent visualization about one or more specific themes within the topic. This allows users to choose the focus of interest from one map to another, either via sequential or random access (Kraak and Ormeling 2002) (discussed more detail in Chapter 5). Maps in electronic atlases can be considered as an interface to spatial databases permitting users to pan and zoom, and to get data and links beyond the symbols (Buckley 2001; Frappier and Williams 1999; Neumann and Richard 1999). Atlas maps symbolize related information of various topics in a uniform format of representations, such as using the same scale, or generalized similarly, therefore allowing for comparisons. The type of comparison can be of a topical, geographical, or temporal nature (Kraak and Ormeling 2002). This makes assessing the relationships between two or more topics concerned possible (see Figure 2.5 for an example).

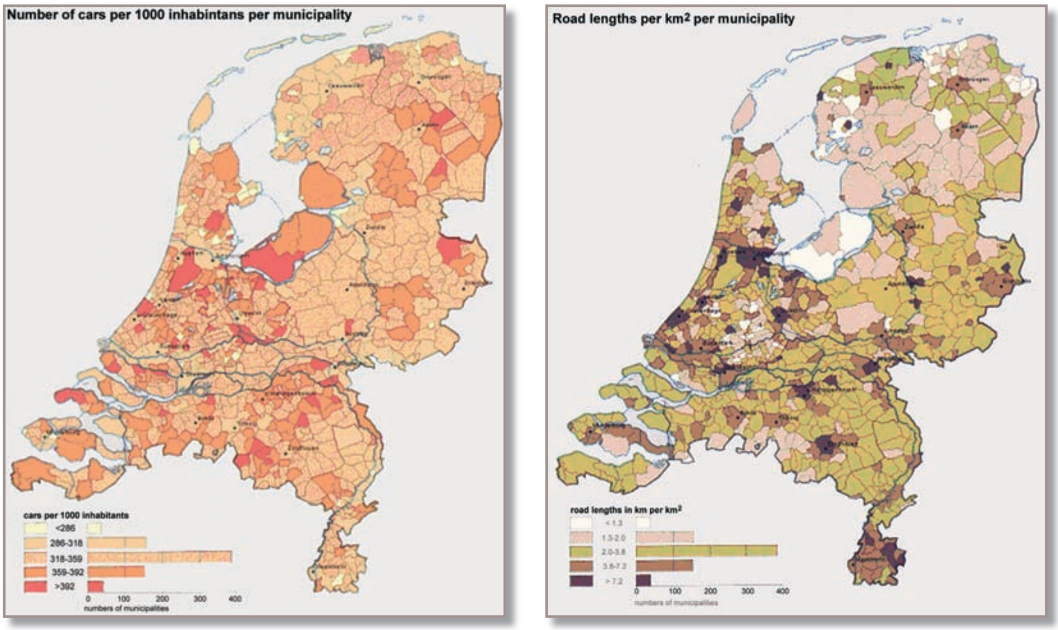



**Figure 2.5.** An example of how the maps in an atlas can be used to provide a comparative view regarding a topic. The left map is concerned with the number of cars per 1000 persons per municipality, while the right map depicts the road lengths per km2 per municipality (translated with permission from: Atlas van Nederland 1985).

The most significant role for web portals is the capability to facilitate the needs of users to initiate searches. The recommendation for developing “search interfaces” is attributed to Shneiderman, Byrd, and Croft (1997), where they describe several principles of search interfaces, such as striving for consistency, offering informative feedback, permitting easy reversal of actions, supporting user control, reducing short-term memory load, designing for closure, and providing shortcuts for experts. The atlas, especially the electronic one, commonly has at least three important aspects that are relevant and confirm some of the above principles. The fact that it provides consistent and easy navigation means that it strives for consistency and permits easy reversal of actions. Additionally, the ability to extend possibilities to access the relevant data and links is relevant to the principle to offer informative feedback. As the atlas enables users to build comparisons or alternatives, users can gain more support in order to control the interaction. These supporting aspects (navigation, access, and comparison) as part of the search interface for the GDI are closely related to the organization of the atlas contents.

The organization of the atlas contents is defined through the atlas information structure. The structure controls the scope of the topics and maps as well as the links connecting an individual map to a set of supportive media. Media, such as tables, charts, images, movies, and explanatory texts, are associated with individual maps as linked multi-views for delivering narrative means of geospatial information exploration. The atlas can be used to deliver data that have been “knowledge engineered” and “expert interpreted” to expose relevant information with “telling of a story” style (Keller 1995). This setting is aimed at providing possibilities to peruse corresponding information for each thematic map while the navigation range is limited within the context of the topic chosen. Navigation options and interactivities offered in the user interface rely on this structure.

A typical characteristic of the atlas information structure is the arrangement of maps. The arrangement based on the area in combination with the scale emphasizes the significance of the region being presented (Ormeling 1995b; Talwar et al. 2003). The arrangement of topic and linkage to related tables, charts, movies or texts for each composed map provides the narrative means for understanding geographic phenomena (Buckley 2001; Ormeling 1995b). Electronic or digital atlases have tools that facilitate user interaction and allow extensive exploration based on the arrangements (Buckley 2001; Frappier and Williams 1999; Hurni et al. 2001; Neumann and Richard 1999).

Like a map schema, which can be seen as a combination of structure and visual images of emphasis of interest, the atlas schema should also be seen as a blend of information structure and its objective. Regarding the atlas as a metaphor in the GDI context, as stated in Section 1.4, its objective is related to GDI access, in which metadata plays a crucial role. Hence, it is essential to incorporate metadata of geospatial resources (including offline datasets available in the GDI) into the structure (see Figure 2.6). In such a setting, it is also possible to compare metadata items based on their geographical, topical, and temporal coverage. As an example, one can judge the importance of a specific region by seeing how many datasets of the transport network are available in comparison to surrounding regions. Yet, analysis can go further by comparing metadata items with the thematic map, for example contrasting patterns of those metadata items with geographic distribution of cycling roads or comparing the density of metadata items with a trend of particular topics. The notion of data and metadata comparisons with the use of map has been introduced for geovisualization, for example by (Howard and MacEachren 1996).

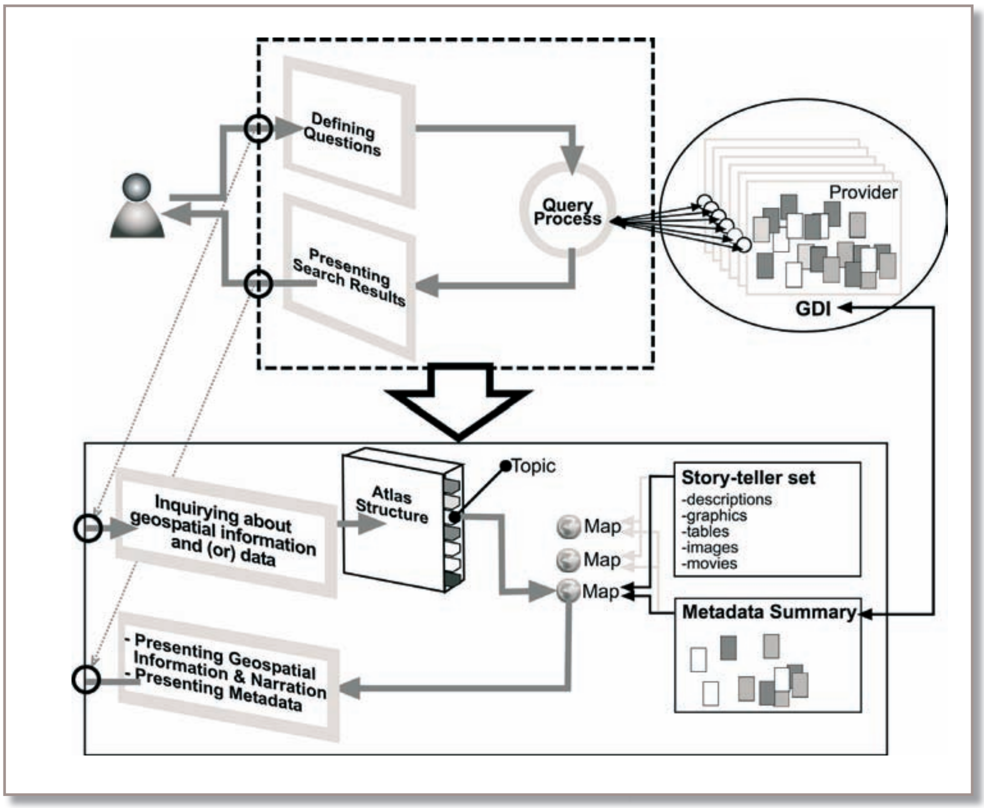



**Figure 2.6.** The search strategies in the available geoportals (the top rectangle with a dashed outline) can be extended with exploiting the atlas information structure (bottom rectangle with a solid outline). In this structure, each topic comprises of related maps. Each map contains a set of layers from the atlas databases that represents a specific aspect within the topic designated. To enhance the narrative means, each of the maps is supported by related information in the forms of linked graphics, tables, or text descriptions. A set of information resources regarding the data availability (in the forms of graphics, table, and text summaries) is also utilized to permit user investigation.

## 2.3.3. Metadata summaries: The link to GDI metadata

From the users point of view, geospatial resources will be more accessible only when providers let users know the characteristics of the resources they posses as well as information on where and how to access the resources. The characteristics of geospatial resources (and here especially referred to geospatial data) can include geographical coverage, quality, source, and lineage. They are expressed as metadata elements (and usually as eXtensible Markup Language (XML) elements), conforming to a particular specification, e.g., ISO 19115 (ISO/TC211 2003). On the data provider's side, such documentation will be useful to support data management.

This study seeks to find a way to effectively link the GDI data or resources to a map in the atlas. The map is seen as an index to which relevant metadata and other geospatial information are related. As shown in Figure 2.6 (shown above), this is realized through the use of metadata summaries. In fact, the 'official' or common approach to index metadata is with the use of a clearinghouse or collection-level metadata (CLM) mechanisms (Tsou 2002) (see also Chapter 4). The clearinghouse refers to a distributed system of metadata servers for data discovery which is implemented using the search and retrieve protocol known as Z39.50 or ISO 23950 (Nebert 2004a). This can be seen as a registry service that applies a mechanism of locating 'query-matched' metadata within participated nodes of providers one at a time. See also the notion of clearinghouse for cartographic information in (Koop and Ormeling 1990; Ormeling and Koop 1990). The U.S. FGDC Clearinghouse is a well-known example of this mechanism. The collection-level metadata meanwhile, in essence, can be differentiated on two levels: *first*, the metadata objects level that require detailed elements encoding, and *second*, the collection level that specifies in which collection the metadata objects can be found. When users search for a specific metadata item, through the interface of a central digital-library, the mechanism applied first is to visit the collection-level and then search 'query-matched' items within the collection (Goodchild and Zhou 2003). A well-known example for this is The Alexandria Digital Library.

From a perspective of users seeking data, the clearinghouse mechanism has disadvantages because of its current implementation. As stated earlier, in Section 2.2.3, reviewing the search results through a clearinghouse interface is considered to be ineffective and inefficient. Further, in order to develop a direct link between the map in the atlas and the clearinghouse system, it would require considerable efforts to adapt and filter the search results every time a user sends a query. Hence, the clearinghouse approach is arguably not suitable for the atlas metaphor design. The CLM approach aims at improving the clearinghouse system by balancing the tradeoffs between simplicity, which places a minimum burden on providers to participate; and richness functionality, that is, richness elements (Janee and Frew 2002). The CLM might work well for geospatial libraries managing large datasets, maps, and images either digitally or manually. However, for the purpose of this work, it is considered to be unsuitable. With the CLM approach, information at the metadata level should be offered in detail. Additionally, it is arguably difficult to link a map in the atlas to the collection level component since the collection might include various topics of metadata sets. Also indicated in Janee and Frew (2002), as one of the CLM limitations, is the provision of a set of ranked results returned from a joined-query (involving geospatial and temporal coverage of one query, for example). This would be difficult, since the underlying statistics of such a joint condition are gathered separately. For this reason, this approach is also not used; instead, the notion of metadata summaries is introduced within the atlas information structure.

A metadata summary is a concise group of metadata elements specifying characteristics of the datasets. Describing data characteristics might require at least forty elements as suggested by Hunter, Wachowicz, and Bregt (2003), but here the purpose is to provide a visual overview at an initial stage before accessing potential datasets. For this reason, the metadata summary only deals with the geographical coverage, topical coverage, temporal coverage, accessibility, and the usage (like scale, format, and data type) of the data. This decision is also based on the design guidelines for information search and visualization: "overview first, zoom and filter, then details on demand" (Shneiderman 1998). In fact, this is also in accordance with the characteristic that usually an atlas has that is being able to provide a concise and coherent visualization of a specific theme.

In the atlas information structure, these summaries are linked to the individual maps based on the similarity between the thematic content of data sets and the theme of the map. The elements of the summaries are represented as symbols to help users visually locate the data required. As an example, the geographic bounding boxes of metadata are represented in Figure 2.8 as stashed rectangles with the name of the provider plotted on top of them. A detailed discussion on the technical aspects, including the symbolization, of metadata summaries is given in Chapter 3.

As mentioned in the beginning of Section 2.3, Howard (1998) sees the linkage between the schemata adaptation and the metaphors generation. Thus far, three basic components of the atlas schemata (i.e., the role of maps, the structure, and the objective) and their adaptation in the context of the GDI have been discussed. With regard to the metaphor generation, by having such an adaptation, the national atlas is intended to activate the so called 'cognitive schemata' (Slocum et al. 2001), so it can be applied appropriately to be the source domain and used to help users make sense of the target domain (the national GDI). The term 'national atlas metaphor' means that the national atlas is used to organise and represent not only various thematic spatial information in the country, but also information regarding metadata within the national GDI through functionalities that are commonly offered on paper and especially in electronic atlases, e.g., navigation and browsing based on area or topic, map syntheses, GIS analysis, and so forth. As such, the target (the national geoportal and generally, the GDI) can be used more by GDI users for exploration and analysis of geospatial resources available in various topics and at varying levels of jurisdictions throughout the country. Using the current portals, those functionalities arguably do not yet exist in a single user-interface. The next section will step further into this topic by discussing the development of the atlas metaphor.

## 2.4. The use aspect of the atlas metaphor

### 2.4.1. Characterizing user tasks

The previous section provided an analytical observation into the reasoning about the design of the national atlas as a metaphor. Such a conceptual background is necessary to set a framework in which design issues are explored and assessed. Howard and MacEachren (1996), among others, recognize conceptual, operational, and implementation levels in the development of interface design for geovisualization. Characterizing user tasks is an important step in order to address fundamental issues in the conceptual level. As already discussed in Section 2.2, defining queries and assessing the search results are important steps in performing search tasks. The geoportal should be considered as a unique search interface since the search task is not just merely about finding the fact, but more about locating the data with geographical, topical, and/or temporal hints leading to useful directions.

Therefore, the discovery task that is required, can occasionally be more extensive than what is described in (Shneiderman 1998) as "task actions" in fact finding. In the geospatial portal, the discovery task can range from ***tightly defined tasks*** to ***loosely defined tasks***. With the first task, the aim of user actions is to locate *specific* geospatial data or services that fulfil their needs and to identify the possibilities of accessing them. The terminology refers to the task for solving "well-defined information seeking problems" (Pirolli 2003, p. 165). For instance, consider a task to obtain a specific set of land use data, required by a farming consultant for a project with strict specifications, as such, that the data must be: (1) in vector format preferably in a shapefile, (2) covering the Province of Overijssel, The Netherlands at a scale of 1:100.000, (3) produced not earlier than 2002, and (4) using the Dutch *Rijksdriehoeksmeting* (RD) co-ordinate system**.** Loosely defined aims at locating data in which the fitness for use is not simply dependent on matching values of certain elements in metadata. Their fitness for use can be determined by the purposes or motivations of data discovery. This can be, for instance, for *study*, *planning,* or *problem solving* purposes with no detailed requirements given at the start of the task. Task II in the interviews (see Section 2.2) can be considered as an example for this type of task. To complete the task, a researcher would seek data that have appropriate currency and geographic distribution in the first place, rather than concentrate the search process on finding a certain data format or a particular resolution.

At an operational level, the developed atlas metaphor provides interfaces to perform required discovery tasks. The interfaces offered should require minimum effort or require a minimum learning curve for users to use and interact with them. The modes in interacting with web pages, searching and browsing, are well known to Internet users (Beale 2006; Bodoff 2006). Browsing, that is, searching by links offered or opportunistic behaviour, is effective where users questions are inappropriately expressed by query for some reason, or in cases where the information and the context can be easily extracted during browsing, e.g., finding special drugs for special diseases. Searching, that is searching by query or structured behaviour, is a favourable mode to obtain specific information quickly (Olston and Chi 2003). However, as also described in Olston and Chi (2003), both have disadvantages. Browsing is not an efficient method of locating specific information, since users must visit link-by-link and examine the content. Also, searching often provides disappointing results when irrelevant information is presented.

Combining benefits of both is a common approach in providing enhanced information retrieval possibilities. Manber, Smith, and Gopal (1997), for instance, developed a system in which the search functionality for each page is adjusted based on the context of that page. Olston and Chi (2003) proposed the adjustment of browsing cues such as hyperlink variables (e.g., fonts and colours presented on the page) for each item within the search results according to the importance of the keywords submitted. Browsing and searching can also be interchanged by using techniques such as subject categorization, faceted metadata, and semantic web in their metadata management. These techniques have been applied to increase the usability of portal interfaces (Hearst et al. 2002; Hyvonen et al. 2004; Schreiber et al. 2001; Yee et al. 2003).

From the interviews (see Table 2.3.), it can be seen that users prefer to use keywords-searching to complete task I, which is seen as a typical tightly-defined task. Meanwhile, to help them complete task II, seen as a typical loosely defined task, most users wanted dataset classifications and browsing possibilities. These findings strengthen the arguments for good searching and browsing strategies as described previously.

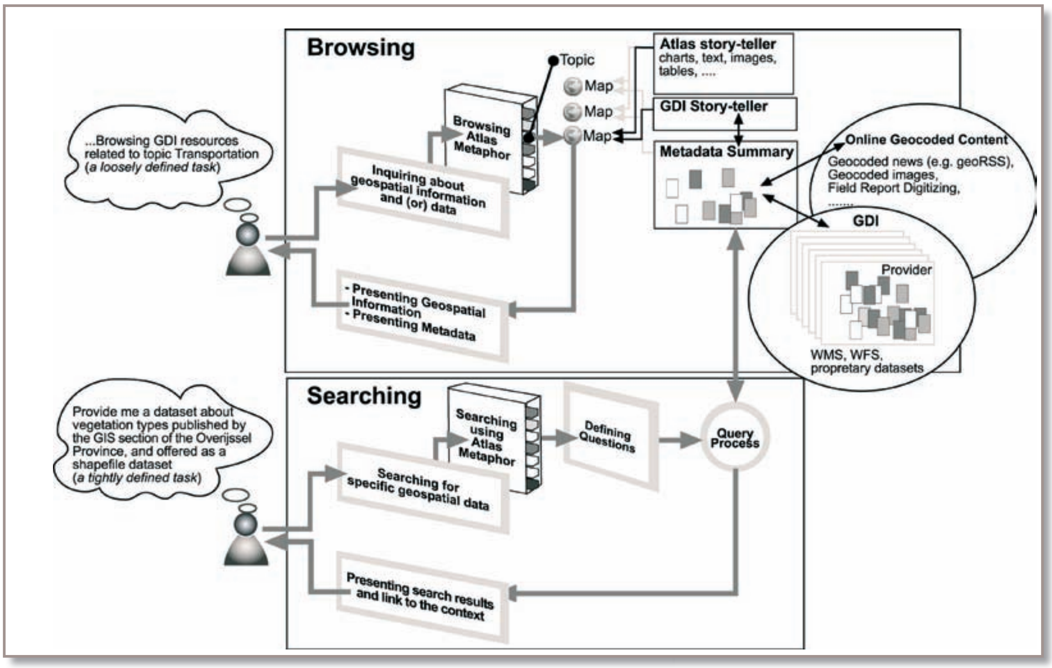



**Figure 2.7.** Tasks to discover data available in the GDI can be accomplished through browsing and searching via the atlas metaphor.

Generally speaking, atlases support directed search and random browsing (Ormeling 1992). In the case of the atlas metaphor, as seen in Figure 2.7, the atlas information structure controls the interface presentation in which the browsing mode can be used as a starting point for completing loosely defined tasks, whereas searching can be applied to perform tightly defined tasks. The next two sections discuss the browsing and searching strategies in more detail.

### 2.4.2. Browsing for completing loosely defined tasks

This section will examine the use of the atlas metaphor to browse geospatial information and metadata. The discussion concentrates on data discovery in a GDI.

As mentioned earlier, browsing is only effective when the context can be easily extracted during the browsing interactions. This requires a clear structure of the webpage in order to allow users access to a broad range topics of geospatial information, via maps as well as associating the content to the relevant information. The functionalities offered are as follows.

**Focusing the interest**

Depending on the users' needs, browsing geospatial information using the atlas can be based on the area or the theme of interest. After selecting the area of interest, users can switch to a particular theme available for that area. This type of navigation should satisfy users looking for data with a certain extent or administrative boundary. On the other hand, in order to facilitate users looking for data with a certain theme, a hierarchical menu of available topics and thematic maps can be used. An ability to interact with the temporal dimension of the map and data offered during the data discovery is not the focus of this study.

**Maps and metadata storytelling**

Whilst using the information structure, relevant media, e.g., tables, charts, images, movies, and texts, can be organized so that users can explore and link to relevant information for each map that is opened. The media can be accessed via a set of interfaces during browsing. Such a set of interfaces is termed by Cartwright (1999) as a 'storyteller'. This can be of an atlas storyteller and a dataset storyteller. The atlas storyteller has the capability to provide relevant information in the form of tables, charts, or descriptions concerning the selected map. The dataset or GDI storyteller provides links to access helpful information about the data. For example, it provides possibilities to load relevant metadata on top of the selected map, to see thumbnails of the typical data offered, or to study data statistics that are relevant to the chosen topic.

**Metadata mapping**

Through the dataset storyteller, users can visualize the relevant metadata on top of a specific map. Mapping metadata to facilitate loosely defined tasks requires effective symbolization. Each metadata element can be represented on top of the corresponding map or another specific map when requested. Projecting data characteristics over the map can present a new and surprising perspective to support data suitability assessment. This supports so-called 'opportunistic behaviour browsing'.

The ability to project metadata footprints allows one to identify the relevance of metadata by investigating two aspects, (1) the geographical nature and (2) the topical nature. The first will give an indication of density (useful to study the concentration of data availability), pattern (useful to distinguish the characteristics of data availability), and extent (useful to examine the coverage of data). The second offers possibilities to derive, for example, trends that relate density and pattern with phenomena found in the thematic maps allowing the user to study the tendency of the available data, or the topical relationships between items and geospatial phenomena that are depicted.

This metadata mapping is also applied to support comparisons among metadata items and between maps and metadata items. Even though comparisons can be extended and involve more symbols and more maps, it should not disturb the readability of the map.

### 2.4.3. Searching for completing tightly defined tasks

This section will discuss the use of the atlas metaphor to search for geospatial information and metadata.

In order to look for specific information or data, functionalities supporting tightly defined tasks must be offered. As mentioned earlier in Section 2.4.1, the searching approach is effective in obtaining specific information quickly. This requires functions to formulate questions that are either very specific (having some detailed requirements) or very short (a single keyword) as well as functions to assess the search results.

**Formulating questions**
Query functionality is essential, since the aim of the search is to look for data matching the questions at hand. The scope of the questions can be combinations of geographic, topic, and time properties, i.e., where, what and when. In case users need to pose questions in detail, a list of possible values for some elements of metadata summaries needs to be shown to the users. In addition, regarding where, what, and when questions, there should be several options to define the query in which one of them might be more preferable and suitable to the user's need. Thus, regardless of the type of user, they should all have sufficient knowledge to initiate searches.

Ideally it should also be possible to combine questions concerning spatial analysis and data suitability. An example is the need to find available data concerning road maintenance at the provincial level, for all provinces having populations over two million.

**Visual search with metadata mapping**
After submitting questions, users need to assess the search results. To support users in assessing the match between their questions and the results, multi-linked views are offered to enable users to perform brushing and comparison. Brushing gives users the opportunity to highlight a specific item of interest in the search

results as the user clicks the mouse. Correspondingly, any co-related information is simultaneously highlighted in other linked views.

Similar to what has been described in the browsing mode section (2.4.2), metadata elements can be mapped on top of the map. Here the items visualized are the metadata summaries found as the search results. Upon request, search results can also be projected over its associated thematic map. Users can examine one item among other items that topically are relevant (the same function as offered in metadata mapping in section 2.4.2).

To effectively assess data suitability, the possibility to examine the relevance of the search should be offered. This is different from solutions that offer a ranking system to indicate the relevance, as implemented for example in (NCGI 2005), where the atlas metaphor looks for an alternative display that capable of providing graphical representations to express the importance of the results (see the bull's-eye view in Chapter 3 and 4 and parallel co-ordinate Plots in Chapter 5). This graphical representation is intended to provide a means to re-check the target, i.e., the data required, with a visual search. In order to verify the initial findings users can go to the provider's site to examine the full XML elements of the metadata, or if available, to view a sample of the dataset.

## 2.5. The design aspect of the atlas metaphor

A design rationale specifies the reasoning behind a design decision (MacLean et al. 1989; Shum and Hammond 1994). This may include the justifications, alternatives, tradeoffs, and the argumentation leading to the design decisions (Lee 1997). The goal of the design rationale is to make sense of the development of an artefact, where, in this study, it is an atlas metaphor. Task-artefact framework (Carroll and Rosson 1992; Carroll and Rosson 2003) can be used to guide and reason the design development. The argument for this approach to be valid is that most technical activities in human-computer interaction can be captured as a transaction between tasks and artefacts (Carroll and Rosson 1996). Tasks that users need to do, which are successfully or problematically accomplished, specify requirements for new artefacts.

The functionalities discussed in Section 2.4.2 and 2.4.3 are considered as a reflection of the possible uses of the metaphor. In other words, those two sections specify in detail tasks that users might complete using the metaphor. The present section will further describe the corresponding user interfaces intended to accommodate the discovery tasks. The detailed discussion on the use of the task-artefact framework and scenario-based design and evaluation in this study will be given in Chapter 6. This section will only concentrate on providing descriptions on the operational level of how the atlas interfaces can be helpful in providing the required functionalities. The atlas interfaces were framed through a rapid prototype. The section will first describe the motivation and some technical details to create a rapid prototype. Subsequently, the results of the rapid prototype will be used to describe interfaces corresponding to functionalities described in Section 2.4.2 and 2.4.3.

### 2.5.1. The use of rapid prototype of an atlas metaphor

A rapid prototype refers to a result of a prototyping activity in the early stages of an interactive system development (Gordon and Bieman 1995; Rosson and Carroll 2001). A well known example of a rapid prototype development in geospatial information retrieval is The Alexandria Rapid Prototype (ARP) (Frew et al. 1995). The ARP was used to evaluate some design and technical implementation issues towards the development of a final prototype.

For this study, the activity of rapid prototyping was aimed at providing an immediate yet convincing 'road map' regarding the overall development of the atlas metaphor. The rapid prototype was created to serve two objectives. Firstly, it was used to primarily assess at the operational level whether the concept proposed is feasible to be implemented. Secondly, it was used to elicit many design questions concerning the concept developed, such as the design of metadata mapping and the data management. This section will only deal with the first objective of the prototype. The discussion related to the second objective is given in Chapter 3.

To develop an immediate application of the atlas metaphor, the rapid prototype was created as a web application combining Flash user interfaces (UI) and an ArcIMS map service. The use of UI components that are available through Adobe Flash (formerly Macromedia Flash) software (Adobe 2007) speeds up the creation of the required interfaces for collecting the user's inputs (e.g., tree menu, accordion menu, textbox, drop-down menu). Meanwhile, the ActionScript libraries available from examples and components exchanged in User Forums in ESRI Support Centre (ESRI 2004) are used to connect Flash user interfaces to ArcIMS map services.

The atlas information structure presented in Section 2.3.2 can be seen in a simple way as the directory of the atlas content. It is used to organize user interactions via the atlas interfaces as well as to organize the links to the metadata summaries and storyteller datasets. For the rapid prototyping purpose, storyteller data sets, interactive legends, and the map window are presented as Flash movies using the SWF format. As mentioned above, the use of UI components makes the development of the required interfaces straightforward.

### 2.5.2 Interfaces built to support browsing

The previous functionalities aim at supporting user activities in browsing the atlas for data suitability assessment in the GDI. A set of interfaces was designated to provide those functionalities.

#### Navigations Tools

In order to facilitate browsing information in the atlas, a set of windows for map selection was provided. For each thematic map selected, the related geospatial information and the related information about the corresponding metadata are displayed as a structured link in a window. This window can be opened as an atlas storyteller or dataset storyteller, depending upon the requirement. The structured links correspond to relevant media categorized and based upon their formats to allow narration and exploration.

When a map is displayed, users can interact with it via a set of navigation tools, e.g., zooming in, zooming out, panning, and identifying attributes. The legend window provides clickable buttons to control the appearance and symbolization of the layers of the geospatial data displayed. Additionally, one can switch between the map legend and the metadata legend. This provides support so that users can control the display of metadata mapped on top of the map. Users can then decide which symbols representing data suitability would be displayed. By clicking the buttons, users can switch on or off the geographical coverage and the topical coverage (Figure 2.8).

### Map Window

A map view is essential since the goal of the atlas metaphor in this instance is to provide a tool for users looking at suitability of geospatial data. To support this, conventional mapping techniques such as choropleth mapping and dot mapping are used frequently to depict thematic phenomena in an atlas. Metadata mapping is realized by superimposition and multiple attributes mapping.

For each map displayed, multiple media, e.g., tables, charts, images, or movies related to a map can also be loaded on demand. In addition, attributes relating specific layer and metadata attributes can also be displayed in the map window. Each attribute is represented using particular symbols and can be mapped on demand using a metadata legend (Figure 2.8).

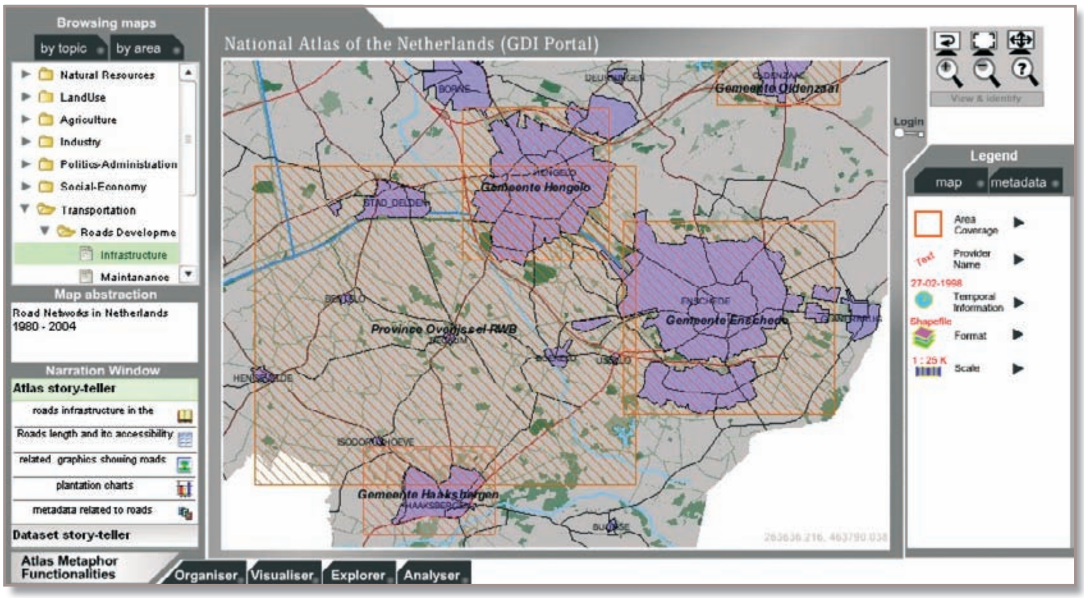



**Figure 2.8.** The interfaces and the contents in the prototype of the atlas metaphor are organized conforming to the atlas information structure. When interacting with navigation tools and interfaces, users are browsing the content via that structure. Users can benefits from this strategy when completing loosely defined tasks.

## 2.5.3 Interfaces built to support searching

Explorer tab options are provided to formulate questions in order to look for data. There are three sub tabs: (1) where, (2) what, and (3) when (Figure 2.9). The 'where' sub tab is used to define the area of interest. This can be defined either by expressing its administrative unit, drawing a rectangle on the map, or just typing a particular place name.

To express questions or queries concerning topical coverage, compatibility, and accessibility within the 'what' sub tab, users have several possibilities of specifying the kind of geospatial data to be located. One can use simple keywords or be more specific. With the use of tree menus, one can specify in which '*category'* the data are grouped (based on the ISO19115 subject of topics), and/or give the '*format*,' the '*scale*,' and the name of '*providers*.'

The 'when' sub tab is used to submit a temporal question. The temporal expressions in metadata can be either the time of acquisition or the time of publication. In addition, the temporal change can also be expressed as the query, e.g., to ask for data about changes in land cover from 2000 to 2004 for a particular area.

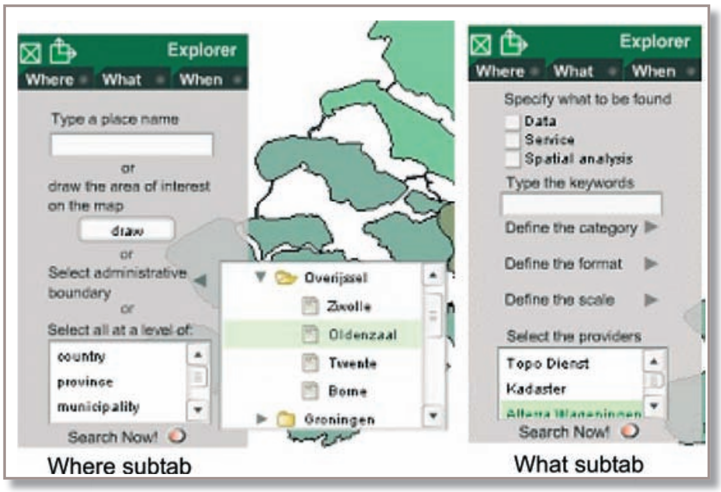



**Figure 2.9**. Defining geographical and topical properties using the Explorer" interface.

**Presentation of search results: listing table + overview + link to map**

The items of metadata summaries that match the questions submitted are listed in a table. The elements of the summaries are transformed as the fields of the table. Furthermore, the items can be sorted based on the field that is considered as the focus of the discovery. Ascending (or descending) sorting can be used to group all data based upon the value of a specific element by clicking the 'format' field, as an example, grouping data that have the shapefile format (Figure 2.10).

A thumbnail and short abstract for each item selected can be viewed to get a general impression of the data. To better differentiate between the items, each item can be mapped either into the related thematic map, as mapped in the browsing mode, or into the basic map. If needed, users can be directed to the XML definition of the data within the provider's site.

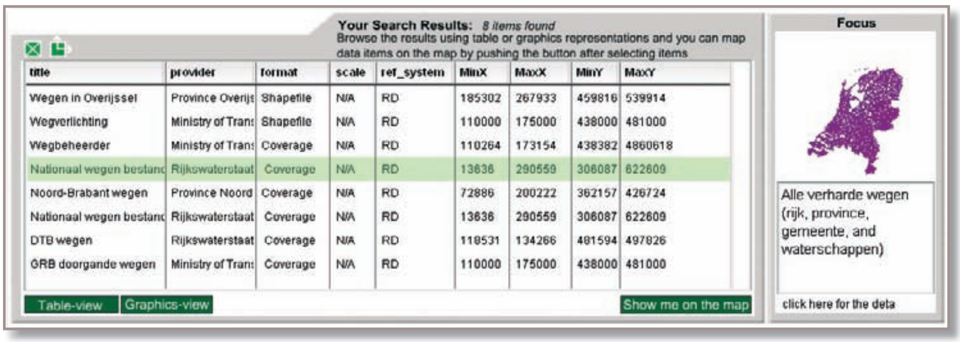



**Figure 2.10.** The search results as a listing table with providing thumbnails and short abstract as the preview of each item in the focus (highlighted). The highlighted item can be projected over the related thematic map or over the basic maps.

**Presentation of search results: bull's-eye pane + overview + link to map**

As discussed earlier in Section 2.4.3, the relevance of the results is an important aspect to assess the suitability of the data. When the results are displayed one can switch between a table-view and a graphics-view. Within the graphics-view, the bull's-eye target (used in archery) is implemented as the metaphor (Figure 2.11), and is already used as a metaphor for describing accuracy and precision of measurements in the field of surveying or statistics, e.g., the more accurate, the closer to the centre; the more aggregated as a group, the more precise. The items are distributed relative to the centre, with geographic co-ordinates of the query used as the centre of the pane. The closer to the query, the closer the items are plotted to the centre. The centre of the symbols refers to the centre of the geographic bounding of the data, such that the relative position of the data to the query can be estimated. The circles surrounding the centre indicate the degree of relevance to the query based on the geographic location. The visual variables used within this representation signify the differentiation of the topical attributes. For example, the topic category is signified by the colour of the item, and the data provider is shown by the text.

The principle beyond this metaphor is that the arrangement of metadata items and the use of colours are important aspects to provide an effective means to support visual search (Montello et al. 2003). At the operational level, the centre of the target pane can be interactively modified which means the geographic location of the query is changed. In addition, weighted-ranking can be applied to accommodate the relevance of the geographic location and the topic of queries in combination. Thus, the centre of the target pane is not merely representing the accuracy of geographical coverage, but the topical coverage, compatibility, and accessibility of the data as well.

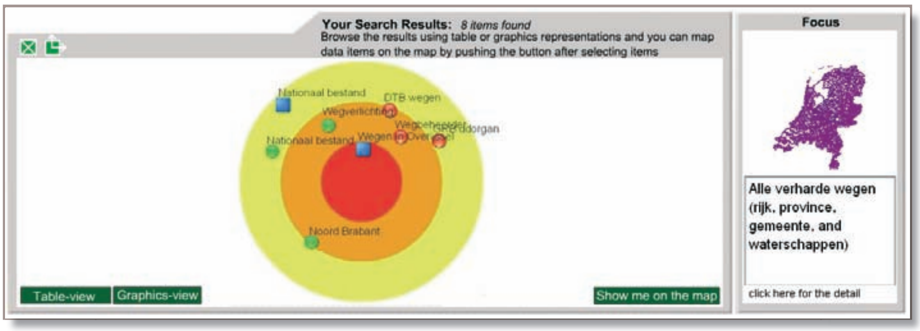



**Figure 2.11.** Search results are mapped into a bull's-eye target pane. Accuracy is measured based on geographic position of the query (closer to the centre is geographically more accurate) while distribution of topic cues (with selected visual variables) used precision as a metaphor.

## 2.6. Discussion

The advent of computer technology is an influencing factor for the development of new atlases. Moving from paper to digital atlases and subsequently to web atlases has opened up new possibilities as well as challenges for atlas design (see e.g. (Buckley 2001)). The format shift is not the only subject in which researchers and atlas designers have been concentrating; the objective of the national atlas is also a subject for change as well. Originally intended to provide a showcase for representing social-economic information or presenting sovereignty of a country, later it was steered towards planning and problems solving (Bakker et al. 1987; Symons 1979), for instance.

The national atlas as a metaphor presented in this chapter is an advancement of a similar idea previously published (Aditya and Ormeling 2004; Kraak 2004; Kraak et al. 2001). This chapter seeks a theoretical background to develop a successful and usable atlas metaphor. In so doing, it goes further by describing an extension of the map approach towards the atlas approach for improved access to the GDI. In envisioning the conceptual and operational levels of the atlas metaphor, it provides an analytical observation to define the atlas structure in the GDI context. When considering the possible use of the atlas metaphor, it considers tasks associated to data discovery and functionalities that should be offered.

In relation to this, the rapid prototype has been useful to justify the functionalities proposed. Through rapid prototyping, the interfaces that were built were self-evaluated together with the author's supervisors. Some design concerns associated with the utility and the usability of the interfaces have been indicated. For example, it was observed that the quality of map displays (presented as map images) could have been improved for clarity. Another clarity issue was the representation of metadata footprints. Using the rapid prototype setting (i.e., ArcIMS), the footprints cannot be symbolized with clarity. Many detail designs in support of functionalities that have been proposed, such as management of the metadata summaries, have not been investigated. This issue will be discussed in Chapter 3. Additionally, the navigation tools used to support browsing, like the atlas storyteller and dataset storyteller, have not really reflected the maps and metadata storytelling presented in Section 2.4.2. In relation to this, Chapter 5 discusses the topic in more detail.

As in the development of traditional national atlases, the development of the national atlas as metaphor described here requires proper planning and efforts in order to coordinate institutions to participate in the mechanism built so far. In this respect, this study does not consider the aspect of scalability of the atlas metaphor development.

## 2.7. Concluding remarks

Using the current geoportals, two problems were found on the basis of user feedback and reviews of the interfaces. Users have insufficient control to perform the discovery tasks, and, users obtain limited support to understand the presentation of the results. This chapter considers the atlas metaphor as a possible solution. The atlas metaphor is concerned with a structured map-based visualization on which maps (as a main component) are used to organize the content and the link to GDI. Regarding the data discovery tasks, there will be two types of tasks that users could complete using the atlas metaphor: loosely defined and tightly defined tasks. Browsing and searching strategies, can be used interchangeably to solve these two tasks.

The atlas metaphor should allow users to browse related information extensively and associate all possible information profitably. Using the designed atlas, search results are presented as a table view in which each item can be projected to a map display in order to provide a different perspective with which to assess the fitness of use of the data. When metadata footprints are mapped on top of thematic layers, the comparisons can be done between metadata items as well as between metadata items and spatial information in thematic layers. The nature of comparisons can be geographical, e.g., a study of the density, pattern, and extent of the data, or topical, e.g., a study of the relationships of the thematic attributes.

In such a user interface, the characteristics of the data are not merely explored for the clarity, but are linked with other supporting resources including thematic maps and graphics to support user understanding in dealing with the search. The notion of an atlas information structure permits the exploration of the different views seamlessly by using hyperlinks and interactivity principles.

While this chapter was mainly focused on the fundamental and operational levels of the atlas metaphor development, the next chapter will go further in order to discuss the implementation level of the atlas metaphor.

CHAPTER 3

# The Application Framework: Facilitating Mapping and Synthesis of GDI Resources*

Based on the concepts developed in Chapter 2, this chapter will elaborate further on the implementation of the proposed searching and browsing strategies as well as on technical aspects in managing, querying, and visualizing metadata of GDI resources and thematic layers.

## 3.1. Introduction

Despite the global awareness of the need for a GDI, today, it can be seen that only few of the GDI initiatives developed are really accessible and operative through the web. Some new research priorities related to the GDI development are required, and, the user-centred research is one of emerging research priorities (Bernard et al. 2005a; Masser 2005b; Wytzisk and Sliwinki 2004). Considering that 80% of public and private decision-making has a geo-component ((Albaredes 1992) in (Frank 1998)) and as the projected GDI benefits are promising, the development of strategies for an improved access and use of the GDI for personal and group work is crucial. The growing use of web mapping applications and adoptions of specifications from Open Geospatial Consortium (OGC) are the two important factors that keep the pervasiveness of the Geospatial Data Infrastructure (GDI) across the local, national, and regional levels extending.

The GDI is intended to facilitate both users and providers' needs. Through the GDI, providers can publish two different types of data: offline datasets and online geospatial web content such as Web Feature Services (WFS), and Web Map Services (WMS). These GDI resources are meant to be discoverable and accessible to users. As mentioned in an OGC paper (OGC 2004), a geospatial portal is a (web) interface to a collection of online geospatial information resources, including offline data sets, online map, and feature services. This includes functionalities to provide clients of viewer, discovery, publisher, gazetteer, data extraction-manipulation, and style management.

*This chapter is based on:
Aditya, T., and Kraak, M.-J. (2007a). "Aim4GDI: Facilitating the Synthesis of GDI resources through Mapping and Superimpositions of Metadata Summaries." Geoinformatica. Online version at: http://dx.doi.org/10.1007/s10707-007-0021-4

Beyond the role of geoportals previously mentioned, the GDI has potentials not only as a means for information access, but also to offer decision support (Feeney 2003; Nedovic-Budic et al. 2003) and to be used to enable geocollaboration, collaboration activities involving GIS technologies (MacEachren et al. 2005). In order to achieve these potentials, some interoperability impediments, like incomplete sets of mapping and chaining specifications and their tools compliance (see e.g. (Bernard et al. 2005b)), as well as usability drawbacks (Aditya and Kraak 2006), have to be overcome. For that reason, this chapter will try to describe first, what kind of decision support that possibly can be facilitated by geoportals in general and the atlas metaphor in particular. This chapter will focus on the improvement of the usability aspects of user interfaces in the GDI to support information discovery and access for decision-support.

## 3.2. Searching and browsing the GDI resources for decision-Support

In relation to the role of visual methods to provide a decision support, a conceptual framework for the use of maps for problem solving in GI Science has been articulated as: exploration – synthesis – analysis – presentation processes (not necessarily in a sequential order) (Gahegan 2005; Kraak 2006). Throughout the processes, the maps (and graphics) or visualization plays an important role to support actions such as: categorizing, formulating hypothesis, generalizing, and modeling. Similar to this idea, earlier, DiBiase (1990) emphasized that the research process with visual methods develops a sequence of 4 stages of exploration of data to reveal pertinent questions, confirmation of apparent relationships in the data, synthesis or generalization of findings, and presentation of the research. These stages involve the use of visual methods to support visual thinking in private realm and visual communication in public realm (Figure 3.1.).

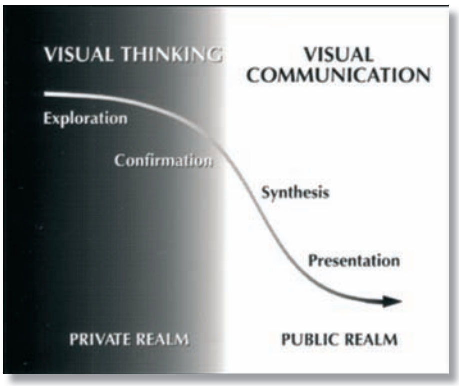



**Figure 3.1.** The range of functions of visual methods in an idealized research sequence that can also be applied for decision making (source: DiBiase 1990).

The Figure 3.1 depicts that, as put by DiBiase (2007): *"…the transition of a creative work from the private realm (dark background) to the public realm (light) advances in an iterative fashion. The trajectory of its advance is complex and multi-threaded, like a braided stream. The stream appears as a simple, singular line on the small-scale map, however"*. Using this perspective, the interface of GDI, that is, the atlas metaphor in this study, can be developed to support all and especially the first three stages mentioned, i.e., exploration, confirmation of hypothesis, and synthesis. While the atlases have been widely recognized for their ability to support geospatial data presentation, this study intends to make a case that the national atlas is not only concerned about presentation, but also relevant at earlier stages of the problem solving using maps and graphics (Gahegan 2005; Kraak 2006). In this regard, such motivation is indeed the point that Figure 3.1 tries to argue that cartography needs not be concerned only about presentation, but is also relevant "*at earlier stages of the knowledge-production process*" (DiBiase 2007).

The objective of the atlas metaphor to support searching and browsing strategies is relevant with exploration of the availability of the GDI resources. Sorting and comparison offered in the atlas, for example, are aimed at assisting users in assessing the fitness for use of the search results returned. Using browsing strategies, open-ended questions regarding data access and data suitability, for example, can be solved. To confirm the data suitability and its relevancy to the users' inquiry, for example, the items can be projected on top of a map or cascaded with other items to see the pattern. Further, the user can directly visit the metadata file offered, and, for instance, load the actual data service. Synthesis, in DiBiase's perspective, refers to "*…summarizing and generalizing the results of exploratory and confirmatory analyses, and articulating a new, integrated conception of how the components [of the] problem interrelate*". In many atlases, that kind of synthesis, as mentioned in Chapter 1, has been used and developed (see for example Figure 3.2.). As it is also mentioned in Chapter 1, it is envisaged that the atlas metaphor can produce a synthesis of statistic information, thematic information and geospatial resources of the country. As such, through searching and browsing strategies, users have abilities to produce a display resulting a synthesis of available information in the country.

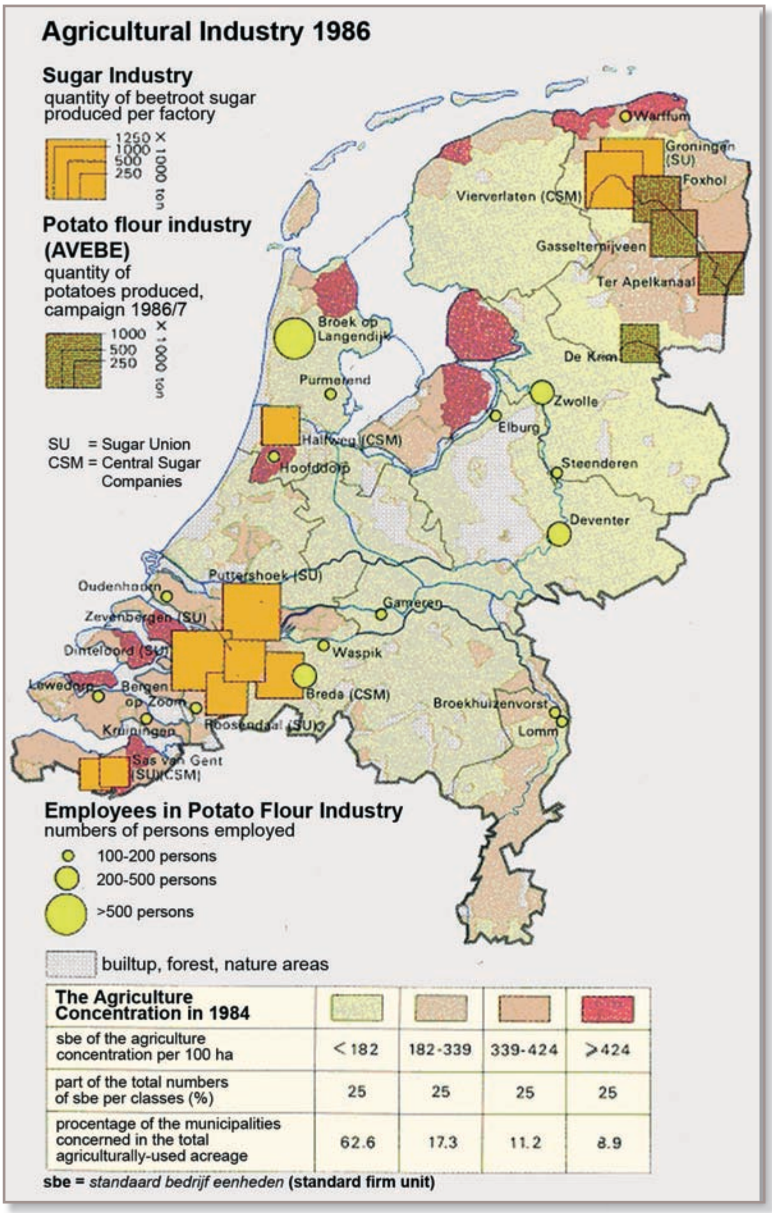



**Figure 3.2.** A map showing the process of combining information regarding the productivity of sugar industry and potato flour industry in the Netherlands in 1986 and their relationships to the agriculture concentration and the number of employees in potato flour industry (translated with permission from: Atlas van Nederland 1989).

Considering the potential uses and richness in content of a GDI, a system that enables users (novice and expert users of various domain applications) to profit from the actions above-mentioned and interaction strategies is needed. The current practices of geoportals seem to be data oriented instead of demand-driven (Crompvoets et al. 2004) and often provide limited support to enable users to effectively and efficiently assess the fitness for use of the data required. Additionally, the visualization and integration of the metadata, map, and feature services required in support of information discovery and access for decision support could be improved.

Using geoportals, users commonly have possibilities to search metadata or browse directories of metadata, to load and cascade WMS, and to share data. To access the information and services through the search interface of the geoportals, users have to provide at least one search term related to location, attribute or time of the required data or map services. This approach is appropriate to support tightly defined discovery tasks. To exemplify this kind of task, consider Danny, a GIS technician who needs a specific dataset for an agriculture map-updating project. He could start the search process by submitting or selecting search terms related to his topic, scale, and area of interest to a geoportal. A common solution that Danny gets using today's geoportals is, as mentioned in Chapter 1, the display of search results in the form of a set of abstracts and thumbnails with links to view data and to review full metadata descriptions.

Since a GDI might cover assorted topics of related geospatial data and maps, browsing through topic directories is a common approach for completing a loosely defined task. This task usually specifies no detailed requirements at the start of the interaction with the geoportal. In this task, the fitness of use is not simply depending on matching values of certain elements in metadata. Consider Lisa, a transportation engineer who requires datasets for her work designing traffic survey activities in support of a road extension project. To get appropriate search results, she might need more than just simply defining format and area of interest. Through browsing activities, a user such as Lisa can page through the links offered via the directory of topics or providers and find some data that can be used for her project. Currently, not all geoportals support browsing activities.

Regarding support for searching and browsing activities through geoportals, the existing set of displays does not facilitate users' needs to quickly compare and sort metadata out. Users must drill down each item to assess the matching of the metadata elements to their queries. Additionally, they also do not permit users to assess the trend and pattern of the data that are available for a specific topic of interest. Furthermore, current geoportals provide minimal contextual support to help users browse (either by topic or by providers) the data and services available. Thus, in such a setting, users only have possibilities to assess the fitness of use based upon the utility or property of the data / services, with for instance no background layers (e.g., thematic maps) offered to assist the data suitability assessment.

In addition to the drawbacks mentioned above, the integration of the GDI resources (WMS, WFS, and metadata characteristics) is not solved thoroughly. Possibilities to combine different resources into one single interface would broaden the use of the data published. The GOS (the US Geospatial One Stop portal) provides a good example of the benefits of interoperability of GDI resources where publicly available WMS can be cascaded and displayed through the viewer. However, using the GOS and other geoportals, the possibilities to perform the exploration, confirmation or analysis, and synthesis previously mentioned, by means of representing metadata and of juxtaposing the GDI resources (not only WMS) are still limited. In so doing, it is envisaged that users have opportunities to study and compare for example, the density, pattern, and distribution of available datasets for a single or multiple topics in support of a “fitness for use” assessment. These prospects suggest the rise of the GDI to reach more users and to be used more to enable information access and decision-making.

As a solution to the above, this chapter presents the development of Aim4GDI (Atlas Interface Metaphor for Improved Use and Accessibility of the GDI), a web-based atlas interface as a portal to facilitate search, mapping, and synthesis of the GDI resources.

## 3.3. From a rapid prototype to an evolutionary prototype: The atlas as an indexing and integration service

Section 2.5. describes the development of a rapid prototype. As mentioned there, that rapid prototype was aimed at assessing, at an operational level, the feasibility of the concept and specifications suggested. As also reported there, most of functionalities designed can be framed through the user interfaces created. Additionally, another aim was to elicit design improvements concerning the concept and functionalities developed. Using the rapid prototype, the exploration of the design ideas was done by the author and supervisors of this study. The rapid prototype stimulated design critics and refinements of specifications of the concept and functionalities defined at the operational level of the metaphor development.

The design critics provide recommendations for more clarity on the links and graphics presented (i.e., the clarity of mapped metadata summaries on top of a basic map), for a more straightforward structure for the users’ navigation, and a direct and simpler use of color hues. Another design issue raised was the continuation of the prototype developed. The study considers the use of the open source technologies and standards as a way forward to ensure the applicability of the concept proposed when it is applied in other GDI initiatives. For this reason, the Flash-based atlas metaphor was deprecated in favor of a Scalable Vector Graphics (SVG)-based atlas metaphor.

In relation to this, in the software engineering and interactive systems, prototyping methods can be classified as “throwaway” and “evolutionary” prototyping. Whereas the throwaway prototyping tends to discard rather than to use the working model produced, the evolutionary prototyping meanwhile, tends to build a robust working model of the future application in which the improvements and refinements are done systematically (Gordon and Bieman 1995). For a software or an interface development, designers can combine both the throw-away and the evolutionary prototype. The Flash version was considered as a "throw-away" prototype, while the SVG version was viewed as an "evolutionary" prototype. With the SVG version was selected as an evolutionary prototype, as it will be discussed in the rest of this chapter and next chapters, the application has been iteratively improved during the course of this research study. Although the rapid prototype (Flash version) was not further developed, as far as the interface is concerned, using the application framework presented in this chapter, the Flash version can be regarded as a potential design alternative.

The refinement of the metaphor's specifications dealt with some unanswered design questions relating to the implementation of metadata management and representations. During the rapid prototyping phase, it was, for instance, not so clear how metadata summaries should be handled and queried in response to users' search requests. It was also not so clear, how they should be projected into a map or cascaded against the other thematic layers. Further, the rapid prototype has not yet been detailing the interaction framework given earlier in Chapter 2. From this perspective, an application framework in managing and visualizing metadata summaries in combination with thematic maps is needed for the atlas metaphor. The following will focus on the technical aspect of the application framework proposed.

The general approach applied in web and book atlases alike is to provide an indexing mechanism on maps and relevant documentation that are available for a list of specific topics. Further it brings a uniform representation of maps and information to users. Through such scheme of visualization, the atlas allows users to build comparisons and syntheses on a specific theme selected. To enhance the user's understanding of the context of the mapped themes, a storyteller view is developed. Through a storyteller view, supporting information related to thematic maps and GDI resources are accessible. Through such a map storyteller and GDI storyteller, users have access to relevant documents, graphics, images, and animation as well as to related online content. They are designed to facilitate a certain rhetoric of communication (see e.g. (Great Britain Historical GIS Project 2006)) in support of browsing activities.

The GDI storyteller resources are to be created and maintained by the atlas editor. The data provider organizations or any registered users can also contribute to the content of the storyteller system by submitting content or graphics related to a specific thematic map. As an example, a user could submit a documentation regarding experiences of the use of a specific map service about road features to be displayed through the storyteller view under topic "Transportation" and listed under the map "road networks" (see more detail on this in Chapter 4).

In some national GDIs, national web atlases have been positioned as one of the nodes of the country's geospatial infrastructure, e.g., (NRC 2006a) and (Interior 2006). To use the atlas as a geoportal, two vital functionalities have been built:

index and superimposition schemes. The index scheme refers to organization and management of metadata of GDI resources (such as datasets and WFS) published into summaries of metadata. These summaries are displayed as textual and graphical representations on top of the interface to support data and information access. The superimposition scheme deals with methods to allow users to overlay metadata items or subset of required feature services on top of thematic maps to enable visual thinking during the searching and browsing process. The superimposition scheme can be seen as cascading GDI resources, thus here, the cascaded "graphics" are not limited only to WMS but also including metadata and WFS visualization on top thematic maps of the atlas.

The following section will look closer at the metadata management of summaries and the atlas directory, query services, and mapping functionality of the proposed Aim4GDI.

## 3.4. Metadata management

### 3.4.1. Generating metadata summaries

Geospatial resources that are commonly published in the framework of the GDI are: proprietary datasets, WMS, and WFS. In the current practice of geospatial data management, these three types of data are documented using related metadata standards or specifications in the form of XML documents. Proprietary vector and raster datasets are documented for example using the International Standard Organization (ISO) standard 19115. Meanwhile, map services and feature services are required to implement OGC GetCapabilities interface to enable clients (human-users or machine) to get a descriptive feedback in the form of XML about the service to be accessed.

To transform geospatial metadata into knowledge, in the context of geovisualization, the semantic web technology can provide a reliable framework to ensure the consistency of semantic aspects of information integration (Brodlie et al. 2005; Schroeder 2005). In line with this view, this work considers the necessity to organize the data model of the harvested metadata (hereafter called as metadata summary) as Resources Description Framework (RDF) data.

As mentioned in Section 2.3.3, metadata summaries are intended to support the idea of presenting interfaces that enable "overview first, zoom and filter, then details on demand" tasks (Shneiderman 1998). During the prototyping process, the RSS format advances as an accepted format for syndicating web content. The RSS in this regard is the RDF site summary (Beged-Dov et al. 2001). The growth adoption for RSS feed format motivated the making of initial metadata summary structures. Some of the RSS elements were seen appropriate to be used for aggregating the metadata offered in a GDI initiative (Aditya and Kraak 2004). At the time when the prototype was initiated in 2003, several options to encode geographic components were available, such as W3C geo vocabulary (W3C 2003) and Dublin Core (DC) terms (Dublin Core Metadata Initiative 2006). As far as the prototype is concerned, at that moment, GeoRSS (OGC 2006) has not been released. It was decided to specify the geospatial component (bounding boxes of metadata) using the DC terms.

A metadata summary is a concise description of a GDI resource. As such, it is outlining the title, abstract, usage, accessibility, geographic coverage, topic, and temporal information of the resource. In fact, this metadata summary has a similar structure and encoding as “common returnable properties” of Catalogue Services specification (OGC 2005). Introducing metadata summaries in addition to metadata documents hosted in the providers’ servers may produce redundancy of datasets’ descriptions. However, this must be done, as the focus is to improve the search, representation and selection of geospatial resources via the prototype, Aim4GDI. The metadata summary is expressed as Resources Description Framework (RDF) and serialized as XML format (RDF/XML (W3C 2004)).

The rationale to use the RDF/XML format was motivated by two considerations. Firstly, RDF is a W3C specification, designed to provide a standard for metadata of web resources (Decker et al. 2000; Klein 2001). The data being described are seen as a directed label graph of the triples (subject–predicate–object or resource-predicate-value) (Lassila 1998). As a graph model, it provides advantages in terms of processing and querying of datasets (Powers 2003). With regard to the metadata summary, an RDF query provides a straightforward approach to reconstruct the relationships between a specific summary and other data within the directory for information integration purposes, for instance. Secondly, the structure of the atlas, as discussed in Chapter 2, is constituted from selected topics, in which for each topic it can include some relevant thematic maps. Having such a structure, a map in the atlas can be seen as an indexer of thematically related GDI resources as well as the atlas resources (including relevant charts, graphics, images, and textual descriptions to the map). In this graph-like construct, the directory data is better represented using RDF/XML than using XML (for tree-like domain application) or relational databases (for table-like domain applications)(Berners-Lee 1998).

In this study, it is envisaged that providers are required to submit the web address of the XML metadata of proprietary datasets and the web address of `GetCapabilities`. For the sake of practicality, providers are also asked to provide detail web access for their `GetFeature` and `GetMap` interfaces. Further, an important requirement at the registration step is that the provider is required to specify the linking of the metadata or WMS/WFS to a specific thematic map in the atlas. This linkage approach is the key to organize the GDI resources into the atlas system (indexed into a particular map within a specific topic in the atlas directory).

Metadata would be processed as summaries after the providers register their metadata through a simple registration web page. Semantic reasoning and crawling of (geospatial) metadata, as for example implemented in (Stuckenschmidt and Harmelen 2001), are beyond the scope of this study. Metadata of geospatial resources (e.g., offline data, WMS, WFS) are indexed into the atlas based upon their thematic similarity to a thematic map.

To handle a dataset registration, a simple Java servlet is used to process the web address of the metadata submitted. Subsequently, metadata summary items are created out of it with the help of an Extensible Stylesheet Language Transformations (XSLT) template *"xml2summary"*. The stylesheet template is applied against the XML metadata to generate geographic, topic or temporal, linkage to a thematic map, usage, and accessibility elements. The generated RDF/XML summary used the Dublin Core namespaces (Dublin Core Metadata Initiative 2006) (i.e., dc-elements and dc-terms), topic category of geospatial metadata standards (ISO 19115), and proprietary namespaces suited for this application (metadata summary). The resulted elements (excerpted) are shown in the following (with "M1" text cue in the box below refers to "M1" circle in Figure 3.6):

```
<ms:item rdf:about=" http://overijssel.nl/dataxml/buszone.xml" >
<!-- Resource general Information -->
<dc:title>Overijssel bus zones</dc:title>
<dc:description>...abstract information...</dc:description>
<dc:created>1999-08-01</dc:created>
<dc:creator>Province Overijssel</dc:creator>
<dc:publisher>Afdeling GIS - Overijssel</dc:publisher>
 <!-- Geographical coverage-->
 <ms:geocov rdf:parseType=" Resource" >
  <dcterms:spatial>
   <dcterms:Box>
     <dcterms:northlimit>539914</dcterms:northlimit>
     <dcterms:eastlimit>267933</dcterms:eastlimit>
     <dcterms:southlimit>459816</dcterms:southlimit>
     <dcterms:westlimit>185302</dcterms:westlimit>
   </dcterms:Box>
  </dcterms:spatial>
 </ms:geocov>
 <!-- Topical coverage-->
 <ms:topicov rdf:parseType=" Resource" >
  <dc:subject>Transportation</dc:subject>
  <iso19115:topicCategory>Transportation</iso19115:topicCategory>
 </ms:topicov>
</ms:item>
```

M1

Summaries of online feature and map services are aggregated in the same way. For WFS and WMS to be included, within the registration page, providers are required to specify the title, abstract, description (in case its GetCapabilities has no sufficient information about title, abstract, and description) and the designated association to a specific map. In addition, for a WFS submission, it is required to specify the access node of DescribeFeatureType, and GetFeature requests. Meanwhile for a WMS to be included, the provider should specify the GetMap access node. Following the submission, the web address of each request is accessed. Subsequently, stylesheet templates *"wfs2summary"* and *"wms2summary"* will summarize the items based on the resulting responses. For a WFS type of resource, for instance, the resulting summary will specify the title, abstract, geographic bounding box, topic, linkage to a thematic map, and the web access of the GetFeature request as an RDF data.

Metadata used in the prototype are extracted from the Netherlands GDI. Metadata concerning roads and agriculture are hosted in the local server and structured to produce metadata summaries as RDF/XML format (W3C 2004). In order to provide a vocabulary for terms used in the summary, this work mixes the DC (Initiative 2006) encoding schemes and the atlas metaphor vocabulary. The atlas metaphor vocabulary is used to provide a vocabulary of terms used in the elements of the atlas information structure.

For experimenting with map and feature services, the GeoServer (GeoServer 2007) and Mapserver (Minnesota and TerraSIP 2007), which both run in the local network, are used as the map and feature servers. For testing purposes, datasets and feature services related to two topics within the GDI: Transportation and Agriculture are used. Figure 3.3. shows the graph representation of a summary.

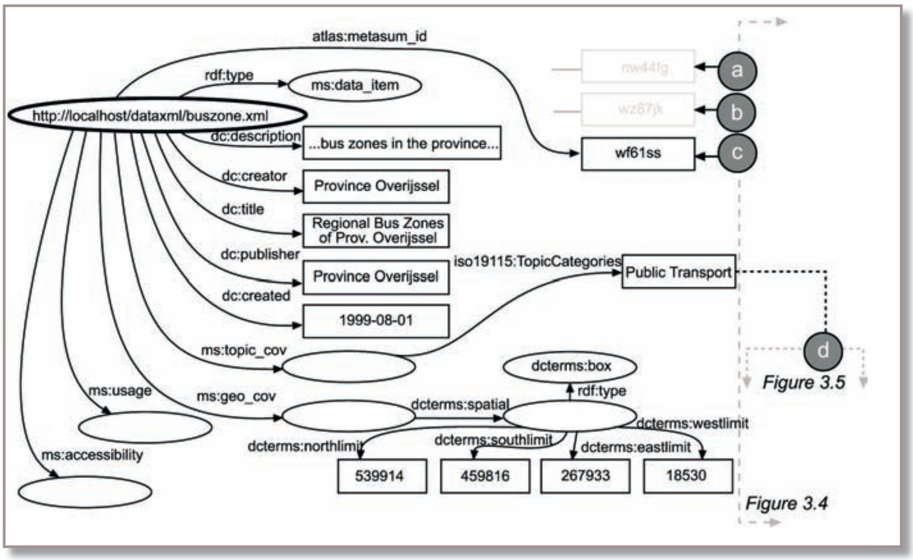



**Figure 3.3** The RDF graphs of metadata summaries.

Metadata summaries are encoded as a graph pattern of "subject-predicate-object" triples. Regarding summaries of GDI resources, they are differentiated by encoding them either as `<ms:dataitem/>` or `<ms:WMSitem>` or `<ms:WFSitem>` elements. As exemplified in the Figure 3.3, the data of "regional bus zone" is a type of dataset item, and contained into the map of public transport.

### 3.4.2. Expressing the atlas information structure

The atlas information structure, as have been described in Chapter 2, is developed to organize the content of the atlas. In a simple way, this can be regarded as the directory of the atlas. Using the atlas, users are expected to get access to the collection of maps and their supporting information as well as GDI resources. The directory indeed is designated to provide appropriate "yellow pages" for users to access and retrieve information required.

Within the directory file, each thematic map is specified as a web resource having a title, abstract, map description. The datasets constituting these maps are collected from various institutions and then compiled by the atlas editor. The thematic maps function to index relevant atlas and GDI resources. In this regard, a thematic map is seen as a container for graphics, images, and documentation that are organised with the atlas and GDI storyteller. This structure is intended to support browsing GDI resources through thematic map in order to provide contextual information for data discovery. This structure is also encoded using RDF/XML (Figure 3.4 depicts the RDF graphs of the atlas directory).

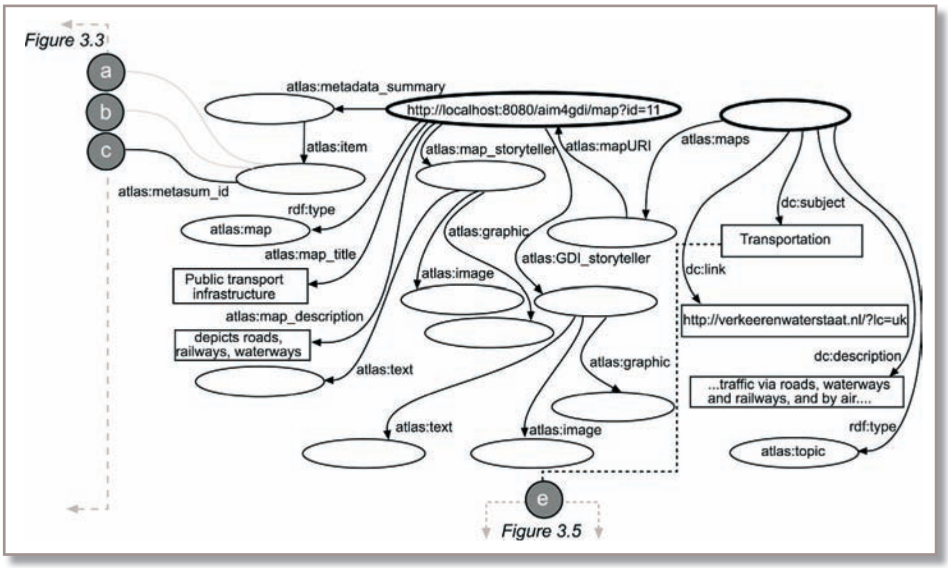



**Figure 3.4.** The RDF graphs of the atlas directory.

Figure 3.5. depicts the schema of topic categories that are used as a reference for elements with dc:subject or iso19115:TopicCategories in the metadata summary and in the directory. The schema is in fact the taxonomy of the topicCategory of ISO19115 (ISO/TC211 2003).

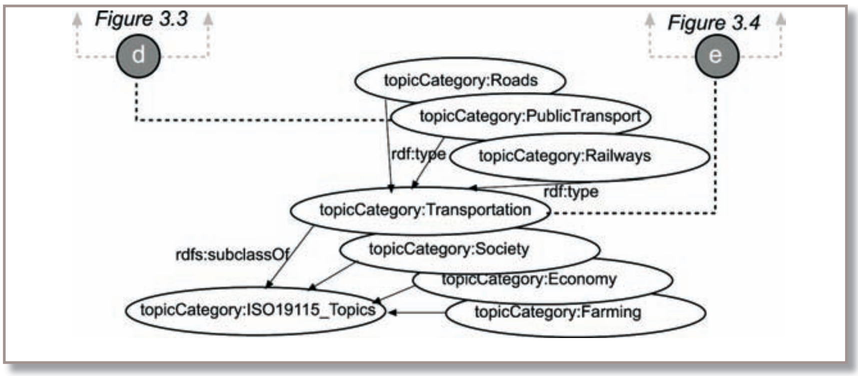



**Figure 3.5.** The RDF graphs of the TopicCategory taxonomy.

## 3.5. Query services

The Jena web toolkit (Carroll et al. 2004) is used in the system to provide query services to RDF data of the metadata summaries and the directory. Specifically, the ARQ query engine (Semantic Web HP Programme 2006) is used to perform queries using SPARQL, the proposed standard for RDF query language (W3C 2006a). SPARQL is built on the `triple pattern components`: a subject, predicate and object that construct a graph pattern. Any of these components or the entire graph pattern can be replaced by a variable. The query attempts to match the triples of the graph pattern to the model (i.e., RDF data). The query solution prescribes the matching of the variables over the model's nodes. For this, each query should use `PREFIX` keyword for handling the namespace issue, includes `SELECT` clause to specify what the query should return, optionally specifies `FROM` that provides the Universal Resource Identifier (URI) of the dataset to query, and defines the `WHERE` clause defining a series of triple patterns. SPARQL also allows the application to matching multiple graph patterns.

To exemplify the SPARQL usage for querying metadata summaries and the directory, two tasks exemplified in section 2 are recalled: a GIS technician, Danny, requires a dataset for his agriculture map-updating project and a transportation engineer, Lisa, who requires datasets for planning a traffic survey.

### 3.5.1. Searching resources through summaries

For Danny's case, the most explicit requirements he could have are: 'provide me a dataset about vegetation types published by the GIS section of the Overijssel Province (GIS_OV), and offered as a shapefile dataset'. This request, hypothetically, is best queried via searching interface. For this purpose, the search parameters that Danny defined through form user interface components (textbox, drop down menus, and combo boxes) are sent to the server and handled by a query program once Danny presses the 'search' button. The SELECT query syntax for this request in SPARQL is expressed as follows (with 'Q1' text cue in the box below refers to the 'Q1' circle in Figure 3.6):

```
PREFIX dcterms: <http://purl.org/dc/terms/>
PREFIX ms: <http://metasum/elements/1.0/>
PREFIX atlas: <http://kartoweb.itc.nl/atlas/elements#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema>
PREFIX dc: <http://purl.org/dc/elements/1.1/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
SELECT ?westlimit ?northlimit ?eastlimit ?southlimit ?item ?resource ?publisher ?title
?abstract ?topic ?format ?scale
FROM  <" +url_ms+" >
WHERE
{
   ?item ?x [?y [dcterms:westlimit ?westlimit],
              [dcterms:northlimit ?northlimit],
              [dcterms:eastlimit ?eastlimit],
              [dcterms:southlimit ?southlimit]].
   FILTER (?westlimit > +qXNW+ && ?southlimit > +qYSE+ && ?eastlimit < +qXSE+ && ?northlimit
   < +qYNW+).
   ?item rdf:type ?resource;
   dc:publisher ?publisher; atlas:metasum_id ?meta_id; dc:title ?title;
   ?item dc:description ?abstract;  ms:topicov [dc:subject ?topic] .
   ?item ms:usage [ms:representation ?datatype], [ms:format ?format], [ms:scale ?scale].
   FILTER (regex(?title, /+qkeyword+/)||regex(?abstract, /+qkeyword+/)&& regex(?topic,
   /+qtopic+/) && regex(?publisher, /+qpublisher+/).
};
```

Q1

`PREFIX` keywords are used to specify the namespaces used in metadata summaries. The query was made against metadata summaries file that reside in the server and filtered according to parameters that Danny specifies (using the `FILTER` keyword).

The "qXNW", qYNW", qXSE, and "qYSE" in the above lines are the corresponding *westlimit*, *northlimit*, *eastlimit*, and *southlimit* of the "Overijssel" dataset. These position values are gained with the help of "PlaceBoxes" data (see Section 3.6). This file can be seen as a simple gazetteer data and used to provide footprints of the geographic place names of the country. The incoming queries having place name or administrative unit parameters are first to be matched with this PlaceBoxes file to gain the corresponding westlimit, northlimit, eastlimit, and southlimit of the area of interest. Other search terms that Danny might have, include the topic, type of data, the name of publisher, format and scale of the vegetation data that Danny is interested in. Those search terms are used as parameters to filter the possible results. Since the ARQ processor support all kinds of data types filtering (e.g., `xsd:date`, `xsd:integer`, `xsd:string`), hence the application provides flexibilities to Danny and other users to define many questions in relation to the data they look for.

### 3.5.2. Browsing resources through the directory

The task that Lisa needs to accomplish is to produce a spatial analysis to support a traffic survey campaign that aims to measure traffic noise level as well as noise perception among the population in the southern part of Overijssel province. Using the Aim4GDI interface, she could browse relevant maps within the "environment" topic to check whether relevant information that might be beneficial to her task can be found. By browsing maps through the directory, she issues a query to populate the map container. Through SPARQL, a request like "provide me a list of summaries of GDI resources related to the map of environmental quality" is built as follows (with "Q2" text cue in the box below refers to the "Q2" circle in Figure 5.11 presented in Chapter 5):

```
SELECT  ?item ?title
FROM <" +url_ms+" >
FROM NAMED <" +dir+" >
WHERE
{
      GRAPH <" +dir+" > {
         ?b ?x [atlas:mapURI ?map].
         ?map rdf:type atlas:map .
         ?map atlas:map_title ?maptitle; atlas:metadata_summary ?gr .
         ?gr atlas:item [atlas:metasum_id ?item_id]
         FILTER (regex (?maptitle, /+qmaptitle+/)).
         }.
         ?item atlas:metasum_id ?item_id .
         ?item dc:title ?title .
         ?item dc:description ?abstract.
};
```

**Q2**

These query lines make use of 2 graphs to retrieve the requested result. In essence, the graph of metadata summary (represented with "url_ms") is matched against the graph of directory ("dir") in which the matching is limited into the pattern that meets string constraint ("qmaptitle") that reflected the map title selected.

The use of the directory linked to summaries offers possibilities to broaden the search scope (involving atlas resources and GDI resources). As an example, consider the following request as Lisa expands her query: "show me summaries categorized as feature services dealing with the environment topic and offered by Ministry of Housing & Environment (i.e., "VROM") provided summaries are within the maps that have documentation and images with keyword 'sound pollution'". This request can be expressed as query string as follows (with the "Q3" text cue in the box below refers to the "Q3" circle in Figure 5.11 presented in Chapter 5):

```
SELECT  ?item ?title
FROM <" +url_ms+" >
FROM NAMED <" +dir+" >
WHERE
{
        GRAPH <" +dir+" > {
        ?b ?x [atlas:mapURI ?map].
        ?map rdf:type atlas:map .
        ?map atlas:map_title ?maptitle .
        ?map atlas:map_storyteller ?gr .
        ?gr atlas:text [atlas:textTitle ?texttitle], [atlas:textURL ?texturl] .
        ?map atlas:metadata_summary ?ms .
        ?ms atlas:item [atlas:metasum_id ?item_id]
        FILTER (regex (?maptitle, /+qmaptitle+/) && regex (?texttitle, /+qtext+/)). }.
        ?item atlas:metasum_id ?item_id .
        ?item rdf:type ?itemtype
        ?item ms:topicov [dc:subject ?topic] .
        ?item dc:publisher ?publisher.
        ?item dc:description ?abstract.
        FILTER (regex (?topic, /+qtopic+/) && regex (?publisher, /+qpub+/) && regex(?itemtype,
        /+qrestype+/)).
};
```

Q3

Such a composite query is intended to get specific items out of a data graph (in this case is the atlas directory) using keywords `FROM NAMED`, `WHERE`, and `GRAPH`. The items returned in that part of query, are then matched against another data graph (in this case is the RDF data of metadata summaries). In Lisa's case, the submitted values of "`qtopic`", "`qpub`", "`qrestype`" to find pattern in the metadata summary correspond to "`Environment`", "`VROM`", "`WFS`". The "`qtext`" in the directory meanwhile, corresponds to "sound pollution". These values are submitted through the widgets form offered within the user interface. As seen in the above code, these values are used to filter the query (using keyword: `FILTER`).

## 3.6. Visualizing the search results & GDI resources

The previous sections discuss the organization of metadata and the query services. This section discusses the visualization of search results and the GDI resources. As our aim is to facilitate discovery and synthesis of the GDI resources, the mapping functionalities play a crucial role to represent the thematic maps of the atlas, the storyteller content, and search results including the visualization of metadata summaries as well as the WFS and WMS accessed.

In handling a query, two important processes within the application take places: (1) processing the RDF query with SPARQL standard and (2) visualizing search results as web pages and graphics (Figure 3.6). Through the browser, users are expected to send a request for a specific information retrieval or presentation, the browser passes this request to the server. At the server side, the corresponding query against the directory and (or) the metadata summary is processed.

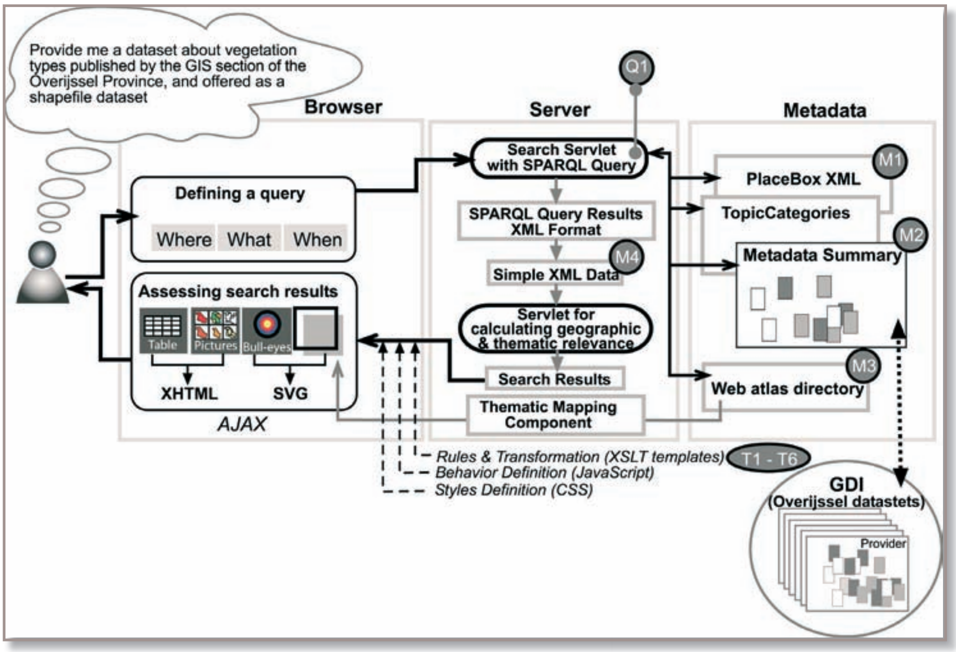



**Figure 3.6.** The RDF Query (with SPARQL) and content transformation (with XSLT) play an important role for presenting the search results and the synthesis of metadata summaries of GDI resources. The figure illustrates the query handling, starting from a user's search terms definition to search results' presentation. Q1 corresponds to an earlier example of SPARQL query syntax. M1 corresponds an earlier code of XML elements of a metadata summary. M2 and M3 refer to code fragments of the place name data and simple XML format discussed below. T1 up to T6 refer to code fragments of XSLT templates discussed in the subsections below.

For processing queries, Java servlets are used. The use of Java servlets can be classified to support four methods: processing the area of interest, executing SPARQL queries with constraint values or multiple graphs, and generating search results as well as shaping them for signifying their relevance to the query.

For processing the area of interest, the values selected or typed respectively via the administrative area and the place name inputs are matched against the "Placeboxes" data. The data, encoded as an XML file, specifies administrative areas in the country as place names with their corresponding bounding boxes. This data can be considered as a simple gazetteer index. For handling this, XPath syntaxes (W3C 1999) are applied to select a specific node with place name requested with the purpose to return the coordinates of its bounding box. In case that the users define the area of interest by drawing a box on top of a map, two sets of coordinates of the drawn box are then used for the query. The following shows an example of a place name of a municipality and its associated bounding box as XML elements (correspond to the “M2” text cue in the Figure 3.6. above).

```
<PlaceBoxes>
  <municipality id=” Steenwijk” >
    <AREA>83749776.000</AREA>
    <XNW>196282</XNW>
    <YNW>541335</YNW>
    <XSE>210208</XSE>
    <YSE>528937</YSE>
  </municipality>
</PlaceBoxes>
                                                                M2
```

The result of the query is encoded as “SPARQL query results XML format” (W3C 2006c). As shown in the following excerpted listing (correspond to the “M3” text cue in Figure 3.6), the response is transformed first into a simple XML data before it is sent into the stream.

```
<results>
 <item meta_id=” http://overijssel.nl/ dataxml/buszone.xml” >
   <westlimit>182000</westlimit>
   <northlimit>540000</northlimit>
   <eastlimit>260000</eastlimit>
   <southlimit>450000</southlimit>
   <publisher>GIS Section of the Province Overijssel</publisher>
   <title>Overijssel bus zones</title>
   <topic>Transportation</topic>
 </item>
</results>
                                                                M3
```

At the browser side, a corresponding XSLT template is used to transform that simple XML data in the stream into a specific requested presentation. The requested presentation, either as a graphical (Scalable Vector Graphic (SVG)) or a textual (HyperText Markup Language (HTML)) element, is then inserted into the corresponding section. As the use of `XMLHttpRequest` object (AJAX - Asynchronous JavaScript and XML approach) in the browser to support server-client communication is proven to give benefits in terms of performance and usability (Charland 2006; Paulson 2005; White 2006), this application implements the AJAX approach in handling requests and responses.

A request, for example a call for projecting the metadata footprint of an item of search results on top of the map, is typically handled in the browser using a JavaScript function like this:

```
function ProjectMetadata(selid){
   if (selid) {
      var params =  'id=' + selid;
         xmlPost( '../servlet/MyFootprint' , encodeURI(params), MetadataPrint);
         }
   else {
      return;
   }
 }
```

Here, the request for mapping the metadata will be forwarded by `ProjectMetadata` function in the browser to an AJAX function called `xmlPost`. This function will send the query parameter (i.e. the metadata identifier referred to as selid) to the Java servlet `MyFootprint`, and set `MetadataPrint` as the "call back" method to handle the returning XML response. As shown in the following excerpted codes of `MetadataPrint`, the returning XML response (like the one shown earlier in the box with "M3" text cue) will then be transformed into SVG elements representing the metadata footprint requested using an XSLT template.

```
xslMS = new ActiveXObject( "Microsoft.XMLDOM" );
xslMS.load( "XSLT/drawMS.xslt" );

function MetadataPrint() {
  if (req.readyState == 4){
        if (req.status == 200){
           if(window.ActiveXObject){
                 var outputSVG = req.responseXML.transformNode(xslMS);
                 if (outputSVG){
                    window.insertFootprint(outputSVG);
                 }else {
                    alert( "your browser doesn't support xmlhttp object" );
                 }
           }
        }
  }
}
```

In essence, the call back method will first check the `readystate` property. When the `readystate` property has value 4, which means the XML document requested is completely loaded and when everything is OK (`status == 200`), the returning XML response is then transformed against *drawMS.xslt* stylesheet template. The resulting SVG elements can then be inserted into the map via `insertFootprint()` method. As a result, the bounding box values, the title, the topic, and the name of the data provider of a specific item identified in the code box "M3" above for instance, can be transformed into an SVG rectangle (discussed further in Section 3.6.2).

**Table 3.1.** A summary of the components utilized in the browser and server side in support of data discovery. In XSLT template column, T1 up to T6 symbols refer to the excerpted codes of stylesheet templates in the following subsections

| | **Server** | | **Browser + JavaScript** | | | | |
|---|---|---|---|---|---|---|---|
| **Display** | **RDF Data queried** | | **XML data** | | **XSLT template** | | **CSS/XHTML/SVG** |
| Table | Metadata Summaries | → | XML Results | → | Table.xslt (**T1**) | → | Table view (XHTML) |
| Thumbnails | Metadata Summaries | → | XML Results | → | Thumbnails.xslt | → | Thumbnails view (XHTML) |
| Bulls eye | Metadata Summaries | → | XML Results | → | DrawBE.xslt (**T2**) | → | Bull's eye view (SVG) |
| Footprints | Metadata Summaries | → | XML Results | → | DrawMS.xslt (**T3,T4,T5**) | → | Metadata boxes (SVG) |
| WFS | WFS access | → | GML | → | WFS2SVG.xslt (**T6**) | → | Features (SVG) |
| WMS | WMS access | → | image | → | | | Image (SVG) |

The following will only focus on the presentation of search results and the visualization of metadata footprints and WFS.

### 3.6.1. Search results presentation

Search results can be represented in forms of: table and thumbnails' views. In conjunction with table and thumbnail views, search results can also be presented as and linked to graphical representations. Metadata mapping and the bull's eye metaphor are the graphical representations that the Aim4GDI provides.

The table displays each item of search results as a row. In the thumbnails' view, sample images (map pictures) of data or map/feature services with their corresponding title are represented for each result. Metadata mapping concerns with the depiction of metadata footprints (taken from metadata bounding box) into the map with stylized attributes are also plotted on top of the map. The bull's eye metaphor represents the degree of relevance of search results against the query (see Figure 3.6.). The relevance can be the degree of closeness of spatial or thematic distance of the search results to the query. The area relevancy of search results is measured using Hausdorff distance. Meanwhile the thematic relevancy is determined by keywords matching in combination with the topic class matching. The techniques used for producing area and thematic relevancy of search results are discussed in Chapter 4. This section will concentrate on the use of XSLT technology to provide a dynamic solution customised for the web atlas interfaces designed.

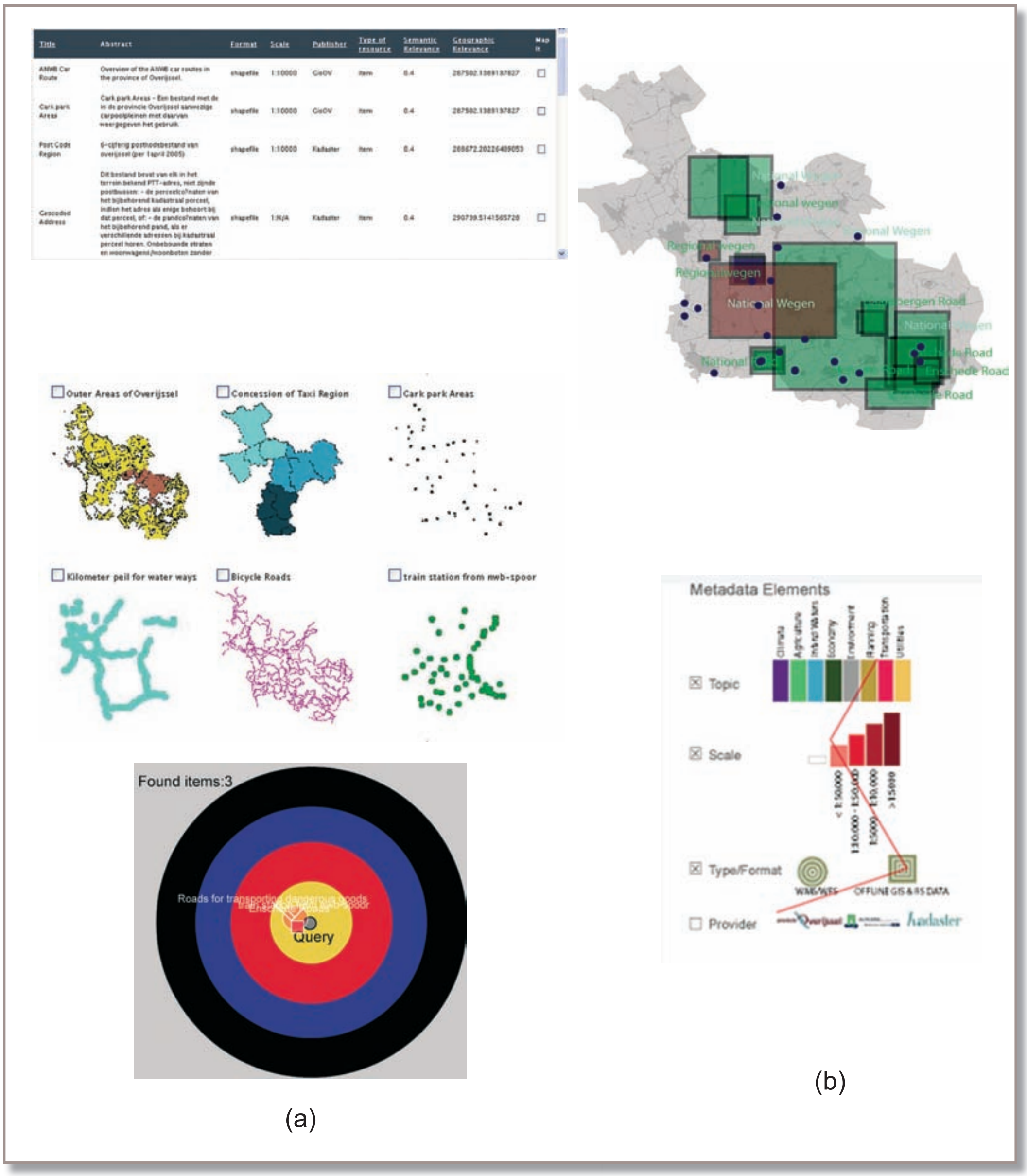



**Figure 3.7.** Searching & browsing interfaces: (a). in case of searching (Danny's case): available road datasets and feature services are presented as a table, thumbnail and a bull's eye view (b). In case of browsing (Lisa's case): metadata regarding road datasets (e.g., boundary boxes with available data) are superimposed on top of point features of WFS concerning the environmental quality and the population density map of the Overijssel province. Next to it is the display of the metadata legend.

To generate the table view, an XSLT template is applied against each item of the returned search results into a rows and columns presentation. Meanwhile to produce a thumbnails' view, the associated stylesheet is used to plot the submitted preview image along with the title of the summaries. Although the table and the thumbnail presentations are common displays to web users, however, they still need functions to conveniently filter the results. Hence, sorting functionality could be helpful to improve the efficiency of searching. In most of today's geoportals (e.g., (INSPIRE 2006a; NRC 2006b)), this function unfortunately is hardly offered to users. Concerning our previous example, Danny could prioritize the scale attribute during his assessment for the fitness for use by sorting out items by its scale or title, for instance. To enable users sorting out the items displayed, a sorting template (an XSLT file) against the XML data is prepared. Suppose a user sorts the results, the parameter value of the selected field to be sorted is passed to the template via a JavaScript function. This value needs to be added into the `xsl:sort` attribute to enable the sorting data is processed.

```
<xsl:param name=" sortKey" />
<xsl:param name=" sortOrder" />
<xsl:template match=" results" >
 <table>
   <tr>
     <th href=" #"  onclick=" sortTable( 'title' ,' ascending' );" >Title</th>
     <th>Abstract</th>
     <th href=" #"  onclick=" sortTable( 'format' ,' ascending' );" >Format</th>
      …
   </tr>
   <xsl:apply-templates select=" item" >
     <xsl:sort select=" *[name() = $sortKey]"  order=" {$sortOrder}" />
   </xsl:apply-templates>
 </table>
</xsl:template>
<xsl:template match=" item" >
 <tr>
    <td><xsl:value-of select=" title" /></td>
    <td><xsl:value-of select=" abstract" /></td>
    <td><xsl:value-of select=" format" /></td>
    …
 </tr>
</xsl:template>
```

T1

As mentioned previously in the beginning 3.6.1, graphical representation of search results include representations of point symbols on top of bull's eye metaphor. With the bull's eye display, the items of search results are represented as the point symbols, which are plotted according to their geographic relevance (in terms of area distance) to the area of interest of the query. The geographic relevance in this work is calculated using the Hausdorff distance measure; meanwhile orientation of each item is defined based upon the centre of metadata footprints towards the centre of area of interest (discussed in Chapter 4).

The stylesheet template that is used to project items of search results on top of the bull's eye is excerpted in the following. The key parameters to plot the items of results are the angle and the scaled-Hausdorff distance (it is represented as 'dhsc' there, with cosX and sinX are respectively, referred as to the cosine and sine of the angle of the item of search results). Different styles of representations are generated based upon the resources' characteristics; thus, the filtering process is applied in the transformation template. This gives wide options to style the display of the GDI resources. As exemplified in the following code fragment, when the type of a resource is WFS, the symbol is a circle and a specific class is assigned, otherwise a rectangle is drawn and another class is used. The style class is assigned based on the value of its attributes, for example its topic, data representation, and scale. This style class corresponds to the Cascading Style Sheets (CSS) fragments that rules the visual appearance of the item displayed.

```
<xsl:choose>
 <xsl:when test=" $stringres = 'http://metasum/elements/1.0/WFSitem' " >
   <circle cx=" {$dhsc * $cosX}" cy=" {$dhsc * $sinX}" >
     <xsl:attribute name=" class" ><xsl:value-of select=" resource" /></xsl:attribute>
   </circle>
   <text x=" {($dhsc *$cosX) + 1.5}" y=" {$dhsc *$sinX}" />
     <xsl:value-of select=" title" />
   </text>
 </xsl:when>
 <xsl:otherwise>
   <rect x=" {$dhsc *$cosX} " y=" {$dhsc *$sinX}" >
     <xsl:attribute name=" class" ><xsl:value-of select=" resource" /></xsl:attribute>
   </rect>
   <text x=" {$dhsc *$cosX} " y=" {$dhsc *$sinX} "/>
     <xsl:value-of select=" title" />
   </text>
  </xsl:otherwise>
</xsl:choose>
```

T2

Results presented in the interface (either in the table, thumbnail, or in the bull's eye view) can be superimposed on top of the default map and the selected thematic layers. The area of coverage is symbolized by the bounding box values of the metadata. The topic is differentiated by different colour hues. Other attributes of the summaries are represented as textual and point symbols within its bounding box. Specifically, symbols referring to scale categories, types of GDI resources as well as providers' logo can be displayed or hided on request (the layer control is offered in the metadata legend).

## 3.6.2. Mapping of metadata summaries

To support the process of data discovery, elements of each summary are mapped as symbols. Using cartographic principles of (Kraak and Ormeling 2002; MacEachren 2001), the nature of elements of metadata summaries and the differences among them can be communicated and compared. Based on the nature of the elements to be mapped, they can be qualitative (ordered) as well as quantitative (proportional) information. Using cartographic guidelines, these differences can be depicted for various levels of measurement. Some graphic variables plus text are chosen to represent the value of each element (Figure 3.8).


**Figure 3.8.** Graphic variables applied to each element of the metadata summary based on their measurement levels and the differentiations to be exposed (based on (Kraak and Ormeling 2002)).

The stylesheet template used for projecting summaries on top of the map has two processing principles: (1) assigning values of the style class of the summary's elements and (2) plotting the bounding box and its correspondent centre. The following exemplifies the syntax used to assign a corresponding style class for the "scale" element of metadata summaries.

```
<xsl:variable name=" plot_scale" >
 <xsl:choose>
  <xsl:when test=" scale &gt; 50000" >
    <xsl:value-of select=" ' scale1' " />
  </xsl:when>
  <xsl:when test=" (scale &lt; 50000) and  (scale &gt; 10000)" >
    <xsl:value-of select=" ' scale2' " />
  </xsl:when>
  <xsl:when test=" (scale &lt; 10000) and  (scale &gt; 5000)" >
    <xsl:value-of select=" ' scale3' " />
  </xsl:when>
  <xsl:when test=" scale &lt; 5000" >
    <xsl:value-of select=" ' scale4' " />
  </xsl:when>
  <xsl:otherwise>
    <xsl:value-of select=" ' scale0' " />
  </xsl:otherwise>
 </xsl:choose>
</xsl:variable>
```

T3

Meanwhile the following fragment shows the syntax used to convert the values of item's bounding box into a rectangle element in SVG with its associated style.

```
<g>
 <rect x=" {$xnw}  " y=" -{$ynw}"  height=" {$diverY}" >
   <xsl:attribute name=" class" ><xsl:value-of select=" $res" /></xsl:attribute>
 </rect>
   <text x=" {$xnw + ($diverX div 2)}"  y=" -{$ynw -($diverY div 2)}" >
      <xsl:value-of select=" title" />
   </text>
</g>
```

T4

While the style class has been defined earlier, such as in the case of the "scale" element shown earlier, the corresponding SVG symbol for representing a specific value of element of metadata summaries can be plotted using this specific processing:

```
<g class=" plot_scale"  visibility=" visible" >
 <use>
  <xsl:attribute name=" xlink:href" >
    <xsl:text>#</xsl:text><xsl:value-of select=" $plot_scale" />
  </xsl:attribute>
  <xsl:attribute name=" transform" >
    <xsl:text>translate(</xsl:text>
    <xsl:value-of select=" $xnw + ($diverX div 2)" />
    <xsl:text>,-</xsl:text>
    <xsl:value-of select=" $ynw - ($diverY div 2)" />
    <xsl:text>) </xsl:text>
    <xsl:text>scale(250)</xsl:text>
 </xsl:attribute>
</use>
</g>
```

T5

### 3.6.3. Map and metadata legend

This section will present the development and intended use of the map and metadata legend offered. The organization of layers and styles of thematic maps as the background information for the superimposition scheme is handled using RIMapper architecture (Köbben 2004). With this approach, thematic layers are stored using MySQL databases system as OGC's Simple Feature in the background and a proprietary XML file is used to configure map elements and styles issues. In addition to the use of RIMapper, a possibility to directly use an SVG map file is also offered. A thematic layer either from a RIMapper configuration or from an SVG file was visualized by means of cascading the layer on top of a static main map (an SVG map file) that was embedded in the main HTML page. The thematic layers, symbols of metadata summaries, and corresponding legend are dynamically inserted into this SVG file on request with help of AJAX approach.

Such application design provides advantages for the atlas editor or GDI administrator to only need to modify the XML file definition and CSS fragments in case of editing the content and styles of the thematic layers and metadata display. In the Legend Box, users can modify the colour values and opacity of the of the layers' display. This could give benefits to users, since users might superimpose the thematic layers and GDI resources as many as they can scrutinize the display for their specific data discovery and analysis purposes.

Metadata legend is intended to support users' assessment when metadata footprints are plotted on top of the map. Four metadata elements can be visualised as graphics: geographic extent, scale, data representation type, and publisher. The geographic extent of metadata is plotted according to bounding box values related to the data with its colour hue represents the topic of metadata. Scale, data representation type, and publisher are represented as pictograph symbols on the centre of the corresponding bounding box. Users can turn on and off each of these layers. To enable users quickly investigate the footprint plotted, every time a user mouse over a unique geographic extent or symbols referring to a data, a dynamic line connecting attribute values of the data is shown on the Parallel Coordinate Plot (PCP) view in the metadata legend (Figure 3.7(b)).

### 3.6.4. Superimposition of summaries and feature services

To superimpose symbols of summaries over the map selected, the query by its linkage to the map selected is processed against metadata summaries (as shown in the first query example in the Section 5.2.). The step to process the output of the query into the SVG format involves the same stylesheet applied to project a single item of search results into the map.

Although the plotting of metadata footprints is not new (e.g., (Cay 2002; Janee and Frew 2002)), however, the approach is commonly applied as the results of search request (as seen in (Cay 2002)) or to give indication of the data coverage (as seen in Alexandria Digital Library (Janee and Frew 2002)). The superimposition scheme is designed to offer possibilities for users to quickly review the area and the topic coverage of the GDI resources. Additionally, it is intended to enable users to compare and check density and pattern of the data and feature services offered within the GDI, either they are in the same topic of interest or cross-topic.

As an example, Lisa's task is recalled. She could compare the availability of datasets related to the map of environmental quality and datasets related to the map of transportation networks. This can be done by loading the summaries that are related to the map of "transportation networks" on top of the displayed map of "environmental qualities" and its related summaries, or vice versa, depending on the focus of analysis. Such an interaction scheme can provide a concise indication about the data and her area and topic of interest, thus she could quickly overview the data availability and hypothesize which datasets or map/feature services could be important to support her job. To help Lisa (and Danny and other users) assess the data suitability, she may use the metadata legend. Through the metadata legend, the visibility of the metadata components can be controlled. A line connecting the values of metadata elements signifies the individual summary inspected (Figure 3.7(b)).

Each summary displayed over the map is accessible. Depending on the type of summaries selected for access, users can get different presentations. In case the summary represents datasets, a new window that displays original metadata descriptions from the data provider web site is shown. If the summary is representing a feature service, the user can get the feature overlaid. For the latter case, a transformation template *WFS2SVG.xslt* is used against the WFS response resulted. The corresponding CSS style class is applied against the feature mapped. The subsequent lines show the principle processes that are applied to convert GML returned from a feature service (polygon features) into the SVG elements to be inserted into the main map.

```
<!-- draw base polygon detail -->
<xsl:template match=" gml:featureMember"  mode=" baseDetail" >
<!-- get key properties -->
<xsl:variable name=" fid" ><xsl:value-of select=" .//@fid" /></xsl:variable>
<!-- write SVG path element -->
<g>
  <xsl:attribute name=" class" ><xsl:text>defArea</xsl:text></xsl:attribute>
  <xsl:apply-templates select=" .//gml:Polygon" >
    <xsl:with-param name=" ID" ><xsl:value-of select=" $fid" /></xsl:with-param>
  </xsl:apply-templates>
</g>
</xsl:template>
<xsl:template match=" .//gml:Polygon"  mode=" class" >
…
</xsl:template>
```

T6

## 3.7. Concluding remarks

What has been discussed in this chapter is the development of an application framework to support the realization of the envisaged atlas metaphor functionalities. This study sees the combination of the use of Semantic Web technology and visualization design templates is necessary and possible in order to deliver visualization methods that are capable of supporting users to deal with searching and browsing information-seeking behaviour to support problem solving processes with the geospatial resources in the GDI via the national atlas.

Metadata summaries and the atlas directory are expressed as RDF triples. The use of SPARQL for querying RDF data make traversing subject, predicate, and object of the GDI resources in support of metadata retrieval more straightforward and well suited for a dynamic web portal such as the Aim4GDI discussed in this chapter. Additionally, the ease to match triple pattern and to combine multiple graphs opens up more possibilities to process complex search terms for discovery purposes and to enrich the visualization and integration of the GDI resources. This includes the simplicity to visually cascade metadata items on top of a relevant thematic map for a data discovery purpose. Such abilities are significant to realize abilities of the national atlas to support exploration and synthesis phases for problem solving with the GDI.

Users can perform searching of the GDI resources through the linked multi-views in forms of table, thumbnail, and bulls-eye metaphor. Using these linked views, users are capable to project a specific item on the map display. This visualization can give a new and unexpected insight during the searching and browsing activities. In addition, to advance the browsing strategies, the synthesis of GDI resources through the storyteller view is offered to improve the use of GDI for decision support.

The storyteller view is intended to provide a tractable navigation scheme that enables users to sequentially look in detail at the thematic-related resources and to interrelate them for comparison purposes (this issue will be discussed in detail in Chapter 5). The navigation scheme in the storyteller view is designed to keep users in control of the display while browsing the GDI resources. The idea of combining thematic maps and the storyteller view in support of the browsing strategy of the atlas content is motivated by the facts that browsing geospatial resources in a GDI organization can be overcrowded and difficult when a systematic and coherent navigation scheme is not available. The development of effective interaction mechanism to develop such storyteller is discussed in Chapter 5.

Although the integration of WMS into this project has not been the focus, arguably the resulting WMS maps can straightforwardly be incorporated into the SVG interface as shown e.g., in (Köbben 2007; Williams and Neumann 2006). Another research agenda item in this project is to test the application effectiveness and efficiency in assisting users' needs and tasks. For this purpose, a usability evaluation using scenario-based development (Carroll and Rosson 2002) involving potential users as test participants has been executed. Certain scenarios of uses, similar to Danny's and Lisa's scenarios mentioned in this chapter, will be used as a framework to evaluate the prototype's abilities to fulfil the required activity, information, and interaction that users might need during their interactions with the Aim4GDI. Chapter 4 discusses and evaluates the use of the atlas metaphor to handle a typical Danny's scenario, while Chapter 5 deals with the use and evaluation of the atlas metaphor to cope with a typical Lisa's scenario.

# Metadata Visualization and Search Strategies*

Chapter 3 presents an application framework describing searching and browsing functionalities. This chapter will follow up the discussion on the search strategies. More specifically, this chapter will elaborate further the design decision to visualize search results in support of data discovery. The evaluation of search interfaces that are developed according to the design strategies discussed will then be presented.

## 4.1. Introduction

As metadata offered by providers are assumed to be complete, correct, and encoded in conformance to a specific standard (e.g., ISO19115), they are accessible through a search engine or a search interface of a catalogue service. Via the search interface, users formulate queries using search terms stating location, attribute, and time properties related to their search interests. Geospatial metadata are considered to be structured documents. Using general web search engines like Google, which primarily deals with unstructured documents, users are still capable to retrieve geospatial metadata. For instance, with the query "filetype:xml road GIS Florida" some metadata of GIS datasets about roads in Florida are listed among the results. However, as search engines treat these metadata just like any other web documents, indications regarding for instance, the bounding box, abstract, currency, and accessibility of datasets are not presented in the list of results. Hence, the use of search engines like Google to perform "unofficial" searches of geospatial resources would be cumbersome.

For a GDI, the "official" proposed solution for dealing with the geospatial data discovery is the so-called Catalogue Services for Web (CSW) and clearinghouses (Nebert 2004c). This approach relies on the connectivity between the coordinated registry and registered metadata. To search the required resource, using this approach, users can make use of geoportals, gateways that facilitate discovery of and access to geospatial resources (Maguire and Longley 2005). The prominent features in this approach are the ability to connect and query the registered metadata using the ISO 29350, also known as ANSI Z39.50 (NISO 2003), as a discovery protocol and the proposed use of Catalogue Query Language (CQL) as the query language (OGC 2005).

---

*This chapter is based on:
Aditya, T., and Kraak, M.-J. (2007b). "'A Search Interface for an SDI: Implementation and Evaluation of Metadata Visualization Strategies'" Transactions in GIS, 11(3), 413 - 435.

From the perspective of users searching data, the current “official” approach does not work properly (Aditya and Kraak 2006). As noted by Tsou (2002), most implementations of this approach place all distributed nodes on the same level under the gateway server. As a result, search results are commonly organised under the data provider links or nodes. As such, supporting tools to simplify users’ search process, such as possibilities to sort results by format or scale of interest or to revisit items that have been previously previewed, are lacking (see Chapter 2).

Alternatives for the “official” approach, among others, include the aggregation of distributed metadata into a few or a single server. This method can be an alternative when bandwidth limitation is a barrier for setting up the suggested distributed catalogue services (Nebert 2004c). However, it is argued that this alternative can be useful not only to anticipate bandwidth limitation but also to provide an improved accessibility of the current geospatial resources; in a way that metadata offered can be summarized and used by a search interface in the GDI. Further, the same set of aggregated metadata can also be used by other web applications in the same GDI organization. The aggregated metadata will be updated once, for example, if there is new metadata published or renewed. Another motivating development is that the emergence of geospatial content syndication and aggregation has now entered a new phase as the OGC launches an initiative to include GeoRSS technology in its interoperability program. This technology is intended to pipeline geo-coded information, for instance updates of feature services or alert services, so applications can share, aggregate, and map this information (OGC 2006).

Considering that search interfaces are crucial to advance the GDI accessibility and that aggregation strategy can arguably stimulate a better dissemination of geospatial resources, this chapter develops a search interface that builds on the approach of metadata aggregation and is aimed at improving the users’ search process. With the aggregation strategy, information summary describing, for instance, the substance, area of coverage, currency, and accessibility of various offline data and geospatial web contents can be integrated and presented through the search interface (Aditya and Kraak 2007a). In this way, the metadata aggregation is “an added value with respect to contents-based access to information” (Stuckenschmidt and Harmelen 2004). For simplifying the users’ search process, along with the aggregation strategy, the visualization of and interaction with metadata are aspects that this chapter will focus on.

Regarding geospatial metadata visualization, multivariate visualizations such as space-time plots, glyph plots, scatter plots, parallel coordinates plots, and Chernoff-faces have all been used to enable users to explore the characteristics of geospatial data during and after the search (Ahonen-Raino and Kraak 2005; Gobel and Jasnoch 2001; Hobona et al. 2006; Klein et al. 2003). Despite these efforts, metadata visualization that goes beyond the exploration of data characteristics has not been solved completely. In particular, as previously exemplified, a support to enable users to sort and to compare is lacking. Additionally most of metadata visualizations only provide limited capabilities to combine metadata and thematic layers that are considered relevant by the users. For example, the possibility for projecting metadata footprints on top of the related thematic map and studying data pattern for a specific topic on top of a specific map is hardly found in a single search interface. Such capability could provide a better insight in relation to the users' search context.

The approach discussed in this chapter is to provide a sophisticated search functionality in a typical geoportal that allows users to integrate thematic mapping (e.g., web atlas) and metadata visualization in the GDI context. As such, geospatial data visualization and catalogue functions are offered through one single interface. This kind of approach has been recently implemented in some GDI portals, e.g., Geospatial One-Stop Shop (USGS 2006) and intended to exploit the GDI as an infrastructure for access and sharing towards its potential.

This chapter aims at examining the use of maps and graphics to facilitate the discovery of geospatial resources in a GDI. The use of maps or geo-referenced visualizations (as implemented for example in the Alexandria Project (Ancona et al. 2002)) or spatialization is a suitable approach to improve usability of geospatial (and non-geospatial) content searches (Aufare and Trepied 2001; Fabrikant 2000b). In this regard, most existing geoportals only provide limited tools to explore their contents with the use of graphics and maps. Evaluation of visual interfaces can provide guidance into the design feasibility of particular displays and interaction strategy for the success of a visualization environment (Fuhrmann et al. 2005b). For geoportals, an investigation into effective strategies for facilitating discovery of geospatial resources with the use of maps and graphics is relevant to advance GDI access and use. This chapter will focus on the aspects of the presentation of metadata as well as the evaluation of the developed graphics and map-based interfaces of Aim4GDI prototype in support of a search task.

## 4.2. Metadata visualization applied

Metadata summary can be seen as an example of the use of metadata aggregation strategy to support data discovery. With respect to the metadata summary, as mentioned in Section 3.4., an RDF query provides a straightforward approach to reconstruct the relationships between the metadata summary and other data within the directory for information integration purposes. In addition, it provides a simple method to retrieve possible matches between an individual metadata summary and its underlying topic category.

With these arguments, providing detailed semantic descriptions to the metadata (as has been applied for enabling semantic chaining and discovery, as implemented in (Lemmens et al. 2006; Lutz and Klien 2006)), is considered not economic for this work. In contrast, the matching between the query pattern and the triple patterns of the metadata summary and semantic references of topics through an RDF query is considered adequate to yield search results. For this purpose, as explained in

Chapter 3, the SPARQL query language (W3C 2006a) is used. SPARQL is a query language and data access protocol for the Semantic Web. There are two types of queries implemented in this work: the constrained graph pattern (e.g., a query against the metadata summary graph) and the dataset pattern (e.g., a query against the metadata summary graph in combination either with the topic category graph or the directory graph). Formal definitions for these two types of SPARQL queries can be found at the SPARQL Query language – Formal Definitions (W3C 2006b).

In comparison to other approaches, such as the CSW with CQL query language (OGC 2005), this approach can provide benefits in data integration and visualization for a geospatial search interface. With a metadata summary technique and with the use of SPARQL as the query language (W3C 2006a), the proposed search interface can deal with various geospatial metadata resources. More importantly, it can offer complex searches, integrating various metadata of geospatial resources within the GDI. Further, the integration of GDI contents and related non-geospatial web contents as well as thematic and general ontology (e.g., WordNet), can also be facilitated. This is possible since SPARQL gives a flexible and extensive way to query RDF data, including RDF Schema and Web Ontology Language OWL. Additionally, it is also plausible to use SPARQL as a protocol to invoke a query via a specific protocol binding like ISO 23950.

As the work here is aimed to grapple with data selection needs, the query matches returned are processed further with a purpose to answer the question: how to effectively signify data characteristics and indicate their relevance to the search query?

### 4.2.1. Previous work

In an attempt to visualize the data characteristics, various forms of exploratory visualizations have been studied. As noted in (Ahonen-Raino and Kraak 2005), according to Keim's typology (Keim et al. 2005), they can be in forms of geometrically transformed displays and iconic displays. These include parallel plot coordinates, scatter plots, star plots, the Chernof faces (Ahonen-Raino and Kraak 2005), as well as tile bars (Gobel and Lutze 1998). When location and time are elements that need more attention, the map-based displays can be offered as temporal box plots, space-time plots, and glyph plots (Gobel and Jasnoch 2001) or as index area (Comenetz 2004) for instance. Certainly the list can be extended, when one considers other aspects to be emphasized: such as dimensionality: e.g. cone trees (Robertson and Mackinlay 1991), comparability: e.g. tabular-based displays (Chi et al. 1998), and perhaps the connectivity and relevancy of the data: e.g. embedded springs (Fluit et al. 2002), 3D scatter plots of thumbnails with spatial, temporal, and semantic relevance as 3D axes (Hobona et al. 2006) or a bull's-eye view (Spoerri 2004) .

In this work, from those various displays for showing data characteristics, tabular-based displays in forms of a table view and a thumbnail view, a map-based display in form of cascaded metadata and thematic layers, and a relevance-focused display in form of the bull's eye display are selected as methods to fulfil those needs. In more detail, motivations for selecting these methods are given as follows.

### 4.2.2. Presenting elements of metadata summaries

A tabular-based or spreadsheet display is chosen for this work since this type of visualization enables users "to build multiple visual representations of several data sets, perform operations on these visualizations together or separately, and contrast them visually"(Chi et al. 1998). Since the search interface is intended for public use, a table display is assumed to give an advantage for its familiarity. Flight planners, stock exchanges or digital libraries are a few of many other public web-applications that present search results as a table view. Filtering and contrasting results can be more convenient with the table view, when sorting tools are available. In this respect, the sorting ability has a top priority to be implemented in the search interface. The sorting tool is considered lacking in most existing geoportals (e.g. Geospatial One-Stop Shop (USGS 2006), FAO portal (FAO 2006)). As a result, users are coerced to drill down and browse through item by item in order to compare data characteristics among the results.

As already mentioned in Chapter 3, two types of table displays are offered in the developed atlas metaphor prototype, Aim4GDI: textual and thumbnail tables. The display of a textual table presents search results as rows with selected elements of the metadata summary (e.g. title, topic, scale) as columns. The thumbnail display presents a graphical overview of the search results. When identification of data requires more information, the user could use a textual table. Meanwhile the thumbnail table is offered since such display have been proven to increase significantly the efficiency of search process (Woodruff et al. 2001). To support a "focus + context" interaction approach similar to the table lens display (Rao and Card 1994) for example, the tool tip box containing related information regarding the data in focus is shown as a result of mouse over action. In case of the thumbnail and bulls-eye displays, a pop-up window specifying the title, an abstract, and selected element of metadata summary, e.g., scale and provider, is shown. Whereas in case of the table display, a tool tip shows the thumbnail of the hovered metadata.

In addition, each result in the table can be superimposed on top of the map being selected as symbols representing metadata footprints. This is to offer possibilities to isolate and investigate the suitability of data in accordance with the user's search context. Further, such functionality is offered to enable users to assess, for instance, the pattern and density of the data being investigated. In this mapping, the elements of metadata specifying the title, bounding box, and topic are displayed with transparency and set as the default visual elements. Other attributes such as scale, type of geospatial resources, and publisher can be displayed on request (see Section 3.6.2.). Strategies to visualize bounding boxes as transparent rectangles and to hide first the detailed presentation of metadata attributes are intended to ensure that the clarity of map does not suffer as the number of displayed variables increases (see e.g. Robinson et al. 1995, p.550-556).

In order to highlight the relevance of search results to the query, geographic and thematic relevance are measured and represented as texts (in the table) and graphics (in the bull's-eye display).

The bull's-eye display is offered to provide a quick overview of the pattern and relevance of the data against the query. With a bull's-eye display, the query is represented as the centre of the display. Search results are plotted surrounding the centre based on their geographic and thematic relevance to the query. In essence, this metaphor ranks the matching. The distance from the search query (i.e. centre) to individual search results represents the relevance of the geographic coverage of the results to the query. Meanwhile, the size of the plotted symbols denotes the thematic relevance between the individual results and the query. The bull's eye has been used in many occasions to ease understanding of the search results, see e.g. (Rorvig and Fitzpatrick 2000; Sutcliffe et al. 2000).

Concerning the Aim4GDI prototype, Figure 4.1., Figure 4.2., and Figure 4.3. show the interfaces developed in relation to two steps required for searching geospatial resources: defining search terms and assessing search results.

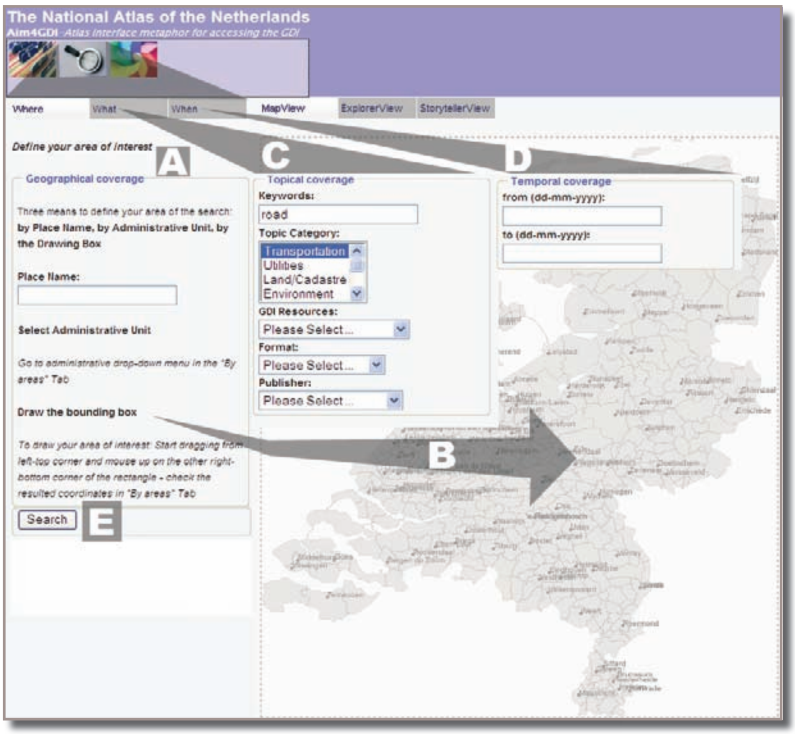



**Figure 4.1.** Defining search terms: In order to search for geospatial resources, a user needs to activate an Explorer tool first (by clicking a magnifying glass icon). In the **where** tab (A), the user can type a placename. An area of interest can also be defined by an administrative unit or by drawing a bounding box over the MapView (B). In C and D, the user can specify search terms related to **what** and **when** questions.

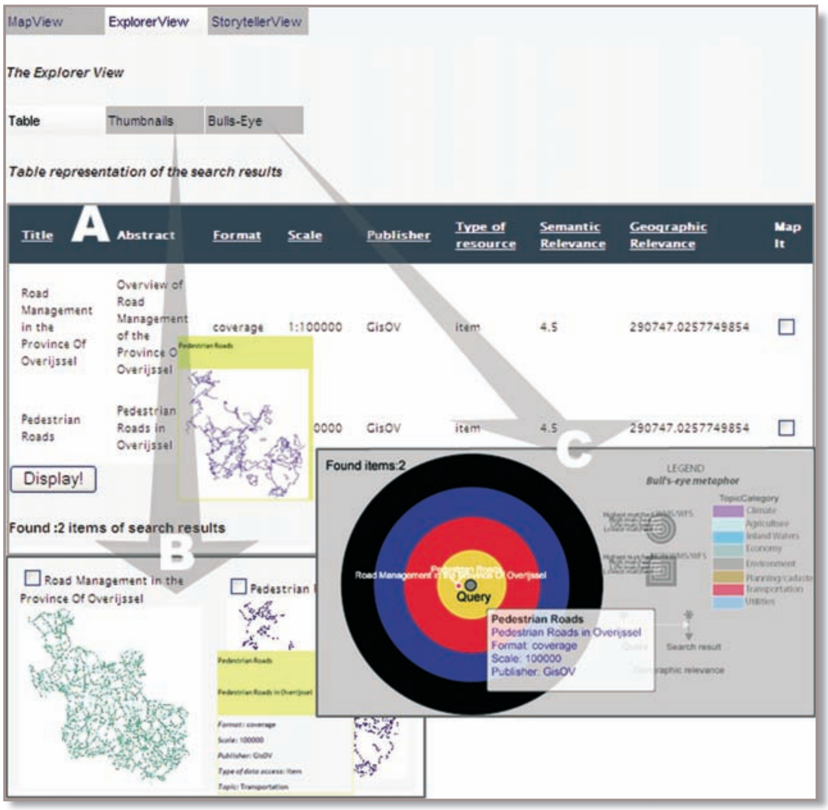



**Figure 4.2.** Search results are presented in ExplorerView as a table (A), thumbnail (B), and bull's-eye (C) view. In all views, a tool tip box containing relevant information regarding the data in focus is shown as a result of mouse over action. Selecting checkboxes in the table and thumbnail views and clicking a "Display!" button means projecting metadata footprints into the MapView (Figure 4.3. below).

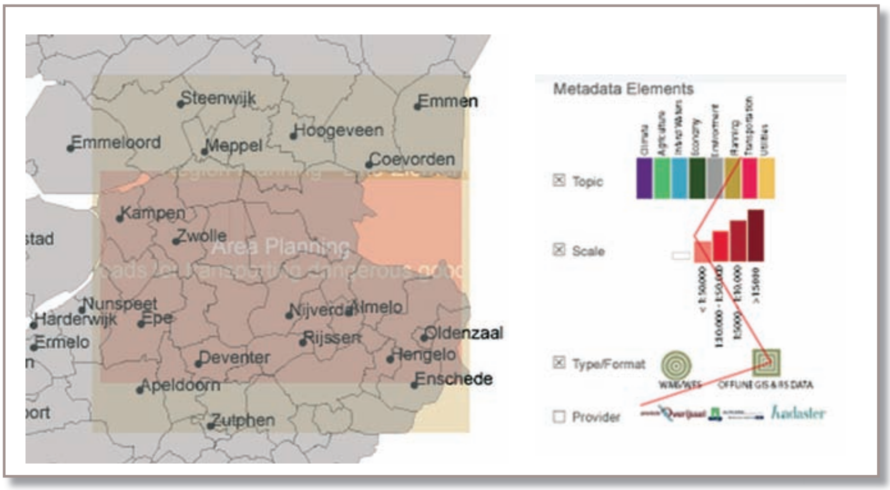



**Figure 4.3.** Metadata footprints of selected items in the search results can be projected into the MapView. As a user interacts with the geographic extent of each footprint, a corresponding line connecting attribute values of metadata is shown.

Corresponding principles to gain geographic and thematic relevance are discussed as follows.

### 4.2.3. Area of interest relevancy

The geographic coverage of metadata (either proprietary data or map and feature services) is commonly expressed as two corner points of a box specifying the coverage extent, known as the bounding box. In this work, the area of interest of the query is conceived as the box too. In this respect, the area of interest of a query can be selected from the list of administrative units or typed as a place name or drawn as a rectangle over the map. To measure the box matching or the proximity between the query and the metadata summary, the Hausdorff distance algorithm is applied. Hausdorff distance measure is commonly applied to detect shape similarity (shape, size, and location) in the fields of image matching and pattern recognition (e.g., Veltkamp 2001). In geo digital libraries, this algorithm has been applied in the Alexandria Digital Library project (Janee and Frew 2004). The algorithm is chosen in this work, due to its simplicity to be implemented and its sensitivity to position (the whole shape of the boxes will be considered) (Grégoire and Bouillot 1998).

The distance, defined in the literature as *"maximum distance of a set to the nearest point in the other set",* is computed using this equation:

$$h(A,B) = \max_{a \in A} \{ \min_{b \in B} \{ d(a,b) \}\} \qquad (1)$$

Here, $h$(A,B) is the Hausdorff distance between two (finite) set points A and B, where $a$ and $b$ are points of sets A and B respectively. In addition, d(a,b) is the Euclidean distance between these points. In addition to this distance calculation, the centres of search results are used to calculate the orientation of search results against the query (in this respect the centre of search area). This information is used to plot search results on top of the bull's-eye display.

This approach, however, suffers for its inabilities to deal with more expressive spatial query such as: 'overlap' and 'contain' as for example implemented in Alexandria Digital Library (Hill 2000) or FAO portal (FAO 2006). Further, more advanced approaches have also been discussed for example in (Jones et al. 2003; Schlieder et al. 2001). As the geographic coverage of metadata is mostly expressed as a simple bounding box, the current "box matching" approach is assumed to be sufficient to yield competent areas of a search.

### 4.2.4. Thematic relevance

This work measures the thematic relevance by combining the matched keywords and the topic class. The notion of the closeness degree in social networks is applied to find the matching of keywords (Wasserman et al. 1994). In this respect, the results are conceived as a radial graph organized by their topics (Figure 4.4.). Here, the values of search terms (topic and keywords inputs) are matched against the elements of the title, abstract, and topic of search results. The use of such a centrality measure is motivated by other works in using the concept to determine the relevancy of search results (Chakrabarti et al. 1999) and to visualize the relationships (Fluit et al. 2002; Golbeck and Mutton 2005).

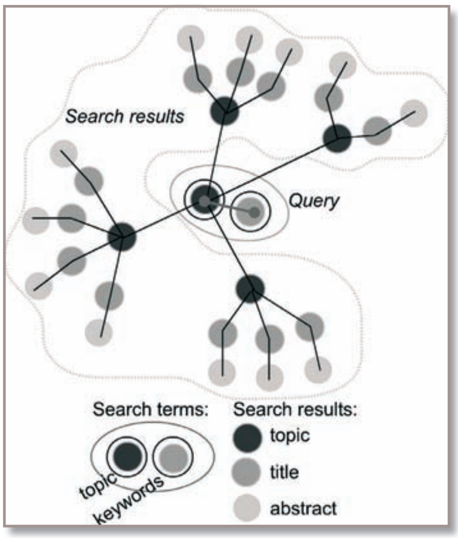



**Figure 4.4.** Measures of the closeness centrality are determined using the search terms of the query and the values of the title, topic, and abstract elements of the search results. The structure of search results is perceived as a radial graph.

To determine the topic class, the value of topic of the results is matched against the topic category graph mentioned earlier. As the classes of topics of search results are returned, only the result that has equal class to the topic of query is given an extra weighting factor. For the sake of clarity, Alani and Brewster (2005) have defined a formal expression of such similar class matching. The strategy of class matching is implemented to identify objects that are conceptually close but not identical or having a same term (Rodriguez and Egenhofer 2004). The formulation for combining keywords matching and topic class matching in attempt to produce the thematic relevance (TR) is given as follows:

$$TR = \alpha[KM.Ti] + \beta\,[KM.TC] + \gamma[KM.Abs] + [CM.TC] \qquad (2)$$

Here, [KM.Ti] refers to a Boolean value of matching in <dc:title/> element, [KM. TC] refers to the Boolean value of matching in <dc:subject/> element, and [KM. Abs] refers to the Boolean value of matching in <dc:abstract/> element. The [CM. TC] corresponds to Boolean value of class matching between the topic of item of results and the topic search term. Meanwhile $\alpha$, $\beta$, $\gamma$ are indexes representing the closeness degree of the title, topic, and abstract element. To attain to these indexes, the following measures are calculated:

$$\alpha = g \bullet \left[\sum_{Ti=1}^{g} d(q_{key}, Ti)\right]^{-1} \qquad (3)$$

$$\beta = g \bullet \left[\sum_{TC=1}^{g} d(q_{topic}, TC)\right]^{-1} \qquad (4)$$

$$\gamma = g \bullet \left[\sum_{abs=1}^{g} d(q_{key}, abs)\right]^{-1} \qquad (5)$$

In these measures, $q_{topic}$ refers to the topic expressed in the search term, $q_{key}$ refers to the keywords in the search term, and *g* refers to the number of items in search results. *Ti*, *TC*, and *abs* denote the title, topic, and abstract of each search results. Here, the distance $d(q_{xx}, Tx)$, refers to number of lines linking “actors” of query and search results, which are 1, 2, and 3 for *TC*, *Ti*, and *abs* respectively. As the structure of networks is perceived as a radial graph, these number of lines are equal across the set of matched elements (Wasserman et al. 1994).

## 4.3. Implementation

The development of user interfaces of search and visualization strategies discussed in this chapter has been discussed in Chapter 3. In particular, query services and search interfaces developed for Aim4GDI prototype have been discussed in Section

3.5 and 3.6. The calculations of formula (1) to formula (5) discussed above are done by a Java servlet that corresponds to “Search Servlet” shown in Figure 3.6. The results are then processed and presented as a table, thumbnail, and a bull’s eye view in the ExplorerView discussed in previous chapter and also in Section 4.2 above. Additionally, the implementation of metadata mapping (projecting a metadata footprint on top of MapView) and the superimposition of the results with thematic layers and WFS in the prototype have also been discussed in Section 3.6.

## 4.4. Evaluation

This section will first describe the test that has been done to evaluate the search interfaces of the Aim4GDI prototype, and then, present the test results. The aim of the test was to collect feedback regarding the design decisions of the table, thumbnail, bull’s-eye display and metadata mapping offered in the search interface. For this test, the approach of scenario-based design (Carroll and Rosson 2003) has been used. It regards the system development as a cycle, and the claim analysis is used to generate and evaluate potential causal relationships between features of a design and both the positive and negative consequences of the design. By explicitly exposing the process of the design into *activity*, *information*, and *interaction* scenarios, the implementation of iterative development can be more systematic and manageable (Carroll and Rosson 2002) (see more detail in Chapter 6).

Seventeen subjects agreed to participate in this test activity. All subjects were graduate students in Geoinformation Management of an MSc programme ran jointly by four Dutch universities (referred to as GIMA in Figure 6.3 of Chapter 6). They could be divided into two groups: group A (mid-career people with GIS background) and B (no GIS background). Group A contained twelve individuals experienced in GIS projects (e.g. GIS specialist, geologist, surveyor), ranging from one up to twelve years. The other five test participants, were individuals working as either IT Specialist, web developer, teacher or student, were put together in Group B.

A scenario of a search task was developed in this test (discussed in more detail in Chapter 6). In summary, the scenario was about creating a noise map for the Province of Overijssel. To complete the task, some data related to roads, noise, and environmental qualities are required. In the test, the participants are asked to only deal with data related to road and transportation in the province of Overijssel. Along with this scenario, activities to be completed are described in the test instructions. These activities can be listed as follows: (1) defining search terms using where and what tabs, (2) assessing search results using a table display, (3) assessing search results using a thumbnail display, (4) assessing search results using the bull’s-eye display, (5) projecting items on top of a map, and (6) cascading metadata items and thematic layers. Test participants were required to step through these activities and to answer the corresponding questions. Each question, phrased as a statement-based question, had five possible answers, ranging from “strongly disagree” to “strongly agree”. Their responses were administered with the Likert scale (Likert 1932), so responses of participants can be seen as ordinal data, and as such, strongly disagree is conceived as 1 and strongly agree is conceived as 5 (Table 4.1. and Table 4.2.). In addition to multiple choices, a blank column was offered to facilitate additional comments the test persons might want to express. Based on several previous trials, the time for each participant was limited to 60 minutes for completing the test.

The focus of this test experiment was to evaluate the effectiveness of the search interface developed to enable users to *interact* (i.e. sorting, previewing with tool tip) and to convey *information* presented (i.e. to indicate, to compare, to relate with the search context, and to assess the geographic and thematic relevance). Responses regarding these aspects are important to evaluate whether the design decisions for visual displays and the interaction strategy proposed will be really useful to the GDI users and have been appropriately accommodated in the search interface developed. After completing the test, test participants were asked to participate in a short focus group discussion (40 minutes), which was used to obtain additional comments and help validate the test. Figure 4.5 shows responses of the test participants regarding the assessment of search results.

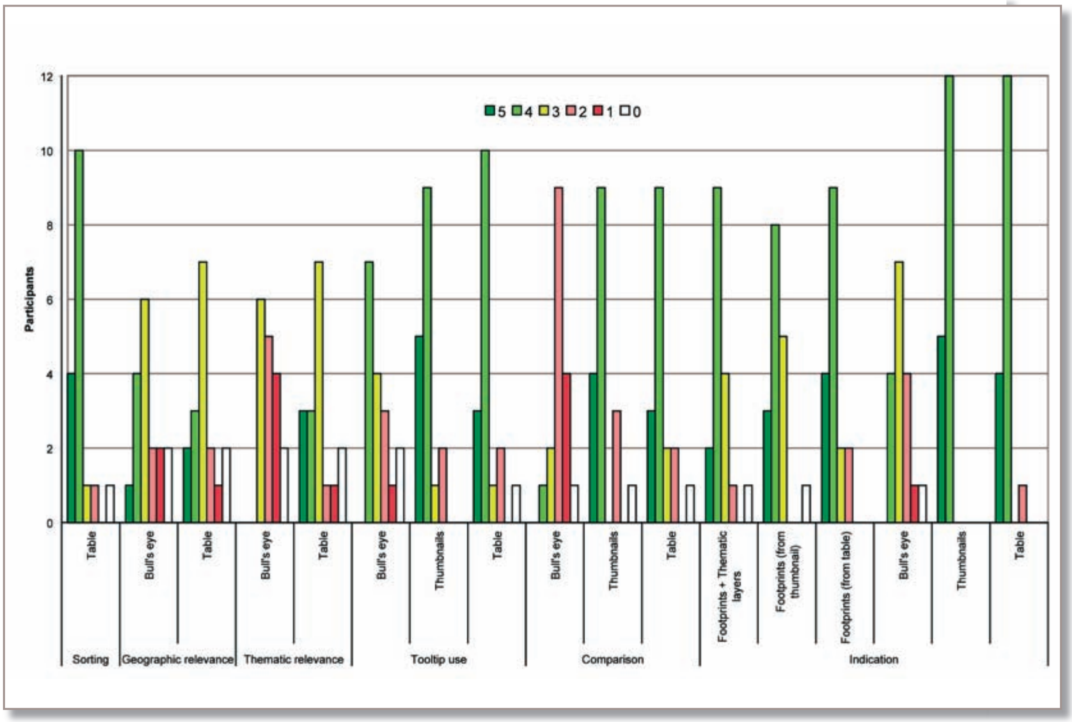



**Figure 4.5.** Feedback regarding the use of visual methods or displays offered in the search interface to support test participants to indicate, compare, overview, assess the thematic and geographic relevance, and sort the search results. Responses were measured on the Likert scale (with 0 = no data; 1=strongly disagree until 5 = strongly agree)

Three statistic tests were used to analyse the feedback gained in the use test. The Friedman's test, a two-way analysis of variances, was used to assess methods for indicating and comparing results (referred to as *Statistical Test A1*). The Wilcoxon signed rank test for a single sample was used to assess whether the designed visual methods or displays were considered helpful to the users (referred to as *Statistical Test A2*). In addition, this study was also interested to see whether there was a difference of perception or preferences between a group with GIS working experiences and a group with less GIS working experience (referred to as Group A and Group B defined above). For this purpose, a Mann-Whitney test was applied to assess whether there was evidence to conclude that the effectiveness of the use of the atlas for the two groups was different (termed as *Statistical Test A3*). In Chapter 6 (Section 6.3.3), the rationale for the use of the tests mentioned above as well as the relationship of these statistic tests to the overall design evaluations done in the study will be discussed. The results and analysis of the evaluation of the visual methods and strategies of the atlas metaphor in this specific test are given in Table 4.1 and Table 4.2 below.

**Table 4.1.** Two-way analysis of variances for inidicating and comparing results (critical significance = 0.05):

| **To Indicate** | | | | | |
|---|---|---|---|---|---|
| | Table | Footprints via the table view | Footprints via the thumbnail view | Bull's eye | Interpretation |
| Thumbnail | 0.696 | 0.402 | 0.131 | 0.000* | The thumbnail view is better used than bull's eye view to indicate the required data |
| Table | | 0.655 | 0.264 | 0.001* | The table view is better used than bull's eye view to indicate the required data |
| Footprints via the table view | | | 0.502 | 0.004* | Footprints via the table view is better used than bull's eye view to indicate the required data |
| Footprints via the thumbnail view | | | | 0.029* | Footprints via the thumbnail view is better used than bull's eye view to indicate the required data |
| **To Compare** | | | | | |
| | Table | | Bull's eye | | Interpretation |
| Thumbnail | 0.927 | | 0.000* | | Thumbnail is better used than Bull's eye to compare the results |
| Table | | | 0.000* | | Table is better used than Bull's eye to compare the results |

**Table 4.2.** The effectiveness of the searching mode: an investigation whether the median of design issues related to the completion of six search activities (listed in the text) is equal to "no effect" or not useful (with 0.05 level for a non-directional test). The results are presented according to the use of visual methods to enable users to interact and to convey information presented (Figure 4.5)

| Use Issues | Visual Methods/ Displays | Ho | M | P-value | Conclusion | Design Implementation |
|---|---|---|---|---|---|---|
| Indication | Table | Ho: M = 3 | 4 | 0.000 | Reject Ho | Acceptable |
| | Thumbnail | Ho: M = 3 | 4 | 0.000 | Reject Ho | Acceptable |
| | Bull's eye | Ho: M = 3 | 3 | 0.781 | Accept Ho | No value |
| | Footprints via the table view | Ho: M = 3 | 4 | 0.004 | Reject Ho | Acceptable |
| | Footprints via the thumbnail view | Ho: M = 3 | 4 | 0.001 | Reject Ho | Acceptable |
| | Footprints and thematic layers | Ho: M = 3 | 4 | 0.005 | Reject Ho | Acceptable |
| Comparison | Table | Ho: M = 3 | 4 | 0.008 | Reject Ho | Acceptable |
| | Thumbnail | Ho: M = 3 | 4 | 0.009 | Reject Ho | Acceptable |
| | Bull's eye | Ho: M = 3 | 2 | 0.001 | Reject Ho | Bad |
| Tooltip | Table | Ho: M = 3 | 4 | 0.014 | Reject Ho | Acceptable |
| | Thumbnail | Ho: M = 3 | 4 | 0.002 | Reject Ho | Acceptable |
| | Bull's eye | Ho: M = 3 | 3 | 1.000 | Accept Ho | No value |
| Geographic relevance info | Table | Ho: M = 3 | 3 | 0.617 | Accept Ho | No value |
| | Bull's eye | Ho: M = 3 | 3 | 1.000 | Accept Ho | No value |
| Thematic relevance info | Table | Ho: M = 3 | 3 | 0.273 | Accept Ho | Not optimal |
| | Bull's eye | Ho: M = 3 | 3 | 0.875 | Accept Ho | No value |
| Sorting | Table | Ho: M = 3 | 4 | 0.000 | Reject Ho | Acceptable |

Ho = Null hypothesis, M = Median of the responses

From the test results, it can be seen that the table view and thumbnail view and metadata mapping (footprints) receive positive user feedback. As shown from Table 4.1, in order to indicate which data matched the search terms test participants had chosen, test participants found that the thumbnail display seems to be the most useful and effective display, followed by the table display. The ability to compare search results textually and visually, as currently implemented in many internet shops, allows users to easily see which datasets matched their needs. Such utility is argued by some participants to be difficult to be found in "official" GDI clearinghouses or geoportals. This is one of the motivating points collected during the focus group discussion. In contrast, as shown in the Figure 4.5 and Table 4.2, they see that possibilities to compare items can be facilitated using the table and thumbnail displays.

The bull's-eye display is proven to be an ineffective means to visualize search results. As shown in Table 4.2, the use of a bull's-eye display to indicate, to compare, and to rank results were more rejected than accepted by the test participants ("no value").

In this respect, only one participant out of group B agreed with the effectiveness of the bull's-eye display to indicate, to compare, and to rank results (Figure 4.5). In relation to the presentation of geographic and thematic relevance, it can be seen that the presentation of Hausdorff distance values and degrees of closeness in the table display were more preferred than graphic representations of geographic and thematic relevance in the bull's-eye display. It should be noted here though, that test participants found that the information regarding geographic relevance and thematic relevance is not so useful ("no value" and implemented "not optimal" as shown in Table 4.2). With regard to the ineffectiveness of the bull's-eye display, during the focus group activity, it was revealed that they have had difficulties with the bull's-eye technique especially when the search produced multiple hits, where metadata items were placed too dense. In the case that the hits were very few (only one or two points on the circles), they perceived the display as expected: the closer to the centre is the best.

From the test, it was apparent that opportunities to project metadata footprints and to cascade footprints with relevant thematic layers on top of a map display are useful to help them assess data suitability. Another feature that was considered useful by test participants in all display types is the tool tip box.

The results of *Statistical Test A3* (comparing the response of Group A and Group B) confirm that there was not enough evidence to reject hypothesis that the responses had the same median. Hence, there was no significance difference in the use of the search interface for a group with GIS experiences and other group without GIS experiences.

In addition to six groups of questions related to the assessment of search results (Figure 4.5.), the participants were also asked to provide feedback of five questions concerning the working environment (Figure 4.6). Questions asked were related to: (a) interfaces to build queries, (b) the strategy of providing multi-linked displays, (c) map supports, (d) perception on the thumbnail view (as they may or may not give more confidence), and (e) their willingness to use this kind of search interface. At least eleven participants answered positively to the question (a) to question (d). From their feedback, it can be concluded that the strategy to allow users to establish metadata mapping and thematic layers cascading are acceptable. This was also one of the important points that many test participants commented on during the focus group. Further, the strategy to provide more than one way to present results in one environment (and to enable them to switch into a specific display easily) was highly appreciated by the test participants. In relation to question (e), it seems that test participants hesitated to comment that they would use or would not use this search interface for their daily GIS projects, as a result, almost half of them preferred to sit on the fence (neutral). This can be understood since they used the prototype for the first time and only to solve one scenario out of many possible search tasks that they could have.

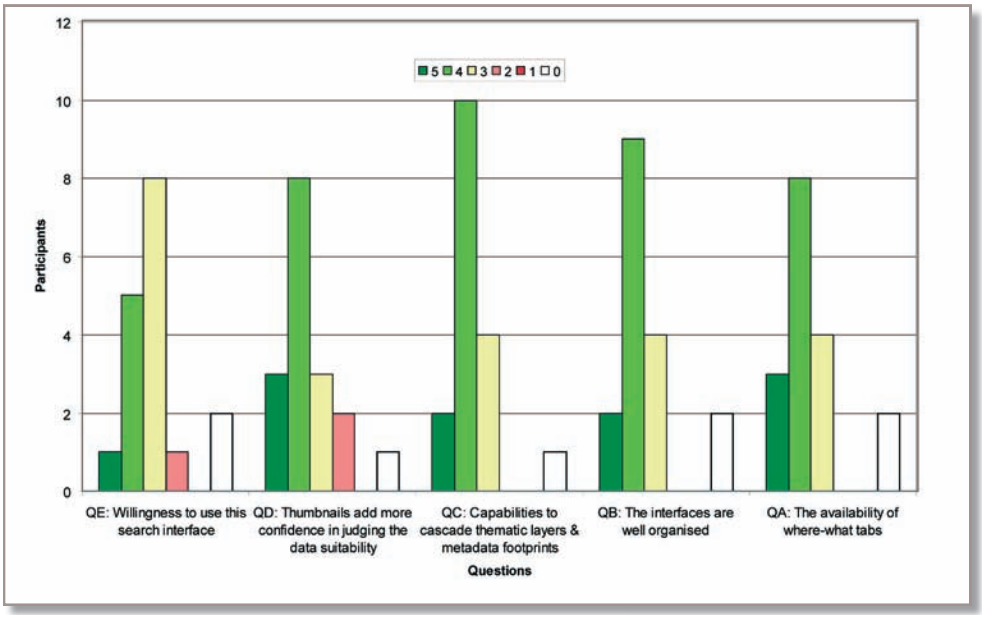



**Figure 4.6.** Responses of the test participants to the questions related to the working environment

Based on these results and the focus group discussion conducted after the test, the claim analysis is developed to guide further the improvement of the prototype (Table 4.3). In relation to the design improvement to support activity (1), minor fixes include improving the clarity to show users how to search, how to select a display of search results, and visual cues for signifying the bounding box definition. Design improvements related to activity (2) and (3) are considered minimal and mainly are concerned with the clarity of the display, such as improving the steadiness of the tool tip appearance. When the bull's-eye display is still to be offered to support activity (4), a major redesign would be required. The current bull's-eye display lacks proper symbol and text placements. Design improvements related to activity (5) and (6) meanwhile should include an enhancement of symbolization of metadata elements and the development of an interactive legend for metadata mapping.

**Table 4.3.** The claim analysis and the indication of the design improvements

| No. | Activities | | Claims | Design Improvement |
|---|---|---|---|---|
| 1. | Defining search terms using the where and what tabs | +<br>+<br>-<br>- | Where-what (and when) tabs were considered effective to express users' search terms.<br>Where-what (and when) tabs were considered easy to navigate and convenient to be used.<br>It lacks clarity: such as many users ask for a normal "search" button (instead of icons of table, thumbnail, and bulls-eye).<br>Previous searches should also be accommodated ("history"/"favourites") | Low |
| 2. | Assessing search results using a table display | +<br>+<br>+<br>-<br>- | A table display gives an advantage to users for its familiarity.<br>The combination of the tool tip and table offers an effective search strategy.<br>Filtering and contrasting results can be more convenient with a table view.<br>Values of geographic and thematic relevance shown to the users can be confusing. Categorical representations perhaps can be of help?<br>The sorting functionality should be offered with more apparent icons (hints for interacting with the table could be improved). | Low |
| 3. | Assessing search results using a thumbnail display | +<br>+<br>- | The thumbnail view (in combination with a textual tool tip) can significantly increase the efficiency of search process.<br>Comparing items can be facilitated well.<br>The quality of graphics preview can mislead the assessment of data suitability | Low |
| 4. | Assessing search results using a bull's-eye display | +<br>+<br>-<br>- | The bull's-eye display can provide a quick overview of the pattern and relevance of the data against the query<br>It can indicate the matching of area of interest and of topic of interest with search results.<br>The method to place symbols and text requires major redesign or reconsideration.<br>The lack of legend and hints for the meaning of symbolization causes users considered this display is difficult to be used. | Very High |
| 5. | Projecting metadata on top of a map | +<br>- | Using this strategy, users are capable to examine the overview the data characteristics and also to compare and interrelate the search results.<br>In the case that a search returns multiple hits that need to be mapped on top of map, users will have difficulties to discern the symbols. | Moderate |
| 6. | Cascading metadata footprints and thematic layers | +<br>-<br>- | Mapping of thematic layers and metadata offers possibilities to investigate suitability of data in accordance to users' search context.<br>But, the clarity of map is easily becoming low as many footprints are projected and many thematic layers cascaded.<br>It lacks information that help users understanding the symbols of metadata (legend) | Moderate |

## 4.5. Discussion

This chapter deals with metadata management and visualization of the search interface component of the Aim4GDI prototype. Metadata offered by the providers are summarized and stored as RDF data. They are organized by their topics, which are expressed as RDF schema topic classes. To transform metadata summaries into textual and graphical representations of metadata, the SPARQL query language is used to process matching of constrained graphs and multiple dataset graphs. In order to highlight these matches, geographic and thematic relevance are examined. For determining the geographic relevance, the Hausdorff distance between the bounding box of individual search results and the query is measured. For defining the thematic relevance, the notion of the closeness degree in social networks is applied. To enhance this, the query against the schema of topic classes was performed.

In relation to the geographic relevance of search results, the measure of Hausdorff distance between the bounding box of metadata (using the values of two corners of the bounding box) and the area of interest of a query may produce inaccurate ranking. Consider a user searching for a road dataset for a specific municipality in the country. The search results may include dataset A and dataset B with the value of Hausdorff distance of dataset A lower than dataset B, whereas in fact the dataset B covers some districts within the municipality that the user is looking for and dataset A covers the neighbouring districts where the municipality is located. Hence, the accuracy of the distance measure can be improved such as with the use of ontologies of place (see e.g., Jones et al. 2001) linked to the Placeboxes data. The same improvement (of the use of additional ontologies) can also be relaised to improve the accuracy of the thematic relevance including the use of WordNet ontology to support the topic class matching (see e.g., Fonseca et al. 2002)

The results of the test experiment indicate the benefits of table and thumbnail displays in combination with graphic previews and metadata mapping. From the test it was also clear that the current bull's eye display is not preferred by most test participants to assess search results. As existing geoportals lack sorting and comparison features as well as the ability to link to the relevant thematic information, the design strategy (combining table and thumbnail displays with metadata mapping and thematic layers) can be really useful when implemented in a search interface for a GDI.

In relation to the effectiveness of metadata visualization in GI retrieval, previous studies revealed that star plots and parallel coordinates plots (Ahonen-Raino and Kraak 2005), SuperTable + ScatterPlot (Klein et al. 2003), and 3D scatter plots of thumbnails (Hobona et al. 2006), are highly appreciated by test participants.

The results of the evaluation of SuperTable (Klein et al. 2003) show that the combination of table-based visualizations: *level table* and *granularity table* are preferred to be used correspondingly to overview and to inspect the results in more detail. This finding is similar to what was found from the test. Whereas SuperTable combines a traditional table with bar charts, tile bars, textual displays, this study uses a simple design of textual table representation. Even though the use of textual and thumbnail tables seems trivial, the decision to present search results as a simple table view was highly appreciated by test participants, as shown in their responses as well as noted in their comments. Three participants in Group A (with GIS background) specifically encourage the design decisions. One of them comments: "*As an interface to find new data, it is very useful*". In this study, the visualization of the geographic and thematic relevance using the bull's-eye display seems to fall short in comparison to 3D scatter plots of thumbnails (Hobona et al. 2006).

The strategy to represent metadata footprints on top of a map has been applied in many GI retrieval systems. Nevertheless, the integration of thematic layers and metadata footprints in a GI retrieval system has not been tested so far. The results of the test experiment encourage the strategy to enable cascading of metadata and thematic layers. During the focus group discussion, it was noted that the ability to cascade metadata footprints and thematic layers is useful and logical to be used for their search task. One of the participants argues though, that to be more useful, the map display in the search interface needs to be bigger or resizable. From the test, it was also confirmed that the depictions of items' relevancy and the legend in metadata mapping and thematic layers cascading need improvements in terms of visual clarity. In response to these design issues, some uses of visual variables in symbolizing metadata elements (such as the level of transparency, colour coding, and symbol selection) were improved.

## 4.6. Concluding remarks

In summary, an alternative strategy to provide visual displays, interaction strategies, and the mapping environment that improve the usability of search process in the GDI context using Semantic Web technology has been discussed in this chapter. The rationale for the need of better indication, comparison, and sorting in current geoportals and clearinghouses has been demonstrated via the developed search interfaces. In general, table and thumbnail displays were seen as useful strategies to complete the data selection. Further, the availability of the combination of search results presentation (i.e. combining table –thumbnail displays, metadata mapping, and thematic layer) was proven to be useful to help users indicating and selecting the dataset required. In this regard, uses of RDF/XML encoding and RDF query fulfil the design rationale to handle organization and semantics consistency of metadata and to enable dynamic approaches to visualize and integrate metadata with thematic layers. This approach offers possibilities for further data integration, for example to search and to juxtapose the content within the GDI organization with the content of non-geospatial web contents.

CHAPTER 5

# A Storytelling Atlas: Facilitating Browsing Interaction & Collaboration with GDI

Chapter 3 focused on the practical aspects of developing the prototype to support searching and browsing modes of information-seeking behaviour. Whereas Chapter 4 went on to focus on the use and evaluation of the searching mode, this chapter will focus on these aspects of the browsing mode of the atlas metaphor. For this, the use of storytelling and information foraging theories, as the underlying principles of the browsing mode, will be discussed first. In addition to the use and evaluation of browsing strategies for individual purposes, this chapter will demonstrate a possibility for extending the atlas metaphor to collaborative efforts with GDI.

## 5.1. Introduction

Popular desktop and web-mapping applications such as Google Earth, Google Maps, and Yahoo Maps are contributing greatly to the public awareness of geospatial information access and sharing. For example, the responses to the Hurricane Katrina and Pakistan earthquake disasters, in which data access and participatory mapping via Google Earth and Google Maps proved to be useful in supporting community-based relief operations in the field (Miller 2006; Nourbakhsh et al. 2006). As explained in Chapter 1, more than two decades before the inception of Google Earth and Google Maps, the idea of building a national and public infrastructure for accessing geospatial data was being discussed through the development of a Geospatial Data Infrastructure (GDI) (Groot and McLaughlin 2000b).

Considering the prospective use of GDI to facilitate access to geospatial resources, utilization of geoportals would have been as prevalent as, or even more prevalent than, the use of Google Earth or Google Maps. Unfortunately, this is not the case, or at least not yet. It seems that more efforts are needed to make GDI more widely accessible and geoportals more useful. The surveys conducted by Crompvoets et al. (2004) observed a declining trend in the use, management, and metadata content of the geoportals. In addition, the surveys also confirmed that geoportals are not used very much: only 30 percent are visited by more than 2000 visitors per month. One of the main reasons for this could be that communities are not satisfied with the functional capability of geoportals, which still seems to be data-oriented instead of application-oriented (Crompvoets and Bregt 2006; Crompvoets et al. 2004). This situation indicates that the user aspect, including the usability of the GDI interface, should be taken into account more seriously.

The usability of the web has been considered crucial in avoiding loss of revenues and profit in E-commerce. The following figures reported by Pirolli (2003) and Chi (2002) illustrate why the usability is so important. In a study of E-commerce sites, the users' success rate in completing their intended tasks was, on average, only 56 percent (Nielsen 2001). DoubleClick reported that 57 percent of all shopping cart sessions were abandoned (Kerner 2004), while Forrester Research reported that 65 percent of all online shopping trips end in failure (Souza et al. 2000), and that 40 percent of every 1 million visitors do not return to a site because of design problems (Manning et al. 1998). Usability aspects of web site design that need serious consideration include strategies to provide effective, efficient, and satisfying navigation and interaction schemes through the browsing session (see e.g., Ivory and Hearst 2002; Shneiderman 1997). For geospatial data access, aspects related to navigation and interaction of the user interface are also considered important in advancing the usability of the interface (Cartwright et al. 2001; Dykes 2005; Fuhrmann et al. 2005b; Plaisant 2005).

The work described in this thesis positions the web atlas as a gateway to information resources associated with GDI. To this extent, the atlas can be used as an alternative to geoportals as a means to discover, interact, and make sense of the GDI resources. This chapter will discuss strategies associated with navigation and interaction schemes in the atlas metaphor to provide users with an effective and helpful browsing experience. As emphasized in Section 2.3.2, the navigation and interaction schemes of the atlas metaphor rely on the atlas structure. As mentioned in that section and also discussed in Section 3.3, the atlas storyteller and GDI storyteller are linked to each of the thematic maps in the atlas structure to provide information that can be useful in improving the user's understanding and assisting in finding the required information.

This chapter will expand on this particular issue and discuss a strategy built upon the concept of storytelling. In this respect, to support navigation and interaction schemes of the atlas metaphor, the possibilities of delivering a narrative style or storytelling type of visualization using the atlas concept (Keller 1995; Monmonier 1992; Ormeling 1995b) are explored. In addition, some principles proposed in the information foraging theory (Pirolli 2003; Pirolli and Card 1995) to provide a "strong" information scent for improving the interface's usability are also applied (see Section 5.2.2). Four crucial aspects in building the storytelling strategy include techniques on: (1) how to organize the resources, (2) how to build the narrative structure, (3) how to manage users' attention and retention through navigation, and lastly on (4) how to present and juxtapose resources for access and analysis purposes.

With regard to the organization of geospatial resources, aspects associated with the management and queries of geospatial resources in the Aim4GDI prototype have been discussed in Chapter 3 (see also Aditya and Kraak 2007a). The organization of geospatial resources is intended to support functionalities required in the atlas metaphor for completing tasks related to the exploration, analysis, and synthesis of geospatial resources. The resources to be indexed and represented are not only limited to data (i.e., proprietary datasets, WMS, and WFS) published by GDI providers, but also encompass online resources published by non-GDI providers, including individuals and any participating parties (e.g., geocoded news and images). The resources are grouped into the GDI storyteller items and will cover those that are from WMS, WFS, offline datasets, or geocoded news or alerts, for instance. If the resources include charts, graphics, or textual narrative related to the thematic maps, they are grouped into the atlas storyteller.

The development of narrative structures as well as the navigation and interaction schemes will be the focus of the following sections. In addition, an extension of these schemes, aimed at supporting collaborative efforts using the GDI resources, will be presented. This chapter will also present the findings from the tests on the browsing interaction for individual use and collaborative use.

## 5.2. Methods

### 5.2.1. Developing a storytelling atlas

Crawford (2005) stated that through the ages, storytelling remains “the most powerful medium for communicating complexly inter-related ideas”. As a means for communicating ideas and experiences, it has been used widely to convey information and messages in entertainment, communication and education, and other areas, in the forms of oral, written, and visual stories (Laurel 1991; Mateas and Sengers 2003). Particularly with respect to visualizing information, Gershon and Page (2001) argued that, in situations where complex and massive amounts of data and information need to be presented, a narrative or story-based visualization could help users understand the content efficiently and coherently.

In the field of geovisualization, the concept of narrative has been applied for instances in the design of atlases (Ormeling 1995b) and interaction systems (Monmonier 1992), as well as in the development of a game-based metaphor for geoinformation access (Cartwright 2004). The following section will look more closely at the narrative aspect of atlas design.

Kraak and Ormeling (2002) stated that the way that maps are arranged in atlases to convey certain objectives is similar to rhetoric: “if a number of arguments are presented in a speech in a given sequence, a specific conclusion is reached”. To give one example from Kraak and Ormeling (2002): an electronic school atlas of Sweden might use the scenario of simulating the flight of geese from south to north over the country. During the flight, a low-pitched view of the landscape is shown. By interacting with the atlas, the students can stopover in a specific place or choose a specific theme, so that they, in place of geese characters, can investigate an area or topic of interest in detail. As such, atlases can be perceived as a geographical narrative (Monmonier 1992; Ormeling 1992) or storyteller since they are built upon several factors: a sequence of events of interaction made to highlight the objective, map layers and datasets to be displayed, choices to find solutions for specific geospatial questions, and structures for elucidating the relationships between the datasets. These correspond to some of the narrative properties (Crawford 2005; Pentland 1999): sequence, someone or something, choices, and plot or structure.

In relation to the ability of atlases to convey a pre-determined sequence, choices, and structure for narrative means, Ormeling (1992) differentiated three typical storytelling manners that atlas readers (or users in the case of digital atlases, including web atlases) can comprehend from the atlases' presentation. These three means are: chronicle, classical epic, and mystery storytelling. As illustrated by Ormeling, for a chronicle type of atlas, the narrative is built upon the sequence of first A happened, then B, then C (e.g., triggered by a cause-effect relationship). An example of this is the Polish primary school atlas for fourth grade pupils, which starts its presentation from a plan of the classroom (A) and ends with the world (C). Whereas a classical epic style could start first with B, and then move back to A and proceed to C. The Dutch secondary school atlas ("de Grote Bosatlas") (Ormeling 1981) is an example of the classical epic type of atlas; it first portrays the Netherlands as a country (B), then focuses on the country's constituent parts (A), and afterwards zooms out to the world (C). A mystery story type of atlas would start with (C) or the world first, and work back to (A) or the parts through (B) the country, with some information being deliberatively hidden in the early stages. The Economic Atlas of Ontario (Dean 1969) first presented the synthesis of the province (C), then worked back to concentrate on all the defining factors in the synthesis process (A) to partial syntheses (B). As such, this atlas can be seen as the spatial equivalent of the mystery story type.

The following section will elaborate further on how a narrative framework should be built to deliver the intended type of storytelling.

### Narrative Structures

In a storytelling system, developing presentation as stories requires a generic process for building the plot or narrative structure (Crawford 2005). In the field of storytelling for entertainment and training, there can be two types of plot generation: linear and branching (Riedl and Young 2006).A linear narrative is an event's arrangement from start to end with no possibilities for users to alter the story (e.g., movies), whereas a branching narrative allows users to alter the way a story progresses. This branching plot can be generated by means of: autonomous agents or character-based planning and use of mediation (Riedl and Young 2006). With the latter, the system provides a linear narrative representing the ideal story and considers all the options that users have – through interactivity – to unfold possible branching stories. Narrative structures built for hypermedia presentation tend to implement this approach. For example, through "structured progressions" (Rutledge et al. 2003), a linear structure of hypermedia can be generated while users are still allowed to interact with the options leading to the branching links.

Similar to this differentiation of linear and branching models, at least three basic models can be distinguished in the narrative structures in book and web/electronic atlases: radial (i.e., centripetal, centrifugal), regular linear (confrontation and regular-linear-interrupted), and irregular linear (or interrupted) models (Ormeling 1995a; Ormeling 1997b) (see Figure 5.1). This narrative structure works as a framework "to which all information items are related" (Ormeling 1997b, p. 28) and as a defining component for delivering narrative means. If these structures are related to the manner of storytelling (that of chronicle, classical epic, and mystery), then radial and regular linear structures might be used to deliver a chronicle type of atlas, while the irregular linear models could be used to support classical epic and mystery-type atlas presentations.

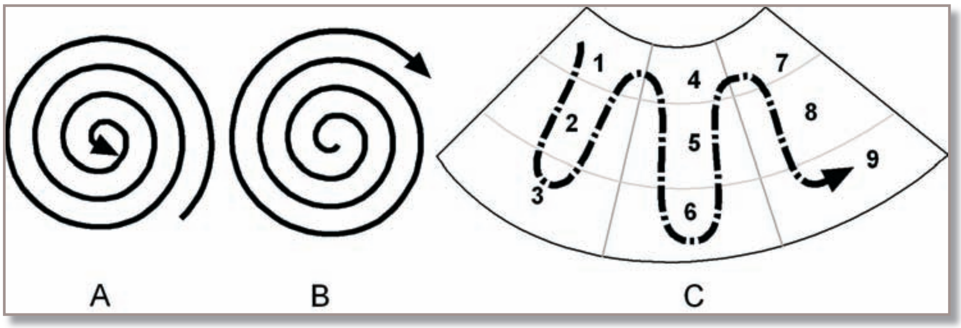



**Figure 5.1.** Some types of narrative structures in the atlases: (A) centripetal (B) centrifugal (C) regular linear interrupted model (source: (Ormeling 1997b))

A radial model applies a gradual surrounding movement of information presentation by constantly using a particular reference as a yardstick or a focus of interest. The focus of interest may be a place, a theme, or a time. The radial structure can use a constant zooming-in sequence (i.e., centripetal) or zooming-out sequence (i.e., centrifugal). In a typical centripetal model, the presentation progresses by referring to one's own habitat, whereas in a typical centrifugal model the focus is to gradually add or accommodate new knowledge according to one's mental map. For example, in an atlas dealing with history from a strictly impartial viewpoint, the reader can learn about historical events by relating them to his or her own time (Ormeling 1992; Ormeling 1997b).

Confrontation models provide pairs of maps related to two opposite issues (e.g., political atlases related to communism versus capitalism, prospective versus capitalized natural resources, or offer versus demand as in tourist atlases). In regular linear interrupted models, all areas (or topics) of interest are given equal emphasis, and the flow of the narrative covers all areas equally (e.g., reference atlases). Irregular linear interrupted models can be found in biographical atlases related to the life of a revolutionary leader of a country: showing the place of birth and the place where the "leader" or "hero" died and events in between, with the atlas progressing to show all the areas where the leader worked and phenomena affecting his or her life.

Advances in computer and web technology permit visualization of geospatial data and information that combine two or more of the models discussed above through one interface. For example, via GoogleEarth (2007a), by utilizing the “Fly-To” or “Tour” navigation in combination with the arrangements of add-on thematic layers and geocoded news related to global awareness on bird flu, one can gain both centripetal and centrifugal presentations. In the case of a centripetal presentation, one may focus on the global distribution, highlights, and probes on the bird flu, while also monitoring the spread of the virus in one’s own country. Meanwhile, if the focus is to observe the progress made by one’s own country in combating its spread in comparison to efforts made by neighbouring countries, then the “Tour” and geocoded news can be prepared according to the centrifugal principle.

The following section will look more closely at the role of the atlas structure in supporting the designated narrative structure for the browsing mode.

**Building the narrative structure for the atlas metaphor**

A scenario of a traveller looking for a path intended to bring him or her to the information destination is used in this work. This scenario is considered appropriate to the activity of browsing geospatial resources. In this respect, an “Ariadne’s thread” navigation scheme similar to the one explained in Ormeling (1993) is used here. Thus, a chronicle type of atlas is envisaged as a narrative framework here. For this work, the narrative structure used is typically that of “structured progressions” or the regular linear interrupted models mentioned in Section 5.2.1.1. The narrative structure involves four steps: sequencing the display, offering the branching scheme through links, focusing on the resource, and inter-relating the resources (Figure 5.2).

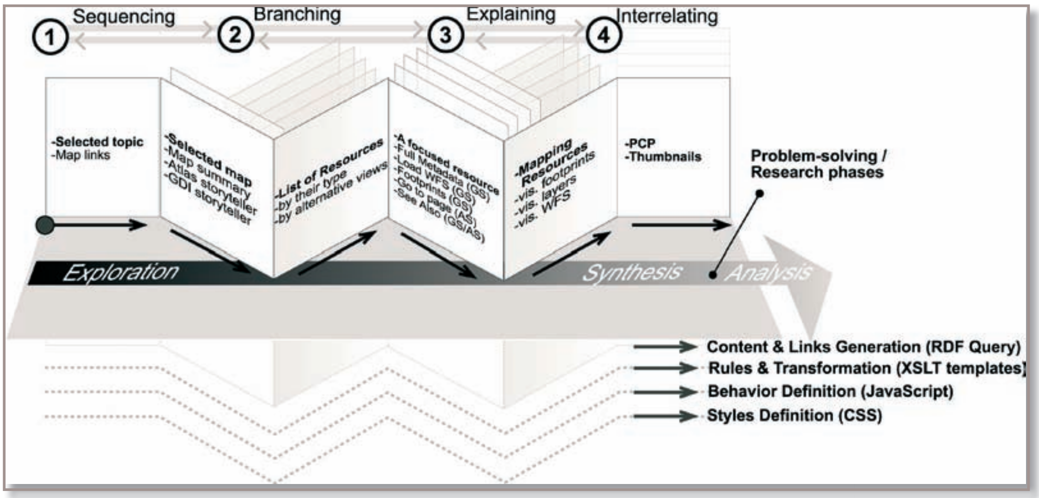



**Figure 5.2.** The conceptual narrative structure used for the atlas metaphor. Four principles of narrative structure are generated on the fly: sequencing the display to attain an emphasis set, offering links of options (branching), focusing on a specific resources (explaining), and interrelating its relevancy to other resources or content (section 5.3 explains how this is implemented as a web application).

For building the display sequences, user interactions are transformed into a chain of visualization: topic à map à atlas and GDI storyteller. This means that for each selected mouse event (mouse-over or mouse click) over the particular link, the relevant query is processed. The corresponding query results are then dynamically populated into the currently sequenced display. For example, when a user selects the GDI storyteller link that is presented in “Road Developments from 1990-2005” in the topic of Transportation, then the query retrieving all geospatial resources for that context is processed (similar to what was presented as the listing Q3 in Section 3.5 in Chapter 3). Using a stylesheet template, the resulting responses are then arranged in a section of the web page with other sections to where the contents of the next display to be populated will also be created.

The branching scheme is offered via links. The links are not bound to specific references but are generated dynamically in response to a user selection. The generation of links is started when the user selects a specific map related to a particular topic. In this context, each thematic map that is incorporated can also be used as a starting point to access resources associated with the atlas and GDI storyteller.

The words of the storyteller in this context relate to the methods for representing an object of interest in certain narrative units. When either the atlas or GDI storyteller is clicked, the relevant information can be accessed through the StorytellerView, which is located next to MapView and ExplorerView (Figure 5.3).

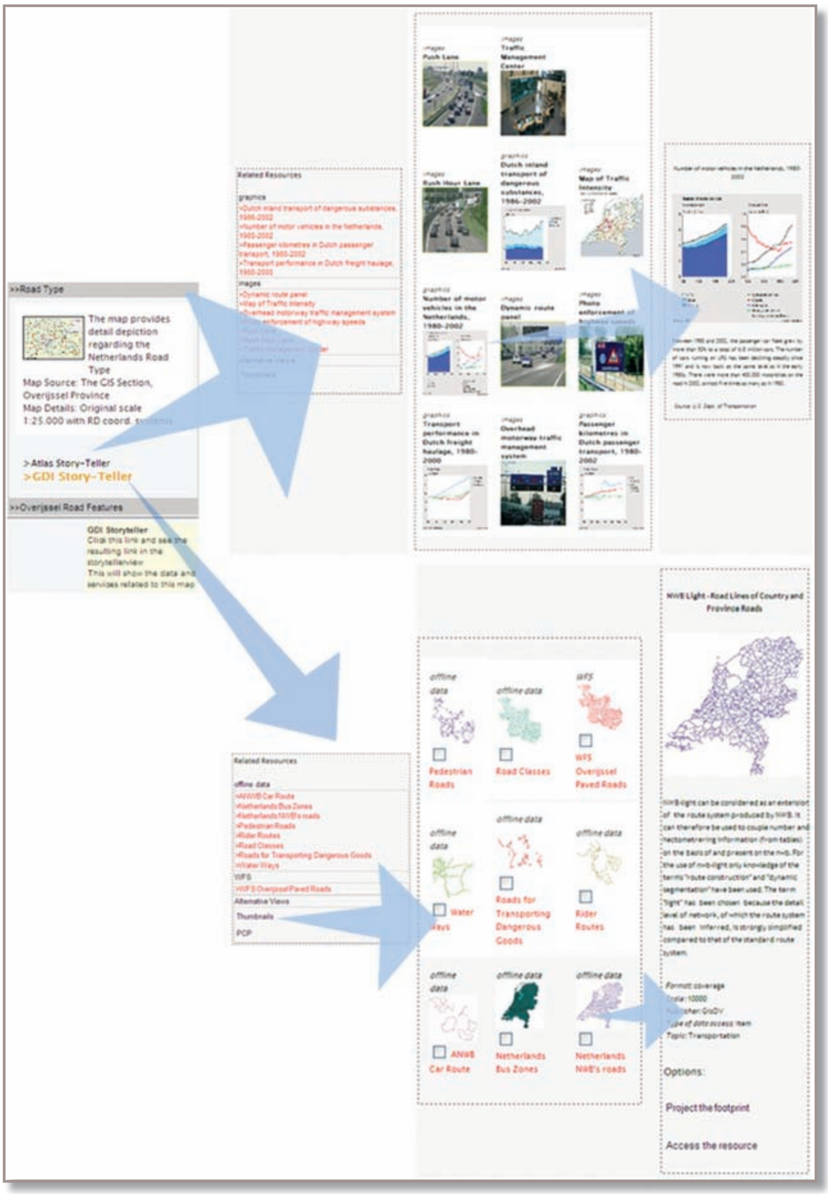



**Figure 5.3.** StorytellerView: The realization of the narrative structure of the atlas metaphor presented in Figure 5.2.

If the user selects the GDI Storyteller, the "Related GDI resources" will be offered according to the types of GDI resources linked to the map (e.g., offline data, WMS, and WFS). In addition, a link for "Alternative Views" is always shown to offer the user displays of all these associated resources as a set of thumbnail displays (similar to the thumbnail view presented in Chapter 4) or as projected lines in a Parallel Coordinates Plot (PCP) view (shown in Figure 5.5). Through thumbnails and a PCP view, the user can be shown the overview of the resource displayed via the mouse-over interaction. Such representation strategies are designed to provide a way for users to inter-relate the topical relevance of the resources.

To focus on a specific resource, the user needs to click on the headings given in the “Related GDI resources” or on an individual thumbnail, or on a line in the PCP. Each time a resource is selected, a new view detailing the description of the selected resource is shown with a bigger thumbnail. This new view also contains links to project the footprint or to load the resource on top of the map (in the case of WMS and WFS) or to access directly the metadata description stored in the provider’s website. If a user selects the atlas storyteller, the “Related atlas resources” will be offered according to the types of narrative resources associated with the map (e.g., images, graphics or charts). The alternative view only contains a link to display the resources as thumbnails.

The combination of the sequenced display with thumbnails and the PCP view aims to enable users to study the relationships among the resources and to ease their navigation of the contents. As such, the navigation can stimulate comprehension and making sense of the information (Gretzel and Fesenmaier 2002).

### 5.2.2. Information scent and navigation schemes: Maintaining users’ attention and retention

In combination with narrative structures, some principles from information foraging theory can be applied to offer users a useful browsing experience.

Information foraging theory addresses issues related to information-seeking behaviour by individuals using the analogy of animals hunting for food (Pirolli and Card 1995). For animals, finding food that provides energy involves strategies of maximizing “the rate of net energy returned per effort expended” (Pirolli and Card 1999). Further, Pirolli and Card (1999) state that the theory assumes that people will probably adapt their strategies in seeking, gathering, consuming, and structuring information to maximize their success in gaining valuable information or “maximum benefit for minimum effort” (Nielsen 2003b).

Information scent refers to the imperfect, subjective perception regarding the value, cost, or access path of the distal content (i.e., page or information at the other end), represented by proximal cues including text- and graphic-expressing web links (Chi et al. 2001; Pirolli and Card 1999). Through the web, users forage for information by navigating from page to page or section to section via web links. In this regard, foragers (i.e., users) use text- or graphic-expressing web links as proximal cues to assess the distal content.

The generation of narrative structure is specifically intended to support browsing. As summarized in Bodoff (2006), browsing is "actively looking through information (active) or keeping one's eyes open for information (passive), without a particular problem to solve or question to answer (unfocused need)". Through the narrative structure defined, users are expected to page through the sequential paths offered. But like cartoons, storytelling should retain the users' attention (Eisner 1996). In information foraging theory, this refers to the stickiness of the web site: how much users stay browsing the paths and do not leave the web site.

Users have a limited attention span, yet the amount of information to consume continues to grow (King 2003, p. 30). Studies show that people tend to switch or leave a web site when the information scent gets low (Chi et al. 2001; Pirolli 2003). In a hierarchical navigation space, a strong information scent requires a low navigation effort (e.g., time allocated and numbers of clicks) (Pirolli et al. 2003). Thus, how to preserve the users' attention and retention are also relevant aspects in developing a storytelling web atlas.

One of the crucial considerations for catching the users' attention includes the provision of web links that have a strong information scent. For this purpose, designers can include more summary words targeted to the links (Pirolli 2003). In addition, cross-references and clear links on the page will give strong information scents (Nielsen 2003a). Further, use of thumbnails in combination with a summary or text, termed enhanced thumbnails, can improve the information scent (Woodruff et al. 2001). As Woodruff et al. explained, enhanced thumbnails were proven to be more consistent and efficient in assisting users searching for Homepage, E-commerce, and Side-effects type of information in comparison to text summaries and plain thumbnails. When looking for Picture type of information though, plain thumbnails seems to be more efficient than enhanced ones. In this regard, the combination of text summaries and thumbnails, images, graphics, and maps is intended to enhance the narrative of the atlas. As Ormeling (1992) showed, the textual commentaries on the maps in the atlas are an analogy to a dialogue or direct conversation in a story or drama. They can provide an interesting perspective to gain users' attention and can further users' understanding. In an interactive geographic visualization, narrative scripts can stimulate users' interest to interact more with the interface (see e.g., Monmonier 1992).

In the Aim4GDI prototype, the techniques applied for strengthening the information scent of links include: enlarging text in active links, inserting a short summary for every thematic map, using thumbnails (plain thumbnails rather than enhanced thumbnails with titles) and cross-references. Here, a cross-reference perspective is facilitated through "alternative views", similar to "See also". Considering that the items in the GDI and atlas storyteller are mainly "pictures" (e.g., offline geospatial data, images and graphics) and as plain thumbnails are good for dealing with pictures, the plain thumbnails with titles are used as an intermediate way to access the actual resources within the GDI and atlas storyteller (Figure 5.4).

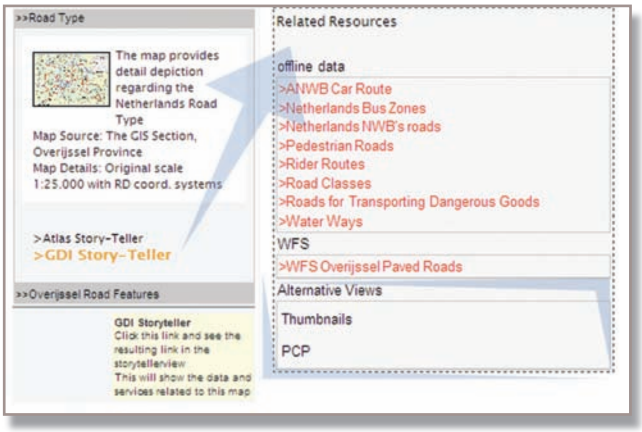



**Figure 5.4.** Strengthening information scent in the StorytellerView. Plain thumbnail of a thematic map or layer and the summary of the map are given for each of thematic layer listed in the topic of the atlas directory.

The automatic narrative generation (Figure 5.2) begins when users start looking through the GDI resources using the directory. Sequential plots are generated as a consequence of user interactions and the contents are dynamically populated. Two principles are applied in sequencing the content: first, the newest items (corresponding to the newly added maps, charts and documentations, or the newly published resources) are displayed first. Secondly, an emerging display box on the screen is displayed in response to users' interactions. In the case of a mouse-over on a link, a pop-up box containing an overview of the content under that link will be shown. Meanwhile, for an interaction with a mouse click, as discussed earlier, the follow-up box containing more detailed information related to the link selected, or graphical overviews of the related resources, will be displayed. For instance, after loading the road networks map into the display for Lisa's task (see Chapter 3), she can open charts on the number of cars per 1000 inhabitants and the length of road developments in the study area while browsing the directory.

To support users' retention, predictable and consistent navigation schemes are offered. For example, as users unfold new sequential plots, the path that led to the current selection can still be re-traced. Thus, in Lisa's case, after she has extracted the most important information from the atlas storyteller, she could then move back to her previous path to start browsing the GDI storyteller. To facilitate this, a pop-up box providing interaction hints is always available along the paths. In addition, visual cues to emphasize new active links and visited links are also offered throughout the links in the Aim4GDI.

Along with taking care of users' attention and retention, the approach described above also aims to maintain the coherency of the overall presentation. In this regard, the graphical overviews of the resources are presented within the browsing path. The views are presented as a set of thumbnails and a Parallel Coordinate Plot (PCP) view (for browsing resources through the GDI storyteller). The goal is to provide users with more than one way of seeing all the related resources within a theme of interest. In this respect, the views are intended to provide different, and sometimes contrasting, points of view on the same subject matter. A similar perception on the importance of providing alternative views in a web portal has been addressed by Gahegan and Pike (2006). They considered that the role of metadata in a web portal could be enhanced by using ontology (see also Schuurman and Leszczynski (2006)), but contended that to better represent meaning, ontology is not the only component that is needed. Providing users with many alternative perspectives helps users to “explore and come to understand the resources and concepts it contains” (Gahegan and Pike 2006). In the context of the atlas metaphor, an opportunity to inspect the spatial component of the GDI resources is not only offered through the PCP attributes of west limit, east limit, north limit, and south limit (the bounding box values of a metadata summary as described in Chapter 3), but also, as briefly mentioned in the previous section, through providing an opportunity to project the metadata footprint once the resource has been selected (in focus) (Figure 5.5).

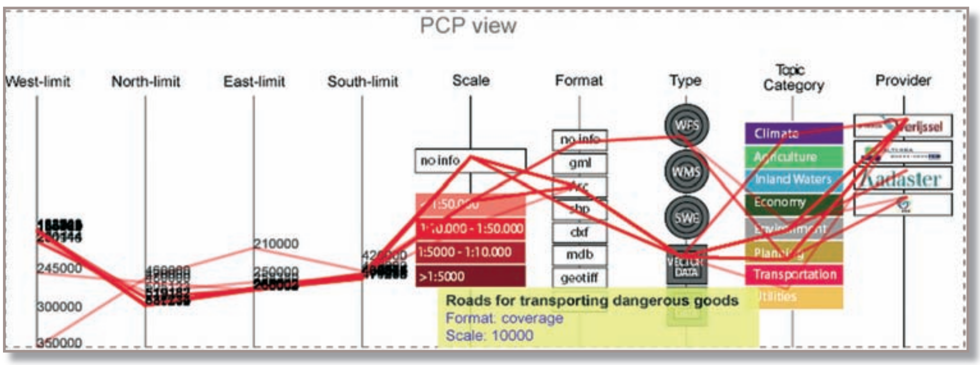



**Figure 5.5.** The Parallel Coordinate Plot view is offered to provide an alternative view to thumbnails and individual links. The view is intended to help users compare and interrelate geospatial resources within the same theme. A tool tip box is shown when a user pointing an individual line. The metadata footprint of the corresponding item is projected on top of a map when the user clicks the line.

In order to maintain the users’ attention and retention, a consistent and clear trail of navigation has to be provided to avoid users’ dissatisfaction during browsing interactions and to help them understand the content (related to the stickiness mentioned above). Modelling users’ paths or navigation pattern has been a point of interest in information foraging studies. The theory states that by providing an optimum predictive model of users’ navigation, the design processes can become more effective and efficient (Card et al. 2001; Chi 2002; Chi et al. 2001; Huberman et al. 1998; Ivory and Hearst 2002). A predictive measure for modelling user and web interaction can be produced using techniques like Longest Repeating Subsequence (LRS) (Pitkow and Pirolli 1999) and Web User Flow by Information Scent (WUFIS) (Chi et al. 2001), for example. WUFIS is a simulation of a number of agents (seen as users) traversing the links and content of a web site, comparing the agents’ information goals against the pages' content. The LRS technique captures surfing or browsing paths that are likely to re-occur and ignores noise from browsing activities. In this regard, WUFIS is better for assessing the information scent of web links, whereas LRS is useful for identifying browsing patterns.

The LRS technique can be used to extract significant surfing paths by identifying the longest repeating subsequences (LRS) of browsing behaviour for both real and simulated users (Pitkow and Pirolli 1999). The LRS is a sequence of items, where the word "subsequence" refers to a set of consecutive items, "repeated" means that the item occurs more than once, and the "longest" determines that at least one occurrence of the sequences has the longest repeat. Figure 5.6 illustrates the pattern of LRS for four possible cases of browsing. The use of LRS in this work will be discussed in Section 5.6.

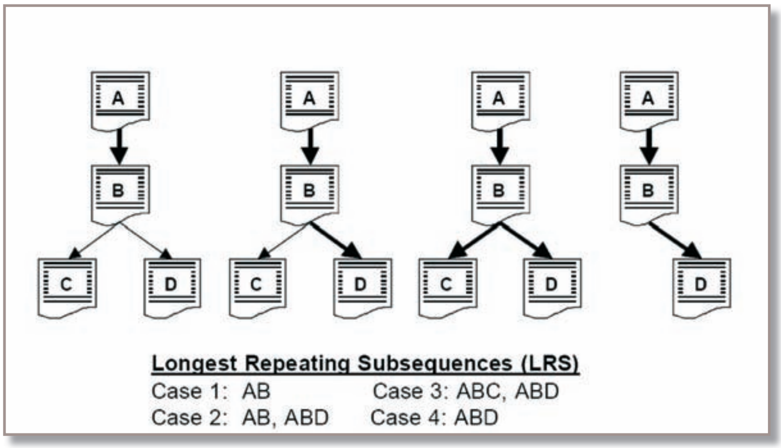



**Figure 5.6.** Four diagrams illustrating the formation of longest repeating subsequences (LRS) for four possible cases of browsing and the corresponding LRS produced. Thick-lined arrows indicate more than one traversal whereas thin-lined arrows indicate only one traversal (source: Pitkow and Pirolli 1999).

## 5.2.3. Advancing the atlas metaphor to support collaborative work

Collaborative GIS deals with the potential for spatial analyses, like multi-criteria decision analysis as well as mapping and discussions, to be used in group work to resolve decision problems and facilitate decision-making (Balram and Dragicevic 2006; Jankowski et al. 2006). This method is applicable for a wide range of group work, including collaborative efforts involving web GIS technology for crisis management (Cay et al. 2004; Tsou 2006) and planning (Mason and Dragicevic 2006; Rinner 2001). The decision-making process in such group work, often, if not always, involves visualization of data and information. Methods and tools associated with collaborative geovisualization have not yet been used optimally to enhance group work using GIS technologies (MacEachren 2005). For this reason, geocollaboration has been considered as a fundamental research challenge for GI science and information science (MacEachren and Kraak 2001).

The reason for extending the concept of the web atlas metaphor to support geocollaboration is based on the potential of GDI resources to provide decision support (Feeney 2003; Groot 1997; Rajabifard et al. 2002). GDI can be seen as a sharing mechanism that inter-relates data, people, and technological components. In the GDI setting, decision-making activities are influenced by defining factors associated with data, people, and technological issues (Feeney 2003). In this respect, the use of distributed geovisualization to support group work can effectively and efficiently connect the supply and demand associated with people, data, and technological resources (Brodlie et al. 2005). As the storytelling atlas is aimed at better structuring GDI resources specifically for knowledge and information discovery, adding extra tools for groups to share knowledge is seen as a pragmatically useful way to further exploit the GDI potential to support coordinated work for various national programmes, including national crisis management and collaborative planning.

The present section attempts to show and assess the possible add-in collaborative tools developed on top of the storytelling atlas. It attempts to present one of many alternatives of how maps and visual displays in the atlas, which is designed as a portal of geospatial resources, can be used to support collaboration activities. In relation to this issue, the need for an integrated portal to access and use spatial data and services for decision support in, say, a critical situation or for planning, has been endorsed, implemented, and tested across academic and industry domains (MacEachren et al. 2005; MacEachren and Brewer 2004; OGC 2003a; OGC 2003b; OGC 2003c). As envisaged by the OGC, the infrastructure of geospatial data and services can be used as a foundation for building a basic geocollaborative environment at national level, such as for a national crisis centre (OGC 2003c). The next section will first revisit the role of maps (and other visual displays) in encouraging collaboration and then go on to discuss some design issues related to the development of add-in tools to facilitate synchronous collaboration efforts.

### The atlas for mediating collaboration with GDI

In a collaboration context, tasks involving maps and graphics span collaborative exploration – collaborative confirmation or analysis – collaborative analysis – and collaborative presentation (MacEachren and Brewer 2004). Indeed, the tasks can be perceived as an extension to the goals of map use proposed by MacEachren and Kraak (1997) that built upon the research or problem-solving steps discussed in Chapter 3 to which the prototype of the atlas metaphor was subjected. The typology of the collaborative tasks mentioned above can be related to four processes that are, in general, required in group work: generate (idea and options), negotiate, choose, and execute (see McGrath (1984) in MacEachren and Brewer (2004)), which are also parallel to the notion of four decision-making phases: intelligence, design, choice, and review (see Simon (1977) in Rinner (2006)). Intelligence involves assessing or exploring the opportunities to make a decision. The alternative solutions are developed in the design phase, and then one particular alternative is decided on in the choice phase and evaluated in the review phase.

With regard to the use of maps for collaboration efforts, as elaborated by MacEachren and Brewer (2004), and building on the notion of Peirce's semiotic triangle connecting referent, interpretant, and sign-vehicle (MacEachren 1995; Peirce 1955), the maps can be valued as sign-vehicles. The maps (and components of maps) can provide a medium to better signify the referent (i.e., objects being represented on a map) and effectively strengthen understanding shared with the interpretant (i.e., the meaning derived by a collaborator from sign-vehicles about the referent) for group work.

A map-based sign-vehicle can have a role as an object of the collaboration, as a visual depiction to support dialogue, or as a device to support coordinated activity (MacEachren 2005). As reviewed by MacEachren (2005), initial attempts to investigate these three types of roles of a map in a collaboration environment include: the design of a map to facilitate location selection (thus, as an object of the collaboration (Armstrong and Densham 1995)), the use of geo-referenced discussions on top of a map to facilitate group dialogue in a planning context (i.e., a device to support dialogue (Rinner 2001; Rinner 2006)), and an analysis resulting in an indication that the group prefers using maps during the analytic-integration phase more than in the exploratory-structuring phase (i.e., a device to support coordinated activity (Jankowski and Nyerges 2001; Jankowski et al. 2006)). According to MacEachren (2005), as an object of the collaboration, the emphasis on using the map is to better deal with the referent, so that collaborators can structure their discussion and understand how their individual perspectives differ or coincide. As a device to support dialogue, when the collaborator's perspectives on a specific issue and its corresponding feature on the map is explicitly connected through a georeferenced link (as in Rinner's work (2001)), the differences in the conception can be better articulated. As a device to support coordinated activity, a map should enable interpretants' differences to be identified and their perspectives on a specific issue to be coordinated (Figure 5.7). A more detailed discussion on this can be found in MacEachren (2005) and MacEachren and Brewer (2004).

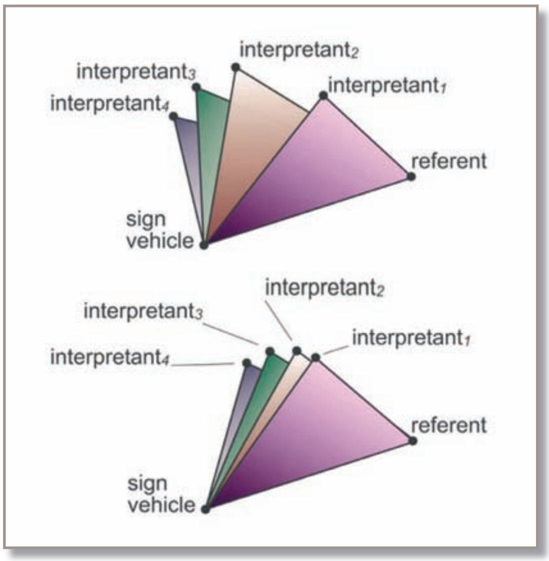



**Figure 5.7.** The semiotic triangle applied to understand geocollaboration. A triangle consists of the referent, the object being signalled; the sign vehicle, which is the object or device (e.g., a map symbol) that stands for or signifies the referent; and the interpretant, the meaning derived from (or perhaps read into) the relationship. Here, two groups of semiotic triangles are presented. The top triangle depicts four users with substantially different interpretants for the same sign vehicle-referent relationship and the bottom triangle shows a subsequent convergence of interpretants as a result of joint work (MacEachren and Brewer 2004) (Reprinted with permission from Informaworld: http://www.informaworld.com).

A thematic map in the atlas functions as an index to various types of information resources related to an issue to be solved jointly by collaborators. For collaboration work, the resources organised in the GDI storyteller can involve not only the GDI resources in the form of offline data, WMS, or WFS, for instance, but also more varied graphics and images including images or digitized features uploaded from the field, for example. In addition, the GDI storyteller may also link to relevant news and alerts as well as online documentation in the form of articles or stories that are georeferenced using GeoRSS format, for example. In this respect, although information resources are not by default taken into account as stories, they can be combined and stylized to develop an integrated form of narrative on the topic or a thematic map to which the information resources are bound. For example: browsing the best practices for, say, on how to handle a new disease outbreak can be done by assessing the links in the GDI storyteller from which the best practices offered by other relief or medical aid groups can be accessed while also accessing relevant GDI resources that can be of help in preparing a relevant response. As addressed in Gershon and Page (2001), a story needs to be effectively structured and built on the fly. Using the atlas as implemented in some European museum- and art projects (e.g., Alani et al. 2002; Geurts et al. 2003), the stories are generated from semantic data using story templates or a narrative structure as shown in Figure 5.2.

In the atlas metaphor, the organization and navigation of GDI resources is intended to support collaborative exploration, analysis, and synthesis of the atlas and GDI resources toward a shared understanding on issues or problems associated with a specific topic in group work. For exploration and partial analysis, the visualization techniques aim to offer descriptive and exploratory visualization, while distributed collaborative analysis and synthesis often require methods and tools for sharing the group members' perspectives while discussing the decision to be made and for facilitating awareness for group cognition.

Regarding descriptive and exploratory visualization, Brodlie et al. (1998) stated that descriptive visualization is used when "*… the phenomenon represented in the data is known, but the user needs to present a clear visual verification of this phenomenon (usually to others)*", whereas exploratory visualization is "*necessary when we do not know what we are looking for … (and need) to understand the nature of the data*". With descriptive and exploratory visualizations, all the collaborators are expected to have opportunities to build a requirement and draw up a possible solution based on their own perspectives, for example, assessing the suitability of datasets and services, mining specific geoinformation on a map, and juxtaposing available datasets or services. To do this, members of a collaboration team might need, for instance, to compare certain items and investigate attributes correlated to a specific GDI resource in more detail. This requires a set of exploratory displays enabling them to overview, sort, drill, and confirm the suitability of the items. They must also be able to display all the relevant data or resources available and compare which resource meets the criteria of use according to a group member's perspective. Using the atlas metaphor, a group member or collaborator can assess and examine the fitness-for-use by making sense of the representation of search results presented in a table, thumbnail, bull's eye, or PCP view through ExplorerView (Chapter 4), as well as through the narrative structures and content presented by StorytellerView (Section 5.2.2).

The following section will discuss methods and tools to facilitate the awareness for team cognition and support collaborative analysis and synthesis tasks.

### Shared visualization in support of collaborative analysis and synthesis

Collaboration activities can be differentiated according to their temporal and spatial situations, such as: same place-same time, same place-different time, different place-same time, and different place-different time (see e.g., Applegate 1991; MacEachren 2005). A list of examples of related work in geocollaboration that involves those different temporal-spatial settings and the role of (map) visualization (as the object, to support dialogue, to support coordinated activity) can be found in MacEachren (2005) and MacEachren and Brewer (2004). To mention some: the work of Schafer and Bowman (2006) and Brodlie (2005), for example, focused on the same time (synchronous) distributed collaboration using a map as the object of collaboration to generate a group decision. The work of Rinner (2006), mentioned earlier, focused on the asynchronous distributed collaboration using an argumentation map that supports dialogue by linking the geographic features on the map to the group discussions. While the work of MacEachren and Brewer (2004) can be seen as an attempt to deal with a synchronous distributed collaboration using graphic displays to support coordinated activity across collaborators.

The add-in collaborative tools developed in this study are aimed at supporting synchronous distributed interactions for a wide range of collaborative activities through a national GDI organization, such as collaborative spatial planning and crisis management. Using these collaborative tools, it is envisaged that GDI users will be able to work together to make sense of GDI resources in combination with the atlas maps and structure through all the phases of decision-making. In this regard, the intelligent, design, and choice phases of decision-making (as explained in the first part of Section 5.2.3) are phases that can be conceptually supported through collaborative exploration, analysis, synthesis and presentation using the web atlas metaphor (Figure 5.8). As a first step toward this idea, this study attempts to assess how shared visualization of GDI resources can be facilitated through the atlas metaphor and help resolve the necessary individual exploration, and group analysis and synthesis.

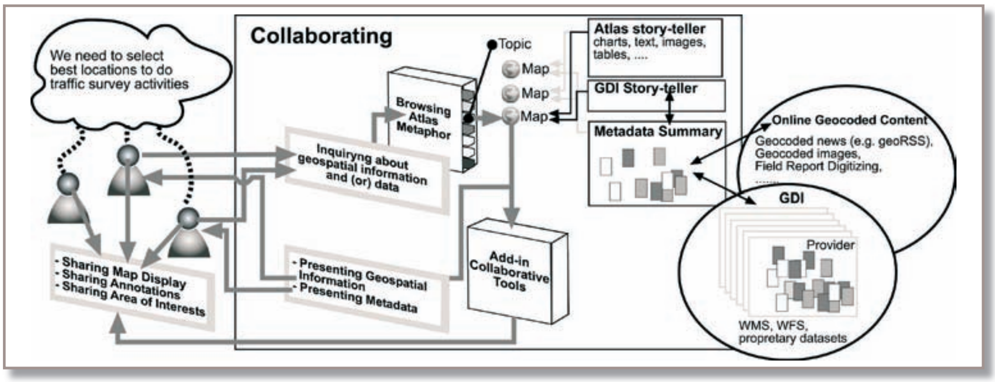



**Figure 5.8.** An extension to the concept of atlas metaphor: in addition to descriptive and explorative visualization by browsing, the add-in collaborative tools are offered. The tools are aimed at supporting shared representations for GDI users involved in a collaboration activity to, for example, plan the traffic survey activities. The shared representation for group cognition is supported by a typical online teleconference or voice-only or text-only communication program.

Sharing map representations means that an exchange of geospatial ideas related to a physical space with contextual reference information is becoming plausible (MacEachren and Brewer 2004). Using the atlas metaphor, the participants involved in the group work can search and browse GDI resources through ExplorerView (Chapter 4) or StorytellerView (Section 5.2) first, before taking part in a collaborative session in which a limited number of alternatives are jointly assessed through synchronous discussion and shared visualizations. The discussion and shared visualization of GDI resources, for instance combining thematic layers for a particular topic with a specific WFS, means the group participants can base their discussion on the same representation to perform a joint collaborative analysis (MacEachren and Brewer 2004).Furthermore, the combined visualizations of different sources of information, including thematic maps and WFS, can hypothetically help develop an understanding of the differences between perspectives, and where practical, can help generate a common perspective (collaborative synthesis) (MacEachren and Brewer 2004)).

Throughout these collaborative tasks, in enabling shared visualizations of thematic layers and GDI resources, the parameter settings that correspond to actions completed by each participant (such as map selection and colour modification) are distributed near real-time. In relation to this, of the three different options in which collaborative visualization can be facilitated: single shared, single replicated, and multiple linked application (Brodlie 2005), the atlas metaphor uses the single replicated approach, which gives full control to each participant for interacting with his or her own user interfaces. Each action taken by a participant will affect the user interfaces of the other participants involved in a synchronous collaborative session.

The shared representation is considered important to build group awareness during the completion of joint tasks. This issue deals with the system's ability to provide awareness of "who does what and where" during the collaboration process. Questions such as: Who is participating? Who is doing that? What are they doing? Where are they working? are typical "workspace awareness" issues required for group work (Cuevas et al. 2006; Gutwin and Greenberg 2004). Graphic representations to build up group awareness include what Gutwin and Greenberg (2004) defined as: embodiments (such as telepointers, video techniques, and avatars), expressive artefacts (such as process feed-through, and graphical or sound cues associated to actions), and visibility techniques (such as radar views). For a synchronous distributed application, such awareness issues as well as the ability to use voice communication to discuss perspectives have been identified as essential elements in supporting collaborative geospatial analyses (MacEachren and Brewer 2004). To share a representation of areas of interests of the collaboration participants, a simple (traditional) radar view (Gutwin et al. 1996; Schafer and Bowman 2006) is used in which information regarding the area of interest for each participant ("who sees what") can be indicated on the overview map as rectangles with different colours representing the roles of each participant (see Figure 5.9).

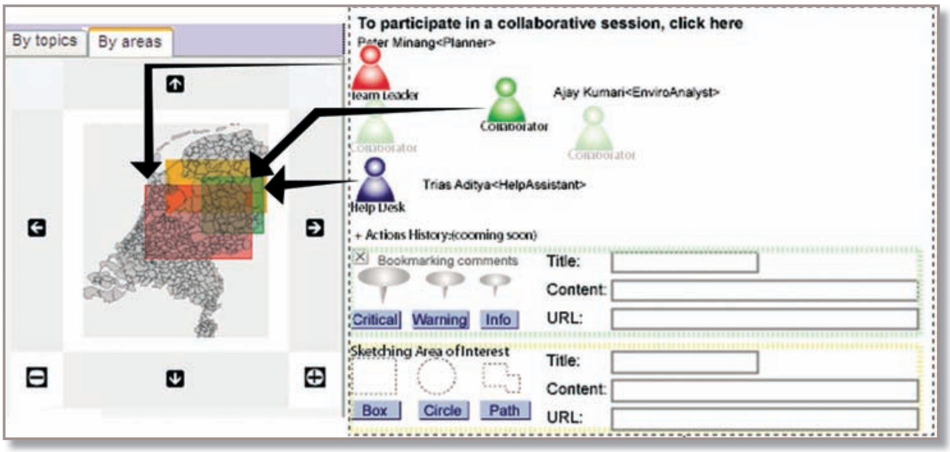



**Figure 5.9.** The developed user interfaces to enable collaborative work through the atlas metaphor. The collaborative features include the functionality to enhance the group awareness. This is offered via presentations of 'who are online' (the right figure) and 'traditional radar views' (the left figure). Other collaborative features include functions to enable collaborators to express their perspectives through graphical representations of pin board points (referred to as user interface components for "bookmarking comments") and areas on top of the map (referred to as user interface components for "digitizing areas").

To facilitate tasks related to collaborative analysis and synthesis, the atlas metaphor offers annotation and digitizing features. Annotation enables participants or group members to express their perspectives on top of a map and, where possible, make a link to a supporting information resource, like a topic thread in a discussion forum or relevant reasoning expressed by a group member (or others) through a blog page. The idea is to provide basic functionalities to manage perspectives and reasoning linked to features on the map as in Rinner's work (2001; 2006), and to guide collaborative learning discourse (MacEachren 2005). With reasoning and perspectives embedded in the graphics, the atlas is intended to be not only the object of collaboration but also a visual interface to support dialogue. Two types of graphics, pin board points and polygon areas, are embedded on top of the atlas interface when a participant uses the annotation and digitizing features (see Figure 5.10).

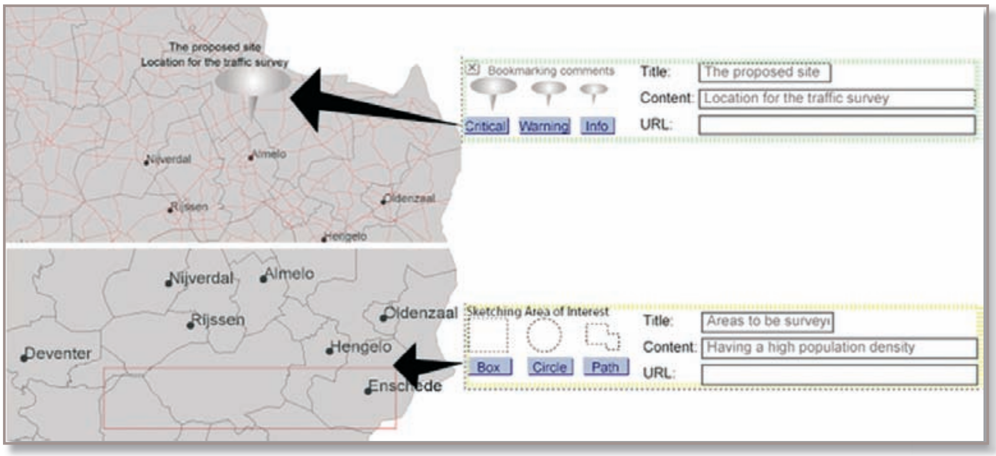



**Figure 5.10.** The pin board plotting with annotation (top) and digitizing features with annotation (bottom) embedded on the map

# 5.3. Implementation

## 5.3.1. Navigation and interaction schemes applied on the web atlas

The application framework presented in Chapter 3 discusses the handling of queries in response to searching and browsing requests. That chapter, however, does not elaborate the techniques implemented in the prototype to generate links and storyteller content in order to comply with the narrative structures envisaged in this chapter. The present section in particular will discuss the techniques used to sequencing the display, offering the branching scheme through links, focusing on the resource, and interrelating resources (correspond to Figure 5.2. shown earlier). Similar to Figure 3.6 in Chapter 3, which focuses more on the system responses to search requests, Figure 5.11. specifically presents the handling of requests and responses associated with browsing strategies.

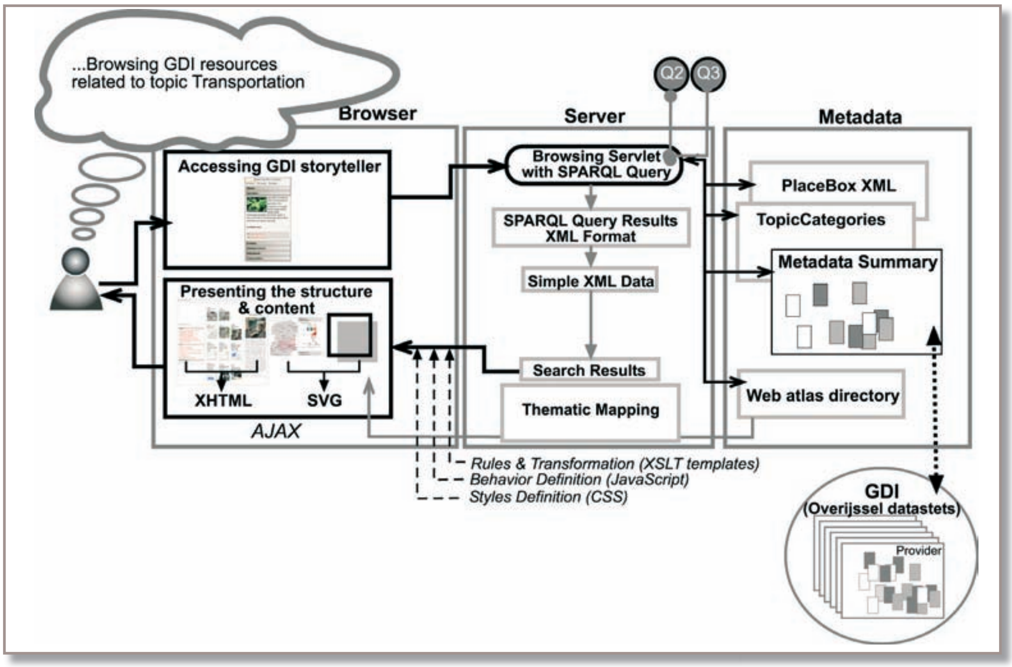



**Figure 5.11.** The flow of the handling of a request for presenting the atlas and GDI storyteller content: Q2 and Q3 refer to possible query syntaxes of the browsing directory given in section 3.5 (Chapter 3).

In general, the handing of requests and responses to facilitate the browsing interaction is similar to the handling of requests and responses for the searching interaction that has been shown in Figure 3.6 as well as explained in Section 3.6. The data queried here is mainly the (web) atlas directory. Meanwhile when the browsing interaction involves the GDI storyteller, the query is processed against the atlas directory in combination with metadata summaries. Table 5.1 provides an overview of the types of displays offered in the prototype that relate to the browsing mode.

**Table 5.1.** A summary of the components utilized in the browser and server side for each particular display presented to a user during the browsing activities.

| | Server | | Browser + JavaScript | | | | |
|---|---|---|---|---|---|---|---|
| **Display** | **RDF data queried** | | **XML data** | | **XSLT template** | | **CSS/XHTML/ SVG** |
| Map Lists | Directory | → | XML Results | → | listmaps.xslt | → | Map Metadata (XHTML) |
| Atlas Resources | Directory | → | XML Results | → | listAtlasST.xslt | → | Related resources (XHTML) |
| GDI Resources | Directory & Summaries | → | XML Results | → | listGDIST.xslt | → | Related resources (XHTML) |
| Thumbnail | Directory & Summaries | → | XML Results | → | ThumbnailST. xslt | → | Thumbnails view (XHTML) |
| PCP | Directory & Summaries | → | XML Results | → | DrawPCP.xslt | | PCP Lines (SVG) |
| Resource in focus | Directory & Summaries | → | XML Results | → | Selid.xslt | → | Highlighted resources (XHTML) |

The content generation is started when a user begins selecting a topic of interest. Accordingly, as a result of this action, a query requesting the list of thematic layers is issued. Once the query produces matches, then the list of thematic layers is dynamically populated. The title, metadata and the thumbnail of each thematic layer are organised as expandable links. To form this presentation, the strategy is to create two sections in which the first is designed as a text link through which users can load the map and to make the second section, which is containing summary and technical details of the map, expand or collapse.

The provision of a summary and a thumbnail surrounding the map link is intended to provide the necessary information scent to users. In this regard, to provide a stronger information scent for each link, a direct indication regarding what will be found for each link is given. In addition, the bigger fonts effect as a result of a mouse over is also applied to all links in the interface with the help of Cascading Style Sheets (CSS). The options to explore the atlas storyteller and GDI storyteller are always offered at the end of the second section within each selected thematic layer.

In case that the user selects the atlas storyteller, a query against the atlas directory to load the graphics and images associated with the thematic layer is executed accordingly. The returning matches of XML elements including their projective navigation trails are visualised in the StorytellerView section. In the case that the user selects the GDI storyteller, a query against the atlas directory in combination with metadata summaries is performed. As in the case of the atlas storyteller, in visualizing the links, the resources are organized according to their types of data, such as: offline data, WMS, WMS, and other relevant GDI information including (although not yet implemented in the system) processing services, updates from the field, gecoded alerts, and geocoded news, for instance.

These two types of representation (Atlas and GDI storytellers) aim at providing a possibility to view all related resources for a selected thematic layer at once. This strategy is related to the design for providing many perspectives to compare and assess the relevant resources. For projecting the resources as a set of thumbnails, the technique involves a similar stylesheet to create a table view presented earlier in Chapter 3, but the cell is filled in with the corresponding resource's thumbnail instead. For a PCP view (Figure 5.5), the attributes of a resource are connected as a line across the attribute lines on the display.

Throughout the trails of navigation, a small pop up window presenting cues relating to description and the use of the resource is consistently given. Additionally, a user can focus on only a specific resource to gain more detailed descriptions regarding the resource and, more importantly, to execute options for projecting its footprint, accessing the full metadata view, and loading directly the resource into the MapView when practical (i.e., the resource is offered as WFS).

### 5.3.2. The add-in collaborative tools applied to the web atlas

The strategy to extend an ordinary single-user visualization (as the case of the atlas metaphor developed in this study) for synchronous collaboration activities requires the ability of the system to manage and share the setting parameters of the intended distributed visualization (Brodlie 2005; Brodlie et al. 1998). Considering the stateless nature of HTTP (Hypertext Transfer Protocol), where an individual request is treated discretely so there is no continuing interaction between a browser and a server, to fulfil the need to share required setting parameters across the collaborators, the AJAX approach (mentioned in Chapter 3) can be of help. Using AJAX, the ways through which the server and browser communicate can be engineered to support synchronous collaboration using techniques such as: distributed events and periodic refresh (Mahemoff 2006). With distributed events, in essence, the parameters are shared only when an event of interaction is initiated in one of the collaborating user interfaces. Meanwhile the periodic refresh sets an interval period during which the changes in each interface is registered and then shared accordingly, so the user interfaces of the collaborators get synchronized. The present collaborative features in the atlas metaphor Aim4GDI prototype implement the periodic refresh technique to synchronize visualizations.

Figure 5.12 illustrates the handling of requests and responses associated with a collaborative action, such as plotting a pin board and its associated annotation. The figure also shows the metadata required for collaboration activities.

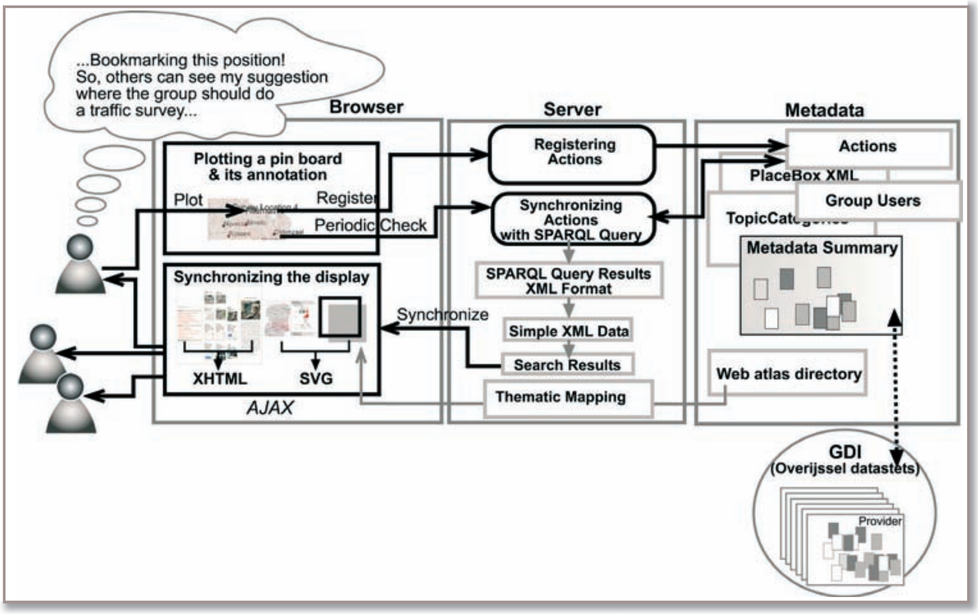



**Figure 5.12.** The handling of a request and synchronization: when one user plots, for example, a pin board, the user interfaces of co-workers in the collaboration replicate the display by executing the same method that has recent parameters through periodic checking.

Every time a collaborator interacts with a user interface component associated with the collaborative use of the atlas, the setting parameters of the corresponding method are registered into an action metadata. In this respect, for each method invoked, the data regarding the name of the method and its corresponding parameters as well as the username and the invocation time are created and grouped in a session the collaboration is subjected to (stored in actions RDF, see the following excerpted as an example).

```
<atlas:session rdf:about=" http://kartoweb.itc.nl/atlas/sessions/fire_test" >
<dc:title>Collaborative Planning</dc:title>
<dc:description>
    This session is intended to facilitate a spatial planning via the web atlas
</dc:description>
<dc:created>2006-12-21</dc:created>
<ms:geocov rdf:parseType=" Resource" >
<ms:placename>Overijssel</ms:placename>
<ms:district>
      <dcterms:Box epsg:code=" 28992" >
         <dcterms:northlimit rdf:datatype=" &xsd;double" >539400</dcterms:northlimit>
         <dcterms:westlimit rdf:datatype=" &xsd;double" >191521</dcterms:westlimit>
         <dcterms:southlimit rdf:datatype=" &xsd;double" >462325</dcterms:southlimit>
         <dcterms:eastlimit rdf:datatype=" &xsd;double" >266068</dcterms:eastlimit>
     </dcterms:Box>
</ms:district>
</ms:geocov>
<atlas:actions rdf:parseType=" Resource" >
 <atlas:action>
   <atlas:action_detail atlas:code=" DESKey@18774" >
     <atlas:actiondate rdf:datatype=" =" &xsd;dateTime" >Mar 2, 2007</atlas:actiondate>
     <dc:created rdf:datatype=" &xsd;dateTime" >8:04:23 AM</dc:created>
     <atlas:doneby>ptr</atlas:doneby>
     <atlas:function>plotCritical</atlas:function>
     <atlas:parameters>ptr;Planner;SurveyLocation ;Alternative;www.itc.nl</atlas:parameters>
   </atlas:action_detail>
 </atlas:action>
</atlas:actions>
</atlas:session>
```

With the periodic refresh approach, within each collaborator browser, a routine retrieving the last actions committed is performed for every specific interval period. This routine is in fact issuing a SPARQL query against the actions metadata to gather last (e.g., ten) actions executed by the other collaborators. The filtering on the time (referred to <dc:created/>) and setting parameters (<atlas:parameters/>) is then performed to make sure that there should be no redundant display. When the action's parameters are unique, they are then processed so the corresponding display is replicated.

## 5.4. Evaluation

### 5.4.1. Case study: Individual use of the atlas metaphor

**Test descriptions**

In order to figure out whether the design decisions related to the browsing mode of the atlas metaphor have met the objectives set, a test focusing on the use of the atlas metaphor for browsing geospatial resources has been held. The feedback gained from this test is used to develop recommendations for further improvements of the Aim4GDI. As has been done in Section 4.4 (Chapter 4), where the approach of scenario-based design (Carroll and Rosson 2002) was used to assist the evaluation of the searching interfaces of the atlas metaphor, the test activity described in this section also utilized the scenario of use of the browsing mode of the atlas metaphor.

The test experiment involved twenty-two individuals and was done in two sessions. Nineteen graduate students of the International Institute of Geo-Information Science and Earth Observations (ITC) participated in the first session of the test. All the first session's test persons were MSc students, except one person who was doing a PhD study and having pre knowledge about the region. Seven test persons had no experiences with GIS or Remote Sensing work before they joined the MSc study courses starting three months before the test was conducted. Further, nine test persons had a professional background as Planners, Geologist, IT Administrator, Lecturer, and GIS specialist with working experiences ranging from one up to two years. Meanwhile the other three test persons in this first session of the test had working experiences in GIS and Remote Sensing for more than 5 years. Test persons did the test simultaneously in computer clusters at ITC.

The second session of the test was done at the Province of Overijssel in Zwolle. The three test persons participated in the test were employees of the Province of Overijssel dealing with GIS management and development. They had been working with GIS for more than 20 years. For the purpose of analysis, these test persons are regarded as Group A, while the test persons in the first session are regarded as Group B.

The browsing test in particular was aimed at investigating the effectiveness of the narrative structure as well as the trail of navigation offered to support browsing interaction with the web atlas metaphor. None of the test persons had been working or evaluating the prototype before the activity. In the beginning of the test, no specific introduction was given to the test participants (no learning). Before the test was started, they were informed that the test was about interacting with a prototype. A scenario of use, through which the test participants provided their feedback to eleven questions (Q1 – Q11) related to their browsing experiences, was introduced (textually) in the beginning of the test (presented in detail in Appendix C).

Similar to the test experiment presented in Chapter 4, each user's answer to a particular question (a statement-based question) was scored on the Likert response scale (Likert 1932). Hence, their responses can be seen more likely as ordinal data. In this regard, strongly disagree is conceived as 1 and strongly agree is conceived as 5. The ten test questions in fact are a reflection of the design evaluation regarding the narrative structure developed: display sequences, branching schemes, in focus visualization, and an ability to compare and interrelate.

In handling the test results, two statistic tests were used. The Wilcoxon signed rank test for a single sample was used to assess whether the designed user interfaces were considered helpful to the users (referred to as *Statistical Test C1*). In addition, this study is also interested to see whether there is a difference of perception or preferences between a group with GIS working experiences and pre knowledge about the region and a group with less GIS working experience (and with relatively less geographic knowledge about the test area). For this purpose, a Mann-Whitney test was applied to assess whether there was an evidence to conclude that the effectiveness of the use of the atlas for the two groups (Group A and Group B mentioned above) was different (referred to as *Statistical Test C2*). Chapter 6 discusses the rationale for the use of these tests as well as the relationship of these statistic tests to the overall design evaluations done in the study. The results and analysis of the evaluation of the navigation and interaction schemes of the atlas metaphor are given below.

### Test Results

The two tables shown below (Table 5.2 and Table 5.3) accordingly correspond to the *Statistical Test C1* and *Statistical Test C2* mentioned above. From Table 5.2, it can be concluded that there is statistical evidence that seven design issues that are focused on in this chapter are acceptable or considered useful by the participants to be useful. On the other four design issues, the test fails to conclude that the interfaces developed are useful. This finding gives an indication that these four issues: the use of Parallel Coordinate Plot (PCP) to indicate and to compare, an ability to cascade Web Feature Services (WFS), and an ability to combine metadata footprints and WFS), require low to moderate efforts of design enhancement when the interface is to be improved (see Table 5.4). In this regard, the findings can also be seen as a consequence for providing no learning opportunity before the test. The results indicate that the use of those four related displays requires a considerable learning curve from the users.

With regard to this issue, it is worth noting to mention here that according to the result of the test referred to as Q10 in Table 5.3, that there is evidence that Group A (with more GIS experiences and skills) has a stronger preference to the Aim4GDI to help them directly display WFS on the interface than Group B. This is understandable, since more than half of the participants put in Group B has less GIS working experiences than participants on Group A and no pre knowledge regarding the essence of Web Feature Services (WFS). Then, it is arguably also understandable that Group A sees the ability to combine thematic layers with metadata footprints and WFS is helpful, whereas with Group B there is no evidence to judge this ability is useful for Group B (the Q11 in Table 5.3).

**Table 5.2.** The effectiveness of the design implementation: The Wilcoxon signed rank test was applied to the test results to check whether the median of eleven design issues is equal to “no effect” or not useful to help them complete the task (with 0.05 level for a non-directional test)

| Question | Use Issues | Ho | M | P-value | Conclusion | Design Implementation |
|---|---|---|---|---|---|---|
| Q1 | Narrative Structure | Ho: M = 3 | 4 | 0.000 | Reject Ho | Acceptable |
| Q2 | Switching topic-area | Ho: M = 3 | 4 | 0.000 | Reject Ho | Acceptable |
| Q3 | Alternative Views | Ho: M = 3 | 4 | 0.030 | Reject Ho | Acceptable |
| Q4 | Thumbnails | Ho: M = 3 | 4 | 0.002 | Reject Ho | Acceptable |
| Q5 | PCP to indicate | Ho: M = 3 | 3 | 0.268 | Accept Ho | Not optimal |
| Q6 | PCP to compare | Ho: M = 3 | 4 | 0.005 | Reject Ho | Acceptable |
| Q7 | In Focus display | Ho: M = 3 | 4 | 0.001 | Reject Ho | Acceptable |
| Q8 | Interrelating Resources | Ho: M = 3 | 4 | 0.002 | Reject Ho | Acceptable |
| Q9 | Mapping footprints | Ho: M = 3 | 4 | 0.004 | Reject Ho | Acceptable |
| Q10 | Loading a WFS | Ho: M = 3 | 3 | 0.073 | Accept Ho | See Q10 at Table 5.3 |
| Q11 | Combining thematic layers, footprints, and a WFS at once | Ho: M = 3 | 3 | 0.267 | Accept Ho | See Q11 at Table 5.3 |

Ho = Null Hypothesis, M = Median of the responses

**Table 5.3.** The comparison of the responses between Group A and Group B: The Mann Whitney test was applied to the test results to check whether the median of eleven design issues between Group A and Group is the same (with 0.05 level for a non-directional test)

| Question | Use Issues | Ho | MA | MB | P-value | Conclusion | Design Implementation |
|---|---|---|---|---|---|---|---|
| Q1 | Narrative Structure | Ho: MA = MB | 5 | 4 | 0.069 | Accept Ho | Acceptable |
| Q2 | Switching topic-area | Ho: MA = MB | 5 | 4 | 0.014 | Reject Ho | Acceptable |
| Q3 | Alternative Views | Ho: MA = MB | 4 | 4 | 0.356 | Accept Ho | Acceptable |
| Q4 | Thumbnails | Ho: MA = MB | 5 | 4 | 0.035 | Reject Ho | Acceptable |
| Q5 | PCP to indicate | Ho: MA = MB | 3 | n/a | n/a | - | - |
| Q6 | PCP to compare | Ho: MA = MB | 4 | 4 | 0.464 | Accept Ho | Acceptable |
| Q7 | In Focus display | Ho: MA = MB | 4 | 3 | 0.185 | Accept Ho | Acceptable |
| Q8 | Interrelating Resources | Ho: MA = MB | 4 | 4 | 0.358 | Accept Ho | Acceptable |
| Q9 | Mapping footprints | Ho: MA = MB | 3 | 4 | 0.087 | Accept Ho | Acceptable |
| Q10 | Loading a WFS | Ho: MA = MB | 5 | 3 | 0.002 | Reject Ho | Acceptable for A |
| Q11 | Combining thematic layers, footprints, and a WFS at once | Ho: MA = MB | 4 | 3 | 0.153 | Accept Ho | Acceptable for A |

Ho = Null Hypothesis, MA = Median of the responses from Group A, MB = Median of the responses from Group B, n/a = no data

*From the test results, it can be seen that offering users a browsing interaction with narrative structures is an acceptable approach*. This finding also suggests that in general, test participants used the links and navigation trails of the atlas metaphor with no difficulties. Additionally, providing alternative views to users to look through the required geospatial resources in forms of thumbnails and a PCP view is an effective approach. In this regard, the PCP can be used specifically to compare the resources within the theme of interest, and not to indicate in detail each of the resources presented in the StorytellerView.

The comparative assessments presented in Table 5.3 give an interesting perspective on the issue of target users of the atlas metaphor. In relation to issues associated with navigation and interaction, the responses are the same for both groups of users (there is not enough evidence to reject the null hypothesis, except for Q4, where the difference is that Group A assesses the thumbnails' view as very useful and Group B assesses it as useful). Although the intended users of the atlas include both novice and expert users, the advanced abilities to deal with WFS (and perhaps the other OGC's web mapping standards) are more seen to be useful by persons who know and have been familiar with WFS. Nevertheless, the test has revealed some issues related to the design implementation. In this respect, when the atlas metaphor is going to be used in a real GDI organization in the country, the improvement is required especially in the clarity of mapping and integration of WFS and other geospatial resources. More detail on this is given in Table 5.4 below.

**Table 5.4.** The claim analysis and the indication of the design improvements

| No. | Activities | | Claims | Design Improvement |
|---|---|---|---|---|
| 1. | Browsing through the links | +<br>+<br>-<br>- | The need to quickly compare, select, and interrelate is supported by the narrative structure<br>The narrative framework envisaged is suitable to support the completion of loosely defined tasks (Chapter 2)<br>The organization of the topics is still too broad, hence users need more time to assess which map to select<br>The clarity of the title of the links of maps, datasets, WFS could have been improved to strengthen the information scent of the atlas. | Low |
| 2 | Making senses the summary of visualization of geospatial resources | +<br>- | The possibility to inspect the resources as a group in alternative views and as an individual resource is useful<br>The PCP is not so useful to assess the suitability of geospatial resources. As suggested by some test persons, the ability to filter only some of attributes in the PCP view would be of usefulness. | Low |
| 3. | Mapping (combining metadata footprints with thematic layers and WFS) | +<br>- | The combination of WFS access and representations of thematic layers and metadata mapping offers possibilities to investigate suitability of data in accordance to users' search context.<br>But, the clarity of map is easily becoming low as many footprints are projected and many thematic layers cascaded. | Moderate |

## 5.4.2. Case study: Collaborative use of the atlas metaphor

### Test Descriptions

While the test targeted for an individual use in Section 5.4.1 was considered as the usability test, the test described in the present section was more considered as a usability inspection. For this activity, four test persons who are active researchers in the field of GIS and environmental studies at ITC were involved to test the collaborative tools of the atlas metaphor. The result of the test was targeted to gather meaningful feedback to advance the design of the atlas metaphor when the collaborative work is to be facilitated. A scenario of use for a collaborative work using the atlas metaphor Aim4GDI was used for this activity (Appendix D).

For the sake of simplicity, the four collaborative test persons are referred to as CTP-1, CTP-2, CTP-3, and CTP-4. All of them had not had any experience with synchronous collaboration using GIS tools. CTP-1 was paired with CTP-2 while CTP-3 was paired with CTP-4. Each of these two pairs completed the test independently. The author was also involved as a technical assistant on both tests. The role of the technical assistant here was to help collaborative test persons to deal with the interfaces when they had difficulties of use and, when needed, to moderate the pair in order to reach the objective set in the scenario of use.

To support the required synchronous communication during the test, the Yahoo! internet messaging system was used. The tests actually were intended to make use of the voice conference function. However, due to an unexpected technical problem (i.e., disconnected internet connection), the voice conference function was only applied at the beginning of each collaboration.

After the collaboration, CTPs were asked to provide feedback to nineteen questions related to exploration (individual use), group awareness and shared representations, and overall tasks. The exploration questions (Q1 – Q11) were in fact the same questions asked in the use test for individuals presented earlier in section 5.4.1. Therefore, to investigate whether the responses of CTPs and Group A plus Group B described earlier in Section 5.4.1 have different median, the Mann-Whitney test was used (referred to as *Statistical Test D1*). The Wilcoxon signed rank test for a single sample was used to assess whether the designed user interfaces related to collaborative features of were considered helpful to the users (referred to as *Statistical Test D2*).

### Test results

During the test or the inspection activity, the pairs were browsing the atlas and GDI resources, loading the thematic layers, discussing the steps taken, and taking a decision (in this case, plotting points on top of the map to indicate the areas or locations where the group should do surveys related to an environmental study).

The results of the test are given in the Table 5.4, Table 5.5., and Table 5.6 below. Table 5.4 below presents the comparative assessment to reason whether there is evidence that the setting of the work (context of use) has been affecting the use of browsing mode of the atlas metaphor (*Statistical Test D1*). Meanwhile Table 5.5 reviews the design decisions of the add-in collaborative tools. Table 5.6 presents a summary as to how the test participants involved in the collaboration judged the feasibility of the atlas metaphor to support their interactions and thinking during exploration, analysis, and synthesis phases (Table 5.5 and Table 5.6 correspond to the results of *Statistical Test D2*).

**Table 5.5.** The comparison between responses of the test persons working for an individual project (Section 5.4.1) and test persons working for a collaborative work: The Mann-Whitney test was applied with 0.05 level for a non-directional test.

| Question | Use Issues | Ho | MI | MC | P-value | Conclusion | Design Implementation |
|---|---|---|---|---|---|---|---|
| Q1 | Narrative Structure | Ho: MI = MC | 4 | 4 | 0.706 | Accept Ho | Acceptable |
| Q2 | Switching topic-area | Ho: MI = MC | 4 | 3.5 | 0.150 | Accept Ho | Acceptable |
| Q3 | Alternative Views | Ho: MI = MC | 4 | 4 | 0.352 | Accept Ho | Acceptable |
| Q4 | Thumbnails | Ho: MI = MC | 5 | 4.5 | 0.543 | Accept Ho | Acceptable |
| Q5 | PCP use | Ho: MI = MC | 4 | 4.5 | 0.252 | Accept Ho | Acceptable |
| Q6 | In Focus display | Ho: MI = MC | 4 | 4 | 0.369 | Accept Ho | Acceptable |
| Q7 | Interrelating Resources | Ho: MI = MC | 4 | 4 | 0.157 | Accept Ho | Acceptable |
| Q8 | Mapping footprints | Ho: MI = MC | 4 | 4 | 0.150 | Accept Ho | Acceptable |
| Q9 | Loading a WFS | Ho: MI = MC | 3 | 4 | 0.389 | Accept Ho | Acceptable |
| Q10 | Combining thematic layers, footprints, and a WFS at once | Ho: MI = MC | 3 | 3 | 0.971 | Accept Ho | See Q11 at Table 5.3 |

Ho = Null Hypothesis, MI = Median of the responses from Test C1 (individual use), MC = Median of the responses from Test D1 (collaborative use)

**Table 5.6.** The effectiveness of the design implementation of add-in collaborative tools: The Wilcoxon signed rank test was applied to the test results to check whether the median of five design issues (Q11-Q15) is equal to "no effect" or not useful to help them complete the task (with 0.05 level for a non-directional test).

| Question | Use Issues | Ho | M | P-value | Conclusion | Design Implementation |
|---|---|---|---|---|---|---|
| Q11 | Who are online | Ho: M = 3 | 5 | 0.125 | Accept Ho | Acceptable |
| Q12 | Simple radar view | Ho: M = 3 | 3.5 | 0.500 | Accept Ho | Not optimal |
| Q13 | Map displays synchronised | Ho: M = 3 | 4 | 0.125 | Accept Ho | Acceptable |
| Q14 | Colour changes syhnchronised | Ho: M = 3 | 4.5 | 0.125 | Accept Ho | Acceptable |
| Q15 | Plotting pin boards | Ho: M = 3 | 4.5 | 0.250 | Accept Ho | Acceptable |

Ho = Null Hypothesis, M = Median of the responses

**Table 5.7.** The responses of test persons in assessing the completion of collaborative tasks with the atlas: The Wilcoxon signed rank test was applied to the test results with 0.05 level for a non-directional test.

| Question | Use Issues | Ho | M | P-value | Conclusion |
|---|---|---|---|---|---|
| Q16 | Helpful for exploration | Ho: M = 3 | 5 | 0.125 | Accept Ho |
| Q17 | Helpful for analysis | Ho: M = 3 | 3 | 1.000 | Accept Ho |
| Q18 | Helpful for synthesis | Ho: M = 3 | 4 | 0.125 | Accept Ho |

Ho = Null Hypothesis, M = Median of the responses

Table 5.5 strengthens the findings regarding the exploration of geospatial resources by browsing, drawn in Section 5.4.1. In this sense, the responses from CTPs have insufficient evidence to reject the hypothesis. Thus, the exploration of geospatial resources with browsing mode is not affected by the context use of the atlas.

The results presented in Table 5.6 indicate that the simple implementation of group awareness such as an indication on who is online is useful for the collaboration activity. The shared representation was made available through synchronization of colour changes and map displays as well as collaborative drawing of points and areas. These displays can reasonably be perceived well by the CTPs. One of CTPs found that the implementation of a simple radar view as shown in Figure 5.9 has a lack of clarity especially when two or more collaborators focused on the same area of interest. This suggests a design improvement on the use of graphic variables to indicate the collaborators' area of interest. The previous findings on the issue of windowing for collaboration activities as presented in the study of Schafer and Bowman (2006) can be of help to improve the clarity of the display.

Meanwhile regarding the collaborative tasks supported by the atlas (Table 5.7), the CTPs or participants regarded the atlas to be more useful during the exploration and synthesis phases than during the analysis phase. This can be understood since the analytical functions like buffering are not available in the current prototype developed. This issue was also pointed out by CTPs during the focus group discussion. For completing such a scenario used in the test, CTPs argues that a wide range of GIS functionalities, for instance buffer creation or multi criteria analysis, should have been available. In response to this feedback, the atlas should indeed provide more analytical functions to make sense of the data and GDI resources accessed. Research has been done in this area where GIS functions are integrated into electronic atlases (Schneider 1999). Using today's web mapping standards, the development of Web Processing Services can also be integrated in the system.

The test results presented in Table 5.6 and Table 5.7 indicate that there is not enough evidence to reject the hypothesis (eventhough the medians for the responses to the questions of Q16 and Q18 are all higher than 3). This can be due to the small numbers of observations. In this regard, when the collaborative features will be offered in the atlas metaphor for real uses, use tests involving more paired individuals trying out the interface are required.

## 5.5. Discussion

***Individual Use***

In relation to Activity 1 in Table 5.3 (Browsing though the links), the browsing test targeted to individuals was also intended to assess whether the browsing behaviour that users show during the test was in accordance with the narrative framework envisaged. As mentioned in the end of Section 5.2.2, the LRS can be used to present a model regarding the actual paths that users take during their interactions with a website. Based on some screen recording data collected during the test, the LRS of the atlas metaphor can be developed. In summary, the LRS constructed during the test matched the hypothesized narrative structure presented earlier in the Section 5.2 and shown in Figure 5.3 (atlas storyteller and GDI storyteller) and Figure 5.5 (PCP). A scenario of a traveller who makes a journey to find the right information is envisaged as a trail of: Topic – Map – Atlas Storyteller (*AS*) – images (*AS-i*) and graphics (*AS-g*) which is connected to GDI storyteller (*GS*) – GDI resources (both WFS (*GS-WFS*) and offline data (*GS-od*) in this case) - Resources as Thumbnails (*GS-av-t*) – Resources as PCP (*GS-av-pcp*) and In Focus (*GS-if*) display (Figure 5.13).

As shown in Figure 5.13, the LRS developed (represented as orange solid flow lines) corresponds exactly to the specific traveller plot mentioned above (see Section 5.2.1). When some individual interactions were plotted, indeed it could be seen that the variation of the paths was very minimal. Figure 5.13 presents the model and some individual users' path as solid flow lines in a Space Time Cube. The lines correspond to the interaction performed by users and the model constructed throughout the StorytellerView. Meanwhile the projected footprint is referred to the browsing path constructed for the model. This result proves that there is more evidence to conclude that the narrative structures developed in the atlas metaphor can be well understood by the users.

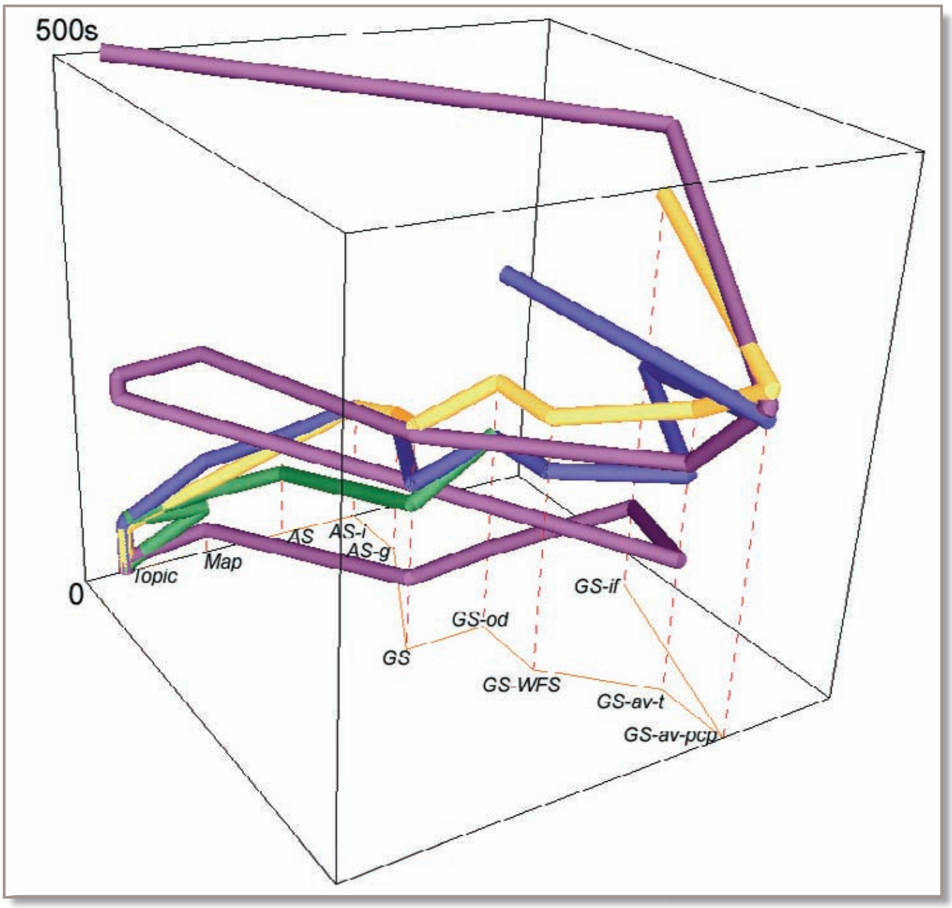



**Figure 5.13.** Users' interactions and the LRS developed are plotted onto a Space Time Cube. The Z axis corresponds to browsing time in seconds (until 500 seconds). Meanwhile the footprints relate to the path constructed by the LRS model (see the detail of the targets plotted in the text). In this cube, the yellow line refers to the LRS model (discussed earlier in Section 5.2.2), while the purple, green, and blue solid lines refer to example trajectory interactions generated by three users.

***Collaborative Use***

In relation to the development of collaborative tools on top of the atlas metaphor, from the test activity, it was clear that the role of atlas metaphor is still limited as an object of collaboration. In addition, to some extent the use of pin board makers and annotation on top of the map can be used to evoke further discussions and exchange ideas (thus, can be used to support dialogue). However, the role of visual methods to support coordinated activity has not been addressed or covered by the atlas metaphor. As also addressed by 2-paired CTPs, the organization of the actions and the execution of the tasks related to collaborative exploration, collaborative synthesis, and collaborative analysis between their private realm and group realm are still in mixture. In that way, the shared representation offered lead to confusion and unawareness.

The problem mentioned calls for a clear structure in the atlas metaphor that allows users to move back and forth throughout different stages of collaboration efforts. On this issue, MacEachren and colleagues (MacEachren et al. 2004) have presented a conceptual approach on how collaborative processes can involve knowledge extraction from data to information sharing to a decision and back to data again, updating procedures and practices (e.g., stored as ontologies for instance) previously visited or chosen. When reflected in Figure 3.1 presented in Chapter 3, the transition (back and forth) between personal realm and group realm (instead of public realm) should be facilitated.

The ability to switch between the personal and group perspectives without necessarily loosing track of collaboration efforts is required. In this context, the notion of group memory and decision history can be introduced to the atlas metaphor. This can be done for example by connecting actions metadata presented in Section 5.3.2 to ontology of methods, data, and procedures, so the actions can be traced (and visualized) based upon their association to particular group tasks or methods, for example (see also (Kemp 2005)).

For this to be effective, maps and graphics developed in the atlas are designed not only to explore-synthesize-analyze-present geodata, but also to depict the effects and connectivity between those processes as a timeline (a kind of decision story (Eisenhardt and III 1988)). In this aspect, the role of maps (and graphics) to help indexing and representing the group memory (e.g. past interactions, goals, and procedures) has not been a research focus in geovisualization. Empirically, the use of group memory speeds up the group decision-making (Paul et al. 2004). Hence, the effective visualization of group memory in combination with decision history is considered promising for collaborative decision-making. As such, the group members can gain insight and guidance not only about ways to reach the final choice (solution) for a problem (*how*), but also the analytical reasoning for that solution (*why*).

## 5.6. Concluding remarks

What has been discussed in this Chapter is the conceptual framework of the navigation and interaction schemes of the browsing mode of the atlas metaphor to facilitate exploration of geospatial resources. By providing a clear navigation trail, the processes of exploration of geospatial resources can be made more meaningful. This has been seen as an important requirement to step further in making sense of geospatial resources during the analysis and synthesis phases. In addition to that, a conceptual approach to extend the use of the atlas metaphor for collaborative efforts has also been demonstrated in this study. From the test activity evaluating the use of the atlas metaphor for an individual use and the group work, it can be concluded that the narrative structure developed can be used with no difficulties. Meanwhile the abilities to support analysis and synthesis efforts via thematic, metadata, and WFS mapping have not been offered optimally, leaving some important issues for design improvements.

Geobrowsing (Peuquet and Kraak 2002) refers to a process of making sense of maps and geo images for data exploration, synthesis, and analysis. In so doing, geobrowsing is not only dealing with a combination of ad hoc query and map displays permitting the user to access geographically indexed information in a database or library, such as using hypermaps concept (Laurini and Milleret-Raffort 1990). But also, the tools and displays developed should facilitate visual thinking by which users are capable to gain insight and to reveal new knowledge during the course of interaction. To effectively support this, tractable navigation trails that enable users to move back and forth from exploration to other phases of map use (i.e., synthesis, analysis, and presentation) are required.

This chapter attempts to address this issue. In this study, the storytelling concept was used to assist users exploring and synthesizing the GDI resources. The concept has been used to tell users: how they come to a selection, which resource is relevant to their needs and how they can interrelate and combine their focused resource with other supporting information. Considering that activities related to geospatial analysis and synthesis could be either with plot or plot-less, to be useful and effective, the use of narrative structures should not limit users' choices to unfold the subsequent series and actions through interactions. In fact this has been considered as a threat in building a storytelling system: how to balance the plot and interactivity (Crawford 2005).

During the exploration phase, an ability to combine searching and browsing interactions at once has not been offered. For general web interactions, best practices have been suggested by scientists and practitioners to how searching and browsing modes can be effectively combined and assess how a seamless transition between the two modes can be delivered to improve users' online experiences. Some of the techniques developed include: exploiting behaviour observation (Beale 2006; Rose 2006), handling the mixed behaviour (Gremett 2006), and advancing the topical relevance (Bodoff 2006). For collaborative efforts, the transition to be facilitated along the narrative structures is not only the map use phases (i.e. exploration, analysis, synthesis, and presentation) and information seeking behaviour (searching and browsing), but also the use context (individual and group use). Chapter 6 will bring back the test, design, and findings resulted from this chapter into the big picture of the development of the national atlas metaphor, relating this chapter to previous chapters.

# Design and Evaluation Revisited: Applying Scenario-Based Development

This chapter will review the use of scenarios to envision, develop and assess the use of the national atlas as a metaphor in the access to a geospatial data infrastructure. As explained in previous chapters, when gathering requirements, illustrating the typical use of functionalities, and assessing the usefulness of the prototype, scenarios were involved. In this chapter, the scenarios discussed in various stages of the design processes will be presented and interrelated as a unifying tool that provides an understanding of the specifications and impact of the envisioned national atlas metaphor.

## 6.1. Introduction

The development of geospatial data infrastructures (GDIs) is evolving. From the literature, one can notice that this was mainly characterized as a collection of at least four defining components, i.e., policy, technology, institution, and standards, served as basis to facilitate geospatial data access and sharing (Coleman and McLaughlin 1997; Groot and McLaughlin 2000). In addition to this idea, to some authors, the emphasis of the GDI should be on the aspects associated with the processes of the facilitation and coordination of the exchange and sharing of geospatial data (Rajabifard et al. 2002; Rajabifard et al. 2000). Moving further from this process-based understanding, the scalability and adaptability to serve users' needs and the required business processes have been considered to be the focal points for the success of the GDI (Morales 2004; Wytzisk and Sliwinki 2004).

For the purpose of serving users' needs, the focus of this study has been on the issues related to the use aspect of the GDI. It deals with the development of the national atlas that is intended to help users understand, make sense, and gain access to geospatial data in the GDI. For this purpose, an understanding of the functionalities and specifications of the atlas is required. To develop this understanding, an analysis of the concept of the national atlas has been presented in Chapter 2. To evoke design ideas on the conceptual level, that analysis has been combined with a review of the current strategies associated with data discovery via geoportals as well as with an inquiry on the Netherlands's clearinghouse. Scenarios of use were used to provide concrete feedback in relation to required activities and interactions that users require when looking for geospatial data. Scenarios have also been used to make sense of technical aspects associated with searching and browsing GDI resources (Chapter 3) as well as to assess the impact of the use of the atlas metaphor (Chapter 4 and Chapter 5).

Scenarios have been used pervasively in website development and software engineering (Bødker 2000; Carroll and Rosson 2002). The most prominent feature of the use of scenarios is that they can be used effectively to support implementation of usability engineering. In this respect, the analysis of the user requirements as well as the usability evaluation can be accomplished using scenarios as the medium. The approach of incorporating scenarios has also been applied in many developments of new visual methods and interfaces associated with geospatial data exploration and analysis. Recent examples that are closely related to this study include use of scenarios during the evaluation and redesign of the National Atlas of Canada (Kramers 2005) or use of scenarios to assess the usefulness of a visualization-geocomputation display based on Self-Organizing Map (SOM) for exploration tasks (Koua et al. 2006).

In contrast to the mainstream of geovisualization research foci in utilizing scenarios to assess the usability of user interfaces (Fuhrmann et al. 2005; Slocum et al. 2001), this study, as mentioned above, incorporate scenarios in various stages of the design process using the scenario-based development principles (Rosson and Carroll 2001). The decision to apply the scenario-based development was motivated by the fact that the real practices associated with the use of the GDI are still limited. This study claims that the potential impact of the use of GDI is more than an improved data access.  Other potential uses of the GDI for decision-support analysis and collaborative planning for instance, have not been extensively exploited. To improve the usability of the GDI interface in order to advance the potential uses of the GDI, the concept of national atlas was introduced. Through an analysis focusing on the structural definition of the atlas (Section 2.3), some potential uses of the national atlas as a metaphor can be specified. However, when moving toward the design activities, these abstract specifications must be transformed into explicit and focused specifications that can be operationalised. In the absence of the detail specifications of GDI use through the national atlas, scenarios can be of help. In this way, the potential use of the national atlas as a metaphor in the GDI context as well as the possible drawbacks from its use for people (human users) can be situated and argued.

This chapter discusses the use of scenario-based development for enabling successful interaction between the users and the national atlas in accessing and making use of geospatial resources in the GDI. The principles will be discussed first. What will be described afterwards is the development of the national atlas metaphor using a scenario-based design paradigm. The evaluation of the prototype of the national atlas metaphor will be reviewed including the comparison between the use of the atlas metaphor and a typical current geoportal. After discussing these stages of development, the effectiveness of the design decisions and the feasibility of the atlas metaphor are discussed.

## 6.2. Scenario-based development

### 6.2.1. Task-Artefact Framework

Section 2.5 (Chapter 2) has briefly mentioned the notion of design rationale and task-artefact framework. As mentioned in that section, a design rationale specifies the reasoning behind a design decision (MacLean et al. 1989; Shum and Hammond 1994). In this regard, the rationale includes "justification, the other alternatives considered, the tradeoffs evaluated, and the argumentation that led to the decision" (Lee 1997). A design rationale can be used in three different ways: a set of records documenting reasons for the choice of an artefact, a set of psychological claims embodied by an artefact (*known as a task-artefact framework*), and a description of the design space (Lee and Lai 1996). It gives an explanation of the reason why the system is the way it is. This approach has been used and represented in software engineering and design interaction in different ways, including as QOC (Questions Options Criteria), Storyboard, usage scenario descriptions, screen shots, textual descriptions (MacLean and McKerlie 1995) and formal programming (Gruber and Russell 1996; Lee and Lai 1996). Some benefits that the design rationale offers during the design process include: structuring design problems, communication throughout the lifecycle, reuse of design knowledge, presenting arguments for design trade-offs, and maintaining consistency in decision-making (Carroll 1997a; Shum and Hammond 1994). In this respect, to some extent, the design rationale can contribute to the usefulness of usability engineering (Carroll 1997a).

Of the three ways of the use of a design rationale mentioned above, this study focused on the use of the notion of task-artefact framework (TAF) introduced by Carroll and Rosson (Carroll and Rosson 1992; Carroll and Rosson 2003). The argument for this approach to be valid is that most technical activities in human-computer interaction can be captured as transaction between tasks and artefacts (Carroll and Rosson 2003). Tasks that users need to do specify requirements for new artefacts.

These new artefacts accordingly unleash new possibilities for human activities, new ways to do familiar things, thus new tasks, as well as impacts and consequences such as new complexities, new errors, and other difficulties that users might have. These possibilities and their consequences have been termed as 'upside' – 'downside', are furthering the cycle of design, leading to new requirements, which are in turn provoking another transaction. To deal with "trade-offs" resulting from those upsides and downsides, claims explicitly specify design rationale relating properties of the artefact with specific consequences for a contextual use. The (upper) claims explore users experience in completing the task and specifying requirements for designing a new artefact in which other (lower) claims will raise opportunities and consequences for human action (Carroll and Rosson 2003).

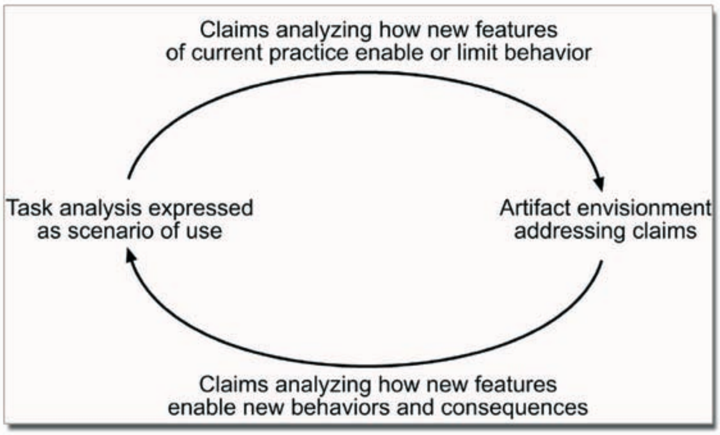



**Figure 6.1.** Task-Artefact Framework (Carroll and Rosson 2003) (Reprinted with permission from Morgan Kaufmann, Elsevier)

Task artefact framework facilitates the use of *scenarios of use* to reason and organise the design process. In this context, use scenarios are a relevant approach for representing, analyzing, and planning how a computer system might affect its users' activities and experiences (Carroll 1997b). Here, a scenario contains a description (in forms of text, storyboard, graphics, or others) regarding what the user might do and perceive during his/her interactions to the interface for a particular context.

Carroll and Rosson (1992) see scenarios as a "vocabulary that can span both descriptions of existing tasks, incorporating existing technology, and of future tasks, incorporating envisioned technology". This study sees that this opinion has fundamental grounds in practice. Indeed, scenarios describe the motivations and experiences of users on specific activities. It is not merely about the interaction's event as recognized in the use-case approach of the object-oriented software engineering (Preece et al. 2002, p.226). Setting scenarios in the task-artefact cycle enables iterative requirements' gathering and artefact improvement. With not merely incorporating empiric results of the evaluation but also analysis regarding users' motivations and experiences, the design process seeks to ensure both usability and use-ability of the artefact or the system. In order to make the use of scenarios in the task-artefact framework is more systematic and organized during the design, Rosson and Carroll (Carroll and Rosson 2002) introduce the scenario-based design.

The scenario-based design regards the system development as a usability engineering process throughout three main spaces: *problem space, design space, and evaluation space*. The **problem space** refers to the exploration of the current setting of the system in accordance with the goal of the design. It is concerned with problems and opportunities of the current setting and aims at supplying a requirement analysis to be used in the design space. The **design space** encompasses three stages of the design: activity, information, and interaction design. The activity design focuses on the basic goals and motivations for the new activities users will engage in, using the system. The information design emphasizes what the users will see and understand about the systems. Meanwhile the interaction design specifies the concrete exchanges between the user and the system. The **evaluation space** deals with feedbacks, reviews, usability inspection, cognitive walkthrough, and usability testing (all analytical and empirical methods of evaluation) of the old & new systems.

Another important aspect of the scenario-based design is that it considers the system development as a cycle. The use of scenarios throughout the cycle is aimed at critically evaluating the design decisions through the claim analysis. The **claims analysis** (Figure 6.1 above) is an analytical method to generate and evaluate potential causal relationships between features of a design and consequences of use (Carroll and Rosson 1992). Inevitably, each design contains claims reasoning about the design decision. Within the scenario-based design, claims embodied in the design must explicitly be specified. That claims analysis enhances reflective design and guides the developer to consider both the positive and negative consequences of the design on the user as well as the "trade-offs" to be decided to improve the design (Carroll and Rosson 1992).

By explicitly exposing the process of the design, the implementation of iterative development can be more systematic and manageable. It enables summative and formative evaluations throughout the iterative development (Carroll 1997a, p.511). A *summative evaluation* aims to quantify a design against a scale (e.g., response time in seconds), whereas the goal of the *formative evaluation* is to delineate aspects of a design for improvement.

### 6.2.2. Tasks to accomplish

Task analysis is used to investigate the underlying principle of users' cognitive processing and action in interacting with a system ranging from high-level abstraction to low level execution. The most common approaches in doing task analysis are: decomposing a task into subtasks and modelling knowledge plus cognitive process of the users based upon the goals, operators, methods, and selection rules for a given context (Preece et al. 2002 p. 231). The first approach is known as Hierarchical Task Analysis (HTA) and usually is resulting in a typology of tasks, as widely applied in the geovisualization studies (see e.g. (Andrienko et al. 2005; Plaisant 2005)). The second approach is known as GOMS, which is used mostly for performing predictive evaluations (John 2003).

The characterization of users' task is an important step in addressing requirements in the interface design. This has been obligatory in the field of HCI from task-oriented interface development and usability evaluation perspectives (Carroll and Rosson 1992; Carroll et al. 1992). For interacting with websites in general, according to

Shneiderman (1997), users can have four possible tasks: specific fact-finding, extended fact-finding, open-ended browsing, and exploration of availability. When interaction is more specific and related to information access, information-seeking behaviour can be addressed using information-foraging theory. The theory, derived from optimal foraging theory in biology and anthropology studying food-foraging strategies, is analyzing "trade-offs in the value of information gained against the costs of performing activity in human-computer interaction tasks" (Pirolli and Card 1995). Within this theory, human activities for iterative information seeking can be identified as the following: (1) looking for specific answers, (2) browsing without a specific representation in mind, (3) using overviews to discover relevance with the need, and (4) aggregating and assimilating related information through information workspaces (Borner 2002).

The practical goal of the GDI is to provide data access mechanisms. The literature commonly discusses this from organizational and institutional points of views (e.g. (Onsrud and Craglia 2003)). While looking from a technological point of view, discussions are centered on the provider-registry-requester paradigm and semantic-syntactic interoperability (e.g. (Maguire and Longley 2005; Tait 2005)). Some also describe the interaction between provider-registry-requester in the form of case scenarios using object oriented modelling (e.g. (Bernard et al. 2003)). However, discussions on the kind of tasks, and more specifically activities, that should be supported by the geoportal for enabling access and sharing practice in the GDI are still lacking.

In a geoportal, the discovery or exploration tasks required can be more extensive than what the fact-finding task (mentioned above) refers to. As discussed in Section 2.4 (Chapter 2), the tasks that users can accomplish through geoportals vary from *tightly defined task* to *loosely defined task* of geospatial metadata exploration. With the first task, the aim of users' actions is to locate *specific* geospatial data or services that fulfil their needs and to identify the possibilities to access them. In contrast, a loosely defined task aims at locating *appropriate* data in which the fitness for use is not simply depending on matching values of certain elements in metadata.

This study is not interested to develop a typology of the tasks for discovering geodata. It is also not to determine discovery tasks to be more mechanistic and predictable, so that they can be modelled and measured against the time scale. It considers that the real-world tasks for discovering data can be very complex. Hence, the description of a complete set of typology of the tasks was avoided from the very beginning of the design. For this study, the focus is more on understanding how human activities for iterative information seeking (i.e., searching, browsing, reviewing and aggregating mentioned earlier), which involve tightly defined and loosely defined exploration tasks, can be facilitated by the user interface. In this regard, tightly defined and loosely defined exploration tasks can be referred to users' abilities to perform some operations related to visual explorations successfully when interacting with the interface. These operations include identification, ranking, comparison, association, and correlation of metadata items. In such a focus, for finding the required geospatial resources, users can require, say, identification and comparison tasks during either their searching or browsing interactions. In this regard, as has been mentioned in Koua et al. (2006), a more comprehensive list of visual explorations or tasks than listed here has been suggested for instance by Keller & Keller (1992) and Wehrend and Lewis (2000).

## 6.3. Design & development revisited

In this study, when the framework reviewed above is associated with the metaphor development levels explained in Section 2.4 (Chapter 2), then, it can be observed that the issues related to the conceptual level were mainly handled in the problem space. The issues associated with the operational level of the metaphor development were sorted out in the problem space (e.g., rapid prototyping) and design space (e.g., activity design). Meanwhile issues related to the implementation level were processed in the design space of the framework. The evaluation space refers to use assessments of the prototype of the metaphor developed. Figure 6.2 presents activities related to the metaphor development as a unifying scenario-based development.

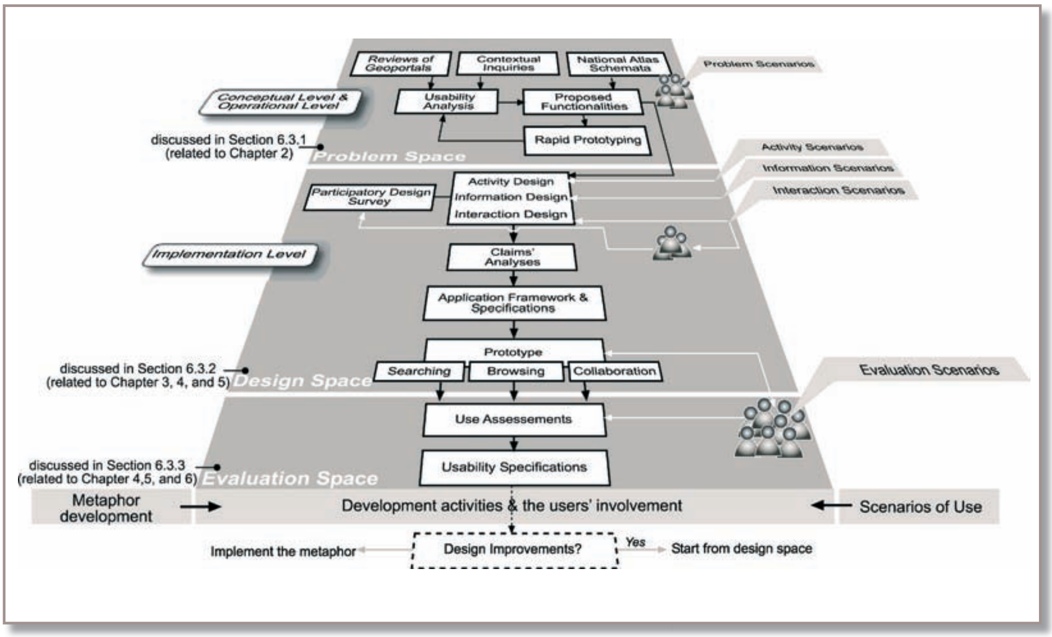



**Figure 6.2.** Development activities accomplished in the creation of a national atlas metaphor. The figure can be seen as a reverse view and detailed steps of thesis execution presented in Figure 1.6 (Chapter 1)

The present section will discuss activities that took place in problem, design, and evaluation spaces in more detail.

### 6.3.1. Problem space

Within the scenario-based design, tasks can be represented through scenarios of use. In this way, scenarios can be useful to gather information regarding the user's strategies. Additionally, they can help designers in understanding why users do what they do (Carroll 1994). Another important aspect to note is that the scenarios developed should not consider the features and functionalities of the current artefact (so, in this regard is the current Netherlands' GDI portal or clearinghouse).

In this study, two problem scenarios were generated and tested to participants. These two scenarios (see Table 2.3) provide descriptions concerning users' needs and users' goal to find data via the current portal, i.e. *Nationaal Clearinghouse Geo-Informatie* (NCGI). Basic guidelines regarding functionalities of the NCGI portal were given, but participants were not given any detailed instructions on how to search and on what tools should be used. They were free to experiment with the tools.

Contextual inquiry is one of the techniques used in user-centered design to gather data for task analysis (Beyer and Holtzblatt 1998). It can help designers or developers understand "the real environment people live in and work in, and it reveals their needs within that environment" (Kuniavsky 2003). This technique is considered good at exploring issues (Preece et al. 2002, p.211). According to a practical guideline (Kuniavsky 2003), five to eight people are sufficient for the first round of inquiry and should give designers a proper idea of how the typical users accomplish their tasks. Since the objective of this inquiry is to develop abstraction of requirements and not to elaborate detailed design using their experiences, thus seven test participants involved (Section 2.2.2) is considered sufficient.

This inquiry activity has two-fold intentions. The first was to investigate users' experiences in making sense of the current portal. The second intention was to test whether the proposed metaphor (i.e. the atlas) provides strong grounds to support the task (especially the loosely defined task). For revealing the users' perceptions in the use of an atlas to help users complete the task, users were asked whether they have a willingness to use an atlas for supporting their arguments to decide which data to select.

A set of inquiries was made to test participants in completing these two exploration tasks using the NCGI interface, and has been described in Chapter 2.

Regarding the use of problem scenarios, test participants were successful in completing a tightly defined discovery task. However, they were expecting more functions in the current NCGI interface like the tools to enable them to sort and compare metadata.

Meanwhile, concerning the second task i.e., finding relevant data to produce a map to support a traffic survey planning, most of them required more geospatial information, such as maps pertaining to demography and the traffic of the area, than what was provided. At the moment, the interface only offers a country map depicting province areas, intended to support the search area definition. Their responses show a lack of schemes in the current portal to support the discovery context and lack of interfaces to accomplish the user's tasks. These findings were relevant to the results gained from the review activity. As discussed in Section 2.2.1 (Chapter 2), from the activity of reviewing geoportals, it can be seen that most geoportals lack abilities to assist users' understanding in making sense of the search results. Additionally, appropriate navigation tools and interactions to enable users review the results were considered not optimal.

As explained in Section 2.5, these findings have motivated the development of an early prototype of the atlas metaphor (a *rapid prototype*) for accessing geodata. As discussed in that section, the goal of this activity was mainly aimed at assessing issues related to the operational level of the atlas metaphor. In other words, the development of a rapid prototype was intended to assess whether the design concept and functionalities proposed are feasible. In addition, as was also mentioned in Section 3.3, another goal of this activity was to elicit design improvements concerning the concept and functionalities developed. Using the rapid prototype, the exploration of the design ideas was done by the author and supervisors of this study. From the rapid prototype development, some design considerations were drawn. Some limitations of the rapid prototype were: no detailed scheme of the GDI resources should be presented, only data discovery was considered, not integrating information. Additionally, the clarity of the projected metadata summaries needed to be improved. Further, a more straightforward structure for the users' navigation and a direct and simpler use of colour hues were needed.

Table 6.1 shows some of functional requirements that can be summarised from contextual inquiries and the rapid prototype development. In this stage, negative consequences of the claims were also considered.

**Table 6.1**. Claims analyses: positive and negative consequences to be considered in the design based on the inquiry and the rapid prototype development activities

| Task I: completing tightly-defined tasks | | | Task II: Issues in completing loosely-defined tasks | | |
|---|---|---|---|---|---|
| 1 | +<br>- | The options to query should be thorough to allow users specifying questions or search terms<br>**But** if too detailed or disorganised, it will require users to spend more time to use it | 1 | +<br>-<br>- | Users intend to browse more for assessing data suitability<br>**But** it may end-up nowhere and users may change their focus of interest<br>**But** users may need to remember some information during their visit |
| 2 | +<br>- | Users prefer to have more tools to control the results and displays, and should not coerce users to adapt<br>**But** users need guidance too | 2 | +<br>- | Visualizations vis-à-vis what is available or not can be helpful to users<br>**But** it can be misleading when the user only depends on the information presented |
| 3 | +<br>- | The completeness and coherence of the presentation of search results are important to users<br>**But** the complete information (mainly textual) can be distracting to users and make the search inefficient. | 3 | +<br>- | An atlas-like structure to browse the content was regarded useful to support the users' task<br>**But** users' strategies during the search process may require quick searching with keywords |
| 4 | +<br>- | Search results can be presented as symbols to offer an efficient exploration or visual thinking<br>**But** users, in some cases, might prefer textual displays to scrutinize the results | 4 | +<br>- | Using graphical cues to assist searching might also be useful<br>**But** the use of too many forms of visual displays can also be confusing and coerce users to understand all the details |
| | | | 5 | +<br>- | Map and metadata can be combined to enhance the data analysis<br>**But** too advanced and too complicated interaction required will limit users interest |

The benefit of the use of problem scenarios and claims analyses is that important features required in the interface can be identified. In addition, desirable and undesirable consequences that the users might gain in using the interface can be listed. The outcomes of this analysis are used to develop an evolutionary prototype, an SVG-based atlas metaphor.

## 6.3.2. Design space

When problem scenarios have been processed and analyzed, from that stage onward, scenarios regarding possible activities engaged by users using the atlas as a portal were outlined. The activity scenario provided solution ideas to how the concept of national atlas should be realized to support users' activities. This activity scenario and its corresponding claims lead to the detailed descriptions for designing possible information and interaction offered in the atlas with the use of information and interaction scenarios. The information scenario provided insight and analysis how the proposed visual methods offered in the metaphor could support this.

The interaction scenario provided a possibility to investigate in details the design alternatives and options to support users' action. In these design stages, possible prospects and constraints, their trade-offs were elaborated.

In the design space, the feedback, ideas, and concepts gained from the problem space were used to develop the user interfaces. In this regard, as described in Chapter 3, the development of user interfaces of an evolutionary prototype, called Aim4GDI, was initiated. The Aim4GDI (Atlas Interface Metaphor for Improved Use and Accessibility of the GDI) was intended to help users complete the tightly defined and loosely defined tasks. With evolutionary prototype, is meant that all or the part of the prototype is retained in the final product (Gordon and Bieman 1995). As mentioned in Section 3.3 (Chapter 3), the prototype has been iteratively improved during the course of this research study.

During the development of the prototype, activity, information, and interaction scenarios and their claims analyses were built in order to guide and improve the design decisions. In this view, the claims analyses can be used to enhance a balanced view in understanding both opportunities and constrains of the proposed functionalities and interfaces. Such analyses are useful to avoid drawbacks from the so-called "solution-first" approach (Carroll and Rosson 2002), an approach in which designers generalize and analyze a candidate solution as a means of clarifying the problem state and the goal. The danger of this approach is that it tends to quickly define the solution, simplifies the problem space, and inadequately analyzes other alternatives (Carroll and Rosson 2002). In the context of the national atlas, the rapid prototype discussed in the problem space can be considered as a solution-first approach. When the design space only looks at the opportunities or positive outcomes of the prototype and the concepts, the resulting solution can be inaccurate and ineffective.

The following sub sections review the design process of two main components built within the Aim4GDI prototype, the ExplorerView and the StorytellerView interfaces accordingly. Users are expected to be able to complete a tightly defined task via visual displays presented in "ExplorerView" as well as to complete a loosely defined task of data discovery using visual displays and navigation schemes related to "StorytellerView" interfaces. For each component, the details on how the activity, information, and interaction scenarios were used to improve the prototype using the claim analysis will be given.

### ExplorerView

In this study, as discussed in Chapter 1, the atlas metaphor is envisaged as an alternative means to discover the required geospatial resources in a GDI organization. Scenarios were used to envision how such an atlas interface could be realized. The activity scenario aimed at making positive consequences of the problem scenario listed in Table 6.1 became more salient to support the users' goal while minimizing the negatives. Table 6.2 below presents the activity scenario used during the prototype development. In this context, the case of Danny the GIS specialist (presented in Chapter 3) is recalled.

**Table 6.2**. Facilitating users' activities for completing tightly defined tasks: the scenario and some corresponding claims

| **A. The activity scenario** | |
|---|---|
| Danny, a GIS specialist at an environmental consulting firm, is involved in a project studying the environmental impacts of roads extensions in the urban areas of the southern part of Overijssel province. One of several items he has to do is to prepare a map depicting the road quality and the zoning of the sound pollution (to be served as map service within his office's intranet). In order to produce this map he needs datasets such as: road network, traffic statistics, health and pollution indicators from the government's environmental bureau, as well as other complementary data such as demography, and land use datasets. The challenging job he faces is to locate suitable datasets for this purpose. He decides to go to the national GDI portal to find the datasets required. With this portal, he can define area of interest by its place name, administrative unit, or by drawing a box over a map. Place name and administrative unit options help him when he knows little about the study area and does not know its position on the map. He also needs to specifically define constrains for selecting the data he wants, including the data currency, level of detail (scale), and coordinate systems as well as their availability and accessibility. In a later stage, he needs to assess the matching of search results presented to his needs. | |
| **B. Activity claims** | |
| Wide-range users' inquiries are systematically categorized by where-what-when constraints | |
| + | In accordance with users strategies to deal with daily problems |
| + | Helps users to decide which categories should be chosen |
| + | Speeds up the inquiries process rather than using the directories approach |
| + | Enables users to submit joined queries |
| - | **But** other users might want to skip them and only want to type in keywords |
| - | **But** too detailed constraints will require more time to discern |
| - | **But** users need guidance for clarity since attributes offered can be overlapping |
| Assessment for the matching and the fitness of use using the summary of metadata | |
| + | Simplifies the understanding of the complexities of geodata characteristics |
| - | **But** the metadata summary can be misleading |

The design process is continued towards more concrete functionalities and more detailed interfaces. Information scenario was built to identify visual methods that can help users during their discovery or exploration interactions. Table 6.3 shows the activity scenario used in this stage.

**Table 6.3**. Information presentation for completing tightly defined tasks: the scenario and some corresponding claims

| **A. The Information scenario** |
|---|
| Danny then opens up the portal application using his favourite browser. He opens up the explorer window. Two tabs are available within the "Explorer" main bar: Defining Questions and Refining Questions. He goes to the "Defining Questions" component to express his inquiries. He wants to assess data pertaining to road infrastructure and road traffic statistics. He first goes to the "Where" subcomponent to exactly define the location of the data he is interested in. He decides to use administrative options since he wants to have data covering two neighbouring municipalities at once. Then he specifies attributes of data to restrict the search through the "what" and "when" subcomponents. Soon after submitting the query, as he expects, the portal is outputting the search results in a table-view depicting a summary of the matched metadata: more than 50 items matching to his queries! This requires him to scroll down the table to examine all items. He can group these results based upon the available fields. For each selection, he can check the geographic extent of the data by projecting this item into the map. |
| **B. Information claims** |
| Search terms are organised into where-what-when sections |
| + It enables users to specify clear questions due to the clarity and familiarity of the "where-what-when" strategy<br>- **But** a nested mechanism can also be confusing and difficult to perceive |
| Combination of textual and graphical displays in information presentation |
| + Visual information is generally remembered better than textual information<br>+ Images are helpful to support users localize information and to provide an overview while text is good in representing abstraction of the data.<br>- But the visual representation can give misleading information |
| Depiction of the metadata summary over a map |
| + The categorization of data based on their geographical coverage, topical coverage, and temporal coverage facilitates users' needs to find suitable data quickly<br>+ Offers possibilities to correlate and associate the two for a particular user's concern<br>+ Users can study the relevance of the data to their goal<br>- **But** the complicated metadata symbols may be distracting and confusing. |
| Familiar displays (e.g. table, map) with linking possibilities |
| + Ease users learning curve<br>+ Allow users to explore more<br>- **But** too many windows and information presented can be an overload for users wanting to understand them. |

Many of the positive consequences presented in Table 6.3 here are based on the guidelines and theories within the field of information visualization. So, in such a way, the information scenario and claims related to it can be seen as a combination of brainstorming of design ideas and best practices from the field of information visualization (and human-computer interaction). Regarding metadata categorization to support searching mechanism for example, it has been confirmed that the search progress can be improved with the use of faceted metadata (indexed metadata) (e.g. Yee et al. 2003). Another example is in the case of the claim regarding combination of textual and graphical displays for presenting information. It has been empirically proven that visual information is generally good for depicting spatial structures, location and detail, whereas words are better for representing procedural information, logical conditions, and abstraction (Ware 2004 p.304). Also, the claim that the table-based visualization is effective was based on previous studies such as (Chi et al. 1998; Rao and Card 1994) (Aditya and Kraak 2007b). As the design evolves, the improvement of the prototype can be managed using this set of information claims. After having clear guidelines what and which kind of information should be presented to support users' activities, subsequently, design guidelines regarding how users interact are the concerns of the interaction design. The interaction scenario (Table 6.4) is employed to guide the concrete development of the user interfaces comprising windows and interfaces of components, menus, navigation tools, and icons.

**Table 6.4**. Interaction possibilities for completing tightly defined tasks: the scenario and some corresponding claims

| **A. The Interaction scenario** | |
|---|---|
| Danny chooses the available values suited to his need through where-what-when components. In addition to drop-down menus, the portal offers the keywords facility as well: He only needs to type in the search term(s) he is interested in. After having the questions completely defined, he needs to click the "Search" button to initiate the search process. The progress bar emerges on the screen, notifying the progress of the query. Almost in no time, the results are then displayed in the table view. He is interested in grouping these results by their currency first, then by their scale and their coordinate systems afterwards. Simply, he just needs to click the labels of the fields on the top of the table. As a result, the items will be sorted into ascending or descending sequence. Every time he changes the item selection by clicking each of them individually, the display of the overview of the data (its abstract and thumbnail) is renewed. The overview window itself is linked to the data providers' web site to process the further order. Each item can be represented into a map. Qualitative and quantitative aspects of the data characteristics are represented as symbols over the map. | |
| **B. Interaction claims** | |
| Formulating questions using where-what-when subcomponents | |
| + | It supports users' presumption and avoids users' confusion |
| - | **But** too many options can be too crowded and complicated |
| Finding matched metadata using a table view or graphic previews | |
| + | It is a simple yet effective means for dealing with a lot of records. |
| - | **But** users need guidance (cues) during their interactions with the table view. |
| - | **But** it should be used with caution since the aggregation of the metadata can give unintended understanding. |
| Visual search with metadata mapping | |
| + | It offers new ways of presenting search results |
| + | The metadata published can be put in a particular context on top of a thematic map |
| - | **But** metadata symbols over the map can introduce confusion to the user. |
| Assessing the data suitability using linked views | |
| + | Expands the perspectives of the data suitability assessment |
| + | It provides supportive context for data discovery |
| - | **But** too many links and windows can distract the users' attention. |
| Controlling the interaction | |
| + | Encourages users to get involved more often with the portal |
| + | Makes users to feel in control with the interfaces |
| + | Permits users to sort and order data |
| - | **But** too many windows and information presented would slow down users' action |

These claims brought up some considerations to proceed. These aspects than were taken into account to improve the prototype built. After some revisions and improvements, the prototype of the design looks as shown in the Figure 4.1 and Figure 4.2 (Chapter 4).

### StorytellerView

In dealing with the loosely defined tasks, the following activity, information, and interaction scenarios have been considered and used to develop the visual methods considering the problem scenarios and claims analyses previously detailed in the section 6.3.1. In this context, the case of Lisa the Transportation Engineer (presented in Chapter 3) is recalled.

**Table 6.5.** The activity scenario and claims for the loosely defined tasks

| | |
|---|---|
| **A. The activity scenario** | |
| The team in which Danny is involved, as has been scheduled, now is busy in preparing a traffic survey. The team gives a mandate to Lisa, an expert in transportation modelling, and Sarinah, an environmental engineer, to combine their expertise in preparing the survey. They agree to design a survey that focuses on gaining the following information. First, the information on the traffic noise, with emphasis on the distribution of sound levels over time-activity patterns of the area, should be collected. Secondly, the results of the fieldwork should provide quantitative data regarding people's perceptions of their noise/sound environments. This data should consider demographic concerns (e.g. ages, and occupation) as well as geographic matters (e.g. high-density populated areas, heavily-trafficked highways).<br>Their goals are to evaluate where and how the survey needs to be done. They consider to access data and information within the GDI that can be reused for their purpose. They know how to use the national atlas which in fact can be used as a GDI portal: they can browse a complete set of national maps, access several institutions' map services, and find the data required. They first open the population map to study the demographic aspects. The road features are also presented in this population map, but it depicts only the main road classes, so then they decide to import a layer of the existing road networks into the population map. They are also interested in importing a physical planning map service offered by the Overijssel province office. Further, they want to access the noise map service recently created by Danny. This map service is available through their office's intranet. Based on this visualization, they identify some potential areas to be surveyed. Now, they have to assess what data are available and which of them are suitable to be reused for this survey. | |
| **B. Activity claims** | |
| Combination of spatial analysis and information access | |
| + | It is a useful strategy that most users are looking forward to for their job |
| + | Shows the usefulness of spatial data sharing mechanism |
| - | **But** users require guidance and it can be too complicated to non GIS experts |
| Combining the metadata presentation over the map(s) visualization | |
| + | Leverages a comprehensive interface to correlate data suitability |
| + | Improves the effectiveness of a research study because it provides information on the datasets that are available or not on a particular topic of interest |
| - | **But** it can provide a wrong impression regarding the real potential or quality of the data |

**Table 6.6.** The information scenario and corresponding claims for completing the loosely defined tasks

| **A. Information scenarios** | |
|---|---|
| Lisa and Sarinah decide to import only recent and planned land use layers into their current map. In relation to the noise map accessible through their intranet, only layers zoning and label of that noise map are loaded and overlaid into the map currently being discussed. Using these maps composition, they discuss the possible areas to be surveyed. Their subsequent inquiries are to know what data are available and how they fit to this fieldwork. Within the dataset storyteller, they can browse the relevant text, images, and statistics graphs concerning the relevant data related to the population map. They then activate the "metadata mapping" icon within the storyteller and get population metadata mapped into the interface. The maps being discussed by Lisa and Sarinah now are very complex; they find it would be easier to limit the graphics and symbols displayed. Hence, they decide to reduce the complexities by unloading some layers from the map. They do this by controlling the layers shown in map and metadata legend in the right side of the interface. Subsequently, they want also to know what data related to road networks are available for this study area. From the help, they found that they could do this by loading metadata items based on their topic or their map. Following the instruction in the help window, now all data pertaining to population and road networks have been displayed. A set of visual variables is used in the metadata symbols to represent quantitative and qualitative information of the metadata. They get a good overview on which data can be reused for the survey. | |
| **B. Information claims** | |
| Combination of web atlas, web mapping service, and information mapping | |
| + | Enables users to benefit from this synthesis |
| - | **But** the map display can be too complicated and difficult to perceive the information presented. |
| Combination of textual and graphical displays in information presentation | |
| + | Visual information is generally remembered better than verbal information |
| + | Images are helpful to support users localize information and to provide an overview while text is good in representing abstraction of the data |
| - | **But** the visual representation can also give misleading information. |
| Depiction of metadata summary over a map | |
| + | Offers possibilities to correlate and associate the two for a particular user's concern |
| + | Users can study the relevance of the data to their goal |
| - | **But** the complicated metadata symbols may be distracting and confusing the user' s attention |
| Familiar displays (e.g. table, map) with linking possibilities | |
| + | Ease users' learning curve |
| + | Allow users to explore more |
| - | **But** too many windows and information presented can prevent users to perceive and understand them |

**Table 6.7.** The interaction scenario and corresponding claims for completing the loosely defined tasks

| **A. Interaction scenarios** | |
|---|---|
| The atlas, functioning as a portal, enables users to browse the maps (either by topic or area). Lisa browses the tree menu within this "Browsing maps" component. She clicks transportation, and finds new folders emerging within the tree menu. Among these folders, she then opens up the road folder. She sees the existing networks road at the first level of the list. Every time Lisa changes the selection, the map description box renews its content accordingly. And as Lisa changes the map selection, not only the map is displayed but also the storytellers' (dataset and atlas story-teller) content is also refreshed. After that, they come to a decision to reload the land use map service and Danny's noise map service using the "Visualise It" button within the dataset storyteller section. After the land use map service and the noise map service are displayed, she then selects a small button with the title "metadata mapping" within the dataset storyteller section. In response, the boxes with different graphical variables representing metadata elements are displayed on top of the map. Using the metadata sub-component in the legend view, Sarinah is asking Lisa to represent only the scale and resolution symbols of the data, because these are their first concern at this moment. The symbols displayed cannot help them to effectively discern the temporal characteristics of the data. For this reason, they decide to use the comparison functionalities offered. The selected data can be compared and displayed according to their interest on specific attributes. They studied these representations for a moment. Among the metadata symbols displayed, they are interested to examine two of them in detail. Lisa then clicks both corresponding boxes; as a result two complete metadata descriptions are opened in two separate windows. Now they get some clarity which data are appropriate for their job. | |
| **B. Interaction claims** | |
| Providing dataset directories and navigation schemes based upon the topics available | |
| + | Provides easier ways to see what is available or not according to the users' preferences |
| - | **But** novice users might need clear guidance to complete steps for comparing the items |
| Focusing the interest on the basis of the concerned area or the topic | |
| + | Provides a sufficient context to start browsing |
| - | **But** topic categorization may introduce overlapping of interest |
| Maps and metadata storytelling | |
| + | Provide more information to broaden users understanding |
| - | **But** when they are too broad, users require more time to complete the tasks |
| Metadata mapping | |
| + | Provides a visual decision-support solution |
| - | **But** is can be frustrating when is too complicated (e.g., metadata with same area extent) |
| - | **But** User might lose attention and interest |

The activity, information, and interaction scenarios and claims related to the development of the StorytellerView presented here were taken into account during the prototype development. The screenshots of the built prototype that are related to the StorytellerView have been presented in Figure 5.3 (Chapter 5).

Some negative considerations mentioned in the claim analysis for interaction designs of the ExplorerView (Table 6.4) and the StorytellerView (Table 6.7) came from a participatory design survey held in the beginning of the prototype development. Four persons provided feedback in this activity. The participatory design survey was done during a workshop organised to restart work on the development of National Atlas of the Netherlands. The persons were asked to provide negative consequences regarding the claims made in Table 6.4 and 6.7 based on their opinions in making sense of the paper-based prototype presented. In the paper work that they received, two graphics depicting the proposed user interfaces of the atlas metaphor to help user search and browse data were presented. The corresponding claims for both searching and browsing visual displays were given. The participants were asked to complete or fill in the "But" sentences (see Appendix Participatory Design Form).

In this way, during the development of the prototype, the scenario-based design was combined with the participatory design. Participatory design is an approach to design with active involvements of the end users in the design process to ensure that the product designed is usable (see for example (Carroll et al. 2000; Kyng 1994)).

The (potential) users are considered to play an important role in determining the functionalities and interfaces of the prototype. The negative considerations that they provided were helpful to manage the trade-offs. In this sense, the outlook on how the users judge the usefulness of the interface can be gained. Additionally, the failure of the system can be avoided by taking into account these considerations appropriately. In this way, urgent needs for specific improvement can be better identified.

From their feedback, it could be assessed that the most frequent concerns addressed by participants are that there was no clear information regarding the where, what, and when subcomponents and their fear that attributes within these three might overlap. They needed graphical cues and instructional assistance for each of subcomponents. Additionally, the clarity of the map display and the storyteller view was another major concerns of the respondents. The outcomes of the activities undertaken in the design space including the participatory design survey were used to guide the prototype development.

**Add-in Collaborative Tools**

As it was mentioned in Section 5.2.3, the motivation for developing the collaborative tools was to demonstrate the ability of the atlas metaphor to exploit the potential use of the GDI to support group work. Based on the activity, information, and interaction scenarios presented in Table 6.5 up to Table 6.7 above, the activity, information, and interaction scenarios were created to envision the possible use of the atlas metaphor to support Lisa and Sarinah tasks to plan a survey related to an environmental study on the traffic development. The scenarios and claims created for geocollaboration are summarised as follows.

**Table 6.8.** The activity scenario and claims for collaboration efforts

| **A. The activity scenario** | |
|---|---|
| Lisa and Sarinah had completed their job in assessing the data that are useful for planning their survey activities. For that purpose (*as also detailed in the previous section*), they explored the atlas content by browsing. The project they carried out was a group work involving another governmental institute, specialised in mapping, as a consortium partner. In this particular institute, the person that is responsible for the project is Ed. It has been planned that they (Ed, Lisa, and Sarinah) will have a collaborative session aiming at selecting locations to determine where should they deploy their people in the field to do a survey. Ed is involved in this activity since he needs to produce a work package for each of the survey teams including the forms, related high-resolution satellite images or topographic maps of the proposed locations. In addition, his local knowledge and past experiences with similar survey are valuable for the group to assess the feasibility of locations.<br>The national atlas that has been used by Lisa and Sarinah provides abilities to a group of people to work together to draw points and areas so users can discuss and exchange ideas toward a decision in addition to their exploration uses, searching or browsing the atlas contents. Ed has been aware that Lisa and Sarinah had prepared some suggestions regarding the data to be used and possible locations. From his perspective, he also has some proposals of survey locations. Using the messenger module that is offered next to the atlas metaphor, they set up a joint conference that enables them to exchange their text messages (and voices, too). Ed, Lisa, and Sarinah log into a specific collaborative session that they have prepared. In this particular session, they share the ideas regarding the location on the map. In fact, the ability of the atlas to share the progress of collaboration is the core functionality that they expect to gain from their join interaction with the atlas metaphor. | |
| **B. Activity claims** | |
| Group awareness and collaboration progress | |
| + | They are useful to provide feedback to each group member to stimulate effective collaboration |
| + | A synchronized view is important to coordinate the discussion and work |
| - | Large volumes and complex shared visualization will require more thinking or processing |
| Combining data access and group decision-making | |
| + | Provide a straightforward impact on the usefulness of the GDI interface to a group of users |
| - | The use of the tools requires assistances. It can cause a complexity of use that will make users dissatisfied with the other tools too. |

**Table 6.9.** The information scenario and corresponding claims for collaboration efforts

| **A. Information scenarios** | |
|---|---|
| In a group work setting, using the atlas, the map and metadata loaded by one of team member is replicated in other screens. Point boards plotting, an annotation tool available in the collaborative tools of the atlas, can be used to identify potential locations. Sarinah and Lisa use the digitizing tools as well to show Ed the areas that they thought are best for conducting the survey. Areas and point boards plotted by Sarinah have different colours with areas and points plotted by Lisa. The colour properties of the areas correspond to the role of the collaborators. In this context, Lisa is a transportation engineer and Sarinah is an environmental engineer. In all areas and points selected, they specify the short title of the features, give a short description for each of them, and when possible provide references or web links to which that particular feature is linked. In their context, the link can refer to a specific term of reference of the project that is available on the web, or it can be a specific issue addressed in the group meeting posted on the web. | |
| **B. Information claims** | |
| The differentiation of visual representations of features made by team members | |
| + | Enables collaborators to identify "who do what where" |
| - | The map display can be too complicated and difficult to perceive the information presented. |
| Synchronization of information displays | |
| + | Makes collaborators participate in the session attentively |
| - | But when the rate of changes is high, the users will have difficulties to follow what others have done |

**Table 6.10.** The interaction scenario and corresponding claims for collaboration tasks

| **A. Interaction scenarios** | |
|---|---|
| The atlas enables collaborators to first individually explore the atlas content before they join a collaborative session. In joining into a collaborative session, Lisa, Sarinah, and Ed need to submit their usernames, passwords, and to select a collaborative session name. Once an individual logs into a collaborative session, his or her avatar is shown active to the other group members. During the collaborative interactions, Lisa and Sarinah point out the proposed locations using the pin boards plotting. In some occasions, they need to draw an area on the map to help Ed understand the reasoning that they made. In return, Ed also needs to express his suggestions by drawing an area on the map and provide a link to a photograph or a location description of the area that he refers to. Every time a collaborator opens up a new thematic layer or cascades a metadata footprint on the map, the similar displays are replicated in the other user's interfaces that joined in the same collaborative session. | |
| **B. Interaction claims** | |
| Pin Boards Plotting and its annotation | |
| + | Provide shared understanding of the specific point of interest |
| + | Description and links to related resources (e.g., images, or group discussion) are useful |
| - | The clarity of the map will decrease as the collaboration involves more participants and more locations to be assessed |
| Drawing an area of interest and its annotation | |
| + | Provide a simple means to express the idea about the location |
| - | The clarity of the map will decrease as the collaboration involves more participants and more locations to be assessed |

The activity, information, and interaction scenarios and claims related to the development of collaborative use of the atlas metaphor presented here were taken into account during the prototype development. The screenshots of the built prototype that are related to the collaborative use of the atlas metaphor have been presented in Figure 5.9 and 5.10 (Chapter 5).

### 6.3.3. Evaluation space

This section will briefly review the implementation of use assessments or tests targeted to the developed ExplorerView (related to the searching mode), StorytellerView (related to the browsing mode), and the collaborative use of the atlas metaphor prototype, Aim4GDI. During each of these tests, the test participants were asked to interact with the interface according to a specified scenario of use.

The use assessment on the searching mode was done twice in this study. Chapter 4 has presented the results of the first test on the searching mode. The second test on the searching mode was done in parallel with the use test on the browsing mode (referred to as browsing test or StorytellerView test and was discussed in Chapter 5). In addition, a use test on the use of GeoNetwork, an open source geoportal, was also done in parallel to these two tests. Thus far, the second test on the searching mode of the Aim4GDI interface (referred to as searching test or ExplorerView test) and the test on the GeoNetwork interface have not been discussed, and it will be described here:

In regards to the second test on the ExplorerView and the test on the GeoNetwork and the StorytellerView, nineteen graduate students completed these tests in one test session. In Section 5.4.1.1 (Chapter 5), when discussing the test participants on the browsing mode of the Aim4GDI with StorytellerView, the profiles of this group of graduate students have already been described. In that section, this group was identified as Group B. That test session was divided into three test activities, which were related to the use of ExplorerView, StorytellerView, and GeoNetwork. The corresponding evaluation scenarios for the three test activities were given to nineteen test participants in a random order. This means some of them tested the ExplorerView first, then moved to the GeoNetwork test, and then the StorytellerView in the end. Some others took the GeoNetwork test first, and then ExplorerView and StorytellerView tests afterwards. The rest of the test participants started the test with StorytellerView, and after that continued with the ExplorerView and GeoNetwork related tests (illustrated in Figure 6.3). The strategy to vary the sequence of the tests was intended to randomize test participants' feedback to eliminate any potential selection bias.


**Figure 6.3.** The sequence of the tests on the ExplorerView (using Scenario A), StorytellerView (using Scenario C), and GeoNetwork (Scenario B) was randomized among test participants (Scenario A, B, C are presented in Appendix A, Appendix B, and Appendix C correspondingly). This test session corresponds to Searching test II and Browsing test I in Figure 6.5.

The use assessment or more precisely the usability inspection of the collaboration features of the Aim4GDI was done once. The corresponding results have also been discussed in Chapter 5. While the browsing mode was tested in parallel to the searching mode of the atlas metaphor (referred to as searching test or ExplorerView test) and the GeoNetwork, the collaborative use tests were done in two separate collaborative sessions. Each collaborative session involved two different individuals and one technical assistant (was performed by the author). Figure 6.4 illustrates the collaboration activities during the usability inspection of collaborative features of Aim4GDI.

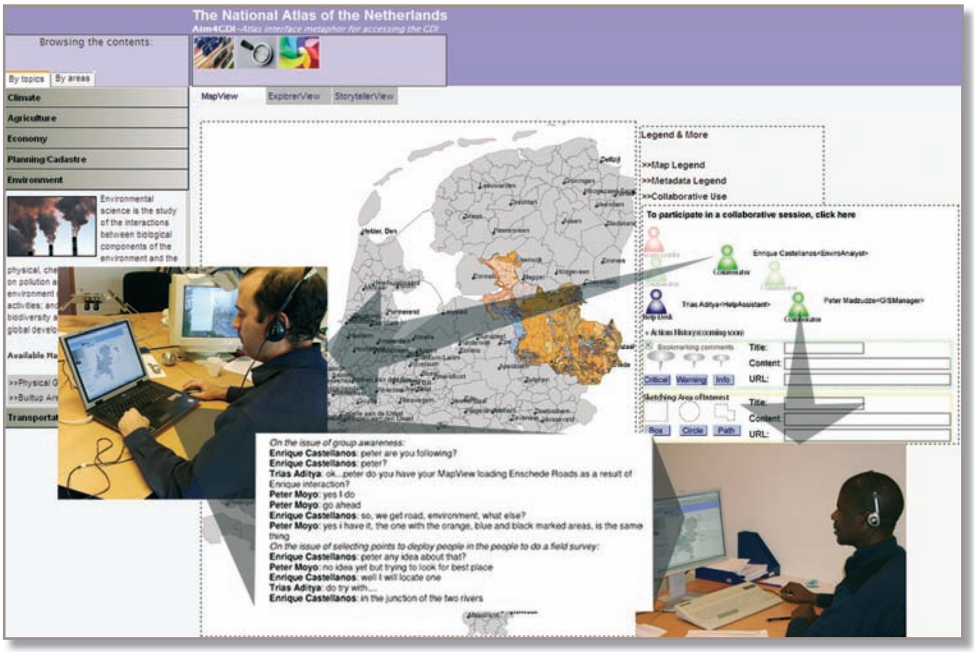



**Figure 6.4.** The activity of usability inspection of the collaborative features of the Aim4GDI.

For analysis purposes, the test participants were asked to provide feedback to questions related to their experiences during the tests on ExplorerView, StorytellerView, and Collaborative features of Aim4GDI as well as on GeoNetwork in forms of “strongly agree”, “agree”, “neutral”, “disagree”, and “strongly disagree” responses. Their responses were measured on the Likert response scale (Likert 1932), ranging from 1 for “strongly disagree” to 5 for “strongly agree”. To assess the significance of their feedback, statistical test were applied to the responses or results gathered.

In this study, test results were analysed with nonparametric statistical methods. Nonparametric methods require no or very minimal assumptions about the normality of the underlying data distributions. In this sense, nonparametric methods can be useful to analyse unexpected and outlying observations that might be problematic with a parametric method (Whitley and Ball 2002). These methods are also very useful for measures that are inherently ordinal like a rating scale (Rosson and Carroll 2001, p.365).

All the tests done in this study do not assume the normality of the data distribution and do not involve large samples (i.e., test participants). In fact, the Kolmogorov-Smirnov normality test was also randomly applied to test results related to searching and browsing mode of the prototype. There was strong evidence to reject the null hypothesis that the samples were normally distributed. Or, in other words the results were not normally distributed. Hence, the use of nonparametric statistic test in this study can be more justified.

Nonparametric methods that were used to analyse the test results in the evaluation space include as follows:

1. *Wilcoxon signed rank test*
   The Wilcoxon signed rank test is a nonparametric alternative to the t-test for two correlated or paired samples. The test is aimed to test the null-hypothesis that the median of a distribution is equal to some value. It can be used in place of a one-sample t-test and in place of a paired t-test. In this study, this test was applied for example to assess whether the designed table view provides effective means to help test participants identify search results.
2. *Mann-Whitney test*
   Mann-Whitney test or Wilcoxon rank sum test is a nonparametric alternative to the unpaired t-test. The test is applied when a comparison is made between two independent samples. In this study, this test was applied for example to compare the use of the searching mode and browsing mode between Group A (employees of the Province of Overijssel with GIS experiences) and Group B (graduate students).
3. *Friedman Test*
   This method compares several related samples and can be used as a nonparametric alternative to the two-way analysis of variance (ANOVA). The test was used in this study, for instance, to assess which interface out of table view, thumbnail view, Paralel Coordinate Plot (PCP), and footprints that was perceived better than at least one of the other three by test participants to identify search results.

The following table summarizes the use of the statistical tests mentioned above to analyse the test results. In accordance to the summary of tests conducted in the evaluation space, Figure 6.5 illustrates the users' involvement and the evaluation steps completed in the evaluation space including their corresponding statistical tests.

**Table 6.11**. A summary of the use of statistical tests in the evaluation space

| Statistical Test | Evaluation Scenario | Group | Statistical Test | Description | Discussed in |
|---|---|---|---|---|---|
| A1 | A | GIMA | Friedman's Test | Two-way analysis of variances for indicating and comparing results | Chapter 4 |
| A2 | A | GIMA | Wilcoxon paired sign rank | Analysis whether the median of responses are equal to 3 | Chapter 4 |
| A3 | A | GIMA: A vs. B | Mann Whitney U | Analysis whether Group A and Group B responses have the same median in case of searching | Chapter 4 |
| A4 | A | ITC & OV | Friedman's Test | Two-way analysis of variances for indicating and comparing results | Chapter 6 |
| A5 | A | ITC & OV | Wilcoxon paired sign rank | Analysis whether the median of responses are equal to 3 | Chapter 6 |
| A6 | A | OV vs. ITC | Mann Whitney U | Analysis whether Group A and Group B responses have the same median in case of searching | Chapter 6 |
| A7 | A | GIMA vs. ITC | Mann Whitney U | Analysis whether Group GIMA & Group ITC + Overijssel responses have the same median in the case of searching (checking the consistency) | Chapter 6 |
| A8 | A & B | ITC | Wilcoxon paired sign rank | Analysis to compare the use of GeoNetwork and Aim4GDI to indicate and compare | Chapter 6 |
| C1 | C | ITC & OV | Wilcoxon paired sign rank | Analysis whether the median of responses are equal to 3 | Chapter 5 |
| C2 | C | OV vs. ITC | Mann Whitney U | Analysis whether Group A and Group B responses have the same median in case of browsing | Chapter 5 |
| D1 | C & D | ITC & OV – Collaborative Test Person (CTP) | Mann Whitney U | Analysis whether samples of Individual Use and Collaborative Use have the same median in the case of browsing (checking the consistency) | Chapter 5 |
| D2 | D | CTP | Wilcoxon paired sign rank | Analysis whether the median of responses are equal to 3 | Chapter 5 |

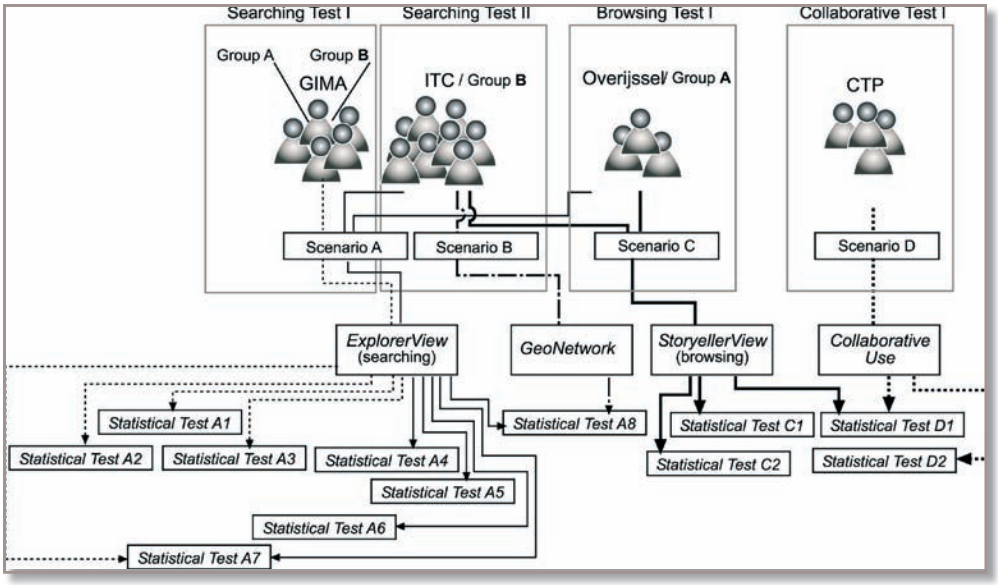



**Figure 6.5.** Use tests and the users' involvement in the evaluation space in this study. Searching Test I was discussed in Chapter 4. The Browsing test and Collaborative test were discussed in Chapter 5. Searching test II is presented in Section 6.4. The focus group discussions were done after Searching test I and Collaborative Test.

In addition to gaining quantitative data regarding the use of the prototype, focus group discussions were also done after the first search test and after collaborative use test. The purpose of the focus group discussions was to provide opportunities to test persons to discuss design issues that were not covered during the use test. Focus groups can be very useful to be used in the evaluation space because they are low-cost, provide quick results, and can easily scaled to gather more data (Preece et al. 2002, p.396) and to discuss crucial issues regarding the use of the tested interface. The results of the focus group discussions have been discussed in Chapter 4 (related to the first search test) and in Chapter 5 (related to collaborative use test).

The following will concentrate on the results of the evaluation space and the overall lessons learned that were gained from the implementation of scenario-based development during this study. As indicated in Table 6.11 and Figure 6.5 above, some of test results have been presented and discussed in Chapter 4 and Chapter 5.

## 6.4. Results & lessons learned

Some of the evaluation activities have been discussed in previous chapters. The results of the first test have been discussed in Chapter 4 (Section 4.4). The discussions on the test on the browsing mode and collaborative use have been presented in Chapter 5 (Section 5.4).

In regards to the test results related to the browsing test and collaboration test, it can be summarised that the developed interfaces gain the expected responses. The exploration and synthesis activities required by test persons to facilitate their needs to plan survey activities can be facilitated by the visual methods presented in StorytellerView. The navigation and interaction schemes developed (in accordance to activity, information, and interaction scenarios of browsing presented earlier) provided a helpful browsing experience to test participants. In the case of collaboration using the Aim4GDI, it has been demonstrated that some of envisioned features (as stated in the collaborative use scenarios) were acceptable and considered useful to advance the group work.

The following will discuss some of evaluation activities that have not been presented thus far. This includes the comparison between the use of Aim4GDI and the GeoNetwork, and the comparison between the first test results and the second test results on the searching mode of the Aim4GDI. Afterwards, some issues and lessons related to the use of scenarios to develop the ExplorerView, StorytellerView, and collaborative features of the Aim4GDI will be discussed

### 6.4.1. Searching through Aim4GDI (ExplorerView)

While Chapter 4 has discussed the results of the first search test activity (indicated as *Statistical Test A1, A2,* and *A3*), the present section will deal with the results of tests indicated as *Statistical Test A4* up to *Statistical Test A7* in Table 6.11 above. The corresponding results of these tests are presented in Table 6.12 up to Table 6.15.

**Table 6.12.** Two-way analysis of variances for identifying and comparing results:

| **To Indicate** | | | | |
|---|---|---|---|---|
| | *Table* | *Footprint* | *PCP* | *Interpretation* |
| The thumbnail view | 0.676 | 0.010* | 0.000* | Thumbnail is better used than footprint and PCP (Parallel Coordinate Plot) to indicate the data to be selected |
| The table view | - | 0.031* | 0.000* | Table is better used than footprint and PCP to indicate the data to be selected |
| Footprints | - | - | 0.107 | - |
| **To Compare** | | | | |
| | *Table* | *PCP* | | *Interpretation* |
| The thumbnail view | 0.877 | 0.004* | - | Thumbnail is better used than PCP to compare search results |
| The table view | - | 0.007* | - | Table is better used than PCP to compare search results |

**Table 6.13.** The effectiveness of the searching mode: an investigation whether the median of eleven design issues is equal to “no effect” or not useful to help them complete the task (with 0.05 level for a non-directional test)

| Question | Use Issues | Ho | M | P-value | Conclusion | Design Implementation |
|---|---|---|---|---|---|---|
| Q1 | Indication by the table view | Ho: M = 3 | 4 | 0.000 | Reject Ho | Acceptable |
| Q2 | Sorting by the table view | Ho: M = 3 | 4 | 0.004 | Reject Ho | Acceptable |
| Q3 | Thematic relevance | Ho: M = 3 | 3 | 0.781 | Accept Ho | No value |
| Q4 | Geographic relevance | Ho: M = 3 | 3 | 0.172 | Accept Ho | Not optimal |
| Q5 | Indication by the thumbnail view | Ho: M = 3 | 4 | 0.000 | Reject Ho | Acceptable |
| Q6 | Indication by PCP | Ho: M = 3 | 3 | 0.807 | Accept Ho | No value |
| Q7 | Comparison by the table view | Ho: M = 3 | 4 | 0.000 | Reject Ho | Acceptable |
| Q8 | Comparison by the thumbnail view | Ho: M = 3 | 4 | 0.000 | Reject Ho | Acceptable |
| Q9 | Comparison by PCP | Ho: M = 3 | 3 | 0.817 | Accept Ho | No value |
| Q10 | Indication by metadata footprints | Ho: M = 3 | 3.5 | 0.048 | Reject Ho | Acceptable |
| Q11 | Metadata legend | Ho: M = 3 | 4 | 0.016 | Reject Ho | Acceptable |

Ho = Null Hypothesis, M = Median of the responses

**Table 6.14.** The comparison of the responses between Group A (Employees in Overijssel Provinces) and Group B (ITC’s graduate students) in the case of searching: The Mann Whitney test is applied on the test results to check whether the median of eleven design issues between Group A and Group is the same (with 0.05 level for a non-directional test)

| Question | Use Issues | Ho | MA | MB | P-value | Conclusion | Design Implementation |
|---|---|---|---|---|---|---|---|
| Q1 | Indication by the table view | Ho: MA = MB | 4 | 4 | 0.857 | Accept Ho | Acceptable |
| Q2 | Sorting by the table view | Ho: MA = MB | 5 | 4 | 0.014 | Reject Ho | Acceptable |
| Q3 | Semantic relevance | Ho: MA = MB | 3 | 3 | 0.634 | Accept Ho | No value |
| Q4 | Geographic relevance | Ho: MA = MB | 3 | 3 | 0.479 | Accept Ho | No value |
| Q5 | Indication by the thumbnail view | Ho: MA = MB | 5 | 4 | 0.035 | Reject Ho | Acceptable |
| Q6 | Indication by PCP | Ho: MA = MB | 3 | 3 | 0.929 | Accept Ho | No value |
| Q7 | Comparison by the table view | Ho: MA = MB | 5 | 4 | 0.125 | Accept Ho | Acceptable |
| Q8 | Comparison by the thumbnail view | Ho: MA = MB | 5 | 4 | 0.047 | Reject Ho | Acceptable |
| Q9 | Comparison by PCP | Ho: MA = MB | 2 | 3 | 0.035 | Reject Ho | No value |
| Q10 | Indication by metadata footprints | Ho: MA = MB | 4 | 3 | 0.191 | Accept Ho | Acceptable for A |
| Q11 | Metadata legend | Ho: MA = MB | 5 | 4 | 0.014 | Reject Ho | Acceptable |

Ho = Null Hypothesis, MA = Median of the responses from Group A, MB = Median of the responses from Group B

**Table 6.15.** The comparison of the responses between the first and second search test: The Mann Whitney test is applied to the test results to check whether the median of eleven design issues between test I and test II is the same (with 0.05 level for a non-directional test)

| Use Issues | Ho | MI | MII | P-value | Conclusion | Interpretation |
|---|---|---|---|---|---|---|
| Indication by the table view | Ho: MI = MII | 4 | 4 | 0.772 | Accept Ho | Consistently acceptable |
| Indication by the thumbnail view | Ho: MI = MII | 4 | 4 | 0.908 | Accept Ho | Consistently acceptable |
| Indication by graphics | Ho: MI = MII | 3 | 3 | 0.940 | Accept Ho | Consistently no value |
| Indication by metadata footprints | Ho: MI = MII | 4 | 3.5 | 0.200 | Accept Ho | Consistently acceptable |
| Comparison by the table view | Ho: MI = MII | 4 | 4 | 0.138 | Accept Ho | Consistently acceptable |
| Comparison by the thumbnail view | Ho: MI = MII | 4 | 4 | 0.315 | Accept Ho | Consistently acceptable |
| Comparison by graphics | Ho: MI = MII | 2 | 3 | 0.002 | Reject Ho | Consistently no value, but the PCP was regarded better |

Ho = Null Hypothesis, MI = Median of the responses from search test I, MII = Median of the responses from search test II

From these details of comparative assessments, the following summary can be made. From Table 6.13, it is apparent that the developed thumbnail view and table view were more helpful to users than the use of graphics (either as bull's eye view as explained in Chapter 4 or Parallel Coordinate Plot (PCP) view that was intended as a replacement to the bull's eye view). From the test results, it is clear that information on the table regarding thematic relevance and geographic relevance were not so helpful. While the information on the thematic relevance was proven to be "no value", the information on the geographic relevance was also not so useful. This issue indicates a need to improve the visualization of the numbers (with more intuitive symbols, for instance) and to provided clearer definition to the terminologies used.

On the issue of target users (table 6.14), it can be seen that there were no extreme differences in the responses between group A and Group B. As in the case in the use of metadata footprints in the browsing, the use of metadata footprints to support searching was regarded to be more useful by Group A than by Group B.

The other aspect that was apparent is that the use of PCP view to indicate and compare search results was not considered so useful to test persons (referred to as "conisistently no value" in Table 6.15). Nevertheless, the use of PCP view to search data was perceived better in comparison to the use of bull's-eye view (referred to as indication Table 6.15). It is interesting to note here that the PCP was perceived to be useful to compare the items to support browsing interactions (Table 5.3 in Chapter 5). Hence, in thinking of the usefulness of the PCP view to support searching and browsing, it can be seen that PCP view was regarded more useful to support browsing than searching interactions. In this respect, further investigation is required to really assess the usefulness of PCP to support search activities. From Table 6.15, it can be seen that the observed responses of test participants in both two tests to the issue of indication and comparison with visual methods developed show no differences. Hence, the visual methods developed including the table view, thumbnail view, and metadata footprints are useful to help users indicate and compare metadata items.

### 6.4.2. Comparing the use of Aim4GDI and GeoNetwork for searching

Since the intended use of the Aim4GDI is to provide an alternative interface to GDI users to look for data, hence this study was interested to investigate whether the developed interfaces are really feasible to be used as geoportals. In this sense, the interface that is considered comparable to the geoportal interface is the ExplorerView or the searching mode of the atlas metaphor.

In this study, GeoNetwork (GeoNetwork 2006) was chosen as the comparative interface. GeoNetwork is an open source catalogue system for geospatial metadata. GeoNetwork was chosen since the search interface components for defining search terms and assessing search results can be seen as a typical interface for today's geoportals (Figure 6.6 and 6.7 below). The analytical observation on this issue has been done in in Section 2.2.1. GDI administrators can make use of GeoNetwork to help them manage geospatial metadata. The metadata management that can be facilitated by a GeoNetwork system includes abilities to index, store, and harvest geospatial metadata as well as to handle the registration of OGC Web Map Services. Once data are published through a GeoNetwork catalogue system, the GDI users can search for data, assessing the full view of metadata descriptions, and viewing the data in the case that the data published is an OGC WMS compliant web maps.

For comparison purposes, the same metadata set used in the Aim4GDI were stored locally into the GeoNetwork system (GeoNetwork open source desktop 2.0.3 was used for this study). The scenario of use for testing the GeoNetwork (the evaluation scenario) was similar to the evaluation scenario for testing the ExplorerView. The differences were only in the detailed steps that the test participants had to follow (i.e., accessing the GeoNetwork web portal available in the intranet) (see Scenario B in Appendix B).


**Figure 6.6.** User interface components of the GeoNetwork to define search terms

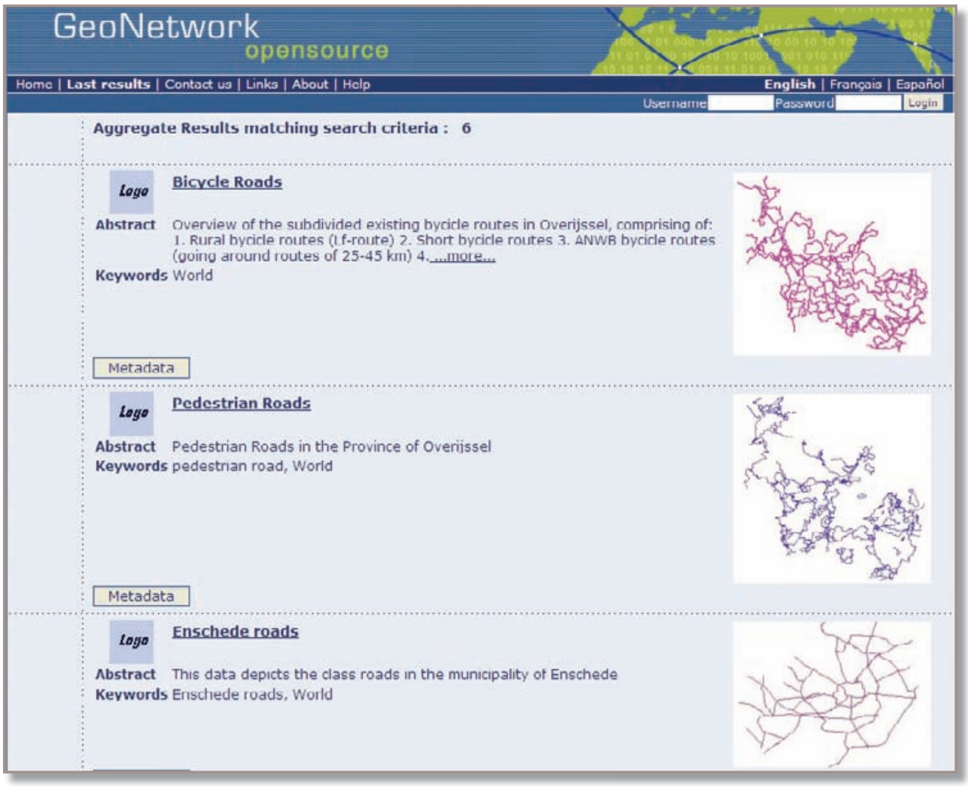



**Figure 6.7.** User interface components of the GeoNetwork to review the search results. Search results are presented as a list of title, abstract, and the corresponding thumbnail of data. Link 'Metadata' gives an opportunity to users to see the full definition of metadata.

The *Statistical Test A8* was applied to the responses of test participants in making use of Aim4GDI and GeoNetwork to indicate and compare the search results. The results of the *Statistical Test A8* are shown in Table 6.16 below. From the test results, it can be concluded that the use of Aim4GDI to indicate and compare the search results was more useful than the use of GeoNetwork. More specifically, the thumbnail view gave better assistance to test persons to indicate and to identify search results. The table view gave better assistances to test persons to compare the results. Meanwhile, to indicate the required data, the table view also gave better assistances than GeoNetwork, but the difference is not significant at alpha = 95%.

**Table 6.16.** The comparison of the responses between the use of Aim4GDI and GeoNetwork to search for data: The Wilcoxon sign rank test is applied on the test results to check whether the median of responses regarding the abilities of Aim4GDI and GeoNetwork to indicate and to compare are the same (with 0.05 level for a directional test)

| Use Issues | Ho | Number of participants | M-A | M-GN | P-value | Conclusion | Interpretation |
|---|---|---|---|---|---|---|---|
| Indication by table vs. GeoNetwork | Ho: M-A = M-GN | 19 | 4 (76) | 4 (66) | 0.063 | Accept Ho | Suggests a difference, not proven at alpha = 95% |
| Indication by thumbnail vs. GeoNetwork | Ho: M-A = M-GN | 18 | 4 (73) | 4 (62) | 0.016 | Reject Ho | Slightly better |
| Comparison by table vs. Geontwork | Ho: M-A = M-GN | 17 | 4 (71) | 4 (62) | 0.047 | Reject Ho | Slightly better |
| Comparison by thumbnail vs. GeoNetwork | Ho: M-A = M-GN | 17 | 4 (70) | 4 (62) | 0.043 | Reject Ho | Slightly better |

Ho = Null Hypothesis, M-A = Median of the responses related to the Aim4GDI's use (with its associated sum of scores), M-GN = Median of the responses related to the GeoNetwork's use (with its associated sum of scores).

The outcomes of the test clearly showed that the Aim4GDI can be used in the place of a geoportal to search for a specific data. In this regard, the processes of data selection (i.e., indicating the required data and comparing search results) can be better performed through the Aim4GDI. Since the GeoNetwork search interfaces have no capabilities to allow users to sort search results and cascade metadata footprints, sorting and mapping capabilities offered through the AimGDI search interfaces can be considered to provide more benefits to users to assess the search results.

It is worth noting that in the context of looking for Overijssel datasets, a comparison test between the Aim4GDI and a specialised data catalogue for the province of Overijssel: *Meta-informatiesystem* (MIS) was not done. MIS is an official metadata catalogue for geospatial data that is accessible via the intranet of the office of the Province of Overijssel and used by employees working in the office (Province of Overijssel 2007).

A comparison test between the use of the Aim4GDI and the MIS may provide a better insight whether the Aim4GDI is also really useful to specialised users or not. However, as the objective of this study is to assess the feasibility of the national atlas metaphor as an alternative to national or regional geoportals, hence, such a comparison test was not considered a priority in this study. Nevertheless, the interfaces of the MIS are presented here to provide an illustration on how a typical Dutch governmental organization provide a data catalogue to enable its employees to look for geospatial data in the house and on how the atlas metaphor (Aim4GDI) can be used instead of a such data catalogue (see Figure 6.8 below in comparison to Figure 4.1, Figure 4.2, and Figure 4.3 presented in Chapter 4).

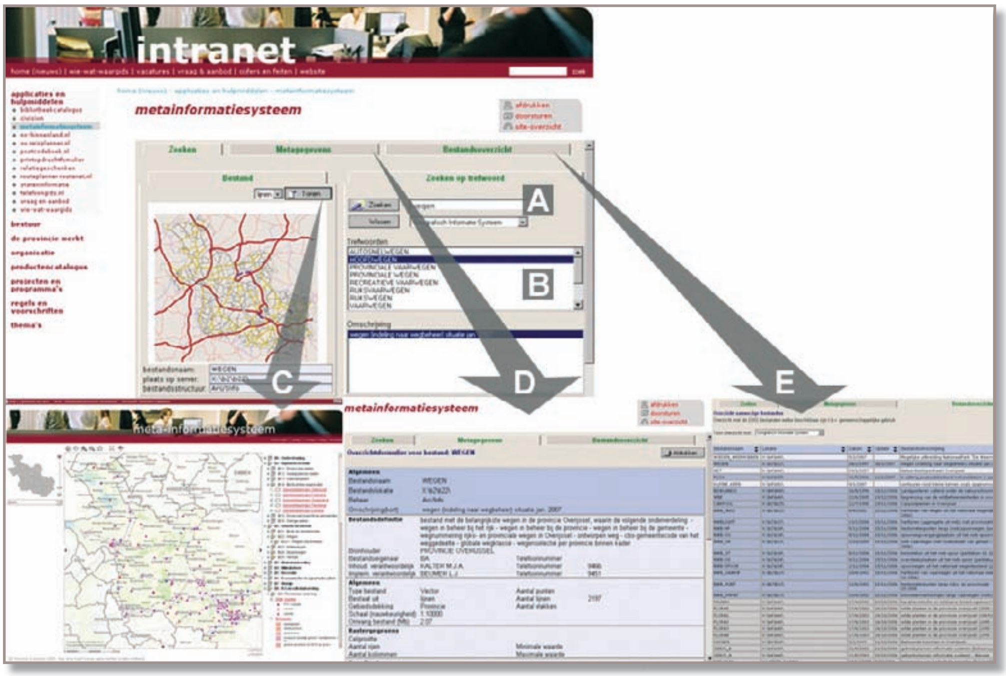



**Figure 6.8.** A Meta-Information System to search for Overijssel datasets. Search terms can be entered through "Zoeken" input textbox (**A**). A list of data titles with matching keywords is presented in the listbox (**B**). The corresponding thumbnail of selected data in B is shown on the left of the MIS's screen. The data can be visualized through a web map interface (presented as a Flash movie format) (**C**). The detail description of the data is given through the tab "Metagegevens" (**D**). The overall list is offered through the tab "Bestandoverzicht" (**E**).

## 6.4.3. The use of claims analysis

In this study, the claims analysis plays a significant role to motivate thinking on the best possible solution and to capture possible drawbacks of the proposed solution (i.e., design tradeoffs). For example, when dealing with metadata mapping, the downsides listed in the activity, information, and interaction scenarios provide a specific direction on the design of symbols to represent metadata elements. Which symbols and colour hues should be used to represent the topic of interest of the data? What tools to be offered to enable users control the clarity of the combination of thematic layers and metadata footprints? Another example was the design of StoryTellerView. In relation to the claim for the need of familiar displays and possibilities to link to the associated resources, the tradeoff to be made was an interface that does not offer many new windows but does ease the users' learning curve to explore the contents. In this regard, the focus was to look at the organization of the atlas contents. How the structure of the atlas can be exploited to facilitate users navigating easily a wide range of associated content and links?

Another advantage of the use of claims analysis is that when it is used in combination with a use test, it can provide a solid reasoning to develop and refine the prototype. In this regard, the claim analysis provided many conceptual insights where the use assessments provided empirical findings concerning a specific design issue. As an example, through information and interaction scenarios, the clarity of metadata mapping has been considered significant. From the first searching test, it could be learnt that when the metadata legend has not been developed properly, users would be unable to control the display of metadata footprints. Such a situation caused confusion for many test persons. In the second searching test meanwhile, when the metadata legend had been developed as was envisioned, the test persons regarded the metadata legend interface to be very useful to support their search context (listed in Table 6.13 and Table 6.14 as Q11).

As addressed by Sutcliffe (2000) the advantages in documenting the claims include possibilities to reuse claims for subsequent interface developments. Some of the design interaction knowledge that had been produced during a prototype development can be reapplied to other design problems in other projects (Sutcliffe and Carroll 1999). As exemplified in the Sutcliffe's work, the claims were stored and indexed for reuse purposes. In this respect, one of the approaches to make claims and their associations more visible and reusable is through the development of a claims map. A claims map is a visual representation of claims in a scenario-based development project that shows the relationships among the claims and the present status of the claims (Wahid and McCrickard 2006). The organization of the claims has not been the focus of this study. At the moment, the claims and the corresponding upsides and downsides have been represented as the concept map (Figure 6.9). However, there is no linking functionality that enables viewers (e.g., other designers) to examine the history of design changes to the specific claim selected, for instance. In this respect, the idea to develop a claims map and its link to the detailed claims analysis deserves a priority in order to better manage changes associated with the interface design during the development of a national atlas metaphor.

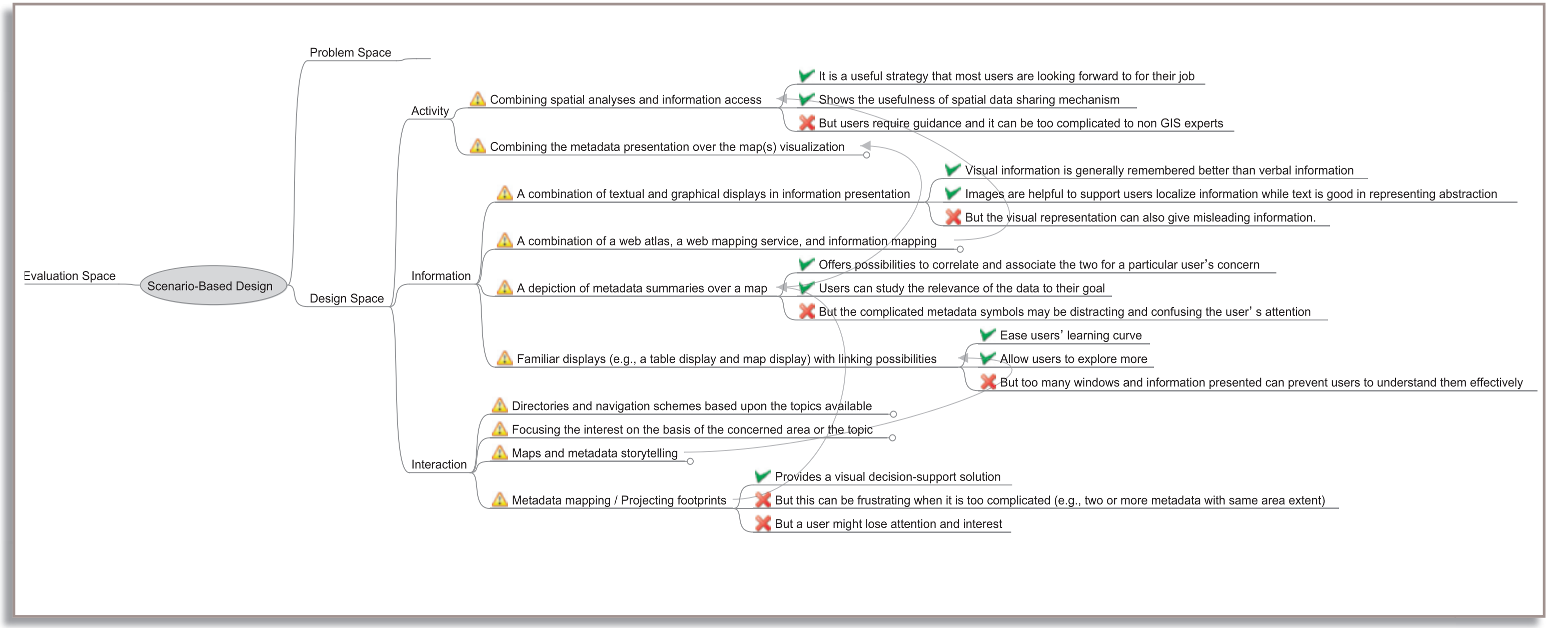



**Figure 6.9.** The claims used in the study are represented as a concept map. A warning symbol is given to each of claims in the design space. The “OK” and “erase” symbols correspond to the upside and downside of the claim. The link symbol signifies that the two claims exist in two different design stages are correlated.

It is also worth noting that many anticipated downsides indeed caused users' dissatisfaction (e.g., metadata footprints combined with thematic layers and WFS). Although users judge this ability to be useful, it seems that the degree of satisfaction of the users on the clarity of the mapping capabilities can be improved. In this regard, the results of use assessments and the claims analysis can be combined to provide a solid basis to find a design solution in the next cycle of the interface development (the cycle of improvement can be started from the design space onwards as shown in the Figure 6.2 above).

## 6.5. Discussion

One of the research objectives of this study (as specified in Chapter 1) is to determine the feasibility of the national atlas concept as a metaphor in the access to the GDI. In Chapter 2, the feasibility was first argued through an analytical observation of the national atlas concept. In looking at the potential use of the national atlas as a metaphor, specific usability problems were defined and the envisioned functionalities to handle the usability problems were also specified. Through the design space, an evolutionary prototype was developed. In this regard, from Chapter 3 onwards, the feasibility of the national atlas as a metaphor was probed and tested.

From the development and evaluation activities, it can be confirmed that conceptually and empirically the national atlas can be used to assist users explore the geospatial resources in the national GDI. In this respect, users can make use of the browsing mode of the national atlas to help them complete a loosely defined discovery task. To complete a tightly defined discovery task, the searching mode of the atlas metaphor was useful to help them indicate, compare, and associate the search results. The extension of the atlas metaphor to facilitate group work has been demonstrated and considered promising. Although the focus of the use of the atlas metaphor was to support exploration of geospatial resources in the GDI, the atlas metaphor was seen useful to help users to synthesize and to some extent analyse the geospatial information in the country.

When analytical functions (intended to support the collaborative use as well as the individual use) of the atlas metaphor are to be enhanced, then, the new problem, activity, information, interaction, and evaluation scenarios need to be developed. For this purpose, a good understanding on the application domain can be helpful to capture the required activities, information, and interactions to be supported when users are making use of analytical functions of the atlas. As an example, this study frames typical activities and interactions required by users for producing a noise map and planning a traffic survey. In actual implementation of such activities, many survey methods like random selection or mesh method and GIS processing like split and buffer operations can be required to complete the job (as indicated by some studies related to the implementation of noise mapping and traffic survey activities (Klæboe et al. 2006; Piccolo et al. 2005; Sommerhoff et al. 2004)).

In relation to the applicability of the atlas metaphor developed in this study for real use, the concept, use assessments, and claims analysis developed during the study can be used as a first step to develop an effective national atlas metaphor. The organization of scenarios of use throughout of the development of the atlas metaphor was useful to deal with the problems and opportunities of the use of the national atlas.

The most prominent feature of the use of scenarios is that they can be used effectively to support implementation of usability engineering. Thus the analysis of users' requirements as well as usability evaluation can be accomplished using scenarios as the medium. This has been seen as a suitable approach to combine developers or designers' ideas with user's mental models. For this reason, scenario-based design has been used pervasively in the website development and the software engineering in the field of HCI (Bødker 2000; Carroll and Rosson 2002). However, the scenarios approach also has drawbacks. Since scenarios are usually concrete stories that concentrate on realistic and specific activities, they can "obscure broader issues concerned with the wider organizational view" (Preece et al. 2002, p. 230). It can be ambiguous especially in the phase of analyzing needs and requirements. One possible solution for overcoming this is to apply a method called as "essential use cases". It combines the user intentions (abstractions of scenarios) and the system responsibility (Preece et al. 2002). Despite this disadvantage, nevertheless, the scenario-based design has been considered to play an important role in the domain of interaction design (Hertzum 2003).

As an evolving concept, the GDI can be seen as the field of study that seeks to implement design in practice and to consider people's intention, motivation, and willingness. The balance of these two must be managed. Scenario-based development can play an important role for this, as exemplified in this chapter for designing the atlas in support of the access to GDI. In fact use of scenarios has been prominent in delivering the understanding about the GDI (see e.g. (McKee 2000; Wegener and Masser 1996)). In addition, the scenario-based design has also been pervasive to fields of distributed cognition and Computer Supported Cooperative Work (CSCW) (Bødker and Christiansen 1997), two types of studies that share a similar vision with GDI on the use of IT to promote usefulness of integration and sharing. As presented in this chapter, the collaboration features were developed by extending the scenarios related to StorytellerView.

## 6.6. Concluding remarks

This chapter attempts to contribute to the design and evaluation of geoportals for the GDI in two ways. It considers the development of the geoportal as activity combining the exploration of design ideas and the investigation of user experience.

In this regard, in reasoning the feasibility of the national atlas as a metaphor, the study is not only specifying the mapping of the source domain into the target domain but also envisioning the metaphor in the contextual uses through problem, activity, information, interaction, and evaluation scenarios. The claims associated with the design tradeoffs in the activity, information, and interaction scenarios were useful to guide the design implementations. In this way, the abstract concept of the national atlas metaphor could be specified more detail and developed to be real. In addition, the impact on the use of the metaphor could be quantitatively and qualitatively assessed. In the field of geovisualization, for developing a map-based user interface, when the use is the aspect to be emphasized (see Section 2.3 in Chapter 2), arguably the deployment of scenarios and claims as what has been done in this study can be very useful to organize the design tradeoffs and to structure the design ideas.

The role of geoportals can be redefined beyond their present term. Geoportals must be seen as a potential interface to enhance the use of and acceptance of Geospatial Data Infrastructures. On the GDI initiative, the national atlas can be developed as a decision-support visual display that enables users to explore, synthesise, and analyse geospatial resources of a country. During the scenario-based design, critical insights and challenges can be better understood. From the prototype developed and from the feedback gained, it is clear that the combination of scenario-based design coupled with usability engineering, constitutes a prospective approach to advance the success of geoportals. In this regard, the atlas is proven to be a feasible metaphor in the access to the GDI. One of the empirical findings that support this argument is that the searching mode of the atlas metaphor was seen more useful by test participants than that of GeoNetwork, a typical current geoportal.

# Conclusions & Recommendations

This study deals with the development of a web national atlas for improved usability and accessibility of a Geospatial Data Infrastructure. In developing the web national atlas as a metaphor in the access to the GDI, this study dealt with the processes of interface design and evaluation. As discussed in Chapter 6, these processes took place throughout the problem space, design space, and evaluation space of the metaphor development.

With regard to research activities associated with the problem space, Chapter 2 delved into the conceptual level of a metaphor development, where the usability issues of the current practices of geoportals were examined and the national atlas was proposed as a metaphor. Chapter 2 also discussed the operational level of the metaphor development in great detail, thus transforming the problem into a potential working solution. Chapter 3 stepped further into the design space, by presenting the application framework of the prototype of a national atlas metaphor, Aim4GDI.

Chapter 4 and Chapter 5 discussed the underlying principles, use, and evaluation of the searching and browsing modes of the atlas metaphor. Searching and browsing were considered important in this study, as they are two main human activities when interacting with a GDI interface. Chapter 6 reviewed all of the methods that were applied when developing the metaphor. Thus, Chapter 4, 5, and 6 in effect tried to confirm the usefulness of the metaphor developed and to analyse how and why the visual methods or displays developed work (or do not work) as expected.

This chapter will present the main findings that resulted throughout the problem, design, evaluation space or phase in this study. In so doing, this will relate the results of this study to the research objectives stated in Chapter 1. Finally, the prospects and any unresolved issues will be discussed.

## 7.1. Conclusions

Surveying and mapping practices have been considered critical in order to sustain the existence of mankind and to advance human abilities to resolve problematic and challenging issues associated with land, water, and natural resources management as well as with the development of society. One of the basic requirements needed to ensure the efficiency and effectiveness of the use of geospatial information products, resources, and services is the existence of an infrastructure of access. The infrastructure of access will thus allow others to have access and use of those products and services (termed as resources). The vision of "created once, used many times" has been spread out across the globe through the development of national geospatial data infrastructure (GDI) initiatives, including their clearinghouses and geoportals. When judged only by their number, national geoportals can be considered a worldwide success (Crompvoets and Bregt 2006). However, as also stated by Crompvoets and Bregt (2006), only few of the geoportals are highly functional in providing effective and efficient mechanisms for data access. Furthermore, this study argued that from the user's point of view, a more effective and efficient data access mechanism and a more useful interaction with the geoportal interface could have been offered. This study proposed an alternative way of thinking about the way users can effectively and efficiently access data, such that they can really make use of the GDI. In this regard, the national atlas was chosen as a metaphor in the access to the GDI.

The findings of this study are presented below, according to the four specific research objectives stated in Section 1.4 (Chapter 1).

### First Objective:

*To design a new paradigm of interaction methods to facilitate the process of searching and browsing geospatial resources and more specifically geospatial data through the atlas metaphor.*

The outcome of this study is the 'national atlas metaphor' developed for a geospatial data infrastructure. The national atlas metaphor is defined as intentional combinations of specially structured maps, text summaries, and visual methods (such as graphics and thumbnails) organized within the atlas information structure. It is aimed at representing a synthesis of knowledge of physical and geographic elements that characterize a country as well as providing a synthesis of accessible geospatial resources in that country. When users look for accessible geospatial resources, the tasks can range from tightly defined to loosely defined discovery tasks. For this purpose, the national atlas metaphor facilitates searching and browsing information seeking behaviour so that users can complete the two corresponding tasks effectively. Such abilities need to be facilitated, since the problems related to data discovery and use can be better solved when users can gain options to get an answer that satisfies their specific search terms. Also, users can find appropriate resources satisfying their needs for data or information that is not simply dependent on matching values of certain metadata elements.

When dealing with a tightly defined discovery task, by searching, users can interact with the table view, the thumbnail view, the bull's-eye view or the Parallel Coordinate Plot (PCP) view in the atlas metaphor in order to review the search results. The rationale for the need of better indication, comparison, and sorting in today's geoportals and clearinghouses has been demonstrated via the developed search interfaces (i.e., ExplorerView). From use assessment activities (Section 4.4 in Chapter 4 and Section 6.4 in Chapter 6), it can be concluded that interaction with the table view and thumbnail view (that were combined with the tool tip box containing related information regarding the data in focus) was considered an effective means in order to review the results. Meanwhile, the use of graphical representations of search results either as the bull's-eye view or as the PCP view is not very effective or even useful in order to help users complete the search task. Also, the ability to combine table and thumbnail views with metadata mapping and thematic layers was proven to be useful in helping users to indicate and select the dataset required. As a contribution to the development of national geoportals, the search strategies and interfaces developed in this study can be used to advance the effectiveness and efficiency of search strategies that are presently applied in many national geoportals.

When dealing with a loosely defined discovery task, by browsing, users can make use of navigation schemes and interfaces associated with the StorytellerView in order to help them explore relevant information during their interaction activities. Information and geospatial resources related to the selected theme can be easily retrieved throughout the navigation trails, which were developed based upon the narrative structures. In the case of geospatial resources, Web Feature Services (as well as Web map Services and metadata footprints) can be cascaded and overlaid in order to support the exploration context. The sequence of displays, the list of links, the 'focus of interest' view, and the alternative views offered as a PCP view and thumbnails (where users can examine all related resources as a one entity) were considered useful to support user needs to indicate, compare, associate and interrelate geospatial resources (as discussed in Section 5.4). Today's geoportals lack such abilities and hence it is necessary to develop navigation and interaction schemes in order to support the completion of a user's loosely defined task. By providing such a set of navigation trails (i.e., narrative structures), users are able to optimally explore and synthesize the GDI resources through one single interface with minimal effort.

## Second Objective:

*To develop visualization methods to produce a uniform design and approach that allows users to easily understand the metadata offered and to assess and indicate the 'fitness for use' of geospatial data.*

This study deals with the issue of aggregation, management, representation, and mapping of metadata of geospatial resources in the GDI. The developed application framework of the national atlas metaphor combines metadata access and visualization/cartographic design templates in order to allow users to search and browse through the atlas metaphor. The metadata that the atlas uses, like metadata summaries and the atlas directory, are represented using the RDF/XML standard. The SPARQL Query Language for RDF and content transformation with XSLT templates play a crucial role for handling and presenting metadata summaries (as search results or browse-able resources) and for synthesizing metadata summaries of GDI data. The combination of SPARQL Query Language and XSLT templates in the Aim4GDI application provides the ability to deliver dynamic metadata and thematic layers mapping as well as abilities to juxtapose geospatial and non-geospatial content for data access.

Using the application framework discussed in detail in Chapter 3, the visual methods developed in the ExplorerView (i.e., table view, thumbnail view, bull's-eye view, and PCP view) and in the StorytellerView (i.e., the sequences of topic and thematic map view, thumbnail view, PCP view, in focus view, and navigation trails and links) as well as in the MapView (map, map legend, metadata legend, collaborative add-in tools) were produced. The use assessments in this study (presented in Section 4.4, Section 5.4, and Section 6.4) confirmed the usefulness of the developed visual methods (except for the bull's-eye and PCP views) to help users understand, indicate, and make sense of the geospatial resources that were offered. In this context, maps in the MapView have a function as information resources that can be used to improve the user's understanding of the search context.

An extensible and reliable RDF data handling as applied in this study can be transformed into usable user interfaces without requiring users to see the complexity of the metadata processing. Opportunities to gain supporting information relevant to the user's search context (i.e., the use of maps in the atlas) as well as abilities to associate and compare the available geospatial resources have been demonstrated as useful features in order to support searching and browsing information-seeking behaviour (see Section 4.4., Section 5.4, and Section 6.4). Such features should also be offered in today's geoportals in order to advance the usefulness of the catalogue functionalities of the GDI, which in turn, could make the GDI much more attractive and 'usable' to the users.

### Third Objective:

*To develop a mechanism for the use of maps as tools for data discovery and for the integration of geospatial resources and non-geospatial resources.*

Maps in the national atlas have a double role. Recall that when discussing the aforementioned second objective, the role of maps as an object to enhance the user's understanding of the search context was highlighted. Also, the other role that the maps in the national atlas should play is to enable users to gain knowledge and investigate the physical, economy, and population developments of the country. This role is essential in order to provide an integrated perspective on the national resources and developments.

By having two roles, the maps in the atlas can be used to support users to explore and synthesize geospatial resources (this refers to that of the 'search context') and to analyze and present a specific theme or concern of interest (this refers to that of the knowledge production and investigation). Thus, the national atlas is important in order to help users structure their view of the national resources and developments while exploring data and information sources required to solve the questions in support of problem solving or decision making processes.

As envisioned through the series of detailed scenarios presented in Section 6.3 (Chapter 6), users can gain benefits from their interactions with the national atlas and on the national atlas. Through the national atlas, a user like 'Danny' could visualise whether the data he looked for fitted into his area of interest. Danny could then cascade one of the Web Map Services listed in the results (indicated as suitable for his needs) on top of a thematic map. However, a more important function of the national atlas is to support a creative work of the users during their interactions with the national atlas. Recall a typical interaction done by Lisa (also presented in Section 6.3, Chapter 6). She could gain access to thematic maps in the national atlas in order to organise her view related to the topic of population and transportation in the area of interest (in order to build an understanding of the research problem she faced). Through the StorytellerView, she could see which pieces of available data and information she could use to deal with the task she had. Therefore, by exploring and presenting the atlas content including geospatial and non-geospatial information resources, Lisa (and other users) could develop a sound understanding of the problem or opportunity associated with the task she must accomplish. In this regard, the mechanism developed in the national atlas metaphor provides an added value to enhance the use of the national atlas.

In order to achieve such a vision, the atlas information structure was developed as a basis for organizing the maps, text summaries and visual methods (such as graphics and thumbnails). The developed structure is seen as a narrative structure of the maps and information resources associated with the atlas, so the users can realize an interactive storytelling session during their browsing interactions (Chapter 5). From "use" tests (Section 5.4.1 in Chapter 5), the narrative structure worked as designed in assisting users to explore and synthesize the GDI resources related to a thematic map. It can help users find answers to questions such as how they arrived at a particular selection, how they assess which resource is relevant to their needs and how they can interrelate and combine their focused resource with other supporting information with minimal effort. This is a significant result, since a tractable navigation or trajectory trail, that allows users to advance from exploration to other stages of research or problem solving (i.e., synthesis, analysis, and presentation) in an iterative fashion, will be very useful to organise the complexity of problem-solving processes and to really make sense of the geospatial resources in the GDI (related to Figure 3.1 in Chapter 3). Unfortunately, many dynamic web map applications, such as map viewers in the GDI setting often do not consider this type of particular navigation aspect. Unawareness of this issue can potentially lead to lower user interaction with the geospatial resources, as the user is dissatisfied with the results that are presented.

This study also demonstrates that the exploration activities for collaborative work with the GDI can be achieved through the developed atlas metaphor. The thematic maps in the atlas and the web maps accessible in the GDI provide a wealth of information resources for users to jointly explore alternatives and to discuss these alternatives in order to find a solution for a problem (seen as an object for collaboration). The collaborative features developed in this study can be considered as an early prototype. Nevertheless, from use assessments (Section 5.4.2 in Chapter 5) it was clear that the exploration and synthesis stages of the collaborative process could also be facilitated by the atlas metaphor. Whereas the GDI mechanisms open up more possibilities for people to collaborate more, only few national GDI initiatives do consider (and effectuate) the potential use of the developed geoportals in order to facilitate synchronous and asynchronous collaborative efforts via the GDI. In this regard, providing collaborative features in the national atlas metaphor could enhance the role of a national atlas not only in providing a synthesis of geospatial knowledge and resources of the country, but also in connecting people, geospatial knowledge, and resources available in the country for making fast and effective collaborative decisions.

### Fourth Objective:
*To test the applicability of the atlas metaphor through use of scenarios of uses in order to assess its feasibility as a metaphor.*

The development of the national atlas metaphor involved the use of scenarios and their associated claims. Use assessments were undertaken in order to collect and evaluate empirical evidence as well as qualitative feedback regarding users' experiences when searching, browsing, and collaborating via the atlas metaphor. From reviewing the results of the use assessments, it can be concluded that the national atlas concept could be transformed into a web interface facilitating data discovery and integration of geospatial resources. Additionally, it can be seen that the use of the national atlas in the access to the GDI is feasible to make the user interactions to the GDI. These can be achieved in more meaningful and usable ways than can be offered through the present geoportals.

Interaction-visualization methods and the metaphor development methodologies that resulted from this study can be of importance not only to the contribution of the development of geoportals for national geospatial data infrastructures, but also to the development of web national atlases. At present, many countries are in the process of creating or reviving web national atlases. The role and objective of the national atlas can have a new meaning, but the structures and schemata underlining the envisioned role and objective of the atlas are still the same (see Chapter 2). In this regard, the scenario-based development (discussed in Chapter 6) is considered suitable to advance the complex processes of the design in order to advance the development of national atlases. The processes of creation, re-designing, or updating of national atlases usually include some objectives on how the national atlas can contribute to solve national challenges or problems. The combination of usability engineering and scenario-based development (as applied in this study) can provide a systematic approach to explore design ideas and at the same time to successfully assess the usefulness of the developed national atlases.

Based on the findings related to objective one to four, it can be seen that the assertion stated in Section 1.4 (Chapter 1) that for useful and effective discovery and integration of geospatial resources, a national web atlas metaphor will be helpful in providing an alternative means of access to support users in searching and browsing geospatial resources via a Geospatial Data Infrastructure, is considered defendable. The national atlas metaphor, that can be defined as a combination of web maps, text summaries, and visual methods including graphics and thumbnails specially organized and presented according to the atlas information structure, can provide an effective means to synthesize the knowledge of physical and geographic elements of a country as well as to synthesize the accessible geospatial resources in that country.

This study was envisioning the use of the national atlas metaphor in the context of the national Dutch GDI. However, the results of this study are also applicable in a broader context in order to advance the role of national atlases in the world of Geospatial Data Infrastructures.

## 7.2. Recommendations for future research

Throughout the research processes, specific assumptions were made and specific methods were selected. As a consequence, some recommendations for future research should be addressed. Based on the outcomes of this research, some items of the research agenda considered as essential are presented below:

1. The interaction methods that this study focused on were targeted at searching and browsing information-seeking behaviour. The possibilities to provide strategies and visual methods as a result of combining searching interaction during the browsing or vice versa, allowing a browsing interaction during the searching have not been addressed in this study. However, providing such ‘possibilities’ is definitely achievable, and is most certainly required in order to enhance the usefulness of the national atlas metaphor.
2. Considering the potential use of the GDI and the development of OGC’s standards for geodata and geo-processing services, the users’ interaction can be more complex than what has been envisaged in this study. In this respect, the complexity of the user information processing to advance the first three stages (i.e., exploration, synthesis, and analysis back and forth) needs considerably more support than has been offered in this study. Thus, the national atlas metaphor should facilitate the user’s needs not only to combine the user’s searching and browsing interaction, but also to gain a meaningful and creative insight to advance the problem-solving stages. For this reason, a development of visual methods on top of the narrative structure built for reducing the complexity of information processing required by users and for advancing the ‘maximum benefit for minimum effort’ principle is required. A pragmatic hypothesis for this can be the use of a PCP view

(similar to Figure 5.5 in Chapter 5) to depict the user's interaction history and to indicate the achievement that the user made with regard to the problem-solving processes, for instance. As addressed in Section 5.6, for collaborative efforts, such a visual method is required to help a collaborator successfully contribute to the collaborative analysis processes without loosing control of the private realm of the user interfaces.

3. Aspects related to the cartographic design in the presentation of maps in the atlas metaphor have not been optimally investigated. This study assumed that the cartographic design practice in the development of (book) national atlases was sufficiently mature whereas in reality, developing web maps is completely different than creating book atlases (see Kraak and Brown 2001). Future research should consider that such an assumption could be misleading and undermining the potential use of the web as a medium of dissemination (and understanding). In this regard, the concept of storytelling used in this study has not been optimally extrapolated to provide an interactive presentation to the users. As an example, the centrifugal and centripetal structure discussed in Section 5.2.1 can be used to support interactive spatial and attribute transformations like classification, aggregation, displacement and symbolization for cartographic generalization. In addition, in this study, the metadata and query language for Semantic Web technology has been successfully used to advance the usability of web mapping interfaces without necessarily coercing users to confront the complexity of metadata queries. However, the real value of the Semantic Web technology is far beyond the mere presentation of search results. For this reason, the interaction modes offered by the user's interfaces should be improved to provide possible inference and reasoning support with Semantic Web technology in order to enhance the visual explanation of the search results (McGuinness et al. 2006) and the exploration and analysis of related geospatial and non-geospatial resources (see e.g., Berners-Lee et al. 2006).
4. In order to gain a deep understanding of spatial-temporal situations and possible group interactions that can be facilitated by the atlas metaphor, in improving the add-in collaborative tools of the atlas metaphor, future research should consider methods in Computer Supported Cooperative Work (CSCW). Some methods like the distributed cognition framework (Perry 2003) and cognitive work analysis (Anderson 2003) can be used as a basis to design a system that enables group members to share a 'common ground' (Klein et al. 2005) (a place within a problem space that accommodates understanding the goals, activities, and priorities) in order to stimulate optimal decisions with less time. This is to ensure that the atlas metaphor for collaboration efforts in the GDI is not only usable but can be used in reality.

# REFERENCES


Aditya, T., and Kraak, M.-J. (2004). "A National Atlas Metaphor in the Access to the GDI." *GSDI 7*, Bangalore, India, 83.

Aditya, T. and Ormeling, F., (2004). National Atlas as Visualiser Interface in the Access to the GDI, 2004 AAG Annual Meeting. AAG, Philadelpia.

Aditya, T., and Kraak, M.-J. (2006). "Geospatial Data Infrastructure Portals: Using National Atlases as a Metaphor." Cartographica, 41(2), 115-134.

Aditya, T., and Kraak, M.-J. (2007a). "Aim4GDI: Facilitating the Synthesis of GDI resources through Mapping and Superimpositions of Metadata Summaries." Geoinformatica. Online version at: http://dx.doi.org/10.1007/s10707-007-0021-4

Aditya, T., and Kraak, M.-J. (2007b). "'A Search Interface for an SDI: Implementation and Evaluation of Metadata Visualization Strategies'" Transactions in GIS, 11(3), 413 - 435.

Adobe. (2007). "Flash Professional 8." Accessed: January 21, 2007, *http://www.adobe.com/support/flash*.

Ahonen-Raino, P., and Kraak, M.-J. (2005). "Towards Multivariable Visualization of Metadata of Geographic Information." Exploring Geovisualization, J. Dykes, A. M. MacEachren, and M.-J. Kraak, eds., Elsevier, Amsterdam, 611-626.

Alani, H., and Brewster, C. (2005). "Ontology Ranking Based on the Analysis of Concept Structures." *K-CAP '05*, Banff, Alberta, Canada, 51-58.

Alani, H., Kim, S., Willard, D., Weal, M., Hall, W., and Lewis, P. (2002). "Automatic Ontology-based Knowledge Extraction and Tailored Biography Generation from the Web." *IEEE Intelligent Systems*, 18(1), 14-21.

Albaredes, G. (2002). "A New Approach: User Oriented GIS." *EGIS '92*, Munich, 830-837.

Ancona, D., Freeston, M., Smith, T., and Fabrikant, S. (2002). "Visual Explorations for the Alexandria Digital Earth Prototype." Lecture Notes in Computer Science, Springer, London, 199-213.

Anderson, P. M. (2003). "Cognitive Work Analysis." HCI Models, Theories, and Frameworks Toward Multidisciplinary Science, J. M. Carroll, ed., Morgan Kaufmann, San Fransisco, 225-264.

Andrews, J. H. (1996). "What Was a Map? The Lexicographers Reply." *Cartographica*, 33(4), 1-11.

Andrienko, G., Andrienko, N., Dykes, J., Mountain, D., Noy, P., Gahegan, M., Roberts, J. C., Rodgers, P., and Theus, M. (2005). "Creating Instruments for Ideation: Software Approaches to Geovisualization." Exploring Geovisualization, J. Dykes, A. M. MacEachren, and M.-J. Kraak, eds., Elsevier, 103-125.

Applegate, L. M. (1991). "Technology Support for Cooperative Work: A Framework for Studying Introduction and Assimilation in Organizations." *Journal of Organizational Computing*, 1(1), 11-39.

Armstrong, M. P., and Densham, P. J. (2005). "Cartographic Support for Collaborative Spatial Decision-Making." *AutoCARTO 12, ACSM/ASPRS Technical papers*, Charlotte, NC, 49-58.

ASDD. (2007). "Australian Spatial Data Directory." Accessed: January 14, 2007, *http://www.ga.gov.au/nmd/asdi/*.

Atlas van Nederland, S. W. (1985). "Atlas van Nederland, deel 12: Infrastructuur." Atlas van Nederland, Stichting Wetenschappelijke Atlas van Nederland.

Atlas van Nederland, S. W. (1989). "Atlas van Nederland, deel 10: Landbouw." Atlas van Nederland, Stichting Wetenschappelijke Atlas van Nederland.

Aufare, M.-A., and Trepied, C. (2001). "What Approach for Searching Spatial Information?" *Journal of Visual languages & Computing*, 12, 351-373.

Bakker, N. J., Elzakker, C. P. J. M. v., and Ormeling, F. J. (1987). "National Atlases and Development." *ITC Journal*, 1(1987), 83-92.

Balram, S., and Dragicevic, S. (2006). "Collaborative Geographic Information Systems: Origins, Boundaries, and Structures." Collaborative Geographic Information Systems, R. Balram and S. Dragicevic, eds., Idea Group Publishing, Hershey, PA, 1-23.

Beale, R. (2006). "Improving Internet Interaction: From Theory to Practice." *Journal of the American Society for Information Science and Technology*, 57(6), 829-833.

Beged-Dov, G., Brickley, D., Dornfest, R., Davis, I., Dodds, L., Eisenzopf, J., Galbraith, D., Guha, R. V., MacLeod, K., Miller., E., Swartz, A., and Vlist, E. v. d. (2001). "RDF Site Summary (RSS) 1.0." *http://web.resource.org/rss/1.0/spec*.

Bernard, L., Craglia, M., Gould, M., and Kuhn, W. 2005). "Towards an SDI Research Agenda." *11th EC-GIS*, Sardinia.

Bernard, L., Einspanier, U., Lutz, M., and Portele, C. (2003). "Interoperability in GI Service Chains - The Way Forward." *The 5th of the Association of Geographical Information Laboratories in Europe (AGILE)*, Lyon, France.

Bernard, L., Kanellopoulos, I., Annoni, A., and Smits, P. (2005b). "The European Geoportal - One step Towards the Establishment of a European Spatial Data Infrastructure." *Computer Environment and Urban Systems*, 29(Geoportal), 15 - 31.

Berners-Lee, T. (1998). "Semantic Web Road Map." Accessed: November 11, 2006, *http://www.w3.org/DesignIssues/Semantic.html*.

Berners-Lee, T., Chen, Y., Chilton, L., Conolly, D., Dhanaraj, R., Hollenbach, J., Lerer, A., and Sheets, D. (2006). "Tabulator: Exploring and Analyzing Linked Data on the Semantic Web." *The 3rd International Semantic Web User Interaction Workshop*, Athens, Georgia, USA.

Beutler, G. (2006). "Revolution in Geodesy and Surveying." *Geodäsie und Geoinformatik der Universität Hannover*, 258, 11-27.

Beyer, H., and Holtzblatt, k. (1998). *Contextual Design: Defining Customer-Centered Systems*, Morgan Kaufmann, San Fransisco, 472.

Bødker, S. (2000). "Scenarios in User-Centred Design - Setting the Stage for Reflection and Action." *Interacting with Computers*, 13, 61-75.

Bødker, S., and Christiansen, E. (1997). "Scenarios as Springboards in CSCW Design." Social Science, Technical Systems, and Cooperative Work: Beyond the Great Divide, G. Bowker, L. Star, W. Turner, and L. Gasser, eds., Lawrence Erlbaum Associates, Mahwah, NJ, 217-233.

Bodoff, D. (2006). "Relevance for Browsing, Relevance for Searching." *Journal of the American Society for Information Science and Technology*, 57(1), 69-86.

Borner, K. (2002). "Visual interfaces for semantic information retrieval." Visualizing the Semantic Web, V. Geroimenko and C. Chen, eds., Springer, 99 - 115.

Britannica. (2007). "Encyclopedia Britannica". Accessed: November 11, 2006, *http://corporate.britannica.com/products.html*.

Brodlie, K. (2005). "Models of Collaborative Visualization." Exploring Geovisualization, J. Dykes, A. M. MacEachren, and M.-J. Kraak, eds., Elsevier, Amsterdam, 463-475.

Brodlie, K., Fairbairn, D., Kemp, Z., and Schroeder, M. (2005). "Connecting People, Data, Resources - Distributed Geovisualization." Exploring Geovisualization, J. Dykes, A. M. MacEachren, and M.-J. Kraak, eds., Elsevier, 425-444.

Brodlie, K. W., Duce, D. A., Gallop, J. R., and Wood, J. D. "Distributed Cooperative Visualization." *EUROGRAPHICS 98*, 27-50.

Buckley, A. (2001). "Atlas mapping in the 21st century." *Journal of Cartographic and Geographic Information Science*, 30 (2), 149 - 158.

Card, S. K., Pirolli, P., Wege, M. M. V. D., Morison, J. B., Reeder, R. W., Scraedley, P. K., and Boshart, J. "Information Scent as a Driver of Web Behavior Graphs: Results of a Protocol Analysis Method for Web Usability." *Conference on Human Factors in Computing Systems*, Seattle, WA, 498-505.

Carroll, J. J., Dickinson, I., Dollin, C., Reynolds, D., Seaborne, A., and Wilkinson, K. (2004). "Jena: Implementing the Semantic Web Recommendations." *The 13th International World Wide Web conference*, New York, NY, USA, 74-83.

Carroll, J. M. (1994). "Making Use of a Design Representation." *Communications of The ACM*, 37(12), 28-35.

Carroll, J. M. (1997a). "Human-Computer Interaction: Psychology as a Science of Design." *International Journal Human-Computer Studies*, 46, 501-522.

Carroll, J. M. (1997b). "Scenario-Based Design." Handbook of Human-Computer Interaction, T. K. L. M. Helander, P. Prabhu, ed., Lawrence Erlbaum Associates, 383-406.

Carroll, J. M., Chin, G., Rosson, M. B., and Neale, D. C. (2000). "The Development of Cooperation: Five Years of Participatory Design in the Virtual School." *Designing Interactive Systems*, Brooklyn, NY, 239-251.

Carroll, J. M., and Rosson, M. B. (1992). "Getting Around the Task-Artifact Cycle: How to Make Claims and Design by Scenario." *ACM Transactions on Information Systems*, 10(2), 181-212.

Carroll, J. M., and Rosson, M. B. (1996). "Deliberated Evolution: Stalking the View Matcher in Design Space." Design Rationale: Comcepts, Techniques, and Use, T. P. Moran and J. M. Carroll, eds., Lawrence Erlbaum Associates, Mahwah, New Jersey, 107-146.

Carroll, J. M., and Rosson, M. B. (2002). "Scenario-Based Design." The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications, J. Jacko and A. Sears, eds., Lawrence Erlbaum Associates, 1032-1050.

Carroll, J. M., and Rosson, M. B. (2003). "Design Rationale as Theory." HCI Models, Theories, and Frameworks Toward Multidisciplinary Science, J. M. Carroll, ed., Morgan Kaufmann, San Fransisco, 431 - 461.

Carroll, J. M., Singley, M. K., and Rosson, M. B. (1992). "Integrating Theory Development with Design Evaluation." *Behavior & Information Technology*, 11(5), 247-255.

Cartwright, W. (1999). "Extending the Map Metaphor Using Web Delivered Multimedia." *International Journal of Geographical Information Science*, 13(4), 335 - 353.

Cartwright, W. (2004). "Using the Web for Focussed Geographical Storytelling via Gameplay." *ICA UPI Map 2004*, Tokyo.

Cartwright, W., Crampton, J., Gartner, G., Miller, S., Mitchell, K., Sierkierska, E., and Wood, J. (2001). "Geospatial Information Visualization User Interfaces." *Cartography and Geographic Information Systems*, 28(1).

Cay, G. "GeoVSM: An Integrated Retrieval Model for Geographic Information." *The 2nd International Conference, GIScience 2002*, Boulder, CO, 65 - 79.

Cay, G., MacEachren, A. M., and Bolelli, L. "GCCM: Map-mediated Collaboration Among Emergency Operation Centers and Mobile Teams." *GIScience 2004*, Adelphi MD.

Chakrabarti, S., Dom, B. E., Kumar, S. R., Raghavan, P., Rajagopalan, S., Tomkins, A., Gibson, D., and Kleinberg, J. (1999). "Mining the Web's Link Structure." *Computer*, 32(8), 60-67.

Charland, A. (2006). "Top Ten Reasons AJAX is Here To Stay." Accessed: May 31, 2006, *http://www.developer.com/design/article.php/3567706*.

Chen, C. (2003). *Mapping Scientific Frontriers*, Springer, London, 240.

Chi, E. H. (2002). "Improving Web Usability Through Visualization." *IEEE Internet Computing*, 6(2), 64-71.

Chi, E. H., Pirolli, P., Chen, K., and Pitkow, J. (2001). "Using Information Scent to Model User Information Needs and Actions and the Web." *Conference on Human Factors in Computing Systems*, Seattle, WA, 490-497.

Chi, E. H.-h., Riedl, J., Barry, P., and Konstan, J. (1998). "Principles for Information Visualization Spreadsheets." *IEEE Computer Graphics and Applications*, 18(4), 30-38.

Coleman, D. J., and McLaughlin, J. "Defining Global Geospatial Data Infrastructure (GGDI): Components, Stakeholders and Interfaces." *GSDI Conference*, North Carolina.

Comenetz, J. (2004). "Visualizing Metadata: Design Principles for Thematic Maps." *Cartographic Perspectives*, 49, 11-21.

Conterra. (2006). "terraCatalog 2.1 - Web Catalogue Service for Geospatial Data Infrastructures." 2007(January 14), *http://www.conterra.de/en/products/sdi/terracatalog/index.shtm*.

Crawford, C. (2005). *Interactive Storytelling*, New Riders.

Crompvoets, J., and Bregt, A. (2003). "World status of national spatial data clearinghouses." *Journal of the Urban and Regional Information Systems Association*, 15(Access and Participatory), 43 - 52.
Crompvoets, J., and Bregt, A. (2006). "Worldwide Development of National Spatial Data Clearinghouses." *GSDI-9*, Santiago.
Crompvoets, J., Bregt, A., Bree, F. d., Oort, P. v., Loenen, B. v., Rajabifard, A., and Williamson, I. (2005). "Worldwide (Status, Development and) Impact Assessment of Geoportals." *FIG Working Week 2005 and GSDI-8*, Cairo, Egypt.
Crompvoets, J., Bregt, A., Rajabifard, A., and Williamson, I. (2004). "Assessing the Worldwide Developments of National Spatial Data Clearinghouses." *International Journal of Geographical Information Science*, 18(7), 665-689.
Cuevas, H. M., Costello, A. M., Bostald, C. A., and Endsley, M. R. (2006). "Facilitating Distributed Team Collaboration." *16th International Ergonomics Association (IEA) World Congress on Ergonomics*.
Darlin, D. (2005). "A Journey to a Thousand Maps Begin with an Open Code." *The New York Times*.
Dean, W. G. (1969). "Economic Atlas of Ontario: Atlas Economique de L'ontario." University of Toronto Press & Goverment of Ontario, 113 plates.
Decker, S., Harmelen, F. v., Broekstra, J., Erdmann, M., Fensel, D., Horrocks, I., Klein, M., and Melnik, S. (2000). "The Semantic Web: the roles of XML and RDF." *Internet Com puting IEEE*, 4(5), 63-73.
DiBiase, D. (1990). "Visualization in the Earth Sciences." *Earth and Mineral Sciences*, 59(2).
DiBiase, D. (2007). "Swoopy Figure." Personal communication. (electronic mail). March 2007.
Dublin Core Metadata Initiative. (2006). "Dublin Core." (November 11, 2006), *http://dublincore.org/index.shtml*.
Duckham, M., Nittel, S., and Worboys, M. (2005). "Monitoring Dynamic Spatial Fields Using Responsive Geosensor Networks." *GIS '05*, Breme, Germany, 51-61.
Duffy, D. (2002). "GIS Soes Worldwide." CIO.
Dykes, J. (2005). "Facilitating Interaction." Exploring Geovisualization, J. Dykes, A. M. MacEachren, and M.-J. Kraak, eds., Elsevier, Amsterdam, 265-291.
Eisenhardt, K. M., and III, L. J. B. (1988). "Politics of Strategic Decision Making in High-Velocity Environments: Toward a Midrange Theory." *Academy of Management Journal*, 31(4), 737-770.
Eisner, W. (1996). *Graphic Storytelling*, Poorhouse Press, Tamarac, FL, 164.
Elzakker, C. P. J. M. v. (2004). *The Use of Maps in the Exploration of Geographic Data*, Netherlands Geographical Studies & ITC, Utrecht, 208.
Erickson, T. D. (1990). "Working with Interface Metaphors." The An of Human-Computer Interface Design, B. Laurel, ed., Addison Wesley, Reading, MA., 65-74.
ESCAP. (2003). "Towards a policy framework for integrating space technology applications for sustainable development on the information superhighway." *ESCAP works towards reducing poverty and managing globalization*, Accessed: December 15, 2006, *http://www.unescap.org/icstd/SPACE/documents/InfoHighway/*.
ESRI. (2004). "ESRI Support Center." Accessed: January 31, 2004, *http://support.esri.com/index.cfm?fa=forums.gateway*.
ESRI. (2005). "U.S. Government Selects ESRI for Next Generation Portal." ArcNews Online.
ESRI. (2006a). "ArcIMS." Accessed: May 31, 2005, *http://www.esri.com/software/arcgis/arcims/index.html*.
ESRI. (2006b). "The Geography Network." Accessed: May 31, 2005, *http://www.geographynetwork.com*.
Fabrikant, S. I. (2000a). "Spatial Metaphors for Browsing Large Data Archives," PhD, the University of Colorado, Colorado.
Fabrikant, S. I. (2000b). "Spatialized Browsing in Large Data Archives." *Transactions in GIS*, 4(1), 65-78.

Fabrikant, S. I., and Buttenfield, B. P. (2001). "Formalizing semantic spaces for information access." *Annals of American Geographers*, 91(2), 263 - 280.

FAO. (2006). "FAO GeoNetwork." Accessed: May 31, 2006, *http://www.fao.org/geonetwork*.

Feeney, M.-E. F. (2003). "SDIs and Decision Support." Developing Spatial Data Infrastructures – From Concept to Reality, I. Williamson, A. Rajabifard, and M.-E. F. Feeney, eds., Taylor and Francis, London, 195-210.

FGDC. (2004). "National Spatial Data Infrastructure: Clearinghouse Search Form." Accessed: May 31, 2004, *http://clearinghouse1.fgdc.gov/servlet/FGDCServlet?srp=2*.

Finley, D., Siderelis, K., Grant, D., and Bregt, A. (2000). "Four Cases." Geospatial Data Infrastructures - Concepts, Cases, and Good Practice, R. Groot and J. McLaughlin, eds., Oxford University Press Inc., New York, 245-268.

Fluit, C., Sabou, M., and Harmelen, F. v. (2002). "Ontology-Based Information Visualization." Visualising the Semantic Web, V. Geroimenko and C. Chen, eds., Springer Verlag, 36-48.

Fonseca, F. T., Egenhofer, M. J., and Agouris, P. (2002). "Using Ontologies for Integrated Geographic Information Systems." *Transactions in GIS*, 6(3), 231-257.

Frank, A. U. (1998). "GIS for Politics." *Workshop on Status and Trends in Spatial Analysis*, Santa Barbara, CA.

Frappier, J., and Williams, D. (1999). "An Overview of the National Atlas of Canada." *International Cartographic Conference - ICA*, Ottawa, Canada, 261 - 266.

Freitag, U. (1997). "National Atlases: Production and Use." *Modern Cartography for Navigating the Information Highway*, Bandung, 15 - 22.

Frew, J., Carver, L., Fischer, C., Goodchild, M., Larsgaard, M., Smith, T., and Zeng, Q. (1995). "The Alexandria Rapid Prototype: Building a Digital Library for Spatial Information." *ESRI International User Conference*, Palm Springs.

Friis-Christensen, A., Bernard, L., Kanellopous, I., Nogueras-Iso, J., Peedell, S., Schade, S., and Thorne, C. (2006). "Building Service Oriented Applications on top of a Spatial Data Infrastructure - A Forest Fire Assessment Example." *9th AGILE Conference on Geographic Information Science*, Visegrád, Hungary.

Fuhrmann, S., Ahonen-Rainio, P., Edsall, R. M., Fabrikant, S. I., Koua, E. L., Tobon, C., Ware, C., and Wilson, S. (2005a). "Making Useful and Useable Geovisualization: Design and Evaluation Issues." Exploring Geovisualization, J. Dykes, A. M. MacEachren, and M.-J. Kraak, eds., Elsevier Science Ltd., 553-566.

Fuhrmann, S., Ahonen-Raino, P., Edsall, R. M., Fabrikant, S. I., Koua, E., Tobon, C., Ware, C., and Wilson, S. (2005b). "Making Useful and Useable Geovisualization: Design and Evaluation Issues." Exploring Geovisualization, J. Dykes, A. M. MacEachren, and M.-J. Kraak, eds., Elsevier, 553-566.

Gahegan, M. (2005). "Beyond Tools: Visual Support for the Entire Process of GIScience." Exploring Geovisualization, J. Dykes, A. M. MacEachren, and M.-J. Kraak, eds., Elsevier, 83-99.

Gahegan, M., and Pike, W. (2006). "A Situated Knowledge Representation of Geographical Information." *Transactions in GIS*, 10(5), 727-749.

GeoNetwork. (2006). "GeoNetwork Opensource." Accessed: May 31, 2006, *http://geonetwork-opensource.org/*.

Geoportal.Bund. (2007). "Geodatenkatalog." Accessed: January 14, 2007, *http://www.geoportal.bund.de*

GeoServer. (2007). "GeoServer - Confluence." Accessed: January 14, 2007, *http://docs.codehaus.org/display/GEOS/Home*.

Geospatial-Solutions. (2006). "Daratech Report Reveals Geospatial Market Growth." Accessed: January 14, 2007, *http://www.geospatial-online.com/geospatialsolutions/article/articleDetail.jsp?id=366737*

Gershon, N., and Page, W. (2001). "What Storytelling Can Do for Information Visualization." *Communications Of The ACM*, 44(8), 31-37.

Geurts, J., Bocconi, S., Ossenburgen, J. v., and Hardman, L. (2003). "Towards Ontology-Driven Discourse: From Semantic Graphs to Multimedia Presentations." *ISWC 2003*, Sanibel Island, Florida, 597 - 612.

Gewin, V. (2004). "Mapping Opportunities." *Nature*, 427, 376-377.

Gigateway. (2006). "Gigateway - Opening the door to Geographic Information." Accessed: January 14, 2007, *http://www.gigateway.org.uk/datalocator/default.html*.

Gobel, S., and Jasnoch, U. (2001). "Visualization Techniques in Metadata Information Systems to Support Geospatial Data." *Advances in Environmental Research*, 5, 415 - 424.

Gobel, S., and Lutze, K. (1998). "Development of Meta Databases for Geospatial Data in the WWW." *ACM GIS '98*, Washington DC.

Golbeck, J., and Mutton, P. (2005). "Spring-Embedded Graphs for Semantic Visualization." Visualizing the Semantic Web, V. Geroimenko and C. Chen, eds., Springer, 172-182.

Goodchild, M. F. (2000). "Communicating Geographic Information in a Digital Age." *Annals of the Association of American Geographers*, 90(2), 344-355.

Goodchild, M. F., and Zhou, J. (2003). "Finding Geographic Information: Collection-Level Metadata." *GeoInformatica*, 7(2), 95 - 112.

Google. (2007a). "Google Earth." Accessed: January 14, 2007, *http://earth.google.com/*

Google. (2007b). "Google Maps." Accessed: January 14, 2007, *http://maps.google.com/*

Gordon, V. S., and Bieman, J. M. (1995). "Rapid Protoyping: Lessons Learned." *IEEE Software*, 12(1), 85-95.

Gosson, C. (2006). "The Evolution of the Atlas of Canada, 1906-2006." *Cartographica*, 41(3), 259-265.

Gould, M., and McGranaghan, M. (1990). "Metaphor in Geographic Information Systems." *Fourth International Symposium on Spatial Data Handling*, Zurich, Switzerland, 433-442.

Great Britain Historical GIS Project. (2006). "A Vision of Britain Through Time." Accessed: May 31, 2006, *http://www.visionofbritain.org.uk/index.jsp*.

Grégoire, N., and Bouillot, M. (1998). "Hausdorff Distance Between Convex Polygons." Accessed: May 26, 2006, *http://cgm.cs.mcgill.ca/~godfried/teaching/cg-projects/98/normand/main.html*.

Gremett, P. (2006). "Utilizing a User's Context to Improve Search Results." *Journal of the American Society for Information Science and Technology*, 57(6), 808-812.

Gretzel, U., and Fesenmaier, D. R. (2002). "Building Narrative Logic into Tourism Information Systems." *IEEE Intelligent Systems*, 17(6), 59-61.

Groot, R. (1979). "Canada's National Atlas Program in the Computer Era." *Cartographica*, 23(The purpose and use of national and regional atlases), 41 - 52.

Groot, R. (1997). "Spatial Data Infrastructure (SDI) for Sustainable Land Management." *ITC Journal*, 2(4), 287-294.

Groot, R., and McLaughlin, J. (2000a). "Geospatial Data Infrastructures - Concepts, Cases, and Good Practice." Oxford University Press.

Groot, R., and McLaughlin, J. (2000b). "Introduction." Geospatial Data Infrastructures - Concepts, Cases, and Good Practice, R. Groot and J. McLaughlin, eds., Oxford University Press.

Gruber, T. R., and Russell, D. M. (1996). "Generative Design Rationale: Beyond the Record and Replay Paradigm." Design Rationale: Concepts, Techniques, and Use, T. P. Moran and J. M. Carroll, eds., Lawrence Erlbaum Associates, Mahwah, NJ, 323-349.

Gutwin, C., and Greenberg, S. (2004). "The Importance of Awareness for Team Cognition in Distributed Collaboration." Team Cognition: Understanding the Factors that Drive Process and Performance, E. Salas and S. M. Fiore, eds., APA Press, Washington, 177-201.

Gutwin, C., Roseman, M., and Greenberg, S. (1996). "A Usability Study of Awareness Widgets in a Shared Workspace Groupware System." *ACM CSCW'96 Conference on Supported Cooperative Work*, Boston, MA., 258-267.

Harley, J. B., and Woodward, D. (1987). "Cartography in Prehistoric, Ancient and Medieval Europe and the Mediterranean." *The History of Cartography*, 1, University of Chicago, Chicago, 622.

Harley, J. B., and Woodward, D. (1992). "Cartography in the Traditional Islamic and South Asian Societies." *The History of Cartography*, 1, University of Chicago, Chicago, 604.
Harley, J. B., and Woodward, D. (1995). "Cartography in the Traditional East and Southeast Asian Societies." *The History of Cartography*, 1, University of Chicago, Chicago, 988.
Hearst, M., Elliot, A., English, J., Sinha, R., Swearingen, K., and Yee, K.-P. (2002). "Finding the flow in web site search." *Communications of the ACM*, 45(9 (September 2002)), 42 - 49.
Hertzum, M. (2003). "Making Use of Scenarios: A Field Study of Conceptual Design." *International Journal of Human-Computer Studies*, 58(2), 215-239.
Hill, L. L. (2000). "Core Elements of Digital Gazetteers: Placenames, Categories, and Footprints." *Research and Advanced Technology for Digital Libraries, 4th European Conference, ECDL 2000*, Lisbon, Portugal.
Hobona, G., James, P., and Fairbairn, D. (2006). "Multidimensional Visualization of Degrees of Relevance of Geographic Data." *International Journal of Gegraphical Information Science*, 20(5), 469-490.
Howard, D. (1998). "Metaphors and User Interface Design." Geographic Information Research Trans-Atlantic Perspectives, H. Onsrud and M. Craglia, eds., 565-576.
Howard, D., and MacEachren, A. M. (1996). "Inteface Design for Geographic Visualization: Tools for Representing Reliability." *Cartography and Geographic Information Systems*, 23(2), 59 - 77.
HP Semantic Web Programme. (2006). "ARQ - A SPARQL Processor for Jena." Accessed: May 31, 2006, *http://jena.sourceforge.net/ARQ*.
Huberman, B. A., Pirolli, P. L. T., Pitkow, J. E., and Lukose, R. M. (1998). "Strong Regularities in World Wide Web Surfing." *Science*, 280, 95-97.
Hunter, G. J., Wachowicz, M., and Bregt, A. K. (2003). "Understanding Spatial Data Usability." *Data Science Journal*, 2(Spatial Data Usability Special Section), 79 - 89.
Hurni, L., Bar, H.-R., and Sieber, R. (2001). "The Atlas of Switzerland as an Interface Multimedia Atlas Information Systems." Multimedia Cartography, W. Cartwright, M. P. Peterson, and G. Gartner, eds., Springer-Verlag, Berlin.
Hyvonen, E., Saarela, S., and Viljanen, K. (2004). "Application of Ontology Techniques to View-based Semantic Search and Browsing." *The First European Web Symposium*, Heraklion, Greece.
ICA. (2003). "A Strategic Plan for the International Cartographic Association 2003-2011." Accessed: May 31, 2006, *http://www.icaci.org/en/strategic.html*.
Image, S. (2007). "SIRUS: The Spot Image Online Catalogue." Accessed: January 31, 2007, *http://sirius.spotimage.fr/*.
INSPIRE. (2006a). "INSPIRE: European Geo-Portal." Accessed: May 31, 2006, *http://eu-geoportal.jrc.it/*.
INSPIRE. (2006b). "Nature GIS." Accessed: May 31, 2006, *http://www.naturegis.net/*.
Interior, US. Department of the (2006). "U.S. National Atlas". Accessed: May 31, 2006, " *http://nationalatlas.gov/*.
Ionic. (2006). "RedSpider Catalog 2." Accessed: January 14, 2007, *http://www.ionicsoft.com/products/main_catalog.jsp*.
ISO-9241-11. (1998). "Ergonomic requirments for office work with visual display terminals (VDT)s - Part 11, Guidance on usability." International Organization for Standardization.
ISO/TC211. (2003). *ISO 19115: 2003 : Geographic Information -- Metadata*, ISO, 140. International Organization for Standardization.
Ivory, M. Y., and Hearst, M. A. (2002). "Improving Web Site Design." *IEEE Internet Computing*, 6(2), 56-63.
Janee, G., and Frew, J. (2002). "The ADEPT Digital Library Architecture." *International Conference on Digital Libraries*, Portland, Oregon, 342-35-.
Janee, G., and Frew, J. (2004). "Spatial Search, Ranking, and Interoperability." *Workshop on Geographic Information Retrieval, SIGIR 2004*, Sheffeld, UK.
Jankowski, P., and Nyerges, T. (2001). "GIS-Supported Collaborative Decision-Making: Results of An Experiment." *Annals of the Association of American Geographers*, 91(1), 48-70.

Jankowski, P., Robischon, S., Tuthill, D., Nyerges, T., and Ramsey, K. (2006). "Design Considerations and Evaluation of a Collabortive, Spatio-Temporal Decision Support System." *Transactions in GIS*, 10(3), 335-354.

John, B. E. (2003). "Information Processing and Skilled Behavior." HCI Models, Theories, and Frameworks Toward a Multidisciplinary Science, J. M. Carroll, ed., Morgan Kaufmann, San Fransisco, 55-101.

Jones, C. B., Alani, H., and Tudhope, D. (2001). "Geographical information retrieval with ontologies of place." *Conference of Spatial Information Theory, COSIT 2001*, Morrow Bay, CA, USA, 322.

Jones, C. B., Alani, H., and Tudhope, D. (2003). "Geographical Terminology Servers - Closing the Semantic Divide." Foundations of Geographic Information Science, M. F. Goodchild, M. Duckham, and M. Worboys, eds., Taylor & Francis, 201 - 218.

Keim, D. "Scalable Visual Analysis of Geo-Spatial Data." *Workshop: Visualization, Analytics & Spatial Decision Support at GIScience 2006*, Muenster.

Keim, D. A., Panse, C., and Sips, M. (2005). "Information Visualization: Scope, Techniques, and Opportunities for Geovisualization." Exploring Geovisualization, J. Dykes, A. M. MacEachren, and M.-J. Kraak, eds., Elsevier, Amsterdam, 23-52.

Keller, C. P. (1995). "Visualizing Digital Atlas Information Products and the User Perspectives." *Cartographic Perspectives*, 20, 21 - 28.

Keller, P., and Keller, M. (1992). *Visual Cues: Practical Data Visualization*, IEEE Computer Society Press, Los Alamitos, 229.

Kemp, Z. (2005). "A Knowledge-based Collaborative Environment for Geovisualization: Ontologies for Multiple Perspectives on Distributed Data Resources." Exploring Geovisualization, J. Dykes, A. M. MacEachren, and M.-J. Kraak, eds., Elsevier, 495-512.

Kerner, S. M. (2004). "Online Shopping Up, Along With Abandoned Carts." internetnews.com.

King, A. B. (2003). *Speed Up Your Site: Web Site Optimization*, New Riders Press, Berkeley, CA, 528.

Klein, G., Feltovich, P. J., Bradshaw, J. M., and Woods, D. D. (2005). "Common Ground and Coordination in Joint Activity." Organizational Simulation, W. B. Rouse and K. R. Boff, eds., 139-184.

Klein, M. (2001). "XML, RDF, and Relatives." *IEEE Intelligent Systems*, 16(2), 26-28.

Klein, P., Müller, F., Reiterer, H., and Limbach, T. (2003). "Metadata Visualization with VisMeB." *Information Visualization 2003*, London, 600-605.

Köbben, B. (2004). "RIMapper - A Test Bed for Online Risk Indicator Maps Using Data-Driven SVG Visualisation." *Location Based Services and TeleCartography*, Vienna.

Köbben, B. (2007). "RIMapperWMS: A Web Map Service Providing SVG Maps with a Built-in Client." *10th AGILE International Conference on Geographic Information Science (Lecture Notes in Geoinformation and Cartography)*, Aalborg, Denmark.

Koontz, L. D. (2003). "Geographic Information Systems: Challenges to Effective Data Sharing." United States General Accounting Office, Washington.

Koop, R. O., and Ormeling, F. J. (1990). "New Horizons in Thematic Chartography in the Netherlands: The national Atlas Information System." *The First European Conference on Geographical Information Systems*, Amsterdam, 614-623.

Koua, E. L., MacEachren, A. M., and Kraak, M.-J. (2006). "Evaluating the Usability of Visualization Methods in an Exploratory Geovisualization Environment." *International Journal of Gegraphical Information Science*, 20(4), 425-448.

Kraak, M.-J. (2000). "Access to GDI and the Function of Visualization Tools." Geospatial Data Infrastructures - Concepts, Cases, and Good Practice, R. Groot and J. McLaughlin, eds., Oxford University Press Inc., New York.

Kraak, M.-J. (2001). "Web Maps and Atlases." Web Cartography: Developments and Prospects, M.-J. Kraak and A. Brown, eds., Taylor & Francis, New York, 135-140.

Kraak, M.-J. (2004). "The Role of the Map in a Web-GIS Environment." *Journal Geographical Systems*, 6, 83-93.

Kraak, M.-J. (2006). "Why Maps Matter in GIScience." *The Cartographic Journal*, 43(1), 82-89.

Kraak, M.-J., and Brown, A. (2001). "Web Cartography: Developments and Prospects." Taylor & Francis, New York, 213.
Kraak, M.-J., and Ormeling, F. J. (2002). *Cartography Visualization of Spatial Data*, Addison Wesley Longman, London.
Kraak, M.-J., Ormeling, F. J., and Smits, J. (2001). "De Nationale Atlas als Organitatiemedium voor de Toegang tot Geo-informatie." *Kartografisch Tijdschrift*, 27, 42-47.
Kramers, R. E. (2005). "The Atlas of Canada after 100 Years - User-Centred Development and Evolution." *22nd International Cartographic Conference*, A Coruña, Spain.
Kuhn, W. (1995). "7 + 2 questions and answers about metaphor for GIS user interfaces." Cognitive Aspects of Human-Computer Interaction for Geographic Information Systems, T. L. Nyerges, D. M. Mark, R. Laurini, and M. J. Egenhofer, eds., Kluwer Academic Publisher, Dordrecht, 113 - 122.
Kuniavsky, M. (2003). *Observing the User Experience: A Practitioner's Guide To User Research*, Morgan Kaufmann, San Francisco, 560.
Kyng, M. (1994). "Scandinavian Design: Users in Product Development." *Human Factors in Computing Systems*, Boston, MA, 3-9.
Lakoff, G. (1980). *Woman, Fire, and Dangerous Mind: What Categories Reveal about the Mind*, Chicago University Press, 632.
Lakoff, G., and Johnson, M. (1980). *Metaphors We Live By*, Chicago University Press.
Lassila, O. (1998). "Web Metadata: A Matter of Semantics." *IEEE Internet Computing*, 2(4), 30-37.
Laurel, B. (1991). *Computers as Theater*, Addison-Wesley, Menlo Park, CA, U.S.
Laurini, R., and Milleret-Raffort. "Principle of Geomatic Hypermaps." *4th Spatial Data Handling*, Zurich, Switzerland.
Lee, J. (1997). "Design rationale systems: understanding the issues." *Expert, IEEE*, 12(3), 78-85.
Lee, J., and Lai, K.-Y. (1996). "What's in Design Rationale?" Design Rationale: Concepts, Techniques, and Use, T. P. Moran and J. M. Carroll, eds., Lawrence Erlbaum Associates, Mahwah, NJ, 21-51.
Lemmens, R., Granell, C., Wytzysk, A., By, R. d., Gould, M., and Oosterom, P. v. (2006). "Semantic and Syntactic Service Descriptions at Work in Geo-Service Chaining." *9th AGILE Conference on Geographic Information Science*, Visegrád, Hungary, 51-61.
Lerner, R. M. (2006). "At the Forge: Creating Mashups." *Linux Journal*, 2006(147), 10.
Liang, S. H. L., Coritoru, A., and Tao, C. V. (2005). "A Distributed Geo-Spatial Infrastructure for Smart Sensor Webs." *Journal of Computer and Geosciences*, 31(2), 221-231.
Likert, R. (1932). "A Technique for the Measurement of Attitudes." *Archives of Physchology*, 140.
Loenen, B. v. (2006). "Developing Geographic Information Infrastructure : The Role of Information Policies," TU Delft, Delft.
Lutz, M., and Klien, E. (2006). "Ontology-Based Retrieval of Geographic Information." *International Journal of Gegraphical Information Science*, 20(3), 233-260.
MacCGDI. (2007). "Malaysia Geoportal." Accessed: January 14, 2007, *http://www.mygeoportal.gov.my.*
MacEachren, A., Cai, G., Rauschert, I., Brewer, I., Bolelli, I., Shaparenko, B., Fuhrmann, S., and Wang, H. (2005). "Enabling collaborative geoinformation access and decision-making through a natural, multimodal interface." *International Journal of Gegraphical Information Science*, 19(3), 293-317.
MacEachren, A. M. (1995). *How Maps Work: Representation, Visualization, and Design*, The Guilford Press, New York, 513.
MacEachren, A. M. (2001). "An evolving cognitive-semiotic approach to geographic visualization and knowledge construction." *Information Design Journal*, 10(1), 26 - 36.
MacEachren, A. M. (2005). "Moving Geovisualization toward Support for Group Work." Exploring Geovisualization, J. Dykes, A. M. MacEachren, and M.-J. Kraak, eds., Elsevier Science Ltd., 445-461.
MacEachren, A. M., and Brewer, I. (2004). "Developing a conceptual framework for visually-enabled geocollaboration." *International Journal of Gegraphical Information Science*, 18(1), 1-34.

MacEachren, A. M., Gahegan, M., and Pike, W. (2004). "Visualization for Constructing and Sharing Geo-scientific Concepts." *PNAS Proceedings of the National Academy of Sciences of the United States of America*, 101 (Suppl. 1)(Mapping knowledge domains), 5279-5286.

MacEachren, A. M., and Kraak, M.-J. (1997). "Exploratory Cartographic Visualization: Advancing the Agenda." *Computers & Geosciences*, 23(4), 335-343.

MacEachren, A. M., and Kraak, M.-J. (2001). "Research Challenges in Geovisualization, Cartography, and Geographic Information Science." *Cartography and Geographic Information Science*, 28(1), 3-12.

MacLean, A., and McKerlie, D. (1995). "Design Representation Analysis and Use-Representations." Scenario-Based Design: Envisioning Work and Technology in System Development, J. M. Carroll, ed., Wiley, New York, 183-207.

MacLean, A., Young, R. M., and Moran, T. P. (1989). "Design Rationale: The Argument Behind the Artifact." *Conference on Human Factors in Computing Systems*, 247-252.

Madsen, K. H. (1994). "A Guide to Metaphorical Design." *Communications of The ACM*, 37(12), 57-62.

Maguire, D. J., and Longley, P. A. (2005). "The Emergence of Geoportals and Their Role in Spatial Data Infrastructures." *Computers, Environment, and Urban Systems*, 29, 3 - 14.

Mahemoff, M. (2006). *AJAX Design Patterns*, O'Reilly, Sebastopol, CA, 635.

Manber, U., Smith, M., and Gopal, B. (1997). "WebGlimpse - Combining Browsing and Searching." *Usenix Technical Conference*, Los Angles, CA.

Manning, H., Souza, R., and McCarthy, J. C. (1998). "Why Most Web Sites Fail." Forrester Research Inc., Cambridge, MA.

Mason, B. C., and Dragicevic, S. (2006). "Web GIS and Knowledge Management Systems: An Integrated Design for Collaborative Commnunity Planning." Collaborative Geographic Information Systems, R. Balram and S. Dragicevic, eds., Idea Group Publishing, Hershey, PA, 263-283.

Masser, I. (2005). "The Future of Spatial Data Infrastructures." *ISPRS Workshop on Service and Application of Spatial Data Infrastructure*, Hangzhou, China, 7-16.

Masser, I. (2005). "Some Priorities for SDI Related Research." *FIG Working Week 2005 and GSDI-8*, Cairo, Egypt.

Mateas, M., and Sengers, P. (2003). "Narrative Intelligence." Narrative Intelligence, M. Mateas and P. Sengers, eds., John Benjamins Pub Co, 340.

McGrath, J. E. (1984). *Groups: Interaction and Performance*, Prentice-Hall Inc, Englewood cliffs, NJ, 320.

McGuinness, D. L., Ding, L., Glass, A., Chang, C., Zeng, H., and Furtado, V. (2006). "Explanation Interfaces for the Semantic Web: Issues and Models." *The 3rd International Semantic Web User Interaction Workshop*, Athens, Georgia, USA.

McKee, L. (2000). "Who Wants a GDI?" Geospatial Data Infrastructure Concepts, Cases, and Good Practice, R. Groot and J. McLaughlin, eds., Oxford University Press Inc., New York.

Microsoft. (2007a). "Live Search." Accessed: January 14, 2007, *http://maps.live.com*.

Microsoft. (2007b). "Microsoft Encarta Premium 2007." January 14, 2007, *http://www.microsoft.com/products/encarta/default.mspx*.

Miller, C. C. (2006). "A Beast in the Field: The Google Maps Mashup as GIS/2." *Cartographica*, 41(3), 187-199.

Minnesota, U. o., and TerraSIP. (2007). "MapServer." Accessed: January 31, 2007, *http://mapserver.gis.umn.edu/*.

Monmonier, M. (1992). "Authoring Graphic Scripts: Experiences and Principles." *Cartography and Geographic Information Systems*, 19(4), 247 - 260.

Montello, D., Fabrikant, S. I., Ruocco, M., and Middleton, R. S. (2003). "Testing the First Law of Cognitive Geography on Point-Display Spatializations." *Conference of Spatial Information Theory, COSIT 2003*, Ittingen, Switzerland, 316 - 331.

Morales, J. (2004). "Model-Driven Design of Geo-Information Services," PhD Dissertation, Twente University ITC, Enschede.

Muehrcke. (1992). *Map Use*, J P Pubns, Madison, Wisconsin, USA, 647.

Muntz, R. R., Barclay, T., Dozier, J., Faloutsos, C., MacEachren, A. M., Martin, J. L., Pancake, C. M., Satyanarayanan, M., and Smith, T. (2003). *IT Roadmap to a Geospatial Future*, National Academic Press, Washington, D.C., 136.

NASA. (2006a). "Earth's Science Gateway." Accessed: January 10, 2007, *http://esg.gsfc.nasa.gov/*.

NASA. (2006b). "MODIS Web." Accessed: January 10, 2007, *http://modis.gsfc.nasa.gov/data/*.

NCGI. (2005). "NCGI Geografische Catalogus." Acessed: May 31, 2006, *http://www.ncgi.nl/catncgi/index.htm*.

Nebert, D. N. (2004a). "The Cookbook Approach." Developing Spatial Data Infrastructures: The SDI Cookbook, D. N. Nebert, ed., The Global Spatial Data Infrastructure Association.

Nebert, D. N. (2004b). "Developing Spatial Data Infrastructures: The SDI Cookbook." The Global Spatial Data Infrastructure Association.

Nebert, D. N. (2004c). "Geospatial Data Catalogue: Making Data Discoverable." Developing Spatial Data Infrastructures: The SDI Cookbook, D. N. Nebert, ed., The Global Spatial Data Infrastructure Association.

Nedovic-Budic, Z., Feeney, M.-E. F., Rajabifard, A., and Williamson, I. (2004). "Are SDIs Serving the Needs of Local Planning? Case Study of Victoria, Australia, and Illionis, USA." *Computers, Environment, and Urban Systems*, 28(4), 329-351.

Neumann, A., and Richard, D. (1999). "Internet Atlas of Switzerland - New Developments and Improvements." *International Cartographic Conference - ICA*, Ottawa, Canada, 251 - 260.

Nielsen, J. (1994). *Usability Engineering*, Morgan Kaufmann, San Fransisco., 362.

Nielsen, J. (2001). "Did Poor Usability Kill E-Commerce." *http://useit.com*.

Nielsen, J. (2003a). "Deceivingly Strong Information Scent Costs Sales." *http://useit.com*.

Nielsen, J. (2003b). "Information Foraging: Why Google Makes People Leave Your Site Faster." *http://useit.com*.

Nielsen, J., and Levy, J. (1994). "Measuring Usability: Preference vs. Performance." *Communications of The ACM*, 37(4), 66-75.

NISO. (2003). "Information Retrieval (Z39.50): Application Service Definition and Protocol Specification." Accessed: September 21, 2003, *http://www.niso.org/standards/resources/Z39-50-2003.pdf?CFID=22924590&CFTOKEN=51214436*. The National Information Standards Organization.

Nourbakhsh, I., Sargent, R., Wright, A., Cramer, K., Mclendon, B., and Jones, M. (2006). "Mapping Disaster Zones." Nature, 787-788.

NRC. (2006a). "The Atlas of Canada." Accessed: May 31, 2006, *http://atlas.nrcan.gc.ca/site/index.html*.

NRC. (2006b). "GeoConnections Discovery Portal." Accessed: May 31, 2006, *http://geodiscover.cgdi.ca*.

Oddens, R.P. (2007). "Bestand Nationale Atlassen - Stand van zaken dd 16-01-2007." Kaartenverzameling Faculteit Geowetenschappen, Utrecht.

OGC. (2004). "Geospatial Portal Reference Architecture." *OpenGIS discussion paper*, Accessed: May 31, 2006, *https://portal.opengeospatial.org/files/index.php?artifact_id=6669*. Open Geospatial Consortium Inc.

OGC. (2005). "OGC Catalog Services Specification." Accessed: May 31, 2006, *http://portal.opengeospatial.org/files/?artifact_id=5929&version=2*. Open Geospatial Consortium Inc.

OGC. (2006). "An Introduction to GeoRSS: A Standards Based Approach for Geo-Enabling RSS Feeds." Accessed: March 3, 2007, *http://www.opengeospatial.org/pt/06-050r3*. Open Geospatial Consortium Inc.

OGC. (2003a). "Critical infrastructure collaborative environment architecture: Computational viewpoint." Accessed: December 10, 2005, *http://portal.opengeospatial.org/files/?artifact_id=1269*. Open Geospatial Consortium Inc.

OGC. (2003b). "Critical infrastructure collaborative environment architecture: Engineering viewpoint." Accessed: December 10, 2005, *http://portal.opengeospatial.org/files/?artifact_id=1282*. Open Geospatial Consortium Inc.

OGC. (2003c). "Critical infrastructure collaborative environment architecture: Information viewpoint." Accessed: December 10, 2005, *http://portal.opengeospatial.org/files/?artifact_id=1271*. Open Geospatial Consortium Inc.

Olston, C., and Chi, E. H. (2003). "ScentTrails: Integrating Browsing and Searching on the Web." *ACM Transactions on Computer-Human Interaction*, 10(3), 177 - 197.

Onsrud, H. J., and Craglia, M. (2003). "Introduction to the special issues on access and participatory approaches in using geographic information." *Journal of the Urban and Regional Information Systems Association*, 15(Access and Participatory), 5 - 7.

Ormeling, F. J. Sr.(1979). "The Purpose and Use of National Atlases." *Cartographica*, 23(1979), 11-23.

Ormeling, F. J. (1993). "Ariadne's Thread - Structure in Multimedia Atlases." *ICA Conference*, Cologne.

Ormeling, F. J. (1995). "Atlas Information Systems." *International Cartographic Conference*, Barcelona, 2127-2133.

Ormeling, F. J. (1996). "Functionality of Electronic School Atlases." *ICA Commisions on National and Regional Atlases Workshop on Electronic Atlases: From CD-ROM to Internet*, Prague.

Ormeling, F. J. (1996). "Teaching Cartographic Concepts to Children." *the Joint ICA Commisions Seminar on Cognitive maps, Children and Education in Cartography*, Gifu, Japan, 120-135.

Ormeling, F. J. Sr. (1981). "Grote bosatlas : School atlas of the world." Wolters-Noordhoff, Groningen, 191.

Ormeling, F. J. (1992). "Traditional and Digital Atlas Structures." *ICA National and Regional Atlases Commission meeting*, Madrid, 355-365.

Ormeling, F. J. (1995b). "New Forms, Concepts, and Structures for European National Atlases." *Cartographic Perspectives*, 20, 12 - 20.

Ormeling, F. J. (1997). "Atlas Terminology and Atlas Concepts." *Modern Cartography for Navigating the Information Highway*, Bandung, 5 - 13.

Ormeling, F. J. (1997). "Cartographic Requirements For School Atlases: Structural Aspects." *Modern Cartography for Navigating the Information Highway*, Bandung, 27 - 34.

Ormeling, F. J., and Koop, R. O. (1990). "The Transition of a Paper National Atlas to a national Atlas Information System." *ICA National Atlases Comission Meeting*, Beijing, 82-90.

Paul, S., Haseman, W. D., and Ramamurthy, K. (2004). "Collective Memory Support and Cognitive-Conflict Group Decision-Making: An Experimental Investigation." *Decision Support Systems*, 36(2004), 261-181.

Paulson, L. D. (2005). "Building Rich Web Applications with Ajax." *Computer*, 38(10), 14-17.

PCGIAP. (2007). "Asia-Pacific Spatial Data Infrastructure (APSDI) Clearinghouse." Accessed: April 4, 2004, *http://nfgis.nsdi.gov.cn/apsdi/msearch.php*.

Peirce, C. S. (1955). "Logic as Semiotic: The Theory of Signs (published first in 1891)." Philosophical Writings of Peirce, J. Bulcher, ed., Dover Publications, New York, 98-119.

Peng, Z.-R. (2005). "A Proposed Framework for Feature-Level Geospatial Data Sharing: A Case Study for Transportation Network Data." *International Journal of Gegraphical Information Science*, Volume 19(Number 2), 459-481.

Peng, Z.-R., and Tsou, M.-H. (2003). *Internet GIS: Distributed geographic Information Services for the Internet and Wireless Networks*, John Wiley and Son, Hoboken, NJ, 720.

Pentland, B. T. (1999). "Building Process Theory with Narrative: From Description to Explanation." *Academy of Management*, 24(4), 711-724.

Perry, M. (2003). "Distributed Cognition." HCI Models, Theories, and Frameworks Toward Multidisciplinary Science, J. M. Carroll, ed., Morgan Kaufmann, San Fransisco, 193-223.

Peuquet, D. J., and Kraak, M.-J. (2002). "Geobrowsing: creative thinking and knowledge discovery using geographic visualization." *Information Visualization*, 1(1), 80-91.

Pirolli, P. (2003). "Exploring and Finding Information." HCI Models, Theories, and Frameworks Toward Multidisciplinary Science, J. M. Carroll, ed., Morgan Kaufmann, San Fransisco, 157 - 191.

Pirolli, P., and Card, S. (2005). "Information Foraging in Information Access Environments." *CHI'95*, Denver, Colorado.

Pirolli, P., and Card, S. K. (1999). "Information Foraging." *Psychological Review*, 106(4), 643-675.
Pirolli, P., Card, S. K., and Wege, M. M. V. D. (2003). "The Effects of Information Scent on Visual Search in The Hyoerpolic Tree Browser." *ACM Transactions on Computer-Human Interaction*, 10(1), 20-53.
Pitkow, j., and Pirolli, P. (1999). "Mining Longest Repeating Subsequences to Predict World Wide Web Surfing." *The 2nd USENIX Symposium on Internet Technologies & Systems*, Boulder, Colorado, 13.
Plaisant, C. (2005). "Information Visualization and the Challenge of Universal Usability." Exploring Geovisualization, J. Dykes, A. M. MacEachren, and M.-J. Kraak, eds., Elsevier, 53-82.
Powers, S. (2003). *Practical RDF*, O'Reilley & Associates Inc., Sebastopol, CA, 331.
Preece, J., Rogers, Y., and Sharp, H. (2002). *Interaction Design: Beyond Human-Computer Interaction*, John Wiley & Sons, New York.
Province of Overijssel (2007). "MIS Metadata Information System." http://intranet.overijssel.nl/.
Rajabifard, A., Feeney, M.-E. F., and Williamson, I. P. (2002). "Future Directions for SDI Development." *International Journal of Applied Earth Observation and Geoinformation*, 4, 11-22.
Rajabifard, A., Williamson, I. P., Holland, P., and Johnstone, G. (2000). "From Local to Global SDI Initiatives: a Pryramid of Buiding Blocks." *4th Global Spatial Data Infrastructure Conference*, Cape Town.
Rao, R., and Card, S. K. (2004). "The Table Lens: Merging Graphical and Symbolic Representations in an Interactive Focus+Context Visualization for Tabular Information." *SIGCHI '94*, Boston, MA., 318-322.
Riedl, M. O., and Young, R. M. (2006). "From Linear Story Generation to Branching Story Graphs." *IEEE Computer Graphics and Applications*, 26(3), 23-31.
Rinner, C. (2001). "Argumentation Maps: GIS-Based Decision Support for Online Planning." *Environment & Planning B - Planning & Design*, 28, 847-863.
Rinner, C. (2006). "Argumentation Mapping in Collaborative Spatial Decision Making." Collaborative Geographic Information Systems, R. Balram and S. Dragicevic, eds., Idea Group Publishing, Hershey, PA, 85-102.
Robertson, G. G., and Mackinlay, J. D. (2001). "Cone Trees: Animated 3D Visualizations of Hierarchical Information." *SIGCHI '91*, 189-194.
Robinson, A. H., Morrison, J. L., Muehrcke, P. C., Kimerling, A. J., and Guptill, S. C. (1995). *Elements of Cartography*, Wiley Text Books, 688.
Rodriguez, A., and Egenhofer, M. (2004). "Comparing Geospatial Entity Classes: An Asymmetric and Context-Dependent Similarity Measure." *International Journal of Geographical Information Science*, 18(3), 229-256.
Rodriguez, M. A., and Egenhofer, M. J. (2003). "Determining semantic similarity among entity classes from different ontologies." *IEEE Transcations on Knowledge and Data Engineering*, 15 (2), 442 - 456.
Rorvig, M., and Fitzpatrick, S. (2000). "Shape Recovery: A Visual Method for Evaluation of Information Retrieval Experiments." *Journal of the American Society for Information Science*, 51(13), 1205-1210.
Rose, D. E. (2006). "Reconciling Information-Seeking Behavior with Search user Interfaces for the Web." *Journal of the American Society for Information Science and Technology*, 57(6), 797-799.
Rosson, M. B., and Carroll, J. M. (2001). *Usability Engineering: Scenario-Based Development of Human Computer Interaction*, San Fransisco, CA, 448.
Rutledge, L., Alberink, M., Brussee, R., Pokraev, S., Dieten, W. v., and Veenstra, M. (2003). "Finding the Story - Broader Applicability of Semantics and Discourse for Hypermedia Generation." *Hypertext 2003*, Nottingham, UK.
Salichtchev. (1972). "National Atlases: Their history, Analysis, and Ways to Improvement & standardization." *Cartographica*, 4(1972).
Schafer, W. A., and Bowman, D. A. (2006). "Supporting Distributed Spatial Collaboration: An Investigation of Navigation and Radar View Techniques." *Geoinformatica*, 10(2), 123-158.
Schlieder, C., Vogele, T., and Visser, U. (2001). "Qualitative Spatial Representation for Infromation Retrieval by Gazetteers." *Conference of Spatial Information Theory, COSIT 2001*, Morrow Bay, CA, 338 - 351.

Schneider, B. (1999). "Integration of Analytical GIS functions in Multimedia Atlas Information Systems." *ICA Conference*, Ottawa.
Schreiber, A. T. G., Dubbelham, B., Wielemaker, J., and Wielinga, B. (2001). "Ontology-based photo annotation." *IEEE Intelligent Systems*, 16 (3), 66 - 74.
Schroeder, M. (2005). "Intelligent Information Integration: From Infrastructure through Consistency Management to Information Visualization." Exploring Geovisualization, J. Dykes, A. M. MacEachren, and M.-J. Kraak, eds., Elsevier, 477-494.
Schuurman, N., and Leszczynski, A. (2006). "Ontology-Based Metadata." *Transactions in GIS*, 10(5), 709-726.
Shiffrin, R. M., and Borner, K. (2004). "Mapping knowledge domains." *PNAS Proceedings of the National Academy of Sciences of the United States of America*, 101 (Suppl. 1)(Mapping knowledge domains), 5183-5185.
Shneiderman, B. (1997). "Designing Information-abundant Web Sites: Issues and Recommendations." *International Journal Human-Computer Studies*, 47, 5-29.
Shneiderman, B. (1998). *Designing the user interface*, Addison-Wesley, Menlo Park, 509 - 551.
Shneiderman, B., Byrd, D., and Croft, W. B. (1997). "Clarifying search: A user interface framework for text searches." *DLIB Magazine*(January 1997).
Shum, S. B., and Hammond, N. (1994). "Argumentation-Based Design Rationale: What Use at What Cost?" *International Journal Human-Computer Studies*, 40(4), 603-652.
Simon, H. A. (1977). *The New Science of Management Decision*, Prentice-Hall, Englewood Cliffs, NJ, 175.
Skupin, A., and Fabrikant, S. I. (2003). "Spatialization Methods: A Cartographic Research Agenda for Non-geographic Information Visualization." *Cartography and Geographic Information Science*, 30(2), 95-115.
Slocum, T. A., Blok, C., Jiang, B., Koussoulakou, A., Montello, D. R., Fuhrmann, S., and Hedley, N. R. (2001). "Cognitive and Usability Issues in Geovisualization." *Cartography and Geographic Information Systems*, 61 - 75.
Souza, R., Manning, H., Goldman, H., and Tong, J. (2000). "The Best of Retail Site Design." Forrester Research Inc., Cambridge, MA.
Spoerri, A. (2004). "Coordinated Views and Tight Coupling to Support Meta Searching." *CMV '04*, London, England, 1-10.
Stams, W. (1978). *National and regional atlases : a bibliographic survey : up to and including 1978*, International Cartographic Association (ICA), . 249
Stuckenschmidt, H., and Harmelen, F. v. (2001). "Ontology-Based Metadata Generation from Semi-Structured Information." *International Conference On Knowledge Capture*, Victoria, BC, 163-170.
Stuckenschmidt, H., and Harmelen, F. v. (2004). "Generating and Managing Metadata for Web-Based Information Systems." *Knowledge-Based Systems*, 17, 201-206.
Sutcliffe, A. G. (2000). "On the Effective Use and Reuse of HCI Knowledge." *ACM Transactions on Computer-Human Interaction*, 7(2), 197-221.
Sutcliffe, A. G., and Carroll, J. M. (1999). "Designing Claims for Reuse in Interactive Design." *International Journal Human-Computer Studies*, 50, 213-241.
Sutcliffe, A. G., Ennis, M., and Hu, J. (2000). "Evaluating the Effectiveness of Visual Interfaces for Information Retrieval." *International Journal Human-Computer Studies*, 53, 741-763.
Symons, T. H. B. (1979). "Some Thoughts on the Nature and value of national and Regional Atlases." *Cartographica*, 23(1979), 1-10.
Tait, M. G. (2005). "Implementing Geoportals: Applications of Distributed GIS." *Computer Environment and Urban Systems*, 29(Geoportal), 33 - 47.
Talwar, S., Journeay, M., Harrap, R., Broadric, B., Ulden, J. v., Grant, R., and Denny, S. (2003). "The Georgia basin Digital Library (GBDL): A Framework For A Place-Based Exploration of Sustainability Issues." *Geomatica*, 57(No. 2), 155 - 164.

Thapa, K., and Bossler, J. (1992). "Accuracy of Spatial Data Used in Geographic Information Systems." *Photogrammetric Engineering & Remote Sensing*, 58(6), 835-841.

Thomas, J. J., and Cook, K. A. (2005). "Illuminating the Path: The Research and Development Agenda for Visual Analytics." National Visualization and Analytics Center, 200.

Tsou, M.-H. (2002). "An Operational Metadata Framework for Searching, Indexing, and Retrieving Distributed Geographic Information Services on the Internet." *Second International GIScience 2002*, Boulder, Colorado, 333 - 345.

Tsou, M.-H. (2006). "Bridging the Gap: Connecting Internet-Based Spatial Desicion Support Systems to the Field-Based Personel with Real Time Wireless Mobile GIS Applications." Collaborative Geographic Information Systems, R. Balram and S. Dragicevic, eds., Idea Group Publishing, Hershey, PA, 317-339.

Tufte, E. R. (2001). The Visual Display of Quantitative Information, Graphic Press, Chesire, Connecticut, 197.

Tversky, B. (2000). "Some Ways that Maps and Diagrams Communicate." Spatial Cognition II: Integration, Abstract, Theories, Empirical Studies, Formal Models, and Powerful Applications, C. Freska, W. Brauer, C. Habel, and F. Wender, eds., Springer, Berlin, 72-79.

USGS. (1995). "USGS natural Hazards Programs: Lessons Learned for Reducing Risk." Accessed: May 31, 2006, *http://water.usgs.gov/wid/html/HRDS.html*.

USGS (2006). "Geospatial One Stop." Accessed: May 31, 2006, *http://gos2.geodata.gov/wps/portal/gos*.

Veltkamp. "Shape Matching: similirity measures and algorithms." *Shape Modelling and Applications SMI 2001*, Genova, Italy.

W3C. (1999). "XML Path Language (XPath)." Accessed: May 31, 2006, *http://www.w3.org/TR/xpath*.

W3C. (2003). "Basic Geo (WGS84 lat/long) Vocabulary." Accessed: May 31, 2006, *http://www.w3.org/2003/01/geo/*.

W3C. (2004). "RDF/XML Syntax Specification (Revised)." Accessed: May 31, 2006, *http://www.w3.org/TR/rdf-syntax-grammar/*.

W3C. (2006a). "SPARQL Query Language for RDF." Accessed: May 31, 2006, *http://www.w3.org/TR/rdf-sparql-query/*.

W3C. (2006b). "SPARQL Query Language for RDF - Formal Definitions." Accessed: May 31, 2006, *http://www.w3.org/TR/rdf-sparql-query/sparql-defns.html*.

W3C. (2006c). "SPARQL Query Results XML Format." Accessed: May 31, 2006, *http://www.w3.org/TR/rdf-sparql-XMLres/*.

Wahid, S., and McCrickard, D. S. (2006). "Claims Maps: Treasure Maps for Scenario-Based Design." *World Conference on Educational Multimedia/Hypermedia and Educational Telecommunications (ED-MEDIA 06)*, Orlando, FL, 553-560.

Wainer, H., and Spence, I. (2005). "Playfair's Commercial and Political Atlas and Statistical Breviary." Cambridge University Press, New York, 248.

Walsh, K. A., Pancake, C. M., Wright, D. J., Haerer, S., and Hanus, F. J. (2002). "Humane" Interfaces to Improve the Usability of Data Clearinghouses." *Second International GIScience 2002*, Boulder, Colorado, 333 - 345.

Ware, C. (2004). *Information Visualization: Perception for Design*, Morgan Kaufmann, San Francisco.

Wasserman, S., Faust, K., and Iacobucci, D. (1994). *Social Network Analysis: Methods and Applications*, Cambridge University Press, Cambridge.

Wegener, M., and Masser, I. (1996). "Brave New GIS Worlds." GIS Diffusion: The Adoption and Use of Geographical Information Systems in Local Government in Europe, M. Craglia and H. Campbell, eds., Taylor Francis, London, 9-22.

Wehrend, S., and Lewis, C. (2000). "A Problem-Oriented Classification of Visualization Techniques." *1st IEEE Conference on Visualization*, San Fransisco, CA., 139-143.

White, A. (2006). "Measuring the Benefits of AJAX." Accessed: May 31, 2006, *http://www.developer.com/java/other/article.php/10936_3554271_1*.

Whitley, E., and Ball, J. (2002). "Statistics Review 6: Nonparametric Methods." *Critical Care Forum*, 6(6), 509-513.
Williams, D., O'Brien, D., and Kramers, E. (2003). "The Atlas of Canada Web Mapping: the User Counts." *Cartographic Perspectives*, 44(Winter 2003), 8 - 29.
Williams, J., and Neumann, A. (2006). "Integrating OGC WMS Services with SVG mapping applications." Accessed: May 31, 2006, *http://www.carto.net/papers/svg/ogc_wms_integration/*.
Williamson, I. (1997). "The Future of The Surveying Profession - an Australian Perspective." *Geomatica*, 51(4), 387-399.
Williamson, I., Rajabifard, A., and Feeney, M.-E. F. (2003). "Developing Spatial Data Infrastructures: From Concept to Reality." Taylor and Francis, London, 316.
Wolf, P. R. (2002). "Surveying and Mapping: History, Current Status, and Future Projections." *Journal of Surveying Engineering*, 128(3), 79-107.
Wood, D. (1992). *The Power of Maps*, The Guilford Press, New York, 248.
Woodruff, A., Faulring, A., Rosenholtz, R., Morrison, J., and Pirolli, P. (2001). "Using Thumbnails to Search the Web." *CHI*, Seattle, WA, 198-205.
Wytzisk, A., and Sliwinki, A. "Quo Vadis SDI?" *7th AGILE Conference on Geographic Information Science*, Heraklion, Greece, 43-49.
Yahoo! (2007). "Yahoo! Local." Accessed: May 31, 2007, *http://local.yahoo.com*.
Yee, K.-P., Swearingen, K., Li, K., and Hearst, M. (2003). "Faceted metadata for image search and browsing." *Human Factors in Computing Systems*, Ft. Lauderdale, Florida, US, 401 - 408.

## URLs

Web addresses of the national / regional geoportals reviewed in Chapter 2

| National / regional geoportals | URL / web addresses |
|---|---|
| Canada Geoportal | http://geodiscover.cgdi.ca/ |
| GOS (U.S. Geospatial One Stop) | http://gos2.geodata.gov/wps/portal/gos |
| ESRI Geography Network | http://www.geographynetwork.com/ |
| Inspire Geoportal | http://eu-geoportal.jrc.it/gos |
| Netherlands | http://www.ncgi.nl/ |
| Germany | http://geoportal.bkg.bund.de/ |
| The Asia Pacific clearinghouse (APSDI) | http://nfgis.nsdi.gov.cn/apsdi/msearch.php |
| Australia | http://asdd.ga.gov.au/ |
| Japan | http://zgate.gsi.go.jp/ |
| Malaysia | http://www.mygeoportal.gov.my |
| South Africa | http://www.nsif.org.za/ |

# Appendix A

**Searching via the Aim4GDI**

The evaluation scenario & questionnaire for assessing the search interfaces of the Aim4GDI

**The evaluation scenario**

Consider the following to be the situation that you face at the moment:
Your GIS group got a new task from the office to start a traffic survey campaign. The objective of this campaign is to study the environmental suitability of the plan by the central government and the province to extend pedestrian and public road networks for the whole Province of Overijssel.

To support this campaign, your team leader requires you as the GIS Specialist in the group to produce a noise map of the Province of Overijssel. To produce this map, you need road networks, environment and sound measurements, and population characteristics. In this search context, **we asked you to focus to search for transportation/road-related and environmental issues-related data covering the province of Overijssel** that are offered **as GIS data format, at a scale**, when possible **larger than 1:25.000.**

**A.1. The first search test (presented in Chapter 4)**

The questionnaire to be completed:

A. The table view

| Statements | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| 1. Presenting the search results as a table view was helpful (in my search's context) to indicate which data matched to what I looked for. | | | | | |
| 2. I was able to compare items in the search results | | | | | |
| 3. The "**Tooltip**" helped me to indicate the data to be selected | | | | | |
| 4. The "**semantic relevance**" information was intuitive | | | | | |
| 5. The "**geographic relevance**" information is intuitive | | | | | |
| 6. Sorting functions helped me to make a priority during reviewing the results | | | | | |
| 7. Opportunities to project the metadata footprints to the basic map was helpful for my search's context | | | | | |

## B. The thumbnail view

| Statements | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| 1. Presenting the search results as a set of thumbnails was helpful (in my search's context) to indicate which data matched to what I looked for. | | | | | |
| 2. I was able to compare items in the search results | | | | | |
| 3. The "Tooltip" helped me to indicate the data to be selected | | | | | |
| 4. Opportunities to project the metadata footprints to the basic map was helpful | | | | | |

## C. The bull's eye view

| Statements | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| 1. Presenting the search results as a set of points on top of bulls-eye display is helpful (in my search's context) to indicate which data matched to what I looked for. | | | | | |
| 2. I was able to compare items in the search results | | | | | |
| 3. The "**Tooltip**" helped me to indicate the data to be selected | | | | | |
| 4. The distance from the query to a single metadata item was understandable (**geographic relevance**) | | | | | |
| 5. The size of metadata item representing the frequency of matched keywords was understandable (**thematic relevance**) | | | | | |

D. The working environment

| Statements | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| QA. I can express my search queries using where-what tabs | | | | | |
| QB. The idea to have linked displays in forms of table, thumbnail, and bullseye can be organised well using tabs: table, thumbnails, bulls eye | | | | | |
| QC. With such a map view and mapping capabilities (cascading thematic layers and metadata footprints), I got supporting information to successfully complete my project | | | | | |
| QD. Thumbnails add more confidence in judging the data suitability | | | | | |
| QE. I would like to use this kind of search interfaces in my daily GIS projects | | | | | |

### A.2. The second search test (presented in Chapter 6)

A.2.1. Steps to follow

1. First, double click **Camstudio** program in your desktop to start recording your interaction
2. Using **Camstudio**, set **Region** as: **FullScreen** and click the red circle to start recording.
3. Navigate your browser (use Internet Explorer only!) to go to the AIM4GDI atlas website using “**Atlas**” internet shortcut located in T:_Mytest\
4. Click once to a small image of magnifying glass to open and close the **Explorer** tool. Use the emerging Explorer window to define keywords and initiate your search.
5. Define your “**where**” and “**what**” search terms (related to location and thematic or usage attributes respectively). Regarding the “what” tab, only keywords (and topic) inputs are activated in this test.
   **Tips**: In defining an area of interest, you can type a place name (e.g., Overijssel) or draw a box on top of the main map.
6. Assess the search results in the **Explorer View** tab using **table**, **thumbnail**, and **PCP** (Parallel Coordinate Plots) views.
7. Stop the **Camstudio** recording and save the file in T:_MYTEST and named it as: [**yourcomputername_ labelled_in_the_computer_case]_A**
8. Complete the following questionnaire.

## A.2.1. The questionnaire for the second search test

Please provide responses to all statements listed (select one of options available) and use “note” column <u>only</u> when you think you need to add comments

| Statements | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| 1. Using the table view, I can indicate easily the data to be selected for my project | | | | | |
| 2. The sorting functionality in the table view helps me to make priority of the selection | | | | | |
| 3. The “semantic relevance” information in the table is helpful | | | | | |
| 4. The “geographic relevance” information in the table is helpful | | | | | |
| 5. Using the thumbnail view, I can indicate easily the data to be selected for my project | | | | | |
| 6. Using the graphic PCP view, I can indicate easily the data to be selected for my project | | | | | |
| 7. Using the table view, I was able to compare items in the search results | | | | | |
| 8. Using the thumbnail view, I was able to compare items in the search results | | | | | |
| 9. Using the PCP view, I was able to compare items in the search results | | | | | |
| 10. Possibilities to project metadata footprints on top of a map view are helpful | | | | | |
| 11. The display & interaction in metadata legend is helpful | | | | | |

Specify at least one (and maximum three) item in the search results that you consider as the best matches suiting your need to produce a noise map.

# Appendix B

**Searching via the GeoNetwork**

The evaluation scenario & questionnaire for assessing the search interfaces of the GeoNetwork

### The evaluation scenario

Consider the following to be the situation that you face at the moment:
Your GIS group got a new task from the office to start a traffic survey campaign. The objective of this campaign is to study the environmental suitability of the plan by the central government and the province to extend pedestrian and public road networks for the whole Province of Overijssel.

To support this campaign, your team leader requires you as the GIS Specialist in the group to produce a noise map of the Province of Overijssel. To produce this map, you need road networks, environment and sound measurements, and population characteristics. In this search context, **we asked you to focus to search for transportation/road-related and environmental issues-related data covering the province of Overijssel** that are offered **as GIS data format, at a scale**, when possible **larger than 1:25.000.**

I. Steps to follow

1. First, double click **Camstudio** program in your desktop to start recording your interaction
2. Using **Camstudio**, set **Region** as: **FullScreen** and click the red circle to start recording.
3. Navigate your browser (use Internet Explorer only!) to go to Geonetwork portal using "**Geonetwork**" internet shortcut located in T:_Mytest\
4. Using the first page of the website, define your search terms via FreeText input widgets or you can click the "advanced search" button to advance your search query.
5. Assess the search results presented in the immediate page returned after you click the search button.
6. Stop the **Camstudio** recording and save the file in T:_MYTEST and named it as: [**yourcomputername_ labelled_in_the_computer_ case]_B**
7. Complete the following questionnaire.

## II. Questionnaire to be completed

Please provide responses to all statements listed (select one of options available) and use "note" column <u>only</u> when you think you need to add comments

| Statements | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| 1. Using the Geonetwork interface, I can indicate easily the data to be selected for my project | | | | | |
| 2. Using the Geonetwork interface, I was able to compare items in the search results | | | | | |
| 3. The preview graphics or thumbnails in the search results are helpful | | | | | |
| 4. The metadata display as a result of a click in the items of search results is helpful for my search context | | | | | |

Specify **at least one (and maximum three)** item in the search results that you consider as the best matches suiting your need to produce a noise map.

# Appendix C

**Browsing via the Aim4GDI**

The evaluation scenario & questionnaire for assessing the search interfaces of the GeoNetwork

### The evaluation scenario

Consider the following to be the situation that you face at the moment:
Your GIS group got a new task from the office to start a traffic survey campaign. The objective of this campaign is to study the environmental suitability of the plan by the central government and the province to extend pedestrian and public road networks for the whole Province of Overijssel.

To support this campaign, your team leader requires you as the GIS Specialist in the group to collect relevant geospatial and non-geospatial information for the topic of Transportation, Environment, and Agriculture. One of information resources that you as a GIS specialist would like to look at is the web national or regional atlas. For this search context, **we asked you to focus to interact with information resources organised in the topics of Environment and Agriculture (or Transportation).**

I. Steps to Follow

1. First, double click **Camstudio** program in your desktop to start recording your interaction
2. Using **Camstudio**, set **Region** as: **FullScreen** and click the red circle to start recording.
3. Navigate your browser (use Internet Explorer only!) to go to the AIM4GDI atlas website using “**Atlas**” internet shortcut located in T:_Mytest\
4. Start your browsing activities by opening topics → available maps → GDI story teller & Atlas storyteller (and the resulting links in storyteller view).
5. See the resulting links in storyteller view
6. Try to interact with geospatial resources available by projecting metadata footprints as well as loading and cascading a WFS (Web Feature Services offered especially linked to Environment) on top of map layers and interact with the legend.
7. Stop the **Camstudio** recording and save the file in T:_MYTEST and named it as: [**yourcomputername_ labelled_in_the_computer_ case]_C**

## II. Questionnaire to be completed

Please provide responses to all statements listed (select one of options available) and use "note" column <u>only</u> when you think you need to add comments

| **Statements** | **Strongly Agree** | **Agree** | **Neutral** | **Disagree** | **Strongly Disagree** | Note |
|---|---|---|---|---|---|---|
| 1. The navigation/browsing system within the atlas application (topic → maps → GDI/Atlas storyteller → GDI/Atlas resources) has a clear structure | | | | | | |
| 2. The switch options: (browsing by topics/area) are helpful. I can be guided easily to browse specific topics for a specific area of interest | | | | | | |
| 3. The presented perspective in the "storyteller-view" is well organised. | | | | | | |
| 4. The thumbnail display is helpful to locate the required information | | | | | | |
| 5. The Parallel Coordinate Plots (PCP) display is helpful to indicate which data id suitable to be used. | | | | | | |
| 6. The Parallel Coordinate Plots (PCP) display is helpful to compare the available resources. | | | | | | |
| 7. The newly emerging box displaying the selected resource in PCP and thumbnail is informative | | | | | | |
| 8. I can see the items displayed as an interrelated group of resources | | | | | | |
| 9. Opportunities to project metadata footprints on top a map view are helpful | | | | | | |
| 10. An Opportunity to load item termed as WFS directly into the map is helpful | | | | | | |
| 11. Combining thematic layers in the atlas with metadata footprints and WFS is helpful in my search's context | | | | | | |

# Appendix D

**Collaborating via the AIm4GDI**

The evaluation scenario & questionnaire for assessing the collaborative use of the Aim4GDI

### The evaluation scenario

***Consider the following to be the situation that you face at the moment:***
Your GIS research group got a new task from the office to start a traffic survey campaign. The objective of this campaign is to study the environmental suitability of the plan by the central government and the province to extend pedestrian and public road networks for the whole Province of Overijssel and especially in the southwest region of the Province (such as the Municipality of Enschede and its surrounding).

The traffic survey aims at measuring traffic noise, with emphasis on the distribution of sound levels over time and over population. Additionally, the survey should also collect people's perceptions regarding their environment. The project considers all factors associated with the physical like *built up areas* and *environmentally dangerous objects* (e.g., ammonia and nuclear from industry) and non physical environments including demography such as the *population distribution* in terms of gender and geographic distribution. For this reason, your group sets up a collaborative work, aiming at **indicating most suitable locations (points) where traffic measurements should be done** and **neighbouring villages should be surveyed**. The point's indication should consider the information resources availability and objectives of the survey (hence, data related to road networks are crucial). Further investigation and clarification should be processed after this session. Your GIS research group is a consortium research built upon two cooperating research institutions in the Netherlands. The points' indication activity will be done collaboratively involving three collaborators. They consist of a spatial planner, an environmental specialist and a technical assistant. During the collaboration, they all work in different places but in the same time (synchronous) using the Atlas Metaphor as a main interface.

The main tasks that should be dealt with involve: browsing information through the atlas (**Exploration**), loading map layers and web feature services (WFS), **deciding where** the survey should be conducted, and discuss the solution (**Analysis & Synthesis**).

I. Steps to follow

| Co-Worker (Role: Planner) | Co-Worker (Role: Environmentalist) | Help Assistant |
|---|---|---|
| • Open the collaboration using YahooMessenger | | |
| | • Join the conference | • Join the conference |
| • Using **Camstudio**, set **Region** as: **FullScreen** and click the red circle to start recording. | | |
| • Navigate your browser (use Internet Explorer only!) to go to the AIM4GDI atlas website using “**Atlas**” internet shortcut located in T:_Mytest\ | | |
| • Login into the atlas, supply: your **username** and password:**aim4gdi** and select : **Collaborative Planning** session | | |
| • Start your browsing activities by opening topics → available maps → GDI story teller & Atlas storyteller (and the resulting links in storyteller view). | | |
| • Try to interact with geospatial resources available by projecting metadata footprints as well as loading and cascading a WFS (Web Feature Services offered especially linked to Environment) on top of map layers and interact with the legend. | | |
| • Load and discuss maps related to environment | • Load a WFS (as a result from exploration activity done earlier – yellow blocks) of Environmental Objects in Environment topic | |
| | | • Do some colour changes to the layers opened by the others |
| • Start indicating the locations for survey | | |
| | • Agree / Propose other / Discuss the alternatives | • Agree / Propose other / Discuss the alternatives |
| • Summarising the discussion | • Discuss | • Wrapping up all points (pins and annotations) made to be accessible as a printable document for further discussion |
| • Stop the **Camstudio** recording and save the file in D:\ and named it as: **yourname_D** | | |

## II. Questionnaire to be completed

Please provide responses to all statements listed (select one of options available) and use “note” column only when you think you need to add comments

| Statements | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree | Note |
|---|---|---|---|---|---|---|
| **EXPLORATION (INDIVIDUAL USE)** | | | | | | |
| 1. The navigation/browsing system within the atlas application (moving from topic → maps → GDI/Atlas storyteller → GDI/Atlas resources) has a clear structure. | | | | | | |
| 2. The switch options: (browsing by topics/area) are helpful. I can be guided easily to browse specific topics for a specific area of interest. | | | | | | |
| 3. The presented perspective in the “storyteller-view” is well organised. | | | | | | |
| 4. The thumbnail display is helpful to locate the required information. | | | | | | |
| 5. The Parallel Coordinate Plots (PCP) display is helpful to indicate which data is suitable to be used. | | | | | | |
| 6. The newly emerging box displaying the selected resource in PCP and thumbnail is informative | | | | | | |
| 7. I can see the items displayed as an interrelated group of resources. | | | | | | |
| 9. An Opportunity to load item termed as Web Feature Service (WFS) directly into the map is helpful. | | | | | | |
| 10. Combining thematic layers in the atlas with metadata footprints and WFS is helpful in my search’s context. | | | | | | |
| **GROUP AWARENESS (COLLABORATIVE USE)** | | | | | | |
| 11. The display of “Who are online” is helpful for the group. | | | | | | |
| 12. Map overview showing my area of interest and others’ area of interest is helpful for the group. | | | | | | |
| 13. Displaying map layers and WFS that are opened or seen by others is helpful for the group. | | | | | | |
| 14. A synchronization of colour changes is helpful. | | | | | | |
| 15. Collaborative drawing of Point Markers (indicating points using critical-warning-info) is helpful. | | | | | | |
| **OVERALL TASKS (COLLABORATIVE USE)** | | | | | | |
| 16. Exploratory work for a collaborative work can potentially be supported by this atlas. | | | | | | |
| 17. I can do some basic analyses of data availability and survey feasibility collaboratively. | | | | | | |
| 18. I can gain an information synthesis from interacting with the atlas collaboratively. | | | | | | |

# Appendix E
## Participatory Design Form

**Providing Claims Feedback:**
Read and follow two scenarios presented below. Your task is to provide us downsides or negative comments regarding the claim that we made concerning the use of a specific interface for the given context. (e.g., - But this may confuse me to compare items…).
You are free to provide your objections as much as you want.

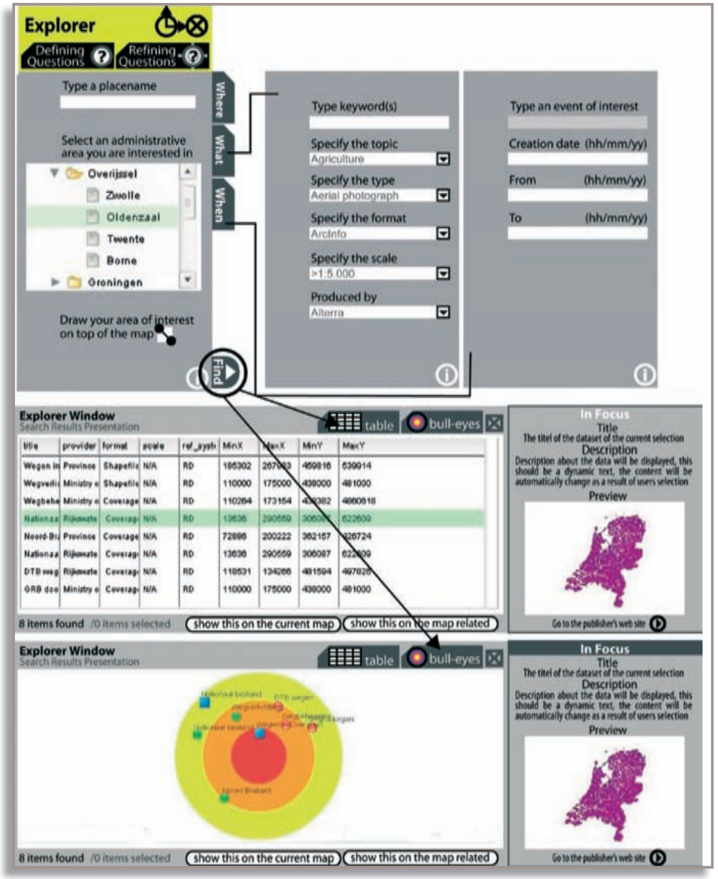
**SCENARIO I**
**Situation:**
"I want to get basic data covering Oldenzal with shp or Arc format and the scale for the data is less than 500,000"
Action:
- Click the Where tab to define area-related questions
- Click the What tab to define attributes (free keywords, the format and scale for example)
- Click the When tab to define the time of interest (when required)
- Click Find …and the results are presented in a table (the results are sortable)

(see the paper prototype for scenario I)

**SCENARIO II**
**Situation:**
For his research project, Andy needs several data sets related to plantation issues and soil type for areas of Haaksbergen and Kampen municipalities in the provice of Overijssel. Using a web atlas: Atlas van Nederland, he browses several relevant maps under the topic of Biota. He knows that using this interface he can also load an OGC compliant web map presenting soil type of the Overijssel province offered by the GIS bureau of the provice. He then load this particular map service. After doing some basic visual analysises he then decide: "I want to select the most recent data related to this particular map (i.e. a plantation map)"
Action:
- Opening the Storyteller View
- Without leaving the current browsing activity, he starts "Comparative view" ("Comparing items" pop-up window on the screen) by click its menu on the bottom of legend window.
- Then he selects datasets to be shown and chooses a specific representation mode for comparing items of metadata
- The items displayed can be filtered by limiting the area of interest or by selecting specific metadata attributes

(see the paper prototype for scenario II)

Paper prototype for scenario I



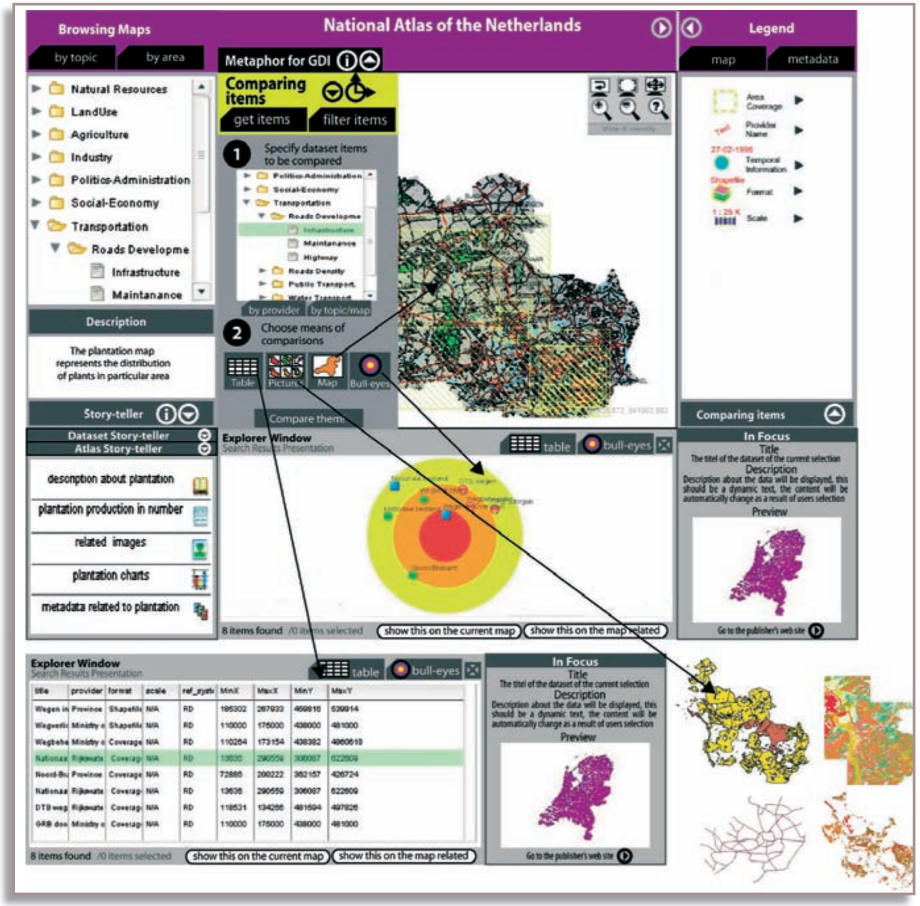

**Claim: Providing systematic means for expressing queries to find specific dataset is urgent**

+ simplify efforts to formulate questions to get data with some already known attributes
- but….
- but….

**Claim: Providing familiar a table representation for assessing the match is effective to help users review the results**

+ simplify efforts to review search results data with some criteria / attributes already in hand
- but….
- but….

Paper prototype for scenario II




**Claim: The ability to compare metadata items during a browsing session is necessary**
+make the search process becomes easier
- but…….

**Claim (for Browsing maps): Allowing users to browse maps by topic or area of interest**
+ Provide a clear structure for focusing the search interest and exploring structure of the atlas
- but…

**Claim (for Storyteller view): Helping users access the related information (using graphics like charts and images) effectively and efficiently**
+ Providing a broad exploration to the epecific context users interested
- but…..

# Acknowledgements

I would like to take this opportunity to acknowledge so many people for their various contributions to my study. However, before to do that, I would first like to thank the ITC for the research funding that I received, as well as to the Utrecht University for their financial contribution during the initial period of my research.

First, I am deeply indebted to my supervisors, Prof. Dr. Menno-Jan Kraak and Prof. Dr. Ferjan Ormeling, for their endless trust and support to turn the initial research ideas over to me. I am honoured to have them as my two outstanding gurus who guided me through my PhD study. I would like to thank them for their insightful and valuable advices and feedback on my work. Their scientific supervision and contribution greatly helped improve the quality of the research presented here. When I needed to talk about my research ideas or my personal difficulties, Pak Menno-Jan always had time to listen and respond with empathy. Pak Ferjan has never run out of thoughtful and encouraging words anytime I needed during my research study.

Next, I would like to convey my sincere gratitude to all GIP staff members at the ITC for an enjoyable working atmosphere. Drs. Barend Köbben provided me with professional advice on SVG matters. Dr. Rob Lemmens introduced me to the wild world of the geo semantic web - which was very useful for the development of this thesis. Wim Feringa supported me with his graphic design expertise. During my literature review, Dr. Corné van Elzakker and Dr. Rolf de By shared their useful hints, and at the end of this study, Corné helped me translate the summary into Dutch. Bas Retsios assisted me with his Space-Time Cube software component. I am also grateful to my fellow PhD students in the department: Ulan Turdukulov, Eddie Poppe, and Theodor Foerster for many discussions that contributed to this work. Theo also helped me on many occasions with his expertise in Java programming.

Doing research at the ITC was a pleasant experience, thanks to the outstanding support from research and library offices as well as from educational and IT affairs. I would like to thank Prof. Dr. Martin Hale, Loes Colenbrander, Carla Gerritsen, Petry Maas-Prijs, Theresa van den Boogaard, Marie-Chantal Metz, Thea de Kluijver, Bettine Geerdink, Ard Kosters, and Ard Blenke. I also wish to thank Drs. Tom Loran, Dr. Yousif Hussin, Dr. Erik de Man and Dr. David Rositter for their prudent advice in various stages of my study. I also like to thank former and current fellow PhD students at the ITC, especially Dr. Etien Koua, Dr. Daniel van der Vlaag, Dr. Arta Dilo, Richard Onchaga, Enrique Castellanos, Ajay Katuri, Peter Minang, Fouad Khaier, Graciela Peters Guarin, Cho Moses Azong, and Istiak Sobhan for the fruitful discussions and kind feedback. This thesis and some papers produced during my study could have not been written without helpful feedback from 64 individuals who participated in various user research activities that I initiated. I thank all of them and I apologize for not mentioning all of their names here.

I would also like to thank people outside the ITC for their co-operation and interests. To Drs. Martijn Sorms and Drs. Elger Heere for their helpful discussions during my research days at the Utrecht University. To Ir. Leen Murre (LSV-GBKN), Dr. Joep Crompvoets (University of Wageningen) for their willingness to be interviewed. To Drs. Ruby Beltman (Geodan), Edmond Muller (Alterra), Lammert Jan Beumer, André Weijmer, Peter Auke Nicoalj (Province Overijssel) for their willingness to share their data for my research. I would also like to thank Andy Seaborne, Leigh Dodd and Andreas Neumann for their useful discussions about RDF Query and SVG. I also enjoyed the discussions on the making of web mapping with Edward Mac Gillavry.

My research trip from the Netherlands to US proved to be very useful. I am honoured to have had the opportunity to meet another inspiring guru in the field of my research, Prof. Dr. Alan MacEachren. I thank him for the financial support that allowed me to study Geocollaboration at the GeoVista Centre and for his helpful comments and suggestions, which have significantly improved the quality of this thesis. I thank members of the GeoVista Centre for useful discussions during my visit at PSU.

I would also like to convey my sincere gratitude to my home organization in Indonesia: the Gadjah Mada Univeristy for their support. I thank Prof. Dr. Sudjarwadi M.Eng (now the Rector) for his encouragement and the members of staff in the Department of Geodetic & Geomatics Engineering, especially: Ir. Aryono Prihandhito MSc., Ir. Sumaryo Msi, Dr. Ir. Subaryono MA., Heri Sutanta ST., MSc., Ir. Djurjani M.Eng, Ir. Priyono Nugroho MS., and Ir. Soeta'at Dipl. PhE. for their support and various help during my study at the ITC. This research was initially targeted Indonesia as one of case studies. However, although that case study is not presented in this thesis, I would thank Dr. Aris Poniman, Ir. Bebas Purnawan MSc., Drs. Suharto Widjojo MA in The National Coordinating Agency for Surveys and Mapping (Bakosurtanal) for their commitment as well as useful discussions and data. I do really hope our shared vision for a National Atlas of Indonesia can be realized in the distant near future.

Returning back to Enschede, I wish to thank fellow Indonesian students and residents for their friendship and solidarity over the years. My personal thanks goes to great individuals of Indonesian ITCers during my stay in Enschede (everyone of them are very special to me!) as well as David, Adit, Dion, Tante Hadi/Oom Stan, Tante Siti, Mbak Rini de Vries, Bu Nung and Pak Hadi for their help throughout many episodes during my stay in Enschede with my family. My sincere thanks and apologies to so many good fellow Indonesians, who have been so kind and helpful but who are not mentioned herein. We got to know and enjoyed the Netherland's hospitality from Joostens's family and Welhuis's family. Gerda and Herman Joostens are especially thanked for their wonderful support and their care. Herman, thanks a lot for your thoughtful friendship and for many exciting discussions; and for your wonderful gift of the *Atlas van Tropisch Nederland*.

Finally, I am truly thankful for the tremendous support from my family, including my sister and brother as well as my wife's brothers and sister and all their families who have always been very helpful and supportive. I wish to express my deep gratitude to my father as well as to my wife's father and mother for their distant support and prayers. My mother was the person who always supported and encouraged me to pursue higher education. I lost her in the early stage of my PhD study long before I could present this thesis to her. But I am glad to still have her in my memories and prayers.

This PhD journey would have never been completed without unwavering support from my beloved wife, Diana, who has always been smart and helpful in all aspects during the ups and downs of my journey. She has sacrificed a lot in so many areas of her life just to make sure everything is going well with me and with this PhD. I am really grateful for her great loyalty in believing in my dreams and abilities. My little girl, Tara has always brought out great joy including in the difficult times during the course of my study with her lovely smile and creativity. There were times I shared the screen, half for my work and half for her favourite cartoon movie, simply just to enable me to listen to her singing along with "Dora the Explorer" or "My Little Pony" to ease the tough parts of my PhD. That was a mutual collaboration, usually. I owe many thanks to them for their excellent companionship and I am optimistic about my future journey after PhD with their company.

# Curriculum Vitae

| | | |
|---|---|---|
| Complete Name | : | Trias Aditya Kurniawan Muhammad |
| Place & Date of Birth | : | Yogyakarta, April 22, 1975 |
| Education | : | - Bachelor of Engineering in Geodetic Engineering, UGM, 1993-1998<br>- MSc in Geoinformatics, ITC, 2001-2003<br>- PhD, ITC/Utrecht University, 2003-2007 |
| Main Research interests | : | Cartography/Geovisualization and Interoperable GIS |
| Address | : | Department of Geodetic & Geomatics Engineering<br>Gadjah Mada University (UGM)<br>Jl. Grafika No. 2, Yogyakarta 55281, Indonesia<br>*http://triasaditya.staff.ugm.ac.id* |

## List of publications


CHAPTER/JOURNALS

Aditya, T., and Kraak, M.-J. (2006). "Geospatial Data Infrastructure Portals: Using National Atlases as a Metaphor." Cartographica, 41(2), 115-134.

Aditya, T., and Kraak, M.-J. (accepted). "The GDI and Its Accessibility." Encyclopedia of Geoinformatics, H. A. Karimi, ed., Idea Group Reference, Hershey, PA.

Aditya, T., and Kraak, M.-J. (2007a). "Aim4GDI: Facilitating the Synthesis of GDI resources through Mapping and Superimpositions of Metadata Summaries." Geoinformatica. Online version at: http://dx.doi.org/10.1007/s10707-007-0021-4

Aditya, T., and Kraak, M.-J. (2007b). "'A Search Interface for an SDI: Implementation and Evaluation of Metadata Visualization Strategies'" Transactions in GIS, 11(3), 413 - 435.

Aditya, T., Ormeling, F.J. and Kraak, M.-J., (submitted). "A Storytelling Atlas for Improved Use of a Geospatial Data Infrastructure" , International Journal of Geographical Information Science.

Aditya, T., Ormeling, F., and Kraak, M.-J. (submitted). "Advancing Atlas for Improved Use of Geospatial Data Infrastructure: Implementing Scenario-Based Development." Computers, Environment and Urban Systems.

Aditya, T., MacEachren, A.M. and Kraak, M.-J., (in preparation). "The Collaborative Use of a National Atlas Metaphor" , Computers and Geosciences.

CONFERENCES

Aditya, T., Kobben, B. and Kraak, M.-J., (2005). "Designing Visual Attention and User Interaction for a Geoportal using SVG", SVG Open 2005, Enschede, the Netherlands.

Aditya, T. and Kraak, M.-J., (2005a). "The Atlas as a Portal for Data Discovery in the GDI: Prospects and Developments", 22nd International Cartographic Conference, La Coruna, Spain.

Aditya, T. and Kraak, M.-J., (2005b). "Reengineering the Geoportal: Applying HCI and Geovisualization Disciplines", 11th EC-GIS. Inspire JRC, Alghero, Sardinia, Italy.

Aditya, T. and Kraak, M.-J., (2004). "A National Atlas Metaphor in the Access to the GDI, GSDI 7". Media Partners / Geospatial Today, Bangalore, India, pp. 83.

Aditya, T. and Ormeling, F., (2004). "National Atlas as Visualiser Interface in the Access to the GDI", 2004 AAG Annual Meeting. AAG, Philadelpia.

Aditya, T. and Lemmens, R., 2003. "Chaining distributed GIS services", Pertemuan Ilmiah Tahunan XII, Masyarakat Penginderaan Jauh Indonesia, Bandung, pp. 8.

Lemmens, R.L.G., Vries, M.d. and Aditya, T., (2003). "Semantic Extension of Geo Web Service Descriptions with Ontology Languages", The 6th AGILE Conference on Geographic Information Science, Lyon, France, pp. 595-600.

# ITC Dissertations

1. **Akinyede** (1990), Highway cost modelling and route selection using a geotechnical information system
2. **Pan He Ping** (1990), 90-9003-757-8, Spatial structure theory in machine vision and applications to structural and textural analysis of remotely sensed images
3. **Bocco Verdinelli, G.** (1990), Gully erosion analysis using remote sensing and geographic information systems: a case study in Central Mexico
4. **Sharif, M**. (1991), Composite sampling optimization for DTM in the context of GIS
5. **Drummond, J.** (1991), Determining and processing quality parameters in geographic information systems
6. **Groten, S.** (1991), Satellite monitoring of agro-ecosystems in the Sahel
7. **Sharifi, A.** (1991), 90-6164-074-1, Development of an appropriate resource information system to support agricultural management at farm enterprise level
8. **Zee, D. van der** (1991), 90-6164-075-X, Recreation studied from above: Air photo interpretation as input into land evaluation for recreation
9. **Mannaerts, C.** (1991), 90-6164-085-7, Assessment of the transferability of laboratory rainfall-runoff and rainfall soil loss relationships to field and catchment scales: a study in the Cape Verde Islands
10. **Ze Shen Wang** (1991), 90-393-0333-9, An expert system for cartographic symbol design
11. **Zhou Yunxian** (1991), 90-6164-081-4, Application of Radon transforms to the processing of airborne geophysical data
12. **Zuviria, M. de** (1992), 90-6164-077-6, Mapping agro-topoclimates by integrating topographic, meteorological and land ecological data in a geographic information system: a case study of the Lom Sak area, North Central Thailand
13. **Westen, C. van** (1993), 90-6164-078-4, Application of Geographic Information Systems to landslide hazard zonation
14. **Shi Wenzhong** (1994), 90-6164-099-7, Modelling positional and thematic uncertainties in integration of remote sensing and geographic information systems
15. **Javelosa, R.** (1994), 90-6164-086-5, Active Quaternary environments in the Philippine mobile belt
16. **Lo King-Chang** (1994), 90-9006526-1, High Quality Automatic DEM, Digital Elevation Model Generation from Multiple Imagery
17. **Wokabi, S.** (1994), 90-6164-102-0, Quantified land evaluation for maize yield gap analysis at three sites on the eastern slope of Mt. Kenya
18. **Rodriguez, O.** (1995), Land Use conflicts and planning strategies in urban fringes: a case study of Western Caracas, Venezuela
19. **Meer, F. van der** (1995), 90-5485-385-9, Imaging spectrometry & the Ronda peridotites
20. **Kufoniyi, O.** (1995), 90-6164-105-5, Spatial coincidence: automated database updating and data consistency in vector GIS
21. **Zambezi, P.** (1995), Geochemistry of the Nkombwa Hill carbonatite complex of Isoka District, north-east Zambia, with special emphasis on economic minerals
22. **Woldai, T.** (1995), The application of remote sensing to the study of the geology and structure of the Carboniferous in the Calañas area, pyrite belt, SW Spain
23. **Verweij, P.** (1995), 90-6164-109-8, Spatial and temporal modelling of vegetation patterns: burning and grazing in the Paramo of Los Nevados National Park, Colombia
24. **Pohl, C.** (1996), 90-6164-121-7, Geometric Aspects of Multisensor Image Fusion for Topographic Map Updating in the Humid Tropics
25. **Jiang Bin** (1996), 90-6266-128-9, Fuzzy overlay analysis and visualization in GIS
26. **Metternicht, G.** (1996), 90-6164-118-7, Detecting and monitoring land degradation features and processes in the Cochabamba Valleys, Bolivia. A synergistic approach
27. **Hoanh Chu Thai** (1996), 90-6164-120-9, Development of a Computerized Aid to Integrated Land Use Planning (CAILUP) at regional level in irrigated areas: a case study for the Quan Lo Phung Hiep region in the Mekong Delta, Vietnam
28. **Roshannejad, A.** (1996), 90-9009-284-6, The management of spatio-temporal data in a national geographic information system
29. **Terlien, M.** (1996), 90-6164-115-2, Modelling Spatial and Temporal Variations in Rainfall-Triggered Landslides: the integration of hydrologic models, slope stability models and GIS for the hazard zonation of rainfall-triggered landslides with examples from Manizales, Colombia

30. **Mahavir, J.** (1996), 90-6164-117-9, Modelling settlement patterns for metropolitan regions: inputs from remote sensing
31. **Al-Amir, S.** (1996), 90-6164-116-0, Modern spatial planning practice as supported by the multi-applicable tools of remote sensing and GIS: the Syrian case
32. **Pilouk, M.** (1996), 90-6164-122-5, Integrated modelling for 3D GIS
33. **Duan Zengshan** (1996), 90-6164-123-3, Optimization modelling of a river-aquifer system with technical interventions: a case study for the Huangshui river and the coastal aquifer, Shandong, China
34. **Man, W.H. de** (1996), 90-9009-775-9, Surveys: informatie als norm: een verkenning van de institutionalisering van dorp - surveys in Thailand en op de Filippijnen
35. **Vekerdy, Z.** (1996), 90-6164-119-5, GIS-based hydrological modelling of alluvial regions: using the example of the Kisaföld, Hungary
36. **Pereira, Luisa** (1996), 90-407-1385-5, A Robust and Adaptive Matching Procedure for Automatic Modelling of Terrain Relief
37. **Fandino Lozano, M.** (1996), 90-6164-129-2, A Framework of Ecological Evaluation oriented at the Establishment and Management of Protected Areas: a case study of the Santuario de Iguaque, Colombia
38. **Toxopeus, B.** (1996), 90-6164-126-8, ISM: an Interactive Spatial and temporal Modelling system as a tool in ecosystem management: with two case studies: Cibodas biosphere reserve, West Java Indonesia: Amboseli biosphere reserve, Kajiado district, Central Southern Kenya
39. **Wang Yiman** (1997), 90-6164-131-4, Satellite SAR imagery for topographic mapping of tidal flat areas in the Dutch Wadden Sea
40. **Saldana-Lopez, Asunción** (1997), 90-6164-133-0, Complexity of soils and Soilscape patterns on the southern slopes of the Ayllon Range, central Spain: a GIS assisted modelling approach
41. **Ceccarelli, T.** (1997), 90-6164-135-7, Towards a planning support system for communal areas in the Zambezi valley, Zimbabwe; a multi-criteria evaluation linking farm household analysis, land evaluation and geographic information systems
42. **Peng Wanning** (1997), 90-6164-134-9, Automated generalization in GIS
43. **Lawas, C.** (1997), 90-6164-137-3, The Resource Users' Knowledge, the neglected input in Land resource management: the case of the Kankanaey farmers in Benguet, Philippines
44. **Bijker, W.** (1997), 90-6164-139-X, Radar for rain forest: A monitoring system for land cover Change in the Colombian Amazon
45. **Farshad, A.** (1997), 90-6164-142-X, Analysis of integrated land and water management practices within different agricultural systems under semi-arid conditions of Iran and evaluation of their sustainability
46. **Orlic, B.** (1997), 90-6164-140-3, Predicting subsurface conditions for geotechnical modelling
47. **Bishr, Y.** (1997), 90-6164-141-1, Semantic Aspects of Interoperable GIS
48. **Zhang Xiangmin** (1998), 90-6164-144-6, Coal fires in Northwest China: detection, monitoring and prediction using remote sensing data
49. **Gens, R.** (1998), 90-6164-155-1, Quality assessment of SAR interferometric data
50. **Turkstra, J.** (1998), 90-6164-147-0, Urban development and geographical information: spatial and temporal patterns of urban development and land values using integrated geo-data, Villaviciencia, Colombia
51. **Cassells, C.** (1998), 90-6164-234-5, Thermal modelling of underground coal fires in northern China
52. **Naseri, M.** (1998), 90-6164-195-0, Characterization of Salt-affected Soils for Modelling Sustainable Land Management in Semi-arid Environment: a case study in the Gorgan Region, Northeast, Iran
53. **Gorte B.G.H.** (1998), 90-6164-157-8, Probabilistic Segmentation of Remotely Sensed Images
54. **Tegaye, Tenalem Ayenew** (1998), 90-6164-158-6, The hydrological system of the lake district basin, central main Ethiopian rift
55. **Wang Donggen** (1998), 90-6864-551-7, Conjoint approaches to developing activity-based models
56. **Bastidas de Calderon, M.** (1998), 90-6164-193-4, Environmental fragility and vulnerability of Amazonian landscapes and ecosystems in the middle Orinoco river basin, Venezuela
57. **Moameni, A.** (1999), Soil quality changes under long-term wheat cultivation in the Marvdasht plain, South-Central Iran
58. **Groenigen, J.W. van** (1999), 90-6164-156-X, Constrained optimisation of spatial sampling: a geostatistical approach
59. **Cheng Tao** (1999), 90-6164-164-0, A process-oriented data model for fuzzy spatial objects

60. **Wolski, Piotr** (1999), 90-6164-165-9, Application of reservoir modelling to hydrotopes identified by remote sensing
61. **Acharya, B.** (1999), 90-6164-168-3, Forest biodiversity assessment: A spatial analysis of tree species diversity in Nepal
62. **Akbar Abkar, Ali** (1999), 90-6164-169-1, Likelihood-based segmentation and classification of remotely sensed images
63. **Yanuariadi, T.** (1999), 90-5808-082-X, Sustainable Land Allocation: GIS-based decision support for industrial forest plantation development in Indonesia
64. **Abu Bakr**, **Mohamed** (1999), 90-6164-170-5, An Integrated Agro-Economic and Agro-Ecological Framework for Land Use Planning and Policy Analysis
65. **Eleveld, M.** (1999), 90-6461-166-7, Exploring coastal morphodynamics of Ameland (The Netherlands) with remote sensing monitoring techniques and dynamic modelling in GIS
66. **Yang Hong** (1999), 90-6164-172-1, Imaging Spectrometry for Hydrocarbon Microseepage
67. **Mainam, Félix** (1999), 90-6164-179-9, Modelling soil erodibility in the semiarid zone of Cameroon
68. **Bakr, Mahmoud** (2000), 90-6164-176-4, A Stochastic Inverse-Management Approach to Groundwater Quality
69. **Zlatanova, Z.** (2000), 90-6164-178-0, 3D GIS for Urban Development
70. **Ottichilo, Wilber K.** (2000), 90-5808-197-4, Wildlife Dynamics: An Analysis of Change in the Masai Mara Ecosystem
71. **Kaymakci, Nuri** (2000), 90-6164-181-0, Tectono-stratigraphical Evolution of the Cankori Basin (Central Anatolia, Turkey)
72. **Gonzalez, Rhodora** (2000), 90-5808-246-6, Platforms and Terraces: Bridging participation and GIS in joint-learning for watershed management with the Ifugaos of the Philippines
73. **Schetselaar, Ernst** (2000), 90-6164-180-2, Integrated analyses of granite-gneiss terrain from field and multisource remotely sensed data. A case study from the Canadian Shield
74. **Mesgari, Saadi** (2000), 90-3651-511-4, Topological Cell-Tuple Structure for Three-Dimensional Spatial Data
75. **Bie, Cees A.J.M. de** (2000), 90-5808-253-9, Comparative Performance Analysis of Agro-Ecosystems
76. **Khaemba, Wilson M.** (2000), 90-5808-280-6, Spatial Statistics for Natural Resource Management
77. **Shrestha, Dhruba** (2000), 90-6164-189-6, Aspects of erosion and sedimentation in the Nepalese Himalaya: highland-lowland relations
78. **Asadi Haroni, Hooshang** (2000), 90-6164-185-3, The Zarshuran Gold Deposit Model Applied in a Mineral Exploration GIS in Iran
79. **Raza, Ale** (2001), 90-3651-540-8, Object-oriented Temporal GIS for Urban Applications
80. **Farah, Hussein** (2001), 90-5808-331-4, Estimation of regional evaporation under different weather conditions from satellite and meteorological data. A case study in the Naivasha Basin, Kenya
81. **Zheng**, **Ding** (2001), 90-6164-190-X, A Neural - Fuzzy Approach to Linguistic Knowledge Acquisition and Assessment in Spatial Decision Making
82. **Sahu, B.K.** (2001), Aeromagnetics of continental areas flanking the Indian Ocean; with implications for geological correlation and reassembly of Central Gondwana
83. **Alfestawi, Y.** (2001), 90-6164-198-5, The structural, paleogeographical and hydrocarbon systems analysis of the Ghadamis and Murzuq Basins, West Libya, with emphasis on their relation to the intervening Al Qarqaf Arch
84. **Liu, Xuehua** (2001), 90-5808-496-5, Mapping and Modelling the Habitat of Giant Pandas in Foping Nature Reserve, China
85. **Oindo, Boniface Oluoch** (2001), 90-5808-495-7, Spatial Patterns of Species Diversity in Kenya
86. **Carranza, Emmanuel John** (2002), 90-6164-203-5, Geologically-constrained Mineral Potential Mapping
87. **Rugege, Denis** (2002), 90-5808-584-8, Regional Analysis of Maize-Based Land Use Systems for Early Warning Applications
88. **Liu, Yaolin** (2002), 90-5808-648-8, Categorical Database Generalization in GIS
89. **Ogao, Patrick** (2002), 90-6164-206-X, Exploratory Visualization of Temporal Geospatial Data using Animation
90. **Abadi, Abdulbaset M.** (2002), 90-6164-205-1, Tectonics of the Sirt Basin – Inferences from tectonic subsidence analysis, stress inversion and gravity modelling
91. **Geneletti, Davide** (2002), 90-5383-831-7, Ecological Evaluation for Environmental Impact Assessment

92. **Sedogo, Laurent G.** (2002), 90-5808-751-4, Integration of Participatory Local and Regional Planning for Resources Management using Remote Sensing and GIS
93. **Montoya, Lorena** (2002), 90-6164-208-6, Urban Disaster Management: a case study of earthquake risk assessment in Carthago, Costa Rica
94. **Ahmad, Mobin-ud-Din** (2002), 90-5808-761-1, Estimation of Net Groundwater Use in Irrigated River Basins using Geo-information Techniques: A case study in Rechna Doab, Pakistan
95. **Said, Mohammed Yahya** (2003), 90-5808-794-8, Multiscale perspectives of species richness in East Africa
96. **Schmidt, Karin** (2003), 90-5808-830-8, Hyperspectral Remote Sensing of Vegetation Species Distribution in a Saltmarsh
97. **Lopez Binnquist, Citlalli** (2003), 90-3651-900-4, The Endurance of Mexican Amate Paper: Exploring Additional Dimensions to the Sustainable Development Concept
98. **Huang, Zhengdong** (2003), 90-6164-211-6, Data Integration for Urban Transport Planning
99. **Cheng, Jianquan** (2003), 90-6164-212-4, Modelling Spatial and Temporal Urban Growth
100. **Campos dos Santos, Jose Laurindo** (2003), 90-6164-214-0, A Biodiversity Information System in an Open Data/Metadatabase Architecture
101. **Hengl, Tomislav** (2003), 90-5808-896-0, PEDOMETRIC MAPPING, Bridging the gaps between conventional and pedometric approaches
102. **Barrera Bassols, Narciso (**2003), 90-6164-217-5, Symbolism, Knowledge and management of Soil and Land Resources in Indigenous Communities: Ethnopedology at Global, Regional and Local Scales
103. **Zhan, Qingming** (2003), 90-5808-917-7, A Hierarchical Object-Based Approach for Urban Land-Use Classification from Remote Sensing Data
104. **Daag, Arturo S.** (2003), 90-6164-218-3, Modelling the Erosion of Pyroclastic Flow Deposits and the Occurrences of Lahars at Mt. Pinatubo, Philippines
105. **Bacic, Ivan** (2003), 90-5808-902-9, Demand-driven Land Evaluation with case studies in Santa Catarina, Brazil
106. **Murwira, Amon** (2003), 90-5808-951-7, Scale matters! A new approach to quantify spatial heterogeneity for predicting the distribution of wildlife
107. **Mazvimavi, Dominic** (2003), 90-5808-950-9, Estimation of Flow Characteristics of Ungauged Catchments. A case study in Zimbabwe
108. **Tang, Xinming** (2004), 90-6164-220-5, Spatial Object Modelling in Fuzzy Topological Spaces with Applications to Land Cover Change
109. **Kariuki, Patrick** (2004), 90-6164-221-3, Spectroscopy and Swelling Soils; an integrated approach
110. **Morales, Javier** (2004), 90-6164-222-1, Model Driven Methodology for the Design of Geo-information Services
111. **Mutanga, Onisimo** (2004), 90-5808-981-9, Hyperspectral Remote Sensing of Tropical Grass Quality and Quantity
112. **Šliužas, Ri ardas V.** (2004), 90-6164-223-X, Managing Informal Settlements: a study using geo-information in Dar es Salaam, Tanzania
113. **Lucieer, Arko** (2004), 90-6164-225-6, Uncertainties in Segmentation and their Visualisation
114. **Corsi, Fabio** (2004), 90-8504-090-6, Applications of existing biodiversity information: Capacity to support decision-making
115. **Tuladhar, Arbind** (2004), 90-6164-224-8, Parcel-based Geo-information System: Concepts and Guidelines
116. **Elzakker, Corné van** (2004), 90-6809-365-7, The use of maps in the exploration of geographic data
117. **Nidumolu, Uday Bhaskar** (2004), 90-8504-138-4, Integrating Geo-information models with participatory approaches: applications in land use analysis
118. **Koua, Etien L.** (2005), 90-6164-229-9, Computational and Visual Support for Exploratory Geovisualization and Knowledge Construction
119. **Blok, Connie A.** (2005), Dynamic visualization variables in animation to support monitoring of spatial phenomena
120. **Meratnia, Nirvana** (2005), 90-365-2152-1, Towards Database Support for Moving Object Data
121. **Yemefack, Martin** (2005), 90-6164-233-7, Modelling and monitoring Soil and Land Use Dynamics within Shifting Agricultural Landscape Mosaic Systems
122. **Kheirkhah, Masoud** (2005), 90-8504-256-9, Decision support system for floodwater spreading site selection in Iran

123. **Nangendo, Grace** (2005), 90-8504-200-3, Changing forest-woodland-savanna mosaics in Uganda: with implications for conservation
124. **Mohamed, Yasir Abbas** (2005), 04-15-38483-4, The Nile Hydroclimatology: impact of the Sudd wetland (Distinction)
125. **Duker, Alfred, A.** (2005), 90-8504-243-7, Spatial analysis of factors implicated in *mycobacterium ulcerans* infection in Ghana
126. **Ferwerda, Jelle, G.,** (2005), 90-8504-209-7, Charting the Quality of Forage: Measuring and mapping the variation of chemical components in foliage with hyperspectral remote sensing
127. **Martinez, Javier** (2005), 90-6164-235-3, Monitoring intra-urban inequalities with GIS-based indicators. With a case study in Rosario, Argentina
128. **Saavedra, Carlos** (2005), 90-8504-289-5, Estimating spatial patterns of soil erosion and deposition in the Andean region using Geo-information techniques. A case study in Cochabamba, Bolivia
129. **Vaiphasa, Chaichoke** (2006), 90-8504-353-0, Remote Sensing Techniques for Mangrove Mapping
130. **Porwal, Alok** (2006), 90-6164-240-X, Mineral Potential Mapping with Mathematical Geological Models
131. **Werff, Harald van der** (2006), 90-6164-238-8, Knowledge-based remote sensing of complex objects: recognition of spectral and spatial patterns resulting from natural hydrocarbon seepages
132. **Vlag, Daniël van de** (2006), 90-8504-384-0, Modeling and visualizing dynamic landscape objects and their qualities
133. **Joshi, Chudamani** (2006), 90-8504-470-7, Mapping cryptic invaders and invisibility of tropical forest ecosystems: *Chromolaena odorata* in Nepal
134. **Bandara, K.M.P.S.** (2006), 90-8504-406-5, Assessing irrigation performance by using remote sensing
135. **Dilo, Areti** (2006), 90-8504-461-8, Representation of and Reasoning with Vagueness in Spatial Information. A system for handling vague objects
136. **Debba, Pravesh** (2006), 90-8504-462-6, Sampling scheme optimization from hyperspectral data
137. **Huisman, Marco** (2006), 90-6164-246-9, Assessment of rock mass decay in artificial slopes
138. **Lemmens, Rob** (2006), 90-6164-250-7, Semantic interoperability of distributed geo-services
139. **Chacón Moreno, Eulogio** (2007), 90-8504-559-2, Ecological and spatial modeling: Mapping ecosystems, landscape changes, and plant species distribution in Llanos del Orinoco, Venezuela
140. **Amer, Sherif** (2007), 90-6164-253-1, Towards Spatial Justice in Urban Health Services Planning
141. **Obakeng, Obolokile Thothi** (2007), 90-6164-254-X, Soil moisture dynamics and evapotranspiration at the fringe of the Botswana Kalahari, with emphasis on deep rooting vegetation
142. **Cho, Moses Azong** (2007), 978-90-8504-622-6, Hyperspectral remote sensing of biochemical and biophysical parameters
143. **Farifteh, Jamshid** (2007), 978-90-6164-259-6, Imaging Spectroscopy of salt-affected soils: Model-based integrated method
144. **Minang, Peter Akong**, (2007), 978-90-6164-260-2, Implementing global environmental policy at local level: community carbon forestry perspectives in Cameroon
145. **Noomen, Marleen F.** (2007), 978-90-8504-671-4, Hyperspectral reflectance of vegetation affected by underground hydrocarbon gas seepage

# Colophon

The main picture on the front cover is the *gunungan* and the globe, with the map related to this study represents the background. The gunungan is a mountain-like object that has an important role in the *wayang kulit* (leather puppet) show, a traditional shadow theatre originating in Java, Indonesia.

The *gunungan* symbolizes the world and everything related to human life. It puts a 'sacred place' in the centre, where its roof is flanked by two *garuda* (eagle) birds and at the top of its roof the tree of life grows upward till the tip of the *gunungan*, where the *tunjung* flower is located. *Garuda* flanks symbolize the freedom of the human soul, where the tree of life represents the spreads of guardian and harmony for nature and mankind. As humans strive upwards throughout their 'tree of life' on their journey to nirvana (symbolised by the *tunjung* flower), they must must learn to overcome their "attachment to the earth" and gain correct guidance in order to navigate the route and to set them free from danger and becoming lost (symbolised by the snake curled around the tree and the faces of *banaspati*).

The *gunungan* is used by the *dalang* (the storyteller) to signify the beginning and the end of the play, or to change the scene or even to represent nature such as: wind, clouds or seas. At the beginning of the show, when the *gamelan* music begins to play and the *dalang* put the *gunungan* into action, the 'sacred place' doors are opened and the audience are invited to enter the magical world of *wayang* where story becomes a parable of reality.

Copyright Information

The figure of gunungan was drawn by David Hartono, its english description was partly taken with permission from http://www.indonesianshadowplay.com, the globe was taken from Mountain High Maps v2.5. Printing by ITC Printing Department .