Lecture Notes in Geoinformation and Cartography

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Geographic Hypermedia

Concepts and Systems

With 158 Figures

Springer

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In memory of

Professor Y.C. Lee (1948-2004)

Preface

This book introduces a new paradigm, *Geographic Hypermedia*, which emerges from the convergence of Geographic Information Science and hypermedia technology. Both GI Science and hypermedia have been rapidly evolving fields. The initial idea of *Geographic Hypermedia* was born in 2004 when the editors had been invited to organize a workshop in conjunction with the 'Hypertext' conference organized annually by the Special Interest Group of the Association for Computing Machinery.

The purpose of the workshop was to examine how hypermedia concepts and tools may be applied in geographical domains. The workshop was eventually held in conjunction with the Maps and the Internet Commission of the International Cartographic Association at the annual meeting of the Association of American Geographers in Denver, Colorado, in April 2005.

The Denver workshop was a successful event, bringing together multidisciplinary researchers and professionals in the area of Geographic Hypermedia. Researchers from four continents and well recognized institutions presented their work and exchanged opinions about the new paradigm, its content and distinct characteristics from other paradigms. Extended versions of the papers presented at the workshop along with some invited chapters from experts in the field led to the compendium of the twenty-five chapters in this book volume.

Geographic Hypermedia is not yet a mature paradigm but we aspire to provide the scientific community with a contemporary view of Geographic Hypermedia, present an overview of its progress and current status, while also promoting further discussion and research.

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PART I

FOUNDATIONS OF GEOGRAPHIC HYPERMEDIA

1 Geographic Hypermedia

Emmanuel Stefanakis, and Michael P. Peterson

Abstract. The convergence between Geographic Information Science and Hypermedia technology leads to the emergence of a new paradigm, named *Geographic Hypermedia* (GH). This chapter introduces GH by presenting the underlying concepts and tools; and highlighting the content and types of services that should be provided by a GH system. The chapter also explains the structure of the book and presents an overview of the twenty-four contributions.

1.1 Introduction

The integration of the web and hypermedia technologies with Geographic Information Science (GIScience) has recently led to the development of new forms of geo-representations. Currently, many geospatial solutions are web-based and provide access to distributed multimedia elements in order to support specific application domains.

Geographic Hypermedia (GH) is an emerging paradigm, which adopts and extends the concepts and tools developed in hypermedia. *Geographic Hypermedia Systems* (GHS) are software systems that allow distributed geographic content (data and services) with various forms of media being interlinked and exploited in different ways. GH supports a wide number of research and professional activities in geographical domains.

This chapter introduces the new paradigm by first defining the underlying technology (Section 1.2). Then, the related paradigms are presented (Section 1.3). Following this, the content and the types of services that should be offered by GH are described (Section 1.4). A short discussion is provided next that attempts to place GH in relation to multimedia cartography and distributed GIS (Section 1.5). The last section explains the structure of the book and introduces the twenty-four contributions (Section 1.6).

1.2 Defining Geographic Hypermedia

The integration of *Hypermedia* technology with *Geographic Information Science* (GI Science; Goodchild 1997) creates a new paradigm in *Geo-*

graphic Hypermedia (GH). GI Science focuses on the collection and manipulation of *geographic information* (GI); i.e., information about places on the Earth's surface. Currently, these technologies make wide use of hypermedia methods and tools to enrich their functionality, effectiveness and usability. After discussing hypermedia technology (Section 1.2.1), the technological aspects of the new paradigm are presented (Section 1.2.2).

1.2.1 Hypermedia and Related Technologies

Hypermedia is a technology that is based on a series of other technologies, including media, hypertext and multimedia. Hence, a short description of these elements is provided here.

According to Webopedia (Webopedia 2006), *media* is the plural of medium and defined as: (a) objects on which data can be stored (these include hard disks, floppy disks, CD-ROMs, and tapes); (b) the cables – in computer networks – linking workstations together (e.g., the normal electrical wire, the type of cable used for cable television, and the fiber optic cable); and (c) the form and technology used to communicate information (e.g., a multimedia presentation combines sound, pictures, and videos, all of which are different types of media). Based on this definition, maps themselves are media, provided that a map can store and communicate cartographic information. Additionally, all output products of any information system or data repository, a GI System, the web, even the computer itself, can be seen as media, provided that they all store and communicate information.

Hypertext (Nelson 1965, FOLDOC 2006) refers to a collection of documents (or "nodes") containing cross-references (or "links") that with the aid of an interactive browser program, allow the reader to move easily from one document to another (Fig. 1.1a). In other words, hypertext is the extension of the traditional form of "flat" or linear text to the nonlinear form, in which the paths through a document can branch-off to other documents via appropriate references. *Hypertext systems* are software systems that allow users to author, edit and follow links between different bodies of text.

Hypermedia is the extension of hypertext to include other media, such as sound, graphics and animation (FOLDOC 2006; Fig. 1.1b). In practice, many hypertext documents have at least some graphical content (just as a text often includes illustrations). Hence, the distinction between hypertext and hypermedia is not clear. For instance, the Special Interest Group of the Association for Computing Machinery (SIGWEB 2006) organizes the

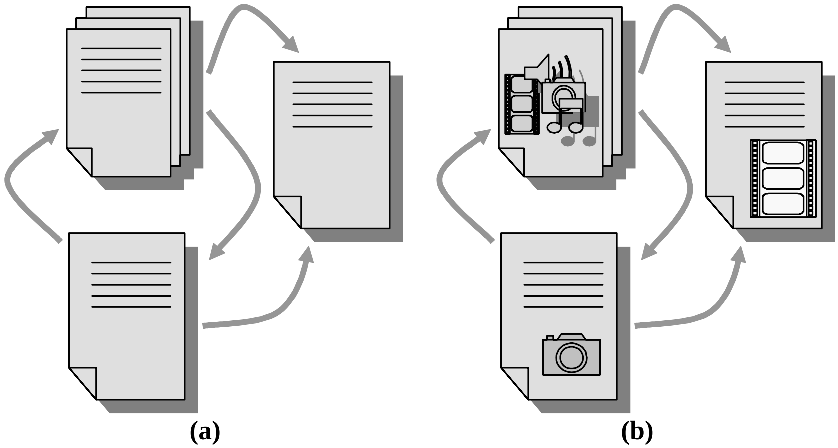

Fig. 1.1. Hypertext (a) versus hypermedia (b). A strict distinction.

foremost international conference annually, named “Hypertext”, that is dedicated to both hypertext and hypermedia.

Hypermedia is an extension to hypertext. In hypermedia, other forms of media are available and it is possible to create a link between an audio file and a body of text. A myriad of hypermedia systems are available today. A list of some major systems can be found at Blustein (2006) and under SIGWEB site (SIGWEB 2006). It is worth noting that the World Wide Web (W3C 2006) is itself a hypermedia system. The web supports hyperlinks to text, graphics, sound, and video files.

An example of how hypermedia content is interlinked is the web (Wiil 1997). The World Wide Web is a subset of the Internet that establishes the communication between two Internet machines, the web browser and the web server, based on the HTTP protocol (W3C 2006) (Fig. 1.2). The browser sends a request (GET) to a specific server though the corresponding URL (i.e., a short string that identifies resources in the web) and the server responds by sending back (PUT) a file in HTML format. Hyper Text Markup Language (HTML) is the basic standard language for publishing hypertext on the web (W3C 2006).

The HTML file is interpreted and displayed by the browser. This file in-

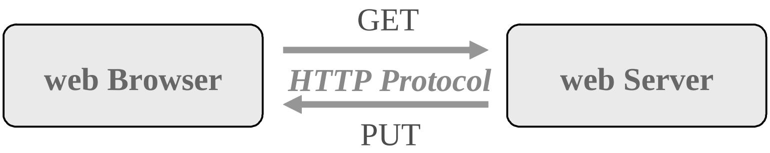

Fig. 1.2. Basic web communication.

cludes a series of anchors to other files distributed through the web. Each anchor is assigned a corresponding URL. By choosing/activating an anchor the browser sends a request to the appropriate server; and the server replies by sending the corresponding file back to the browser.

This new file may be a file in either HTML format or in another format. In the former case, the file is interpreted and displayed by the browser. In the latter case, there are two possibilities: (a) the browser is able by itself to interpret and display the file (this is feasible for some file formats, such as gif and jpg images); (b) the browser launches a plug-in or another application to interpret and display the file (e.g., the Adobe's Acrobat Reader for pdf files; or Macromedia Flash for the swf files).

If the plug-in or the application used to interpret and display the file is *non-hypermedia-aware*, i.e., it is not capable of supporting anchors, the user reaches a dead-end in the hypermedia with no links to follow. Alternatively, if the application above is *hypermedia-aware*; i.e., capable to recognize and display the anchors and the corresponding URLs; the user may activate them and get additional resources from the web. The second alternative is aligned with the framework of *Open Hypermedia Systems (OHS)*.

OHS focus on the architectural, modeling and rendering issues regarding the standardization of hypermedia services (OHSWG 2006). An OHS provides a general set of hypermedia services that can be used by other applications, programs and services in the computing environment. The minimal requirement for an OHS is the provision of basic hypermedia linking services to an open set of applications; i.e., the ability to create, delete and modify anchors and links and the ability to traverse links (Wiil 1997, Nürnberg *et al.* 1998).

The conceptual architecture of hypermedia systems that demonstrate their evolution (Nürnerg and Leggett 1997, Nürnberg *et al.* 1998) are shown in Fig. 1.3. *Client* is a frontend unit that interacts with the hypermedia system. *Storage engine* is a backend repository of hypermedia content. *Structure processor* is a server that provides structural abstractions to clients. *Link server* implements the linkage between the client and the hypermedia content.

In early hypermedia systems, a single process implements all aspects of the system (Fig. 1.3a). These systems are called *monolithic*. In a later stage (late 1980's), hypermedia systems abstracted their frontend to an open set of clients (Fig. 1.3b). This evolution led to the *open link service* systems. Next, the backend store were abstracted and opened (Fig. 1.3c) and led (mid 1990's) to the so-called *open hyperbase systems*. The current trend focuses on the abstractions at the middleware units (i.e., the structure proc-

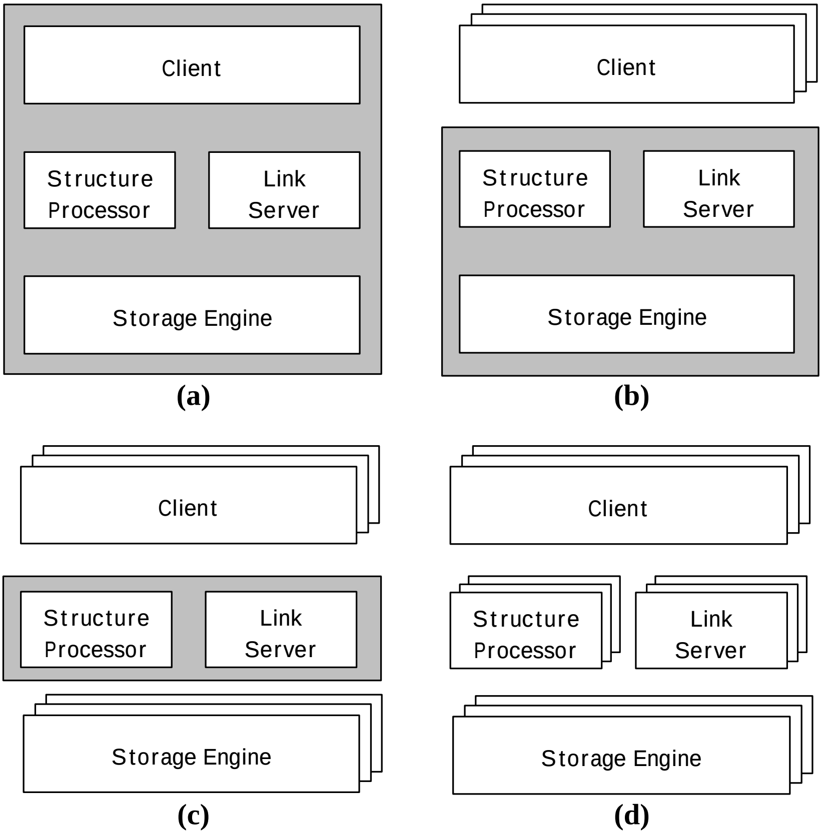

Fig. 1.3. The conceptual architectures of hypermedia systems: (a) monolithic systems; (b) open link service systems; (c) open hyperbase systems; (d) open hypermedia systems. The shading encloses the "closed" components.

essor and the link server) and leads to the development of *open hypermedia systems* (Fig. 1.3d).

A technology, which has been developed in parallel with hypertext and hypermedia is multimedia. *Multimedia* refers to "multiple media" or "a combination of media". According to FOLDOC (FOLDOC 2006), multimedia often includes concepts from hypertext and is defined as the human-computer interaction involving text, graphics, voice and video. The term "multimedia" became synonymous with CD-ROM in the personal computer world, because of the large amounts of data involved that are currently best supplied on CD-ROM, and more recently, the DVD.

In attempting to distinguish multimedia from hypermedia, it can be argued that hypermedia is a wider term, which includes multimedia. Multimedia is the combination of text, graphics, audio, video and animation that

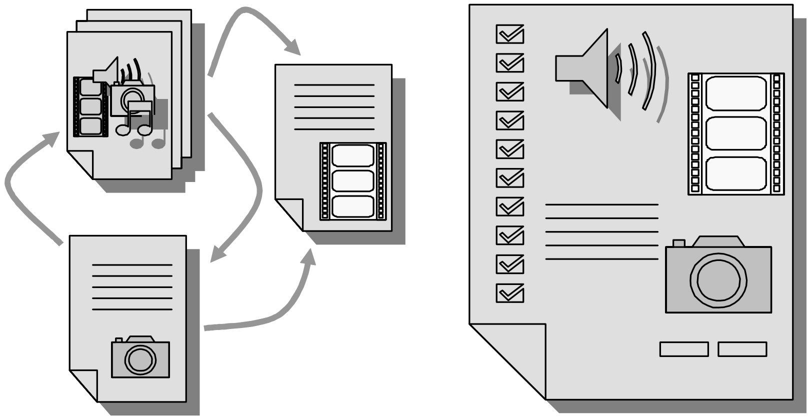

Fig. 1.4. The strict distinction between hypermedia (a) and multimedia (b). In practice, the two terms have come to have the same meaning.

are created and delivered on the screen (Fig. 1.4b). Hypermedia is a hypertext multimedia, i.e., media items from all over the world that are logically connected with hypertext links (Fig. 1.4a). However, in current usage, the distinction between multimedia and hypermedia has faded. Multimedia is commonly used to also describe the combination of distributed media. The purpose of this chapter and this book is to create a stronger linkage between GH and GI Science.

1.2.2 Geographic Hypermedia

GI Science is focused on the collection and manipulation of geographic information. Goodchild (1997) lists three main types of technologies: (a) positioning (e.g., GPS); (b) remote sensing; and (c) Geographic Information Systems (GIS).

The rapid development of the Internet has changed dramatically the collection and processing of geographic information. The Internet is already the most widely used system for the dissemination of information and services. As a consequence, it affects GIScience technology in at least three aspects (Peng and Tsou 2003): (a) the accessibility to data and information, (b) the dissemination of geographic information, and (c) the modeling and analysis of geographic information.

This situation forces a dramatic change on the architecture of systems used for the management and handling of geographic information. GI desktop systems (e.g., GIS, and remote sensing software packages) are be-

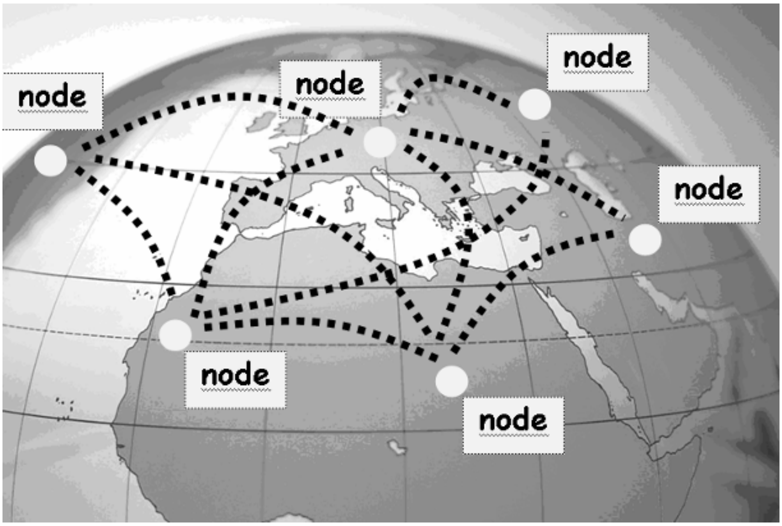

Fig. 1.5. The architecture of distributed GI Services.

ing replaced by distributed systems, called *Distributed GI Services* (Peng and Tsou 2003).

Distributed GI Services are based on an advanced network scheme (Fig. 1.5), where the individual modules of traditional GI desktop Systems as well as geographic information are distributed on numerous network nodes and are offered to other nodes upon request. A node acts either as a client or a server in this architecture; and, hence, there is no distinction between nodes.

Obviously, the individual nodes comprising the whole network adopt heterogeneous platforms and software systems. Therefore, the whole network must support the connection and interaction between heterogeneous components. Additionally, it must support the simultaneous many-to-many communication between the individual nodes.

Hypermedia technology offers a set of concepts and tools that are applicable to this new era of distributed GI Services. Each node in the architecture above is a repository of GI elements. Each GI element may be either a data/information set or an analytical/processing module. These elements are encoded in various formats and media, and are interlinked with other elements that reside in the same or other network nodes. Hence, they all together compose a hypermedia system. Provided that they focus on GI, this is a *Geographic Hypermedia System* (GHS). The associated paradigm is named *Geographic Hypermedia* (GH).

1.3. Parallel Paradigms

A series of paradigms related to GH have been developed during the last couple of decades. These paradigms concentrate on the dissemination of geographic information through the use of maps. They all enrich the content of traditional map products through the use of other media, while they simultaneously exploit the advantages of the Internet technology. These paradigms are: multimedia cartography, hypermaps, and web mapping.

Multimedia cartography is the combination of maps with multimedia (Peterson 1999). A multimedia map combines cartographic entities with different types of media, such as text, audio, animation, etc., and may lead to more realistic representations of the world. Defining interaction as key to knowledge formation, Cartwright and Peterson (1999) argue that multimedia cartography is the interaction with maps supported by multiple forms of media.

A *hypermap* is an interactive multimedia map that allows users to navigate through the map, zoom and find locations. This functionality assists the interpretation of maps and queries. The term has been first introduced by Laurini and Millert-Raffort (1990). Later, Kraak and Driel (1997) have proposed the basic functionality of hypermaps.

The web has become a widespread means for the dissemination of mapping products. The maps available through the web can be distinguished based on varying terms of interaction, with static maps incorporating no interaction at all. The dissemination of geographic data on the web in the form of maps is accompanied with special requirements for map design and a new paradigm has emerged, that of *web mapping* (Kraak and Brown 2001, Peterson 2003).

1.4. Geographic Hypermedia Systems: Content and Services

The scope of Geographic Hypermedia Systems (GHS) is twofold. Firstly, to interlink geographic content, that is available in various forms and types of media and distributed in pieces. Secondly, to support a wide number of research and professional activities in geographical domains, such as Spatial Decision Support, Geographic Database Management and Exploration, Geovisualization, Virtual and Augmented Reality, Location Based Services, Geographic Messaging Services, Hypermedia Cartography, Hypermaps and Hypermedia Atlases, and web-based and Virtual Wayfinding Services, to name a few.

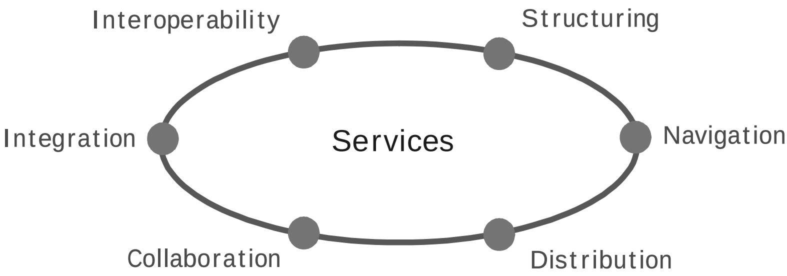

Fig. 1.6. The types of services in an Open Hypermedia System.

The development of advanced GHS should exploit the recent outcomes of the Open Hypermedia Systems (OHS) research community (OHSWG 2006). In an ideal situation, OHS constitute a central paradigm for structuring and navigating among pieces of information. This would be accomplished if all operating systems support six types of services (Grønbæk and Wiil 1997; Fig. 1.6): *integration*, *interoperability*, *structuring*, *navigation*, *distribution* and *collaboration*. Geographic Hypermedia Systems have special requirements including that these services must be able to handle geographic content.

The following subsections describe the geographic content (Section 1.4.1), the types of services that a GHS must provide (Section 1.4.2), and the efforts towards the development of geospatial standards and specifications (Section 1.4.3).

1.4.1 Geographic Content: Data and Services

GHS handle geographic content, which consists of: (a) geographic *data/information*, and (b) geographic *services*. The following paragraphs provide a brief description of these.

Geographic data constitutes a special category of data that is distributed in *space* and changes over *time*. As regards to its distribution in space, geographic data is accompanied with references to the locations in space where it occurs or the places it describes. On the other hand, as regards to its change over time, this change can be so slow, that it can be ignored (e.g., change of the seashore, climate, or distribution of ages in a country, etc.); or so fast that the rhythm of changes is of high importance (e.g., the traffic load of a highway, the temperature, the fire front in a forest fire, etc.).

Geographic data is usually classified into four categories (Maguire *et al.* 1991): (a) the physical objects (e.g., houses, roads, lakes, forests, etc.), (b) the administrative units (e.g., land parcels, prefectures, national parks, military camps, etc.), (c) the geographic phenomena (e.g., temperature, humidity, accidents, distribution of sea mammals, etc.), and (d) the derived information (e.g., poverty level, land suitability for cultivation, etc.).

In order to describe the complex world (as it is perceived by an application), it is assumed that the world consists of a set of discrete and interrelated units, which are named *entities*. An entity is any unit or object with physical or conceptual existence. Each entity is described by a number of attributes (properties or characteristics), that are explicitly related to the application. The attributes associated with geographic entities are classified into three basic categories, which are named *dimensions* of geographic entities. These dimensions are (Fig. 1.7): (a) the *identifier*, (b) the *spatial* dimension, and (c) the *thematic* dimension.

The *identifier* is the dimension which provides a means to refer to (or name) geographic entities. The *spatial* dimension incorporates all attributes that describe the spatial characteristics of geographic entities. The spatial characteristics of an entity consist of: (a) its position, (b) its geometry, (c) its graphical representation, and (d) its spatial relationships with other entities. Additionally, the *thematic* dimension includes all thematic or non-spatial attributes of geographic entities. The thematic dimension accommodates all *multimedia data* that accompany the geographic entities of an application. Multimedia data consists of sound, images, video data, virtual and augmented reality data, and describes the geographic entities.

In fact, all entities are dynamic in nature, since they lie in a continuously changed world, while time is a dimension that is tightly connected to space. However, in practice some geographic entities are usually treated as *static entities*. This is related to a time interval during which the entity attributes remain unchanged.

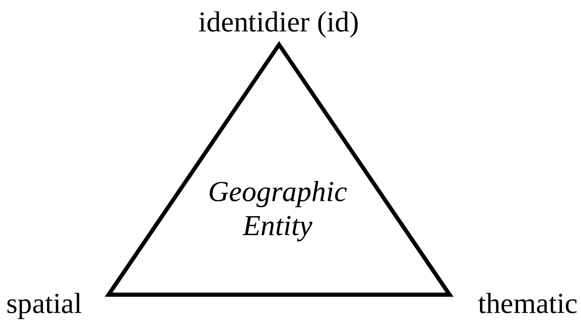

Fig. 1.7. The dimensions of a static geographic entity.

It is a common practice (which comes from traditional methodologies on handling spatio-temporal phenomena) to examine spatial and thematic properties of entities over time. This consideration highlights the behavior of an entity over time, namely *entity change*. Change takes various forms, all falling within two general categories (Frank 2001, Stefanakis 2003): (a) *life* and (b) *motion*. Life refers to change in the existence status of entities, whereas motion refers to change in the spatial and/or thematic attributes of entities.

The life and motion of individual entities, physical or conceptual, dominate our existence and perception of the environment that surrounds us. An entity may appear and disappear (e.g., a residential zone or a forest), may merge with other entities or split into two or more new entities (e.g., collection of parcels, or towns). These changes concern the life of the entity of interest. On the other hand, an entity may move with or without changing its form at the same time (e.g., pollution, a boat). Additionally, an entity may change its thematic properties without change in its spatial properties (e.g., parcel owner). These changes concern the motion of the entity of interest. Fig. 1.8 highlights some common life and motion type changes.

Geographic data is usually collected by applying error prone methodologies. Hence, the attributes of geographic entities (e.g., parcel area, street width, person age, etc.) are assigned values that decline more or less from the real ones. For a better understanding and exploitation of geographic data, a *measure of its quality* is needed. This measure includes the positional and attribute accuracy of entities, and the completeness and

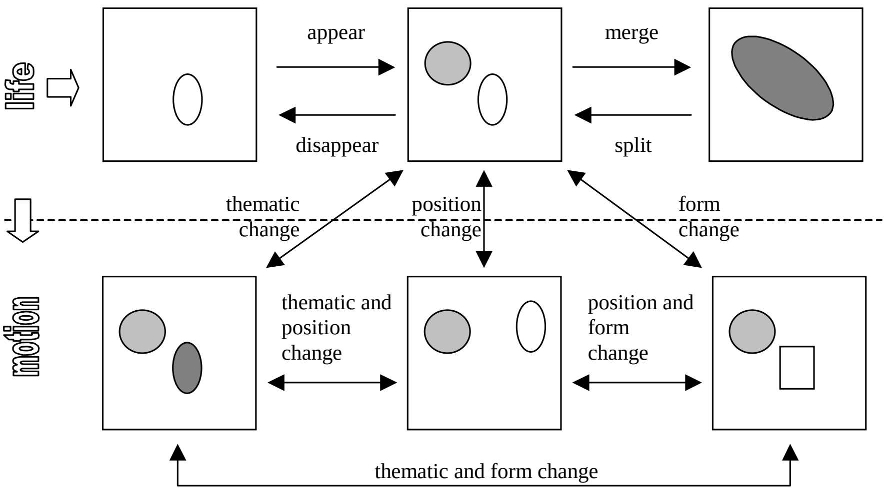

Fig. 1.8. Entity's life and motion.

logical consistency among data elements (Maguire *et al.* 1991).

Geographic services are based on the set of operations to process and analyze geographic data. The fundamental operations can be grouped into three types (Tomlin 1990): (a) data preparation, (b) data presentation and (c) data analysis operations.

Data preparation operations encompass a variety of methods for capturing data from different sources (e.g., digital or paper maps, geographic data repositories, land measurements, positioning and earth observation systems), editing and storing them appropriately in a data repository.

Data presentation operations encompass a variety of methods for the presentation of data, such as drawing maps, drafting charts, generating reports, and so on. Geographic applications have special requirements at the user interface level. This is because the appropriate visualization of geospatial data may assist people to discover or evaluate the geographic content (Andrienko and Andrienko 1999, Kraak and Brown 2001). Hence, the quality of geovisualization products must be promoted. Semantics associated to geospatial content may be exploited at this stage and lead to effective geovisualizations. Current research on the development of metaphors and graphical user interfaces (GUIs) as well as on issues related to multiple representations and interoperability of geographic data are aligned to this new trend.

Data analysis operations transform data into information and include (Maguire *et al.* 1991): classification and recording, generalization, spatial join and overlay, neighborhood analysis, connectivity, interpolation and surface analysis, measurement operations, etc. A classification of these operations can be found at Stefanakis and Sellis (1998).

1.4.2 Geographic Hypermedia System Services

Current computing environments do not allow the development of OHS. There are several reasons for this, such as the lack of widely adopted standards, missing open hypermedia services at the operating system level, and the inability of existing services, applications and stores to use open hypermedia services.

As mentioned already, there are six types of services (Fig. 1.6) that an OHS should provide (Grønbæk and Wiil 1997). These services must be adopted and extended in an Open GHS to meet the special requirements of geographical domains. These extended types of services are described next.

Integration

An OHS must be able to integrate (Grønbæk and Wiil 1997): (a) existing services, (b) third party applications and (c) third party stores. Existing services consist of scripts, programs, software agents and hardware devices.

In geographical domains, the scripts and programs involve geographic analytical and processing tools; the software agents deal with GI Systems, Mapping and/or Remote Sensing software packages; while the hardware devices involve specific devices for collecting and displaying geographical information, such as GPS receivers, geodetic stations, earth observation systems, digitizers, plotters and projectors.

Third party applications include editors, browsers, email systems, calendars, etc. Geographical third party applications (e.g., editors and browsers), should provide enhanced functionality for mapping, searching and retrieval of geographical content by spatial and/or temporal predicates.

Third party stores include databases, data and services repositories, file systems and media in general. In geographical domains, maps in digital or analog form are also present. Additionally, the repositories accommodate geographic data and services and obviously they have advanced requirements and capabilities (in modeling, processing and analysis).

Interoperability

An OHS must insure (Grønbæk and Wiil 1997) that all integrated services, applications and stores interoperate with each other; as well as with the components of other OHSs. One important issue of interoperability is how to handle the heterogeneity between data collections.

The *heterogeneity* of data collections may be considered as syntactic, schematic or semantic heterogeneity (Bishr 1998). *Syntactic* heterogeneity refers to the differences in the logical data models (e.g., relational versus object-oriented) or in spatial representations (e.g., raster versus vector). *Schematic* heterogeneity refers to the differences in the conceptual data models (the data are organized in different schemas and structures). *Semantic* heterogeneity refers to the differences in meaning, interpretation or usage of the same or related data. Semantic heterogeneity is further divided into naming (i.e., synonyms and homonyms) and cognitive (i.e., different conceptualizations) heterogeneity.

Semantic heterogeneity between data collections causes most integration problems. These problems refer to (Bernard *et al.* 2003): (a) metadata interpretation, and (b) data interpretation. As regards to metadata interpretation, different providers may use different terms. This makes it difficult for both the humans and the computers to recognize the coherence between similar terms. As regards to data interpretation, the properties of the entities involved in an application domain are expressed based on various standardized (e.g., CORINE vocabulary for land cover classification; EAA 2000) or not vocabularies. Data and metadata interpretation problems must be overcome when data from different sources have to be integrated into a single collection. This requires the adoption of common terms, which are usually provided by a standardized vocabulary with unchanged terms. All terms coming from other vocabularies will be translated in the adopted vocabulary using tools for semantic translation.

The use of *ontologies* (Fonseca and Egenhofer 1999, Guarino 1998, Wache 2001) as semantic translators is a possible approach to overcome the problem of semantic heterogeneity (Bernard *et al.* 2003). Ontologies play a critical role in associating meaning with data that computers can understand and process data automatically. Ontologies may be used (a) to assist the translation of a term (i.e., a concept) from one vocabulary (i.e., one ontology) into a term from another vocabulary; and (b) to derive super-concept and sub-concept relationships.

However, currently ontologies only define data semantics under very controlled situations. They cannot yet fully support semantic translation. They fail to cope with the semantics of services (Bernard *et al.* 2005). The GI community now addresses the following three research issues (Fonseca and Sheth 2003): (a) the creation and management of domain specific geo-ontologies for both data and services; (b) the matching geo-concepts available in the web to geo-ontologies; and (c) the integration of different ontologies as regards to both the geographic dimension and the non-geographic domain.

Structuring

An OHS must provide a rich set of structuring services (Grønbæk and Wiil 1997). Structuring services support the authoring of hypermedia scenarios. Hypermedia technology already has numerous structuring services available, such as anchors, links, presentation specifiers (pspecs), location specifiers (locspecs), file-wrapper nodes, spatial hypertext, etc.

There are special requirements for structuring services in geographic hypermedia. These services need to take into consideration the nature of geographic data involved (e.g., their spatial and temporal dimensions) as well as the individual features of the processing and analytical operations (as regards to the input parameters and the results produced). Appropriate graphical user interfaces must be available to GH scenario authors, so that they will be capable to discover, exploit and highlight the geographic content.

Navigation

An OHS should provide a rich set of navigation services (Grønbæk and Wiil 1997). These services assist the user to understand the OHS content and prevent him by being “lost in the hyperspace”. Examples of typical navigation services are link traversal, querying, graphical overviews, guided tours, fish-eye views, paths, etc.

A geographic hypermedia system must provide advanced navigation services, where the location and distribution of geographic objects will be highlighted. Geovisualization techniques (Kraak and Dreil 1997) must be adopted and extended for an enhanced understanding of the distribution and behavior of spatio-temporal phenomena.

Distribution

The pieces of hypermedia content interlinked by an OHS may be running on different computing environments in local area network and across different Internet domains. The wired (e.g., web) and wireless (e.g., mobile systems) environments accommodate the hypermedia content and are interlinked with each other.

Geographic hypermedia systems must exploit and extend the outcomes of the research and professional activities towards the development of Internet and mobile systems, such as distributed GI Systems (Peng and Tsou 2003).

Collaboration

The collaborative authoring of both hypermedia contents and structure is proved very valuable in the hypermedia community (Grønbæk and Wiil 1997). Hence, an OHS should provide support for collaboration. The collaboration can take place in asynchronous or synchronous mode, depending on how the authors interact with each other in the creation of content and the structuring of the individual sessions in a hypermedia scenario.

The nature of geographic domains forces the adoption of collaborative authoring in geographic hypermedia systems. The involvement of the user at all stages of the development of a GI application has also proved valuable in the past.

1.4.3 Developing Standards and Specifications

A reference needs to be made to the geospatial standards and the proposed specifications that have been widely adopted recently. These standards and specifications affect the way geographic content is described and inter-linked in the Internet; hence they affect the evolution of Geographic Hypermedia.

The Open Geospatial Consortium (OGC 2006) in parallel with World Wide Web Consortium (W3C 2006) and the International Standards Organization (ISO 2006) develop standards and specifications to support the interoperability between repositories of geospatial information. Table 1.1 provides some representative standards/specifications related to information content.

The scope of these standards and specifications is to enable an application developer to use any geospatial content (data and services) available on “the net” within a single environment and a single workflow (McKee and Buehler 1998). However, it should be noticed that standardization might not solve the problem of interoperability by itself because of the following reasons (Stoimenov and Dordevic-Kajan 2002):

– The construction and maintenance of a single and integrated model is a hard task.
– The requirement to communicate with geospatial sources that do not conform to the adopted standard will always be present.
– Existing geospatial sources have their own models which may not always be mapped to the common model without information loss.

Table 1.1. Standards and Specifications for geospatial content.

Organization	Standard/Specification name
W3C	HyperText Transfer Protocol (HTTP)
W3C	Simple Object Access Protocol (SOAP)
W3C	Web Services Description Language (WSDL)
OGC	Web Map Server (WMS)
OGC	Web Coverage Server (WCS)
OGC	Web Feature Service (WFS)
OGC	Geography Markup Language (GML)
OGC	Catalog Service (CS)
ISO-TC211	Rules for Application Schema (DIS19109)
ISO-TC211	Methodology for Feature Cataloguing (DIS19110)
ISO-TC211	Spatial Referencing by Geogr. Identifiers (CD19112)
ISO-TC211	Metadata (IS19115)
ISO-TC211	Metadata Implementation Specification (DTS19139)

– The standards/specifications are subject to continuous change, but systems will not all simultaneously change to conform.

1.5 Discussion

Geographic Hypermedia (GH) involves the interlinking of geographic content and media. The geographic content (data and services) is distributed with various forms of media being interlinked and exploited in different ways. Special attention is given on the integration of heterogeneous geographic content and consequently on interoperability issues. Additionally, the issues related to authoring and effective use of GH applications are considered.

In contrast to multimedia cartography or multimedia GIS, GH focuses on the integration of distributed geographic content, whereas multimedia cartography/GIS (Cartwright *et al*. 1999) mostly avoids the use of any integration and leans to a more "artistic" considerations that is usually not dependent on a database. Hence, GH encloses a wide research field, that of content integration, which affects the design, implementation and use of GH applications. In addition, GH subsumes multimedia cartography/GIS provided that their concepts and tools are used in GH system development.

In contrast to a distributed GIS, GH interlinks geographic content that may be available at, and offered through, any software package and device. On the other hand, a distributed-GIS (either web-GIS or Internet GIS; Peng and Tsou 2003) focuses on the integration of GI-driven data and services that are usually available at a GIS or Map Server. Hence, GH is a wider term that encompasses the specialized field of distributed-GIS.

1.6 About this Book

This Book consists of twenty-five (25) chapters, including this one. These chapters present different issues related to Geographic Hypermedia and concentrate either in the concepts or in the tools involved in this new paradigm. An attempt to group these chapters based on their content and scope leads to five groupings.

Part I, entitled "Foundations of Geographic Hypermedia" comprises of three chapters. Chapter 1 provided a definition of Geographic Hypermedia, and presented its components, services and related technologies. Chapter 2 gives an introduction to new media tools, investigates how they affect the mapping paradigm, and poses the question which media is appropriate for a specific case. Chapter 3 provides design guidelines for hypermedia GI Systems, distinguishes between discrete and distributed systems and describes the software requirements, the file formats, and the data structures involved, including a prototyping system.

Part II, entitled “Data Resources and Accessibility Issues” consists of six chapters. Chapter 4 provides a survey of geographic data resources and gateways, and shows how to search and retrieve geospatial data from the web. Chapter 5 highlights the use of metaphors to access geographic information. Chapter 6 provides a definition of atlases and digital atlases, describes their characteristics, the alternative delivery media, and proposes a classification of them. Chapter 7 highlights the accessibility issues; specifically how the accessibility of hypermedia maps can be assisted. Chapter 8 focuses on the way to provide accessibility using mobile hypermedia systems. Chapter 9 proposes a new medium/platform for publishing, searching and enhancing communication on the web.

Part III, entitled “Technologies for Content Integration” comprises of five chapters. Chapter 10 gives an introduction to Spatial On-Line Analytical Processing (SOLAP) and how it can be combined with hypermedia technology; it suggests the management of geographic hypermedia documents into a data cube and presents a prototype system. Chapter 11 introduces a conceptual approach to integrate geographic, multimedia and cultural heritage information and collaborative aspects into a single model; this approach may be used to design and implement a web-based information system on top of a database. Chapter 12 considers the development of open hypermaps to achieve the effective information and the exchange of services between them. Chapter 13 presents the main existing standards for open GI Systems, hypermedia systems and cultural heritage systems; it provides a comparison between them and discusses interoperability issues. Chapter 14 focuses on the role of semantics in a geographic hypermedia system; the issues of extraction of geosemantics, ontology engineering and ontology integration.

Part IV, entitled “Analytical Functionality and Geovisualizations” consists of six chapters. Chapter 15 provides a typology of functions for visual exploration on thematic maps. Chapter 16 proposes a comprehensive data exploration through the combination of multiple tools; it sketches a taxonomy of tool and display combinations described in terms of possible input data and tool outputs. Chapter 17 discusses the role of geovisualization and hypermedia, and in concepts in decision-making; two prototype systems are presented. Chapter 18 shows how geovisualization techniques may assist the extraction of spatial relationships and thematic/geometric inconsistencies. Chapter 19 presents hypermedia-based concepts and techniques that lead to effective visualization of time-dependent geographic information. Chapter 20 provides a gallery of Scalable Vector Graphics (SVG) based applications and interfaces for geographic hypermedia.

Part V, entitled "Geographic Hypermedia: Applications and Services" comprises of five chapters. Chapter 21 discusses the principles and communication methods to assist wayfinding in urban areas. Chapter 22 presents the development of a campus location based service (LBS) and investigates the necessary infrastructure for LBS's. Chapter 23 proposes the development of a web-GI System according to human-computer interaction (HCI) guidelines; an example context is examined. Chapter 24 provides guidelines to compile hypermedia content and educate people with various experiences/training on earth and biodiversity issues using high definition video (HDTV) technology. Chapter 25 shows how mobile GI Systems may support education, presenting an example application at a university campus.

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2 New Media: From Discrete, to Distributed, to Mobile, to Ubiquitous

William Cartwright, Michael Peterson, and Georg Gartner

Abstract. *New Media* includes a range of new delivery and display platforms; among them are the World Wide Web, interactive digital television, mobile technologies, interactive hyperlinked mapping services, and enhanced mapping packages that are “linked” to large databases—national or global (Cartwright *et al*. 2001). New Media now provides a unique conglomerate media form for representing geospatial information in innovative ways. The many cartographic products developed and published using New Media illustrate the enthusiasm with which the geospatial science community has embraced it as a tool for representing geography. It is argued that this 'new' method of access to and representation of geospatial information is different to aforeused methods and therefore, whilst New Media applications can be considered to be at a fairly immature stage of development (compared to paper maps – here paper maps have a 500 years or so ‘start’ on electronic counterparts), much research has been undertaken to develop strategies for ‘best practice’ so as to overcome any deficiencies. This chapter gives an overview of how multimedia / hypermedia mapping has developed using discrete, distributed, mobile and ubiquitous media and devices. It provides an overview of the applications of New Media tools and communications systems that cartography has adopted / adapted to deliver timely and appropriate geoinformation. It provides examples of the use of discrete interactive multimedia, distributed interactive multimedia, and delivered via the World Wide Web (Web) or via intranets and mobile information delivery applications. Finally, it looks at how the concept of ubiquitous computing might be used to facilitate a ‘different’ paradigm for geographical information delivery.

2.1 Introduction

Cartography has always used / developed New Media mapping tools. When map cartographers/publishers applied printing to map production they used this 'New Media' to facilitate quicker, more accurate and cheaper versions of their works. The quest for more speed, lower compilation and production costs and an efficient communication system has led cartographers to embrace new technology. Developments in printing, were employed by cartography in its various guises - woodblock printing, letterpress, gravure, lithography and offset lithography, it was the norm for over 500 years. And, different ‘manuscript to plate’ methods were developed and used, like the application of photography, computer-driven exposure devices and direct computer-to-plate systems. Printing was complemented and enhanced by precision machines, computers (at first for computational mapping applications and later as complete interactive publishing systems). Later, optical storage media like videodisc, CD-ROM, DVD and their many configurations, communications systems – intranets and the Internet, and interactive installations in the form of hypermedia provided alternative publishing vehicles. Then visualization systems became mobile, providing geographical information ‘where needed’ and delivered on different, smaller platforms. Finally, the provision of this information became ubiquitous, delivering information in a manner that is virtually invisible to the final information consumer. Different and innovative mapping systems have developed and products have been produced to show 2D, 2½D, 3D and 3D+time (4D), plus n-dimensional data elements. There has been a digital convergence, and relatively inexpensive tools exist to develop and provide a plethora of (geo) information exploration devices. Tools and techniques are readily available, and the best methods for delivering effective geoinformation tools are being explored.

The following sections of this chapter provide information about how the tools for delivering geohypermedia have developed: from systems ‘sitting’ on a multimedia computer to systems that are now so commonplace that they have become ubiquitous.

2.2 Discrete

Here, discrete cartographic media refers to products made available through the use of isolated computers regardless of whether they are desktop, notebook or personal assistant. Nevertheless, it is recognised that all cartographic media can be discrete. However, the focus here is on discrete publishing media, and not discrete cartographic products *per se*. The packages are stored in digital form on floppy disk, hard disk drive, optical disk, videodisc or computer tape. They were applied to provide innovative access to image collections, data, information sites brimming with maps, ‘do-it-yourself’ map generation, map collections, atlases and hybrid products.

The analog videodisc was the storage medium used on the first product where the term ‘multimedia’ was used. In fact it was a mapping project:

the *Aspen Movie Map*, produced by MIT's Machine Architecture Group (which later led to the creation of the Media Lab) in 1978 (Negroponte 1995b). Videodiscs stored analogue video signals and were controlled by programs executed on a computer to which the videodisc was attached. This storage medium provided 36 minutes of PAL or NTSC read-only video from a 12" standard disc or 60 minutes from an extended play disc. They could store the equivalent of 52,000 slides and provided two audio tracks. As well as the MIT product, other examples of the application of videodiscs to the visualization of geographical information were The *Domesday* videodisc system (British Broadcasting Commission 1985), the Canadian Energy, Mines and Resources prototype, *Canada on Video Disk*, produced in 1987 (Duncan 1992) and the *Queenscliff* prototype videodisc, 1987 (Cartwright 1990).

Limited as they were, and constrained by underdeveloped user interfaces and interrogation routines, interactive videodisc products heralded the future of the application of hypermedia to geography. Products published on the 'Laservision' videodisc standard proved to be the forerunner of later products developed using CD-ROM.

CD-ROM, jointly developed by Philips and Sony in 1982, proved to be a most popular medium due to its (relatively) large, robust storage capacity. The media stored a minimum of 540 MB of data made it attractive to map producers looking for a robust storage medium that could store the large amounts of data associated with maps and other geographical visualization artefacts. CD-ROM was overtaken by DVD-ROM during late 1995 and by early 1996 some titles previously published on CD-ROM were reissued on DVD (Hamit 1996). By around 1998 DVD generally replaced CD-ROMs in most machines that required large storage capacities. Maps and other related products were published using this medium, and a wide range of innovative products resulted. Typical of these products were early publications that consisted of scanned maps from existing paper products.

Also around the same time, the introduction of the World Wide Web focussed interest away from discrete media to distributed applications. Writers like Negroponte (1995a) saw all kinds of package media slowly dying out. This was predicted for two reasons: the approaching 'costless' bandwidth of the Internet, allowing almost a limitless distribution system; and solid-state memory catching-up to the capacity of the CD, giving the prospect of massive data storage at minimal cost. The future demise of discrete multimedia was predicted by Louis Rosetto, the founder of *Wired*, and he called CD-ROMs the 'Beta of the '90s', referring to the quickly-defunct 'Betamax' video format (Negroponte 1995a). Negroponte (1995a, p. 68) agreed with him and said that: "*It is certainly correct that, in the long term, multimedia will be predominantly an on-line phenomenon.*"

By the mid to late 1990s the Internet, and more particularly the use of the World Wide Web (web), became the focus of interactive multimedia developers. Discrete media was pushed aside somewhat in the move towards the communication system that changed forever how we access information, including geoinformation.

2.3 Online / Distributed

From its beginnings in 1969 until about 1983, the Internet was under the control of the U.S. military. In that year, the U.S. National Science Foundation (NSF) began a major investment in the network through funding for a series of supercomputer centers. The purpose of these centers was to allow access to high speed computers by researchers from different locations. The NSF investment led to increased data communication speeds but the system was primarily still relegated to academic research scientists and the U.S. military. Email began to be used in the 1980s and this slowly increased the number of Internet users but the system was still difficult to use. Sending and receiving files required memorizing text commands. The initial World Wide Web, as conceived and implemented by Tim Berners-Lee at the beginning of the 1990s in a research laboratory in Switzerland, was still based on text. His hypertext WWW system allowed text elements to be linked to other text files.

Bringing the Internet to the masses required adding graphic elements to Internet information delivery. The first graphical WWW browser was a program called Mosaic introduced by the National Center for Supercomputer Applications at the University of Illinois in the US. Marc Andreesen and Eric Bina designed the program as a “consistent and easy-to-use hypermedia-based interface into a wide variety of information sources.” The concept, Andreessen says, "was just there, waiting for somebody to actually do it."

The Internet facilitated the wide-spread adoption of the Mosaic program in a matter of months. Never before had a program enjoyed almost immediate success – and distribution via the Internet made it possible. The appeal of Mosaic was primarily the incorporation of graphics. Not everyone was pleased with this new development. Tim Berners-Lee, who designed the Web only a few years before, admonished Andreesen and Bina by telling them that adding images to the Web was going to bring in a flood of new users who would do things like post photos of nude women. Andreesen later admitted that Berners-Lee was right on both counts.

Table 2.1. Browser market share first two months of 2006 and the last two months of 2005. Explorer and Netscape both lost market share to Firefox.
[IE: Internet Explorer; Ffox: Firefox; Moz: Mozilla; O: Opera; N: Netscape]

Month	IE6	IE5	Ffox	Moz	N7	O8	O7
February 2006	60.5%	5.8%	25.4%	2.9%	0.4%	1.4%	0.1%
January 2006	61.3%	5.5%	25.0%	3.1%	0.4%	1.4%	0.2%
December 2005	61.5%	6.5%	24.0%	2.7%	0.4%	1.3%	0.2%
November 2005	62.7%	6.2%	23.6%	2.8%	0.4%	1.3%	0.2%

Source: http://www.w3schools.com/browsers/browsers_stats.asp March 2006.

The commercialization of the Internet in the decade following 1995 is marked both by a large increase in the number of Internet users and a “browser war” with companies attempting to gain control of commerce through a standard browser. Mosaic had morphed into a commercial product called Netscape by October of 1994. Microsoft’s Explorer was released in 1996. Toward the end of the decade, an open source program called Firefox began to break the hold of commercial interests (see Table 2.1). *Firefox* is viewed as a faster, trimmer Web browser that isn’t subject to the crashes and security gaps that afflict the market-leading Internet Explorer. A general trend toward open source software, including a hugely popular web server program called Apache, began to take hold as dissatisfaction increased with commercial control of the Internet.

Tracking the number of Internet users is an inexact science. According to the Computer Industry Almanac, there are currently one billion Internet users or nearly 16% of the world’s population. This is up from 533 million Internet users worldwide at year-end 2001 which at that time represented only 8.7% of the world’s population. There were only 200 million Internet users at year-end 1998. It is expected that the number of Internet users will reach 1.46 billion by 2007. Most of the current Internet users are located in the top 15 countries (see Table 2.2). The major growth in the use of the Internet is coming from the East and South Asia, Latin America, and Eastern Europe. India is now ranked 5th in terms of the share of world Internet users. In 2001, India was not even in the top 15 (see Table 2.3).

It has also been observed that there is a disparity in the number of male and female Internet users, particularly in certain countries. In 2000, male-female ratio ranged from 94:6 in Middle East to 78:22 in Asia, 75:25 in Western Europe, 62:38 in Latin America, and finally 50:50 in USA (Dholakia, et.al, 2003). Updated data are presented in Table 2.4.

There has been great interest in the Internet by cartographers. Research has examined a variety of issues associated with the distribution of maps through the Web. The 2003 volume entitled Maps and the Internet (Peter-

Table 2.2. Top 15 nations in Internet use at year-end 2004. The last column indicates the percent of the world total. Data for some countries are not available.

Rank	Nation	Internet Users 2004 (millions)	Share of World Users
1	United States	186	19.86%
2	China	100	10.68%
3	Japan	78	8.35%
4	Germany	42	4.48%
5	India	37	3.96%
6	UK	33	3.54%
7	South Korea	32	3.39%
8	Italy	26	2.73%
9	France	25	2.72%
10	Brazil	22	2.39%
11	Russia	21	2.27%
12	Canada	20	2.19%
13	Mexico	14	1.49%
14	Spain	13	1.44%
15	Australia	13	1.39%

Source: Computer Industry Almanac (2004)

son 2003) identified five areas of study: Internet map use, Internet map delivery, Internet multimedia mapping, Internet mobile mapping, and Internet cartography theory. Research in Internet map use has found that usage grew rapidly after 1997, particularly at commercial sites. It has been shown that the growth in the use of maps through the Internet expanded at an exponential rate. Users were quick to adapt to map delivery through this new medium.

In 2005, Google.com introduced two online map services. The first, Google Earth, allowed the user to fly in a virtual sense between locations using a combination of satellite images, air photos, and maps. The second, Google Local, made it possible to add features to a map based on an address. Both services allow users to interact with representations of the earth in different ways than was possible in the past and many see these services as the beginning of a new era in Internet cartography. While Google Earth has gained considerable attention, the major development may be Google Local because it allows users to add information to maps for everyone else to see. Analogous to a Wiki, these maps represent a type of collective online map that a community of users can help construct. Rather than a cartographer deciding what to include on a map, this Google map will be made by users to show what they think is important.

Table 2.3. Top 15 nations in Internet use at year-end 2001. The last column indicates the percent of the world total. Data for some countries are not available.

Rank	Nation	Internet Users 2001 (millions)	Share of World Users
1	United States	149	41.92%
2	China	33.7	9.48%
3	UK	33	9.29%
4	Germany	26	7.32%
5	Japan	22	6.19%
6	South Korea	16.7	4.70%
7	Canada	14.2	4.00%
8	Italy	11	3.10%
9	France	11	3.10%
10	Russia	7.5	2.11%
11	Spain	7	1.97%
12	Netherlands	6.8	1.91%
13	Taiwan	6.4	1.80%
14	Brazil	6.1	1.72%
15	Australia	5	1.41%

Source: Computer Industry Almanac (2001)

Whether the change brought by the Internet is an evolution or a revolution for cartography has yet to be determined. Cartography has always been subject to developments in technology. Printing may represent the best analogy to the Internet because it also increased the distribution of maps. But, the medium of paper also limited their distribution. In addition to increasing the distribution of maps, the Internet also has the potential of changing the way spatial information is communicated to people. It is clear that maps will continue to evolve to take advantage of this new medium.

2.4 Mobile

In Europe, the first generation of mobile telephones appeared in the mid 1970's in Scandinavia and was based on analogue techniques. The second generation of mobile handheld devices brought digital transfer technologies as the "Global System for Mobile Communications" (GSM) and made the wireless phones a mass market phenomenon. Today, multiple standards are used in worldwide mobile communications. Different standards serve different applications with different levels of mobility, capability, and ser-

Table 2.4. Gender differences in Internet use by country ranked by disparity in male usage.

Internet Users by Gender		
Country	*Male %*	*Female %*
Germany	63.4	36.6
France	61.9	38.1
Italy	60.9	39.1
Spain	60.9	39.1
Belgium	60.6	39.4
Netherlands	59.8	40.2
Brazil	59.7	40.3
Switzerland	58.7	41.3
Japan	58.4	41.4
Austria	58.1	41.9
Norway	58.0	42.1
UK	57.2	42.8
Israel	57.1	42.9
Hong Kong	56.6	43.4
Singapore	56.5	43.5
Denmark	55.9	44.1
Taiwan	55.8	44.2
Ireland	54.8	45.2
Sweden	54.8	45.2
South Korea	54.4	45.7
Mexico	54.0	46.0
Finland	53.9	46.1
New Zealand	52.5	47.5
Australia	51.6	48.4
Canada	49.0	51.0
United States	47.3	52.2

Source: Nielsen/NetRatings, 2003

vice area (paging systems, cordless telephone, wireless local loop, private mobile radio, cellular systems, and mobile satellite systems). Many standards are used only in one country or region, and most are incompatible. GSM is the most successful family of cellular standards, supporting some 250 million of the world's 450 million cellular subscribers with international roaming in approximately 140 countries and 400 networks.

When “Wireless application protocol” (WAP) started some years ago it was for the first time ever that mobile devices had restricted access to the Internet and content that was prepared especially for the use on mobile clients with small displays. Although it does not allow the provision of graphics other than in a very basic presentation, it has been used for first attempts. With 3rd generation technology UMTS it is possible to give continuous access to most of the internet sites, graphical presentations included.

The new so called "3rd Generation" (3G) of mobile phones features not only an IP-based technology but allows also for the first time so called “rich calls” transferring several user data streams simultaneously. This is also often referred to as “multimedia calls”. It was a question of data transfer rates which did not allow other than voice calls up to now. But users and developers of wireless devices always had the idea not only to transmit “simple” voice calls but also all other forms of digital data. The new technologies as "Global Packet Radio Switch" (GPRS) and the latest, on air since 2001, "Universal Mobile Transmission System" (UMTS) seem to make this idea become true for the first time in mobile communication. This will be possible only with the transmission rates proposed for the third generation of mobile devices as UMTS will be. The difference in speed between GSM and UMTS can be given by factor 50, in rare cases up to a factor of 200. This is a factor of 6 compared to ISDN and enables video transmission as well as audio files. Because UMTS technology enables the transfer of many different data formats in fast growing transmission rates, the development of complete new and attractive applications is initiated. Still, there are only very few ideas, prototypes and even less running applications trying to take advantage of the UMTS possibilities. But due to telecommunication companies this market will grow up and is currently highly focused in research and development.

There has been a massive growth in the use of the wireless Internet via cell phones. The wireless Internet share is increasing and it is predicted that that most of the growth in the use of the Internet will come from the wireless sector. However, it is likely that a wireless Internet user will also use a wired network.

Telecommunication infrastructure (mobile network), positioning methods, mobile in- and output devices and multimedia cartographic information systems are prerequisites for developing applications, which incorporate the user’s position as a variable of an information system. Integrating geospatial information into such a system, normally cartographic presentation forms are involved. Thus, the resulting system can be called a "map-based location based service" (LBS).

Different levels of solutions for presenting information within map-based LBS have developed:

- Cartographic presentation forms without specific adaptations
- Cartographic presentation forms adapted to specific requirements of screen display
- New and adapted cartographic presentation forms
- Multimedia add-ons, replacements and alternative presentation forms

Rules and guidelines have been developed during the last years to adapt cartographic presentations to the specific requirements of screen displays (Neudeck 2001). A lively discussion about new and special guidelines for map graphics regarding the very restrictive conditions of TeleCartography and mobile internet has brought up various suggestions and proposals (see Reichenbacher 2003, Gartner and Uhlirz 2001).

Common rules or standards for cartographic presentations on screen displays are not defined yet, due to the permanently changing determining factors. Display size and resolution of state-of-the-art devices are permanently increasing and colour depth is no longer a restricting factor. Parameters of external conditions during the use of the application (weather, daylight) are hard to model. The needs of an interactive system have to be incorporated into the conception of the user interface, which includes soft keys as well as functionalities for various multimedia elements. As a general approach for including the various parameters within a model of map-based LBS the concept of "adaptation" (in terms of user-dependent adaptation of a cartographic communication process) has been brought up (Reichenbacher 2003). The concept is to describe links or mutual dependencies between various parameters and the results are connected to impacts to the data modelling and cartographic visualization. Furthermore, new cartographic presentation forms especially designed for restricted and small screen displays have been developed (see e.g. “focus-map” by Klippel 2003).

For the presentation of geospatial information within LBS and on small displays additional multimedia elements and alternative presentation forms may become potential improvements. Methods of "Augmented Reality" (AR) link cartographic presentation forms (e.g. 3D graphic) to a user’s view of reality, e.g. at applications like navigation systems. Cartographic AR-applications try to create a more intuitive user interface (Reitmayr and Schmalstieg 2003). Kolbe (2003) proposes a combined concept of augmented videos, which realises positioning and information transfer by means of video.

2.5 Ubiquitous

Ubiquitous computing has been named as the ‘third wave’ in computing, or “...the age of calm technology, when technology recedes into the background of our lives” by the father of ubiquitous computing, the late Mark Weiser (1996). In his disquisition on “The Computer for the 21st Century” he assumed that in the near future a great number of computers will be omnipresent in our everyday life and that they will soon be interconnected in a ubiquitous network. We now see this type of computing in the form of handheld PCs, mobile phones, wireless sensors, radio tags and Wi-Fi (Baard 2003). Designers of ubiquitous systems envision seeding private and public places with sensors and transmitters that are embedded into objects and hidden from view, providing for the deployment of things like ‘Audio Tags’, which plays an infrared sensor-triggered message once a person is within a pre-determined proximity (Wired News 2003). In the mapping world, the interest in ubiquitous cartography has been formalised with the International Cartographic Association’s Commission on Ubiquitous Mapping (http://ubimap.net/). It has as a goal to explore the potential that ubiquitous computing has for mapping.

Currently ubiquitous mapping is being delivered via cellular telephone systems, through the use of wireless Internet ‘zones and sensors that upload current data like train timetables etc. to users who have subscribed to a service. Such services are deemed to be ubiquitous when a user does not need to ‘log-in’ or actively connect to a service. According to Morita (2004), ubiquitous mapping provides the ability to create and use maps any place at any time to resolve spatial problems.

Most recently geo-scientists started to discover the possibility to use the omnipresent computer landscape for exploring our spatial environment. Fairbairn (2005) explains the term ‘Ubiquitous Cartography’ as a technological and social development, made possible by mobile and wireless technologies, that receives, presents, analyses and acts upon map data which is distributed to a user in a remote location. Furthermore he predicts that this new approach to maps will revolutionize the way many people interact with maps. To Ota (2004) “the definition of ubiquitous mapping is that people can access any map at (sic) anywhere and anytime through the information network” (pp. 167).

A prominent field of application in the context of ubiquitous cartography is the support of orientation and navigation functions. Within the last few years a lot of research and development has taken place concerning Location Based Services, which could now be supplemented and expanded with the help of ubiquitous methods, and maybe in the future they could even be replaced. Yet research is still in the early development stage that still requires many new challenges. The improper usage of ubiquitous systems could easily lead to an overload of impressions. A lot of information that might even be completely independent from each other could overstrain the user and hinder effective information extraction. To avoid this effect the aim of such a system should concentrate on providing information about the environment without overstraining the user. At decision points the information should be unmistakably clarified but everywhere else, where guidance is not implicitly necessary, additional information should be provided in an unobtrusive way. User friendliness is therefore the main ambition of ubiquitous cartography applications.

The concept of ubiquity requires an intensive analysis of appropriate presentation forms for particular contexts. Beside the yet unspecified visualisation of the basic data material, namely the depiction of three-dimensional space on a two-dimensional display, additional visualisation techniques need to be considered that evolve from the possibility of interconnected data exchange. The basic assumption in this context is that a harmonized combination of active and passive systems with various presentation forms supports the wayfinding process best. Radoczky (2003) has shown that various presentation forms used for navigating a mixed indoor/outdoor environment lead to different mental representations and subjective acceptance.

The development of ubiquitous cartography so far gives an indication, that although maps will play a prominent role in ubiquitous environments, the nature of quick and individually tailored presentations of location-based and time-dependent information will lead to a wide variety of different cartographic presentation forms, from schematic 2d-graphics to interactive 4D-presentations. In terms of the contents, which are presented by these various forms, the concept of ubiquitous cartography implicates individually tailored contents, which remains a major challenge for contemporary cartography.

2.6 Conclusion

We now have access to information online, wired and ubiquitously. We can receive information about geography, our geography and related services. Access to information has changed forever and we are living in an information era that provisions information to us at home, in the workplace, in school and whilst we are ‘on-the-move’. For designers and provisioners of geographical information artefacts this wealth of information-provision tools and communications systems offers challenges that ask us to question which delivery mode / media composite is appropriate for consumers, sometimes unknown, and geographical information delivery, chosen from a plethora of continually-updated data sources that are available and usually accessible. GeoHypermedia installations and products, built from data provisioned via discrete resources, on-line, wirelessly and ubiquitously provide users with a choice of information resources hitherto unimagined.

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3 Design Issues Associated with Discrete and Distributed Hypermedia GIS*

Shunfu Hu

Abstract. The advancement of computer technology enables the integration of geographic information system (GIS) and multimedia technologies that allow to incorporate not only spatial-temporal geographic information in image/vector format, but also multimedia geographic information in descriptive text, scanned ground photographs, graphics, digital video and sound. The concept of hypermedia GIS is defined in this chapter. Design issues on the development of hypermedia GIS for use on individual personal computers (PC) (i.e., discrete system) and on the Internet (i.e., distributed system) are discussed. Software requirement, file format and data structure used in each system are described. The discrete and distributed hypermedia GIS provide the essential concepts and techniques for many new GIS applications such as visualization, spatial decision support systems and spatial database management and exploration.

3.1 Introduction

The advancement of computer technology enables the integration of digital geographic information systems (GIS) and multimedia technologies to incorporate not only spatial geographic information in image/vector format, but also multimedia information. The term “multimedia” implies the use of a personal computer (PC) with information presented through the following media: 1) text (descriptive text, narrative and labels); 2) graphics (drawings, diagrams, charts or photographs); 3) digital video (television-style material in digital format); 4) digital audio sound (music and oral narration); and 5) computer animation (changing maps, objects and images) (Bill 1994). Multimedia technology has been extensively utilized by commercial encyclopedia CD-ROMs (e.g., *Microsoft Encyclopedia*) to provide a multi-sensory learning environment and the opportunity to improve concept understanding.

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The integration of multimedia technology and computer-assisted mapping systems has gone through several stages. The first stage was the development of interactive maps and electronic atlases during the 1980s. The interactive map is a computer-assisted form of map presentation and is characterized by an intuitive graphical user interface that allows the user to manipulate the map features (points, lines or polygons) through a computer mouse (Peterson 1995). The link to multimedia information is achieved through superimposing "hotspots" on the cartographic features of the map or on digital remote sensor data (e.g., digitized aerial photographs). Interactivity becomes a key feature of the interactive maps, which allow the user to explore more detailed information in the area predefined by the map developer. Examples of early electronic atlases include the *Domesday Project* and *Goode's World Atlas* (Openshaw and Monnsey 1987, Rhind *et al*. 1988, Espenshade 1990).

The second stage was the development of the "hypermap" in the early 1990s. Coined by Laurini and Milleret-Raffort (1990), the term "hypermap" was described as multimedia hypertext documents with geographical access. In other words, the hypermap is an interactive, digital multimedia map that allows users to zoom and find locations using a hyperlinked gazetter (Cotton and Oliver 1994). The underlining principle of the hypermap is the concept of hypertext. Hypertext represents a single concept or idea. By activating pre-defined hyperlinks, it is possible for the user to connect a hypertext to other non-linear text information (Nielson 1990). If the hypertext is linked to multimedia information, the term "multimedia hypertext" or "hypermedia" is used. Therefore, hypermap is also called "cartographic application of hypertext" or "hypermedia mapping" (Cartwright 1999). The development of hypermaps was made possible with Apple Corporation's Hypercard software developed for the Macintosh computer released in 1987 (Ravenau *et al*. 1991). Examples of hypermaps include the *Glasgow Online Digital Atlas* (Raper 1991) and HYPERSNIGE (Camara and Gomes 1991).

The third stage was the integration of hypermedia systems (which feature hypertext, hyperlinks and multimedia) and geographic information system (GIS), referred to as hypermedia GIS. A GIS is used to capture, retrieve, manipulate, and display geographic information. It is used to link cartographic features and their alpha-numeric attributes to perform spatial analysis (Burrough 1986, Star and Estes 1989, Clarke 1995). However, GIS is limited in handling multimedia information (Shepperd 1991). Recently, there has been increasing interest in integrating multimedia information in GIS (Bill 1994, Hu 1999, Hu *et al*. 2000, Hu *et al*. 2003). GIS development in recent years has seen fast advancement in both the desktop computing environment and on the Internet. The former is referred to "discrete GIS" and the latter is "distributed GIS" (Peng and Tsou 2003). "Discrete GIS" is a standalone GIS software package such as ArcView 3.3. or ArcGIS 9.0 that is installed typically on a PC or Unix machine. This traditional GIS is a closed, centralized system that incorporates a graphical user interface, programs, and data. Each system is platform dependent (e.g., Unix, Windows, Macintosh) and application dependent (e.g., ArcView, Arc/Info, or MapInfo). Data to be used in the discrete GIS application can be stored on computer hard drives or compact discs. Access to the data by the GIS program is usually fast. The term "Distributed GIS", on the other hand, is defined as GIS software and related data that are distributed via different computers located in different physical locations through a computer network such as a local area network (LAN) or the Internet. A distributed GIS applies the dynamic client/server concept in performing GIS analysis tasks through standard interfaces of the World Wide Web (WWW). Web-based GIS applications provide GIS database query or interactive map exploration on the Internet (Peng and Nebert 1997, Abel *et al*. 1998, Peng 1999, Dragicevic *et al*. 2000, Myer *et al*. 2001, Zhang and Wang 2001). Unfortunately, access to the data (stored on a computer server) by the Internet user (client) through the computer network is usually relatively slow when compared to processing in a discrete GIS environment.

Since discrete GIS and distributed GIS are different computing environments, the integration of a hypermedia system within a discrete or distributed GIS needs to be addressed in an appropriate manner. There is currently no single literature available that discusses the design issues related to the development of discrete hypermedia GIS and distributed hypermedia GIS. The objective of this chapter is to describe software requirements, file formats and data structures for the development of discrete and distributed hypermedia GIS, respectively. In order to explain how the two systems are developed, the author will use a portion of the vegetation database generated for the Everglades National Park (Welch *et al*. 1999). In both cases, emphasis is placed on the design and development of the hypermedia GIS system that includes: 1) a hypermedia vegetation plant community database; 2) a hypermedia browser; and 3) the integration of the hypermedia system and GIS application.

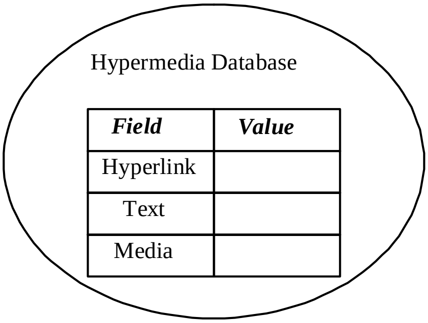
3.2 Design of a Discrete Hypermedia GIS

The discrete hypermedia GIS can be seen as an integrated system between a standalone GIS that provides tools to manipulate map features and their attributes stored in a GIS database and a hypermedia system that includes a hypermedia database (including hypertext and hyperlinks) and a browser. The linkage between the two different structured databases can be established through a common identification number (ID) as seen in a relational database management system. The map features can be manipulated through commercial GIS software (e.g., ArcView) or customized GIS program developed using Visual Basic (Microsoft 1994) and MapObjects (ESRI 1996). In the design of the hypermedia system, hypertext is employed to highlight key features (e.g., plant species) and to facilitate access to further detailed information about these features. The development of a hypertext document on the WWW requires the use of the Hypertext Markup Language (HTML - a programming language for publishing text-based documents on the Internet), and an Internet browser (e.g., Microsoft Internet Explorer or Netscape Navigator). The following sections discuss the design of a discrete hypermedia GIS, including: 1) the data structure of a hypermedia database; 2) the development of a standalone browser to visualize and explore the hypermedia database; and 3) the integration between the hypermedia system and a GIS application.

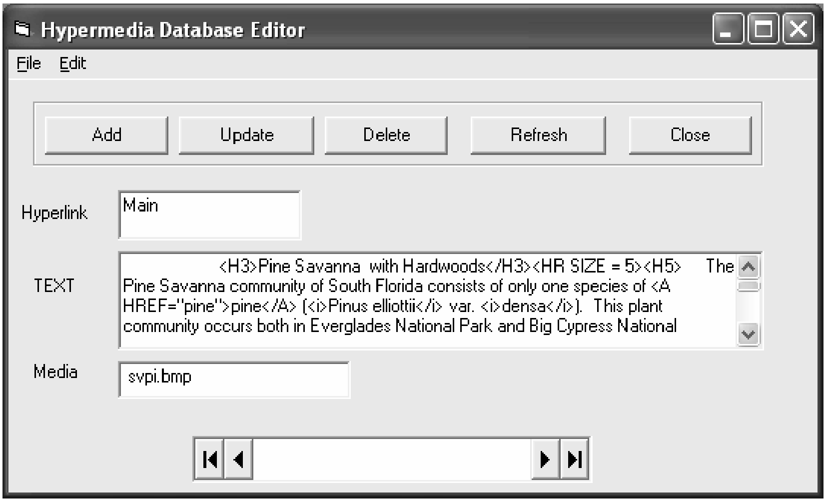
3.2.1 Hypermedia Database

Descriptive text information about the plant community is fundamental to the preparation of the Everglades hypermedia vegetation plant community database. Hypertext is employed to highlight key features (e.g., plant species) and to facilitate access to additional detailed information about these features (e.g., text, ground photographs, digital video and sound). The construction of hypertext involves the use of three elements: 1) a hyperlink; 2) the text information associated with the hypertext, and 3) the media (i.e., scanned photographs or digital pictures, video or audio) associated with the hypertext. Accordingly, the data structure of the hypermedia database will contain three fields, namely, Hyperlink, text and Media (Fig 3.1a).

Visual Basic 6.0 comes with a utility called Visual Data Manager that allows the development of databases in various formats such as Microsoft Access 7.0 and dBASE 5.0. Fig. 3.1b displays a Hypermedia Database Editor, generated in Visual Basic to create, update, and save a hypermedia database in Microsoft Access Database format (.mdb). The Hyperlink field stores the name of the hyperlink for each hypertext. The Text field stores the descriptive text information associated with the hypertext. The syntax of HTML was used to organize text information, set up hypertext and establish hyperlinks. The Media field of the database stores only the file names of photographs (.bmp), digital video (.avi) or audio sound (.wav)



(a)



(b)

Fig. 3.1. Hypermedia database structure (a). Hypermedia database editor (b).

associated with the hypertext. In Fig. 3.1b, the Everglades SVPI plant community (i.e., Pine Savanna with Hardwoods) is used as an example for the field value. The Hyperlink field contains the value of “Main”, indicating that it is the main page of the database, the Text field contains the entire HTML document, and the Media field contains the file name (e.g., svpi.bmp) of the scanned ground photograph for the panoramic view of the SVPI plant community.

There are multiple levels of hypertext within a hypermedia database. The first level is the main page of hypertext document for a plant community, which may contain hypertext and hyperlinks. The user is able to click on any hypertext in the first level and reach the second level hypertext document which may contain other hypertext and hyperlinks, and then the third level hypertext document, and so on. As a result, the values of the three fields need to be changed based on different circumstances. For instance, if the main page of descriptive text for SVPI contains a hypertext "pine," then, the Hyperlink field value needs to be changed to "pine," the Text filed will contain the entire HTML document for descriptive information about the pine plant species, and Media field contains the file name of a close-up picture (e.g., pine.bmp) of the plant. In another instance, if a digital video or sound is linked to a hypertext (e.g., deer), then the Media field contains the file name of a digital video clip (e.g., deer.avi) or an oral narrative (deer.wav).

Conversely, the user is also able to backtrack from a lower level hypertext document (e.g., third level) to an upper level hypertext document (second level) in the hypertext network. The user must also be able to backtrack to the main page of hypertext document from any level of the network. This provides an opportunity for the user to control the flow of information presentation in a non-linear manner, a characteristic of a hypermedia system.

3.2.2 Hypermedia Browser

The hypermedia browser is simply an application program designed specifically to visualize the hypermedia database in an efficient way. The browser will provide the user an interactive tool to explore multimedia information by clicking on any hypertext.

In the design of hypermedia database, text information is separated from photographs, digital video and audio files so as to utilize separate windows to convey information associated with the same text. The utilization of both descriptive text and a photograph for the same hypertext typically improves understanding. Consequently, two display windows, namely a Text window and a Graphic window, may be required to display descriptive text and photographs, respectively. No display window is required for the digital video and sound because the digital video can be played back in a window provided by the Windows operating system, and audio sound can be played back as background.

A few procedures are required in order to display text information (including hypertext and hyperlinks) in the Text window, display photographs in the Graphic window and play back digital video or sound (Fig. 3.2). The procedure, OpenDatabase( ), is required to open the hypermedia database in Access format and then split it into two streams: Text and Media, corresponding to the Text and Media fields of the database. For the

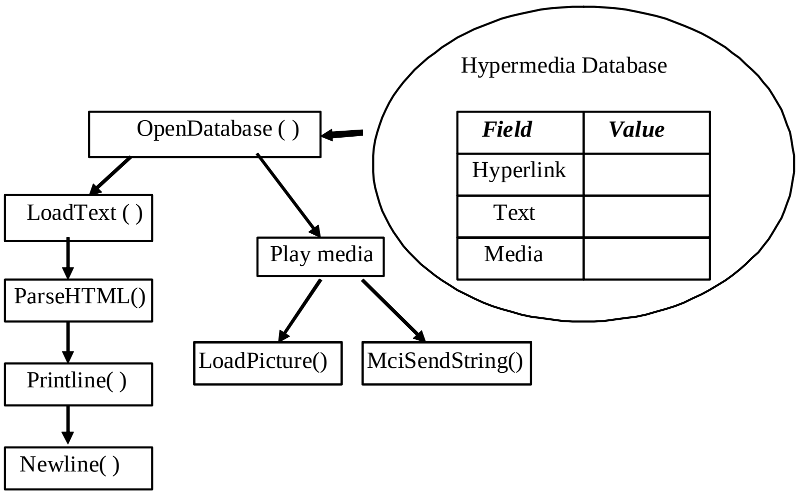


Fig. 3.2. Basic procedures to create a hypermedia browser.

Text stream, LoadText( ) is used to load text from the Text field and to check if there is any HTML syntax. If the HTML syntax exists, a third procedure, ExecuteHTML( ), is used to process the HTML syntax which includes the one used to set the hypertext in blue and underlined, and the one used to establish the hyperlink. This process continues until all HTML syntax in the Text field has been checked. Two other procedures are required to print a line of text and start a new line in the Text window.

For the Media stream, there are three cases: 1) scanned photograph (.bmp); 2) digital video (.avi); and 3) audio sound (.wav). In the case of a scanned photograph, the *LoadPicture ( )* function, available in Visual Basic, can be used to display the photograph in the Graphic window. The code in Visual Basic is:

```
Case “bmp”
GraphicWindow.Picture = LoadPicture(App.path & media)
```

In the case of digital video file (.avi) or sound file (.wav), a specialized function, mciSendString ( ), can be used (Aitken 1996, Jarol and Potts 1995). The Visual Basic code is:

```
Case  “wav”, “avi”
Dummy = mciSendString (“play” & App.Path & media, 0, 0, 0)
```

3.2.3 Integration of a Hypermedia System with a GIS

The key feature of a hypermedia GIS lies in its ability to provide the user with the means to explore cartographic features (e.g., points, lines, polygons) interactively and to link the features not only with their attributes stored in GIS database but also within the hypermedia database. This requires the development of both a GIS application and hypermedia system in a coherent software environment. ESRI's MapObjects can be used as component software (i.e., ActiveX) in Visual Basic to develop a sophisticated GIS application (ESRI 1996). With Visual Basic, GIS application developers are able to provide GIS functions to allow the user to explore the GIS database interactively (e.g., zoom in/out, pan, identify, label, search).

In our example, the hypermedia database is developed for each plant community. The name of each plant community is stored as an attribute of the GIS database developed for the Everglades National Park. It is feasible to establish the linkage between the GIS database and hypermedia database through this common key (i.e., the name of the plant community, or just its abbreviation). In addition, since both GIS application and hypermedia system are all developed in the Visual Basic programming environment, they are coupled coherently. Further more, both the application software and the databases can be stored on a CD-ROM or DVD-ROM for wide distribution.

Fig. 3.3 demonstrates a prototype hypermedia GIS developed for the Everglades National Park in which basic GIS tools are provided to the user to manipulate the GIS database. At the same time, the user can identify the name of the plant community (e.g., SVPI) by clicking on a polygon feature from the digital map and a hyperlink is activated with the hypermedia system which displays the panoramic view of the plant community and the main page of the descriptive text information. The hypertext and hyperlinks in the Text window allow the user to explore more detailed information about this plant community.

3.3 Design of Distributed Hypermedia GIS

The distributed hypermedia GIS is designed for use on the Internet. Such applications are based upon the interactions between client and server computer systems through network technology. The client side allows Internet users to access remote computers on the Internet by providing requests through standard Web browser software such as Microsoft Internet

Explorer, Netscape Navigator, or other custom-generated software such as ESRI ArcExplorer.

The server side consists of at least three components, including the web server, the map server and the data server. Web server software such as Netscape's FastTrack Server or Microsoft's Internet Information Server provides the capability to manage and respond to requests from the client side.

The map server, interacting with the web server, implements data processing in a GIS application. Examples of such map servers include ESRI ArcView Internet Map Server (IMS), MapObjects IMS, and ArcIMS, MapInfo MapX and MapXtreme. The data sever provides various data sets such as ESRI ArcView shapefiles, ArcInfo coverages, remotely sensed data, and/or other statistical data. Typically, the components on the server side can be placed on more than one computer.

The network technology provides Internet software components that communicate with each other on various computers connected by the network. Those components include HTTP (i.e., hypertext transfer protocol), and TCP/IP (transmission control protocol / Internet protocol). Protocols are the languages that make Internet communication possible.

The distributed hypermedia GIS is based upon interactions between three components: 1) a web-based GIS application developed to manipulate the cartographic features and their attributes; 2) a web-based hypermedia system designed to manipulate multimedia information including hypertext, hyperlinks, graphics, photographs, digital video, and sound; and 3) a mechanism linking the web-based GIS application and the hypermedia system.

3.3.1 Web-based GIS application

In addition to the requirement of developing a standalone GIS application running on a PC, the web-based GIS requires additional software components: web server and map server. In the design of a distributed hypermedia GIS, the Microsoft Internet Information Server (MIIS) is employed as the web server and the ESRI MapObjects Internet Map Server (IMS) as the map server. MapObjects IMS is the IMS extension to MapObjects (ESRI 1998). It provides ready-to-use software components such as ESRIMap(n).dll, IMSAdmin.exe, IMSCatalog.exe, IMSLaunch.exe, and WebLink.ocx that enable the developer to run MapObjects applications on the Internet.

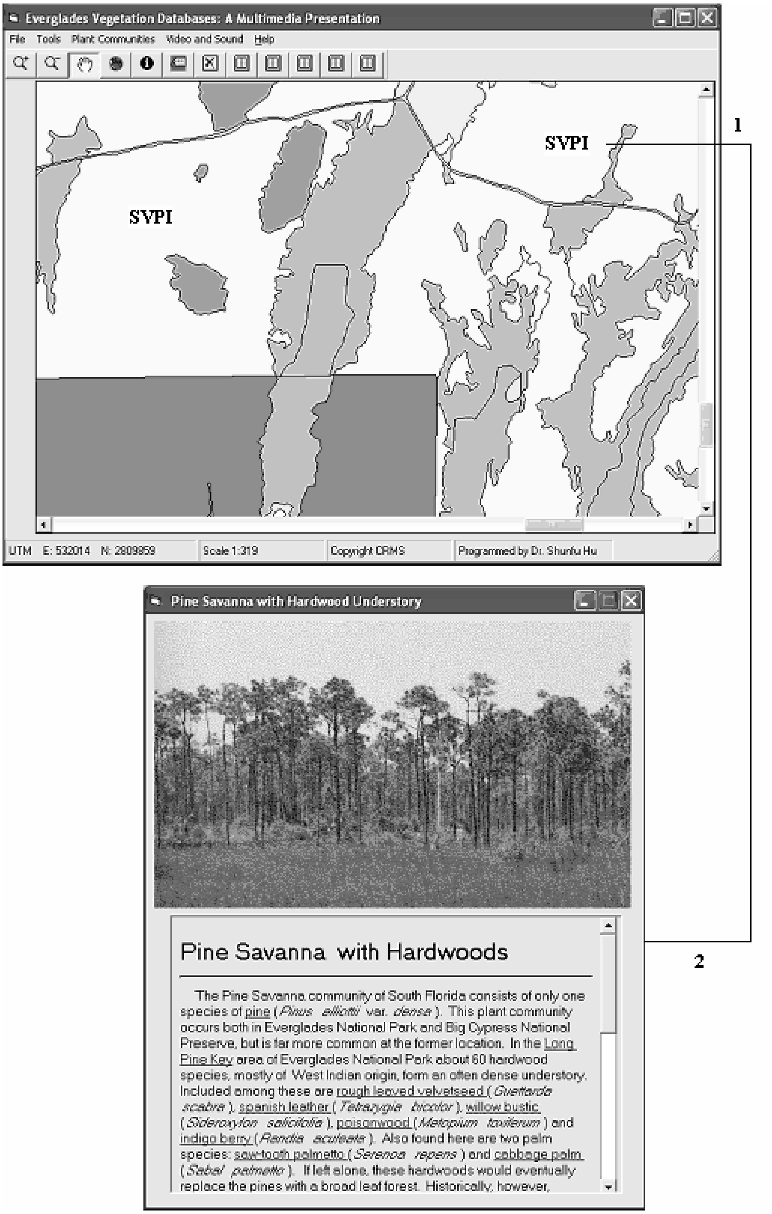


Fig. 3.3. The two basic components of a discrete hypermedia GIS for the Everglades vegetation database: (1) the GIS component used to explore the GIS database of a vegetation plant community via standard GIS operations; and (2) the Hypermedia component to access the hypermedia database for the same plant community.

3.3.2 Web-based Hypermedia system

With the essential features of a hypertext system commonly seen on the WWW, it is feasible to develop a web-based hypermedia application or web homepage. There are numerous ways to design excellent hypertext documents for use on the Internet. Software for developing interactive hypermedia presentations for use on the Internet includes HTML, Macromedia Director and Dreamweaver, and Adobe Streaming Media Collection, to name just a few. Since the hypermedia database developed for each plant community in the discrete hypermedia GIS was edited in HTML, each hypertext document is now readily employed on the WWW. All the HTML syntax in each hypertext document can be interpreted by the Internet Explorer without an additional hypermedia browser.

Due to the limitation of the current Internet speed, a digital video file that usually can be played back efficiently on an individual PC is not suitable for use on the Internet because of its large file size. The remedy for that is to change the format of the digital video file from Windows AVI (Audio Video Interleave) to Apple QuickTime movie format (.mov). The only additional requirement for the client computer is to install a QuickTime movie player (a free shareware that can be downloaded from Apple's website). Similarly, scanned pictures in Windows bitmap format (.bmp) need to be compressed to JPEG (Joint Photographic Experts Group) format (.jpeg) to allow fast delivery over the network.

Fig. 3.4 is an illustration of the web-based GIS application for visualizing the Florida Everglades vegetation database. Once the program is up running on a computer server and the user knows the web address or the server name, he/she is able to access the GIS database through standard Internet browser. GIS functions such as Zoom, Pan, and Identify are provided to allow the user to manipulate the vector GIS database. For instance, the user can select the "Zoom in" option and zoom into an area on the digital map, then select the "Identify" option, click on any polygon, and the alphabetic letters representing the plant community in that polygon will be displayed on the client's computer screen. Further, the user can select the "Hyperlink" option, click on one polygon, and be directed to the web-based hypermedia system or web site containing a ground panoramic view of that plant community and a descriptive text, including hypertext and hyperlinks, about the plant community (Fig. 3.5). Video clips can be either linked directly to a map feature or to hypertext.

3.4 Conclusions

Hypermedia GIS provides more visualization capabilities over traditional GIS: interactivity, user control of information flow, and multimedia presentation. The design of an operational hypermedia GIS can be a challenging task for the GIS community. The developers of hypermedia GIS applications need to clearly understand the difference between the one used on a PC by individual users and the one used on the Internet. The former has the flexibility of being able to deal with large file sizes associated with both the GIS database and hypermedia database, especially when digital video and high-resolution photographs are utilized. The later has the advantages of platform independence and wide accessibility.

Both discrete and distributed hypermedia GIS are generating great interest in the GIS community. With the integration of multimedia information in GIS, the hypermedia GIS is able to handle geographic information in

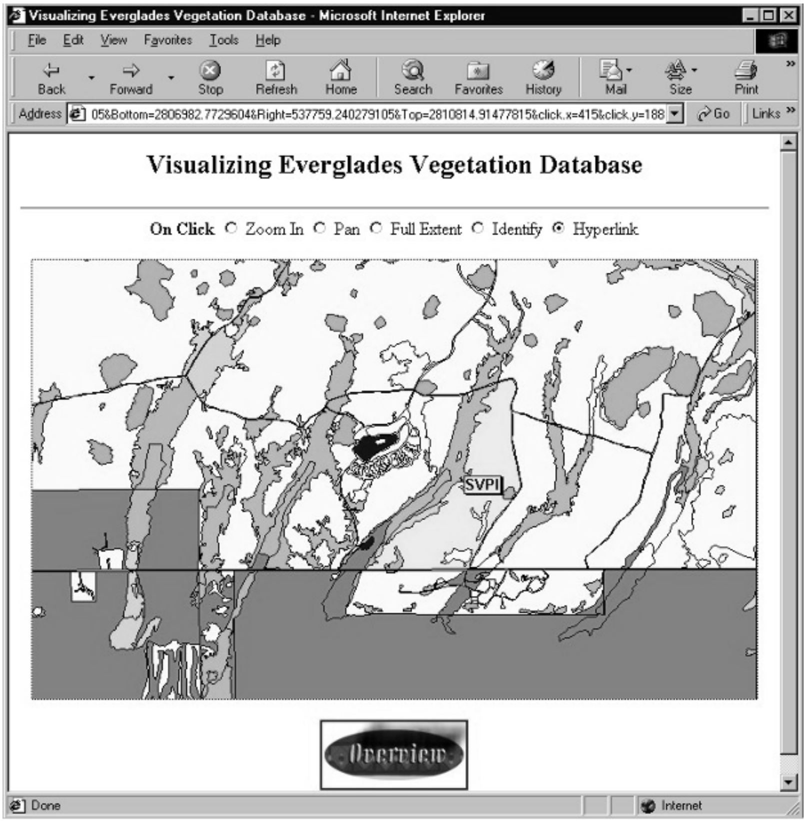


Fig. 3.4. Interactive map interface of a web-based GIS application.

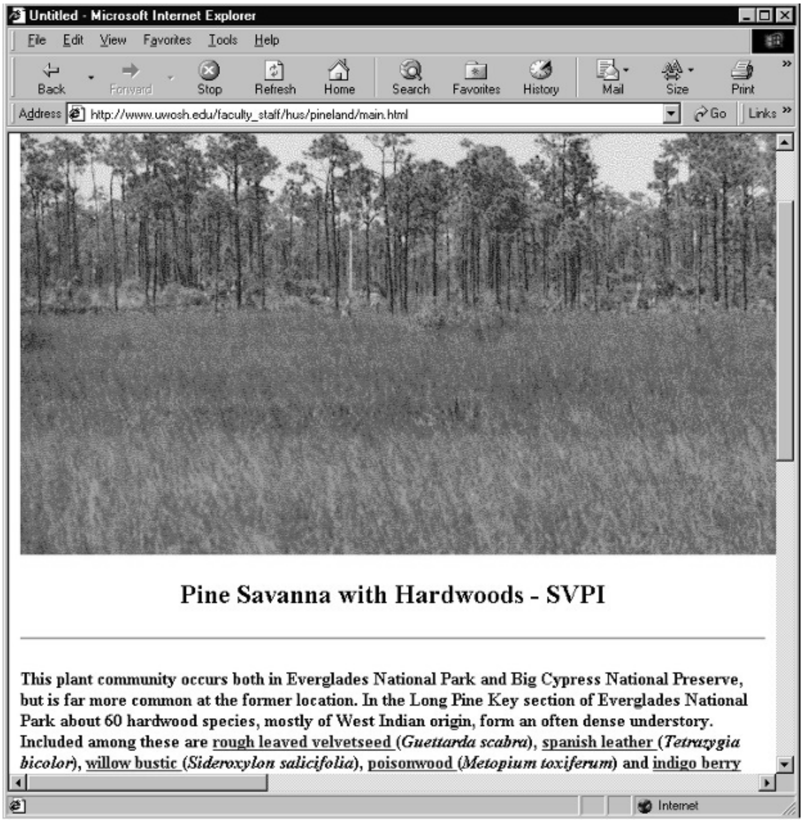


Fig. 3.5. Web-based hypermedia system (hypermedia database, hypertext, hyperlinks via Internet Explorer).

any format (e.g., spatial data in image/vector format, attribute data in alphanumeric format, and multimedia data in the form of text, graphics, photographs, and digital video). It provides the essential concepts and techniques for many new GIS applications such as visualization, spatial decision support systems and spatial database management and exploration.

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PART II

DATA RESOURCES AND ACCESSIBILITY ISSUES

4 Using Data from Earth Orbiting Satellites in Geo-Hypermedia Applications: A Survey of Data Resources

Danny Hardin

Abstract. Every day a suite of satellites in orbit about the Earth captures massive amounts of data in a vast spectrum of wavelengths. The Earth's systems are being measured more accurately, more frequently, and with higher resolution than ever before in our history. The amount of data generated is prodigious, pouring into data archive centers at over 1000 GBytes per day. This presents a challenge to those who wish to locate and use data for a specific application over a constrained geospatial area and time span. The vast majority of the data are free, or available at low cost. However, there remain barriers to its use because in many cases the data are not in a preferred format, it is difficult to locate, it is hard to extract a specific data item from the massive inventories, or simply because users are not aware that an important data set exists. In this chapter, you will learn how to find data, by using data catalog services, and how to order data, by using data search and order systems. You will also be presented with summary information on the data resources available from NASA's nine data archive centers.

4.1 Introduction

At this writing, there are18 active NASA satellite missions dedicated to measurements of the Earth's systems – atmosphere, ocean, ice, land, and life (NASA Current Missions). There are many other Earth orbiting satellite missions from US government agencies such as the National Oceanic and Atmospheric Administration (NOAA), and from other countries such as the European Space Agency and the Space Agency of Japan. Unclassified data from military satellites such as the Defense Meteorological Satellite Program (DMSP) contribute further volume. And imagery from commercial orbiters such as IKONOS and SPOT round out a comprehensive suite of instruments aimed at the Earth. Added to this are measurements from instruments at the Earth's surface (land and oceans), and from short duration orbital and atmospheric flights. The total amount of available data is enormous. In this chapter descriptions are limited to data that are generally available at little or no cost to researchers, educators, and the general public. This can be done by considering only data sets that are (or have been) collected by NASA funded instruments or are available from NASA funded data archive centers. This is not a significant limitation as there are thousands of data sets that fall into this classification. In the following sections, you will discover how to find data by using data catalog services and how to order data by using data search and order systems. Summary information pertaining to data resources available from NASA's nine data archive centers is provided.

4.2 Discovering Data

There are thousands of data sets available from a variety of sources, including satellites, ground-based instruments on land and ocean, aircraft, balloons, rockets, and special spacecraft such as the Space Shuttle and Space Station. While the vast majority of data are from the past 30 years, there are many that date back over a century. Data sets exist in a variety of forms and resolutions. And, they are stored in archive centers, research labs, universities, and desk drawers around the world. Given all this, how is it possible to determine the kind of data available and its location? Fortunately, there are data directories that make the task simple. If you want to know what data are available, a directory should be your first stop. This section describes some of the best.

4.2.1 The Global Change Master Directory (GCMD)

If you need to know what data are available there is no better starting place than the Global Change Master Directory (GCMD) (Global Change Master Directory). Do not let the "Global Change" part of their name mislead you. The GCMD is a comprehensive directory of Earth and space science data sets collected worldwide (and interplanetary) over the past century. However, you must remember that you cannot get the actual data from the GCMD. It is a directory of information, not a data archive. The listings provide detailed descriptions of the data including, resolution, spatial and temporal coverage, location, and information about the data providers. In some cases, there are hyperlinks that will take you directly to a data ordering system for the data set or collection.

The GCMD contains more than 13,500 Earth science data set descriptions. Approximately 2,500 new descriptions are added annually in one of thirteen classifications. More than 25 percent of the data listings refer to data from NASA's Earth science missions and from the Federation of Earth Science Information Partners (Federation of Earth Science Information Partners). More than 1,200 data providers contribute to the GCMD. If you have a data set that you want listed then you can fill out a data set description form online at the GCMD website – gcmd.nasa.gov.

The directory can be searched in many different ways. Users may choose from one of the topics listed in Table 1 and “drill down” by successively clicking on additional parameters that appear at each level. For example, clicking on “Solid Earth” will take you to a new page with parameters such as geochemistry, geomagnetism, seismology, volcanoes, etc. Then clicking on volcanoes will take you one level lower with parameters like lava, magma, volcanic ashes, etc. At each level, the number of listings for each parameter is given. Table 4.1 shows the total number of listings as of July 2005 for the top level parameters (State of the GCMD 2004).

Listings in the directory may also be displayed and searched by platform (or spacecraft), instrument, data center, geographic location, or project. For example, a user can search for all data sets from the Terra satellite or for data sets collected by the MODIS instrument aboard Terra. Location listings are not strictly for geographic regions either. There are choices such as oceans, space, and vertical location (like troposphere). To aid in narrowing a search, users may enter a keyword at any point. For example, if a user has selected “Solid Earth” followed by “Volcanoes,” all listings for Mount St. Helens can be located by typing “Mount St. Helens” into the

Table 4.1. GCMD Listings by Earth Science Topic

TOPIC	2003	2004
AGRICULTURE	139	130
ATMOSPHERE	617	728
BIOSPHERE	798	545
CLIMATE INDICATORS	21	80
CRYOSPHERE	218	145
HUMAN DIMENSIONS	398	302
HYDROSPHERE	332	382
LAND SURFACE	553	452
OCEANS	702	468
PALEOCLIMATE	93	203
SPECTRAL/ENGINEERING	160	156
SUN-EARTH NTERACTIONS	13	53
SOLID EARTH	322	140

free text box. Fig. 4.1 shows the results of this search.

Users may also choose the free text search option that operates similar to many Internet search engines. Users may enter keywords with Boolean operators and wildcard symbols. Spatial extent may be expressed by typing in latitude/longitude values or by drawing a rectangle on a world map. A time range may also be specified. This search technique is very powerful, producing listings of interest with only a few mouse clicks.

Data set listings are only part of the capabilities of the GCMD. In addition, the GCMD also maintains listings for more than 750 applications that operate on data sets (software, analytical tools, educational resources, etc.). These applications are known as data set services and can be invaluable when working with data sets. Examples range from specialized tools for browsing, manipulating, and visualizing data products to Earth science educational products and environmental hazard advisory services. Users can search for services using controlled keywords or free-text to discover data-set-specific tools. Table 4.2 shows the service classifications and number of listings for each (State of the GCMD 2004).

4.2.2 Federation Interactive Network for Discovery (FIND)

Another useful directory is the Federation Interactive Network for Discovery or FIND (Federation Interactive Network for Discovery). This directory maintains listings of data sets produced and held by the Federation of

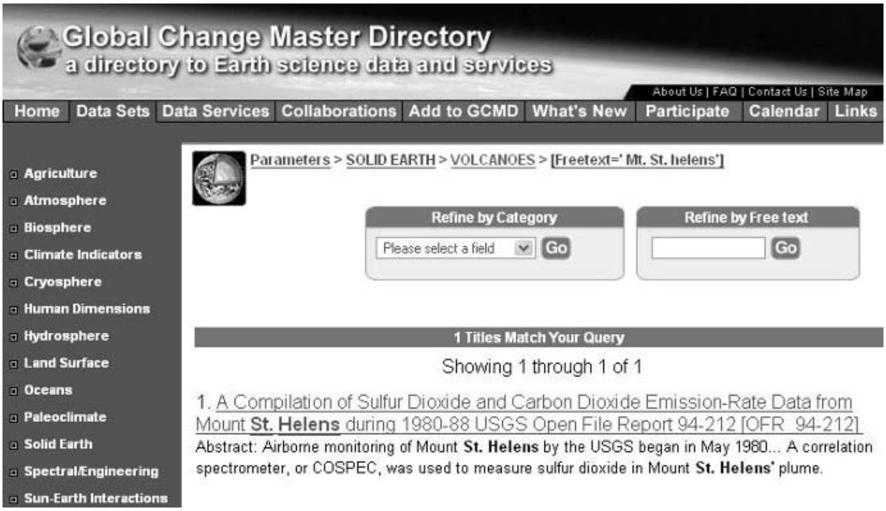

Fig. 4.1. GCMD search results page.

Earth Science Information Partners (ESIP Federation). There are fewer listings than that of the GCMD, but the focus is strictly on Earth science data sets. The Federation partners (over 75 at this writing) bring together government agencies, universities, nonprofit organizations, and businesses, in an effort to make Earth science information available to a broader community. One objective of the Federation is to evolve methods that make Earth science data easy to preserve, locate, access, and use for all beneficial applications. The Federation maintains a comprehensive inventory of information about its data holdings — over 3,500 data sets and services (Federation of Earth Science Data Partners – Data Center). Data set and service listings of FIND are closely matched with the GCMD. In fact FIND utilizes metadata from the GCMD in its search domain. FIND is able to search in many databases (GCMD, ESIP Partners and ESIP Partner websites) simultaneously via a single query, using the underlying Mercury (Mercury Search Engine) search system. Users may search for data sets by specifying a keyword (default search) or define a more sophisticated query using the spatial, temporal, and data center search screens.

The keyword search is very simple to use. Just enter a parameter or geophysical term into the text box and hit enter. The keyword search allows you to search for words or phrases within a specified field or within the entire metadata record. As with the GCMD, Boolean operators and wildcards are supported. There are optional temporal and spatial search capabilities also. Pull-down menus can be used to specify a time interval. Geographic regions can be specified by entering latitude/longitude pairs or by drawing a rectangle on a world map. FIND also has a list of over 175 data centers. By selecting a specific data center, this option produces a listing of all ESIP Federation data sets held there. This is useful when you know that

Table 4.2. GCMD Service Listings by Earth Science Topic

Topic	2003	2004
Data Analysis & Visualization	374	499
Data Management/Data Handling	206	262
Education/Outreach	199	251
Environmental Advisory	78	115
Hazards Management	28	47
Reference and Information Services	96	137
Metadata Handling	25	41
Models	126	192

data of interest reside at a particular archive. More information on data centers appears later in section 4.3 below.

Once the search parameters have been specified the search begins. Results are returned (Fig. 4.2) as a page with lists of: successful searches, databases searched but with no hits returned, and databases with failed connections. By clicking on the search results a short summary of each record is displayed. More in-depth information can be retrieved by clicking on the title.

4.2.3 The Geospatial One-Stop

The data resources listed by the GCMD and FIND are in a wide variety of data formats. If your data interests fall strictly within the area of geospatial information systems, then the Geospatial One-Stop (GOS) (Geospatial One-Stop) may be the best choice. GOS serves as a public gateway for improving access to geospatial information and data under the United States' e-government initiative (United States' Electronic Government Initiative). Located on the Web at geodata.gov, GOS is designed to facilitate communication and sharing of geospatial data.

The second version of GOS (GOS2) was released in July 2005. It employs new portal technologies, the Google search engine, and the latest

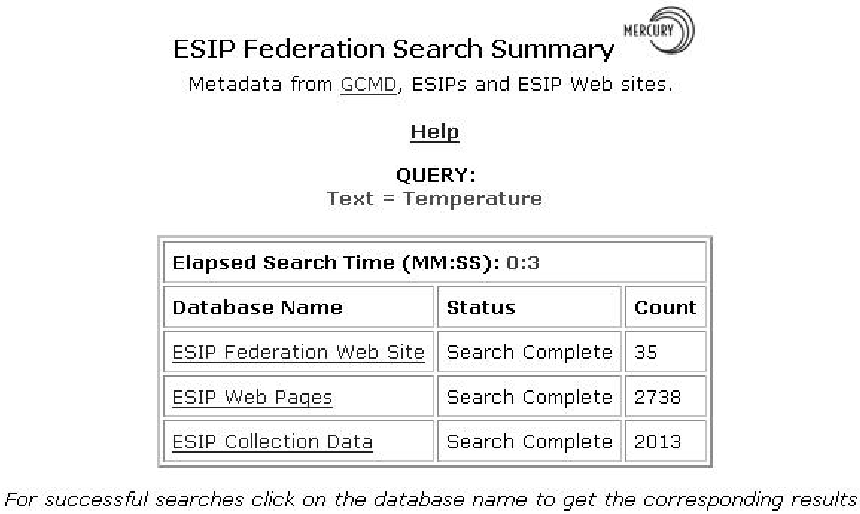

Fig. 4.2. Search results from the FIND search engine using parameter "temperature."

GIS map creation and viewing software. This makes GOS2 very powerful. Users can register and create their own custom portal. They can use the powerful search interface to access a wide variety of geospatial information. Maps can be created and saved from one session to the next. Search parameters can also be saved. GOS2 has a catalog of thousands of metadata records and links to web map servers, web feature servers, web coverage servers, and catalog services. Data sources are classified by the communities shown in Table 4.3. Additional classifications can be suggested such as the special community set up following the December 2004 tsunami in Indonesia. Users can download data sets, images, clearinghouses, map files, and more. Registered users can easily contribute their own resources making the Geospatial One-Stop a rapidly evolving system.

As of this writing the geographic coverage of almost all resources within the GOS are within the United States. As more resources are contributed this limitation is expected to ease.

4.3 Accessing Data

Once the data has been identified, the next step is to access a data archive and order or download the data. Fortunately, the vast majority of data from NASA's Earth orbiting satellites, aircraft, ocean and land based instruments is located in one of nine cooperating data centers known as the

Table 4.3. GOS Communities

1	Administrative Boundaries
2	Agriculture
3	Atmosphere
4	Biology
5	Business
6	Cadastral
7	Demographic
8	Elevation
9	Environment
10	Geology
11	Health
12	Imagery and Basemaps
13	Inland Water
14	Locations
15	Oceans
16	Transportation
17	Utilities

DAAC Alliance (DAAC Alliance). The DAACs (Distributed Active Archive Centers) were formed in 1991 as part of NASA's Mission to Planet Earth Program, now known as the Earth Science Enterprise (NASA ESE). Their primary objective was to make the vast amount of NASA's data holdings readily available to researchers, educators, students, and the general public. Today the DAAC Alliance is home to over 3000 data sets. They continue to ingest data at over 1000 GBytes per day, mainly from the instruments aboard the suite of Earth Observation Satellites like Terra and Aqua. In addition to holding the actual data files, the DAAC Alliance provides a vast selection of software applications, documentation, and user services assistance for interpreting and using the data. And, except for a very few special cases, the data are free.

There are several ways to access data from the DAAC Alliance. Each data center operates a data search and order system tailored to the respective data holdings. All nine data centers can be searched at one time by using the EOS Data Gateway (EDG) (Earth Observing System Data Gateway). The result of using these search and order systems compared to the GCMD or FIND is that the user is given a list of actual data files instead of descriptions of the data. But, it should be pointed out that the DAAC Alliance data search and order systems are not comprehensive as compared to the GCMD and FIND.

In the following sections, I will describe the EOS Data Gateway and give a summary of each data center in the DAAC Alliance. Before venturing into those topics, a quick tutorial on data product processing levels and formats will help the first time user of those systems.

4.3.1 Earth Science Data Terminology and Formats

Data Processing Levels

Data products from the DAAC Alliance exist at five processing levels ranging from level zero to level four. These processing levels were defined by the Data Committee of the Earth Observing System Data and Information System (EOSDIS) and are consistent with the Committee on Data Management, Archiving, and Computing (CODMAC) definitions (NASA 1993).

Level zero products are raw data directly output by instruments at full resolution with engineering and communications information removed. Level zero data is the base from which all other data products are produced. The unprocessed level zero data are always archived because it represents the purest form of the measurements. This level of data is rarely used for research.

Level 1A data products are constructed by adding a time reference and annotations to the level zero data. The annotations include information such as radiometric and geometric calibration coefficients and georeferencing parameters.

Data from some instruments are processed to level 1B by adding a step that makes the data conform to sensor units. Data products at levels zero, 1A, and 1B generally are very large in volume since individual wavelengths or bands have not been separated out.

Level two data have derived geophysical variables at the same resolution as that of level one. These data sets can directly yield information in terms of geophysical parameters such as temperature. Level two data sets are commonly used in research where the maximum resolution and completeness of geographical coverage is desired.

Perhaps the most recognizable form of data is level three. Level three data products are normally mapped onto a uniform space and time grid. This means that they can readily be viewed as imagery or other visual product. Level three data best matches data products normally affiliated with GIS systems.

There is a special data level (level four) for data products generated from models and simulations based on analyses of lower level products or fused from multiple instruments.

Data Format Descriptions

Data from EOS instruments are primarily formatted using either HDF (Hierarchical Data Format) or HDF-EOS (Hierarchical Data Format for the Earth Observing System). The Hierarchical Data Format (HDF) is designed to facilitate sharing of scientific data. Its features include platform independence, user extendibility, and embedded metadata for units, labels, and other descriptors. Standard data types include multidimensional array, text, table, raster image, and palette. HDF files are portable and can be shared across most common platforms, including many workstations and high-performance computers. An HDF file created on one computer can be read on a different system without modification. HDF was developed by the National Center for Supercomputing Applications (NCSA). This format is extensible and can easily accommodate new data models, regardless of whether they are added by the HDF development team or by HDF users.

The HDF for the Earth Observing System (HDF-EOS) data format is standard HDF with EOS conventions, data types, and metadata. HDF-EOS adds three data types (point, grid, and swath) to the HDF structure that allow file contents to be queried by Earth coordinates and time. An HDF-EOS file also contains metadata essential for search services. An HDF-EOS file can be read by any tool that can read standard HDF files. A data product need not fit any of the grid, point, or swath models to be considered HDF-EOS. HDF-EOS is implemented as a C library extension of the standard HDF library. Use of HDF-EOS can eliminate duplication of software development efforts, especially for analysis and visualization software.

Another widely used format is the network Common Data Form (netCDF) (Network Common Data Format). The netCDF software was developed at the Unidata Program Center in Boulder, Colorado, and augmented by contributions from other netCDF users. The netCDF libraries define a machine-independent format for representing scientific data. Together, the interface, libraries, and format support the creation, access, and sharing of scientific data. The HDF and HDF-EOS data formats include features of netCDF.

4.3.2 The EOS Data Gateway

The EOS Data Gateway system provides a single interface through which users can find and order data from multiple participating archives. You may use the EDG as a guest or you can create an account. Signing in as a guest will create a transient session. All information will be deleted after you sign out. It is better to create a user account (there is no cost), so that you can set up preferences and preserve your information. You can log out, and sign back in at anytime and pick up where you left off. Click on the “Create Account” button to create a new account. You will be asked to select a password and enter user contact information. Once you have submitted the information, you can then sign into your user account. The EDG is an old system and as such does not have a good intuitive user interface. It is best to take an hour and read the tutorial before beginning. The time spent in doing so will pay off later.

The EDG offers the following capabilities: a) search; b) browse; c) order; and d) guide. The search feature allows the user to search for data based upon specific criteria such as location, time, and geophysical parameter (e.g. temperature). Searching should be the first step of your EDG experience. After the search completes, returning a set of data files (known as granules), the user may browse the results, by viewing a reduced resolution image depicting the data, or inspect metadata about the granule. Following this inspection, the user may choose to do another search – likely in most cases since a typical search will return hundreds of granules – or proceed to place an order for selected granules. The order feature allows the user to select data for ordering, choose packaging information, enter ordering information (such as shipping address), and place the order. Since the EDG contains complete information from all nine data centers a data order may be sent to multiple data centers for filling. In this case, the user will receive packages (or e-mail notifications) from several data centers. In addition to the raw data, users will require documentation to help them decode the granules and use the data. Every data set is required to have a set of guides for this purpose, containing information on data sets, platforms, instruments, etc. Depending on the sophistication of the user, different guides will be needed. The EDG allows users to locate this information and have it delivered with the data package. The EDG may be accessed at the following URL: http://redhook.gsfc.nasa.gov/~imswww/pub/ims-welcome/

4.3.3 The DAAC Alliance

Each of the nine data centers of the DAAC Alliance serves a specific Earth science discipline. However, this should not be taken as a strict classification and separation of data sets. In every case, the data centers hold a rich variety of data products. In fact the data inventories are of such magnitude, it is not possible to list all of them in this chapter. In the sections below, a short summary is given that highlights the main data products and data access services. The URL for each data center is included for more information.

The Alaska Satellite Facility (ASF)

The ASF (Alaska Satellite Facility) is located in the Geophysical Institute at the University of Alaska in Fairbanks. It maintains a variety of data sets applicable to the geophysical phenomena of sea ice, polar processes, and geophysics. Its primary data sets are those from the Synthetic Aperture Radar (SAR) instruments aboard the RADARSAT-1, the European Sensing Satellite-2 (ERS-2) and legacy SAR data from the ERS-1, and the Japanese Earth Resources Satellite -1 (JERS-1). All SAR data sets are restricted and available only to NASA-approved researchers.

The ASF does have several mosaics derived from SAR data that are generally available. The mosaics show complete detailed views of the Antarctic, boreal forests of Alaska, Canada, and portions of the Northeastern

United States. Other SAR imagery reveals rainforests in the Amazon, Central America, Africa, and the Pantanal region.

Sea ice imagery provides a detailed view of sea ice movements. The Glacier Power CD, designed for the classroom, uses SAR data to lay a foundation for the study of glacier dynamics through the use of imagery and cartoon characters.

Data products can be obtained through the ASF website, via ftp or through the EOS Data Gateway. For more information: www.asf.alaska.edu

The Goddard Earth Sciences Data and Information Services Center (GES DISC)

The GES DISC (Goddard Earth Sciences Data and Information Services Center) provides an immense volume of data. It offers data sets that pertain to the study of the upper atmosphere, atmospheric dynamics, global precipitation, global biosphere, ocean biology, ocean dynamics, and solar irradiance. It also provides services that enable users to fully realize the scientific, educational, and application potential of the data sets. The list of data products is far too long to fit into this chapter, see their website at daac.gsfc.nasa.gov for further information. Here are a few highlights.

The GES DISC archives and distributes data products from many very popular instruments including the Moderate Resolution Imaging Spectroradiometer (MODIS) on both the Terra and Aqua satellites. MODIS acquires data in 36 discrete spectral bands, and the data almost cover the Earth every day. MODIS data has a high radiometric resolution (1KM, 500M, and 250M), global coverage, and accurate calibration. MODIS data are useful for long-term climate and global change studies, as well as for short-term monitoring of natural disasters. The GES DISC distributes level one radiometric and geolocation data products and other ocean and atmosphere products at higher levels

Data products are also available from the Atmospheric Infrared Sounder (AIRS), Sea-viewing Wide Field-of-view Sensor (SeaWiFS), Total Ozone Mapping Spectrometer (TOMS), and Tropical Rainfall Measuring Mission (TRMM) to name a few.

The GES DISC offers five methods for locating and ordering data products. There is a simple search interface built into the index page of its website. It offers a massive amount of data for direct download through the data pool, which includes its own search capability. Data sets can also be located through parameter based searches. All data are also orderable through the EOS Data gateway. For more information: daac.gsfc.nasa.gov

The Global Hydrology Resource Center (GHRC)

The GHRC (Global Hydrology Resource Center) offers data products that focus on the study of the global hydrologic cycle, severe weather interactions, lightning, and convection. The GHRC is the national repository for lightning data, holding data sets from the Lightning Imaging Sensor (LIS) and its predecessor the Optical Transient Detector (OTD). Available data sets include sea surface temperature, atmospheric water vapor, wind direction, and atmospheric temperature derived from passive microwave instruments like the Special Sensor Microwave Imager (SSMI) and the Advanced Microwave Sounding Unit (AMSU). The GHRC also has many data products relating to hurricane structure, dynamics, and motion from the series of Convection and Moisture Experiments (CAMEX) field campaigns.

You can locate data products from the GHRC through a local search and order system known as HyDRO or through the EOS Data gateway. Passive microwave data sets may be downloaded directly from the GHRC data pool. For more information: ghrc.msfc.nasa.gov

The Atmospheric Sciences Data Center (ASDC)

The ASDC (Atmospheric Sciences Data Center) has more than 800 data sets relating to radiation budget, clouds, aerosols, and tropospheric chemistry. Radiation budget data sets pertain to the variability of total solar irradiance, radiation properties of the atmosphere and of the Earth's surface. Cloud data sets contain information on the radiative properties of clouds; cirrus, marine stratus, and arctic cloud field studies and subsonic aircraft effects on contrails and other cloud systems. Aerosol data sets contain information on the spatial and vertical distribution of aerosols, as well as their chemical, physical, and optical properties. Tropospheric chemistry includes biomass burning, concentrations of atmospheric chemicals, and the distribution and behavior of carbon monoxide, ozone, and water vapor.

The ASDC, like the GES DISC, maintains massive amounts of data mainly due to data products derived from instruments aboard the EOS satellites such as Aqua and Terra. Radiation budget data sets are derived from several instruments. There are five Clouds and the Earth's Radiant Energy System (CERES) instruments active at the time of this writing. There are two on Aqua, two on Terra, and another aboard the Tropical Rainfall measuring Mission (TRMM) satellite. CERES data is also used to develop data products for cloud studies.

Massive amounts of data are collected each day from the Multi-angle Imaging SpectroRadiometer (MISR) aboard Terra in support of cloud and aerosols studies. Aerosol data sets are also derived from data measured by the Stratospheric Aerosol and Gas Experiment (SAGE), MISR, and others. Data sets for tropospheric chemistry investigations are currently produced from data from the Measurements Of Pollution In The Troposphere (MOPITT) instrument aboard Terra and will soon be supported by results from the planned Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) mission.

Users may use the local ASDC search interface to locate and order data, or they may access the massive on-line data pool to download data directly. All data sets held by the ASDC may be ordered through the EOS Data gateway. For more information: http://eosweb.larc.nasa.gov/

The Land Processes Distributed Active Archive Center (LP DAAC)

The LP DAAC (Land Processes Distributed Active Archive Center) maintains data sets that are focused on investigation, characterization, and monitoring of biologic, geologic, hydrologic, ecologic, and related conditions at the surface of the Earth. It is this focus that matches the LP DAAC with users of geospatial information systems. GIS users are certainly frequent users of imagery from Landsat and MODIS. The LP DAAC also offers imagery from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instruments aboard Terra and Aqua. ASTER offers the highest resolution image data in visible and near-infrared (15M), shortwave infrared (30M), and thermal infrared (90M) wavelengths. AVHRR as well as aerial photography, are also available. Related data sets include the Global 30-Arc-Second Elevation Data and the NASA SIR-C Precision Data.

Two of the most desirable data sets – Landsat and ASTER – are not free. Pricing changes so you will need to check with the LP DAAC for actual costs. At this writing, the cost for ASTER was $80 per scene via FTP or $91 on CD or DVD media.

Data products are available from the LP DAAC through an online data pool or through the EOS Data Gateway. For more information: edcdaac.usgs.gov

The National Snow and Ice Data Center (NSIDC)

The NSIDC (National Snow and Ice Data Center) provides data sets that focus on the study of snow and ice processes, particularly interactions among snow, ice, atmosphere, and ocean that influence global change detection and model validation. Data subjects include permafrost, frozen ground, glaciers, ice shelves, icebergs, ice sheets, snow cover, ice velocity, and ocean chemistry and temperature. It offers a CD-ROM collection containing millions of vertical soundings of temperature, pressure, humidity, and wind from Arctic land stations at 100KM resolution from 1950 to 1996. The NSIDC distributes a host of ancillary sea ice products, including ice extent, melt onset data, ice persistence, total ice-covered area, and ocean masks.

The extent of snow and ice cover is given by MODIS data products from both Terra and Aqua. The Advanced Microwave Scanning Radiometer-EOS (AMSR-E) on Aqua yields data products that include soil moisture, ocean products (water vapor, cloud liquid water, sea surface temperature), rain, snow, and sea ice.

The NSIDC also maintains an extensive suite of passive microwave data products. Near-real-time maps, a best estimate of current ice and snow conditions, are available at 25KM resolution. The Advanced Very High Resolution Radiometer (AVHRR) data set provides nearly complete coverage of sea ice, land ice, and land in polar regions at 1.1-kilometer resolution for all 5 bands of the AVHRR sensor. Data from the Ice, Cloud, and Land Elevation Satellite (ICESat) Geoscience Laser Altimeter System (GLAS) provide ice sheet elevations and changes in elevation through time. GLAS data sets also include measurements of cloud and aerosol height profiles, land elevation, vegetation cover, and sea ice thickness.

Data orders may be placed at the NSIDC through the EDG data search-and-order system or directly through the online data catalog. For more information: nsidc.org

Oak Ridge National Laboratory (ORNL)

The ORNL (Oak Ridge National Laboratory) data center specializes in data about the dynamics between the biological, geological, and chemical components of the Earth's environment. These dynamics are influenced by interactions between organisms and their physical surroundings, including soils, sediments, water, and air.

ORNL also archives and distributes data from a number of field campaigns. The list is too extensive to fully provide here but a few examples are: the Boreal Ecosystem-Atmosphere Study (BOREAS), Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA), and the Southern African Regional Science Initiative (SAFARI 2000). The BOREAS project investigated exchanges of energy, water, heat, carbon dioxide, and trace gases between a boreal forest and the atmosphere. LBA data include measurements of precipitation in Bolivia, Brazil, and Peru, plus Synthetic Aperture Radar (SAR) imagery from the rain forest region during 1995 and 1996. SAFARI 2000 studied the linkages between land and atmosphere processes in southern Africa, especially the relationship of biogenic, pyrogenic, and anthropogenic emissions and the functioning of the biogeophysical and biogeochemical systems.

There is a significant number of historical data sets available from ORNL. Historical climatology, mean climatology, and precipitation data date back to 1753. Hydroclimatic data collections such as streamflow, wetlands, precipitation, and temperatures exist from 1874 to 1988. River Discharge data from 1807 to 1996 containing long-term monthly averaged values for river discharge measured at various stations is available. Soil characteristic data measured at sampling sites or estimated for grids of various sizes are available from 1940 to 1996. Holdings pertaining to vegetation characteristics, including the distribution of vegetation types, as well as leaf area index calculated from field measurements, can be obtained from 1932 through 2000.

ORNL DAAC data are available through an online search-and-order system at www.daac.ornl.gov and through the EDG data search-and-order system. For more information: daac.ornl.gov

The Physical Oceanography Distributed Active Archive Center (PO.DAAC)

The PO.DAAC (Physical Oceanography Distributed Active Archive Center) provides global oceanographic data derived from NASA satellites. Its primary holdings include data sets about ocean surface topography, ocean winds, and sea surface temperatures. Other data sets include ocean wave height, electron content of the ionosphere, atmospheric moisture, and heat flux.

Ocean surface topography data holdings are derived from the TOPEX/POSEIDON and Jason-1 missions. These data products include sea surface height, wind speed, significant wave height, tropospheric water vapor, electron content of the ionosphere, and ancillary information along the track of the TOPEX/POSEIDON satellite. Jason-1 is a follow-on mission to TOPEX/POSEIDON primarily yielding surface topography along a 10-day repeated ground track.

Ocean vector winds data are available from the SeaWinds instruments on board the QuikSCAT satellite and the Advanced Earth Observing Satellite II (ADEOS-II). Twenty-five kilometer wind vector data is also available from the NSCAT scatterometer on a daily 0.5- by 0.5-degree map.

Sea Surface Temperature data from AVHRR are available as daily, 8-day, and monthly averages. Daily, weekly, and monthly sea surface temperature data, from the very popular MODIS instrument on board Terra and Aqua, are available in thermal infrared or mid-infrared mapped products.

The PO.DAAC also provides many other surface and multi-parameter products, including significant wave height, chlorophyll concentration, near-surface currents, atmospheric moisture, brightness temperatures, and heat flux.

Data may be accessed through the PO.DAAC online search-and-order service. Data is also available through the EOS Data gateway. For more information check the PO.DAAC catalog of products at the web site: podaac-www.jpl.nasa.gov

The Socioeconomic Data and Applications Center (SEDAC)

The SEDAC (Socioeconomic Data and Applications Center) data focus is much different than the other data centers described above. It specializes in data sets that focus on human interactions in the environment. They combine satellite data with socioeconomic data to create an "Information Gateway" between the socioeconomic and Earth science data and information domains.

Much of the SEDAC data relates to population statistics. In the Gridded Population of the World (GPW) data set, land area, population counts, and densities are available for the entire globe and six continental regions. Land data and population counts are also available for each country. The Population, Landscape, and Climate Estimates (PLACE) data set gives population and territorial extent overlaid with biophysical parameters such as biome, climate, coastal proximity, elevation, population density, and slope, resulting in a data set of population estimates and area. This is valuable for researchers who require tabular data aggregated to the national level.

Another category of information from SEDAC is hazard and impact reports. They include “Potential Impacts of Climate Change on World Food Supply: Data Sets from a Major Crop Modeling Study,” which provides data on projected crop yield changes for major world regions based on climate model estimates, increased atmospheric carbon dioxide concentrations, and alternative adaptation scenarios. The “Central American Vegetation/Land Cover Classification and Conservation Status” report assesses the degree to which both existing and proposed terrestrial protected area networks protect or would protect landscape-level biodiversity, which is represented as vegetation types delineated from remotely sensed imagery.

Also of interest is the Environmental Sustainability Index (ESI). The ESI is a measure of overall progress toward environmental sustainability developed for 142 countries. The ESI permits cross-national comparisons of environmental progress in a systematic and quantitative fashion. This index represents a first step toward a more analytically driven approach to environmental decision making.

SEDAC has developed an electronic gateway to provide access to the catalogs of a diverse international group of data archives and other institutions. For more information: sedac.ciesin.org

4.4 Other Data Centers

The data centers described above offer a wealth of data sets and services. However there are many, many others. In this closing section, I will provide a list of selected data centers that users may wish to peruse.

4.4.1 Data Centers of the National Oceanic and Atmospheric Administration (NOAA)

The NOAA Satellite and Information Service (NESDIS) (NOAA Satellite and Information Service) operates four national data centers for climate, geophysics, oceans, and coasts. The National Climatic Data Center (NCDC) is the world's largest active archive of weather data. It produces numerous climate publications and responds to data requests from all over the world. The National Geophysical Data Center (NGDC) provides over 300 data sets describing the solid Earth, marine, and solar-terrestrial environment, as well as Earth observations from space. The National Oceanographic Data Center (NODC) holds global physical, chemical, and biological oceanographic data sets used by researchers worldwide, and the National Coastal Data Center (NCDC) has a diverse inventory of coastal data.

4.4.2 The United Nations Environmental Programme (UNEP)

Another massive source for data is the United Nations Environmental Programme (United Nations Environmental Programme). As expected these data sets are generated for decision makers worldwide and tend to be higher level products that may typically be displayed with GIS applications. The Global Environmental Outlook data portal is the authoritative source for data sets used by UNEP and its partners in the GEO. You may search the online database, holding more than 450 different variables, such as national, subregional, regional, and global statistics, or as geospatial data sets (maps), covering themes like freshwater, population, forests, emissions, climate, disasters, health, and GDP. The data may be displayed online as maps, graphs, or data tables, or you may download the data for desktop display.

4.4.3 International Data Centers

My limitation of speaking only the English language does not detract from pointing out the existence of data centers located in countries worldwide. From Argentina (National Antarctic Data Centre) to Uruguay (Centro Uurguayo de Datos Antarticos) data sets are available. The GCMD, introduced in section 4.2 at the beginning of this chapter, contains data set listings from 45 countries. There is indeed a world of data available.

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Federation Interactive Network for Discovery, http://www.esipfed.org/inter-com/index.html

Geospatial One-Stop. http://www.geodata.gov/

Global Hydrology Resource Center. http://ghrc.msfc.nasa.gov/

Global Change Master Directory. http://gcmd.nasa.gov/

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United Nations Environmental Programme. http://www.unep.org/

United States' Electronic Government Initiative. http://www.whitehouse.gov/omb/egov/

5 Exploring the Use of a Virtual Map Shop as an Interface for Accessing Geographical Information

William E. Cartwright

Abstract. The need for designers to consider the wide range of user preferences and how they (the users) interact with contemporary map information packages is paramount when developing effective interfaces for information access, retrieval and use. It is argued that a suite of metaphors, allowing users to choose the most effective access method for their application makes for a more effective package. This chapter describes the theory of the Map Shop, which could be provisioned with maps, videos, books, guides, games and databases of facts and could provide expert tips. The Map Shop can be linked locally or internationally through the Internet and, more specifically, the World Wide Web. From the users' perspective the boundary between discrete and distributed multimedia would be transparent, presenting them with the most current and customised information possible. It also describes the use of the metaphor suite developed as part of the GeoExploratorium, a tool for the provision of geographic information in a manner that is complementary to the map metaphor. Finally, it describes the building of a prototype Virtual Map Shop, a discrete / World Wide Web tool for exploring its use as an innovative geographical information access (virtual) resource.

5.1 Introduction

With the sheer number of publications readily available through contemporary communications and multimedia publishing systems the way in which we access information has changed forever. The geospatial sciences are no different. It is argued that a new genre of spatial artefact has now stabilised and become an accepted tool for exploring geography and for mining geographical information. This has resulted in adapting new ways to use these products and new ways of assembling data into a personalised cartographic product.

Traditionally, data and user were 'merged' by the provision of a particular mapping product that was generated to meet a certain usage requirement for viewing geographical information within a designated area. Contemporary products have changed the process. Users can become the map drawer, data can be assembled from many discrete and geographically dispersed sites and visualization products can be generated using a plethora of depiction techniques that interpret data into usable maps using software that is both available and inexpensive.

According to Fisher (2003), changing trends in Media Technology, with the use of multi-sensory display systems, allow the viewer's movements to be non-programmed - they are free to choose their own path through available information rather than being restricted to passively watching a 'guided-tour'. The advantages are that the viewer's access to greater than one viewpoint of a given scene allows them to synthesise a strong visual perception of geography from many points of view. This enlarges and enhances the traditional view of geography, through only one visualization window. The multiple points of view places an object in context, animating its meaning. Providing different views of reality, through, say maps, books, (virtual) field trips and videos, can enlarge a somewhat restricted view and enhance the user's perception of reality. There are a number of possible views with existing approaches, but these can be enhanced with more intuitive tools and strategies that guide designs of products that control how users use a product, without removing any perceive freedom of use. This is illustrated in Fig. 5.1.

So how can we best use these tools? How much control over the use of the product can we implement? And, how can we ensure that, when New Media installations are employed, that users see essential views of geography?

The following sections develop the idea of the related *Map Shop*, and how it might be further explored as a means of allowing users perceived freedom when using New Media cartographic products, but ensuring that they do not overlook essential information. The current stage of this ongoing research has developed the concept of the Virtual *Map Shop* and then built a prototype that allows for a hybrid discrete / Web multimedia product to be delivered. The following section begins with discussing the theory behind how such tools might be used for exploring and accessing geographical information.

5.2 Underlying theory

The underlying theories behind this research are:

– The concept of the *Map Shop* and the *Literate Traveller*, was developed by almost a decade ago (Cartwright 1997, 1998) as part of a product

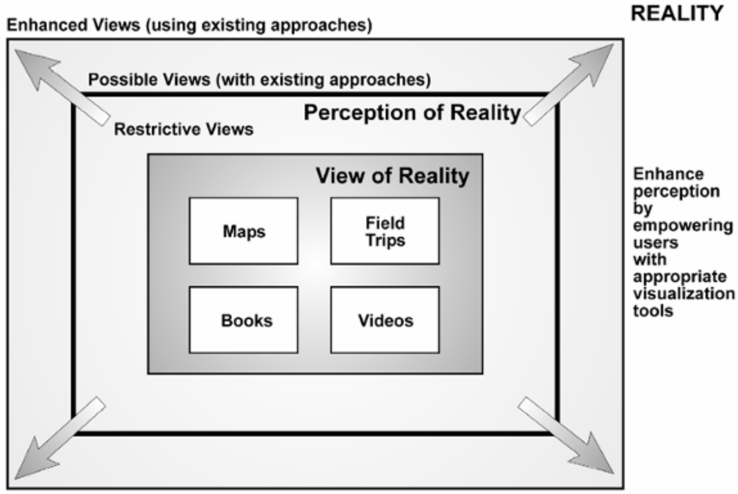

Fig. 5.1. Building more intuitive tools.

called the *GeoExploratorium,* a system for providing access to Rich Media that could aid the building of Geographical Knowledge.

– The use of a metaphor suite (also developed under the general 'umbrella' of the *GeoExploratorium)* for providing information in a user-preferred way.
– Engineered Serendipity – ideas that related to design of interactive multimedia products that allow users to explore information in a serendipitous way, but having some designer control over what they see and how they collect information.

The following sections elaborate on these foundation concepts.

5.3 Map Shop concept

The idea behind designing the method of information enhancement through the provision of Rich Media via the *Map Shop* is that of the *Literate Traveller*. As consumers we use real-world images as artifacts for constructing mental images of places that we intend to visit. We are used to using many artifacts to enable us to build a better mental map of places we are yet to visit. We ‘arm’ ourselves with appropriate information so as to become a *Literate Traveller*. The requirements of the *Literate Traveller* were developed as part of the theory for building the *GeoExploratorium (*a hybrid CD-ROM/Web resource that enabled users to understand geography by exploring geographical space using metaphors that were user-driven, enabling access to geographical information for 'non-elite' users and the general public). By applying the concept of the *Literate Traveller* provisions for the pre-journey deliberations and decisions could be assembled from tactile, discrete and distributed resources. If these resources were made available along the lines proposed in the *GeoExploratorium*, a composite and comprehensive collection of ‘at hand’, on computer and on-line interactive tools could be assembled. However, a method for making these resources easily accessible and made available in a variety of different multimedia types is needed. It was always assumed during the development of the *GeoExploratorium* that the Rich Media repository associated with it would be the *Map Shop*. Therefore the *Map Shop* was considered to be a virtual resource that provides geographical information through the conventional tools of maps, air photographs etc., but also via books, games, videos and expert advice. This concept is illustrated in Fig. 5.2.

The *Literate Traveller* is seen to be the ultimate user of the *GeoExploratorium* and the consumer who uses the *Map Shop* as a source of Geographical Knowledge.

To enable efficient access to external information, the *Map Shop* would

Fig. 5.2. The Map Shop concept.

need to go online. Then the product could connect to on-line interactive books, current travel information via travel guide publisher Web sites, get expert tips and information via email, update databases and offer distributed multi-player games. Fig. 5.3 illustrates this enhanced version of the *Map Shop*.

5.4 Metaphors

Using different metaphors to access geographical information does this. The metaphor set includes the Storyteller, the Navigator, the Guide, the Sage, the Data Store, the Fact Book, the Gameplayer, the Theatre and the Toolbox (Cartwright 1999). This concept is shown in Fig. 5.4, which illustrates how the metaphor set contributed to the information delivered via the *GeoExploratorium*.

These metaphors were acknowledged by Laurini (2001) as suitable access genres for visualising and access urban information. The combination of these metaphors, when used with the map metaphor would provide the means to deliver the contents of the *GeoExploratorium* using multimedia components.

To enable the *GeoExploratorium* metaphors to be applied to developing

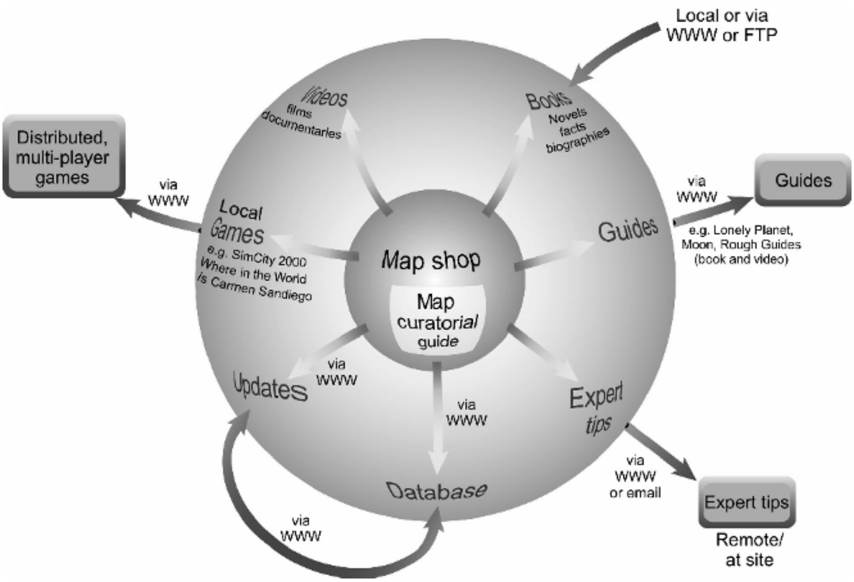

Fig. 5.3. Layout and connections proposed in the on-line *Map Shop*.

Fig. 5.4. GeoExploratorium schema.

an installation for exploration, the metaphors will require some modification to enable a package to be produced. For example, if the prime requirement of such a package is to tell a geographical story, than all of the metaphorical approaches developed as part of the *GeoExploratorium* could be delivered via the Storyteller metaphor. In this particular application the games metaphor is the prime metaphor employed, with other metaphor-assembled information being available to the user.

5.5 Engineered Serendipity

Using geographical information tools means that the user actually works in a 'space', which can range from the real to the virtual. Virtual space can be three-dimensional or four-dimensional (or, with maps, n-dimensional), and it can be modified by new or generated data plus 'things' can 'exist' which do not in the real world. A user can become confused and, at worst, lost in an interactive package. So, there needs to be a method provided for controlling exploration. According to Laurel (1993), computer and machine are two distinct parties, and dialogue between them is complex and something that should not be thought of in terms of linearised turn taking. Entrances into and exits from interactive processes should be synchronised and a 'common ground' for exploration should be found.

Designers of interactive multimedia products for geographical information provision face a major problem: the balance between 'Free-range' vs specific whey-points to guide exploration of geographical information. On one hand users need to be guided to specific information to ensure that they are provided with a complete picture of the area of geography being studied. But, on the other hand, information 'discovered' as users wander in a serendipitous manner, 'falling upon' information that they were not looking for. And, in this way a more interesting, and potentially more effective way of exploring geographical information can be provided. But, how to provide some kind of author control, whilst enabling the user to make their own explorations in a serendipitous way? Hence the concept of 'Engineered Serendipity' (Cartwright 2004a).

'Engineered Serendipity' could be used to extend and control geographical exploration and access in a multimedia cartography environment. Engineered Serendipity might be used to ensure that products that include both Geographical Visualization (GeoViz) tools and New Media artefacts are presented to users in such a manner that different information prospecting methods can be offered. Certain, different, design elements should be considered if such a hybrid as geoinformation product is to provide this information in such a way that serendipitous discovery is supported.

Engineered Serendipity was therefore a core idea that was incorporated into the overarching design of the prototype. It was envisaged that the application of this concept would be done through the application of games-like tools. The research is designing and producing interactive multimedia cartographic artefacts to complement the concept of *Engineered Serendipity* so as to be better informed about how to best design and deliver such geographical information exploration tools via computer game devices, with use strategies built around the methods and theory of gameplay using computers, and particularly connected computers.

5.6 Concepts Behind the Interface and Exploration Tools

In previous research the concepts of the *GeoExploratorium,* the *Map Shop* and the *Literate Traveller* were developed theoretically. Both the *GeoEx-*

ploratorium and the *Literate Traveller* concepts were further developed, prototypes built and subsequently evaluated. This research focusses on information provision via the use of the *Map Shop*, a virtual repository of (geo)information that can be delivered via interactive multimedia. The overarching framework for this research is to provide an exploration tool by using New Media. As stated earlier, this was first realised through the development of the *GeoExploratorium*a and then the *Literate Traveller*. Now the elements that form the theoretical information provision model of the *Map Shop* have been developed, a prototype built and this information provision approach will be evaluated.

The theory underwriting the design of a suitable prototype for evaluation is the Virtual *Map Shop*. As explained earlier, it was conceived as a Web resource that would provide enhanced interactive multimedia products so that users could appreciate and explore geography in the manner that is most appropriate for their particular usage patterns and preferences. The *Map Shop* was conceived as a virtual resource that provides geographical information through the conventional tools of maps, air photographs etc., but also via books, games, videos and expert advice.

To actually design and develop this product, research conducted with earlier, but related, interface tools was used as a general guide for what was appropriate, and could be built. Previous efforts related to the development of a suitable interface tool using the *Doom* games engine, 3D Web-delivered information using VRML and a hybrid Web product that contained a number of evaluation elements, the *Townsville GeoKnowledge* project (Cartwright *et al.* 2003a). Experience from these previous products, and associated evaluations, allowed a number of decisions to be made relatively quickly. These were related to the actual development of the prototype in terms of using the metaphor set as a general concept, designing the product to have the 'look-and-feel' of a computer game and using VRML as a development tool.

Previous evaluations about the use of metaphors found that they help to better understand the information depicted (Cartwright 2004b). During this research a prototype was developed and a questionnaire was used to obtain feedback from a so-called Nintendo Generation user group (Ormeling 1993), that group of users that have been brought-up in a world where computer games pre-existed. This generation are comfortable using computer games and adapt quickly to packages that 'work' like computer games do. Candidates were first asked to complete a simple profile information section and then to answer questions specific to their use of the test product. Candidates thought that metaphors helped to better understand the information depicted. They did not think that maps alone are best to gain geographical information, and that the metaphor set illustrated is a useful adjunct to simply using maps.

As noted earlier, the *MapShop* interface was deliberately designed to have the look-and-feel of a computer game. Again, this decision was made from experience gained from previous research. Test candidates who evaluated the games interface (Cartwright 2004b) found that the games-like product could be used with little prior experience and that this type of interface was easier to use than ‘conventional’ geographical information product user interfaces. Satisfying results were the facts that the interface could be used with little instruction and it was immediately obvious how to use the product (for this user generation). Candidates generally felt confident using the product. They noted that they would choose this type of interface over a conventional one if they were offered such a choice. Finally, they saw this type of interface as being appropriate for a first-time user.

Summarising, the results from previous evaluations indicated that this particular user group deemed that an interface that appeared more like a computer game, and one that required navigation through a 3D information display, was in fact the preferred interface. In general terms, the focus group of used, a Nintendo generation expert user/producer group supported the concept of using a different metaphor, and having a metaphor ‘suite’ delivered using a games metaphor.

From these explorations of the use of New Media for the provision of geographical information the idea was developed that using a 3D product that is designed to appear to be more game-like might provide an appropriate tool schema, and one that the further development of the Virtual *Map Shop* (and associated research) should take. The interest of the author here is related to developing and testing strategies that would provide innovative access to geographical information, but also ensure that users acknowledge that they are in fact using a scientific product. The following sections describe how this next phase of the research is being conducted – designing, building and evaluating the effectiveness of a Virtual *Map Shop* built using a 3D games-like interface.

5.7 VRML Map Shop Prototype Design Ideas

The ‘proof-of-concept’ product was designed to emulate what the user might like to find by exploring the virtual space in a serendipitous way, with the actual information access and subsequent provision engineered so as to ensure that all needed information was assured. It was envisaged that the user would access the information access ‘cues’ in a serendipitous way and in so doing, ‘discover’ information about the town. The initial ideas about how the Web-delivered 3D *Map Shop* might look are shown in Fig. 5.5.

The ideas about how the product would work guided the actual development of the prototype. The concepts behind the design were that a prod-

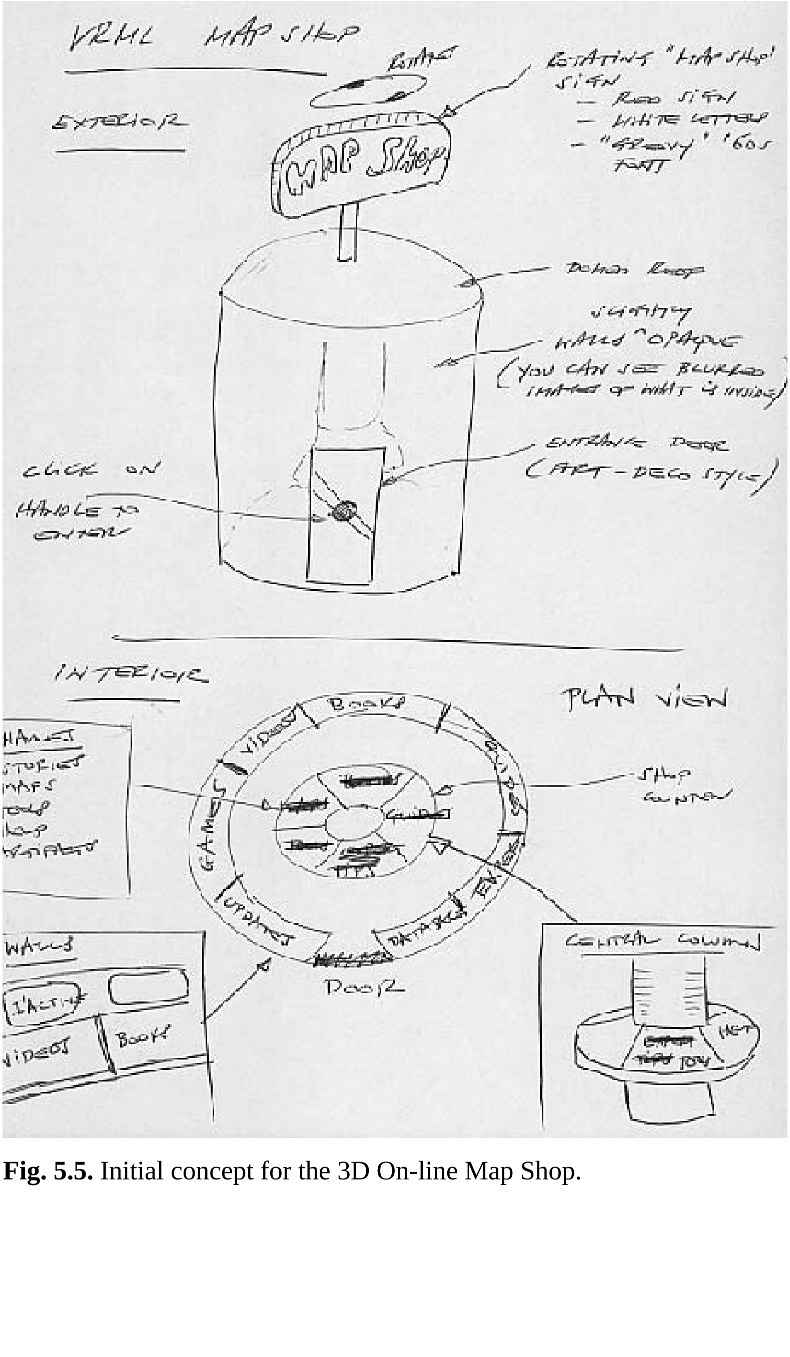

Fig. 5.5. Initial concept for the 3D On-line Map Shop.

uct should be built to have the look-and-feel of entering and exploring what information is available in a contemporary map shop. Using controls provided with standard VRML browser plug-ins the user moves towards the Map Shop and then opens the door to the shop by clicking the mouse button on the door. The user can then move into the ‘shop’, but only via the front door. Just inside the front door is a map curator, willing to guide and assist. The shop comprises a central pillar that has lists of information under selected categories. The lists are interactive and, once clicked, lead to related information via appropriate Web sites. Users can also access packaged information, available on another Web site built by the author – the Townsville GeoKnowledge product) - via maps and graphics that are ‘placed’ (virtually) on tables directly below the information lists. It also contains a number of map drawers. These map drawers have interactive products available on the tops of the drawers and also inside the drawers. The user ‘explores and discovers the information resources in a serendipitous way.

In the completed prototype the information provided to the user was designed to contain information about Townsville, Australia. The *Townsville GeoKnowledge* product contains similar, complimentary (but different) information. Web-linked information can be accessed via a hot links on the central ‘information’ pillar, by clicking on the items or ‘link’ buttons placed atop of the map drawers or in the drawers. These link to additional, on-line information accessible when a new Web browser is activated, providing that information. As well as the map drawers that have map information viewable on top of the drawers, additional and video information is provided on the top and within one of the drawers. The drawers can be ‘opened’ by the user and their contents inspected (this is explained later in the chapter). The map drawers were provisioned with information catalogued according to the metaphor set defined previously in this chapter, allowing the user to ‘browse’ this information according to their preferred metaphorical exploration choice. Around the walls are images depicting panoramas of the town. A hot-spot on the panorama wall links from the *Map Shop* browser to another browser containing the selected panorama.

5.8 Building the Map Shop prototype

A decision needed to be made about the development media and tools to be used. For the tool to be effective it needed to be:

- 3D;
- Allow users to explore information in a serendipitous manner;

– Games-like;
– Delivered as a discrete / Web hybrid product; and
– Developed using Open Source coding (to conform to the general developmental objectives of the author).

Web delivery was essential to ensure that the Web-facilitated components of the *Map Shop* could be provided (see Fig. 5.3). Delivering a 3D games-like tool via the Internet thus required the use of a 3D coding application.

VRML (Virtual Reality Modelling Language) was chosen to develop the proof-of-concept prototype. Some may argue that X3D should have been used, rather than VRML. However, many developers take the VRML 'track', rather than the X3D track. If the use of XML is not required, then the use of X3D for a prototype cannot justified. A useful product can be developed with VRML. Also, again as this was a prototype, the use of VRML provided greater confidence that a suitable browser/plug-in could be employed. If, later in the research project, XML is incorporated, the VRML code can easily be transported into X3D.

Finally, to implement games-like controls, a *Nostromo* controller was employed. This games controller provides the facility to code the controller keys, wheels and toggles to emulate the mouse/keyboard controls needed to navigate through a 3D VRML world. It also enables the speed of travel through the virtual world to be 'dialled-in' via a wheel that is part of the device.

For the actual delivery of the product the MicroSoft *Internet Explorer* browser was employed, and combined with the VRML browser plug-in from Bitmanagement Software (Germany). It has been found that this combination provides the most effective tool delivery, considering that this is such a mid-resolution image-laden product. The browser plug-in also provides the facility to move through the model in a games mode, allowing the programmed functions of the *Nostromo* controller to be employed. The browser can also include an avatar.

5.9 Exploring the Product

How this was realised can be seen in Fig. 5.6 (outside the *Map Shop*), Fig. 5.7 (the front door, with Map Curator) and Fig. 5.8 (the core display 'pillars). The outside of the *Map Shop* was developed to give the impression of a resource that invited further investigation and exploration. The walls are opaque, providing a glimpse of what is inside the product. Using the browser controller tools the user can approach the door, click on the door

Fig. 5.6. The Map Shop.

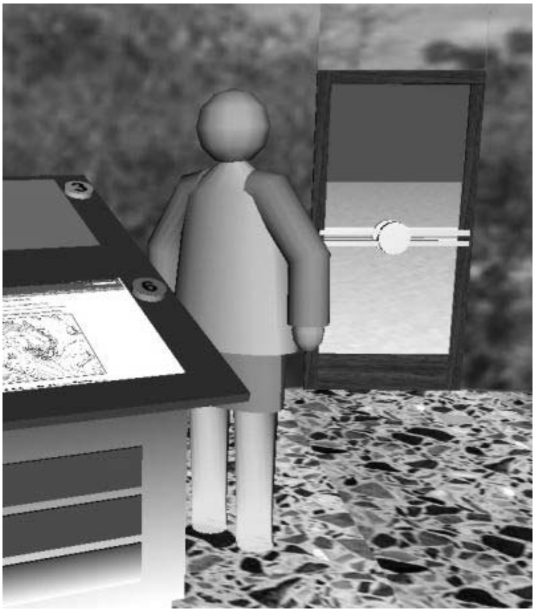

Fig. 5.7. Map Curator at the front door.

handle and then enter the shop by navigating the product with mouse or selected keyboard keys. Users can also move from one viewpoint to another, in a pre-programmed manner or by selecting particular viewpoints of interest. At the door has been placed a Map Curator avatar. This is not yet

Fig. 5.8. Map Shop central information column and map table. The walls have images from the available product panoramas.

functional, but it is will be the focus of on-going prototype development and evaluation. Once inside the *Map Shop* users are free to explore the central column information resource, the map drawers and tabletops and the panorama that adorns the walls.

The central column lists the information available about Townsville (Fig. 5.8). By zooming into the column and moving the cursor over individual ‘entries’ on the information list, the cursor icon changes, indicating that by clicking the named link a new Web page will open and the information displayed. Users need to be on-line to access information outside the package. At the base of the column is a table, or information plateau. Here, the maps link to the complimentary Townsville GeoKnowledge Web site (Cartwright et al. 2003b), a 2D interface information package. Similar information resources are provided on other faces of the column and the plateaus – for databases, expert tips and images.

The *Map Shop*, which already provides information via the central column, was enhanced via a number of ‘workstations’ situated on the floor. Each of these workstations provides information access using these different metaphorical approaches. At the design stage it was envisaged applica-

Fig. 5.9. Map Shop drawers – contain information arranged by metaphor.

tions ‘built’ using these different metaphors would allow for 'everyday' tools and computers to empower users to more easily get access to comprehensive geographical databases using methods that they feel most comfortable with. The way in which the workstations would be placed in the *Map Shop* is illustrated in Fig. 5.9. ‘Tools’ and other resources placed on top of the workstation, and other artefacts made available in the drawers of the workstation provide information access tools.

Discrete interactive multimedia objects ‘reside on the top of the workstation (Fig. 5.10). Items located in each of the drawers (that can be opened by ‘pulling’ the drawer handle with a mouse held down (Fig. 5.11)).

If the user wishes to view a larger version of the information that resides on top of the drawers, a mouse click enables an enlarged (and higher resolution) view to be viewed (Fig. 5.12). Users can also explore the contents of the drawers. The images of the maps and artifacts inside the drawers have been ‘collected’ and arranged in metaphorical sets. If a map or artifact in the drawer is of interest the user can click on the mage and, once clicked, this will link to and open a browser to outside information.

The manner in which it is envisaged that users will use these drawers, and the items atop the drawers, to explore the information in a serendipitous manner. The arrangement in metaphorical sets and providing links to pre-determined information sites allows the users serendipitous ‘wanderings’ within the *Map Shop* to be Engineered. Serendipitous movement

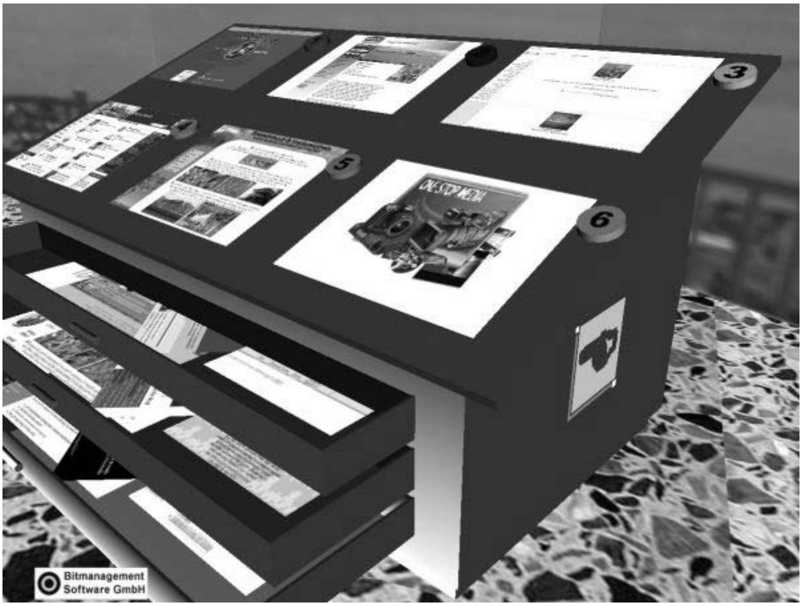

Fig. 5.10. Zooming in to the map drawers showing 'clickable' links to external Web resources on the drawer tops.

within the package + engineered information provision = Engineered Serendipity!

As well as static images, the VRML World contains links to videos. To access these, the user needs to move to the map drawers with the video images on the top (Fig. 5.13). They are activated by clicking on the button to the right of the drawer top image. Once the button is clicked a movie player is activated and the user can view the video using the standard controls. Note - clicking on the image itself provides an enlarged vertical view of a still from that particular video (Fig. 5.14).

Surrounding the *Map Shop* floor is an image collection from one of the panoramas available. The panorama image has been 'sliced' to manufacture wall panels. Hot spots (with the camera icon) have been placed to indicate the further links to panoramas in the package. A click on the selected icon leads to a panorama (Fig. 5.16), created with the package *PixAround*. It is envisaged that eventually these panels could be changed via a user-selected graphic device.

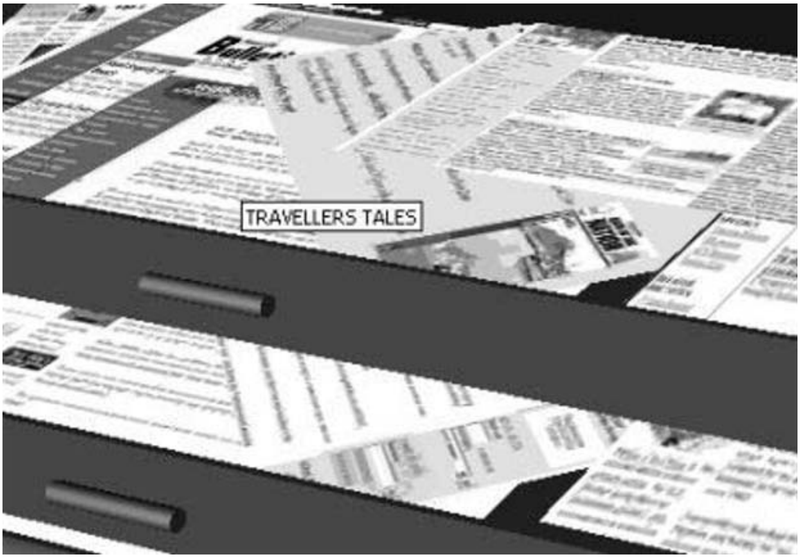

Fig. 5.11. Information links inside drawers.

Fig. 5.12. Zooming in to the map drawers showing ‘clickable’ links to external Web resources on the drawer tops.

Fig. 5.13. Movie top.

Fig. 5.14. Clicking on image enlarges image. Clicking on button to right of image on tabletop opens and plays movie in new browser window.

At the side of each drawer cabinet is an icon illustrating the metaphor that was used to define the ‘collection’ of online artifacts available (see Fig. 5.16). Clicking on this item leads to another Web page that describes the icon, for example the Navigator metaphor in Fig. 5.17.

5.10 Further Development of the Package – Adding Map Curator

The links to all of these resources need not require the user to be physically in the *Map Shop*, nor should it be imperative that all of the participants in the total exploration of all of the resources be there as well (or at all). Communication with experts could be made through electronic means, and access to other collections and artifacts could be made possible via electronic links. However, what happens to the novice user of this enhanced

Fig. 5.15. Panorama and metaphor hot-spots

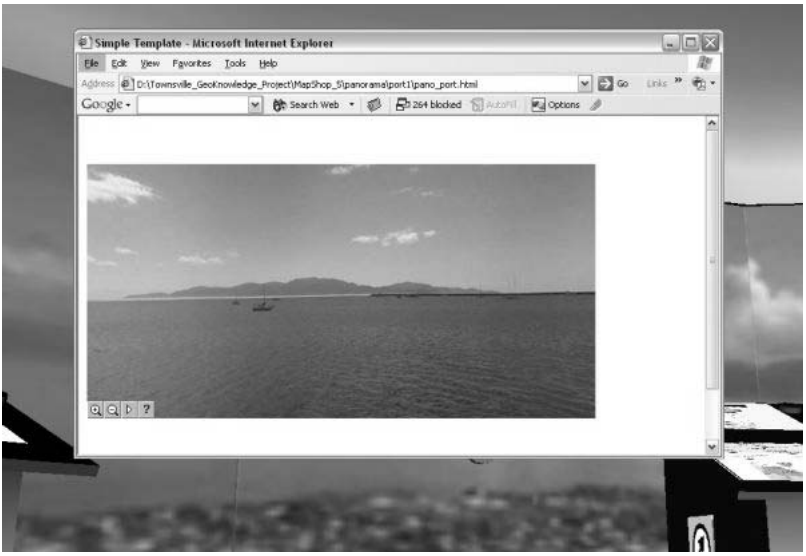

Fig. 5.16. Panorama.

Map Shop? Are they allowed to wander aimlessly around, looking for information that is irrelevant to their particular application, or not available or completely misleading? Or should a map curator (either real or virtual) be provided to assist them with their quest? There are many curators of map collections who are expert in both their own collection and have knowledge about other collections, and the availability of maps from international providers and private repositories. The expanded Map Shop should be manned with a curator to provide advice and guidance on finding the most appropriate resources and assistance in the best way to use these products and resources. The curator can 'reside' (as an avatar) in an on-line shop or be a real curator, available at the end of an Internet connection. The curator would be an invaluable component of the Map Shop.

A curator could assist users in selecting the appropriate metaphors to use and find the required information through links to distributed resources. When using the World Wide Web for resource access, this curator could be developed as an Agent. Agents, according to Maes (1996, p. 1) are "active entities that can sense the environment - the digital world - and perform actions in the digital world and interact with us". These active entities can be called software agents. They can be semi-intelligent, and they can be born, reproduce or die. Shapiro (1992) saw the need to pursue the 'Intelligent Agent' approach to user interfaces for GIS. In an ideal package, the human would be able to interact with such a system through a mix of natural language and gestures. Agents could be used as a surrogate curator, constantly seeking out information and 'directing' users to its location. Rodrigues *et al.* (1995) noted that intelligent agents have been used for information retrieval, assisting in the operation of intelligent networks, for task execution and for collaborative processing. They further noted that spatial intelligent agents could be used for locating and retrieving spatial information, to automatically generate templates for spatial modelling, to automatically monitor spatial model execution and to allow for collaboration between GIS and other specific use packages. The *Map Shop* Curator could ensure that the user obtained the required or ideal mixtures of resources from the *Map Shop* (discrete and on-line resources).

As explained earlier, the Map Curator can be developed for the package by developing the 3D character located just inside the front door of the Map Shop. Alternatively, the browser plug-in provides a built-in avatar. This would provide another route for Map Curator development. Both the Map Curator and the browser-facilitated avatar can be seen together in Fig. 5.18.

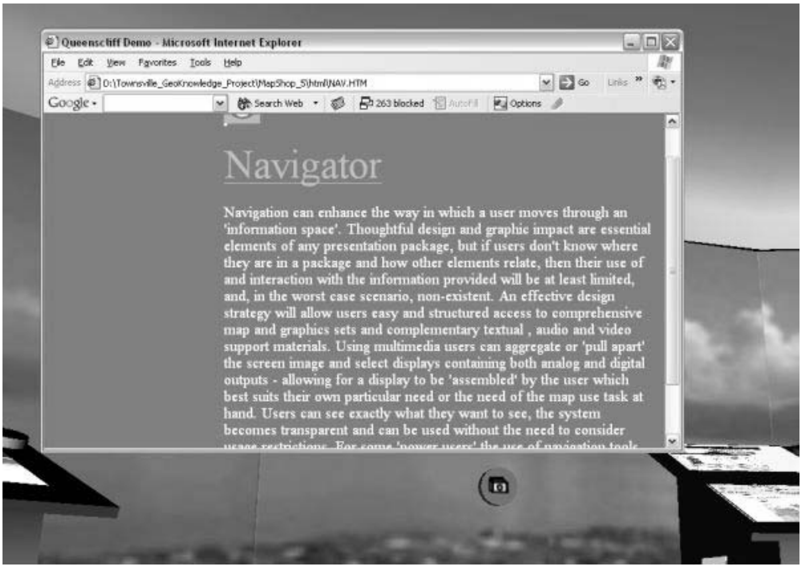

Fig. 5.17. Metaphor information.

Fig. 5.18. Map Curator and browser-facilitated Avatar.

5.11 Conclusion

The chapter has described the underpinnings of current research – the *Geo-Exploratorium*, a metaphor suite for the provision of geographic information in a manner that is complementary to the map metaphor. The theory behind how the *Map Shop* would operate has also been explained. And, the ‘proof-of-concept’ prototype, being built to examine the usefulness of such a product, has been outlined. This is being developed and further enhanced to be provisioned with maps, videos, books, guides, games and databases of facts and could provide expert tips. The *Map Shop* will be linked locally or internationally through the Internet and, more specifically, the World Wide Web. From the users’ perspective the boundary between discrete and distributed multimedia would be transparent, presenting than with the most current and customised information possible. Finally, areas of future research were identified and described. It is believed that if this research were continued to include the addition of the Map Surator, then the real potential for using interactive multimedia, the Web and contemporary delivery mechanisms can be tested.

Acknowledgements

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6 Atlases from Paper to Digital Medium

Cristhiane da Silva Ramos, and William Cartwright

Abstract. This chapter analyses the concept of digital atlas, analysing different definitions found in the literature. Additionally, the characteristics and different classifications of digital atlases are analysed. The lingering question about the difference between GIS (Geographical Information Systems) and digital atlases was also addressed in the chapter. It is believed that a better understanding of what a digital atlas can be will facilitate the development of future digital atlas projects.

6.1 Introduction

The main purpose of this chapter is to define atlases in general, and particularly digital atlases. Additionally, the chapter focuses on gaining an understanding about what constitutes digital atlases: defining their characteristics, classification and delivery medium. It is believed that this is important to better understand atlases in this contemporary context, as atlases are no longer restricted to just paper and, as well, they are not necessarily comprised of just maps.

Many researchers have reviewed the definition of what an atlas is. However, although many definitions of digital atlases have been made, digital atlases encompass such a wide range of features and technologies, it is necessary to extend these by defining their characteristics and different atlas types. Also, the recent advances in atlases production have raised the question of: are digital atlases a kind of GIS? This question is inevitable as, in some ways, atlases cannot just be comprised of functions for spatial analysis, but also GIS objects as well. If there was a dividing line separating the definitions of GIS and digital atlases, one could say that it is becoming fuzzier.

Atlases are, probably, the best known and the most flexible of popular cartographic products. Atlases can be used to address different issues and to target different audiences. Historically, atlases have played different roles - from instruments of power, in the renaissance to current decision and planning support tools. Atlases can be used for general reference, education and business. As they evolved, atlases were produced in different ways, from the initial manual production to current computer-generated applications. Atlases have experienced many changes in the way they are conceived, produced, disseminated and used.

6.2 Technology and Cartography

Technology can also be considered to be an underlying concept for understanding the development of cartography. Traditionally, cartography has been quick to adopt technological advances from other fields. However, as stated by Robinson *et al.* (1995), it seems that every new technology that has been introduced has caused greater changes in cartography than the previous one, and, as well, it can be argued, the time between technological changes seems to be diminishing.

These advances changed the way cartographic products were produced and distributed. As humanity evolved technologically, these advances were adopted by cartography. Initially, mediums such as clay tablets, leather and papyrus were used to convey maps. Each of these maps was unique, just like the first map drawn in the sand. Maps had to be reproduced one by one using a painstaking process mostly done by high-skilled workers. Therefore, even after the use of durable media, maps were still not widely available.

During the 20th century many other advances were introduced to cartography from field equipment to the use of satellite images. The introduction of computers represented a significant revolution to the cartographic process, because they not only changed the way that cartography is produced, but they became a medium for cartography.

Considering changing technologies as a guiding concept to understand cartography, Robsinson *et al.* (1995) emphasised the technological periods in cartography. This is summarised in Table 6.1.

Due to the advances summarised above, maps became increasingly present in everyday life, not only for decision makers, but also for ordinary people. In the news, in weather forecasts, in multimedia kiosks in shopping centres, in street directories, in tourist brochures, schoolbooks, maps are omnipresent.

6.3 Atlases: A Definition

Atlases are probably one of the first cartographic products that people use, because they are introduced to students in early at school. Atlases can be considered the most widely known cartographic products (Kraak, 2001b)

Table 6.1. The six major technological revolutions that affected cartography, after Robinson *et al.* (1995).

Technology	Beginning	Effects on Cartography
Manual	Pre-history	The beginning of cartography. Maps were result of field observations and were made by skilled hand-workers, one by one. The authors highlight that the techniques developed during this period remained in use in the following periods.
Magnetic	12th Century	The introduction of the magnetic compass, brought from China, represented a major change to cartography. After this technology, angles could be measured.
Mechanical	12th Century	The introduction of the printing process, first in China during the 12th Century and later in the Western culture, by Johannes Gutenberg in Germany during the 15th Century, made possible to reproduce maps more rapidly and efficiently
Optical	17th Century	The introduction of the telescopic and magnifying lenses enhanced the human sight. Other important optical technologies such as the stereoscope and CD-ROMs for data storage were also introduced in the following centuries.
Photo-chemical	18th Century	Lithography, which is a chemical printing process created in the late 17th Century, make it easier and cheaper to reproduce maps. Another remarkable advance in this period was the introduction of photography, first for field observation and later the use of aerial photographs made possible perpendicular view of geographical space.
Electronic/ Digital	20th Century	Electronic technology changed cartography as a whole. Electronic devices, mainly computers, are used to collect data, to produce and print maps and even as the medium in which the map is to be used. Digital technology is used to store data, and millions of maps as digital files are exchanged daily over the internet.

and a high point for cartography (Kraak and Ormeling, 1996, Kraak, 2001b).

The original meaning of the word atlas refers to ancient Greek mythology. Atlas was one of the twelve Titans, sun of Uranus (God of the sky) and Gaea (Goddess of the earth), brother of Zeus, the supreme governor of the universe, and father of Pleiades and Hesperides. According to the ancient Greek beliefs, Atlas was the God who was condemned to hold the vault of the sky, represented by a globe, on his shoulders. (Aghion *et al*, 1996).

According to Thrower (1972), the use of the word atlas to describe a collection of maps was introduced by the famous cartographer Gerhardus Mercator, who, after publishing his world chart in 1569, dedicated his final years to produce a large atlas, which was released in 1595, one year after his death. Thrower (1972, p. 56) claimed that "it is undoubtedly because Mercator used the term 'atlas' for a book of maps that it is in use today".

In general, atlases can be understood as a collection of maps with a specific purpose and organized in the form of a book, which usually includes tables, graphs and text. The word "atlas" can also be used to describe a collection of information that covers a field of knowledge, for example, an Atlas of Anatomy or History. However, in this chapter the word refers to geographic atlases.

'Traditional' atlases, such as books, are bound publications and therefore have a fixed linear structure. Topics are developed linearly throughout the publication. The maps are developed according to a fixed format, limited to the size of the page. However they cannot be considered to be books, as noted by Alonso (1968):

> "To the layman, any book consisting mainly of maps is an atlas, but technically to the geographer, no cased collection of maps deserves the name unless it be comprehensive in its field, systematically arranged, authoritatively edited and presented in a unified format." (Alonso, 1968, p. 108)

According to Keates (1989) the use of maps in atlases is very flexible, he argued that "Although the term 'atlas' is frequently associated with the concepts of 'world' and 'small scale', there are atlases with large-scale plans (city street guides), special-purpose atlases (such as road atlases for motorists), and special-subject atlases (such as an atlas of agriculture)" (Keates, 1989, p.235). Generally, Keates (1989) highlighted that one could discern atlases by its scale; topic; and target audience.

Maps have been present throughout the human history and their evolution can be looked at from different viewpoints. Atlases can be classified by several aspects. Ormeling (1995, p. 2128) classified traditional atlases in regarding to their contents with respect to: geographical atlases; historical; national/regional; topographic; and thematic atlases. Considering communication purposes, the following types of atlases that could be identified are: educational, navigational, physical planning, reference, and management/monitoring. Furthermore, Borchert (1999) stated that different categories of atlases can be distinguished according to format, geographical coverage, thematic content, information level, purpose, publisher, quality and price.

Focussing on how atlases were used interactively, Peterson (1998) has stated that, despite new advances in interactive cartography, the concept of interactivity itself is not a new one for cartography. He divided the history of cartography into three periods. The first is characterised by interactivity, but consisted of ephemeral, maps. According to Peterson it is very probable that the first maps were results of conversations. Maybe, these maps could have been the consequence of discussions about the location of enemy tribes or better sites for hunting. Perhaps, they were drawn on sand. What is clear is that they were not meant to last, but to enrich communication, at the same time providing additional information – the result of the conversation. About interactivity in early cartography Peterson (1995, p. 10) had this to say:

> "That map in the sand was not the kind of static map that we find today on paper. The meaning of the symbols would have been explained as the map was created. The second person would have asked questions that influenced how the map was drawn. As new features were added, they may have obscured part of the existing map. Indeed this first map would have been very much like the kind of interactive and dynamic map that we are attempting to create today with the computer."

About the second atlas period, Peterson (1998, p. 3) argued that "A major shift occurred long ago as a stable medium was used and maps were transformed into static objects, first on clay and later on paper", in this way, it was possible to create durable maps that could also be distributed to map users in different locations. Therefore, the cartographer was necessary just to create the map. Once the map was ready it could be distributed and used by anyone, anywhere. This was an important transition for cartography and was crucial for the history of the mankind. However, this evolution separated cartographer from map user and, hence, the interactive factor was removed. Cartography, as a result, dived into a static period".

The third period has seen the introduction of computers. They were initially used as a tool and later as a medium, bringing back interactivity to cartography. However, as Peterson has highlighted, it is a different kind of interactivity - human vs. computer. Nevertheless, after centuries of static maps (mainly on paper) people got used to think maps as static representations. This thought, which Peterson (1998) called 'paper thinking', now provides one major drawback for interactive cartography - it is hard for the present atlas-user generation to overcome the way they were initially taught to conceive maps. But, as technology and interactive maps become ubiquitous, this obstacle should tend to vanish in the near future.

6.4 Digital Atlases: the Search for a Definition

The technological advances represented by the use of computers for the production and distribution of maps have had a major impact since the early eighties and, therefore, created a new category of atlases: digital (or electronic) atlases. Atlases, as described previously, were studied and produced for centuries, however, digital atlases have a shorter history and, consequently, concepts have been developed over the last few years. The first digital atlases were developed during the eighties and an increasing research effort in the field has been carried out since then (Rystedt, 1996).

Ormeling (1995) and Kraak (2001b) also noted that the development of digital atlases started in the late eighties. The authors consider the *Atlas of Arkansas*, presented in 1987 during the 13th International Cartographic Conference of the International Cartographic Association (ICA), the first digital atlas to be developed.

According to Siekierska and Williams (1996), the first digital atlas developed was the *Electronic Atlas of Canada*, in 1981. This pioneer atlas was the result of a long Canadian tradition in producing national atlases. Afterwards, the Canadian government created the *National Atlas Information System* (NAIS), aiming to create digital databanks for mapping as well as facilitating the digital production of paper maps. Thenceforth the following years were distinguished by the development of many other digital atlases either by governments, universities or private companies.

In 1986 the *Digital Atlas of the World* was created by Delorme Mapping Systems. Analysing the use of that atlas, Siekierska and Taylor (1991, p. 12) stated that “apart from scale change and the additions of overlays, the analytical capabilities are limited”.

Kraak (2001b) considered this first digital atlas as an extension of a paper atlas, in digital media, as it was comprised by a set of static maps accessed via a menu. As stated by the author the development of digital atlases presents similarities with the history of computers in cartography. The beginning was characterised by hardware limitations, such as storage capacity, and software, represented by the lack of authoring tools for developing more interactive applications.

According to Kraak and Ormeling (1996, p. 183) atlases are “intentional combinations of maps, structured in such a way that given objectives are reached. In a way, atlases are similar to rhetoric: if a number of arguments are presented in a speech in a given sequence, a specific conclusion is reached.”. This definition can be applied either to paper or digital atlases, however, the idea of defining an atlas as a bound collection of maps should be reviewed.

Siekierska and Taylor (1991, p. 11) tried to fill the existing gap between the traditional definition of paper atlases and digital atlases by creating a new definition of digital atlases, which stated that “The electronic atlas is a new form of cartographic presentation and can be defined as an atlas developed for use primarily on electronic media.”

Koop (1993, p. 129), created a more flexible definition of atlas, as a “Systematic and coherent collection of geographical data in analogue or digital form, representing a particular area and/or one or more geographical themes, based on a narrative together with tools for navigation, information retrieval, analysis and presentation.”

Elzakker (1993) claimed that a digital atlas, and particularly an analytical atlas, is a special kind of GIS. In his opinion the main difference between digital atlases and GIS is that digital atlases have a narrative faculty, once they are designed to attend a specific purpose. He defines electronic atlases as “a computerised geographic information system – related to a certain area or theme in connection with a given purpose – with an additional narrative faculty in which maps play a dominant role” (Elzakker, 1993, p. 147).

The same definition was adopted by Ormeling (1995, p. 2127). Other authors such as Richard (1999) and Borchert (1999), also stated that nowadays atlases could be considered a collection of maps distributed either on paper or by digital means.

Kraak and Ormeling (2003, p. 154) considered that “If paper atlases are considered intentional combination of maps, then not all electronic atlases might fit in this definition. Some could better be defined as intentional combinations of specially processed spatial data sets, together with the software to produce maps from them”. In other words, maps do not comprise digital atlases necessarily, but according to the authors the narrative is a cornerstone concept to define atlases.

As can be seen by these many definitions of digital atlases, the development of digital atlases has fostered an increased research focus since the early nineties. It is important, however, to highlight that as the development of digital atlases constituted a new field at that time, the first definitions tried to explain digital atlas by comparing them to paper atlases. In this way the first, and most obvious, difference emphasised was the medium. Further definitions focussed not only the medium but atlas use as well, by putting the emphasis on aspects such as the narrative or navigation tools.

6.5 Digital Atlases: Characteristics

With the introduction of this new field of research in cartography, these researchers tried to summarise differences and similarities, as well as advantages and disadvantages that could be identified between digital and paper atlases.

As stated previously, Canada played a pioneer role in the field of digital atlases. Siekierska (1984), explaining the procedures adopted for elaborating the early version of the *Electronic Atlas of Canada*, stated that the important aspect of digital atlases is that they made it feasible to generate maps that were user-demanded or user-created. In this way the user's needs would be more likely fulfilled. The author argued, however, that the main difference between digital and paper atlases is that with digital atlases the analysis is made directly on the data set, the input data, instead of the traditional analysis being made directly in the final product, the printed map.

In other words, in the early eighties Siekierska proposed that digital atlases could provide an exploratory environment in which the user interacts with the information directly stored in the data bank, using the map only as an interface. In this way, she saw that the proliferation of digital atlases would be an important field of research for cartography in years to come.

Summarising the characteristics of electronic atlases, Siekierska and Taylor (1991) indicated that important advantages were the fact that those products provide tools for innovative displays and analysis such as queries, overlay, animation, interactive zoom, scroll and pan. In addition, they emphasised the reduced cost of producing a digital atlas as a significant advantage, once they could be reproduced and distributed to a wider audience with lower costs, when compared to paper atlases.

Bakker *et al* (1987), analysing national atlases, foresaw that digital production of national atlases would be an important trend in the future, however, it was very unlikely that national atlases on paper would disappear completely. It is impossible to verify, by official statistics, if the authors were right, nevertheless sixteen years later papers presented and published on the proceedings of the 21st International Cartographic Conference, supported what the authors predicted, that digital atlases have become paramount atlas products. At that conference, digital and hybrid atlases represented 83% of the atlases presented (Table 6.2).

The *National Atlas of Spain*, for example(Aranaz *et al.* 2003), was first published on paper, afterwards a digital version in CD-ROM was implemented and at that time a future version for the Internet was being developed. However, the paper atlas was still being produced and new formats were being released to provide better user handling. Other examples of national atlases produced both on paper and digital formats presented in that conference are the *National Housing Spatial Investment Potential Atlas of South Africa* (Biermann and Smit 2003); the *Census Atlas of the United States*(Brewer *et al.* 2003), the *Atlas of Oregon* (Buckley *et al*. 2003) and the *National Atlas of Russia* (Zhukovsky and Sveshnikov 2003). The atlases presented just in digital version were the *Atlas of Switzerland* (Huber and Schmid 2003) and the *Statistical Atlas of the European Union* (Pucher *et al.* 2003).

In a similar way to Bakker *et al.* (1987), Ormeling (1995) predicted that by the year of 2000 paper atlases would be published with a CD-ROM as a digital complement. Even though after a decade his prediction was not achieved, the number of digital and hybrid atlas, atlases available both on paper and digital formats, has increased sharply. The number of paper atlases presented, on the contrary, decreased considerably (Table 6.2).

Ormeling proposed digital atlases should have three main functions:

- *To provide background information:* which could be tables with the statistics used to create the maps, photos, texts, graphs or drawings;
- *To expose other geographical views of the data:* the digital complement should be able to produce maps different from those published, based on the same data. This function would be possible by using different classification systems and changing the number of classes or even different boundaries; and
- *To provide additional information:* paper atlases have a series of issues to consider regarding their development. However, the cost of the publication could be isolated as the main issue. In this way the digital counterpart could provide more information than that published, with re-

Table 6.2. Number of atlases presented in the International Cartographic Conference, in percentage.

Type of Atlas	1995	2003
Paper*	74%	17%
Digital	14%	50%
Hybrid	12%	33%

* Atlases presented with no reference to the medium were considered paper atlases.

duced cost.

Rystedt (1996, p. 1) considered that “An electronic atlas can contain data and software giving the user possibilities to more thoroughly investigate the topics presented in the book version of the atlas”. The author claimed that the use of different media and GIS functions would improve the potential of the new kind of atlas and furthermore the challenge would be to develop digital atlases for the Internet.

It seems, despite the advantages highlighted, that both paper and digital atlases have theirZ advantages and disadvantages. Analysing this issue, Koop (1993) claimed that the main asset of paper atlases is the “lazy armchair function”. In contrast the major drawbacks of paper products would be the high cost of such products and the time spent to update them. The author also noted the advantages of digital atlases: they are easy to update and provide new forms of cartographic communication.

Kraak and Ormeling (1996) considered that the advantages of digital atlases are: the possibility of creating customized maps; the immediate provision of geometric information; the possibility of going beyond static map frames by using interactive tools (such as pan and zoom); the use of animations to depict data over time; links provided with databanks to provide additional information regarding features highlighted or clicked by the user (and here interactivity is, once more, an important point); the integration of multimedia; and the possibility of improving manipulation and display of information by different levels of aggregation of data, from small to large regions.

Additionally, Peterson (1999, pp. 35-36) analysed the advantages of paper for cartography over digital media and saw two major advantages: paper maps are easy to carry and paper supports higher spatial resolution. However, Peterson argued that, although paper is better for cartography, it is incompatible to represent dynamic phenomena. On the other hand, he considered the major advantages of digital maps to be that: they are more effective in representing dynamic phenomena; when distributed by networks they can be delivered much quicker than paper maps; they are more current; and they change the traditional map use, as digital maps can be interactive, and therefore the user’s attitude towards the map is different as they engage the information more deeply.

Comparing digital and paper atlases, Schneider (2002, p. 24) stated the following about the advantages of digital atlases over its paper equivalents:

> *“Sie können neue Karten erstellen oder bereits bestehende ihren eigenen Bedürfnissen entsprechend flexibel anpassen. Die Informationsübermittlung erfolgt dabei nicht linear, sondern über eine thematische oder räumliche Orientierung.*

> *Durch die Verwendung von Multimedia kann ein bestimmter Sachverhalt dem Atlaspublikum über verschiedene Medien präsentiert werden. Zudem besteht die Möglichkeit, mittels Animationen zeitliche und räumliche Prozesse zu simulieren. Die grossen Speicherkapazitäten von elektronischen Medien erlauben ferner, nicht nur eine Auswahl von Daten, sondern komplette Datensätze in verschiedenen Massstabsstufen anzubieten. Schliesslich können AIS leicht aktualisiert und erweitert werden."*[1]

Analysing the same issue, advantages of digital atlases, Borchert (1999) assembled a comprehensive list that is summarised in Table 6.3. Also focussing on the differences between paper and electronic atlases, Ormeling (1996) summarised what he saw to be the main differences between them. These are shown in Table 6.4.

Ormeling (1996) considered view-only atlases and paper atlases in the same category because, according to his arguments, view-only atlases do not use technology "adequately", which can be understood as, although view-only atlases are digital atlases they do not take advantage of the resources available in the digital medium. He made use of multimedia and the dual concepts static vs. dynamic, passive vs. interactive to analyse the differences between paper and digital maps.

6.6 Digital Atlases: classification

Digital atlases are a type of atlas that can be distinguished by its digital format, either discrete (produced for distribution in floppy disks, CD-Rom or DVD) or networked. Besides the traditional classification of atlases, more specific classifications considering only digital atlases have been developed. Siekierska (1991) cited by Elzakker (1993) classified digital atlases in three groups, considering basically the level of interactivity and

[1] "They (the user) can generate new maps or can adapt existing maps according to their needs. The transmission of information takes place in real time, not linearly, but rather via a thematic or spatial-oriented navigation. The use of digital multimedia, over different media, allows presenting a specific issue to the atlas audience. Moreover, it is possible to simulate temporal and spatial processes by using animations. The large storing capacity of electronic media permits furthermore, not only a selection of data, but rather to offer complete records in different scale levels. Finally AIS (Atlas Information Systems) can be updated and expanded easily."

Table 6.3. Summary of the advantages of digital compared to traditional atlases, after Borchert (1999, p. 76).

Attribute	Description
Exploration	Exploration can be understood as the amount of freedom given to the user in order to explore the contents of the atlas. The use of GIS functionalities can be included in this concept. Interactivity is a key component in an exploratory atlas.
Dynamics/Animation	The use of animation and its new visual variables brings new forms of communicating spatial data.
Customisability	Once more the issue of interactivity is present, at this point the concept is to allow the user to customise the map as the interface of the information, by changing layers or visual variables for example, in order to attend individual requirements.
Integration with diverse media	It is possible to integrate the digital atlas with textbook, paper atlas, working sheet, wall map, and so on. In this way new didactic perspectives could be reached.
Current contents	A digital atlas can be easily updated; if the product is networked its contents are current and immediately available to the user.
Portability	The digital atlas is easier to transport when available in discrete media, moreover if it is available on the Internet portability is not an issue. However, the computers are still heavy.

Table 6.4. Differences between paper and electronic atlases, after Ormeling (1996, p. 33).

Paper Atlases/View-only Atlases	Interactive Atlases/Analytical Atlases
Static	Dynamic
Passive	Interactive
Maps only	Maps and multimedia
Limited/selective	Complete
Fixed map frames	Panning and zooming possible
Compromise for all types of use	Customised
Maps as final product	Maps as interface

the analytic potential provided. There, digital atlases were subdivided as being:

– View-only atlases;
– Atlases that generate maps on demand; and

– Analytical atlases based on GIS capabilities.

Also, analysing the ‘state-of-the-art’ in atlas production and describing the procedures adopted to develop the *Electronic Atlas of Canada*, Siekierska and Taylor (1991) implied that one could discern basically between two types of digital atlases:

– View-only atlases, which could be considered an extension of paper maps in digital form because this kind of atlas allows the user to access stored static maps; and
– Atlases with dynamic interaction and analysis, which would provide more flexible functions such as selection of particular features, addition of data, changes of scale and customisable interface, for instance.

Moreover, Kraak and Ormeling (1996) stated that one could discern the following types of digital atlases:

– View-only atlases, in the same way as Siekierska and Taylor (1991), the authors considered this kind of atlas to be an extension of paper atlases, however they noted three advantages as being: the reduced cost of reproducing digital atlases, the possibility of consulting more than one map at the same time (by dividing the screen) and random access to the maps (instead of the linear structure of paper atlases). It is believed, however, that bound publications can be considered hypertextual, because the reader can read them at random and the author can use footnotes.
– Interactive atlases that provide the user the opportunity of interacting with the data set, either by changing colour schemas, classification methods or the number of classes displayed.
– Analytical atlases, where queries to the databank can be made directly from the map, as the map is just a graphical interface to the data. In addition, data sets could be combined in order to create new data sets. Therefore the user is not restricted to the data provided within the atlas itself. Although this kind of atlas incorporates most GIS functions the authors re-state that the emphasis is on analysing the data and visualizing the results.

Which classification to choose? When considering the various classifications outlined previously, the work of Kraak and Ormeling (1996) is considered to be the most appropriate, because it not only considers and expands previous upon discussions and classifications; but it also takes into account the structure of the atlas, the level of interactivity and the technology employed. The inclusion of all of these elements provides what is considered to be the best classification.

6.7 Digital Atlas: Merely a Variant of a GIS?

It seems that some categories of atlases are somewhat similar to GIS, however the authors argued that the main difference is that atlases "give major importance to the presentation and display of spatial information while in most GISs is on information retrieval and analysis of data" (Siekierska and Taylor 1991, p. 14).

It is undeniable that there are similarities between Geographic Information Systems and some kinds of digital atlases. Conversely, as stated by Elzakker (1993) probably the main difference is that digital atlases emphasise the use of cartographic methods to improve the analysis and presentation of the maps and on the narrative, which intends to improve the user's comprehension of the atlas information.

However, the question remains. If today's atlases are not necessarily comprised of maps, but also by data sets and software that allow the creation of maps on-demand, just like a GIS, what is the real difference between GIS and digital atlases?

Kraak and Ormeling (1996, pp. 183-184) addressed this question as follows:

> "The maps in electronic atlas function as an interface with the atlas database. This combination of database and graphical user interface (GUI) and other software functions developed to access the information is different from a GIS: special care is taken to relate all data sets to each other, to allow them to be experienced as related, to let them tell, in conjunction, a specific story or narrative. There will usually be a central theme"

Bär and Sieber (1999) proposed three approaches for using GIS when developing digital atlases. The first they called Multimedia in GIS, which can be understood as the integration of multimedia functionalities within GIS systems in order to create cartographic products such as atlases and decision-support systems. The advantage of this approach, according to the authors, is that as multimedia is introduced into the GIS, all spatial and geometrical functions are predefined within the system and, hence, there is no need to develop them. The authors claimed, though, that this approach is "the fastest way of bringing full GIS functionality to multimedia" (Ibid., p. 236). However, the main drawbacks outlined were that: GIS systems provide limited multimedia functionalities, the design of the application can not be made independently and the user interface is not friendly, as GIS users are not necessarily multimedia developers.

The second approach is called GIS in Multimedia. According to Schneider (2001) this approach corresponds to the integration of GIS functionalities into multimedia authoring systems. On one hand, the advantage of this approach is that the user interface can be created with more flexibility, as the developer is not restricted to a GIS environment. Another advantage is that cartographic functions can be customised in order to meet a particular user's needs. Conversely, this approach had some disadvantages, among them the fact that this approach is hard to develop, because "even low level analytical functionality, data structures and GIS techniques have to be explicitly defined and implemented by the authors" (Bär and Sieber 1999, p. 236). Also this approach does not provide the same cartographic quality as well as analytical tools as the previous approach.

This approach was adopted by Ramos (2001) for developing a prototype digital atlas of agriculture in Sao Paulo state, Brazil. In her research the author summarised the disadvantages of the GIS in Multimedia approach, which were the painstaking work of development could dissuade people of working in this field, particularly professionals with little programming expertise, and the cost of the developer license of GIS packages is extremely high compared to the standard license. This second point is particularly important in developing countries such as Brazil, where research funds, most of time, are not sufficient to cover research expenses.

With the aim of overcoming the drawbacks associated with these first two methods, Bär and Sieber (1999) proposed a third approach, GIS Analysis for Multimedia Atlases. The authors claimed that none of the previous approaches were meant to specifically respect cartographic characteristics, thus, the proposed approach was intended not only to overcome the known limitations of GIS-based approaches, but to preserve its analytical potential as well. This approach is based on a multimedia atlas development environment, which is comprised of a GIS, the authoring system and a multimedia map extension that transforms GIS objects into cartographic objects. In this way GIS features would be preserved.

Schneider (1999) stated that the focus of digital atlases is on information presentation and summarised the main differences between GIS and digital atlases, or multimedia atlas information systems. These are shown in Table 6.5.

The differences between GIS and digital atlases shown in Table 6.3 are, sometimes, tricky or even subtle. For instance, the use of interfaces in digital atlases should be easy, but with these applications the interface is customised, but this does not necessarily result in an easy to use product. In addition, the control of digital atlas is said to be done by the author, however, as can be noticed by the many different kinds of atlas discussed, in

Table 6.5. Main differences between GIS and Multimedia Atlas Information Systems, after Schneider (1999).

	GIS	**Multimedia AIS**
Use of interface	Complex	Easy
Users	Experts	Non-experts
Computing time	Long	Short
Control by	Users	Authors
Main focus	Handling of data	Visualization of topics
Data	Unprepared	Edited
Output medium	Paper	Screen

some situations the author has full control over the atlas and in other situations they have little control.

The main focus of GIS, as claimed by Schneider (1999), is on data handling. However, it cannot be overlooked, though, that without proper visualization of the results of analysis, the analytical work in GIS environment would be compromised. It is believed that, considering this focus issue, the difference between GIS and digital atlases is that the first comprises the four classical functions: data capture, manipulation, analysis and presentation; and the second can comprise manipulation, analysis and presentation. These functions in digital atlases can be implemented at different levels of complexity, depending on the purpose of the atlas.

Additionally, the output medium for both, GIS and digital atlases, could be either paper or screen, therefore it is considered that this particular feature should not be used to distinguish between them.

Considering the comments above, it is believed that another view of the differences between GIS and digital atlases is necessary. The differences are shown in Table 6.6.

Finally, it is important to note that the subject of the similarities between atlases and GIS is not a new one. This question was raised by Bakker *et al* (1987); at that time, comparing national atlases on paper and GIS. The authors argued that:

> "The traditional national atlas can therefore be conceived as a non-characterised geographic information system in its own right: it was the first medium which enabled users to compare, overlay or otherwise combine data, for the first time presented at similar scales at a similar degree of generalization." (Bakker *et al*. 1987, p. 83)

Table 6.6. Differences between GIS and Digital Atlases, after Schneider (1999).

	GIS	Digital Atlases
Interface	Complex and complete	Customised according to the purpose and the target audience of the atlas
Users	Experts	Non-experts
Computing time	Depends on the project	Short
Controlled by	The user	The author, who allows different levels of control to the user.
Focus	Data capture, manipulation, analysis and presentation	Data manipulation, analysis and presentation. Not all these function must be provided, depending on the purpose of the atlas.
Data	Unprepared	Edited
Purpose	There is no purpose in GIS, the application is open for any kind of data input and analysis	The digital atlas has a purpose, and it was prepared to deliver the conveyed information.

Considering their point of view, as the first national atlas, the atlas of Finland, was published in 1899, one could assume that the question should be: is GIS a kind of atlas? The answer is, undoubtedly, not; but the converging point between atlases (in any medium) and GIS is that both are tools for spatial analysis and cognition.

6.8 The Evolving Medium: the Transition from Discrete Atlases to Internet Atlases

The study of contemporary atlases involves two distinctive transitions: from paper to digital and from discrete to networked atlases. Cartwright (1999) provided an extensive analysis on the evolving technology of optical storage media, from Videodiscs, in the early seventies to the modern DVDs. However, the rise of the Internet as a medium for cartography in the mid-nineties has changed the research focus of digital atlases developers: from discrete storage to the World Wide Web.

Peterson (2003) indicates the advantages of the Internet as a medium to cartography, for the author although the screen is still a major drawback for using computer as a medium for cartography " (…) the Internet makes it possible to distribute the map to many people. Therefore the sum total of map use/communication across all individuals is greater with the Internet" (Peterson 2003, p. 443). In this way, recent figures of Internet audience provide extra support for using Internet as a medium to digital atlases. According to the Computer Industry Almanac (http://www.clickz.com/stats/sectors/geographics/article.php/151151) the global online population corresponded to 934 million people in 2004, however the predicted figures for the following years show a steady increase of about 130-140 million people a year (1.07 billion in 2005, 1.21 billion in 2006 and 1.35 billion in 2007).

The expressive growth of the Internet audience makes it a very effective way of distributing cartography, and particularly atlases. There are many ways of publishing maps on the Internet. Kraak (2001a) provided an analysis on different Internet maps, identifying the following map types:

- *Static Maps* – Static maps are those maps that offer no more than a basic level of interactivity. In a way they are similar to paper maps and they are a very common way of publishing Web maps. The author identifies two kinds of static maps:
  - View only **–** Static view only maps are those maps where there is no interaction and/or dynamics whatsoever. Still raster maps are considered to fit in this category; and
  - Interactive interface and/or contents **–** This kind of Web map comprises clickable maps, maps where the user will get responses depending on the map element clicked. Maps where the user can switch layers on and off and use zoom and pan are examples in this category.

- *Dynamic Maps* **–** Dynamic maps are maps that show dynamic processes and/or contents. The author subdivides dynamic maps into two groups:
  - *View only* **–** Simple cartographic animations are examples of dynamic view only Web maps. Some examples are developed using animated *GIFs* or vector animations, the last can be developed, for example, using Flash (*Macromedia*) or SVG (Scalable Vector Graphics). These maps show the spatial dynamics of a feature usually over time. In this kind of Web map the user is generally provided with controls to pause, play, go forward or backwards, however, in some kinds of formats (such as animated *GIFs*) this kind of control is not viable and the animation is executed continuously; and
  - *Interactive interface and/or contents* **–** In this kind of Web map, the user can interact with the map in a more immersive way. Three-dimensional cartographic models are considered to fit in this category

as the user can literally freely navigate throughout the map. Other kind of interactive can be implemented as objects within the model can be linked to other Web pages.

However, the definition and classification of different Web maps is not a simple task because technology is constantly evolving and providing new capabilities and perspectives to Internet Cartography. For instance, it is fairly straightforward to implement Web links to any map object in vector maps, raster maps can also be linked to other pages, the whole map can be a hyperlink or the image can be subdivided into several different links. Therefore this kind of feature cannot be used to distinguish different kinds of Web maps.

Internet maps can be classified according to several aspects. Considering technology, they can be divided into maps based on proprietary technology or open standards. Considering architecture, they can be divided into client-side maps and server-side maps. Considering contents they could be divided into stand-alone maps and data-driven maps, and so on.

The GIS industry have early noticed the potential of the Internet as a medium for cartography and have developed a number of tools for Internet map publishing, therefore, Internet applications based on GIS tools are very common. A recent trend in Internet cartography is the use of open standards for publishing on the Web.

Recent developments in cartography for the Internet have been done towards using open standard technologies for Web publishing. *Open standards* can be understood as standards established by a public body (comprised by members of industry and/or public sectors) with the purpose of providing guidelines for their field of activity. By definition open standards are not proprietary, in other words, they do not belong to any individual or company. The World Wide Web Consortium (W3C) has focused on developing open standards for publishing on the Internet. The W3C developed the eXtensible Markup Language (XML), which is a standard for exchanging data via the Internet. Other standards were developed based on XML, amongst them the Scalable Vector Graphics (SVG) that corresponds to a standard for publishing vector graphics on the Internet.

SVG maps are basically text files that are rendered on the Web browser through a SVG viewer. It is expected, however, that as the format becomes popular further versions of Web browsers will be able to interpret SVG files with no need of a plug-in. Several examples of Internet cartography, and atlases, based on SVG can be found. Also, Newmann and Winter (2003) provided an extensive overview on the use of SVG and open standards for Internet cartography.

It is believed using SVG will allow publishing maps on the Internet in a more extensive and flexible way; however some programming knowledge is required in order to develop SVG maps. To minimize this drawback it is believed that further research is necessary to develop self-explanatory SVG map templates. Such templates would foster the use of SVG as a tool for Internet map publishing and provide means for developing interactive Internet maps at low cost.

6.9 Summary and Conclusions

Computers have become not only a tool for producing cartography, but a medium for it. It is difficult to find statistics about the number of atlases produced annually; as a result one could argue that any analysis regarding the importance of computers as a medium for cartography, and particularly for atlases, is nothing but conjecture. It is believed, though, that despite the lack of official figures, computers have emerged as a major medium for cartography, and the increasing number of digital atlases presented in the last international cartographic conferences corroborates it.

This chapter focused on understanding digital atlases by assuming that, as they are meant to be used in a different medium, they need a particular definition. However the search for a definition of digital atlases raises other questions for reflexion. The main point is the blurred distinction between digital atlases and GIS. As the technology for production of digital atlases evolves, it is harder to distinct between them. However, it is important to remember that digital atlases not necessarily include GIS.

The chapter also focused the Internet as a medium for digital atlases. Internet maps can be classified through different points of view and some definitions were discussed. Recently open standards technologies have emerged as an significant research trend in the field, it is believed that such technologies offer not only the opportunity of delivering interactive Internet atlases at low cost, but they can be used to involve more atlas developers in Internet publishing as well.

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7 Hypermedia Maps and the Internet

Michael P. Peterson

Abstract. The highly-interactive, map-based multimedia presentation known as the hypermedia map has emerged along with the development of the interactive personal computer since the 1980s. Although combining maps with other forms of representation such as pictures is not new, this particular interactive type of map required an effective electronic form of distribution. The CD-ROM served that capacity briefly but was soon replaced by the Internet which emerged in the mid-1990s as the major form of information delivery. More maps are now distributed through the Internet than through any other medium. But, most of the maps that make their way to the Internet are simply static maps, often scanned from paper, not the highly-interactive hypermedia maps that were expected with this new medium. There are very few examples of hypermedia maps currently available through the Internet, and those that do exist are very difficult to find. The continued development of hypermedia is based on both the accessibility of hypermedia maps through the Internet and a system of remuneration so that the authors of these time-consuming products can be compensated.

7.1 Introduction

The Internet has changed the process of mapping and map use. The new medium has drastically increased the availability of maps and led to more interactive forms of mapping. The distribution of maps through the Internet is still relatively new and much work lies ahead in order to make the Internet an effective means of transmitting spatial information, particularly developing forms of mapping that use the potential of this new medium.

Based on the concept of hypermedia (Nielsen 1990), the hypermedia map is a map-based interactive multimedia presentation that combines some mix of text, pictures, video, graphic images, sound and other forms of media. For example, a hypermedia map presentation on Africa might include links to regions, countries, music, climate, or population—all linked together with maps that emphasize both location and thematic information.

The hypermedia map has evolved since the mid-1980s as methods of map delivery have evolved from the CD-ROM to the Internet. With the growing interest in interactive forms of communication, the integration of media with maps has become a major area of research and development. The goal is to transcend the static and sequential nature of information presentation and ultimately create a greater and broader understanding of the world in which we live (Peterson 1995, p. 127-128). The overall objective is nothing less than a revolution in how spatial information is communicated.

While we can envision and even implement highly interactive hypermedia maps that help guide users to a greater and broader understanding of the world, bringing such maps to a large audience through the Internet is an entirely different matter. If we are to be successful, the challenge is to not only conceive of useful hypermedia maps but also finding ways of marketing these maps, funding their creation, and making them available to people at a reasonable cost. This chapter examines the current status of Internet-delivered hypermedia maps, and ways of making these highly interactive maps more available. We first examine the Internet as a means of dissemination.

7.2 Maps and the Internet

7.2.1 Current Status

Concomitant with the increased use of other forms of media with maps has been the rise of the Internet as a major form of information delivery. According to the Computer Industry Almanac in 2005, there were 935 million Internet users or nearly 16% of the world's population (see Table 7.1). This is up from 533 million Internet users worldwide at year-end 2001 which at that time represented only 8.7% of the world's population. There were only 200 million Internet users at year-end 1998 and 61 million in 1996. It is expected that the number of Internet users will reach 1.46 billion by 2007.

With the growth of the Internet comes the expansion of map use through this medium. Internet map use was tracked at four major sites between 1997 and 2001. The growth in Internet map use was compared to the growth in the use of the Internet itself. It was found that while both growth rates are strongly exponential, the growth in the use of maps through the Internet exceeded the growth rate for the Internet itself (Peterson 2003). It can now be said that more maps are now distributed through Internet than through any other medium. Estimates put the number at over 200 million a

Table 7.1. Number of Internet Users

Year	Internet Users in Billions
2007	1.46
2005	1.00
2004	0.935
2001	0.533
2000	0.327
1996	0.061

Source: Computer Industry Almanac (2001, 2005)

day. This change in map distribution happened over only a decade. Never in the history of cartography has there been such a dramatic shift in how maps are delivered to the map user.

7.2.2 Experiments in Finding Online Maps

A variety of experiments have been conducted beginning in 2001 to examine the state of maps and the Internet, particularly in reference to their availability through search engines. Search engines are viewed here as a window to the Internet, a way of understanding what types of maps are easily available to Internet users. In order to improve the Internet as a medium for cartography, we need to understand the current state of map availability.

In an experiment conducted in 2001, a series of high school and college freshman were asked to find map resources through the Internet (Peterson 2001). Over 100 students were tested in five groups in a computer user room with 25 Pentium III 500Mhz computers. Every student had their own computer with Microsoft Internet Explorer and a relatively fast Internet connection. They were instructed to find three maps: 1) a map of Africa by country; 2) a map of Africa by country in PDF format; and 3) a map that places a star on a street map showing where they live.

Students could find these maps in remarkable speed. For example, it took only 16 seconds for some students to find a map of Africa. Almost all of the students found such a map within 45 seconds but some students required slightly more than a minute. The search strategies differed slightly between the high school and college students. The college students had learned to simply use the search field in the toolbar area of Microsoft Explorer that linked to Microsoft's MSN search engine. The high school students first went to Google to start the search and this slowed their search times.

It is interesting to note which map of Africa was most commonly found by students. It was not an interactive map. Rather, it was a scanned paper map in JPEG format (see Fig. 7.1). The map exhibits the typical JPEG compression artefacts that make this file format less than ideal for use with

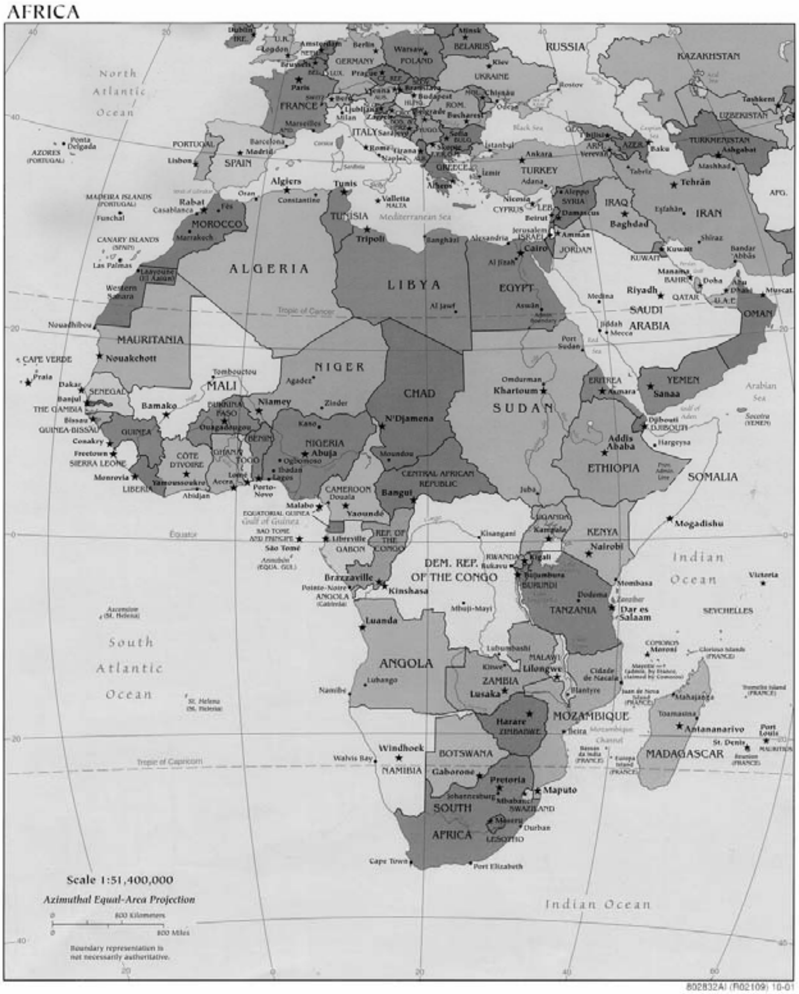

Fig. 7.1. High school and college students were asked to find a map of Africa. Most found this scanned JPEG map of Africa in under 30 seconds. The fastest search time was 16 seconds. Only a few had not found the map in 45 seconds. The map cannot be zoomed and most of the text is illegible because of the small size or JPEG compression artefacts.

maps. But, that didn't seem to matter to the students. It was the map that students were expecting to find of Africa and, although the map is barely legible and could not be zoomed or queried, they were quite happy with what they had found.

To find the PDF map of Africa, the Google search engine helped the high school students find this type of map faster than their college counterparts. Their fastest response time was 28 seconds while the fastest college student required 40 seconds. Loading the Acrobat plug-in took a good portion of this time. Some students required over a minute and were then provided help. Few could explain the advantage of the PDF file type and only a couple students knew that zooming was possible. They did know that PDF files took longer to load because the plug-in needed to start first, and they found this to be annoying and mentioned that they would often cancel the process when this happened with other documents. While they seemed impressed that one could zoom into the PDF map, in the end, many liked the JPEG map better because it loaded faster, although it was essentially illegible.

Making a map of home proved more difficult because the search engine was less useful for this task. Students tried to search for "map of home" but this did not yield links to any of the interactive street mapping programs. Some remembered MapQuest.com from a previous visit and went directly to that site. For the few students using the Yahoo search engine, they were provided a link directly to MapQuest.com. The main Yahoo page has a link to Yahoo's interactive mapping site but students did not look for this indicating that these students preferred using a search engine to a directory list. At that time, about 1/3 of the students had never used an online mapping site to find a particular location. In the end, the fastest map of home was produced in 30 seconds but most students could not complete the task in one minute and some had to ask for help. Once the map was made, students complained that the star indicating their home was not in the right location. This is a common complaint and results from the address matching process in which locations of addresses are estimated along street segments. This process often produces an incorrect location.

The most interesting observation from these experiments was that static maps are much easier to find than interactive maps. Search engines are oriented toward static pages because these are indexed more easily, and these pages usually have links to static files. Another observation was that students didn't understand how the interactive map was made. One student said it was "magic." Others said that the interactive street map was made through satellite imagery or used GPS. Although these may be involved, the process of bringing such a map to map user is much more complicated.

7.2.3 Finding Maps – A 2005 Update

The same experiment was conducted in early 2005, nearly four years after the first study in 2001. This time students in a third year college course were asked to find the same three maps but with faster computers (Pentium 4, 2.4GHz with 512 MB of memory). The results remained remarkably similar. Almost everyone found a similar map of Africa in less than 30 seconds. Some required less than 10 seconds. Finding the PDF map took slightly longer but most students were still able to locate the map in under 40 seconds.

The most interesting finding was that all of these students had been previously exposed to interactive street mapping sites and everyone completed this map in less than 45 seconds. About half completed this task in less than 30 seconds.

7.2.4 Finding Hypermedia Maps

To determine the level of difficulty in finding online hypermedia maps, an experiment was first conducted by the author with the Google search engine. The purpose of the experiment was to determine what type of hypermedia sites could be found within the top 20 links provided by Google's first two pages. Six different text strings, such as "Maps Hypermedia Africa," were entered into the search engine. Each of the top 20 links were examined and potential links were followed through two additional links to see if a desired page could be found. Further links may have been followed if a promising lead was found in the first two links.

The results of the search are presented in Table 7.2. As can be seen, very few hypermedia or multimedia maps could be found. No true hypermedia maps were found using a typical search string that most people would use. Many links were to commercial sites (.com), particularly to books on hypermedia. Other links were to libraries that would list library audio-visual collections but there were no links to hypermedia materials. The only hypermedia maps that were found during the entire search resulted from a search on "Africa Flash." In this case, Flash is referring to an online multimedia authoring program. Most people would not know to perform a search using the name of the proprietary file format.

A similar experiment was conducted with the same upper-division college students. In this experiment, the students were instructed to time themselves as they attempted to find a variety of maps of Africa that included pictures, sound, or video. An electronic stop watch implemented

Table 7.2. Summary of Google search for hypermedia maps of Africa. Although many maps and photographs of Africa were found, few sites integrated maps with other media. Those that did could only be found using the "Flash" file type keyword.

Google Search Text*	Sites with Maps in top 20	Sites with Pictures of Africa in top 20	Sites other Media of Africa in Top 20	Hypermedia Maps
Maps Hypermedia Africa	I	I		
Maps Multimedia Africa	~~IIII~~ IIII	III	II	
Maps Pictures Africa	II	II	I	
Maps Sound Africa	II	IIII	I**	
Maps Movies Africa	~~IIII~~		II	
Flash Africa	~~IIII~~	III	III	II

*Resource found within 2 clicks. Additional clicks may have been needed to activate resource.
**Only site with sound presented bird songs.

through a web page was used as the timer. Students were given the instructions as shown in Fig. 7.2.

The results largely paralleled what was found by the author. In many cases, students could not find any maps of Africa that included the desired media. Many students spent over five minutes trying to find a suitable map before giving up. This is far longer than most people would normally devote to such a task unless they were highly motivated.

Pictures were the most common media element found with maps. Maps with pictures were found with many of the search strings that were used. Even searching for "Maps Sound Africa" produced hits to maps of Africa that included pictures. "Flash Africa" led to the most sites with hypermedia maps. Searching for hypermedia content using the Flash keyword is problematic because it requires that one be aware of a program that is used to create hypermedia content.

A major advantage of the Internet is the ability to include pictures, sound and video with maps. Try finding maps that include one of these elements using the following text in the search engine. If you can't find a map with pictures, sound or video in the top 20 links provided by the search engine, enter "Not found." Do not proceed down more than 2 links in any page provided by the search engine.

Search Engine Text

1. Maps Hypermedia Africa
2. Maps Multimedia Africa
3. Maps Pictures Africa
4. Maps Sound Africa
5. Maps Movies Africa
6. Maps Flash Africa

Fig. 7.2. A portion of a questionnaire given to students in an upper-division geography course. Many students could not find examples of the desired maps on the Internet. Those that could find examples sometimes required over 8 minutes of search time. The search for Flash files produced the most results but required the knowledge that hypermedia maps would be presented using the Flash file format.

7.3 The Information Landscape

Landscapes come in many shapes and sizes. There are tropical valleys and windswept desert plains. There are landscapes formed by methods of farming and urban landscapes develop as a result of human patterns of habitation. O'Day and Jeffries (1993) use the term "information landscape" to refer to the landscape of information that we traverse when we venture into a hypermedia environment. They study the specific process used by individuals in finding information through hypertext. Researchers also examine what patterns of behaviours are exhibited when users browse information landscapes, how performance varies across the two distinctive tasks and how different navigational aids influence patterns of use Toms (1996). It has even been suggested that maps can serve as a guide to the information landscape (Block 2002).

The information landscape that most people experience is the one presented by search engines. It is the only effective tool at present to traverse the information landscape. These automated systems explore this ever growing landscape and collect keywords that are entered into a database. Keyword searches are subsequently made by the search engine user. Of course, there is more to this landscape than can be found by the search engine. Some estimate that search engines have only indexed a third of all web pages. Before we proceed, it is useful to examine how these systems work.

7.3.1 Search Engines

Search engines are based on a program called a web robot or a spider that traverses web pages in an automated fashion. There are two steps in the traversing process: 1) words are entered into a special index; and 2) other links are found for later traversing. Web robots only need to be told to search the main page and they find all linked pages automatically. If a page has links to 100 pages, and each of these has links to another 100 pages, a web robot, in theory, will create an index for all of these of pages – and this can soon number into the millions. The index created by the web robot cannot be too large, no more than about 2 KB. If the index were larger, it could essentially be making a copy of the entire page.

After making a collection of these small index files of billions of pages, the web robot begins to prioritize the links by keyword. This is where problems start because the process is inevitably arbitrary and based on inadequate information. Each search engine also prioritizes in a different manner as well. Companies do not provide the exact algorithms because this would lead to abuse by those people who trying to get their web pages to show up near the top. There is somewhat of a Catch-22 situation in which we need to know how the web robots work so that they provide better matches, but as soon as we know how the robots work, they get abused by those that want to manipulate them and they no longer provide good matches.

The ranking system used by Google, called PageRank, relies on a system that counts the number of times pages are linked from each other. It also incorporates a weighting factor that analyzes the “importance” of the page that is making the link. Important, high-quality sites receive a higher ranking, which Google remembers each time it conducts a search. Google states that it goes beyond the number of times a term appears on a page and examines all aspects of the page's content (and the content of the pages linking to it) to determine if it's a good match for a query.

Some basic search engine rules seem to be shared by all search engines. Smaller pages are given preference over longer pages with a similar set of keywords. The text in the title of the page is given a higher priority than text in the page. The META tag, listed near the top of the page, is another way of making the web robot assign a high priority. Before the META tag was available, a high rank for a page was only possible if a phrase was used repeatedly throughout the text. Now, the phrase just has to appear in the META tag. Popular pages that have more links directed to them are listed higher. This tends to cause new pages to fall into an "anonymity trap" since they are not linked from other pages, and they can’t be linked because they can’t be found.

Search engine rankings are extremely competitive and the operators of websites are under pressure to make sure that their sites are listed near the top. Webmasters will spend a considerable amount of time making sure that their sites are highly placed on the major search engines. Most search engine companies now accept cash in return for a high placement. Search engines have become a necessary if frustrating part of people’s lives.

Sherman and Price (2001) identify five major problems with search engines:

1. Cost of crawling: Crawling the web is very expensive and time-consuming, requiring a major investment in computer and human capital.
2. Crawlers are dumb: Crawlers are simple programs that have little ability to determine the quality or appropriateness of a web page, or whether it is a page that changes frequently and should be re-crawled on a timely basis.
3. Poor user skills: Most searchers rarely take advantage of the advanced limiting and control functions that all search engines offer.
4. Quick and dirty results: “Internet Time” requires a fast if not always thorough, response. A slower, more deliberate, search engine would not gain user acceptance although it might lead to better results.
5. Bias towards text: Search engines are highly optimized to index text. For non-text pages, such as images, audio, or streaming media files, the search engine can do little more than record filename and location details.

7.3.2 Media Search Engines

Media search engines are designed to index images, sound, or video files, sometimes collectively referred to as “multimedia.” Image searching is the most common and is offered by major search engines like Google and Yahoo. WAV, MIDI and MPEG sound files can be found through specialized search engines like MusicRobot.com. Music sharing programs like Kazaa and Limewire locate and download music and other types of media through a point-to-point protocol. Yahoo includes a search for video files on its search page. Media search engines represent an alternative to the text-based search engine and represent a more promising technology for finding hypermedia maps.

Image search engines generally index images in the GIF, JPEG, or PNG format and represent a major way that Internet users find maps. Google reports an index to more than 880 million images. Of these, approximately 3,750,000 are images associated with the “map” keyword. These dominate in any type of place name search. For example, an image search for “Africa” results in 12 maps in the top 20 links, and 23 in the top 40 links. Of these 23 maps, 13 are in the JPEG format. The Yahoo image search finds 10 maps in the top 20 images and 14 maps in the top 40 image links. Google finds a total of 145,000 hits for “Africa map” while Yahoo has 30,400 hits. Maps, in the form of images, represent a major component of Internet image content.

The primary problem with image search engines is that the indexes are created from words associated with the images, and not the images themselves. This is because the image file cannot be searched for keywords. Rather, the indexing of the image is done by examining the title or other words associated with the image. It might also take into account any accompanying 'ALT' picture tags coded into the HTML page or look for clues from the image's context – for example, the words or phrases that are close to the image, or the 'META' tags found at the top of the HTML coding. The nature of the Web site and its provider may also be taken into account. The image search indexing process can easily be fooled with a non-descriptive filename or associated text that does not relate to the image. For example, a search engine would likely be fooled by a page on South America with a mislabeled link to a map of Africa.

An alternative to the automated approach are collection-based search engines that index a single or small number of image collections. Commercial stock photo collections, like Corbis, that offer images for sale, will implement their own search engine-like procedure to find images from within their collections. These search engines are augmented with “human indexers” that assign keywords for each picture.

All of these types of image search engines are text-based in that their indexes are created from words associated with the images. There have been attempts to create *content-based search engines* that 'index' visual characteristics of an image, such as its shape and colour. However, these attempts are still largely experimental and are often limited to single, proprietary image collections (TASI 2004).

Yahoo is the only major search engine that provides a video search option. The search engine returns links to movies in five different formats (AVI, MPEG, QuickTime, Windows Media, and RealPlayer) but few movies of these movies incorporate maps. For example, “Africa map” returns only one movie that includes a map in the 96 movies that it returns for this search. The 7,800 video files that are listed for “Africa” contain very few map examples. Even a search for “animated map” that should be represented in a video database leads to only about 100 hits. Clearly, the current video search option is not an effective way to search for hypermedia maps.

7.3.3 Map Search Engine

A search engine that is designed specifically for maps would serve many purposes. Most of the maps that are currently available through the Internet are classified as pictures. As a result, a place name image search results in a confusing mix of maps and pictures. The image search engine would benefit from a clear distinction between pictures and maps, something that could be determined in an automated way by looking at the level of pixel color variability in a file. Presumably, the map would have large areas that have the same color or shading and this would not be true of ordinary pictures that are characterized by gradations of pixel values.

Determining map content in other types of multimedia files would be more difficult. These files have a more complicated structure and performing similar automated inspections of files may not be sufficient to separate map and non-map content. An author could self-define the map content of a hypermedia product and insert this into an associated header or metadata file but enforcing such a self-classification of content would invariably lead to problems. A workable, automated map search would provide a better alternative and could categorize content by both file type and media content.

7.4 Online Commerce

7.4.1 Internet Marketing

The major problem with finding hypermedia maps on the Internet may not be that search engines can’t find them. The problem may be that they just don’t exist in great numbers. The ones that do exist have been produced by large print organizations like National Geographic that are promoting their publications through their online hypermedia products. The production of hypermedia map products requires a considerable capital in human and computer resources. Without a system of remuneration, these types of maps are simply not profitable to make.

Like the map houses in ancient port cities that served sailors, one could envision hypermedia map houses, where groups of cartographers would craft hypermedia maps for sale. The maps would embody the latest in mapping and multimedia technology and the products would be eagerly anticipated by a devoted group of students and scholars. As an independent map house, the cartographers would not need to orient their maps toward the sale of a physical product like a magazine, CD-ROM or DVD. Instead, the maps could take full advantage of the interactive and multimedia elements embodied in the new medium. No such map houses exist and the reason is not related to a lack of appropriate technology. Rather, it is because the marketing of such maps is problematic.

Marketing has been the bane of the Internet since the appearance of the Web. The lack of a workable model to make money through the Internet was one factor in the downfall of the Internet speculation bubble beginning in 2000. While a great many purchases are now made through the Internet, most of these are for physical goods or travel. The purchase of Internet-delivered content has not fared well. The one exception is the online music industry and this deserves a closer look.

7.4.2 Apple’s iTunes

Apple's iTunes store was so successful that in first few weeks online, the company sold over two million songs. This was particularly remarkable because only individuals with Macintosh computers running later versions of their operating system could initially buy songs from their store. Apple has since added iTunes for Windows. The iTunes store is such a success story that it might be worth taking a closer look at what Apple managed to get right and consider if the approach can be applied to market other products.

Prior to iTunes, attempts to sell music through the Internet were based on a subscription service model that used proprietary formats. Copy protection schemes were incorporated into the music files that prevented copying. One service not only made it impossible for consumers to burn CD's of music they downloaded, it also required consumers to pay a monthly fee in order to keep listening to music they had already downloaded. Essentially, consumers were not purchasing music, they were renting it.

Apple was the first business to understand that consumers want music purchased on the Internet to have the same properties as music they buy on a CD. So, Apple allowed consumers to buy individual songs for 99 cents each, or albums for ten dollars. Once downloaded, consumers can easily burn a CD or transfer the music to a portable MP3 player.

Apple's success with iTunes marked a milestone in the history of electronic commerce and sent shockwaves through the Internet marketing business (Morris 2003). It provided a model for marketing something besides a physical product. iTunes was able to sell music in the form of bits and bytes, rather than a physical product like a CD.

7.4.3 The 99¢ Map

For centuries, printing was the only practical method of transferring large amounts of information. Publishers and bookstores sold the artefacts and libraries developed to store them. As Libicki, et.al. (2000, p. 75) point out, words differ from books: "Their pricing, the property rights inherent in their expression, and the challenges of their distribution follow from the physical form they take." But, implicit in the idea of intellectual property rights in information is that authors need to "be compensated with money lest their creative incentive whither" (Libicki, et.al, 2000, p. 76). As they point out, it is very easy to copy information electronically and without a model that makes such copying difficult, there is little reason to "liberate the content of information" from its form.

The model chosen by Apple's iTunes is to make material available at a low enough price so that copying becomes more of a hassle than it is worth. Although one can still obtain music files for free through point-to-point protocols, this illegal method of file exchange has drastically declined. If 99¢ can help stop the illegal copying of music, it may represent the price point of individual maps if marketing can create a demand.

7.5 Summary

The hypermedia map offers the potential of more engaging forms of interactive maps, and the Internet is a functional method of delivery. While examples of hypermedia maps are available through the Internet, they are difficult to find with current search engines – even with the newer media search engines that have recently appeared. Hypermedia maps are not well represented on the Internet. As a result, people don't see the advantages of combining maps with other types of media.

Search engines are based on creating indexes of words. The specific words that are used in labelling material is extremely important in the indexing process. Not only does the word need to be unique so that it is distinctive from other resources but it needs to have a meaning that is generally understood by most people. While hypermedia is a unique concept, the word is not generally understood and most people do not use it in referring to interactive material. Other terms like “interactive multimedia” are recognized by more people, and more people would likely use this in a search. While hypermedia maps would have a broad appeal, at present, there are few online examples, and these can only be found with great difficulty. In order for this type of map to be more mainstream, academic terms like *hypermedia* will either need to become more broadly understood, or new terms will need to be introduced that more effectively describe this type of map to the public.

The real challenge for hypermedia maps will be to create a demand and market that would fairly compensate hypermedia cartographers for their efforts. The 99¢ solution may represent a possible method of marketing. But, a demand needs to be generated for such maps and it seems that most people are perfectly satisfied with the “static” maps that are currently available for free.

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8 In Pursuit of Usefulness: Resetting the Design Focus for Mobile Geographic Hypermedia Systems

Karen Wealands

Abstract. Mobile geographic hypermedia provides a means whereby geospatial data can be delivered to users as ‘rich’ information via highly portable devices and wireless telecommunication networks. To operate successfully, systems based on mobile geographic hypermedia combine geospatial information perception, knowledge generation and communication. Each of these aspects may be largely ineffective, however, without in-depth consideration of the usefulness (utility + usability) of the representations and the methods of interaction involved. It is argued here that rather than being driven by the underlying technology, the design of mobile geographic hypermedia systems should be approached from a usefulness perspective. Not only will this ensure their use, but ultimately their commercial success.

8.1 Introduction: Mobile Geographic Hypermedia

Geographic hypermedia is a form of cartographic representation based on the combination of interactive computing tools with advanced distribution techniques (e.g. the Internet and the World Wide Web), that is intended to address the growing need for more intuitive geospatial information presentation (Cartwright & Peterson 1999). More specifically, it is the use of multimedia – e.g. maps, text, speech, sounds, images, video, animation, and so on – within computer-based cartographic systems, allowing for double encoding of information, interactivity and the use of complementary information, in order to produce more realistic representations of geographic space, support knowledge construction and ultimately ensure efficient communication of the underlying geospatial data (Buziek 1999).

Whilst the majority of geographic hypermedia systems are designed for and accessed using stationary (e.g. desktop, laptop) computing devices and wired distribution networks, a subset are based around highly mobile devices (e.g. mobile phones, SmartPhones and handheld computers) and wireless telecommunication networks. Such infrastructure provides a greater degree of physical freedom and enables an array of mobile geographic hypermedia systems that are potentially available anywhere, at any time. By way of example, mobile Location-Based Services (mLBS) are a specific class of mobile geographic hypermedia systems, which additionally incorporate device positioning and thus enable applications that can utilise a user's location as a filter for data querying and representation. A useful working definition for mLBS is thus: *wireless services which use the mobile Internet, along with the location of a portable, handheld device, to deliver applications that exploit pertinent geospatial information about a user's surrounding environment, their proximity to other entities in space (eg. people, places), and/or distant entities (eg. future destinations), in real-time* (Urquhart *et al.* 2004).

MLBS incorporate diverse sets of geospatial (and other) data and appeal to a wide variety of users, ranging from everyday consumers to private industry, governments and the military (Niedzwiadek 2002). As a result, numerous applications are possible, with Table 8.1 providing some common examples. In general, mLBS rely on: (i) the accurate determination of a device's location (e.g. via automatic positioning techniques such as mobile cell-based triangulation or GPS); (ii) connectivity to the mobile Internet over a wireless network; (iii) access to geospatial search engines incorporating relevant data; and (iv) useful applications allowing the user to access the geographically-related information they require to achieve their goals. It is in this last point that the role of mobile geographic hypermedia becomes most evident, since it provides the interface to the underlying data.

8.2 Challenges to Mobile Systems Design

There are numerous benefits that can be attributed to mLBS and mobile geographic hypermedia systems in general. Firstly, the high mobility of the devices and networks used to deliver the services makes them equally as convenient to carry and use as paper maps. Secondly, mobile Internet connections ensure that the geospatial and other information being represented are always as current and as accurate as the underlying data. And finally, where real-time positioning of the user is available, context can be incorporated into representations in order to increase their relevance to the user's current situation. Countering these advantages, however, there are new challenges for cartographers brought about by the combination of technologies and dynamic environments characterising mobile geographic hypermedia systems. Indeed, just as the introduction of interactive computing required new developments in cartographic theory and methodology

Table 8.1. Examples of mLBS-driven applications (based on Niedzwiadek 2002).

Types of Location Information	**Applications**		
	Consumer	*Business*	*Government*
Positions	Where am I?	Contact nearest field service personnel	Location-sensitive reporting
Events	Nearest theatre playing the movie I want to see?	Local training announcements	Local public announcements
Distributions	House hunting in low density area	Sales patterns	Per capita open space
Assets	Where is my mobile phone?	Status of utility field devices	Where are the street sweepers?
Service Points	Where are the sales?	Targeted advertising	New zoning
Routes	How do I get there?	Taxi dispatch	Emergency dispatch
Context	Show me the nearest…	Nearby competitors	Local commerce
Directories	Where can I buy …?	Best supplier within 50km	Public services
Transactions	Must purchase in a specific location	Location-sensitive billing	Location-sensitive tolls
Sites	Tourist attractions to visit	Candidate store sites	Environmental monitoring stations

(Dransch 2001), the fields of *Mobile Cartography* (Reichenbacher 2001) and *TeleCartography* (Gartner & Uhlirz 2002) have emerged to respond to the constraints of the mobile medium. Table 8.2 divides the limitations into two major categories – technical infrastructure and context of use – which are discussed in detail below.

8.2.1 Infrastructure Constraints

Despite continuing improvements in the mobile devices and wireless networks used to deliver mobile geographic hypermedia systems (Hassin 2003), they will never truly equal the capabilities offered by desktop computers and wired networks in terms of display, interaction and performance

(Weiss 2002). Perhaps the most apparent limitation in this respect is the restricted screen size and resolution of most mobile devices: for example, the user interface of a typical handheld computer measures 240 × 320 pixels and supports 16-bit colour, which is much lower than that of a desktop computer (commonly larger than 800 × 600 pixels, with 32-bit colour). Faring even worse are mobile phones, with screen resolutions around 100 × 80 pixels and 256 colours (Weiss 2002). These screen real estate limitations pose implications concerning how much information can be visually represented to a mobile user at any one time (which varies according to device type), and the need to ensure that the information displayed is pertinent and useful to the user (Holtzblatt 2005). Related to this are issues concerning wireless networks, which have comparatively slower connections, higher latencies, lower bandwidth and less coverage than wired networks (Hassin 2003), limiting the amount and timeliness of data that can be reasonably delivered to a mobile device. Further compounding the problem is: (a) the limited storage and processing power of many mobile devices – with the data and processing that underlies most systems having to reside on the networks rather than the devices (Weiss 2002; Lee & Benbasat 2003) – and (b) their high rates of power consumption, combined with short battery lives – diminishing device operation and requiring frequent recharging, which is unsuitable for, and difficult during, prolonged mobile use (Hassin 2003).

Positioning accuracy is another concern, with various techniques in existence. These range from network based solutions (with accuracies anywhere from 50m to upwards of 2km) to satellite-based, handset-centric positioning (e.g. GPS – accurate to 10m or better) and hybrid techniques such

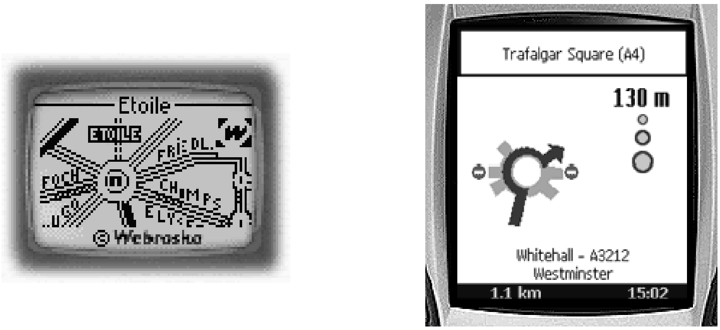
Table 8.2. Limitations related to mobile geographic hypermedia systems.

Technical Infrastructure	**Context of Use**
Display	*Situation*
• Small screen size / limited resolution [D]	• Location
• Low colour range [D]	• Time
Interaction	*Environment / surroundings*
• Limited input opportunities [D]	• Dynamic settings
• Restricted output capabilities [D]	
Performance	*User characteristics*
• Slow connections / high latencies [N]	• Goals
• Limited storage / restricted processing [D,N]	• Tasks
• High power usage / short battery life [D]	• Interests
• Variable positioning accuracy [D, N]	• Abilities
[D] Device related [N] Network related	

as network-assisted GPS (A-GPS), which provides location accuracies up to 1m (Zeimpekis *et al*. 2002; Mountain & Raper 2000). Unfortunately, the inequitable availability of the technologies involved, and their widely varying accuracies, impacts on the representation of the user's location within any given mobile geographic hypermedia system. In terms of user interaction with the service, and ultimately the data, a further issue involves the limited input capabilities inherent with most mobile devices. Keyboards are generally small or absent, often replaced by touch screens, predictive text, handwriting recognition and/or voice input – each of which lacks the speed and accuracy of a desktop computer's input techniques (Weiss 2002; Sandnes 2005). Output capabilities are again restricted (introduced above with respect to screen displays), with early mobile geographic hypermedia consisting of simplistic text and/or low-level graphics (e.g. Fig. 8.1a). Fortunately, today's devices are becoming more sophisticated in terms of providing true multimedia output – i.e. audio (voice, sound), visual (text, graphics, animation) and/or haptic (vibration) techniques, e.g. Fig. 8.1b – however device size and network performance remain limiting factors.

8.2.2 Contextual Constraints

Schmidt (2000) describes context as a combination of location, environment, situation, state, surroundings and task, among other things. For the purposes of this chapter, however, a simplified definition is adopted, focussing on the user aspects of *location*, *time*, *goals*, *tasks* and *environment*. With this in mind, it is generally assumed that different users in different



(a) **(b)**

Fig. 8.1. Examples of geographic hypermedia in (a) early mobile systems and (b) more recent mobile offerings (images reproduced with permission of Webraska Mobile Technologies, SA).

contexts have differing goals, thus they require different sets of geospatial (and other) information, as well as alternative representations of, and methods of interaction with, the data. This makes it both important and difficult for mobile geographic hypermedia systems to present the user with only the information that is genuinely of interest to them in their current context (Coschurba *et al.* 2001). Moreover, the dynamic nature of the user's location is an integral aspect, requiring the underlying content to be both up-to-date and accurate and introducing the idea of 'time-critical' information. Finally, the environmental aspect of context emphasises the importance of mobile geographic hypermedia techniques being sensitive to the dynamic settings within which they are accessed. Lumsden & Brewster (2003) contend that when a mobile device is used in the context of mobility, the user's visual attention must remain with the surrounding environment, rather than the device. Kjeldskov (2002) sees this as a significant consideration affecting the amount of information that should be presented to the user and the level of interaction required, since small and cluttered displays place high demands on a user's attention.

Despite identifying these issues, it can be argued that mobile geographic hypermedia systems has thus far been largely driven by the underlying technology, as opposed to the needs of the end users. The next section discusses this, along with the limitations of such an approach, by introducing a different focus for mobile hypermedia research and development.

8.3 Usefulness and Geographic Hypermedia

Technology-driven development concentrates on applying new technology and investigating technical issues in its application (Cartwright *et al.* 2001), and can be a major facilitator of innovation, enabling new technologies and concepts that may never have been arrived at by other means. While this may be sufficient for research purposes, in a development sense it has become generally accepted that the 'build and they will come' and 'one tool fits all' attitudes typical of technology-driven development do not guarantee the success of new products (MacEachren & Kraak 2001; Gould & Lewis 1985). This is because user needs and expectations are seldom considered as part of technology-driven development, and as with most products and services, unless mobile geographic hypermedia products are considered useful to, and therefore adopted by, their target markets, they will not be commercially successful. Therefore a supplemental approach is advocated, focused on the optimisation of system usefulness. Note that this perspective does not seek to discount the value of taking a technology-driven approach early on, when cutting-edge technologies are still in their infancy. Rather it describes a complementary, user-driven methodology for further development, capitalising on the technology whilst ensuring the usefulness of products.

8.3.1 The Concept of Usefulness

Whilst there are numerous characterisations of the term *usefulness*, and seemingly no general consensus on its definition, this chapter takes the lead of Nielsen (1993), viewing it as the degree to which a system can be used to achieve a given goal, and acknowledging its component concepts of utility and usability (after Grudin 1992). According to Nielsen (1993), *utility* concerns whether the system can (at least in theory) do what the user requires it to do, whilst the International Organization for Standards formally defines *usability*, in the context of human-computer interfaces, 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” (TC 159/SC 4 1998), where:

- Effectiveness is the accuracy and completeness with which users achieve specified goals;
- Efficiency concerns the resources expended in relation to the accuracy and completeness with which users achieve goals; and
- Satisfaction relates to freedom from discomfort, and positive attitudes toward the use of the product (Jokela *et al.* 2003).

These concepts, and inherently the users themselves, are of paramount importance to the acceptance of mobile geographic hypermedia products. If users cannot use the services to (a) achieve their goals, and (b) do so with efficiency, effectiveness and satisfaction, they will be unlikely to adopt them.

8.3.2 Designing for Usefulness

As Dransch (2001) identifies, cartographic research has long been dominated by issues of technique (e.g. the possibilities for interaction) and data (e.g. what can be done with it), rather than user needs. She goes on to recommend that future studies in this area should support both map-making and map-using and should target the specific tasks the maps are used for as well as how they are used. MacEachren & Kraak (2001) support this view, highlighting a need to integrate work on human spatial cognition with technological development, and address user differences. In more general terms, Slocum *et al.* (2001) propose a research agenda dealing with the development of a methodology based on a user-centred approach for evaluating the usability of alternative geovisualization techniques.

Usefulness of Geospatial Information

In 2002, a workshop was held to develop a research agenda related to improving the usability, and thus accessibility, of geospatial data in general (Wachowicz *et al.* 2002). Whilst outwardly focused on usability, a large number of concepts and issues arose from the discussions which were equally applicable to usefulness as a whole, including:

- Geospatial data has the potential to support decision-making that is faster and more informed, however poor data *usefulness* can counteract this and ultimately inhibit geospatial data usage.
- The effects of geospatial data (e.g. information acquisition, time saving and satisfaction measures) use can help to characterise its *usefulness*.
- Geospatial data usage is no longer confined to the realm of expert users, with benefits to be gained from targeting non-expert users with a view to improving *usefulness*.
- Representation of existing geospatial data sets (i.e. the ‘human interface’) is an area for constant improvement.
- Important research priorities include: the development of formal rules for ensuring geospatial data *usefulness*; linking *usefulness* to user tasks; and the differences between geospatial and non-geospatial data *usefulness*.

Even more recently, the International Cartographic Association established a new ICA Working Group on Use and User Issues, concerned with addressing the subject of usefulness within cartographic data, systems, products, interfaces and research. In particular, the group aims to focus on (i) the user – their characteristics, use contexts, goals, tasks and requirements; (ii) usability – including User-Centred Design and methods of evaluation; and (iii) improving user abilities – from user training to collaborative mapping to map use in education. In light of both of these initiatives it is clear that the cartographic community has become increasingly concerned with the user and their experiences with geospatial information.

Research in Pursuit of Useful Mobile Geographic Hypermedia

In the realm of generic mobile Internet services, developers and researchers have begun to realise the benefits of making utility and usability a focus of development, in order to design products that meet users' needs and expectations. Wireless Application Protocol (WAP) services are a prime example of the failure of technology-driven development in this realm, with studies uncovering numerous usability problems leading to user rejection of the earlier services (Ramsay and Nielsen 2000). Building on such experiences, others have endeavoured to improve new mobile Internet services by conducting research early in the product development lifecycle, in order to understand user requirements and thus design for them from the outset (Helyar 2002).

Specific to the area of mLBS, the focus has also turned to usefulness. Much activity in this respect comes from the field of Human-Computer Interaction (HCI), which categorises mLBS under the broader topic of 'context-aware' computing (Cheverst *et al.* 2000). A number of studies have sought to define user needs for location-aware services (Kaasinen 2003), with projects such as GUIDE (Cheverst *et al.* 2000) and HIPS (Broadbent and Marti 1997) having employed techniques for ensuring systems that meet users' goals and are easy to use.

These projects have, however, been mainly concerned with issues of overall system appearance, functionality, information content and methods of interaction, with little or no emphasis on the appropriateness of the component geographic hypermedia, with one notable exception (Chincholle *et al.* 2002). Taking a different approach, researchers within Cartography have been working to specifically develop geographic hypermedia for mLBS that will support users' geospatial tasks. Particular attention has been paid to map design (Uhlirz 2001, Wintges 2002), with some treatment of non-map geospatial information presentation (Brunner-Friedrich and Nothegger 2002).

Whilst these studies are undeniably revealing, it may be argued that the resulting representations and services are bound by the same constraints as technology-centred development, and thus their usefulness cannot be assured (a review of the related literature suggests that the design work is not based on an assessment of user needs, nor have the results been evaluated).

This chapter therefore recommends an approach to designing mobile geographic hypermedia systems that is more in line with that of the HCI researchers, namely User-Centred Design.

8.3.3 A User-Centred Approach

User-Centred Design (UCD) is an approach commonly employed in computer systems design, having developed under the premise that in order to ensure the usefulness and commercial success of a system, all design activities should position the end user as their focus so that the final product is easy to use and ultimately meets their needs (Gould and Lewis 1985). Essentially a UCD approach addresses the questions: '*How do I understand the user?*' and '*How do I ensure this understanding is reflected in my system?*' (Holtzblatt and Beyer 1993).

The ideals and techniques of UCD originated in the early works of researchers Gould and Lewis (1985) and Norman and Draper (1986), with the former proposing three basic principles: (1) an early focus on understanding users and their tasks; (2) empirical measurement of product usage by *representative users*; and (3) an iterative cycle of design, test and measure and redesign. Since that time, UCD has become the subject of much research and literature, having come to be viewed by many as an integral factor in the development of successful commercial software products (Bias and Mayhew 1994, Butler 1996, Mayhew 1999, Nielsen 1993, Rubin 1994). In 1999 an international standard was established – 'ISO 13407 Human-Centred Design Processes for Interactive Systems' – providing guidance for UCD by way of describing the rationale, planning, principles and activities of UCD practice (Jokela *et al.* 2003). Developed by a board of international researchers and practitioners in the field, the standard discusses the four main activities of UCD which are carried out iteratively until the defined objectives (in terms of usefulness) have been met. These are presented in Fig. 8.2 and described below (Jokela *et al.* 2003, Maguire 2001).

A. *Understand and specify the context of use* incorporating user characteristics (e.g. knowledge, skills, experience, education, training, attributes, habits, preferences, capabilities), user goals/tasks (including system use) and the environment of use (technical, physical and social); in order to support user requirements specification and provide a basis for later evaluation activities.
B. *Specify the user and organisational requirements* using the previously defined context of use (particularly user goals and tasks), in order to evolve measurable criteria against which the usefulness of the product will be evaluated, and to define user-centred design goals and constraints.
C. *Produce design solutions* based on the established design goals, guidelines and constraints and incorporating HCI knowledge (relating to visual design, interaction design, usability, etc.). An iterative process of design production to support evaluation at different stages of the system development lifecycle.
D. *Evaluate designs against requirements* throughout development, employing appropriate prototypes and applying the goal-/task-based crite-

ria developed previously. Important for determining the degree to which the user/organisational objectives have been met and in obtaining feedback relating to design refinements.

As Jokela *et al.* (2003) identify, ISO 13407 does not aim to outline detailed methods for completing the activities, with such descriptions already contained within numerous methodology publications. There are in fact a multitude of methods available for conducting UCD, with Table 8.3 providing an illustrative selection, grouped by the main activities identified above.

The ideals of UCD are grounded in a number of disciplines, most notably cognitive psychology (the study of human perception and cognition), experimental psychology (the use of empirical methods to measure and study human behaviour) and ethnography (the study, analysis, interpretation and description of unfamiliar cultures) (Mayhew 1999). Furthermore, it aligns closely with the social sciences – concerned with the study of peoples' beliefs, behaviours, interactions and institutions (Neuman 1997) – which is particularly noticeable in the correlation between specific UCD techniques and social research data collection methods, both quantitative and qualitative (Urquhart *et al.* 2004).

Comprehensive models exist for implementing a UCD methodology for the development of a system, complete with detailed discussions of optimal activities and methods (see for example Nielsen 1993, Mayhew 1999). It is not the purpose of this chapter (nor is it desirable), to provide a definitive UCD methodology for developing mobile geographic hypermedia sys-

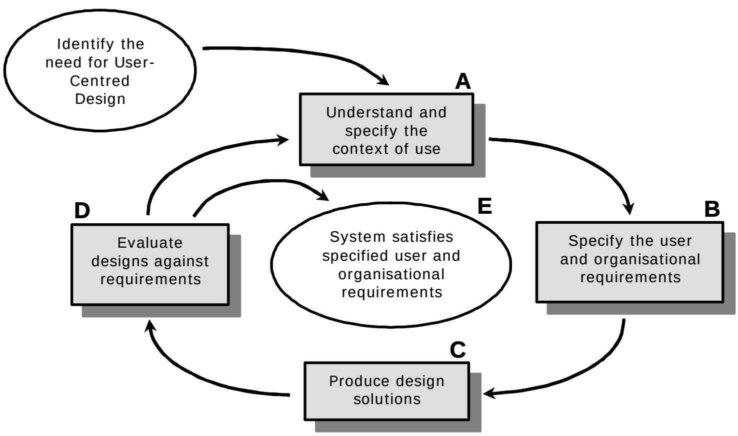


Fig. 8.2. The main activities of UCD (ISO 13407 in Jokela *et al.* 2003).

tems. In fact, the final set of methods used in any one undertaking must be carefully selected and tailored to meet the unique requirements of the system. Moreover, factors such as time, budget and available resources will dictate the feasibility of using individual UCD techniques. Ultimately however, provided that Gould & Lewis' (1985) base principles are adhered to and a rigorous process is followed, any combination of UCD methods maybe employed to achieve the required aims (Nielsen 1992).

8.4 Discussion

It is the intention of this discussion to build on the ideas presented above, providing further justification for a user-driven approach to the design of mobile geographic hypermedia systems. In doing so, it is fundamental to highlight the role of the user in the process. Undeniably, the user is the central figure in the success of any mobile geographic hypermedia system, which is directly related to their adoption or rejection of the product. Adoption is in turn contingent on usefulness which, when optimised, should benefit the user through increased productivity (via effective operation), reduced errors (caused by inconsistencies, ambiguities, etc.), and less need for training and support (via reinforced learning), thus leading to improved acceptance (through satisfaction and ease of use) (Maguire 2001). As discussed previously, the usefulness of a system is measured by its util-

Table 8.3. Methods for UCD (Maguire 2001; Mayhew 1999; Butler 1996; Holtzblatt & Beyer 1993; Rubin 1994; Nielsen 1992).

Understand and specify the context of use	*Specify the user-organisational requirements*	*Produce design solutions*	*Evaluate designs against requirements*
• Context of use analysis • Survey/interview of existing users • Focus groups • Field study / user observation • Diary keeping • Task analysis	• User requirements interviews • Focus groups • Personas • Scenarios • Existing system / Competitor analysis • User / task / domain models	• Brainstorming • Parallel design • Design guidelines and standards • Storyboarding • Affinity diagrams • Card sorting • Prototyping	• Participatory evaluation • Assisted evaluation • Usability Inspections • Usability testing • Satisfaction questionnaires • Post-experience interviews

ity and usability in the eyes of the user. Herein lies the major limitation of technology-driven development, which rarely involves consultation with the user – least of all during the design process. In contrast, a UCD methodology requires that the user is actively involved *at all stages* of the project lifecycle, from gathering and specifying requirements through to evaluating design solutions. Only in this way can the final product truly be claimed to have been designed for the user.

A UCD approach to the design of mobile geographic hypermedia systems may be considered especially crucial in light of the characteristics of the users themselves and their use contexts. Returning to the example of mLBS, arguably the most profitable market segment for these systems are consumers, a large proportion of whom have little or no formal training in the interpretation and analysis of geospatial information. Such people are considered 'non-expert' users who are generally less adept at understanding cartographic representation forms than 'expert' users of traditional geospatial systems – who are often formally trained in spatial thinking and reasoning (Golledge 2003). Cartwright *et al.* (2001) emphasise the importance of understanding and designing for a range of user abilities stating that "access to geospatial information and the interfaces that provide the 'gateways' to this information, need to be designed in sympathy to all users, so as to ensure equity of access and use" (p.48). Looking to the actual use of mobile geographic hypermedia systems, this takes place in dynamic, changing environments which will naturally take the primary focus of the user's attention. Hence the operation of these systems are relegated to lesser levels of user focus, and thus attention, making the optimisation of their usefulness (and in particular their usability) under distracting conditions especially important.

So what does the new approach to system design advocated by this chapter really mean for mobile geographic hypermedia systems and geographic hypermedia in general? To deal first with the latter, the concepts and processes related to usefulness and UCD are indeed generic and have been employed in computer systems design for many years (as the references attest). Therefore they can be easily applied to the design of all types of geographic hypermedia systems with the following benefits also universally relevant. Of major benefit, adhering to the guidelines of UCD compels creators of geographic hypermedia systems to find out who their end users are and exactly what types of geospatial information they need at the outset, which they can then use to drive design, rather than making assumptions and designing for 'what is possible'. This is particularly pertinent for mobile systems, which combine innovative technology with new and inexperienced users, and arguably results in a greater likelihood that the final product will be adopted. Furthermore the involvement of end users, together with an associated expenditure of time and effort, throughout the design and development lifecycle helps to identify and eliminate problems of usability with the component geographic hypermedia as they arise, thus avoiding the time and expense associated with resolving usability issues within a completed product. This equates to ‘getting it right the first time’.

Another benefit involves the consideration of specific constraints within the delivery medium, including both technological and context of use, which is especially important for mobile systems. This ensures that inappropriate geographic hypermedia forms are discarded early on (e.g. detailed visual media designed for the desktop environment that will likely be inappropriate for use within display-limited mobile systems), and thus enables the design to focus on more suitable representations. Complementary to this, speaking with the end users may even prompt novel forms of geographic hypermedia which would not otherwise have been revealed through the application of pure theory and/or the technological possibilities of the medium. In closing, a final benefit comes from the iterative nature of the UCD process. By employing a cycle of design evaluation and refinement, alternative forms of (mobile) geographic hypermedia can be trialled and compared through feedback from real users before being committed to development, again optimising the efficiency of the development process whilst ensuring the most appropriate result.

8.5 Conclusion

Mobile geographic hypermedia systems have the potential to deliver geospatial information to (often new) users where and when they want it. To date, however, user needs have been largely assumed while developers race to produce novel applications based on cutting-edge mobile technology. While the resulting systems are often highly desirable (e.g. for their innovation and attractiveness), they do not necessarily meet real users’ needs or account for the unique cartographic constraints of the medium, and therefore they run the risk of rejection in the marketplace. This chapter has argued that in order to ensure the commercial success of mobile geographic hypermedia products (and indeed geographic hypermedia products in general), usefulness should be the key driver of system design. In this way, the user should be made the focus of all design and development activities so that the final product not only meets their requirements but is effective, efficient and satisfactory to use. A focus on usefulness does not only benefit commercial products, however. It also has the potential to drive research resulting in new forms of geographic hypermedia for the mobile medium, which will in turn benefit the mobile geographic hypermedia systems of the future.

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9 Cruiser: A Web in Space

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Contribution: Nectaria Tryfona

Abstract. This chapter presents Cruiser, a geographically-oriented content management and delivery system, providing a platform for developing rich internet applications and services that make use of spatial data, maps and location-aware information. The chapter addresses the technological and business need behind it, and discusses Cruiser's unique feature, namely the *channel*, that allows for tuning, navigation, browsing, searching, enriching and sharing of geographic space, at a personal level. Finally, the target application domain as well as, the benefits of adopting this platform are presented.

9.1 Introduction

In the many facets of everyday communication activities that take place over the internet, there is a need to refer to issues of spatial nature and geographical concepts. This is typically accomplished through the use of verbal descriptions or through maps. Nevertheless, the use of maps over the internet for conveying and manipulating geographic positions, regions, itineraries, distributions, and networks is a difficult task, while the typical practices used for displaying image-based maps in web-pages result in a very poor user experience. What's more, advanced uses, such as, for example, the combination of textual references with their map representations (e.g., displaying the multimedia description of an entity whenever it is selected on the map, or vice versa), searching with spatial criteria, or dynamically simulating physical phenomena, require expertise and technical infrastructure that are beyond reach in most cases.

Cruiser, a new medium for publishing, searching and communicating on the web, based on maps and geographic space, was conceived and developed to address the aforementioned business and technological need. It provides a geographically-oriented content management and delivery platform for developing internet applications that make use of spatial data and geo-coded information.

By adopting modern software architectures and state-of-the-art technologies, Cruiser provides unique quality of user experience by offering the ability for:

- Real-time fly-over 3D terrains and seamless map browsing over the internet. Using Cruiser, users can freely navigate and pan-around in terrains of great detail and maps of any scale, zoom-in/out at will to any place of interest, measure distances, and print personalized maps with suitably chosen symbols of interest (e.g., eliminating places or marks of non interest). Flying and map browsing can be achieved even over dialup internet connections.
- Access to any type of geo-coded information based on its spatial distribution. As users browse maps and navigate through landscapes, they can selectively display or hide descriptive information of the various land features and geographic entities (e.g. cities, road network, companies, products, etc) by applying various filters and criteria (e.g., "show only 3-star hotels", or "cities with population greater than 3000"). Information is displayed on the maps and landscapes with various symbols which can be selected to display linked multimedia information (html links, videos, animations, photographs, etc).
- Criteria based searches. In addition to accessing information while browsing, users can search for in-formation by issuing structured queries and then selectively jump to the places conveying the re-quested information. Queries can be based either on pure lexicographic criteria (e.g., by specifying the name of a place, a city, a company, etc), or on spatial criteria, like "distance from point", or "inclusion in shape" which are graphically determined on the maps, or both.
- Embedding of personal content. Cruiser offers users the ability to attach various types of objects and personal information like points (flags, notes, photos, etc), itineraries with commentaries and polygon shaped regions of interest, again, accompanied by information. In that way users can create their "personal excursion albums" or "personal cadastral", and share this information with friends who can dis-play this information on their own Cruisers.

It important to note that the Cruiser user interface experience avoids the pitfalls of fragmented web-page based applications which suffer from interruptions, and slow responsiveness, as web pages are reloaded after every user interaction. Wait times are eliminated, thanks to effective data compression techniques which are deployed for the geographic data, while data caching allows the off-line use of Cruiser, in cases where an internet connection is not available.

The rest of the chapter is organized as follows: Section 9.2 presents the unique feature of Cruiser, namely the ‘channel’ and discusses the way it works. Section 9.3 gives the technical description of the platform, focusing on the Cruiser server, Cruiser clients, and Cruiser applications. Section 9.4 discusses the benefits of adopting and using the Cruiser environment. Section 9.5 presents the application domain and finally, Section 9.6 concludes and gives related work in this field.

9.2 The “Channel” Feature

Cruiser-based applications are offered as “channels” through a game-like interface which allows seamless navigation within the 3D geographic space and 2D maps. Fig. 9.1 depicts a snapshot of the navigation in 3D Greece.

Users can just “tune in” to a desired channel (see below), and visit places, browse available information, inspect objects and geographical features, access web sites that are linked to the objects of concern, conduct searches using spatial criteria, add notes and place-marks, share geographic content with others, personalize the views and print customized maps. Fig. 9.2 shows the use of the Barcelona area channel.

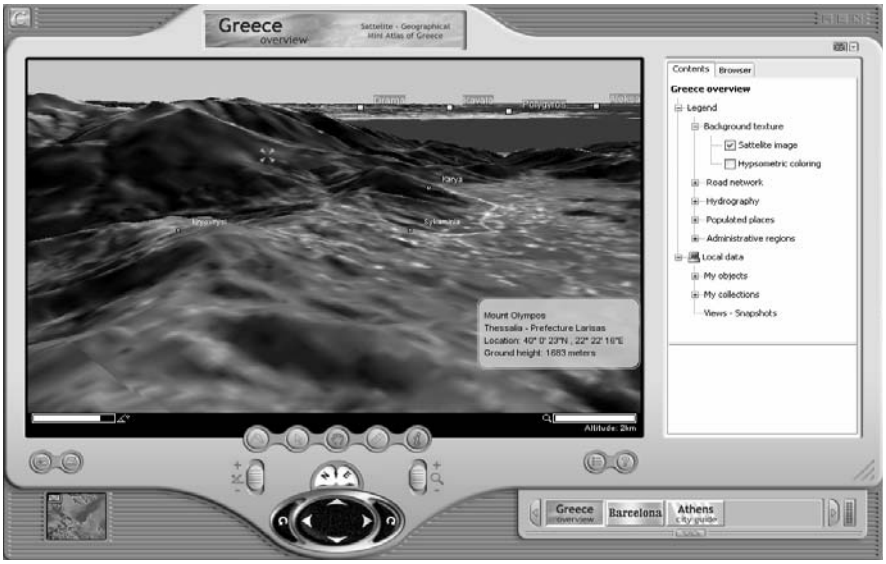

Fig. 9.1. Flying over Greece with Cruiser

Fig. 9.2. A Cruiser channel for Barcelona

Cruiser channels can be setup on demand, managed and branded by interested customers (service or content providers, governmental organizations, companies for enterprise uses, individuals, etc). The geographic and multimedia content, the look & feel and the functionality of a Cruiser channel is specified by its owner, and each channel works independently from others conveying strictly channel-specific information to its targeted audience. All channels share a common geographic digital terrain on top of which channel-owners add their own multimedia geo-coded content (e.g. advertisements, classified-ads, real-estate property, photos, notes, annotated routes, etc). Each channel works independently from others conveying strictly channel-specific information to its targeted audience. Cruiser applications are hosted by Cruiser servers which stream content and services to the Cruiser clients through channels over the internet or intranets.

Fig. 9.3 depicts the basic concepts of the channel architecture. Cruiser clients can tune to Cruiser servers and browse all available channels (Fig. 9.4).

9.3. Technical Description of Cruiser

The Cruiser platform consists of the Cruiser server and the Cruiser client. The latter is a rich internet client that provides a shell that hosts and exe-

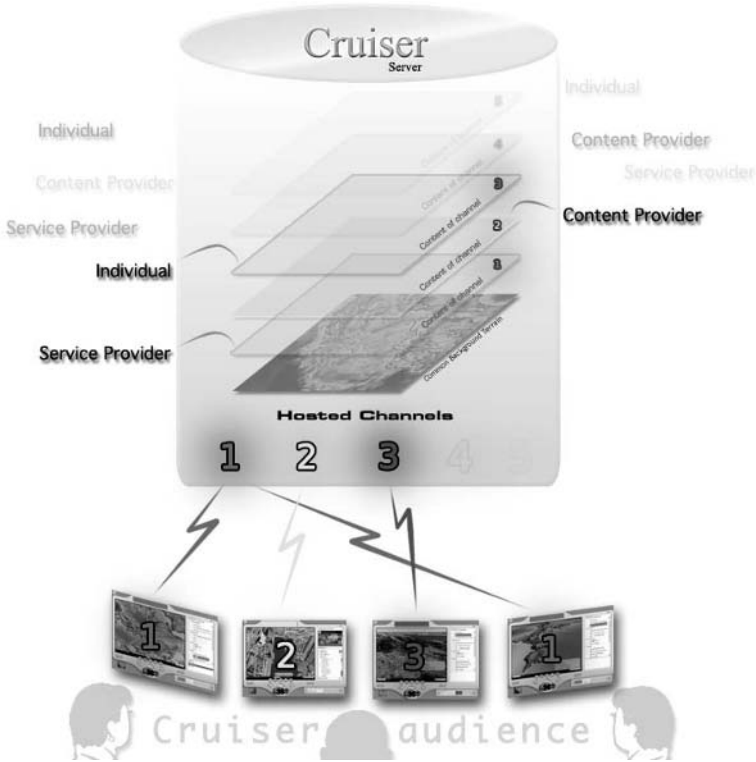

Fig. 9.3. Architecture of Cruiser Channels

cutes applications composed by *software components* in various combinations of user interface and functionality. This gives Cruiser the ability to be "*polymorphic*", i.e., to adapt dynamically to the requirements of many different applications, which implement, each time, the targeted services, by changing user interface, look & feel (skins) and functionality, according to each case.

Fig. 9.5 presents the platform architecture. Next, the parts comprising the platform are described.

9.3.1 Cruiser-Server

The Cruiser-server consists of the following parts (modules):

1. *Geographic Database*. It includes the set of geographic data which are used by all the hosted channels-applications: three-dimensional terrain models, satellite images, and vector maps in various scales.

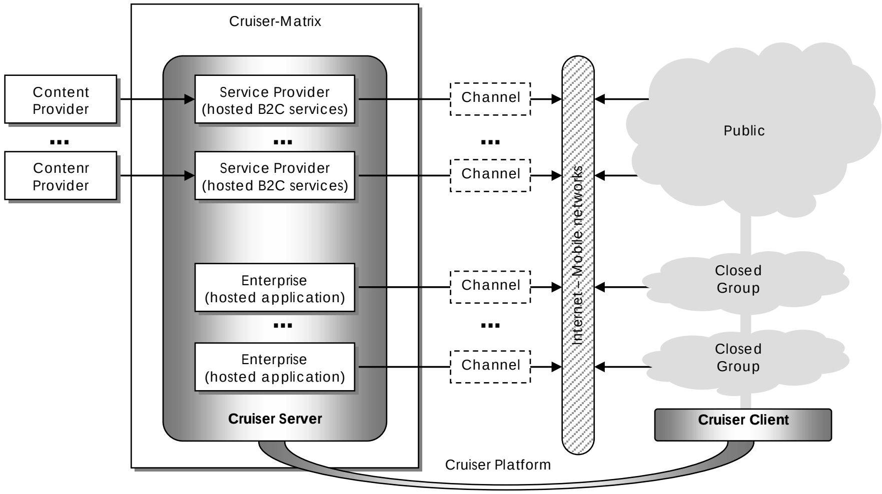

Fig. 9.4. Hosting of applications and services based on the Cruiser platform

2. Content & User Database. Includes: (a) multimedia data (rich media) accompanying the geographic objects; and (b) data about the users-subscribers registered for the various channels.
3. *Channel Manager*. This is the central channel management module. It manages the descriptions and the activation of the hosted applications, as well as their connection with the required geographic substratum and multimedia content.
4. *Geo-spatial data streaming module*: It manages the data requests by the Cruiser clients and handles the real-time transmission of the geographic data..
5. *Query-Lookup processing module:* It manages the requests by the Cruiser channels for searches for geographic objects and descriptive data through structured queries.
6. *Geo-spatial processing module.* All maintenance, extension and processing (translation to internal formats, compression, etc.) operations for the total of the data, used by each service, take place through this module.
7. *Data entry & geocoding module*: Through this module are entered new geographic objects. Either by the service support personnel or by remote users of the system, using the Cruiser client and web-forms (e.g., input of the position of a real estate property and its descriptive data by the seller).
8. *Real-time feeds module*: It manages real-time geographic data sources that are used for display by the channels (e.g., weather satellite images, GPS streams of moving vehicles, etc.).

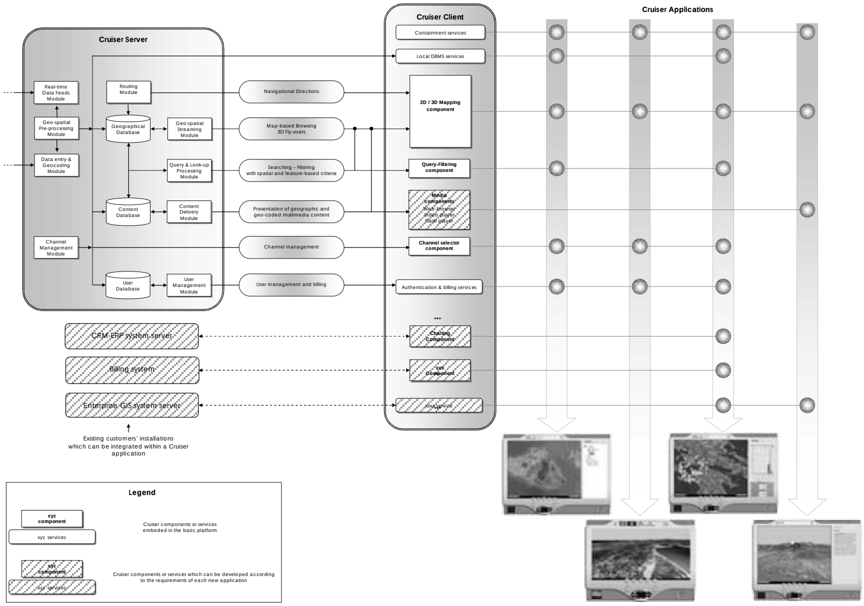

Fig. 9.5. Block diagram of the architecture of the Cruiser platform

9. *Subscription management module*: It implements the various subscription charging schemas for the information providers (e.g., the time an entry will be kept, according to the charging package) and for the consumer, per service, producing the necessary operation and usage statistics of the services.

9.3.2 Cruiser-Client (Cruiser)

This is the specially designed, rich client application, through which all provided services are used. Cruiser is installed as a desktop application using a simple procedure, and is updated continuously, with any updated versions, in a user-transparent manner. Cruiser can be used either of-line or on-line. In the latter case, it is connected to the Cruiser server (through a proprietary API) and has access to services and content provided by the server.

From a technical viewpoint, Cruiser is a shell that hosts application (Cruiser-applications, section 9.3.4) which are composed by software components (Cruiser-components, section 9.3.3), providing them with a series of services regarding their appearance and operation. Furthermore, Cruiser is itself a component that can be incorporated in other applications (as an applet/plug-in in web pages or as a programmable module in other applications).

9.3.3 Cruiser-Components

These are software components implementing a “packaged” functionality, however simple or complex, and are the building blocks for Cruiser applications (section 9.3.4). Cruiser-components, in addition to whatever autonomous functionality they have, they support certain necessary programming interfaces for the communication with the environment-Cruiser shell client.

Cruiser components that are the common functional denominator of many applications, and which are part of the basic platform, are the 2D/3D mapping component, the Navigation Panel component, the Query-Filter component, and the Channel selector component. In addition, other components can be developed for the implementation of specialized operations required by particular applications, as, for example, the logic for the connection to remote e-commerce, ERP, CRM, booking, etc. system for the implementation of buying or selling products, room reservations, etc.

9.3.4 Cruiser -Applications

A Cruiser-application is composed, regarding its user interface layout and its functionality, by Cruiser-components, and is distributed by the Channel manager of the Cruiser server. This architecture of composing applications using components gives the ability to implement a wide range of applications even with a small number of Cruiser-components.

A typical Cruiser-application consists of a client and a server part. The client part is installed in each Cruiser-client, while the server part may be distributed in many servers, including the Cruiser-server. In addition, a Cruiser-application can be only a local (desktop) application.

All Cruiser-applications are available to the Cruiser-client through the Cruiser environment. Each application comprises a different channel. The Cruiser platform offers the following services to its applications:

- Automatic deployment wherever there is a Cruiser-client. The client has a list of all available applications. When the user selects an application, it is automatically downloaded and installed in the Cruiser-client. In addition, there is completely transparent support for the distribution of newer versions of an application, centrally by the Cruiser server. Apart from the application code, the deployment refers to its database information, as well as the parts of the information about the geographic substratum, related to the application.

- The geographic substratum in various levels of detail. The navigation and management, in general, of the substratum is done through the 2D/3D navigation component, as well as the geographic information management component. The former provides visual map management services, while the latter provides services accessing the geographic information and incorporating it in the application logic.
- Geographic services, as, for example, distances between points, the points of interest that are within a certain distance from some other point, and many others. These services are provided to the application either in the form of a local API, by the Cruiser-client, or in the form of remote web services, by the Cruiser-server.
- The local relational DBMS services, which the application can use for the deployment of database information used locally. Through the same DBMS, access is provided to the descriptive information of the geographic substratum.
- Local caching capabilities of the remote database information of the application, and access of this information via the same API with which the local database information of the application is accessed.
- Uniform user management system, with profiles, access rights to operations and data, identification. Using the same id, the user can subscribe to different services of Cruiser-Matrix. In every case, user management is a service provided centrally by the platform to its users, and, through this service, subscribers to services/applications are managed.
- Support for various charging schemas for the use of the services of an application. An application will be able to charge for parts of its functionality or for its full use, in various ways. Some of the basic ways that must be examined are time-based charging (for services whose use is priced based on time), volume-based charging (for services priced based on data volume), charging based on how many times a function was used, with support for different charging for each function.
- Complete control of the user interface by the application. An application can use diverse technologies (Flash, .Net, Java) and different components, to compose both its user interface and functionality. For example, the platform offers applications the ability to handle a wide spectrum of multimedia content types.
- A Cruiser-application (stand-alone of rich internet client) can run as:
  - An application inside the Cruiser client. The application UI is surrounded by the UI of the Cruiser client.

- An autonomous application. In this case, the application runs inside the Cruiser client again, since in every case it uses its services. In this mode, however, the Cruiser UI is the minimum that is required to host the UI of the application. In this case, Cruiser operates in single-application mode.
- A component, part of more complex applications. The intent is for a Cruiser-application to be able to become an ActiveX / .NET and Java component of other applications. In this case, as well, the application runs inside Cruiser, which is in single-application mode.
- As a browser plug-in, comprising part of the web interface of a web-based application, i.e., an application used inside a web browser.

9.4 Benefits

End-users enjoy a wealth of innovative characteristics offered by Cruiser which resembles more of video-games than of classical «applications». Unique features such as combination of 2D and 3D navigation, configurable level of detail, graphical querying and embedding of personalized content bring advanced GIS technologies to the non-expert large public.

From a business perspective, for service and content providers, Cruiser offers an innovative service/application deployment model with very fast development cycles, low costs and small time-to-market. Cruiser's application-hosting model, in combination with its component-oriented architecture, ensure:

- Flexibility in developing new applications with rich functionality supplied to order.
- Flexible charging model: Customers pay only for what they use (from a single to thousands of geo-coded items) and for just the amount of time they use it (from a single day to many years).
- Turn-key solutions which eliminate the need to invest in infrastructure, geographic data, and techno-logical know-how (as is typically required by other existing solutions) in order to provide services which make use of maps and geo-coded data.
- Low costs thanks to the economies of scale in development and time resources that are made possible through the re-use of software modules and geographic data.

9.5 Application Fields

Cruiser has a potentially huge application domain. Some of the more prominent sectors include: Advertising, Directory Services, Tourism, Real Estate, Navigational services, Portal / informational services, Education, On-line Gaming, Location Based Services, Geo-Marketing, CRM Applications, Fleet Management, Property Management, Risk Management Applications, User Communities, Governmental applications (Fig. 9.6). Both the private sector and the public can use Cruiser. An example of private channel for enterprise use by authorized users can be, the Fire Department hiring a channel, and using it to coordinate its fire-fighting work by monitoring the development of a fire and the movement of its vehicles.

On the other hand, examples of channels providing services to the broad public are travel channels (to plan excursions, vacations, etc.), real estate channels (for both sellers and buyers), directory services channels(Yellow Pages) and many others.

9.6. Conclusions and Related Systems

This chapter presents Cruiser, a new medium for publishing, searching and communicating on the web, based on maps and geographic space, was conceived and developed to address the aforementioned business and tech-

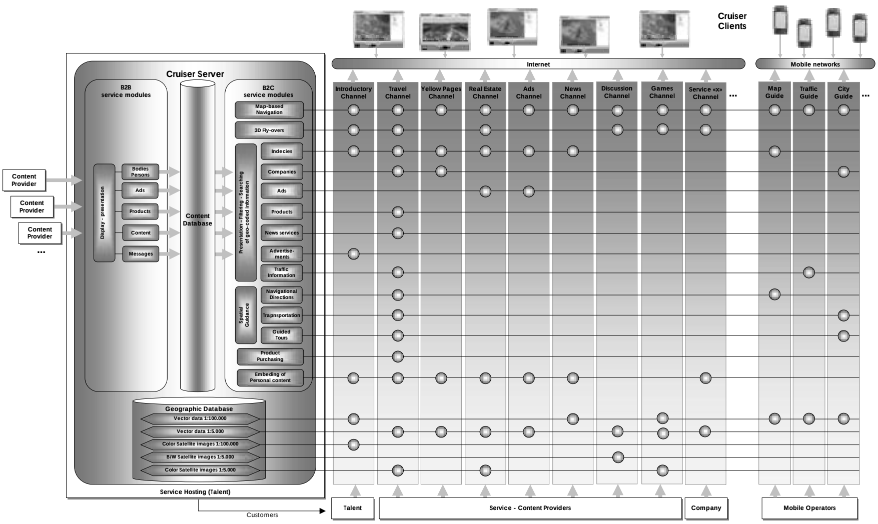

Fig. 9.6. Setup of channels – integrated services based on primitive basic services of the Cruiser platform

nological need. Cruiser provides a geographically-oriented content management and delivery platform for developing internet applications that make use of spatial data and geo-coded information.

In the spectrum of publishing, searching and communicating geographic content on the web. Cruiser can be compared with Google Earth (beta version). It has two main advantages to the latter public domain software:

- One user client – Many service providers.

While Google Earth is based on the 1-1 relation between provider and client (i.e., the client can only see what the one (only) provider has to offer), Cruiser follows the ‘TV principle’: *one* client sees what *many* providers are offering (the concept of channels). Users can 'tune' to their favorite channels or zap through them at any time via the Cruiser controls.

- One user client – Many applications.

As described in Section 9.3, Cruiser is not *one* 'application', but rather a “shell” capable for hosting *many* geo-spatial and mapping internet applications. This allows for multi-working on the user side.

The vision is, for the digital geographic space, Cruiser to become what a web-browser is for the web and eventually create a «web in space».

Acknowledgements

Cruiser's development is co-funded by GSRT through the European Union 3rd Community Support Framework for Greece (Action PPAXE, phase 2, project “Greek Matrix”). The Cruiser platform (v. 1.1) is available to the public for download as of 12.12.2005 from the www.cruiser.gr web site.

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PART III

TECHNOLOGIES FOR CONTENT INTEGRATION

10 Merging Hypermedia GIS with Spatial On-Line Analytical Processing: Towards Hypermedia SOLAP

Yvan Bédard, Marie-Josée Proulx, Sonia Rivest, and Thierry Badard

Abstract. Geographic Knowledge Discovery (GKD) requires systems that support interactive exploration of data without being slowed down by the intricacies of a SQL-type query language and cryptic data structures. GKD requires to compare maps of different phenomena or epochs, to dig into these maps to obtain detailed information, to roll-up data for more global information and to synchronize maps with tables and charts. This can be done by combining the capabilities of GIS with those of OLAP, leading to SOLAP (Spatial OLAP). To enrich the GKD process, we added hypermedia documents to SOLAP. Hypermedia SOLAP provides a more global perception of the situation without requiring the advanced knowledge typically required by Hypermedia GIS. This chapter presents hypermedia SOLAP concepts and gives an example dealing with the erosion of lands and roads.

10.1 Introduction: The Power of Coupling SOLAP with Hypermedia

According to Wikipedia (2005), the first hypermedia system was the MIT Aspen Moviemap. From a Hypermedia GIS point of view, it is interesting to note that this project merged a digital map of the city of Aspen (Colorado, USA) with hypermedia information, namely digital movies (Naimark 1997). Built in 1978 for military purposes as an ARPA (Advanced Research Projects Agency) project, this system allowed the user to select any point in the city of Aspen to start a virtual visit by viewing, on-demand, a film in the selected direction. This freed the users from following a given route that was predefined by somebody else.

Hypermedia is an extension of hypertext that uses intertwined hyperlinks. It is essentially used to access multimedia information in a random manner at the will of the user. Such flexibility in the search for new information replicates to the way human brains think, that is in a non-linear manner. The type of information provided by such systems uses various digital media to present documents such as texts (descriptive text, narrative and labels), graphics (drawings, diagrams, charts or photographs), videos, sounds (music and oral narration) and animations (changing maps, objects and images) (Bill 1994). Having such information at hand enriches the perception of the users as more senses are actively recruited.

An interactive manner of navigating through information bears many similarities with the manner used by OLAP technology. Both Hypermedia and OLAP systems allow the user to see the desired information by clicking on a word, on a spreadsheet cell, on a piece of a pie chart and so on without forcing a given sequence to navigate into the database. However, two major differences exist between these two families of technologies: the types of data that are used and the media that are supported. OLAP technology uses multidimensional datacubes to manage numeric data called “measures” that are aggregated and cross-referenced for several axes of analysis, each having several levels of details and that are called “dimensions” (see next section). Typically, such measures are derived from detailed data imported from heterogeneous transactional sources and restructured for OLAP navigation through a data warehouse architecture and ETL (Extract, Transform, Load) processes. These measures can then be visualized as values through two media: spreadsheets and statistical diagrams (pie chart, bar chart, histogram, etc.). However, as opposed to a conventional spreadsheet, data can be drilled down, rolled up, drilled across, sliced and diced easily and rapidly. This allows the user to interactively explore the data from one level of detail to another and to see how the different axes of analysis interact together (see next section for examples and Bedard *et al.*, 2002). The capability to interactively explore multi-resolution cross-referenced aggregated numerical data is not an objective of hypermedia technology. However, as opposed to OLAP, hypermedia technology supports a large variety of digital media (photos, videos, sound tracks, etc.). Consequently, hypermedia supports both the reproduction of raw signals (e.g. audio waves in record tracks, emitted light in pictures) as well as the presentation of explicit data that have been interpreted *a priori* (e.g. words, numbers), while only the latter is possible with OLAP.

In spite of such capabilities, these technologies do not harness the full power of map data. Map data are the raw materials that produce the geographic information that leads to knowledge regarding the position, extent and distribution of phenomena over our territories. Visualizing geographic phenomena on maps facilitates the extraction of insights that help to understand these phenomena. Such insights include spatial characteristics (position, shape, size, orientation, etc.), spatial relationships (adjacency, connectivity, inclusion, proximity, exclusion, overlay, etc.) and spatial distribution (concentrated, scattered, grouped, regular, etc.). Like other media, maps do more than present phenomena, they help to place them in context and they support the thinking process. Integrating maps with other digital media naturally leads to applications that allow the user to investigate cartographic elements in an interactive mode and to link these elements with a hypermedia database. Such applications are called Hypermedia GIS and typically emphasize the exploration of a hypermedia database using spatial data as the starting point (e.g. a position). Hypermedia GIS provide the essential concepts and techniques for many new GIS applications in visualization, spatial decision support systems and spatial database management and exploration (Hu 2004). Numerous studies in cognitive sciences have shown the superiority of images over numbers and words to stimulate understanding and memory (Buzan and Buzan 2003, Fortin and Rousseau 1989, Standing 1973). Similarly, SOLAP provides new capabilities to explore cartographic data interactively in ways not available in today's GIS. Thus, properly combining maps, spatial analysis, hypermedia navigation and OLAP capabilities should help users to compare different regions, create global views, investigate details, get new hints, discover correlations between phenomena in the same region, see the evolution of the phenomena over different epochs, understand spatial relationships between phenomena, better sense a phenomenon, better communicate findings, etc. In other words, combining Hypermedia GIS with SOLAP (Spatial OLAP) should offer a very promising environment for the user.

Since the fundamental concepts as well as examples of Hypermedia GIS are provided throughout this book, we focus on introducing the new technology that is SOLAP and on showing the potential of Hypermedia SOLAP for spatially-referenced hypermedia applications. Using the first Hypermedia SOLAP application ever developed, we illustrate the inherent capability of SOLAP to support the non-linear approach for accessing information at different levels of abstraction as well as its "natural fit" with hypermedia. Finally, we describe the potential evolution of Hypermedia SOLAP from the traditional architecture to a web service architecture.

10.2 SOLAP Concepts

Geographic Information Systems (GIS) have successfully provided users with new capabilities not available 25 years ago. They have been developed for gathering, storing, manipulating, and displaying spatial data (see Longley *et al.* 2001) and to put the power of digital maps in the hands of users. However, these systems are transaction-oriented, and like every transactional system (e.g. database management systems), they do not efficiently address summarized information, cross-referenced information, and interactive exploration of data. Furthermore, GIS do not efficiently deal with temporal data or with multiple levels of data granularity. Finally, GIS are still difficult to use for non-expert users while the demand for geographical information by many different professions or the general public is increasing (Viatis and Tzagarakis 2005).

Besides transactional technologies, there exist specific tools to easily query and navigate datasets with optimized data structures specifically built for knowledge discovery and decision-support. This category of tools, called OLAP (on-line analytical processing), is designed for rapid and easy exploration of different levels of aggregated data that are cross-referenced among themselves. This approach is intuitive and allows users to construct their analysis by clicking and navigating directly on the data (Yougworth 1995), in a way that is similar to the use of hyperlinks. The general architecture of an OLAP application is composed of a multidimensional database, an OLAP server, and OLAP clients (different implementation strategies are described by Thomsen *et al*. (1999).

OLAP allows users to navigate within data without knowing query languages such as SQL. With simple mouse clicks, a user may “drill down” within different levels of data and “drill up” to a more general level of data. Several books and papers address the fundamental concepts of OLAP and their underlying multidimensional databases (e.g. Berson and Smith 1997, Gouarné 1999, Thomsen 2002, Vit *et al*. 2002). An OLAP user interface displays data into statistical charts and spreadsheet tables that are dynamic and that directly support OLAP operations such as the different types of drills. Although OLAP does not address spatial data, one can combine OLAP and GIS software to create SOLAP applications. Three combination approaches were described by Bédard *et al.* (2005): GIS-centric, OLAP-centric and hybrid.

We define SOLAP as a category of software that allows rapid and easy navigation within spatial databases and that offers many levels of information granularity, many themes, many epochs and many display modes synchronized or not: maps, tables and diagrams. SOLAP relies on the multidimensional paradigms and on an enriched data exploration process made available by explicit spatial references and maps. SOLAP adds dynamic navigation into spatial data, maps, and symbols on maps. SOLAP maps are created dynamically from multidimensional data combined in the spatial datacube. This differs from some visualization and multimedia tools where navigation operations are associated to a sequence of predefined maps stored on the server. In comparison to the latter and to some commercial OLAP with minimal graphic capabilities, SOLAP facilitates the update of cartographic data. In comparison to most geo-visualization solutions (e.g.

as presented in Dykes, MacEachren and Kraak 2005), SOLAP adds new visualization challenges in order to maintain a continuous train-of-thought in an interactive analysis process. These challenges have been described by Rivest *et al.* (2005).

SOLAP fills the "analysis gap" between spatial data and geographic knowledge discovery since response times remain below Newell's cognitive band of 10 seconds (Newell 1990) and therefore can support this process in an interactive manner at whatever level of abstraction. It has been demonstrated that it is possible to achieve such performance for large datasets (Marchand 2004). In spite of a short history, SOLAP already reaches a first level of maturity with its own concepts, technologies and applications. Commercial solutions have recently become available and have been implemented in Canada, the United-States, France, Portugal and other countries. The number of scientific papers and book chapters on the subject has also begun to multiply (for more details, see Bedard *et al.* 2005).

The datacube, or multidimensional database approach introduces new concepts such as "dimensions", "members", "granularity", "measures", "facts" and "datacubes". For example, in a digital library where we need to calculate the number of documents for different types (e.g. digital maps, raster images, photographs), different publication dates and different regions, the *dimensions* are the themes to be analyzed (i.e. "documents", "time", "territory"). Each dimension contains *members* (e.g. "map", "2001", "Quebec City") that are organized hierarchically into levels of *granularity*, or levels of details (e.g. "province" ->"county" -> "city" for the "territory" dimension). The members at one level (e.g. "municipality") can be aggregated to give the members of the next higher level (e.g. "county") within a dimension. Three categories of dimension can be defined: descriptive (thematic), temporal and spatial ("non-cartographic" in the case of a conventional OLAP tool, "cartographic" in the case of a SOLAP tool). The *measures* (e.g. the number of documents) are numerical values calculated from the cross-reference of all the dimensions, for every combination of members from all levels of abstraction. A measure can be considered as the dependent variable while members of the dimensions are the independent variables (e.g. the measure "number of document" depends on the members of each dimension, such as "2003" for "time", "map" for "document" and "Quebec City" for "territory"). Each unique combination of dimension members and measures represents a *fact* (e.g. "3000" documents of type "map" were produced in "2001" for "Quebec City"). Those facts are aggregated according to the hierarchies of each dimension to finally obtain the total number of documents of all types for all publication dates and the entire country. The resulting set of facts is called a *datacube* (or *hypercube* if there are more than 3 dimensions). An impor-

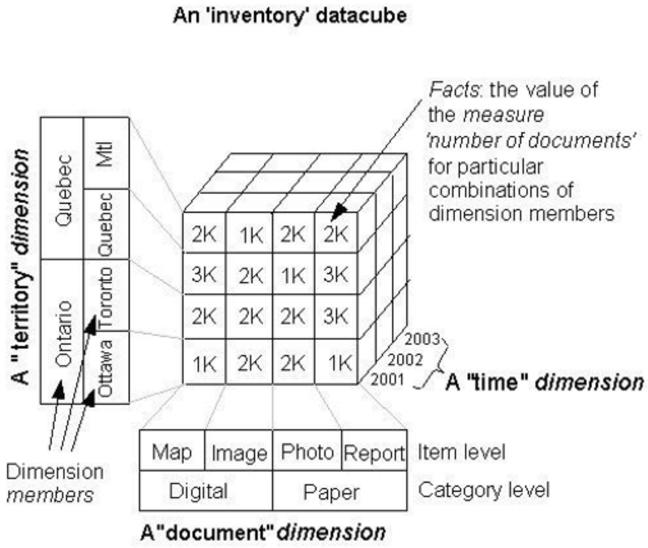

Fig. 10.1. A datacube showing the multidimensional database concepts

tant part of the datacube is typically pre-computed to increase query performance. This performance depends on the number of hierarchical levels for each dimension and on the number of members that compose the hypercube. Fig. 10.1 presents the multidimensional database concepts of the explained datacube.

This datacube can be described in UML (Unified Modeling Language, Blaha and Rumbaugh 2005) using packages for dimensions and cubes, and of classes for dimension levels and cube measures (Fig. 10.2).

Regarding spatial dimensions, three types can be defined: non-

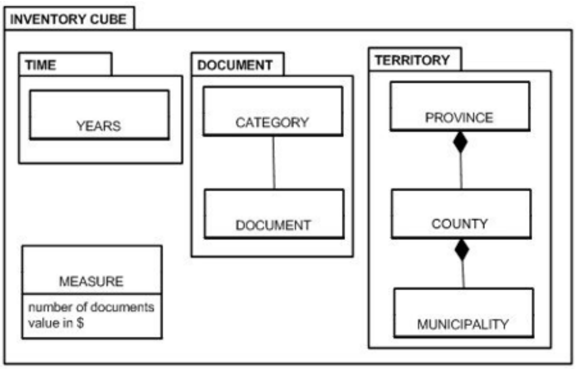

Fig. 10.2. A datacube expressed using the UML formalism where packages are cubes and dimensions and classes are dimension levels and measures

geometric, geometric, and mixed (Bédard *et al.* 2001). For the first type, spatial reference uses nominal data only (e.g. place names), i.e. no geometry or cartographic representation for the dimension members. It is the only type of spatial dimension supported by non-spatial OLAP and it is treated like other descriptive dimensions, leading to poorer spatio-temporal analysis and the non-discovery of certain correlations between phenomena that do not follow predefined boundaries. On the other hand, geometric spatial dimensions comprise, for every level of detail, the geometric shape(s) of every member (e.g. polygons to represent the boundaries of each municipality). This allows the dimension members (e.g. Quebec City) to be displayed and drilled on maps. The mixed spatial dimensions comprise geometric shapes for every member of only a subset of the levels of details. The members of the geometric and mixed spatial dimensions can be displayed on maps using visual variables (e.g. color) that relate to the values of the measures contained in the datacube. Fig. 10.3 shows an example of the three types of spatial dimensions expressed with spatially-extended UML.

The same classification can be made with the hypermedia aspect of a dimension. First, a non-hypermedia dimension exists when no dimension members are associated to hypermedia documents. Every SOLAP project seen so far fits in this category. Second, a dimension is said to be hypermedia if all dimension members, at all levels of detail, are associated with multimedia documents. The mixed hypermedia dimension is comprised of hypermedia documents for every member of a subset of the levels of the dimension. The hypermedia aspect can be applied to the highest level of aggregation only, to the finest level of detail only, or to intermediate levels. Furthermore, hypermedia documents can enrich non-spatial, mixed or

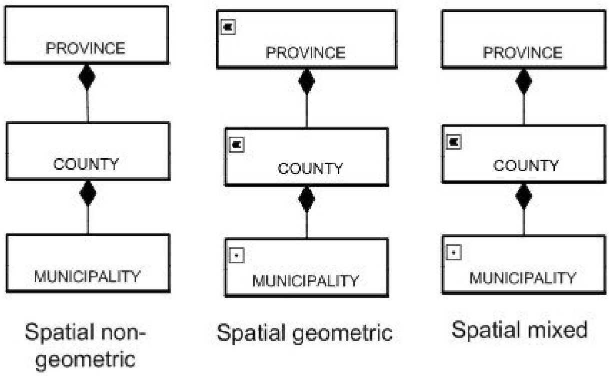

Fig. 10.3. Three types of spatial dimensions from left to right: non-geometric, geometric (2 polygonal levels, 1 punctual level) and mixed (1 polygonal level and 1 punctual level)

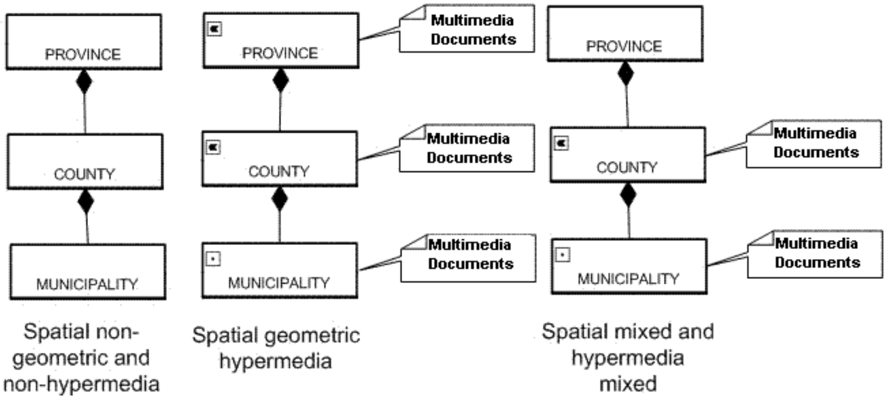

Fig. 10.4. Three different combinations of hypermedia and spatial aspects of a dimension

spatial dimensions. Fig. 10.4 illustrates an example of the three types of hypermedia dimensions, applied to a spatial dimension.

In a SOLAP user interface, navigation operators are similar to those used in OLAP but they take advantage of the spatial datacube structure. For example, two basic operators are drill-down and drill-up. Drill-down allows digging into lower levels of detail of a dimension and drill-up allows climbing into higher levels of detail. These operations are now available in the different types of displays, including maps, and can be specialized according to the type of dimension they manipulate (Rivest *et al.* 2003). One can drill on a dimension independently of the other dimensions. For example, a spatial drill allows the user to alter the level of granularity of a spatial dimension (e.g. territory) while maintaining the same level of thematic and temporal granularity. Such navigational operations can be executed by clicking directly on the elements that compose a display (e.g. a geometric element on a map, a bar element of a histogram, a cell of a spreadsheet table).

10.3 Application Example of Hypermedia SOLAP

To illustrate Hypermedia SOLAP, we show a project concerning the monitoring of erosion rates at selected sites along the road infrastructure in the Gaspésie and Îles-de-la-Madeleine regions, in the province of Quebec, Canada (Bilodeau 2005, Grelaud 2005). This project aims to supply decision-support tools to the Quebec Ministry of Transportation (MTQ) to help insure a better follow-up of erosion problems along roads in these regions.

The tool that was developed allows users to synthesize, to centralize, to aggregate, and to represent, in a simple way, all the pieces of information required to facilitate visualization, analysis and decision-making. In other words, the Quebec Ministry of Transportation (MTQ) faces erosion problems for road infrastructures in coastal areas and wants to improve the monitoring, control, and planning of the protection of coastal banks. Erosion is a natural process that has been progressing for millenniums as the coasts are subject to winds, waves, currents, tides, storms and to human activities. The MTQ identified 60 sites where the erosion of the coast is or will be a problem along highways 132 and 199. To solve these problems, the department builds infrastructures such as bridges, shoulders, and walls.

To support their work, the MTQ produces a large amount of documents (maps, plans, aerial photographs, LIDAR profiles, softcopy photogrammetry, research and technical reports, etc.) when inspections, measurement sessions, or research projects are conducted on the erosion sites. The first part of the project consisted in the inventory of all collections of documents related to erosion sites. To query this data inventory, a datacube was produced with 3 dimensions: time (production date), erosion site and document type. For this first datacube of the project, we had to allow easy visualization of the number, location and types of documents for each individual site or group of sites. In particular, we had to consider the cases where one specific document, for example a digital map of the coast of Bonaventure, is linked to more than one erosion site, leading to an aggregation formula that counts the documents only once at aggregated levels (i.e. municipality and county). This simple datacube is the example used to introduce hereafter the Hypermedia SOLAP. First, Fig. 10.5 presents the navigation that will be used in Figs. 10.6 to 10.9 and where all multimedia document types are linked at the lowest level of detail.

For this datacube, the user interface starts with two panels. First, in the left panel, the user selects the dimensions and measures from the upper section to drag and drop them into the lower section boxes called “columns” and “rows”. This allows the display of the selected dimensions and measures (e.g. “type of documents” per “region”) using only select, drag and drop (no SQL-type query to select the desired elements). Then, for the right panel (the display panel), the user selects from the horizontal toolbar the desired display type (maps, tables or graphics). Now, the user can “drill down” or “drill up” into the different levels of details of the selected dimensions using the navigation tools of the horizontal toolbar. For example, it is possible to create a map presenting the “number of documents” by “document type” for “counties” (general level of information) simply by dragging the measure and two dimensions into columns and rows and by clicking on the map display button (3 drags, 1 click, 3 seconds to produce

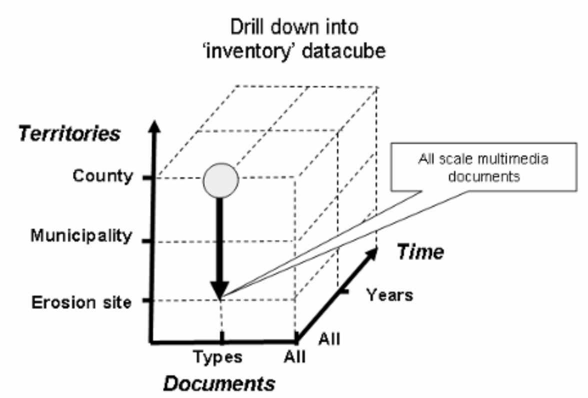

Fig. 10.5. Navigation into the territory dimension where all multimedia document types are linked to the lowest level of detail

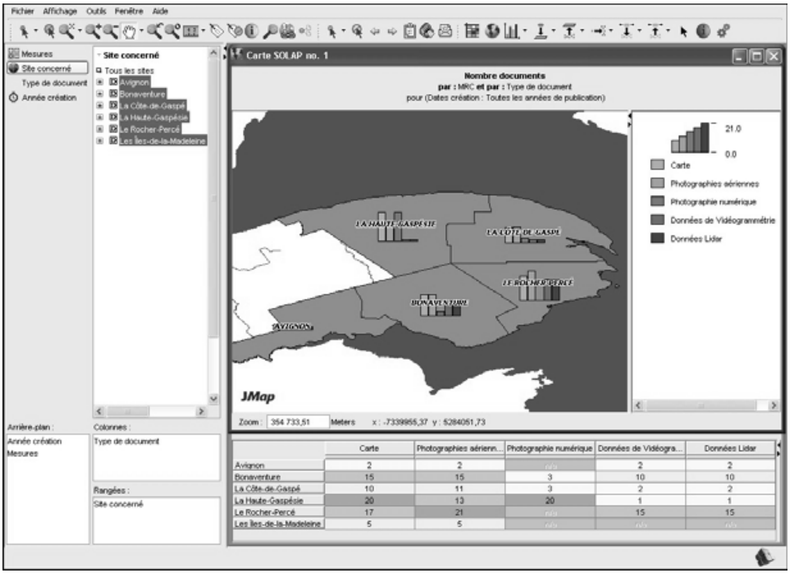

Fig. 10.6. Map and table displays presenting the "number of documents" for some "document types" and "county"

the map). Different displays for the same information are just one click away (e.g. table, histogram, pie chart) and they can be synchronized or not according to the demands of users. For example, Fig. 10.6 shows the number of documents, for several document types, per county (in both map and table).

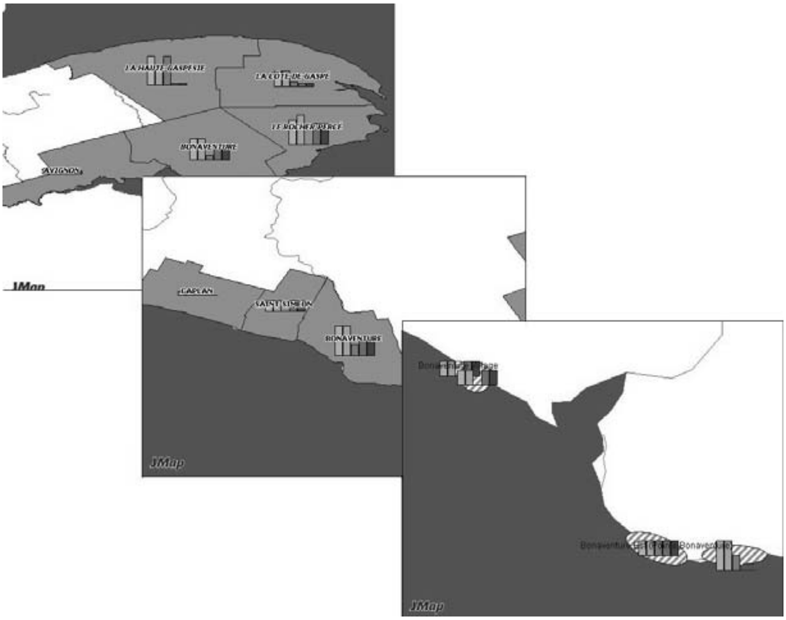

Fig. 10.7. Number of document by “county” (first map), by “municipality” (second map) and by “erosion site” (third map)

The advantage of SOLAP truly starts here, i.e. when one wants to explore the data from the first display. To navigate within this datacube in order to visualize the “number of documents” by “erosion site” (more detailed level of information), the user can simply navigate interactively at the various levels of details of the data. For example, to get information about a particular erosion site, the user can drill down spatially through the spatial dimension, i.e. from “county”, to “municipality” and then to “erosion site”. With 2-3 mouse clicks, users navigate in those map displays, tables or charts within seconds (Fig. 10.7).

In a SOLAP tool, different display types (map and table in this example) can be synchronized together to always reflect the actual analysis results. Thus, if the user desires such behaviour, a manipulation (drill down or drill up, for example) in one of these displays propagates the navigation operation in all active displays (Fig. 10.8).

Therefore, when users identify a site of interest (e.g. Bonaventure Est) in a natural way that fits with hypermedia navigation (i.e. simply clicking on the item of interest, no SQL-type query language or cryptic database structure), they can continue working this way and use the multimedia tool in the horizontal toolbar. They can then open the form related to the element of interest where hyperlinks provide access to multimedia documents

(Fig. 10.9). It is possible with this added information to better evaluate the erosion of the site itself.

This application includes three other datacubes managing the “erosion” characteristics, the “erosion sites” and the “structures” erected by the MTQ to solidify the road infrastructures (e.g. ripraps, shoulders, walls). These cubes contain different dimensions and measures (e.g. total length of structures and number of structures). For the “structures” datacube, two time dimensions are defined: the “date of inspection” and the “date of construction” of the structures. Thematic dimensions are “coast type”, “structure status” and “length of structure”. Finally three spatial dimensions are used to produces maps: “structures” represented by points, “erosion sites” represented by polygons, and “roads” represented by lines of road segments.

Now with the “structures” datacube, it is possible to create, in 2-3 mouse clicks and within 3-5 seconds, a map and a table of the number of structures at the most general level of the “site” dimension, i.e. in the different “counties” (Fig. 10.10). These two different displays (map and table) allow the user to identify the sites that contain the largest number of structures.

Once again, it is possible in a hypermedia SOLAP application to link multimedia documents to all levels of detail of information. Fig. 10.12 presents the navigation example that will be used in Figs. 10.13 to 10.15 and where different document are linked to different levels of detail.

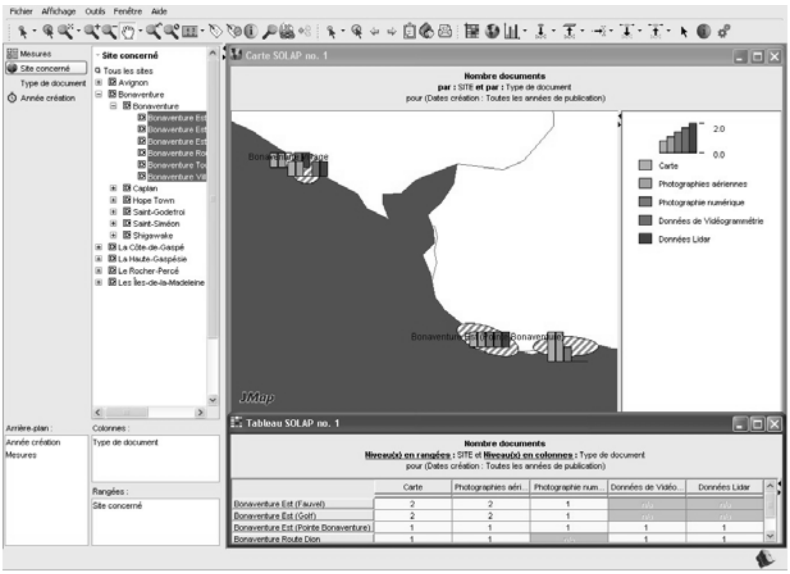

Fig. 10.8. Erosion sites map and table where documents are counted by “document type”

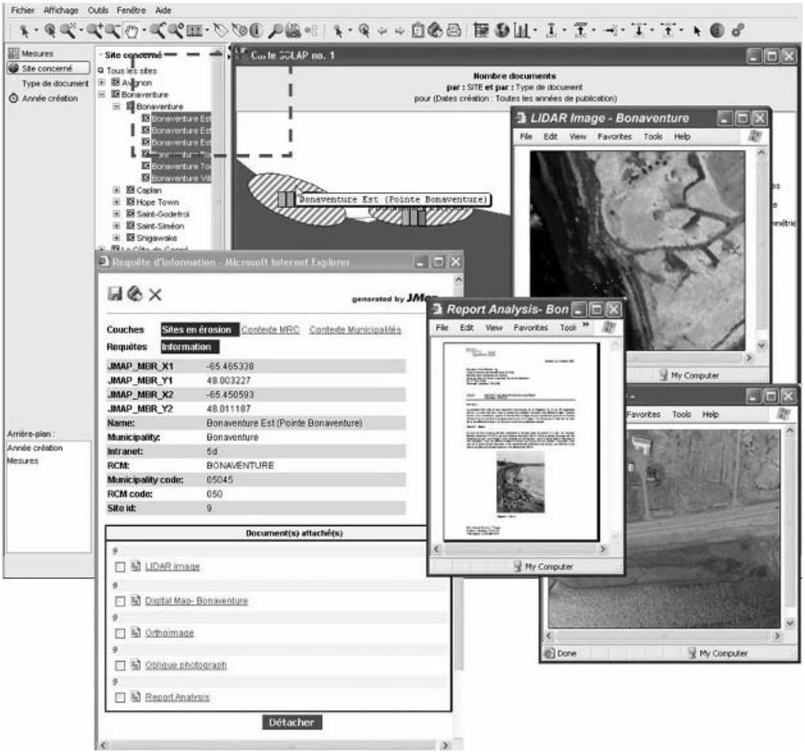

Fig. 10.9. Access to multimedia documents (e.g. report, digital map, LIDAR data and Orthoimage) of the Bonaventure "erosion site"[1]

As explained before, from this point, the user can drill down spatially to see more details through the spatial dimension (Fig. 10.11).

At the municipal level (second level of detail), it is possible to visualize multimedia documents linked to a municipality by opening the municipal "form"; here the user finds a list of hyperlinks to the municipal multimedia documents. At this level of detail, only documents that show the municipality level of information are linked, i.e. small-scale digital map. For example, for Bonaventure, there exists a digital map of the coast that localizes all the structures built on this littoral (Fig. 10.13). In our application, documents exist for the three most detailed levels ("municipality", "erosion site" and "structure"). Eventually, it would be interesting to find more general documents to link to the county level (e.g. very small-scale remote sensing images).

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[1] For this figure and the following ones, SOLAP environment and toolbars were removed to increase picture size and improve readability.

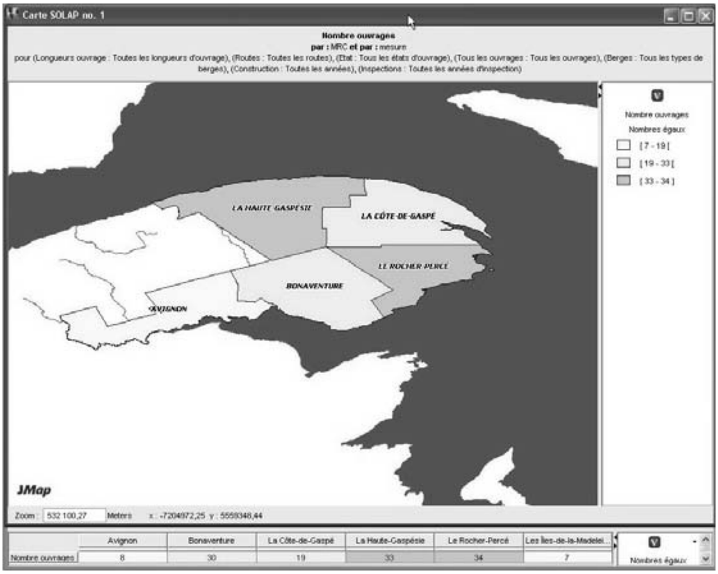

Fig. 10.10. Number of structures by "county"

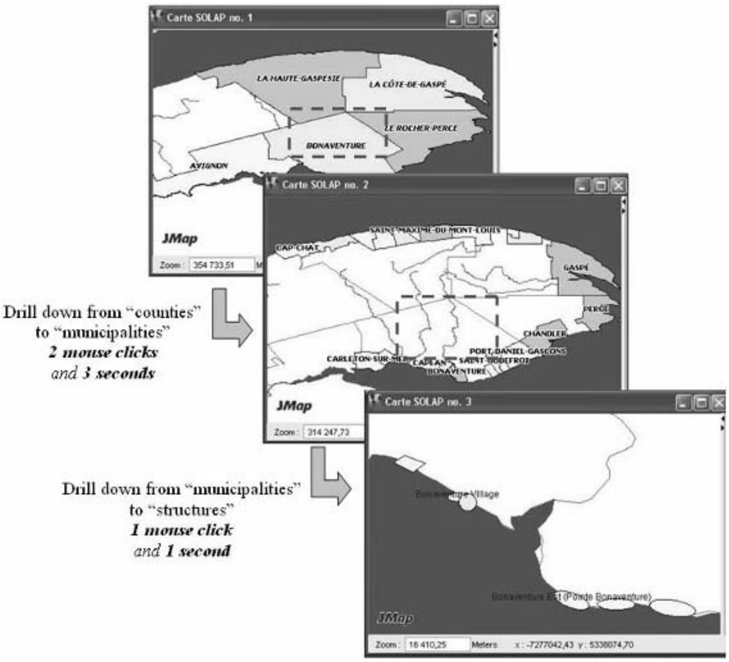

Fig. 10.11. Number of structures by "county" (first map), by "municipality" (second map) and by "erosion site" (third map)

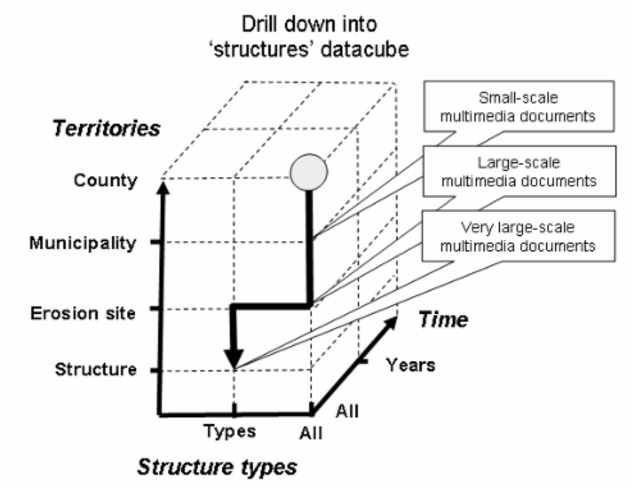

Fig. 10.12. Navigation into the territory and structure types dimensions where different document scales are linked to different levels of detail

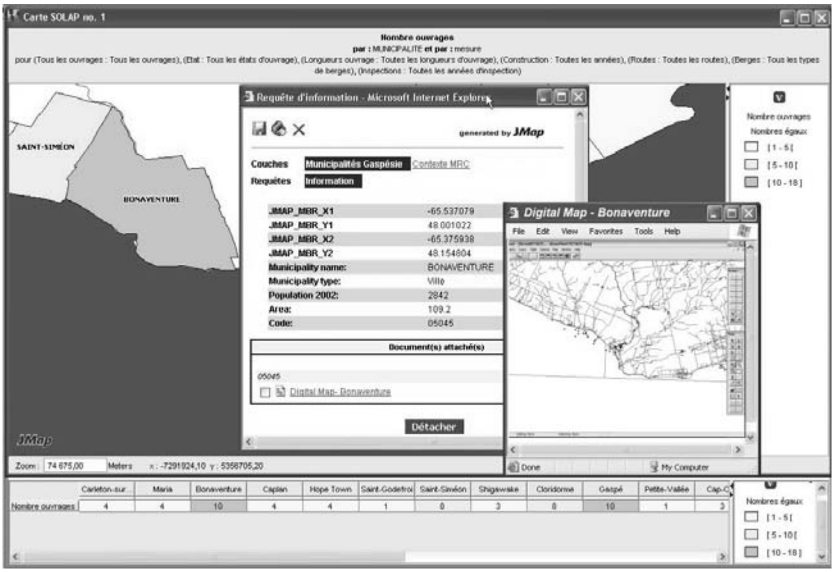

Fig. 10.13. Access to multimedia documents (e.g. a digital map) liked to the "municipality" level of detail

The user can then drill down "spatially" to produce a map of "erosion sites". In this view, the user can drill down "thematically" in the structure dimension (in the left panel) to show, on the map display, the number of structures per "structure type". In this case, the tool uses histograms, su-

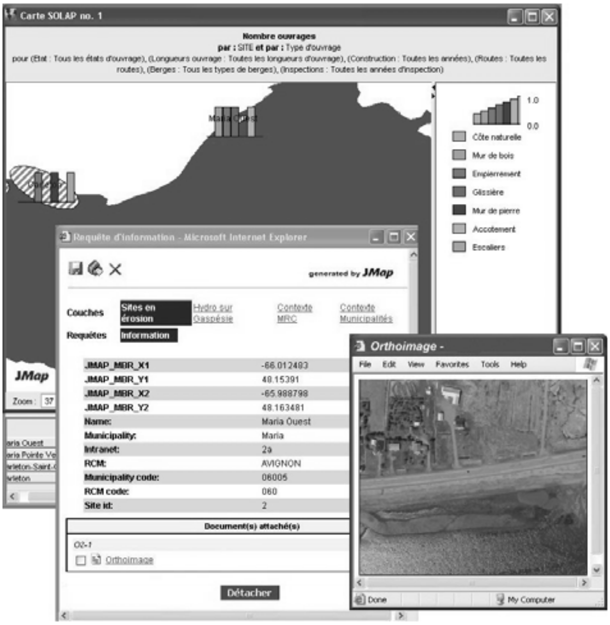

Fig. 10.14. Access to multimedia documents (e.g. an orthoimage) linked to the "erosion site" level of detail

perimposed on each erosion site polygon, to display the distribution of structure types using colors (see Fig. 10.14). When the user identifies an erosion site of interest (e.g. Maria), it is possible to visualize multimedia documents linked to this erosion site. At this point, only links to documents that display information at the level of the erosion site are provided, for example, a large-scale orthoimage of the coast.

Finally, a drill down operation to the "structure" level of detail can be executed to individually show each structure at a specific erosion site (see Fig. 10.15). By clicking on a specific structure, it is possible to access the associated multimedia documents. At this level of details, only links to documents that supply information at the structure level are provided, i.e. very large-scale images, detailed photographs, videos, graphs or reports. It is possible, with this complement of information, to better evaluate the condition of a structure site itself.

10.4 Evolution of SOLAP Hypermedia

Future work in this field will focus on the definition of location based (web) services, and the design of Service Oriented Architectures (SOA) to

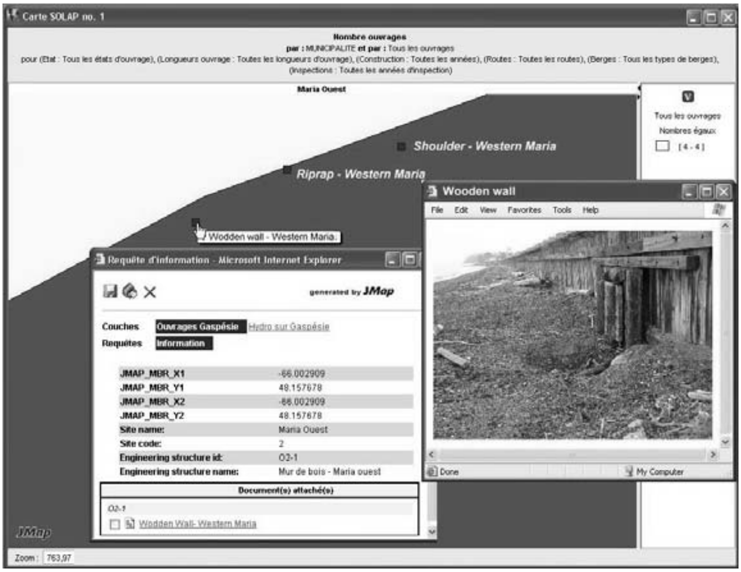

Fig. 10.15. Access to multimedia documents (e.g. a photograph) liked to the “structure” level of detail

support these services, in order to enable the real time delivery of contextual hypermedia information to the end user. By contextual we mean that the information provided depends on the “context of the user”. For a mobile user, who accesses the system through a wireless network, on a device like a PDA or a smartphone, the context could be defined by his location and his surrounding. A context aware hypermedia SOLAP application (or service) could thus enhance the map and all the information already provided to the user through the real time delivery of hypermedia information in relation with the location of the user. Such services could be of great importance in emergency or crisis situations. For instance, different groups of firemen at the same operating theatre could have real-time access to specific information (e.g. reports of difficulties encountered by other groups; the position and the movements of other units, video images stemming from cameras in the surroundings or filmed by other units, detailed maps of a specific building sent from headquarters, etc.). This could significantly influence the way they will perform their work. In addition, they could cross-reference data on-the-fly and they could obtain global pictures on-demand through the aggregation of information, with the simplicity and speed of a SOLAP user interface. In this example, not only the absolute location of a specific unit, but also the relative positions of the different groups, have an impact on the information delivered to users.

The previous example also illustrates the possible role of such Service Oriented Architectures in the sharing of hypermedia information between different users. An extension that we intend to implement in a web-service architecture is the enhancement of the hypermedia SOLAP maps with annotations or with the addition of ad hoc multimedia documents that allow the sharing of information between different users in real-time. The delivery of hypermedia documents could, for instance, be based on a peer-to-peer architecture approach in order to increase the transfer rate and to avoid the storage of shared resources in a unique place, which may require large storage infrastructures. A user could select hypermedia documents to display on the basis of metadata which describe the said resources, or, they could automatically be displayed on the users' screen, if they correspond to the "user profile". While such developments will enhance the experience of the user with the system, important questions remain with respect to the competing objectives of providing documents to fulfil the requirements of specific users and concomitantly respecting privacy concerns. Future works related to the NSERC Industrial Research Chair will take such considerations into account and will address some technological and legal issues raised by the distribution and the sharing of such Hypermedia and SOLAP information over networks. As we have designed and developed the SOLAP technology used for the project presented in this chapter (now commercially available as JMap Spatial OLAP Extension, see Kheops 2005), we will continue improving this technology, including its enrichment with other types of data such as hypermedia.

10.5 Conclusion

Although it was beyond the goal of this chapter to present in details the new technology called SOLAP, we have provided an overview of this technology and attempted to demonstrate, using examples, that SOLAP technology naturally fits with hypermedia GIS. The "document inventory" datacube shows interesting ways to query inventory results such as statistics on documents types, areas covered, publication dates and so on. The "structures" datacube shows interesting ways to get statistical data at the appropriate level of analysis along with the corresponding hypermedia documents. The management of multimedia documents into a spatial datacube is innovative. Such Hypermedia SOLAP uniquely combines explicit spatio-temporal aggregated data (to get the global views) with statistics resulting from the cross-referencing of all dimensions at all levels of analysis. Furthermore, Hypermedia SOLAP also combines the above with implicit information from hypermedia documents at the corresponding levels of analysis (to get more insights from raw information). In addition, the inherent capability of SOLAP to support a non-linear approach for navigating within databases is also a novel way to provide access to hypermedia documents at different levels of detail. As we have seen, it is possible, within a Hypermedia SOLAP datacube, to organize documents by spatial level of detail, i.e. by the region of interest shown or studied by the document. However, other classification alternatives could have been implemented, such as creating groups of documents by level of detail (e.g. digital vs non digital document types) or groups of epochs to produce temporal levels of detail (e.g. publication epochs 1995-99, 2000-04). Also, we have illustrated that users can access multimedia documents by clicking on the geometric elements shown on a map, as is done with Hypermedia GIS; however, all the other types of SOLAP displays can also provide access to hypermedia documents (e.g. by clicking into a table cell or a histogram bar). Finally, we have described the potential evolution of Hypermedia SOLAP from the traditional architecture to a web service architecture.

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