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Metadata Management Services for Spatial Data Infrastructure

- A Case Study of a User-centric Implementation Strategy for an Academic Institution

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GLOSSARY

BOUDING BOX
The geographic coverage of a resource, commonly expressed as two corner points of a rectangular or as four coordinates describing spatial extent in direction of four geographic directions.

CATALOGUE
Service / component / arrangement for discovering resources through metadata registry service / component / arrangement for managing catalogues and registers through metadata about metadata

CLEARINGHOUSE
Broker for access to capabilities, particularly metadata resources.

CS/W
A Metadata Catalog Service is a mechanism for storing and accessing descriptive metadata and allows users to query for data items based on desired attributes. CS/W may be used for storing and accessing metadata about logical files.

ebRIM
"e-business Registry Information Model" - an information model from Organization for the Advancement of Structured Information Standards (OASIS) for documenting and managing metadata objects in a Web registry. Paired with ebR, which is an interface specification for a combined registry - repository (reg-rep) service.

METADATA
Roughly: Data about data, information about information.
Metadata is structured information that describes, explains, locates, or otherwise makes it easier to retrieve, use, or manage an information resource.

METADATA REPOSITORY
Persistence / storage function particularly for metadata resources (access by ID)
Archive Function/service/capability for managing the persistence of data resources (lifecycle, lineage, provenance).

RESOURCE
In at hands work the term resource is used for digital or analogue information, data, or a repository that hosts information or data. Resources can be spatial and aspatial data, metadata records, web services, all kinds of documents and media, RSS feeds, KML documents, REST URLs, metadata catalogues, and more.

SOAP
The Simple Object Access Protocol (SOAP) is a lightweight, XML-based protocol for transfer of structured data and type information across a net- work in a stateless manner. Web services use SOAP for communication between WS registries, remote WSs and client applications.

UDDI
The Universal Data Description and Integration (UDDI) is the global look up for locating services. The standard provides an information repository and query

service for WSs. UDDI is domain-independent standard method allowing publishing and discovering information about WS.

WEB INTERFACE
An interface between user and web server, via HTTP protocols using web browsers. It's where the interaction between human and machine occurs (Redlin, 2010).

WEBSERVER
A computer or application being part of a network (e.g. the world wide web or a local network) offering services.

WSDL
The Web Service Definition Language (WSDL) is an XML based language used to describe WSs and how to locate them (Chinnic, Moreau, Ryman, & Weerawarana, 2007). WSDL gives details of how communication with a remote WS is done. Using standard XML schema, it describes how to interpret the messages, how to contact the WS and the protocols to use. WSDL helps avoid the misinterpretation of data between client and services.

ZUSAMMENFASSUNG

Am Geographischen Institut der Humboldt Universität zu Berlin wird täglich mit räumlichen Daten gearbeitet. Die erfolgreiche Arbeit von Forschungsgruppen, Lehrtätigen und Studenten basiert auf brauchbaren Datengrundlagen. Um diese Fülle von Ressourcen überschaubar zu organisieren wird seit einigen Jahren eine Geodateninfrastruktur unterhalten. Sie verfügt - neben anderen Anwendungen - über ein Geoportal, das dem Benutzer erlaubt auf die Geodatenbanken des Instituts zuzugreifen. Die Geodateninfrastruktur erlaubt dem Benutzer Ressourcen institutsweit zu suchen, anzuzeigen und (wieder) zu benutzen. Durch dieses kooperative Netzwerk sollen Synergieeffekte erzielt werden da Beschaffungskosten für Neudaten entfallen. Zusätzlich kann die Geodateninfrastruktur Lehrtätigkeit unterstützen und als praktisches Beispiel in den Lehrplan integriert werden. Kernstück dieses virtuellen Netzwerks sind Metadaten. Sie ermöglichen die umfassende Beschreibung der Ressourcen des Instituts, sowie Suche und Identifikation von Ressourcen durch das Geoportal. Der Metadaten Katalog des Instituts dient der Organisation dieser Metadaten in standardisierter Form.
Das Ziel der vorliegenden Arbeit ist es, ein neues Metadaten Management Systems für die Geodateninfrastruktur des Geographischen Instituts zu implementieren. Der am Ende stehende funktionsfähige Prototyp soll vom Leitbild des „user-centric SDI“ Ansatzes geprägt sein. Dieses Konzept repräsentiert die nunmehr dritte Generation von Geodatenbanken und rückt den Benutzer in das Zentrum der Aufmerksamkeit - und dies von Beginn des Implementierungsprozesses an. Der gesamte Arbeitsfluss soll demzufolge stark vom Feedback der späteren Benutzer und deren Anforderungen geprägt sein. Mit „Joint Application Design“ und „Rapid Prototyping“ wurden Methoden gewählt, die diese Art von Software Entwicklung unter aktivem Nutzerengagement unterstützen. Als Folge nehmen Nutzerbefragungen, Präsentations- und Informationsveranstaltungen sowie Fragebogendesign und Auswertung in dieser Arbeit prominente Stellungen ein. Viele Weichen in der Softwareentwicklung wurden nach Auswertung von Nutzerbefragungen gestellt. Im Vorfeld wurde eine Unterteilung der Institutsmitglieder in „Experten“ und (potentielle zukünftige) „Nutzer“ getroffen. Wenige Experten wurden für grundlegende Entscheidungen herangezogen; die Nutzergemeinschaft wurde zu Informationsveranstaltungen eingeladen und mittels Fragebogen zum Thema Interface Design und der

optimalen Bedienbarkeit des Geoportals befragt. Diese Veranstaltungen sollten über die Vorteile der Geodateninfrastruktur informieren, und durch aktive Beteiligung die Nutzergemeinschaft zu stärken und zu vergrößern. Jede GDI basiert auf Kommunikations- und Kooperationsprozessen, weshalb diese Aktivitäten Garanten für eine langfristig erfolgreiche Initiative darstellen.
Eine vorangegangene Software Evaluation ließ, unter Berücksichtigung der gesammelten Nutzeranforderungen, für das Softwarepacket *GeoNetwork open source* entscheiden. Die Technische Entwicklung und die Gestaltung der Computer-Nutzer-Schnittstellen des GeoNetwork Prototypen wurden in sich wiederholenden Feedbackschleifen geplant. Abwechselnd soll die Generierung neuer Prototypen auf erneute Präsentationen inklusive Nutzerbefragungen folgen. Die Ergebnisse dieser Befragungen geben die Richtung für weitere Arbeit am Prototyp vor. Als methodischer Rahmen diente der „Rapid Prototyping“ Ansatz. Diskussionen in der Runde der Experten sowie die ständige Einbindung dieser in wichtige Entscheidungen rund um die GDI soll Teambildung fördern und die Mitglieder der Expertenrunde an das Projekt binden. Sie sind es, die später Verantwortlichkeiten für Metadaten übernehmen und delegieren können und damit einen wichtigen Beitrag zur Wartung und Instanthaltung der Infrastruktur leisten.
Vorliegende Arbeit beschreibt Planung, Umsetzung und Ergebnis des Implementierungsprozesses dieses Prototyps unter Anwendung spezieller, auf Benutzer Partizipation und Feedback aufbauender Methoden. Es wird am Beispiel der speziellen Fallstudie diskutiert wie weit die gewählten Methoden im Sinne des Konzept des „unser-centric SDI“ eingesetzt werden und wie diese Praxis nachhaltig die Benutzerzufriedenheit steigert und zum Erfolg einer GDI langfristig beiträgt. Die Arbeit schließt mit einem Ausblick in die nahe und ferne Zukunft der möglichen Weiterentwicklung der GDI des Geographischen Instituts.

ABSTRACT

Working with spatial data is “daily bread” at the Department of Geography at Humboldt Universität zu Berlin. The success of research projects, staff members’ work and students’ university routines depends on high quality data and resources. A couple of years ago the department’s own Spatial Data Infrastructure was founded to organize and publish these resources and corresponding metadata. This virtual infrastructure offers a geoportal that allows the user to discover, visualize and (re-)use the department’s spatial and aspatial resources. Maintaining this cooperative network aims at synergy effects like reduction of costs for the acquirement of new resources. Moreover, SDI can be used to support teaching activities and serve as a practical example in the curriculum. Central for SDI are metadata; they represent a comprehensive structured description of the department’s resources and are a core piece of the geoportal’s functionalities to discover and identify data. The department’s Metadata Catalogue serves as a container for structured organization of metadata.
This project goal is the implementation of a new metadata management system for the department’s Spatial Data Infrastructure. The resulting prototype should be developed following the user-centric SDI (third generation SDI) paradigm. This approach considers the (possible future) user community’s requirements and feedback as highly important and suggests an implementation process with continuous user participation. Both methods, “Joint Application Design” and “Rapid Prototyping”, rely on active user participation and were chosen and applied to support this concept. As a consequence, user assessments, information and dissemination activities and design and analysis of questionnaires occupied a prominent part of this study; the most important decisions during the implementation process were based on user feedback. In the forefront, users were distinguished between (possible future) “users” and “experts”. A small group of experts was asked to discuss and make fundamental decisions about the department’s SDI development, and the community of users was invited to informative events and to participate by filling out a questionnaire about the geoportal’s usability and interface design. These events were expected to raise user interest, foster a user community and user participation and to provide information about usage and benefits of the department’s SDI. SDI, as a

communication and cooperation network, benefits from these activities in the long run.

A preliminary software evaluation and the assessment of user requirements led to the decision that *GeoNetwork open source* was the most promising software to replace the department's current metadata management system. Technical development and implementation of GeoNetwork prototype and its interfaces was accompanied by continuous feedback loops in accordance with the concept of "Rapid Prototyping". The development of each new version of the prototype is followed by the presentation to users and collection of feedback. This feedback sets the agenda for further developments. Members of the expert group were constantly invited to participate in the SDI implementation process. Discussions regarding elemental SDI issues should foster team building and should bind experts to the project. They are the ones who are needed to take over custodianship for resources and metadata and to therefore play central roles in maintaining the department's SDI.

The thesis at hand describes the planning, design, realization and results of the implementation of a metadata management system prototype, by facilitating special, user participation methods. Using the example of this special case it discusses the combination of these methods with a user-centric SDI approach and implications in terms of user satisfaction and long-term SDI success. The final chapter offers a discussion about the implementation process and closes with an outlook on the possible short and long term development of the department of Geography's SDI node.

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1. INTRODUCTION

At the beginning there is a question, asked by both, resources' stakeholder and users:
"How do we improve access to resources and achieve interoperability?"
A possible answer appears as:
"Publish and re-use your resources with a Spatial Data Infrastructure".

The introductory chapter presents the initial motivation behind the idea of implementing a system to manage metadata within a Spatial Data Infrastructure – an infrastructure which is built to share resources. The design of the implementation process for this special case, anticipated goals, useful methods, planned work procedure and research objectives are highlighted and introduced. A chapter-by-chapter summary of the structure will guide the reader through this thesis and completes this introduction.

1.1. MOTIVATION AND THE UNDERLYING IDEA

Spatial Data Infrastructure (SDI; sometimes also "GDI" for Geo-Data Infrastructure) is all about facilitation and coordination of the exchange and sharing of spatial data. It constitutes a set of relationships and partnerships that enable data sharing, updating and integration. This thesis represents a manifestation of this SDI approach within the frame of a special case study.
The anticipated goal is the implementation of a new metadata management system for the Spatial Data Infrastructure of the Department of Geography at Humboldt Universität zu Berlin. This special case study brings about a unique initial situation and a set of specific user requirements. The finally implemented metadata management system should enable users to easily search for, discover, find and visualize spatial and aspatial data. A successful implementation process is designed based on the department's currently used SDI architecture, and tries to carry on with its' goals and vision and respects Department's SDI users' requirements.

The Department of Geography's SDI consists of just one single SDI node without vital connections to other, external nodes. Nonetheless, long-term plans for the department's SDI do not rule out the establishment of such connections with external SDI nodes in the future. This case study tries to build on widely accepted SDI concepts, its framework, standards and technology. Know-how about existing SDI solutions and proven SDI components and technology are adapted and adopted for this special case.

The implementation process follows a number of predefined key principles. They are collected to ensure high quality and high user satisfaction with the finally implemented metadata management system:

-the implementation process is designed using a user-centric concept to achieve high levels of user feedback and participation, SDI dissemination, user satisfaction and SDI usability and long-term success;

-the solution shows a common, re-usable modular architecture;

-its framework and agreements are based on common, re-useable concepts of SDI and can be discovered and re-used in turn;

-chosen agreements and standards have inheritance patterns (e.g. OGC standards);

-the software solution is published under a free and open source license;

-requirements to use a specific reference system (UTM), services are classified using specific, SDI-community-conforming vocabulary;

-the department's SDI exists as a "standalone" SDI node; this basic architecture must not be changed;

-internationally agreed SDI technologies, frameworks and standards should be respected to support possible future data sharing with external nodes

-the solution features one central database holding all metadata;

Basically, users should be better informed about SDI, implemented metadata management services, and its capabilities and possible benefits for the user community. This increases the number of users which are consuming SDI services and their satisfaction. The finally implemented geoportal and metadata management system aims at easily enabling consumers to discover, access, visualise, combine and use department's resources.

To ensure the long-term success of the development process of the department's SDI, this thesis attempts to combine methods available in Joint Application Development (JAD), Rapid Prototyping (RP) and in human-computer interaction, especially interface design. This should lead to a high level of feedback and collaboration with experts and user groups. Experts as well as future users are constantly asked for feedback and participation. It is a strategy following approved standards, aiming at increased user satisfaction and higher long-term participation and motivation from experts and SDI stakeholders. This approach intends to help overcome prominent barriers for a successful SDI, such as custodianship for and maintenance of data and metadata.

The term used above "resources", refers to all kinds of searchable content within an SDI: spatial and aspatial data, media, services, etc. That means that SDI is not restricted to only spatial data, it can be put in place to administer the sharing of various kinds of resources.

1.2. RESEARCH OBJECTIVES

The design of the new metadata management system implementation process plays a prominent role in this thesis. This design process is strongly influenced by the special case of the Department of Geography's SDI, its architecture and future user requirements. The present study's research objectives are strongly connected with the intention to optimize implementation design and are defined as:

Can the approach chosen ensure long-term SDI success?

-Are the implementation strategy and methods applied adequate for the chosen software solution?

-How can user satisfaction with the metadata management system be increased under the conditions of this case?

-How can the implementation process be designed to respect the user-centric SDI concept?

1.3. STRUCTURE

The first section introduces the essential concepts of SDI and of the main SDI components. To this end, a variety of SDI approaches and classification systems are presented, including their development over time. Furthermore, this first section is devoted to metadata and metadata standards.

To make metadata usable within an SDI, some kind of system is needed that manages metadata in a standardized way and enables data users to create, share and maintain their metadata. Therefore the principle of operation of metadata management systems (or: metadata catalogues) is illustrated, as well as how they are interacting with other SDI components such as geoportals. These interfaces, where user-computer-interaction of an SDI takes place, are discussed with reference to technical and conceptual specifications as well as historical development.

Moreover, it covers relevant issues and current concepts and tries to tie up with actual research streams. In the course of this, the issue of developing SDI-concepts and its ontology are broached. The idea of Service Oriented Architectures (SOA) in connection with SDI finds a place in the discussion.

The present study focuses on current issues regarding metadata, such as the development of metadata standards and their semantics. Together with OGC service schemata and specifications, they provide the basis for metadata management systems such as metadata catalogues. The relevance of metadata catalogue standard specification for interoperability in distributed systems is presented. This section closes with the topic of designing user-interfaces to increase usability, concentrating especially on geoportals, metadata queries and visualization.

The subsequent chapter describes this study's special case of the Department of Geography's SDI node at Humboldt Universität zu Berlin. It explains the present SDI^{light} approach and specific institutional, technical and legal restrictions and specifications of the Department's infrastructure. Established frameworks, together with the technical architecture of the existing SDI node provides essential insight in this work's initial situation and starting point. Further, this part of the work presents the chosen software solution and its basic features.

The section entitled "Methods" describes step-by-step how the anticipated goals were pursued and justifies the methods used to find approaches to solve problems.

It opens with a description of this work's underlying implementation concepts, and closes with methods used in the research process from the user assessment questionnaire to presentation and discussion of prototype's interfaces.
The subsequent part presents intermediate and final results. Outcomes are presented in a chronological order, illustrating the implementation process by describing step-by-step the intermediate results, logically based on each other and justifying the design of the research procedure.
The present study finishes with a brief discussion and reflection on the whole implementation process and its results, ending with comments on further development and continuation of metadata management system development.

2. STATE OF PLAY

Recent scientific work in the fields of SDI, metadata and metadata management, geoportals and related international standards and specifications and computer user interaction studies contributes essential knowledge to this thesis. Chapter 2 introduces the most important approaches and developments, starting with SDI. For this, aspects of recent developments and the historical context, benefits and purposes, technical structure and functionality, as well as different specifications and applications of this virtual infrastructure and related concepts, are described.

2.1. SPATIAL DATA INFRASTRUCTURES

Spatial Data Infrastructure has become a very relevant topic in recent years. Its history is rather short – the concept referred to as "SDI" has existed since 1993. For organisations working with spatial resources it is a widely used concept for collaboration across all kinds of hierarchical levels and in many different variations. It is a concept based on international standards providing us with interfaces and services, like catalogue services, to individually set up organisations' infrastructure. The situation in the field of searching for, sharing and integrating spatial data and affiliated resources is a very heterogeneous one and there is a wide range of nameable international and national organisations and collaborations engaged in developing SDI and related concepts (Grill & Schneider, 2009).

From a conceptual point of view, SDI is a virtual network infrastructure based upon a series of institutional, technical, cultural and economic arrangements and standards. Its purpose is to establish an interactive framework to facilitate access to and use of geospatial resources like data, data services (e.g. Web Mapping Services [WMS], Web Feature Services [WFS], and Sensor Web Enablement [SWE]), processing services (e.g. Web Processing Service [WPS]) and applications (e.g. GIS software and software clients), which vary in whether they are online or offline, proprietary or without an official owner (Aditya & Kraak, 2007).

One of the most important components of an SDI is its access gateway or catalogue service which manage methods of facilitating data access through the SDI (Bishr & Radwan, 2000; Masser, 2005). These catalogue services which are vital and of the highest priority for the success of SDI list descriptions about geospatial resources, namely the metadata records.

Access to the richness of spatial data collection throughout nations receives plenty of attention since it can probably be used for a large number of applications and as a basis for a wide range of decisions (Nebert, 2004). Through a Spatial Data Infrastructure private institutions, governmental organizations and scientific institutions can share and access geospatial resources. In this way, cooperating agencies achieve synergy effects and avoid expenditure in a cost-intensive section. It is estimated that about 80% of the cost of GIS projects goes towards acquiring data (Aditya & Kraak, 2009).

The vision of “created once, used many times” was created in late 1970s. National agencies identified the need for standards and strategies for a coordinated and cooperative use of geospatial data (Grooth & McLaughlin, 2000). Since then, apart from a huge number of regional and institutional efforts, more than 100 national SDI initiatives have been established within and between many countries at local, regional, national and global scales (Crompvoets, et al., 2005).

SDI initiatives follow the purpose of promoting sustainable development, economic development, and more efficient governance, as well as from disaster awareness and mitigation action at all levels, be it global, national or local (Williamson, Rajabifard, & Feeney, 2003).

2.2. SDI COMPONENTS

Grill & Schneider (2009) distinguish three main components of SDI: the database system, the catalogue system and the visualization system or user interface. These components are not created from one single software application and there are many possible solutions available.

For metadata management and catalogue services, the application bundle GeoNetwork can be used as a key tool. It will be the topic of detailed discussion later; let us first take a look at other parts of the system.

Since the database is a very basic and prominent feature of every SDI, database sciences become a crucial part of this stream of contemporary Geomatics and

Geoinformatics. Only a database system which supports spatial data – called a “spatially enabled database” - can be implemented in SDI; in most cases, a standard database system is used and extended by a spatial extension (e.g. PostGIS). This combination is well known, involves a very stable and big community, and in most cases supports the “free and open source” -paradigm. Visualization of the outputs brings the user to a point where he/she sees the actual resource for the first time. This service is often provided by a geoportal application (e.g. providing a screenshot view of a spatial data set) with an integrated web mapping service (WMS). This geoportal is the actual access point for users providing a user interface, and enabling the user to search the metadata catalogue and to discover resources.

2.3. SDI CLASSIFICATION

Amongst other aspects, it is possible to distinguish SDI by:
-Its institutional scope,
-Its geographical dimension (and resulting level of detail), and
-Its conceptual approach (or generation of SDI).

Frameworks for sharing geospatial resources vary from global SDI initiatives, to regional and national ones, down to local or institutional SDIs. The most common one is the National SDI (NSDI). Supranational SDI initiatives additionally involve a greater number of cultural, political and security driven, and linguistic questions to be asked, issues to be tackled and agreements to be found. Since the present study deals with an SDI of modest dimensions these issues are negligible.

Furthermore, according to SDI conventions and standards, each SDI can be characterized as being of the first or the second generation of SDIs and are divided into those seen as having either classic infrastructure, or as a network infrastructure.

2.3.1. FIRST AND SECOND GENERATION SDI

First generation SDI can be recorded from the mid 1980 on. USA and Australia became precursors in this development when they started to develop data access relationships and frameworks.

At the times of these first SDI initiatives, concepts of different levels of SDI, as defined in the current SDI hierarchy model, were not developed yet; nor a consistent framework for planning, developing and standards. Instead, each country set up rudimentary, rather data driven systems according to national requirements and priorities.

The main goals of the first generation of SDIs were to promote economic development, to stimulate more efficient government and to foster environmental stability and sustainability. Data was the key driver and since the development of SDI models has moved on, first generation SDI is seen as a basis for second generation SDI to be built upon (Williamson, Rajabifard, & Feeney, 2003).

SDIs of the second generation announce a different focus. SDI communities arose around the world and started to exchange know-how and experiences through conferences, workshops and forums. Doing this, they developed the new SDI conceptual models of the second generation, which nations started to create around the turn of the millennium.

SDI of the first generation focuses on data and products, whereas SDI of the second generation is process-based. The key driver is no longer data; instead, development is driven by the use of that data, and the need of users.

The approach of second generation SDI concentrates on facilitation of and coordination between different groups of users. The techno-centric viewpoint of first generation SDI has shifted to a more socio-technical one with a focus on communities of stakeholders, providers and users (Figure 1). This new point of view underlines that, besides the technical level, implementation strategies should also address the respective community barriers and societal issues to ensure the success of a spatial infrastructure. For many infrastructures, this approach is still used today.

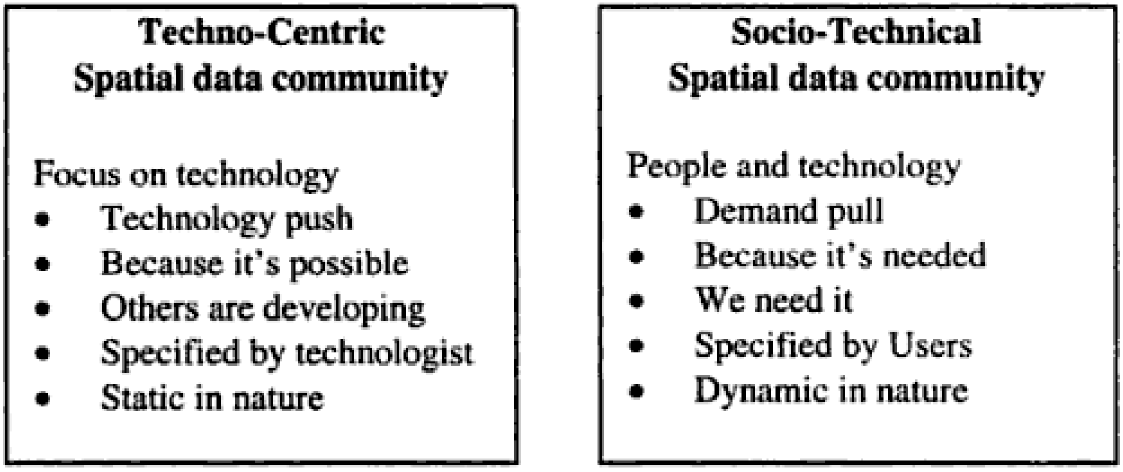

Figure 1: Techno-Centric vs. Socio-Technical position.
(Williamson, Rajabifard, & Feeney, 2003)

The value of first generation SDI was measured by the amount of shared data, by the output of the network, and by the monetary savings for both, producers and users of spatial data. For the second generation, there exists a more holistic understanding of financial and socio-cultural benefits for society. For example, the fact that SDI contributes to a range of decision making processes, including those of national security and disaster management (Rajabifard A. , 2009; Masser, 1999), is taken into account and valued.

Second generation SDI are developed in accordance with conceptual and funding models, a development strategy including implementation timeline and milestones, and elaborated concepts for participation and benefit sharing. This generation respects the advantage of an independent coordination entity, be it a committee, a governmental-, or a private organization. Cooperation and coordination with other SDI initiatives throughout nations and regions are seen as essential, especially when adopting technical specifications and standards. This enables a seamless combination and usage of neighbouring SDIs and the support of cross-border decision processes (Williamson I. P. et al. 2003).

Current research aims at promoting the new paradigm, called user-centric SDI. It can be seen as a further development of the second generation. In view of the possibility of adopting these standards and structures, it is introduced as the third generation of SDI.

Recent developments in Spatial Data Infrastructure design show again a change in paradigm; from data-centric and process-based paradigms, which were true for first and second generations of SDI as described above, SDI development aims at user-centric strategies. The starting point of this new concept was to support decision making processes in *spatially enabled* societies and governments (Rajabifard A. , 2009; Sadeghi-Niaraki & Rajabifard, 2010; Song, 2003; Kim, 2003).

2.3.2. EVOLUTION AND UNDERSTANDING OF SDI ONTOLOGY

In an attempt to identify phases of knowledge development in the subject of information infrastructure, Kahin & Wilson (1996) took a historical perspective and found four phases: the “technical”, the “mythical”, the “socio-technical” and the “multi-disciplinary” phases.

The basis of Wilson’s “technical” phase, as Georgiadou (2006) points out, is formed by the assumption that SDI can be ‘constructed’ by selecting, putting together and arranging a number of technical, managerial and institutional artefacts. These artefacts will function in predictable ways very much like the ingredients prescribed in a ‘cookbook’ and put together they represent the end product, an SDI. Wilson’s “mythical” phase is the notion that when SDI is available, data will be available as well, used by users with minimal pre-processing to enhance decision processes. This ideal condition will lead to cost saving, job creation, improved service delivery, competition and innovation etc.

Both phases rely on certain implicit assumptions about and ideal conditions for decision processes, people, management methodologies,

and social structure. People are seen as “decision agents”, rational thinking and predictable regarding their actions and motivations. Information technology is seen as value-neutral, a historic and globally enabling, helping us to realize the human dream of instant access to the world’s store of information – with little effort.

The “technical” and “mythical” phases imply that we can stick together often tested and widely accepted technical, institutional and organizational artefacts to create a standardized SDI framework in a context-free process of SDI “construction”. This idea’s beliefs in standards and uniform solutions defy heterogeneity and ignore complexity and risks. Ciborra (2002) followed along the same line when criticizing the idealization of IT and calling people “rational human agents”. In doing so, he warned about the resulting long way back to fields of practice in the real world. Understanding the user-centric paradigm, users still do need raw data, but emphasis lies on the question of which kind of data and services users prefer and need, how users understand and think of central SDI concepts such as information, decision processes, people, management methodologies, social structure and information technology (Georgiadou, 2006).

Concepts	**Current understanding**	**Alternative understanding**
Information	Standardised, formal, quantitative	Contingent, informal, qualitative
Decision Processes	Stable, straightforward and formal based on logical criteria	Flexible, complex, based on ideology and power games
People	Universal rationality	Diverse rationalities, culture, values
Management methodologies	Formal objective processes and structures	Muddling through and tinkering
Social Structure	Dualism of social structure and managerial agency Dualism of social structure and SDI implementation	Mutually reinforcing social structure, managerial agency and SDI implementation
Information Technology	A value-neutral, globally enabling mechanism, ‘ending’ history.	A complex, value laden, socially shaped, historically contingent entity

Table 1: Traditional and alternative understandings of key SDI concepts
Source: Georgiadou, 2006.

The assumptions that we make about the nature of reality (SDI ontology) influence the criteria we choose for evaluating knowledge claims and influence our SDI design approach. These assumptions are opposed by alternative viewpoints (Table 1). This thesis follows an implementation strategy which tries to develop SDI jointly with users and SDI experts, maintaining close and continuous communication to “SDI reality”, and leaving space for “alternative understanding” of SDI concepts. A common SDI ontology, combining the understanding of reality of users, experts, and SDI developers, is the anticipated outcome.
Concentrating on user needs and examining users’ understanding of SDI and its key concepts leads to a cultivation of SDI design and implementation. In at the

work at hand the documented process does not contribute to a "construction" view of SDI implementation and its apparent disconnectedness from users' requirements, know-how, and reality.

This can be obtained by defining ontologies[1] within the information system SDI, to indicate a formally represented knowledge and to improve data sharing and information retrieval. An ontological decision making approach is used to present user behaviour and context information to meet users' needs and satisfaction. Hence, data providers integrate various technologies and strategies to respect users' requirements. The user-centric paradigm aims at the realization of a spatially enabled society, where geospatial information (GI) is regarded as a common good made available to ordinary users and businesses to promote creativity and product development (Rajabifard A. , 2009).

2.3.3. THIRD GENERATION SDI

This new paradigm of a third generation SDI was branded by Sadeghi-Niaraki & Rajabifard (2010) with the term "user-centric platform". Accordingly, it is a platform which pays more attention to the needs of the users.

In contrast, the first generation of SDI mainly concentrated on data collecting and sharing, the second generation of SDIs focused on services and were designed based on specifications of available data. In both cases, the final resulting infrastructure was delivered not fully based on user preferences.

On the way to a user-centric SDI, traditional definitions of an SDI (e.g. "the term Spatial Data Infrastructure (SDI) is often used to denote the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability and access of spatial data", (Nebert, 2004)) needs to be redesigned since they are based on standards and architecture models of first generation SDI.

[1] Ontologies are structural framework for organizing information. They define the basics of a system, its objects, concepts, entities and their properties and relations. Ontologies provide shared vocabularies to describe system's entities and are used as a form of knowledge representation about the world or some part of it (see http://de.wikipedia.org/wiki/Ontology). This formal representation of knowledge is strongly connected to the concept of *semantic web*. Data can be accessed automatically by applications within the distributed environment of the *semantic web* understanding and using ontologies (Kalfoglou & Schorlemmer, 2003).

While in both data-centric and process-centric SDI models, users receive data passively; in user-centric SDI users can play a more active role (Budhathoki, Bruce, & Nedovic-Budic, 2008). In the early design phase of SDI users' needs are assessed, considered and applied to infrastructure building. The involvement of the user community in this process triggers a remarkable increase in user participation compared to previous concepts. First generation SDI's data was gathered by governmental agencies, supported by various organizations and the infrastructure design focus lay on that data only. Second generation SDI started to involve users more closely in the development and implementation of services. User participation was already on the agenda. The huge number of free and open source services receiving essential user contribution shows the idea's success and broad support. However, even process-centric second generation SDI paradigms have not developed further beyond seeing the user as an active recipient (Budhathoki, Bruce, & Nedovic-Budic, 2008). However, there is an obvious shift first from passive users of first generation SDIs, and then to active users of second generation SDIs to the second and third generation of SDIs, the latter of which took place between 2000 and 2007. Still, user preferences are not fully considered in the early infrastructure design phase (Sadeghi-Niaraki & Rajabifard, 2010).

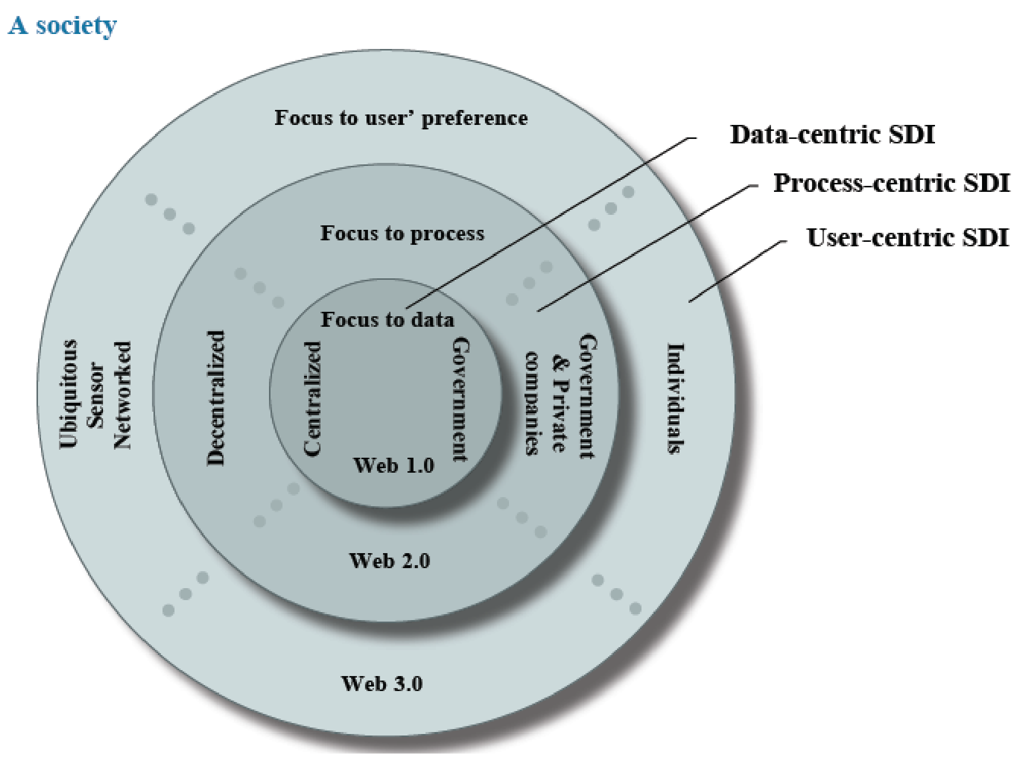

Figure 2: Three generations of SDI paradigms, design and user-roles.
(Sadeghi-Niaraki & Rajabifard, 2010)

This is exactly what the user-centric SDI concept aims at, based on and continuing past developments. Figure 2 visualizes three generations of SDIs as building blocks, based on each other. Concepts and structures such as metadata, standards, interoperability, policy and organization of second generation SDIs were developed on those of first generation SDIs and can be applicable to the third generation as well.

The present study's undertaking of enhancing existing SDI with a metadata management system combined with a geoportal respects the user-centric paradigm. This was achieved, as described in detail later, through an assessment of user needs at the beginning. Moreover, after implementation a test phase collected users' suggestions and opinions. Modifications suggested in the feedback were incorporated directly or documented for further development.

A different, but also widely accepted approach to classifying SDI is to distinguish between Classic Infrastructures and Network Infrastructures. The former type of infrastructure provides public goods and reveals itself as non rival; it can be compared with other public infrastructure such as for example a road network. The latter offers, among other things, private goods and raises investment interests. These investments boost fast development. Especially in early years, effectual network capacities and bandwidths represented an important aspect of its success. Diversity and the disparities of the described concepts and types of SDI illustrates, that a clear and straight forward classification at an early stage of the planning phase is an essential prerequisite for every successful SDI. This choice shapes all subsequent planning efforts for development and maintenance, like the identification of proper financing models, way of implementation and the establishment of institutional and technical frameworks.

2.4. SDI DEVELOPMENT FRAMEWORK

Planning and development of a successful infrastructure requires a combination of technical, institutional, legal and social partnerships, arrangements and restrictions (Rajabifard A. , 2009; Williamson, Rajabifard, & Feeney, 2003).

The technical framework addresses standards, metadata, search engines, available resources and their integration and communication networks. If an

existing SDI is going to be upgraded, a preliminary analysis of its technical specifications is inevitable to secure compatibility of newly integrated components and seamless functioning.
SDIs technical architecture is built on previously set up organizational arrangements. They have to be established at the beginning and can be summed up under the term institutional framework.
Amongst them are for example the choice of organizational structure and business model, partnerships and custodianships, maintenance issues and long term planning. For example in the case of an SDI for an academic institution, custodianships and long term planning may be more prominent topics, whereas the issue of choosing a proper business model becomes less relevant.
The legal framework comprises data access policy, pricing policy and possible fees and data ownership. Pricing and fees have to be defined and adjusted according to user groups. Of much higher importance is data ownership and consequential data access policy. Data ownership and responsibility for quality and maintenance of that data and respective metadata entry are closely related and generally join at the same person or legal body.
The social framework comprises considerations regarding the cultural, religious and political issues, possibilities and differences. The scope of view is related individually to (e.g. a region, a country, a state, etc.) the SDI's coverage area. These can be negligible issues for small, local or institute-based infrastructure. Issues within the scope of the social framework which are of high interest for every SDI, regardless of its dimension, are awareness raising and capacity building. Here, infrastructure advertisement and promotion are put in place to raise both, number of users and number of participants and collaboration partners.

2.5. METADATA

Metadata is structured information commonly called data about data. It describes, explains, locates or makes it easier to retrieve and manage information resources. "Metadata is key to ensuring that resources will survive and continue to be accessible into the future" (NISO, 2004).

The term metadata is used differently depending on its application. It is the essential component of catalogues, for example in a library; it can be used for catalogues when machine-understandable information is created, and it can stand for records which describe electronic information. Metadata is essential for libraries; in a library environment metadata makes up the formal scheme of structured resource description. It is applied to any kind of resource, digital or non-digital, spatial or aspatial.

Metadata is essential for libraries; in a library environment metadata makes up the formal scheme of structured resource description. It is applied to any kind of resource, digital or non-digital, spatial or aspatial. Metadata is organized following metadata standards which are set up according to the respective context. And there is a wide range of standards which are applicable to geospatial resources.

2.5.1. METADATA STANDARDS

Metadata standards are needed to enable standardized data discovery. They are agreed upon conventions about how to list and thematically order information about data. The main purpose lies in the question of where data is and in what form. This section gives an overview of the currently accepted and implemented standards with special emphasis on the European area. Moreover, it includes a short discussion about semantics and geographical data and tries to close the circle to metadata standard conceptualization.

Metadata standards for spatial data were first suggested in the Proposed Standard for Digital Cartographic Data (DJDSTF, 1988), and are respected in many standards for spatial data and their metadata standards elaboration since (FGDC, 2010; ANZLIC, 2001; ISO, 2003b; ISO, 2003a).

Important and widely implemented interdisciplinary standards for metadata are established by, among others, the International Standardization Organization (ISO) and by the Dublin Core Metadata Initiative (DCMI).

Well-established metadata standardization themes for spatial data are the American National Standards Institute's (ANSI) standards framework, the content standard for digital geospatial metadata maintained by the Federal Geographic

Data Committee (FGDC) or the Australia New Zealand Spatial Information Council's (ANZLIC) metadata standards. ISO standards in general are widely used and respected in the western hemisphere. It consists of a set of standards which are the ISO 19115 for geodata and geoservices, the ISO19119 for geoservices, the ISO19139 for XML schemata, the ISO 19110 for feature classification, ISO 15836 for resource description, and the ISO Profiles) (ISO, International Organization for Standardization, 2010). The INSPIRE initiative adopted ISO 19115, ISO 19119 and ISO 15836 (JRC, 2007). The USA based FGDC created, together with Canadian affiliates, the North American Profile (NAP), which is a derivate of ISO's 19115 standard.

The Dublin Core standard was established by the Dublin Core Metadata Initiative (DCMI) in 1994 and defines cross domain information resource description as describing the components and character of information sources in general. Considering only the most necessary metadata entries, is the "Dublin Core Metadata Element Set". It consists of only 15 elements like Title, Description, Author, Format, etc., falling into the three groups called "Content", "Intellectual Property" and "Instantiation"[2].

It has been formally endorsed by the ISO Standard (ISO 15836), by the National Information Standards Institute (ANSI/NISO) as "Standard Z39.85" and by the Internet Engineering Task Force (IETF) as "Standard RFC 5013" (DCMI, 2010).

In general, metadata information can be organized in different ways; in the case of digital organization, it can be stored using XML format, it can be embedded in HTML documents or it can be integrated in the header of the resource's file (e.g. in an image file). The latter example describes a way of combining metadata and resources within one file, eliminating the need to link them. On the other hand, storing metadata in separate, standardized files simplifies the management of metadata itself and the facilitation of search and retrieval.

A common means of metadata implementation is the XML format. ISO 19139 provides the XML implementation schema for ISO 19115 specifying the metadata record format and may be used to describe, validate, and exchange geospatial metadata prepared in XML (Nebert, 2004).

Metadata describes resources' substance, quality, currency, purpose and accessibility (Aditya & Kraak, 2009) in a standardized way. In this respect, it is a

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[2] See http://www.ietf.org/rfc/rfc2413.txt & http://dublincore.org/ (retrieved Dec.2010)

crucial component in SDI and contributes to its central aims of faciliting access to and use of geospatial resources like data, data services, processing services and applications; To make this information accessible and systematically search and editable, some kind of SDI conforming metadata management framework needs to be implemented in the SDI architecture. Metadata catalogue services are set up to fulfil these requirements.

2.6. METADATA CATALOGUES

Since the beginning of SDI, the topic of metadata management and its standardized and structured organization has always been an important one. Metadata catalogues act as SDI's metadata management systems, offering a wide range of functionalities fulfilling this purpose. Data owners can create, edit and publish metadata. In many solutions – they come as software packages – a geoportal is included which represents the entry gateway for users to search and find these metadata entries in a standardized way.

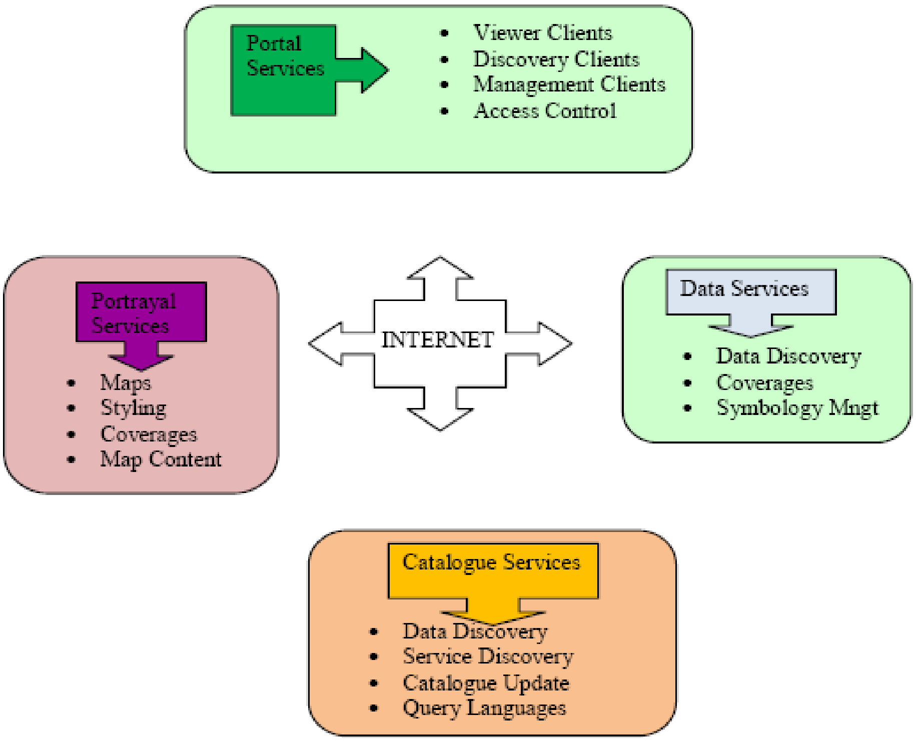

Figure 3: Geospatial portal reference architecture.
Source: OGC, 2004.

OGC defined the geospatial portal reference architecture standards (OGC, 2004). It describes a reference architecture of geoportals on top of a metadata catalogue, herein called metadata management system, and lists support for four service classes: portal service, catalogue service, data service and portrayal service. Tasks and functionalitites that come with these four service classes are given in Figure 3. Geospatial metadata are considered structured documents, encoded respecting a specific standard (e.g. ISO19115); they are accessible through a search engine or a search interface of a catalogue service (Aditya & Kraak, 2007). The use of conventional web search engines to find geospatial metadata would be cumbersome. Even though the search result includes geospatial data, they are listed as normal documents amongst the other results. This is because traditional search engines primarily deal with unstructured documents and are not specifically designed to identify and present typical geospatial attributes like bounding box, abstract or accessibility.

Within the framework of SDI, metadata is usually collected in central nodes. These nodes can be compared with a library's catalogues. Both are metadata management systems and provide access to resources. Correspondingly, the part of an SDI where metadata is collected and is made available is called the "metadata catalogue".

For an SDI, the currently "official" proposed solution for dealing with geospatial data discovery is the so-called Catalogue Service for Web (CSW) (Nebert, 2004). The prominent feature enabling these functionalities are the capacity to query registered metadata in metadata registries using discovery protocol standards (ISO29350, also known as ANSI Z39.50)(NISO, 2004) and the use of Catalogue Query Languages (CQL) (OGC, 2011) such as the SPARQL query language (W3C, W3C SPARQL Query Language for RDF, 2011). Most of the currently working implementations of catalogue services consume SOA (see so-called chapter) concept guidelines and the CSW application schemata (OGC, 2011).

The metadata catalogue is an essential part of an SDI: it allows for finding a resource by specific criteria, it identifies resources, it brings similar resources together and distinguishes different ones, and it locates a resource unambiguously. It enables distributed search functionality across remote nodes, maintained by all kinds of institutes, private bodies and organizations that hold spatial data and related documents. The unambiguous identification of resources is achieved based on the concept of *universally unique identifiers* (UUID).

SDI nodes are built most often with the idea of collaboration and seamless integration with other, remote catalogues. As a result, developers and communities realized early the need for widely accepted standards for metadata catalogues and related services. This work was done by the Open Geospatial Consortium (OGC), which is an international industry consortium of 421 companies, government agencies and universities. It participates in a consensus process to develop such publicly available interface standards.
The Catalogue Service for the Web (CSW)[3] is such an OGC specification. It defines standards for frameworks, interface and protocol bindings for metadata catalogue services which are commonly used for internet based publishing of geospatial metadata (Aditya & Kraak, 2009). It standardizes catalogue services to discover, edit and manage metadata as well as to harvest (import new and update existing) metadata records from other catalogues. These CSW standards specify design patterns that allow for the definition of interfaces. Interfaces are called application profiles and support the ability to publish and search for collections of descriptive information (metadata) about geospatial data, services and related aspatial resources (OGC, OGC (Open Geospatial Consortium) Website, 2008). Currently, there are several solutions of reasonable capacity available, including ESRI Geoportal Server (ESRI, 2010), Voyager (Voyager, 2010), Terra Catalogue (Conterra, 2010) and GeoNetwork(GeoNetwork, 2010). These software are called Geographic Metadata Information Systems (GeoMIS) and have been designed especially for Geomatics and related fields of application. GeoMIS generally function as adjustors for all kinds of resources like (a)spatial data, geoservices, geoapplications and related documents and media. Its user interface, offering access for users, is called a geoportal.

[3] also called Web Catalogue Service (WCAS)

2.7. GEOPORTALS

(Web)portals in a common sense are web environments acting as gateways to a collection of information resources including data sets, services, cookbooks, news, tutorials, tools and an organized collection of links to many other sites, usually through catalogues (Maguire & Longley, 2005).

Portals can be differentiated according to the content they are connected to. Tait (2005) defines a geoportal as “a web site considered to be an entry point to geographic content on the web or, more simply, a web site where geographic content can be discovered”.

The birth of geoportals can be dated to the 1980s when national mapping surveys started the undertaking of providing greater access to standardized Geographic Information (GI). Geoportals administer “standardized access” to this information through frameworks, called “SDI”. Geoportals act as World Wide Web gateways that organize spatial content and geoservices such as directories, search tools, community information, support resources, data and applications (Maguire & Longley, 2005).

Geoportals can be classified according to the type of geographic resources they deliver and are then called thematic geoportals. Further, they cover different scopes; there are national and regional geoportals (Aditya & Kraak, 2009), local and global ones. Examples for regional geoportals are the US Geospatial One Stop GOS (USGS, 2010) and the INSPIRE geoportal (INSPIRE, 2010b). Thematic geoportals, covering a special area of interest, are for example the Food and Agriculture Organization (FAO) Portal (FAO, 2010) and the European Protected Areas portal (INSPIRE, 2010a).

Maguire and Longley (Maguire & Longley, 2005) distinguish between catalogue portals, where the main purpose is the facilitation of access to GI, and application portals, which are more advanced versions offering on-line dynamic geographic web services. Nowadays almost every portal includes at least some basic application services like routing[4] or mapping[5] functionality (Aditya & Kraak, 2009).

Technically speaking, a geoportal is a master web site connected to one or more web servers which contain databases of metadata about geospatial resources. It

[4] E.g. Mapquest (http://www.mapquest.de/mq/home.do)

[5] E.g. National Geographic Maps (http://maps.nationalgeographic.com/maps)

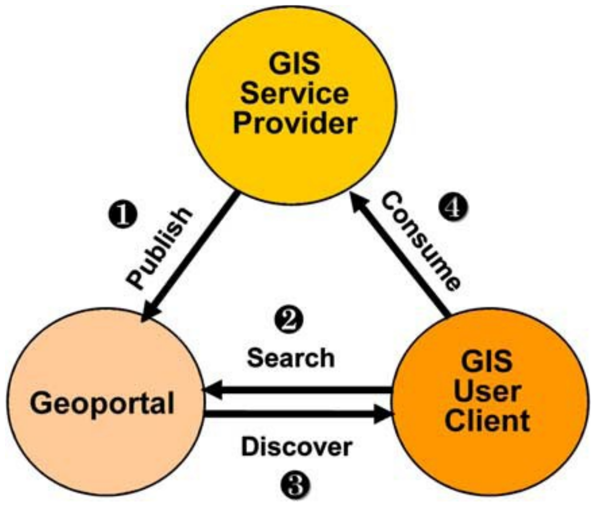

Figure 4: The Publish-Find-Bind concept. (Aditya & Kraak, 2009)

offers web services and applications that can be invoked using messages encoded in XML (eXtendable Markup Language) and transmitted using HTML. The interaction between providers and users follows the "Publish-Find-Bind" paradigm which frames the resource-discovery process. Users can issue queries against the metadata database using light-weight web applications or desktop clients to find resources published by providers. Depending on defined user roles and service capabilities, data can be found, visualized, edited, ordered, processed, uploaded or downloaded (see Figure 4). Common interfaces for metadata search and discovery ask the user for "what", "where" and "when" attributes. Common search results provided to the user deliver a list of metadata records with a set of abstracts and thumbnails and links to data previews and full metadata sets.

The predecessors of geoportals are known as clearinghouses or geoportals of First Generation SDI. They offered metadata and basic framework datasets (e.g. administrative boundaries rivers or orthophotos) covering the whole area of interest - be it a district or any other small administrative entity in the case of a local SDI, a country in the case of a national SDI (Longley, Goodchild, Maguire, & Rhind, 2001). An example of geoportals of Second Generation SDI was seen first in 2002 in the form of the USA's e-government program, improved by two technological breakthroughs:

-first, in addition to metadata discovery, direct access to actual resources are offered, and

-second, access to resources is not restricted to desktop GIS clients (thick clients) anymore, but can now also be requested using online web map services (thin clients).

Both types of clients access the portal over HTTP internet connections. The geoportal interface front end typically sits on top of an Internet Mapping Server

(IMS). This IMS locally provides services for metadata management, data transfer and links to remote sites. One standard specification for such a server is the OGC Web Map Server (WMS). Local data and services are organized in a Database Management System (DBMS) that is accessed and linked to the IMS through a DBMS Gateway (Figure 5).

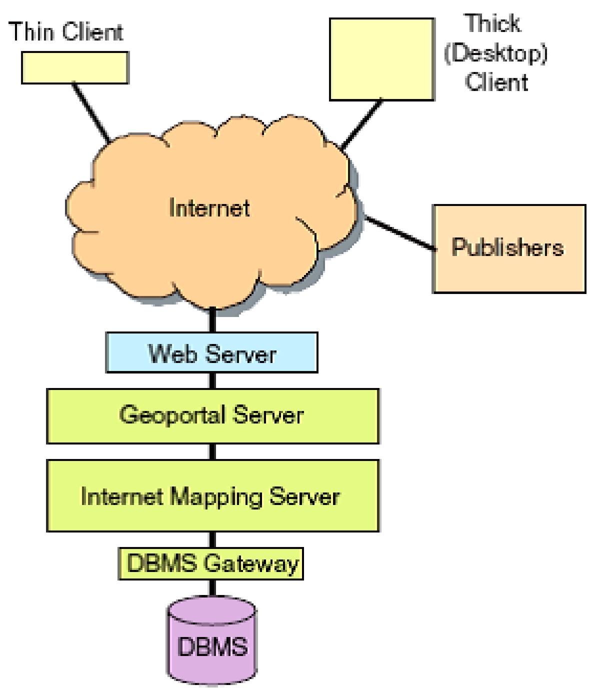

Figure 5: The role of a geoportal within SDI. (Maguire & Longley, 2005)

Understanding the technical specifications helps to know what a geoportal is and how it works. To render this service's full significance and understand its applicability, Maguire & Longley describe as an example the institutional and organisational perspective of the Geospatial One-Stop (GOS)[6]. This geoportal was initialized as part of the United States e-government initiative (FGDC, 2005) to facilitate collaboration between government agencies and to stimulate efforts in sharing data and stewardship of data. The hope was to increase synergy effects and to reduce costs and duplication. Community building should underline the importance of spatial data for decision making processes and the portal's value. Available up-to-date regional spatial data and services, that can be gathered from many sources, should be used for a wide range of activities such as community planning, improving disaster preparedness, economic development, environmental impact assessment or security.

Tge dynamic development in recent decades of information technology has brought about fundamental improvements to SDI and geoportals; and development and improvements to these concepts has paved the way to easy data access for a broad community. In the course of research and progress, the focus has recently shifted to issues like the legal, economic and social dimensions of resource

[6] See http://gos2.geodata.gov/wps/portal/gos, retrieved May 2011

sharing. SDI communities each work on the establishment of agreed upon legal frameworks to address these questions.

Geoportals imply the idea of cooperation, integration and connection with other portals within an SDI framework. Ensuring seamless usage throughout different metadata catalogue nodes, geoportals are based on commonly accepted standards and techniques and are often built using *off the shelf* information technology systems. User oriented applications and services add value to raw data. Application Geoportals provide advanced GIS functionality (supported by e.g. a web GIS) as well as non-spatial sub-services.

SDI and Geoportals are part of a much wider trend promising further developments. One manifestation of this tendency is the great number of governments throughout the world heavily investing in e-government and e-governance. Song (2003) defined cost reduction, social inclusion, redundancy reduction, better use of information and a better accessible government amongst others as key benefits of e-government initiatives.

Estimating the possible impacts of geoportals in the socioeconomic system brings about not only advantages and benefits; Kim (2003) stresses an emphasis on the digital and financial divide which is evident in many societies. Issues of security and privacy arise as more and more information is collected and made accessible and the term “mass surveillance” with all its negative connotations must be kept in mind my SDI and Geoportal planners.

2.8.SERVICE ORIENTED ARCHITECTURE (SOA)

The SOA approach evolved in connection with the development from monolithic and tightly coupled systems to swarms of loosely connected and cooperating applications in distributed environments. SOA seeks to chain remote services according to the outcome required. Chained services are separated from users. Distributed environment’s services and application functionalities are delivered to either end-user interfaces or other services (Endrei, et al., 2004).

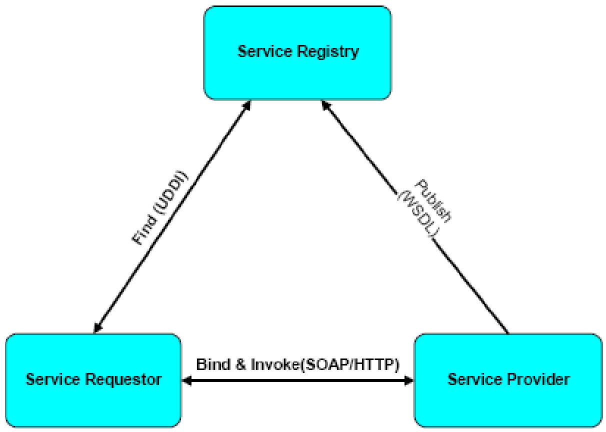

Figure 6: Interactions in a Service-Oriented Architecture (Gwenzi, 2010)

Three types of actors are distinguished within a SOA: the service provider, the service consumer and the discovery agency (W3C, 2011) (Figure 6). The edges of the triangle, formed to connect these three actors, represent their interactions:

-the publish operation is used by providers to register resources (data, services, etc.), for example with a catalogue registry;

-the find operation is used by service consumers to discover resources. They send requests and the registry answers with matching entries. Typically, this operation uses published metadata;

-the bind/interact operation is used when a service consumer invokes a service by using service metadata provided by the registry.

These three basic interactions are supported by Web Services. Gwenzi (2010) describes a WS as

"…a software application identified by a URI[7] whose interfaces are binding and capable of being identified, described and discovered by XML artefacts and supports direct interaction with other software applications using XML based messages via Internet-based protocols."

Enabling an environment of WSs, interacting with each other, creates synergy effects and can increase each WS's efficiency. Such architecture of cooperating WSs is called Web Service Architecture.

[7] Unified Resource Identifier

2.8.1. WEB SERVICE ARCHITECTURES

WSA feature four central functionalities, which are transport, messaging, description and discovery. These functional components are implemented, consuming three core technologies:
(1) the Simple Object Access Protocol (SOAP) is a simple XML based protocol for transfer of structured data and type information across the web in a stateless manner. Web services use SOAP for communication between each other, with remote registries and with user applications; (2) the Web Service Definition Language (WSDL), which is XML based as well, is used to describe and locate WS and to manage communication with a WS. Simple XML schemata regulate how messages and protocols are interpreted with the aim of avoiding misinterpretation in client-service-communication (Booth & Canyang, 2007); (3) the Universal Data Description and Integration is a platform-independent standard method allowing the publishing and discovery of meta-information about WSs.
WSAs offer specific capabilities, made available through protocols which employ the technologies described above. The WSA transport protocol is responsible for message transport between remote network services; messages are transported in SOAP format via HTTP. The messaging protocol encodes messages in XML. The description protocol, handled by WSDL, defines languages for service description. Finally, the discovery protocol facilitates registration and discovery of services using UDDI and metadata catalogues. Therefore, UDDI plays a pivotal role when it comes to registration and discovery of services (Gwenzi, 2010). Figure 6 illustrates WSA functionalities in the context of SOA.
If a Web Service's scope is enhanced by a spatial component and enlarged by geospatial content, the result is a Geospatial Web Service. GIS functionalities may be supported to manage, analyze and distribute spatial (and aspatial) content (Zhao, Yu, & Di, 2007). The geospatial part of the architecture is concerned with the support of maps, their visualization and their spatial attributes. The web part enables the sharing of distributed resources and interoperability of services. This specific category of services includes for example web map services or geospatial catalogue services.

2.9. OGC SPECIFICATIONS

To enable SDI users to visualize geospatial data, web services as the technical basis are necessary (Nebert, 2004). Widely accepted standards for these services are established and developed by the ISO Technical Committee 211 and the Open Geospacial Consortium (OGC). The latter has its origin in private sector and concentrates on issues of technical implementation of geoservices. The ISO in contrast represents the public sector and both organizations aim at the cooperation and harmonization of their standards(Peng & Tsou, 2003).

OGC offers a whole list[8] of implementation standards, recommended for SDI implementation. They address a technical audience and detail the interface structure of SDI components with the aim of seamless interoperability of services, regardless of implementation contexts. For efficient discovery of resources, published through a metadata catalogue within an SDI, semantic heterogeneity has to be overcome and applications have to be designed to be interoperable, supporting both providers and consumers (Gwenzi, 2010).

The present study relies and focusses on metadata catalogues. For technical issues ensuring seamless interoperablity, OGC *Catalogue Service for Web* (CSW) implementation standard are an essential basis and recommended practice.

2.9.1. CATALOGUE SERVICE FOR WEB 2.0.2

Catalogue Service for Web (CSW) is HTTP binding of CS. The CSW defines application schemata for catalogue services handling metadata in a structured way following metadata standards such as ISO19115. The overall goal is to support interoperability. OGC defined a minimal set of queryable attributes (*CSW core queryable properties*), enabling cross-catalogue discovery (Ozana & Horakova, 2008). It supports XML encoding to ensure seamless interoperability and data transfer following the ISO19139 standard.

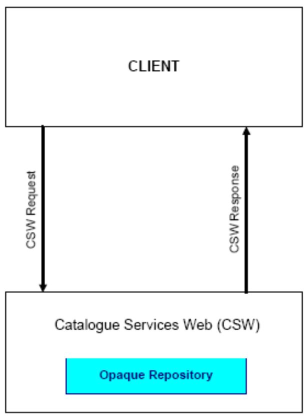

Figure 7: Architecture principles in CSW.
Source: Gwenzi, 2010.

[8]See full list: http://www.opengeospatial.org/standards/is (May 2011)

Operation name	Implementation	Note
GetCapabilities	Mandatory	Allows a clients retrieve service metadata from a server.
DescribeRecord	Mandatory	Allows a clients to discovery elements of the information model supported by target catalogue service.
GetDomain	Optional	That operation is used to obtain information about the range of values of metadata record element or request parameter.
GetRecords	Mandatory	GetRecords operation is used for resource discovery – search and obtain metadata from catalogue.
GetRecordById	Mandatory	That operation is used for request the default representation of catalogue records using their identifier.
Harvest	Optional	Is an operation that “pulls” data into the catalogue.
Transaction	Optional	Transaction operation define interface for crating, modifying and deleting catalogue Records.

Table 2: Summary of CSW operations.
Source: Ozana & Horakova, 2008.

In the CSW the registry service UDDI is used for registration and discovery of web service applications. Queries are executed following the request-response model of the HTTP protocol as shown in Figure 7. A request sent for a metadata search of metadata catalogues returns as a result a list of resources' references matching the query. This interaction between client and server and a list of operations is defined by Catalogue Service specifications. A list of CSW operations is shown in Table 2.

2.10. DESIGN AND USABILITY OF COMPUTER USER INTERFACES

Search interfaces are essential components of Spatial Data Infrastructure and in this context are often called geoportals. For the work at hand the most relevant ongoing research issues for the development of search interfaces are concentrating on effective design and high usability. Nowadays geoportals' complex architecture implies reasonable hurdles, since current interfaces offer not only a catalogue function but a wide range of additional services, such as thematic mapping data visualization. This demands a series of different interfaces, like for example for query and for result visualization. For every SDI, an access gateway or catalogue function is mandatory (Bishr & Radwan, 2000; Nebert, 2004), moreover methods of offering data facilitation and services through a highly usable interface is considered vital for a successful SDI (Masser, 2005). Consequently, an easy to use, efficient and effective design and presentation of that interface is of highest priority.

2.10.1. SEARCH INTERFACES

Considering that search interfaces are crucial to SDI success and user satisfaction, it is of high interest to current research to improve users' search progress. Aditya & Kraak (2009) focused on simplifying search processes. At the same time, strategies for search result aggregation, visualization and interaction with metadata are identified as important aspects in this context.

A typical benefit of a geoportal is to allow users to integrate search functionalities, thematic mapping and metadata visualization in an SDI context (Aditya & Kraak, 2006), merged in one single platform. The great advantage of a geoportal, in comparison to traditional search engines like Google, is the use of maps, or geo-referenced visualizations or spatialization, to improve usability of spatial and aspatial content searches (Fabrikant, 2000). Actual research seeks to overcome, with the use of maps, the existing limitation of content exploration tools and techniques with the use of maps.

The notion of usability engineering is a central concept in user-centric SDI development. ISO defines usability and characterizes it with the terms *effectiveness* (refers to accuracy and completeness required), *efficiency* (refers to resources needed to achieve a goal) and *satisfaction* (refers to user comfort and acceptability) (ISO-9241-11, 1998).

Research for effective and efficient interaction between humans and computers through interfaces is an interdisciplinary field and called Human-Computer Interaction (HCI) (Shneidermann, Desinging The User Interface, 1998)(Preece, Rogers, & Sharp, 2002).Following the HCI approach, success depends on the suitability of the interface for humans and on design evaluation of users' perception, action and information processing when working with interfaces (John, 2003).

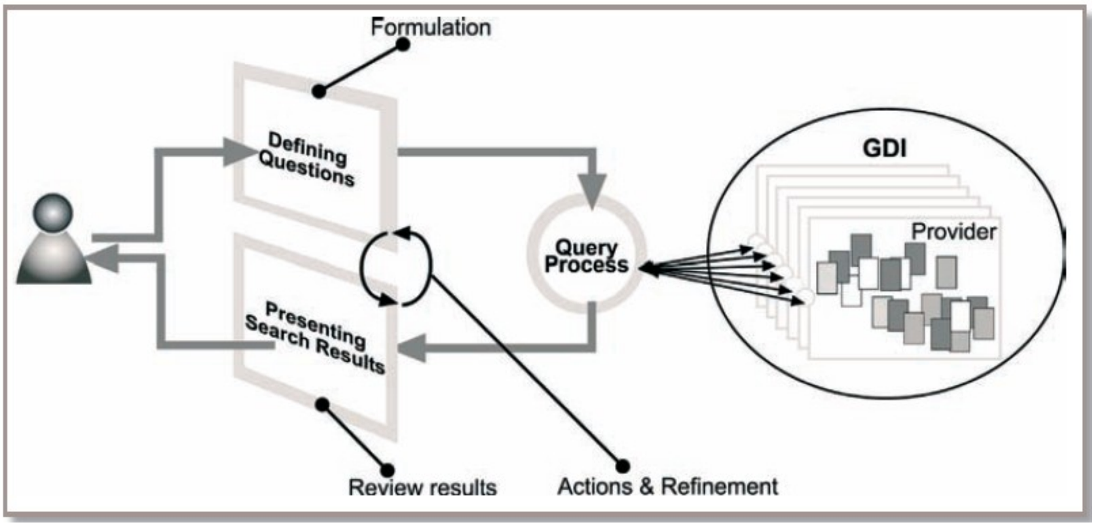

Figure 8: Separation of the geoportal's search mechanism into two components
Source: (Aditya & Kraak, 2009)

Most geoportals enable the user to search, edit, publish and visualize metadata records and resources. Focussing on the search functionalities of geoportals, it can be divided into two main tasks (see Figure 8):
-providing an interface for querying geographical, thematic and/or temporal properties to query, and
-providing a proper, correct and easily useable presentation of search results.

Design and usability of both interfaces should be well examined and planned since they represent the basis for user interaction and therefore for user satisfaction and for successful long-term SDI maintenance.

2.10.2. METADATA QUERY

The process of searching for metadata can be divided into three main phases(Shneidermann, Byrd, & Croft, 1997): formulation, action review and result refinement. Enabling first phase called “formulation”, most current implementations of geoportals offer thematic (“what”), spatial (“where”) and temporal (“when”) query options.

Thematic query is initialized by keywords. Optional attributes such as for example *topic, data category, format, scale* or *data provider* can be made the subject of the search by including them in the query interface. Additionally, geoportals enable users to search by category (based on ISO19115 *topicCategory*[9]).

In a spatial search, making a query with the “where” property, the user can draw a rectangle (“area of interest”) using a small map in the search interface. Moreover, spatial attributes can be expressed as place names (using gazetteer services) or administrative areas. Many interfaces lack the possibility to enter and search for coordinates. Furthermore, the map used to define an area of interest often cannot be used as a thematic viewer; no thematic information can be displayed on top of the search map. As a consequence, spatial queries cannot be set into thematic contexts (Aditya & Kraak, 2009).

To express queries concerning time, the user can limit searches to specific points in time or periods regarding data creation or publication. Moreover, users can search for a specific period of time (e.g. changes in land cover) with respect to implicit temporal information of the resource.

Authors of metadata information can be separated by thousands of miles. This distance might be enlarged through different educational, lingusitic, religious and cultural backgrounds of the users. Metadata is collected with the goal of being available to and understood by every user, regardless of age, education, culture or language spoken. Moreover, metadata ought to be understood by computers, allowing automatic data recognition and processing in SDI. (Data) semantics is the principal field of research dealing with issues like this.

[9] See http://gis.glin.net/ogc/themes.html (May 2011).

2.10.2.1. SEMANTICS AND GEOGRAPHICAL INFORMATION

Semantics is the study of the meaning encoded in language. It typically concentrates on the meaning of signifiers (words phrases signs and symbols or longer textual descriptions of a phenomenon) and the relations between them[10]. Within a technical description of data, semantic descriptions ought to be an important adjunct, filling out the labels and codings of classes and providing justification for measurements (Comber, Fischer, & Wadsworth, 2008).
The Semantic Web (SM) is a concept of the currently existing web, extended by well defined meanings provided to information. This can be achieved by applying metadata to web data, and introducing data processing techniques and automatic methods. These improvements are sought to increase the ability of computers to understand (meta)data automatically and to “cooperate” with people in a more efficient way (Berners-Lee, Hendler, & Lassila, 2001). Standards like UDDI or WSDL form the basis of the SW, following the idea of creating machine understandable data which can be used and shared (Mutton & Golbeck, 2003). Data semantics also includes the general description of a dataset and its characteristics and limitations. This metadata information can be interpreted differently due to, for example, different linguistic, socio-political or academic backgrounds of users, bringing the issue of user focused extension of metadata into discussion. The need for a semantics dimension to be included in metadata standards definitions derives from the increasing distance between users and publishers. The important dialogue between users and producers of data is removed. Instead, it has been replaced by short, and or some users cryptic metadata statements which refer to production rather than understanding or meaning. Data users are left in the situation of having more access to spatial data than ever before, but they know less about the meaning behind the data.
Instead of the commonly used metadata definition (“data about data”), a user focused variant could provide a better understanding of datasets and its conceptualization. Ongoing research lays emphasis on the question of what metadata should be included apart from the documentation concerning the technical aspects of data production (Schuurman & Leszczynski, 2006). Chen, Zhu, & Du (2008), for example, propose additional metadata structures to augment

[10] See http://de.wikipedia.org/wiki/Semantik (Nov. 2010).

existing metadata standards described in ISO 19115 by translating the metadata UML model for imagery into an Web Ontology Language (OWL) ontology.
An OWL document is an ontology or thesaurus[11]. Metadata portals' dicovery function could be enhanced providing an integration point with OWL ontologies. This would extend the full text search available in many portals by providing the user with a graphical interface to search and traverse the portal's thesaurus classification. Gwenzi (2010) describes this approach using the example of GeoNetwork; main goal of which is to register a pesonalized ontology with the local GeoNetwork installation. This can be realized by applying the list of terms from a self-established ontology to GeoNetwork's repository items (ISO19139 documents). As a result, registry objects describing repository items are linked with registry objects describing the personalized ontology.

2.10.3. METADATA EXPLORATION & VISUALIZATION

Regarding geospatial metadata visualization, various forms of exploratory visualization such as space-time plots, glyph plots, scatter plots, parallel coordinates plots, and Chernoff-faces have been explored and are used to enable consumers to explore the characteristics of geospatial data during and after the search.
Despite that, metadata visualization is limited; capabilities that support sorting and comparing of data are missing in many portals. Moreover, most interfaces do not enable the user to combine and analyze both metadata and thematic layers that are considered relevant. With thematic layers as indexes, the portal can be built as a web atlas (Aditya & Kraak, 2009) using the *topicCategory* taxonomy of ISO19115 (ISO, 2003a) as an underlying schema.

[11] A thesaurus is a reference work that lists words together according to similarity of meaning,containing synonyms and sometimes antonyms. Compare http://en.wikipedia.org/wiki/Thesaurus (received May 2011).

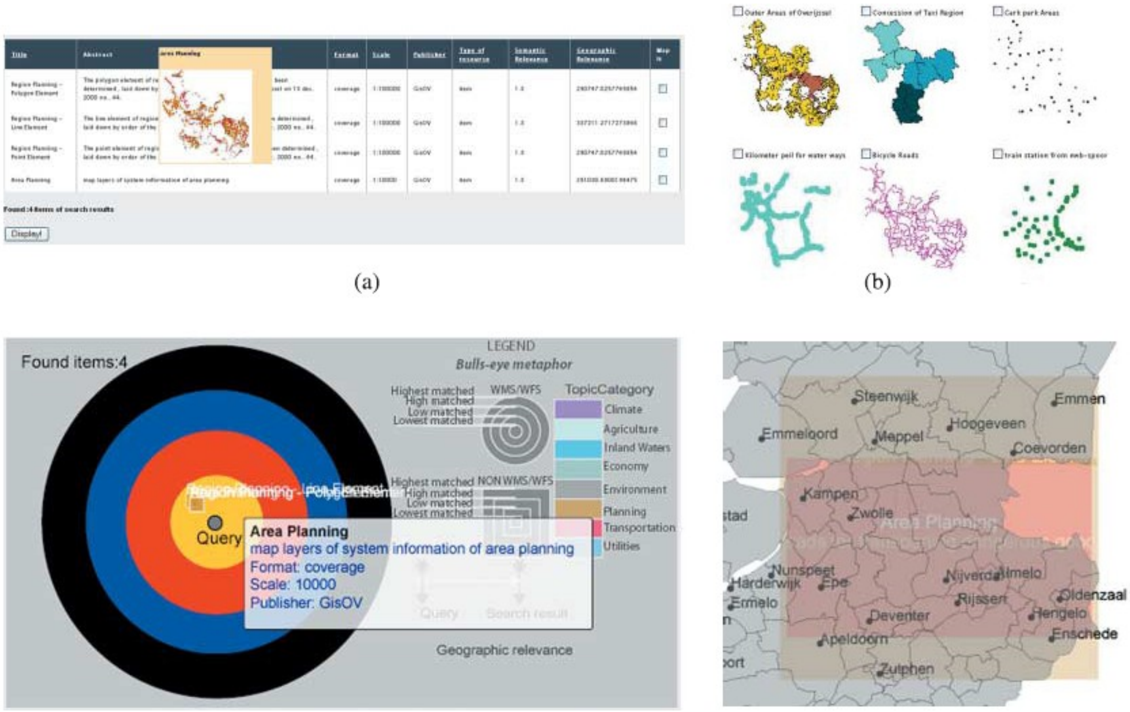

Figure 9: Strategies for Visualization of Search Results.
Source: Aditya & Kraak, 2007.

The task of designing and implementing a user interface (e.g. in the form of a geoportal) raises the question of how to present search results. As mentioned above, there are many multivariate strategies for visualization of search results. Aditya & Kraak (2007) especially concentrate on a tabular based, map based and a "relevant-focused" display in the form of a bull's eye.

Tabular-based or spreadsheet displays present metadata entries in a familiar way; most users are used to tables since there are many public web applications presenting search results that way - for example online libraries. Filtering and contrasting results visually can be more convenient than having tables. In this respect, sorting and filtering tools are a necessary choice (Chi, Riedl, Barry, & Konstan, 1998).

Aditya & Kraak (2009) investigated two types of tables: on the one hand textual tables, giving an overview of the most important metadata (e.g. spatial, temporal, contextual information plus usage and accessibility), and on the other hand thumbnail tables, which have been proven to increase the efficiency of search processes (Woodruff, Faulring, Rosenholtz, Morrison, & Pirolli, 2001). To support both possibilities' enhancements, the mouse over functionality can be used to show vice versa contexts.

Search results visualization by means of a bull's eye places search results within a circle a circle, where the centre represents the query; and the more centrally entries are placed, the more relevant they are. The bull's eye provides the user with a quick overview of the pattern of relevance of the data against the query. To support a "focus +context" interaction approach (Rao & Card, 2004), pop-up windows can provide more specific information for selected resources.

In a map-based means of visualization, geo-referenced representations of data, for example a thumbnail or a symbolic footprint area, can be displayed and cascaded in a map viewer. Such a presentation offers users enhanced possibilities to isolate and investigate data suitability and to examine patterns and density of data. Map based presentations are well-established nowadays. In most geoportals it is realized with an implemented web map service.

Adytia & Kraak's (2007) user evaluation resulted in high user preferences for simple table displays. The bull's eye on the other hand was not preferred by most test participants. Results further indicated the benefits of graphical previews such as thumbnails or metadata mapping. These results are significant for the present study's software evaluation and for the final choice of solution. Additionally, user preferences and feedback will contribute to the selection of best metadata visualization technique.

3. CASE STUDY: METADATA MANAGEMENT SYSTEM FOR ASDI IN AN ACADEMIC INSTITUTION

This chapter describes the Department of Geography's Spatial Data Infrastructure in terms of technical structure, architecture and design. It represents the basis for the design and implementation process of the new metadata management system. The subsequent part describes the main features and characteristics of the free and open source software GeoNetwork, which was identified through software evaluation as the best choice for a new metadata management system.

3.1. SDI^light FOR ACADEMIC INSTITUTIONS

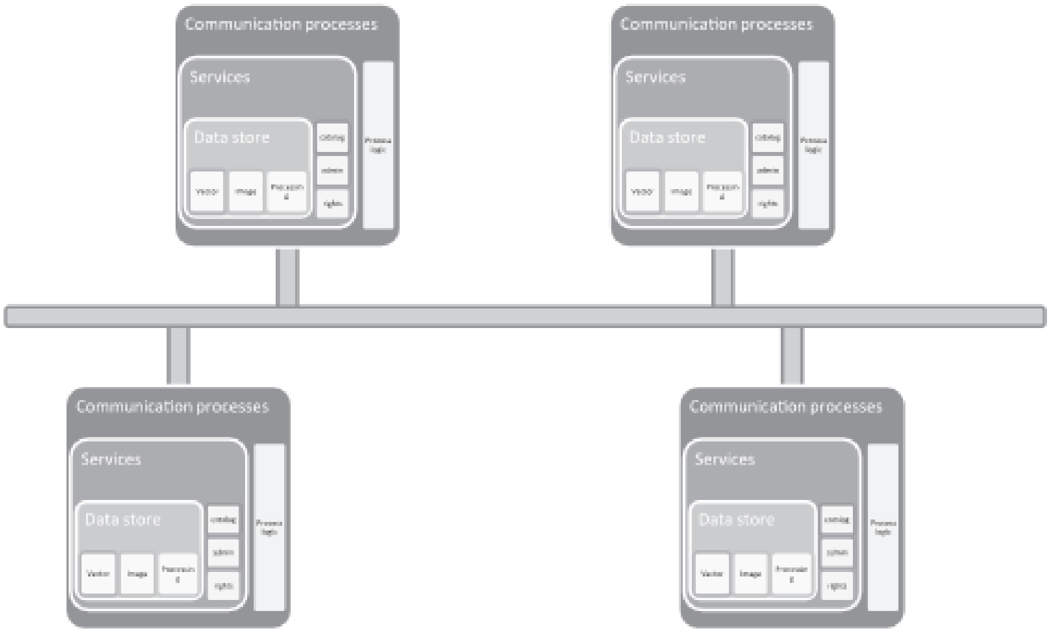

Figure 10: SDI as a network of communicating nodes.
Source: Köbben, de By, Forester, Huisman, Lemmens, & Morales, 2010.

SDI can be seen as a network of communicating nodes (Figure 10). Each SDI node has a similar structure and consists of a similar arrangement of essential features like a database, metadata catalogue and a geoportal. Moreover, each node is based on agreed standards and technical, legal and institutional frameworks.

These requirements are all fulfilled to enable seamless communication and cooperation between SDI nodes.

The Spatial Data Infrastructure at the Department of Geography at Humboldt-Universität zu Berlin is based on agreed standards and rules as well but it is not a communicating network of nodes. It only consists of one single SDI node and does not support connections to and cooperation with other, external entities' nodes. Instead, its aim is to foster cooperation and data sharing within the Geography Department, using one central metadata catalogue and one central geoportal.
The Geography section of the Faculty of Mathematics and Natural Sciences II is the biggest department working with spatial data and resources at Humboldt-Universität zu Berlin on a daily basis. With Physical Geography, Human Geography, Geomatics and Didactics, it supports four research branches. Each of them hosts teams and projects which need spatial (and a-spatial) resources for research functions. All use spatial data and spatial services which are partly overlapping or which can be reused. To bridge the gap between them and to initiate stronger collaboration between the department's data owners, resources need to be organized in a standardized way to make them easily discoverable within a geoportal - which is a matter of SDI.
Besides the goal to foster department-wide data sharing and collaboration, this SDI node was established to support typical activities of an academic institution as a practical example and subject in curricula and for training purposes, used by students, tutors and professors. Students have the chance to better understand the communication processes between SDI node and SDI users. Important insight into the service oriented architecture of this collaboration network, its concept and benefits can be illustrated practically. Moreover, it helps in understanding the process of designing and shaping an SDI node and its basic components.

The subjects covered in SDI tutorials overlap with a number of other prominent topics of Geomatics; SDI is closely related to data storage structure and functions, catalogues and other middleware, service functionality, communication process functionality, etc.(Köbben, de By, Forester, Huisman, Lemmens, & Morales, 2010). The term SDI may usually lead one to think of large, far reaching (inter-)national network infrastructures with huge databases, based on complex legal, institutional

and technical frameworks. In most cases this requires a high level investment of human and monetary resources. However, the principles of SDI can be applied in a far more simple and cost-effective way, called SDI^{light}. This concept was branded by Köbben (2007) and provides researchers and students alike with a proof-of-concept platform to share data in a relatively simple, low cost way. To achieve this, free and open source software components and open standards are used as far as possible to build one single SDI node. That leaves the possibility to have Geomatics students and engineers actively involved in further development of such systems (Köbben, de By, Forester, Huisman, Lemmens, & Morales, 2010).
The department's SDI node is based on ESRI technology at the moment. In the near future, free and open source PostgreSQL will replace the commercial DB2 database management system. Further, the presents study recommends a free and open source metadata catalogue and geoportal solution instead of the currently used ESRI products which run under commercial licenses. However, free and open source metadata management system is no hindrance to commercial components and is being used along with products like ESRI's ArcMap.

3.2.EXISTING SDI NODE

The Department of Geography's SDI node is based on characteristic technical, institutional and legal arrangements and restrictions. To conduct development in an informed way, each aspect has to be addressed and analyzed. The following section describes existing SDI architecture from the viewpoint of an SDI node being as a combination of these frameworks.

3.2.1. TECHNICAL FRAMEWORK

The present case study aims at improving the software services within the Geography Department's infrastructure. Therefore, the design and development of its technical framework takes a prominent part. First, the SDI's existing technical framework and specifications were analyzed. That preliminary step was necessary

to secure full compatibility of the existing infrastructure with new components and guarantees a seamlessly functioning infrastructure after the integration process.
In order to discuss the technical framework in a standardized and organized way, organizational arrangements (subsumed under the umbrella of the institutional framework) had to be set up beforehand.

Design of the technical framework was a fusion of facts collected through
-the assessment of user requirements,
-the software evaluation, and
-the analysis of currently existing SDI.

With the agreement of the expert group members, the implementation process was undertaken following this technical framework. Agreements and specifications were not “carved in stone” but rather have been subject to continuous discussion during the whole implementation process.

3.2.2. INSTITUTIONAL AND LEGAL FRAMEWORK

Within this case study the institutional framework is set up to analyze existing and contribute to
- necessary responsibilities for resources,
- custodianship of corresponding metadata records,
- user roles and rights,
- agreements to share resources and define restrictions of sharing.

The Joint Application Development (JAD) approach that was sued proved to be highly valuable for the implementation of SDI. It contributes especially to the establishment of an institutional framework, where SDI stakeholders and expert group members take on prominent roles.
The issue of responsibility for and custodianship of resources and corresponding metadata is especially crucial to the infrastructure’s long-term success.

Representatives in charge are needed to put in effort to create, upload and keep metadata up to date.

Most of the department's staff members who were chosen for the "expert group" are in charge of maintaining great amounts of the department's resources. Therefore they are an excellent choice for the to supervision and maintenance of SDI's metadata entries in the future as well.

According to their roles in the JAD concept as "SDI experts and stakeholders", they are awarded wide reaching determination power. This empowerment during the SDI design and development phase is a good mechanism, not only to improve user satisfaction. It also aims at motivating them to take part in SDI's institutional framework in the future. Responsibilities for resources and metadata are distributed amongst them to ensure long-term maintenance at a high quality level and, based on this, a successful infrastructure.

Questions regarding access to resources, fees and pricing are within the scope of the legal framework. Again this is strongly related to data ownership and was discussed with SDI owners and stakeholders in expert group meeting series. Pricing and fees are not main aspects of this case study's SDI but it may be necessary to address these issues in the case of requests from external users. Of much higher importance are data ownership and consequential resources access policy.

Data ownership and responsibility for the quality and maintenance of that resource and respective metadata entry are closely related and generally are connected in the same person or legal body. In an academic institution such as that which is the subject of the present study, the department as a legal body holds ownership of most resources, while the people responsible for maintenance will change over time.

3.2.3. TECHNICAL ARCHITECTURE

The Department of Geography at Humboldt University zu Berlin started its effort to establish an SDI in 2003. It maintains a Spatial Data Infrastructure (SDI) to enable staff, involved scientists and affiliates to search, visualize and use all institute-wide available spatial data. The technical environment includes ArcSDE (Spatial Database Engine) 9.3, running on top of a DB2 database. This DB2 is used for managing vector data. Raster data is organized in a file-folder system. The system runs on an Apache web server and a Tomcat servlet engine (Dransch, Schwedler, & Beyer, 2005; Beyer, 2007).

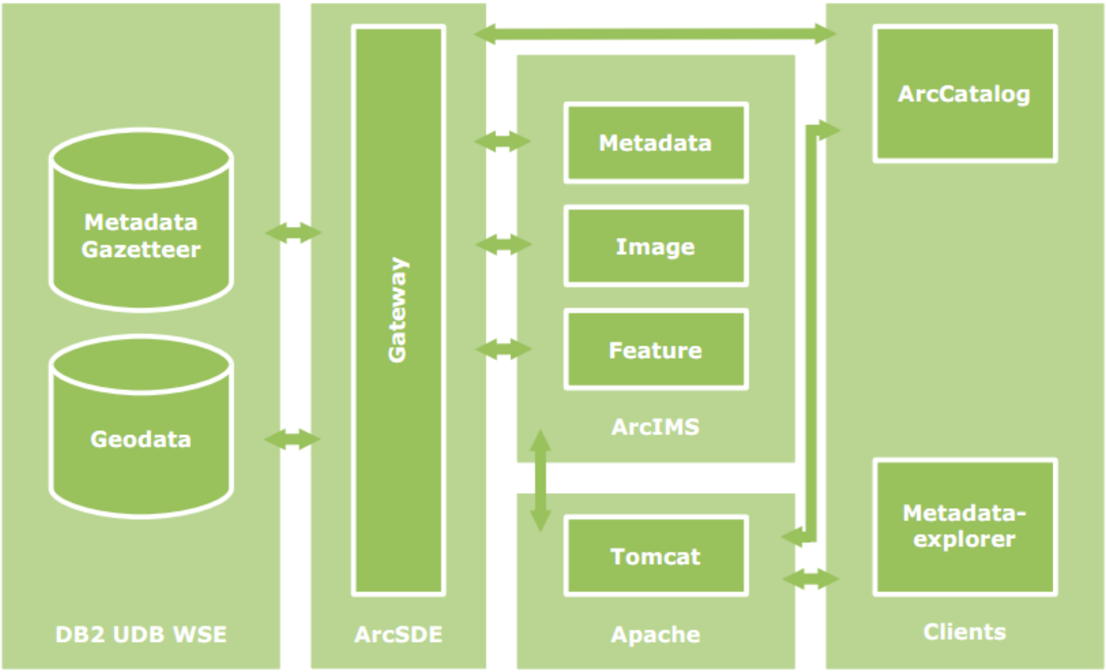

Figure 11: Department of Geography SDI node.
Source: Dransch, Schwedler, & Beyer, 2005.

Standardized resources and metadata have been prepared and have been made available. Until now, the department's SDI metadata information system was accessible in three ways:

First, an online metadata explorer, based on ESRI's ArcExplorer technology, was implemented in 2005. That geoportal provides the user with a range of services such as metadata discovery, data visualization and printing.

Second, a desktop client called "gdiExplorer"[12] was introduced in 2007, developed by, at that time diploma student, Robert Beyer. It uses the Google Earth desktop client for resource visualization. ESRI's ArcCatalogue desktop client represents a third possibility to browse the institute's metadata.

[12] http://gdi.geo.hu-berlin.de/gdiExplorer/ (received May 2011)

Following this thesis' aims, the existing SDI node's metadata management system should be upgraded. Technically speaking, Spatial Data Infrastructures and their nodes consist of a number of components which have to be implemented in a way in which they can interact. These components seamlessly interacting and fulfilling their special purposes are what make SDI work (Figure 11). Upgrading the metadata management system means in the present case study, upgrading two of the main SDI components, namely the metadata catalogue (managing the metadata database) and the geoportal. Other components like the databases remain unchanged. Nonetheless, existing architecture and components are essential through the planning phase to guarantee seamless compatibility with new components.

The Geography Department SDI node's technical architecture exists and operates according to legal and institutional arrangements and restrictions. These frameworks are not the subject of this thesis and remain untouched. It is nevertheless important that they are taken into account and respected during the planning and implementation process of new metadata management and accompanied services. This ensures that there are no regulations violated and should contribute to higher user satisfaction.

3.2.4. DEPARTMENT'S DATABASES AND RESOURCES

In terms of available resources, the Geography Department is about to establish a PostgreSQL spatial database cluster with eight databases holding project related and administrative vector data (Figure 12). A migration from the existing DB2 database to the free and open source database management system PostgreSQL 8.3 was still in progress while this thesis was being written. This database holds, beside digital orthophotos and administrative data, a huge amount of vector data. The minority of that data is described through metadata organized in FGDC metadata standard.

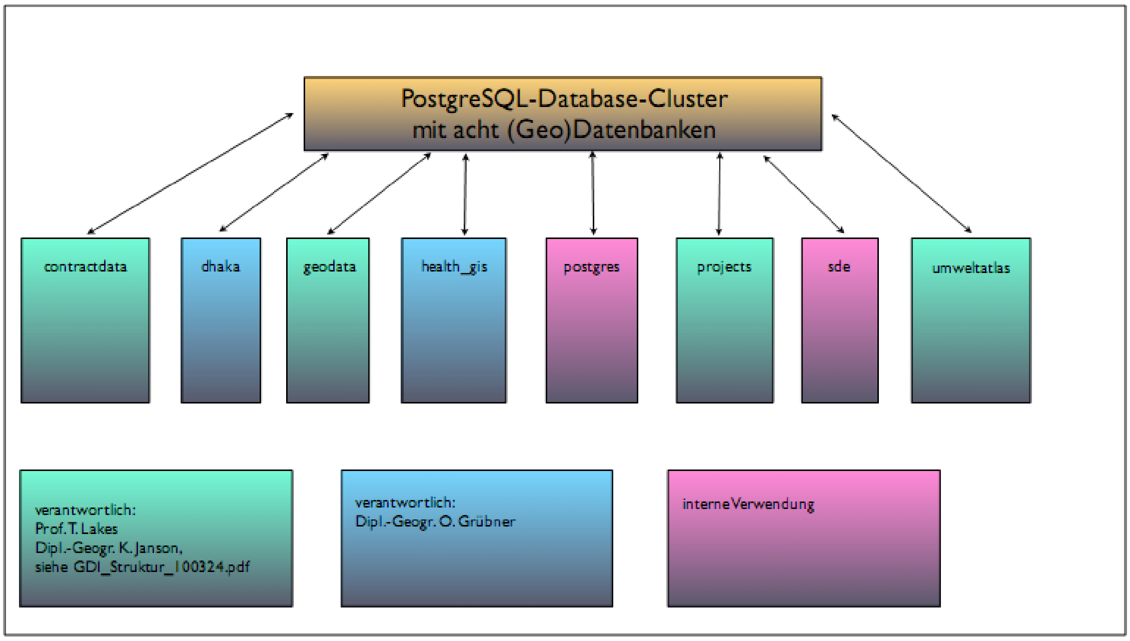

Figure 12: Currently implemented: department's PostgreSQL database cluster.
Source: Department of Geography, internal document.

Moreover, the Geography Department maintains a collection of over 75,000 analogue maps (Figure 13). The attempt to digitize these resources is in continuous progress. Digitized maps are managed using FileMaker Pro database. At the same time, metadata records of this data are collected in a separate metadata catalogue but this metadata is organized following no international standard. This catalogue can be accessed through one's own portal. The new metadata management system can accommodate this metadata for users to easily access it through the geoportal.

The Department's SDI provides spatial data for research and teaching purposes such as topographic maps, data from the "Amtliches Topographisch-Kartographisches Informationssystem" (ATKIS) and orthophotos. A collection of digital height models is available as well as spatial data from a wide range of projects and working groups, such as historical data from the "Historischen Atlas Schleswig-Holstein".

The appearance of existing data varies from spatial geometric raster or vector data to non-spatial documents or media and topologies.

	Collection of Analogiue Maps		
	before 1870	1870-1945	after 1945
Analogue Maps	5.000	50.000	20.000
Atlases	20	100	250
Globes		2	9
Wall Maps		200	550
Relief		6	

Figure 13: Department of Geography's collection of analogue maps.
Adapted from: Dransch, Schwedler, & Beyer, 2005.

Moreover, a geo-service is provided through the SDI. The "Auskunftssystem Adlershof"[13] offers web based services using the Mapserver API and is free to use by projects teams and working groups.

Access to resources is organized according to the protocol of user groups and user rights management. Basic topographic data is freely available for everyone with the required account credentials. Each resource holds its own metadata record, which is an operational basis for metadata discovery.

3.3. GEONETWORK CATALOGUE APPLICATION

A preliminary software evaluation was conducted to identify the best fitting solution for the new metadata management system. This evaluation, as described further down, defines GeoNetwork opensource as being the best choice for the present case since it fulfils all requirements. It is a standard based metadata management

[13] See http://gdi.geo.hu-berlin.de/adlershof/index.htm (reached 5.1.2011).

system, designed to enable access to geo-referenced databases, cartographic products and a-spatial resources from a variety of providers through descriptive metadata. It supports main metadata catalogue capabilities like metadata editing, storage and management, metadata publishing, search and share functions, metadata synchronisation and harvesting of remote catalogues, and support of data distribution and publication. Further, the application offers an administration tool to setup and manage the geoportal.

GeoNetwork enables users to exchange and share resources using the capacities of the Internet. The system provides a community of users with easy and timely access to available spatial data and thematic maps from multidisciplinary sources through one central portal. The main goal of the software is to increase collaboration within (and between) organizstions in order to reduce duplication, enhancing information consistency and quality and to improve the accessibility of a wide variety of resources along with the associated information, organized and documented in a standard and consistent way(GeoNetwork User Manual, 2011).

The first prototype of the GeoNetwork catalogue was released in 2001 by the Food and Agriculture Organization of the United Nations (FAO) with the aim of systematically managing and publishing spatial datasets produced within the organization. Later, the World Food Programme (WFP) of the United Nations joined the program and released the first version in 2003. Simultaneously, both UN agencies established operating catalogues. Jointly with the UN Environmental Programme (UNEP), FAO developed a second version in 2004. The new release allowed users to work with multiple metadata standards (ISO 19115, FGDC and Dublin Core) in a transparent manner. It also allowed metadata to be shared between catalogues through a caching mechanism, improving reliability when searching in multiple catalogues.

3.3.1. TECHNICAL ASPECTS

GeoNetwork is a platform independent application, basing on Java for server pages. Database connections are established using a standardized interface. Pre-installed McKoi is used for desktop environments, PostgreSQL or MySQL databases for large system environments. Metadata is maintained by PostgreSQL database management system. All HTML and XML requests and responds are managed by Java Easy Engine for Very Effective Systems (JEEVES).

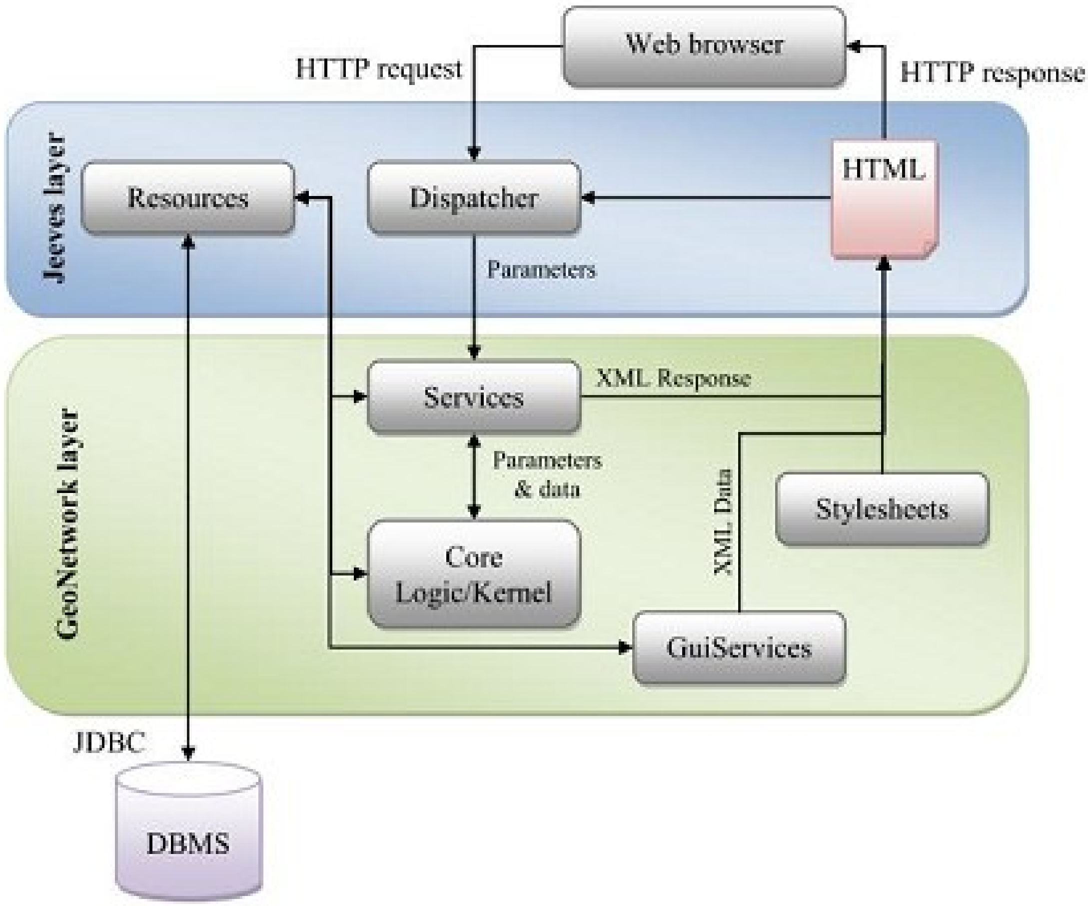

Figure 14: Technologies in GeoNetwork.
Source: Gwenzi, 2010.

Further, it provides database access, multilingual support, manages service chain and sessions. A XML+XLSEngine supporting both XML and HTTP message formats, represents the basis of JEEVES. It enables server architectures with multiple access modes and allows for a separation of presentation layer and business logic layer (Figure 14).

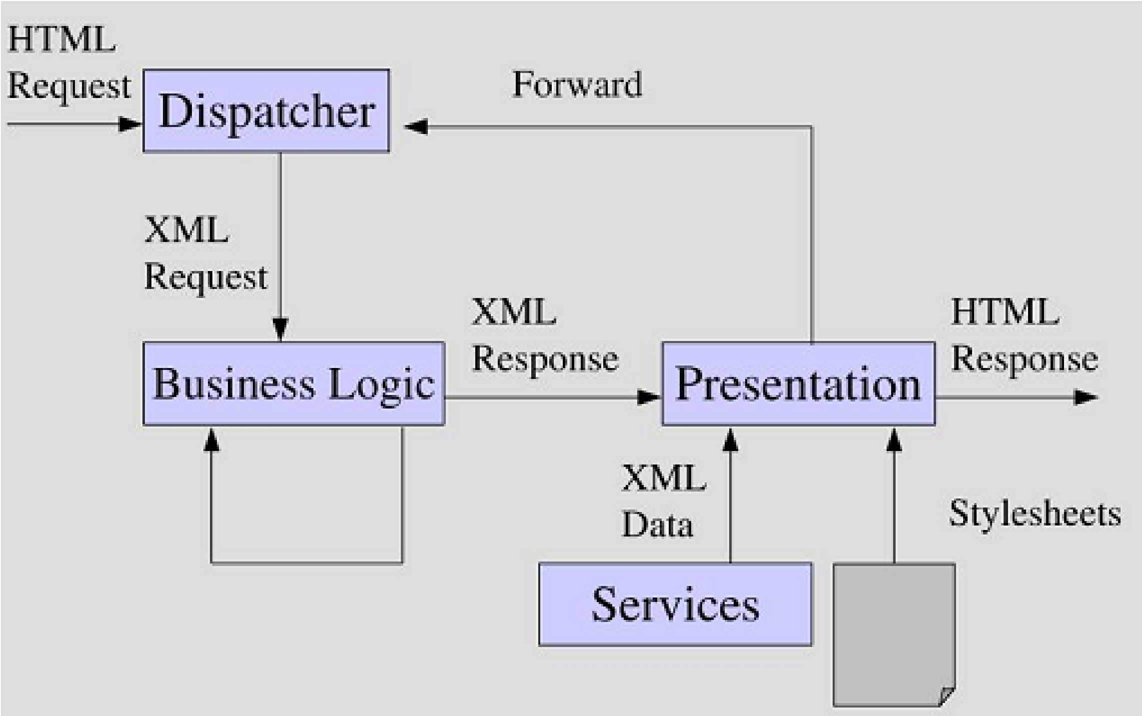

Figure 15: HTML request workflow in GeoNetwork.
Source: Gwenzi, 2010.

JEEVES uses XML as internal data representation and XSL to producing HTML output. The Z39.50 catalogue allows access modes such as SOAP for searches. All HTML requests are sent in HTTP format and converted to XML with the GeoNetwork layer. Responses are delivered in HTML format (GeoNetwork User Manual, 2011; Gwenzi, 2010). Requests made in *GeoNetwork* are transformed into XML and handled by the Business Logic Unit which accesses the internal DBMS holding metadata (Figure 15). The service layer receives requests and dispatches the output.

The metadata and access manipulation allows for editing metadata according to its schema and stores it in XML form in the database supported by the GeoNetwork-ebRIM registry (Gwenzi, 2010). This service is based on OGC specifications and runs as a separate servlet. It securely manages any type of electronic content (e.g. XML documents, text documents, images, sound and video) and standardized metadata that describes it by generating instances (e.g. *RepositoryItem* = instance of content, *RepositoryObject* = instance of metadata). Further, it provides services that enable sharing of content and metadata between entities in a distributed environment. It is kept synchronized, which means that whenever metadata in

ISO19115/19139 format is added or updated in the *GeoNetwork* database it is imported to the ebRIM repository. The ebRIM repository is also updated immediately after editing or deleting a particular metadata record (Figure 16).

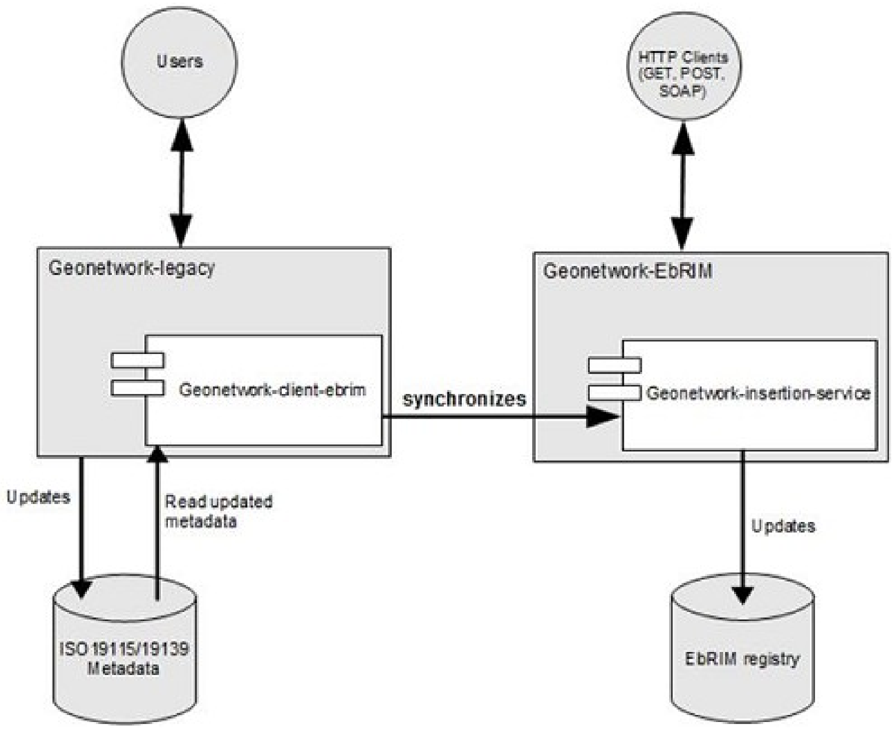

Figure 16: GeoNetwork-ebRIM registry service.
Source: Gwenzi, 2010.

Indexing takes place simultaneously allowing faster searching. A GeoNetwork-client-ebRIM component resides in the GeoNetwork-legacy which ensures that every change in the GN metadata catalogue is reflected in the ebRIM registry.

3.3.2. INTERNATIONAL STANDARDS

From the first version on in 2003, GeoNetwork has been developed following the principles of Free and Open Source Software (FOSS). Its services and protocols are based on international and Open Standards such as ISO standards and OGC specification. At early stages, the application was based on the –at that time – generally accepted ISO19115:DIS metadata standard and embedded the Web Map Client InterMap that supported Open Geospatial Consortium (OGC) compliant Web Map Services. Distributed searches were possible back then using the standard

Z39.50 catalogue protocol, which is still active in the current version. At that time it was decided to develop that the program would be developed as a Free and Open Source Software to allow the whole geospatial user community to benefit from the development results and to contribute to the further advancement of the software. The GeoNetwork architecture is largely compatible with the OGC Portal Reference Architecture, a guide to implementing standardized geoportals. Its structure relies on the three main modules identified by the OGC Portal Reference Architecture, which are spatial data, metadata and interactive map visualization. The system is also fully compliant with the OGC specifications for querying and retrieving information from Web catalogues (CSW). The current version supports the most common standards to specifically describe geographic data (ISO19139 and FGDC) and the international standard for general documents (Dublin Core). It uses standards (OGS WMS) also for visualizing maps through the Internet (GeoNetwork User Manual, 2011).

GeoNetwork open source is the result of the collaborative development of many contributors. Since the first version in 2003, developed by the Food and Agriculture Organization (FAO) and the World Food Programme (WFP) a long list of organizations joined the project, for example the UN Office for the Coordination of Humanitarian Affairs (UNOCHA), the Consultative Group on International Agricultural Research (CSI-CGIAR), The UN Environmental Programme (UNEP) and The European Space Agency (ESA). Support for the metadata standard ISO19115:2003 has been added by using the ISO19139:2007 implementation specification schema published in May 2007. The release also serves as the open source reference implementation of the OGC Catalogue Service for the Web (CSW 2.0.2) specification.

Continuous development generates substantial improvements and includes a new Web map viewer and a complete revision of the search interface.

3.3.3. HARVESTING IN A SHARED ENVIRONMENT

The Geography Department's SDI can be described using the SDI^{light} approach. There are no short or middle-term plans to connect the internal SDI node with external ones. Therefore, the harvesting functionality is of no concern in the present study. However, this section will be dedicated to a short description of this functionality since it is central in GeoNetwork catalogue applications.

Increased collaboration between data providers within the geographic information environment and their efforts to reduce duplication have stimulated the development of tools and systems to improve sharing of resources. The main idea is to enable easy and quick access of resources from a variety of sources without undermining the ownership of the information.

The harvesting functionality in GeoNetwork is a mechanism of data collection in perfect accordance with both rights to data access and data ownership protection. Through the harvesting functionality it is possible to collect public information from remote GeoNetwork nodes and to copy and periodically store this information locally. In this way a user from a single entry point can discover resources from distributed catalogues (GeoNetwork User Manual, 2011). The OGC Web Catalog Services Z39.50 protocol allows distributed search capabilities.

Usually, in an SDI network each node takes care of a specific region. It is necessary to be able to perform a search in all external SDI nodes at the same time. This so-called “distributed search” consumes high bandwidth capacities. Harvesting is the process of collecting remote metadata and storing them locally for faster searching. This has to be done periodically to keep remote and local metadata aligned. GeoNetwork is able to harvest from a number of different sources: WebDAV server, CSW catalogue server (version 2.0.1 or higher), OAI-PMH server or OGC services using its GetCapabilites document (e.g. WMS, WFS etc.) can be contacted beside GeoNetwork nodes (version 2.0 or above).

Harvested metadata cannot be edited or else the process would be compromised. Every change to a record is documented with the attribute “last change date”. This parameter is used to find out whether the record was changed since the last harvest. If the remote harvested node is removed, all harvested and locally saved metadata is removed too. The harvesting mechanism identifies metadata records using universal unique identifiers (UUID) which are worldwide unique IDs. It is a combination of the node’s MAC address, a timestamp and a random number; every time a metadata record is created it receives its own UUID.

4. METHODS & WORKFLOW

This chapter provides a description of the research process of the present case case study and illustrates the methods chosen. It starts with the conceptual background, aspects of metadata management, its requirements, and the goal of reaching a high level of user satisfaction. Then the methods used for the research are described chronologically. This research included a questionnaire developed for a preliminary assessment of user requirements, followed by a software evaluation for metadata management systems. Finally, the methods used for the actual software design and the implementation process are described.

4.1. IMPLEMENTATION CONCEPT

This project aims to provide scientific staff and students a well adapted service to meet the need to be able to centrally search, edit and manage the institute's resources.

The final anticipated outcome is the implementation of (1) a metadata manager, and (2) an easy to use and barrier-free reachable online tool usable for everyone according to defined rights and user roles. (2) refers to "geoportals" which are capable of meeting these needs providing a list of geo-services (e.g. a WMS). The geoportal should furthermore feature a preview functionality to visualize discovered resources.

With the realization of so-called "bindings", users can visualize the geospatial data found using an embedded web mapping service. Through these capabilities the "Publish-Find-Bind" concept of SDIs are respected and data usability for rather inexperienced users ought to be increased.

The implementation process, which aims to reach a high level of user satisfaction, follows two concepts: (1) the Joint Application Development (JAD), which is an application implementation concept with an emphasis on the constant involvement of future users and continuous feedback loops; and (2) Rapid Prototyping (RP) which is an approach where application prototypes are built in a short time to enable fast user feedback loops. It is used as an extension to JAD to possibly shorten the implementation process. These two concepts are described in the following chapters.

4.1.1. JOINT APPLICATION DEVELOPMENT

Phase	State	Description
Collaboration	Problem-setting stage	Definition of the needs of potential users. All actors must agree on what exactly the common issue is.
Cooperation	Direction-setting stage	Each owner of the spatial data begins to discuss
Coordination	Structuring stage	The structure of the planned infrastructure is proposed. All individual data owners and users have to agree on a common solution.
Implementation	Problem – solving stage	The project of the common spatial data infrastructure is implemented and tested in the real organization's environment.
Evolution	Relation – maintaining stage	The users assess the resulting outcomes of the SDI. They can come up with new suggestions and influence the future development of the system.

Table 3: JAD phases for SDI building process.
Source: Grill & Schneider, 2009.

To achieve the anticipated goal of high user satisfaction and cooperation throughout the SDI implementation process, the concept of JAD was chosen and to a great extent the work follows this concept's guidelines. It is a well elaborated and broadly accepted design for a user integrative software implementation process. Users and designers are in constant contact. The continuous feedback increases user satisfaction and the success of final solution.

A simplified version of this concept and its divisions into five "Phases of Awareness" are listed in Table 3.

From the point of motivation, there is a demand for knowledge and awareness about spatial data. It is important to know about resources available in departments' databases, at least for the purpose of minimizing redundancy.

Awareness regarding data is very important for an SDI. Moreover awareness about the geoportal and the SDI itself is at least as important. Users should be informed about the benefits of this concept and they should be able to participate in the design process. This participation ensures higher user satisfaction and represents a major driver to encourage infrastructure development (Thellufsen, Rajabifard, Enemark, & Williamson, 2009).

Sometimes it is difficult to motivate users to share their data. Furthermore, data sharing brings about a higher investment in time and effort to set up and maintain corresponding metadata. But in the long run, every user of an SDI benefits to a disparately higher degree from having access to a large amount of resources ready to use.

To overcome this first "hurdle of investment", awareness of the benefits of the SDI should be raised following a five-phase plan (Table 3); and the fifth phase in particular should be used to reach out and involve a wider user community. It should ensure that users' opinions about the look and feel of the new geoportal are heard during the design process. This will be realized through regular meetings with the staff members involved, who are also the supervisors of this work. After the implementation phase, a feedback loop with a wider range of users should raise constructive and inventive comments and proposals for modification of the services.

This concept of user participation in JAD requires active participation from future users and system professionals. For most of the implementation process, this participants' group is ideally kept small to reduce costs and managing effort. For the work at hand, most effort was concentrated on phase two ("Cooperation") and phase three ("Coordination") of JAD. These two phases consisted, as described by Yeung & Hall (2007), of a series of participant meetings. These meetings aimed at harvesting concentrated feedback from the department's three or four main "SDI experts" or "SDI stakeholders". The criterion for selecting the expert group members was their interest in the software to be developed, the proximity of their professional interest to the topic of SDI and their engagement in the department's currently existing SDI.

In addition to these periodic meetings, possible future users and experts have been given two more opportunities to contribute their opinions: (1) a preliminary expert

questionnaire, and (2) a final expert and user feedback questionnaire.
(1) covers the problem setting stage and JAD phase one (“Collaboration”) and resulted in a list of basic user requirements and functionalities which should be included. (2) relates to phases four (“Implementation”) and five (“Evolution”), even though the last phase number five extends this work’s scope in terms of time and effort.

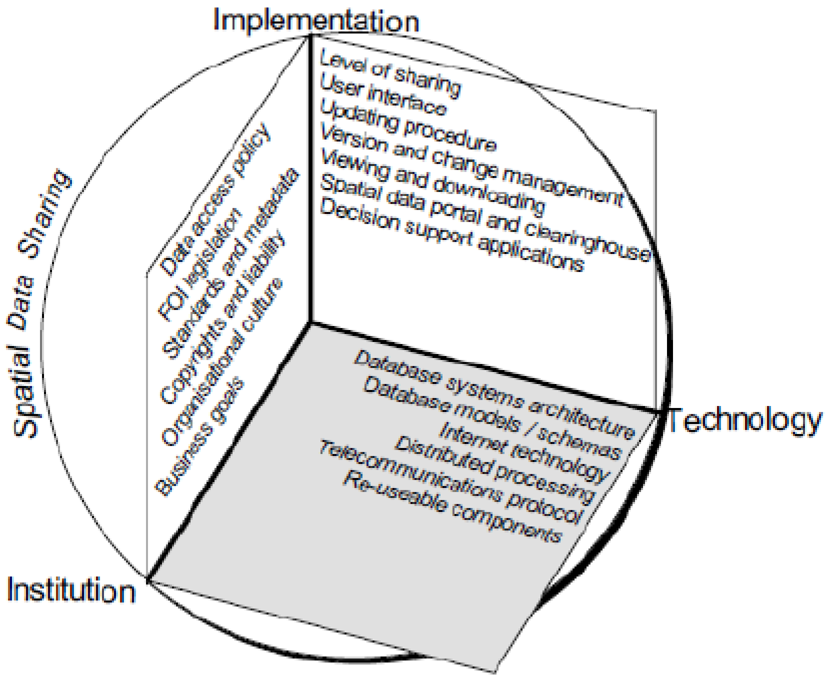

Figure 17: Spatial data sharing from different perspectives.
Source: Yeung & Hall, 2007.

Grill & Schneider (2009) indicate another important consideration in the process of setting up an SDI for an academic research institution: what is the role of the viewpoints “institution”, “technology” and “implementations”, and how do they interact? To understand the proposed perspective, one must distinguish between different points of view (Figure 17). SDI is created for a specific user group who is working or studying somewhere (where) SDI is established following a defined goal and a planned result (what) and it is implemented in a chosen way (how). Answering these three questions is essential to building an appropriate information system.
For the present study the “where” question examines the SDI requirement profile of the Department of Geography. General requirements ensure basic functions and general schema for catalogue systems like discovering, sharing and managing

resources. Specific requirements largely depend on the kind of institution. SDI for academic facilities has the potential to support research, teaching and learning activities and could for example offer an extension for academic output (students' maps, diploma theses, etc...). However, the business oriented possibilities can be left aside here.

As shown above, the main goal of establishing SDI and a geoportal centres on data sharing. The aim of sharing spatial and aspatial resources comes along with a range of challenges and questions. One attempt to tackle this challenge is to follow different points of view onto the sharing activities. Figure 8 visualizes the breakdown of perspectives according to the three different viewpoints.

The adaption of the methods of JAD requires constant adaptation of software development processes, respecting user feedback. To guarantee continuous sequences of user opinion surveys and adaptation in a reasonable timeframe, user feedback has to be framed into rapid prototype. Methods from the concept of rapid prototyping fulfil these requirements.

4.1.2. RAPID PROTOTYPING

The attempt to create prototypes in a short time refers to early stages of interactive system development (Rosson & Carroll, 2001), such as for example the widely known Alexandria Rapid Prototype (ARP). The prototype was used to evaluate issues regarding design and technical implementation before final prototype creation (Frew, et al., 1995).

For this study, the method of RP aims at providing a nearly up-to-date and convincing "road map" of implementation process. Current implementation status, development of interface design and of functionalities can be demonstrated to experts and users. Through these continuous presentations, user feedback and expert recommendations are collected. Design and implementation processes are adapted and modified on the basis of these inputs.

The technical architecture of the GeoNetwork accommodates the PR approach, since it is available as an easy to install software bundle. Changes made regarding design and basic functionalities can be applied in a rather short time and almost without any downtime. This ensures that the whole implementation process follows experts' and users' requirements and increases usability and user satisfaction with the end product.

In the case of far reaching changes in design or functionality, which cannot applied to the GeoNetwork basic configuration in short time, Flash can be a possible solution for creating a rapid prototype. This can be realized through combining Flash user interfaces (UI) and web map services, e.g. an ArcIMS map service as seen in a study by Aditya(2009). Flash speeds up the interface, allowing for a collection of user inputs (e.g. choice of menu style). Meanwhile, the Action Script libraries available from examples and components exchanged in User Forums in the ESRI Support Centre enable compatibility and seamless interaction between Flash UI and ArcIMS map services.

4.2. WORK PROCESS

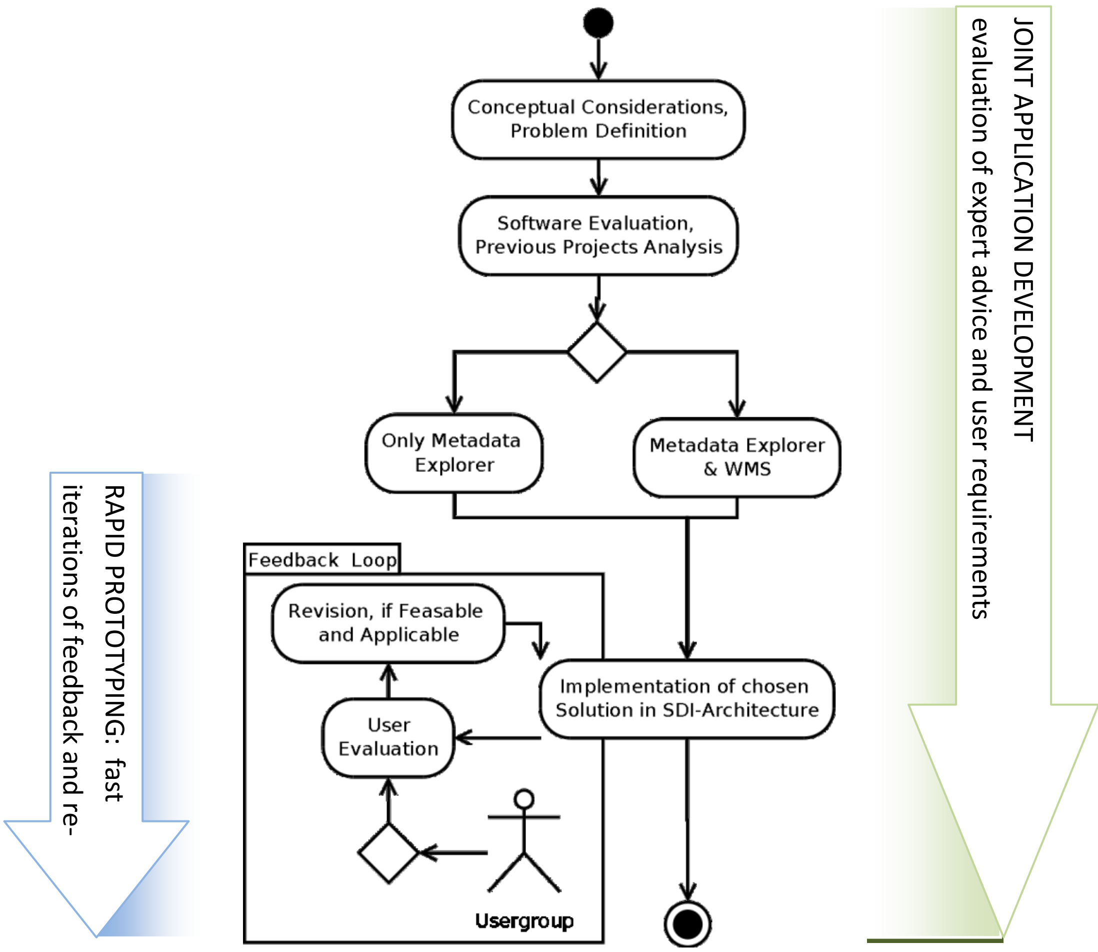

Figure 18: Planned implementation process..

Conceptual considerations, organizational framework establishment and project planning constituted the necessary preliminary steps of the work at hand. A practical part of this case study starts with a definition of the problem and the development of a corresponding project goal.
A software evaluation compares possible solutions for department's new metadata management system. Taking into account the software evaluation's outcome, project goals, experts' advice and user requirements, the most promising metadata management system is chosen.
From there, the implementation process underlies the continuous feedback generated through a Joint Application Development, assisted by the concept of Rapid Prototyping. Experts' advice and feedback regulates the whole implementation process users' feedback comes later into play later regarding the design and usability issues of a first prototype. The design and implementation process respects the feedback obtained and the user requirement information with the aim of increased user participation, user satisfaction and service usability which should be a good basis for a successful SDI (Figure 18).

4.2.1. ASSESSMENT OF USER REQUIREMENTS

Software implementation's central goal by definition is to meet user requirements and achieve a high level of user satisfaction. To assist in accomplishing these goals, close contact with users and experts throughout the designing process and implementation phase is cultivated. Considering Grill & Schneider's (2009) basic question "how?" in the lead-up to designing an SDI, the answer is "with the desire for higher user satisfaction and user participation". Therefore, initial discussions were opened for the expert group members in the lead-up and started officially with a preliminary expert questionnaire. The questionnaire's question style was "open-ended". This allowed experts to formulate their answers individually. The possibility for individual answers ranks experts' answers as highly valuable; chances to obtain diverse and far reaching insights and thoughts would be limited by using a closed-ended question style (e.g. dichotomous or polytomous). This document (ANNEX A) builds the basis for defining and discussing user needs and user requirements. On

the basis of the outcomes of these discussions and the questionnaire,
-the initial problem,
-possible solutions
-user (and expert) groups and
-the exact project goals
were defined under the condition of agreement of each expert group member. Going through the JAD concept's workflow (see Table 3), these activities cover the "Collaboration" phase - phase one.

Both design of questionnaire and design of discussions were put together respecting Yeung & Hall's theory of different perspectives of spatial data sharing (Yeung & Hall, 2007). Of high interest were the edges of the cube as shown in Figure 8, which are the lines where different viewpoints meet. The way of implementation, the choice of technology (with all restrictions and possibilities) and the setting of that specific case study (and kind of institution) do interact and affect each other. Similarly, these three different viewpoints were taken into account when collecting questions and discussion infrastructure design and implementation issues.

The paradigm of far reaching user involvement throughout the whole designing and developing process, as well as the concentration on user preferences from the beginning, is consistent with the idea of the new generation of SDI. The agenda of that so-called "third generation of SDI" defines the user as an active recipient instead of a passive one; moreover it envisages extensive user participation. The art of incorporation of users' needs and user feedback loops into infrastructure design and implementation workflow, as proclaimed for "third generation SDIs", represents an essential part of this work's theoretical basis.

4.2.2. SOFTWARE EVALUATION

The preliminary questionnaire and interviews with expert group members revealed the necessity for scientific staff and students to have a well adapted service that meets their needs to search, edit and manage the institute's resources.

The software evaluation was carried out to clarify the question of whether an application has to be built or if there are existing solutions which can be adapted and implemented in a reasonable and feasible way.
This study's software comparison was not meant to cover a great number of solutions; instead, thetwo most promising solutions were compared. According to consensus that has been achieved during early expert group meetings, the chosen software solution should be based on internationally accepted standards, and likewise metadata should be organized following international standards. Further, it should be developed under a free and open source (FOSS) license and the metadata catalogue should be capable of handling spatial as well as aspatial resources. As an essential requirement, a central portal should enable users to publish, search and discover resources; moreover it should be capable of visualization of resources. Most geoportals embed such functionality, based on free and open source Web Mapping Services (WMS).
Respecting these main criteria, the two most promising software solutions – namely the Esri Arcgis Server and Geoportal Server v.10 on the one hand and GeoNetwork opensource Catalog v.2.6.4 on the other hand – were chosen for a closer analysis. The comparison is based on a literature review, extended by user forum discussions and expert input. Experts and developers were contacted by email; contacts were found at both software websites, further in discussion boards and user forums.

4.2.3. SOFTWARE IMPLEMENTATION PROCESS

In accordance with the JAD concept, the implementation process was influenced and followed by continuous feedback from, and discussion with the four expert group members. Experts were chosen according to their roles as main stakeholders of the department's SDI and as custodians of the department's resources and metadata.
Expert group meetings were organized periodically. They served as a forum where current implementation status, development of interface design, technical capabilities and metadata standards were demonstrated and discussed

periodically. ANNEX B has the information handout as preparation for the experts meeting of May 20th, 2011, showing the planned agenda and additional information for metadata standards and design considerations. After the meeting a report (ANNEX C) was prepared and disseminated. It lists the decisions arrived at, a revised version of the new metadata standard set, and the next steps planned.

4.2.3.1. NEW METADATA STANDARD SET

The metadata standard consists of specifically chosen metadata entries. It frames metadata search and metadata publishing activities. Moreover, entries can be classified as being “mandatory”, “conditional mandatory” or “optional”.
Discussion rounds with experts defined the goal of creating the department’s own standard set. This is necessary to merge all existing metadata resources at the Department of Geography which profed to be very inhomogeneous. For the new metadata standard set, all existing metadata standards were compared and analzsed (ANNEX C, Table 1). For all entries of the metadata standard sets used, a corresponding placeholder entry must exist in new standard set. This should reduce the complexity of converting all existing metadata standard sets into the one new standard.
Moreover, international metadata standards like DCMES, ISO minimum and ISO core, FGDC and INSPIRE metadata set (profile of ISO19115 and ISO19119) were analyzed and taken into account. This should guarantee seamless compatibility with external nodes in cases in which the department’s SDI node joins to cooperate in a distributed infrastructure. ANNEX B shows a first draft of the new metadata standard and the comparison with DCMES, ISO and FGDC standards.
This draft version underwent further development following expert advice. During the course of this, compatibility with INSPIRE metadata standard was given high priority due to its role as the dominant SDI initiative in Europe. ANNEX C (Table 1) lists comparison of the department’s draft metadata standard with the INSPIRE metadata set in tabular format. Further, an older draft metadata standard set from 2010 was consulted as a very important source and was used both as a good reference point and as verification for completeness.

The finally agreed upon standard set is a list of metadata records which are not applicable to all kinds of resources. The department's SDI is designed to manage a number of different types of resources like vector data, raster data, geospatial services, videos, tables, photos, etc. This variety of resources was classified into four main categories: (1) vector data, (2) raster data, (3) geospatial services, and (4) aspatial content. Correspondingly, four sub-sets of metadata standards were developed to meet special resources' requirements in consequence of different resources' attributes (ANNEX D). More on that, including detailed metadata record descriptions can be found in the results section later.

In a summary, the department's SDI stakeholders accompanied the whole implementation process of the GeoNetwork catalogue and geoportal. Close contact was maintained through expert meetings and user requirements were evaluated through a preliminary expert questionnaire. In this way, constant contact was maintained with members of the expert group. The implementation process was enabled by that feedback and informed about user needs to reach a high level of user satisfaction.

Beside activities with the expert group, the present project aimed at dissemination and information activities to reach possible future users. Since SDI is a communication network, its success highly depends on high user numbers and high user satisfaction. This can be achieved through information dissemination and training activities. The course *Geomatic Colloquium*, held weekly at the Department of Geography, was used twice as a platform for the presentation of the new metadata management system and geoportal. Regularly, the audience consists of Geomatics students, tutors, project affiliates, lecturers and professors; and all of them are users of the department's SDI and possible future users of the new metadata system and geoportal. Both presentations concentrated on the geoportal's prototype, its user-computer interfaces, its functionalities and the magic behind it.

The second presentation served as an opportunity for the completion of a user questionnaire (ANNEX E) to collect user feedback regarding the design of the geoportal's main interfaces (search interface, results visualization) and regarding the new metadata standard set. For the latter, user opinion was collected to help in deciding about the status of metadata elements, that is, whether they are set to "mandatory", "conditional mandatory" or "optional".

This questionnaire only covered metadata elements for spatial resources (raster & vector) as they represent the most prominent groups of resources. As a consequence, metadata elements, characteristically describing geoservices or aspatial resources, were not covered.

4.2.4. PROTOTYPE CREATION

The prototype was developed based on agreements achieved in the expert group. GeoNetwork Version 2.6.4 installation package comes with Jetty Java servlet and a McKoi database, both of which are classified by experts as inappropriate. Jetty was replaced by Apache server. There are two main prerequisites for the web server to be capable of hosting GeoNetwork: it must support servlets and it must support data base systems. Apache server fulfils both requirements.

File/Setting	Original	...changed to	Comments
Folder "geonetwork"	Was in base folder of Jetty servet	folder of Apache Tomcat (...\Tomcat 5.5\webapps\)	Preliminary organization of files and folders: copying of Geonetwork's application folder into the folder which Apache Tomcat servlet reserves for web applications
Folder "data"	Was in base folder of Jetty servet	Copy to base folder of Geonetwork (...\Tomcat 5.5\webapps\geonetwork\)	Preliminary organisation of files and folders II: Lifting Geonetwork's "data" folder into Geonetwork's base folder.
Set port	8080 (Jetty)	***80*** (Tomcat)	Necessary due to conflicts at port 8080
Set initial memory pool	-	***256MB***	Using Tomcat's software configuration application Java tap
Set maximum memory pool	-	***1025MB***	
Add definitions	-	***-XX:MaxPermSize=256m -XX:PermSize=128m***	
Create ...\Tomcat 5.5\conf\Catalina\localhost\geonetwork.xml	-	***<Context docBase="/webapps/geonetwork" crossContext="false" privileged = "true" antiResourceLocking="false" antiJARLocking="false" reloadable="false" />***	Apache Tomcat servlet configuration file for Geonetwork defining base folder ("docBase") and basic web application parameters

Create ...\Tomcat 5.5\conf\Catalina\localhost\geoserver.xml		***<Context docBase="/webapps/" privileged="true" antiResourceLocking="false" antiJARLocking="false"> </Context>***	Apache Tomcat servlet configuration file for Geoserver defining base folder ("docBase") and basic web application parameters
Install latest Java Database Connectivity (JDBC) into ...\Tomcat 5.5\webapps\geonetwork\WEB-INF\lib\	postgresql-8.2-504.jdbc3.jar	postgresql-8.4-701.jdbc4.jar	New Java Database Connectivity API installed and old one deleted.
…\Tomcat 5.5\webapps\geonetwork\WEB-INF\config.xml		<uploadDir>***data/tmp***</uploadDir> <param name="dataDir" value="***data***" />	Define the directory to where loaded data goes first
...\Tomcat 5.5\webapps\geonetwork\WEB-INF\db\db.conf		database_path=***data*** log_path=***log***	Define database folders and path to log file
...\Tomcat 5.5\webapps\geonetwork\WEB-INF\log4j.cfg		log4j.rootLogger = ***ON*** log4j.appender.jeeves.file = ***/srv/tomcat5.5/webapps/geonetwork/geonetwork.log***	Enables debugging log mode and defines log file's path
.../Tomcat 5.5\webapps\geoserver\WEB-INF\web.xml		<param-value>***../../geonetwork/data/geoserver_data***</param-value>	Points Geoserver to its data folder

Table 4: Changes made to GeoNetwork and Geoserver configuration files to run on Apache Tomcat servlet container.

Apache can serve more complex and heavier applications and was favoured since it is currently used for existing SDI as well; therefore an implementation approach which is based on Apache Tomcat instead of Jetty profed more reasonable for this case study. Moreover, the McKoi database, which is installed by default, is insufficient for the department's SDI and PostgreSQL database technologies proved more suitable (Grill & Schneider, 2009). This decision corresponds with the current effort to convert the department's database from DB2 to PostgreSQL.
The required migration from Jetty to Apache Tomcat[14] implied a number of changes in file-folder-structure and within configuration files of Tomcat, GeoNetwork and Geoserver. The latter comes as an implemented component of GeoNetwork and serves as WMS for data visualization. These changes are listed in Table 4. In this process, GeoNetwork was implemented on top of an Apache HTTP web server and

[14] Apache HTTP server: version 2.4.4; Tomcat java servlet: version 5.5

Tomcat servlet container. The operating system for the prototype is Windows Vista Business.

Tomcat deployed Geoserver automatically to its web application directory (...\Tomcat 5.5\webapps\). Having GeoNetwork running on top of Apache Tomcat servlet, the configuration documented in Table 4 sets new contexts and enables Geoserver to properly show the map viewers within this new environment.

The migration from Jetty to Tomcat is based on a conglomerate of sources. OSGeo maintains a forum website which has a “GeoNetwork opensource” section[15]. Apart from that, OSGeo features the “GeoNetwork opensource Developer website”[16]. The U.S. Geosciences Information Network website of Arizona Geologic Survey (AZGS) and GeoNetwork project website are offering tutorials referring to older versions of GeoNetwork. The U.S. Geoscience Information Network Commons website has collected cookbooks for a wide range of related topics[17].

After changes are applied and configuration is rounded up to run the metadata catalogue on Apache Tomcat, the configuration tool “GAST” can be used to finish the installation process and choose basic settings. The tool can import test metadata records, set up the metadata catalogue database and allows for basic settings like user management, language settings and metadata standards. After the completed migration of the department’s database management system to PostgreSQL, GAST can be used to establish connection.

4.2.5. USER EVALUATION AND FEEDBACK

Having a working prototype up and running, it can be presented to possible future users, representing the first user-feedback-loop (according to the research process outlined previously). For a second time, the Geomatics Colloquium at the Department of Geography served as a stage; after the new geoportal prototype

[15] E.g.: http://osgeo-org.1803224.n2.nabble.com/ and http://osgeo-org.1803224.n2.nabble.com/Linking-Tomcat-to-Geonetwork-2-6-x-td5747050.html (visited 3/2011).

[16] E.g.: http://trac.osgeo.org/geonetwork/wiki/HowToRunUnderTomcat (visited 3/2011).

[17] E.g.: http://lab.usgin.org/applications/doc/running-geonetwork-241-under-tomcat-55-windows-xp (visited 4/2011).

was presented, the audience was asked to give feedback by filling out the user questionnaire (ANNEX F).

Exploring the geoportal's metadata means that the user will come across two main interfaces: (1) the search interface, and (2) the results visualization interface. This questionnaire was designed to collect user opinion about (1), the search interface and about metadata standard set specifications. Design decisions for (2) were taken based on a literature review (mainly Aditya & Kraak, 2007; Aditya T., 2009; Chi, Riedl, Barry, & Konstan, 1998; Rao & Card, 2004; Woodruff, Faulring, Rosenholtz, Morrison, & Pirolli, 2001; see chapter "Metadata Exploration & Visualization").

4.2.6. INTERFACE DESIGN

The search interface and the result interface are the portal's two main interfaces. The work at hand put special emphasis on the design of these interfaces. It is where communication processes take place. User satisfaction and SDI long-term success strongly depends on barrier-free and effective facilitation of these processes.

The geoportal's search interface enables the user to discover resources. The search process accesses information, which was previously recorded in metadata. Only these resources' attributes, collected in metadata records, are available through the search process. As a result, the search interface design is restricted by the records of the metadata standard set. To find the best composition of searchable attributes, experts and users were asked to fill out the metadata standard questionnaire (ANNEX E). The questionnaire lists metadata elements of the new metadata standard set for the department's SDI. Possible future users (n=16) and three members of the expert group were asked to identify metadata elements which are essential for the search interface.

GeoNetwork offers two setup options for search interface: (1) the basic search and (2) the expanded search. The basic search (1) is left unchanged in the prototype. The expanded search interface (2), offering a broader variety of searchable attributes, was set up following an analysis of the results of the metadata standard questionnaire. In this analysis, collected votes for each metadata element from experts and users were summed up and compared. The final decision about the question of which elements to choose was taken mainly according to experts' votes; user votes served as a supporting deciding factor.

The interface for result visualization sums up search results briefly and in a way that is clearly arranged for analysis and comparison. Further, detailed resource information should be made retrievable in an interactive way. The articulation of these basic requirements and the outcome of different strategies for search result visualization were adopted from Aditya & Kraak (2007; 2009). They are open for discussion in future expert meetings or user-needs assessment activties.

5. RESULTS

The following chapter describes the results of the present study following the chronological order of the research plan. First results were generated by a preliminary questionnaire to assess user requirements. Based on this questionnaire's outcome, the two most promising software solutions were chosen for a software evaluation. This evaluation generated a significant software comparison, a number of comparison aspects and a final decision.
The implementation process, accompanied by continuously collected expert feedback, resulted in a working metadata management system prototype. A new metadata standard set, the search interface and the result visualization interface are well elaborated aspects of this prototype. They are based on expert and user feedback activities and are presented in the last part of this section.

5.1. USER REQUIREMENT ASSESSMENT

Question	Essence of answers
1 Main users now?	Internal use, user groups: admin, student, staff (dept. admin, research, externs)
2 Main users future?	No change in terms of users
3 What kinds of resources are supported now?	Various spatial & aspatial contents, no services or applications
4 What kinds of resources to support in the future?	Possible extension by aspatial content, services & applications
5 Support for activities, typical for an academic institution now?	SDI is a data discovery tool for educational and research purposes, part of curricula
6 Working Security framework, user-management (user roles and levels of access) now?	No elaborated user management that should be used in the future
7 Security framework, user management required future?	User management and levels of access regulations required
8 Local or distributed catalogue now?	Local catalogue node
9 Distribution and connection to remote SDI nodes, other changes to SDI architecture planned future?	Middle to long-term distribution planned, maybe establishment of university SDI, spatial database migration, file system for raster data
10 New SDI-functionalities needed in the future?	Elaborated user friendly metadata management system including geoportal, search map for spatial search, access to data beyond geodatabase & access to services, establishment of project categories
11 Special requirements for future SDI in respect to department's data(base)?	Access to data beyond geodatabase, geoportal as central portal to access resources, institutional framework defining clear (meta)data custodianship and responsibilities for maintenance of metadata

Table 5: User assessment questionnaire result summary.

JAD and user-centric SDI approaches are basic concepts for the present work's software implementation process. Accordingly, it started with all four members of the SDI expert group being asked to complete a questionnaire (ANNEX A). The results of this preliminary assessment of user requirements build the basis for decisions concerning architecture and capabilities of the metadata management system to be implemented. The most important findings from the questionnaire are summed up in Table 5: detailed results are given in ANNEX G.

From the experts' point of view, the main purpose is to foster cooperation and exchange of resources within the Department of Geography and its affiliates in research groups and projects. Further, the SDI node will be a subject for curricula and a working example for education and research purposes.

The new metadata management system should be the central point to access, preview and download data, administrated through a user-roles system defining the rights (and responsibilities) of each user. User-responsibility means that every user is responsible for the correctness of the metadata he/she is publishing. The software solution implemented should be based on internationally accepted standards, such as the ISO standard framework or the OGC standards and specifications for services. The idea behind this is to ensure interoperability and seamless compatibility with external services and data in the future, such as remote metadata catalogue nodes or web services. However, there are no short-term plans to establish connection and cooperate with external entities' SDI nodes. Likewise, data and metadata should be recorded and organized following international standards. Metadata catalogues represent the appropriate solution for this purpose since they are built for this purpose.

Another essential criterion found through the evaluation of user assessment and early expert group meetings was a metadata catalogue that can map and visualize spatial resources found. A geoportal with an embedded web mapping service could be a very suitable solution. This should enable users to search, discover, edit, create, and visualize metadata records at one central node.

Spatial data often comes along with associated aspatial content (e.g. documents, links, media, etc.) - these resources should be covered by the metadata catalogue as well, since it represents an essential help for users to make spatial data understandable and usable.

5.2. SOFTWARE EVALUATION

Software evaluation was undertaken to compare two OGC conform metadata management services. GeoNetwork and ESRI Server and Portal were chosen for evaluation through expert group discussions with the aim of finding a suitable solution to browse, edit and manage the Department of Geography's metadata. There exists a number of other software packages for metadata management, not chosen for the present work's comparison; for example the Earth Information exchange (ESIP) client, "eXcat" CSW server and client, the "Deegree" Spatial data infrastructure, the "CarbonArc® PRO" Client for CSW, WFS, WMS, and the CatalogConnector.

5.2.1. METADATA CATALOGUE ANALYSIS

GeoNetwork is an Ajax based web framework, which offers a wide range of XML data handling for search and update and is especially designed to meet the ISO19115/19139 standard. It can be defined as an HTTP Catalogue Service for ISO 19115 Metadata encoded according to the ISO 19139 schema.
FAO and WFP, and more recently UNEP, have combined their research and mapping expertise to develop GeoNetwork open source as a common strategy to effectively share their spatial databases including digital maps, satellite images and related statistics.
GeoNetwork open source is a standardized and decentralized spatial information management environment, designed to enable access to geo-referenced databases, cartographic products and related metadata from a variety of sources, enhancing the spatial information exchange and sharing between organizations and their employees over the internet. This metadata catalogue provides institute-wide easy and timely access to available (meta)data stored in the PostgreSQL database and the file system.
GeoNetwork is attracting considerable attention with its adoption by a number of international programs, countries and regional SDI initiatives, including the USA, Australia, France, Czech Republic and Hungary adopting this software (OSDM, 2007). This ensures continuous development. Moreover, it is an official community-led OSGeo project. This encourages collaborative development of the software.

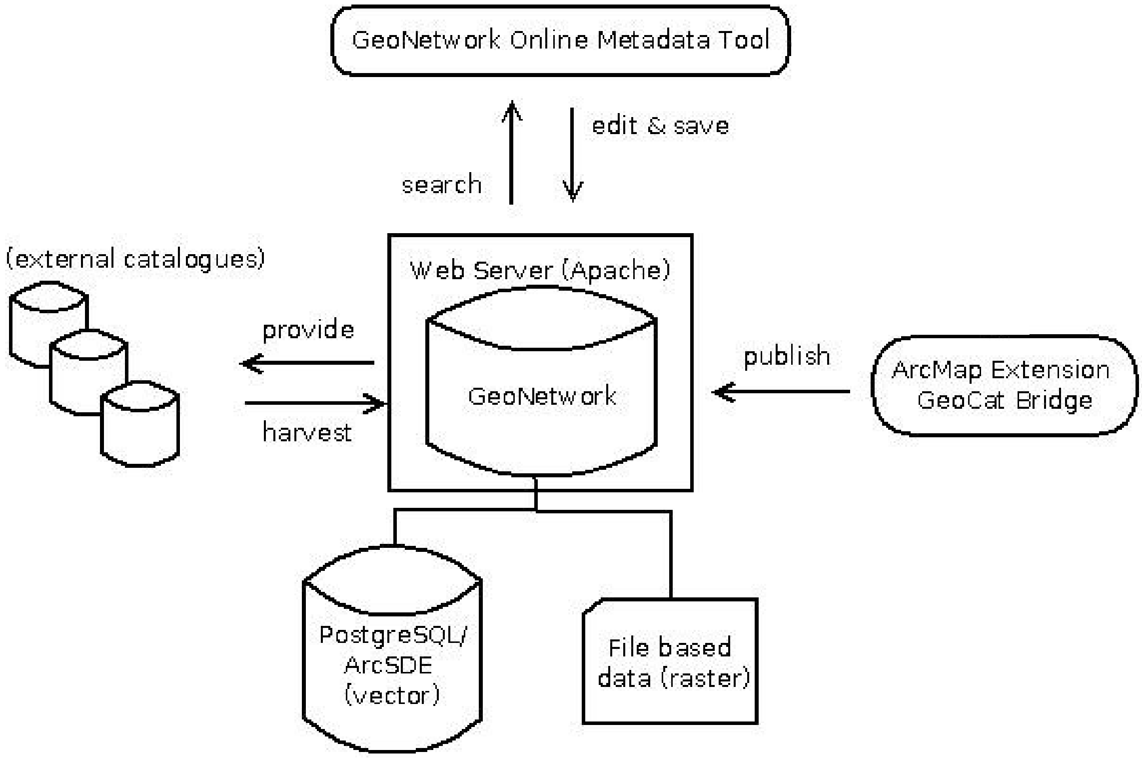

Figure 19: Simplified possible schema of future SDI architecture using GeoNetwork.

Figure 19 shows how GeoNetwork would interact with existing spatial data infrastructure architecture. Data can optionally be obtained from and shared via external catalogues using the harvesting tool. The user can either use GeoNetwork's own online metadata tool for searching, editing, and uploading metadata, or the ArcMap extension GeoCat Bridge which allows "one-click" publishing. Though, the seamless combination of these two tools requires testing first. Instead of the embedded GeoNetwork online metadata tool, other portal software can be alternatively integrated. MapBender for example can be suitable as well for saving, editing and maintaining metadata on top of GeoNetwork (vgl. Hüben, 2010).

ESRI recently introduced the new version 10 of ArcGIS Server and Geoportal Server (formerly Geoportal Extension). The package allows the quick setup of geoportals to manage and share geospatial information externally with the public or internally with colleagues.

Geoportal Server allows management of resources by registering (storing and cataloguing) the resources' metadata. In version 10, the extension provides tools to simplify registering, managing, using, and integrating these resources by introducing server-side resource synchronization, which replaces the harvesting tool and services from earlier versions. Once a resource is registered with the geoportal, the geoportal will monitor the resources for changes and availability and automatically update its catalogue entry.

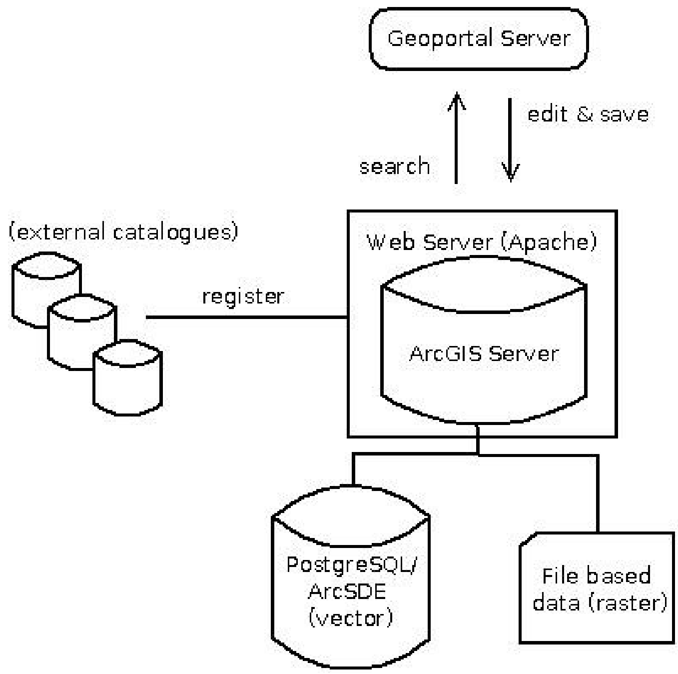

Figure 20: Simplified possible schema of future SDI architecture using ESRI Server and ESRI Geoportal technology.

The updates also give users the ability to search ArcGIS Search Services, which is an ArcGIS Server service that makes available, to the local network, a searchable index of an organization's GIS content. This search service is integrated into the geoportal's interface (ESRI Website, 2010). Figure 20 visualizes SDI architecture schema having integrated ESRI server software. ArcGIS Server "spatially enables" the database and web server architecture. The ESRI Geoportal Server enables the user to search, edit, manage and administer metadata resources (as well as other kind of resources like metadata catalogues, documents, URLs, media etc.). GeoCat Bridge does not work within this environment since it will only publish metadata as a map service on a Geoserver or GeoNetwork instance.

5.2.2. COMPARISON OF METADATA MANAGEMENT SYSTEMS

Compatibility: Both solutions could be used together with existing SDI architecture. GeoNetwork offers good compatibility. ESRI server products fit together seamlessly with the implemented ArcSDE technology. Since Version 9.2 ArcSDE is integrated into ArcGIS Server.

License: GeoNetwork is totally free and open source. ArcGIS Server is commercial software. For the case at hand, no additional license needs to be purchased, since the active “Campuslizenz Berlin” meets the requirements.
Handling (user): Usability of evaluated software is tested by investigating computer-user-interfaces using the example of searching for (meta)data.

Figure 21: GeoNetwork’s interfaces: search metadata (left), resource visualization (right). Source: OSGF, 2010.

Metadata search: GeoNetwork allows a free text search, a geographic search, and a search by category. Moreover, an “advanced search” can be performed which allows the user a combination of more specific search criteria. Figure 21 (left) shows the advanced metadata search screen in wihich search criteria are sorted according to “what”, “where”, and “when”. The output of the search provides the user with a list of metadata records, each showing title, abstract, keywords and an enlargeable preview. If privileges are provided, the user can download the data directly from the portal. An interactive map viewer can optionally be integrated. It enhances the user’s possibilities to visualize and analyze data (Figure 21 right).
ESRI Geoportal Server provides similar search and visualization functionalities. Basic options are a free text search and a geographic search using the interactive map Figure 22 (left). Additional search criteria are temporal search and search by category. As output metadata records are listed following a user defined sorting attribute Figure 22 (left). Data can be accessed using the given URL, moreover data can be previewed as SVG within the interactive map viewer Figure 22 (right),

in ArcMap, in ArcGIS (nmf or lyr file) Explorer, or in Google Earth (as KML). Additionally, all metadata can be inspected.

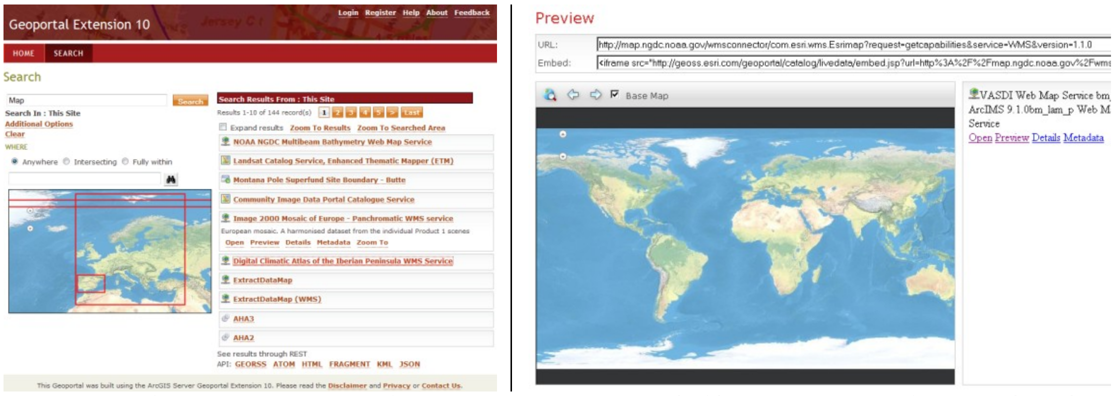

Figure 22: ESRI's geoportal interfaces: metadata search (left), visualization of results (right). Source: ESRI Geoportal Server Website, 2010.

The search functionalities of both, the ESRI Geoportal Server and the GeoNetwork Server are at comparable levels regarding usability, interface design and functionality.

Aspatial Content: GeoNetwork seamlessly handles spatial as well as non-spatial data in contrast to ESRI's portal server which does not perform well in adapting aspatial content. GeoNetwork provides tools to describe any type of geographic data (vector layers, raster, tables, map services, etc.) as well as general document like reports, projects, papers, etc.; a feature which properly works in a number of examples[18].

Metadata management:

Both solutions offer an integrated geoportal to edit, save and upload metadata records. Furthermore there are a number of possible alternative services for metadata management. A good example is GeoCat Bridge. This ArcMap extension enables one-click data publishing. It was optimized to work with the Geoserver map server and the GeoNetwork open source metadata catalogue. It complies easily with INSPIRE directive (GeoCat Website, 2010), but is not compatible with ESRI ArcGIS Server.

Metadata harvesting / update:

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[18] For example the Mountain Geoportal of the International Centre for Integrated Mountain Development, ICIMOD (http://www.icimod.org/?page=abt), or the Ocean Survey 20/20 Portal (http://www/os2020.org.nz).

In the new version 10 of ESRI Geoportal Server, the harvesting tool was replaced by a service which automatically updates registered resources' metadata if changed. GeoNetwork still uses common harvesting functionality. It is performed periodically based on the concept of a universally unique identifier (UUID)[19].
Both GeoNetwork and ESRI Server & Geoportal server include an interactive web map viewer to preview geospatial data. Both cover WMS functionalities and are adequate to meet the need to preview found (meta)data. Therefore the implementation of an external WMS is not necessary. GeoNetwork includes Geoserver as a WMS, both are Java based; this enables easy interoperability.

5.2.3. GEONETWORK AS NEW METADATA MANAGEMENT

The outcome of the software comparison built the basis for an expert group discussion, where GeoNetwork was chosen as the most appropriate solution. The decision was taken mainly on the grounds that GeoNetwork runs under a free and open source license and capable of handling spatial and aspatial content. Moreover, basic requirements like compatibility with existing architecture are fulfilled. ESRI Server and Geoportal hold the advantage of being highly compatible with existing ArcSDE architecture as the spatial component of the database. It was therefore not a clear-cut decision. Nevertheless, the experts agreed in preferring GeoNetwork since it is more easily customizable using CSS and HTML scripts. Moreover, the list of operating implementations done by international organizations like FAO, UN and INSPIRE related bodies throughout Europe are impressive references, guaranteeing vital future developments. Still to be clarified is a possible integration with ArcGIS extension GeoCat Bridge which would bring about enhanced usability by enabling the user to publish directly from ArcGIS desktop application. Both services are highly comparable in terms of supported standards, technical background and capabilities.

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[19] A special ID because it is not only unique locally to the node that generated it but it is unique across all the world. It is a combination of the network interface's MAC address, the current date/time and a random number. Every time you create a new metadata in GeoNetwork, a new UUID is generated and assigned to it (GeoNetwork website; Open Source Geospatial Foundation, 2010).

5.3. GEONETWORK AS NEW METADATA MANAGEMENT SYSTEM

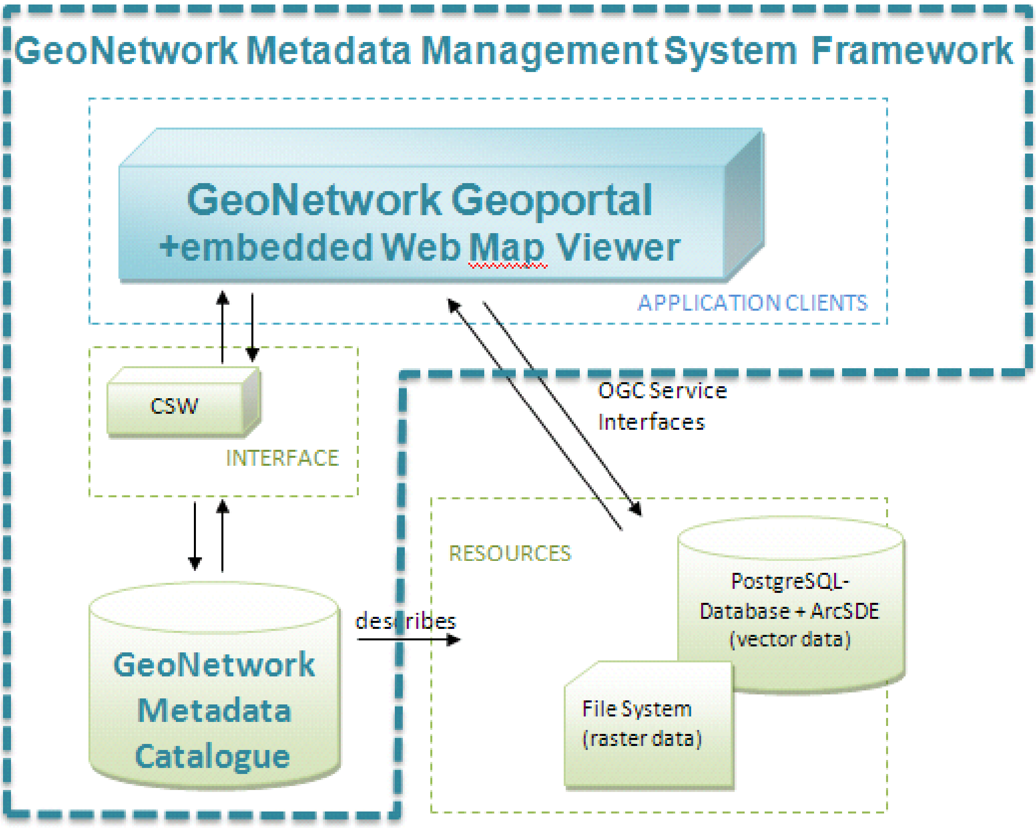

Figure 23: Schema of SDI node architecture after implementation of GeoNetwork.

The implementation process of GeoNetwork was conducted in accordance with JAD concept proclamations and the user-centric SDI approach. Continuous expert group meetings and discussions accompanied the process. Expert opinion and feedback shaped the work process and its results. Finally, a prototype of GeoNetwork was ready for presentation and further discussion. It was set up locally, and can be used for presenting main functionalities, like searching for resources or editing metadata records. For this purpose, test metadata and resources were imported.

This prototype, though installed locally, was set up respecting the existing server and software environment and could seamlessly be implemented at the Department of Geography. Consequently, Apache Tomcat was used as servlet container and configuration files were modified for successful migration Jetty servlet. Figure 21 shows the planned SDI architecture after implementation of GeoNetwork in existing SDI node.In an attempt to balance the variety of the department's resources and its different kind of metadata sets, new metadata standard sets were designed.

5.3.1. NEW METADATA STANDARD SET

In accordance with decisions taken in expert group discussions, new metadata standard sets were developed. They are conglomerates of international standards (INSPIRE set of ISO metadata standard), existing metadata standard sets used in Department of Geography databases, and an internal draft metadata standard version (ANNEX C, Table1). All these metadata standards were compared and merged to a new metadata standard which is characterized by the highest possible compatibility with each of them. This should ensure easy and fast integration of existing metadata resources.

The first result was the master metadata standard set of 32 elements, representing the maximum possible amplitude of attributes when describing a resource. But not every attribute is applicable to each type of resource. All available resources are divided into four groups. Amongst the four defined groups are three groups for spatial resources (vector data, raster data and geospatial services) and one group holding aspatial resources (compare ANNEX D, Table 1). This classification was taken regardless of resource representation type (e.g. hard copy, digital map, etc.) which would be a suitable classification factor, too; instead, representation type information is covered by corresponding metadata elements.

SPATIAL: VECTOR	**SPATIAL: RASTER**	**ASPATIAL (TABLES, DOCS, PHOTOS, ETC.)**	**SPATIAL: SERVICES**
RESOURCE			
Title	Title	Title	Title
Date	Date	Date	Date
Date Type	Date Type	Date Type	Date Type
Edition	Edition	Edition	
Presentation form	Presentation form	Presentation form	
Abstract	Abstract	Abstract	Abstract
Status	Status	Status	Status
Descr. Keywords	Descr. Keywords	Descr. Keywords	Descr. Keywords
Topic category	Topic category	Topic category	Topic category
Temportal extent -	Temportal extent -	Temportal extent -	

begin date	begin date	begin date	
Temporal extent - end date	Temporal extent - end date	Temporal extent -end date	
Spatial extent (bounding box): north east south west coordinates	Spatial extent (bounding box): north east south west coordinates	Spatial extent (bounding box): north east south west coordinates	Spatial extent (bounding box): north east south west coordinates
Lineage	Lineage		
Reference system (e.g.WGS84)	Reference system (e.g.WGS84)		
Equivalent scale, denominator	Equivalent scale, denominator		
	Resolution		
Spatial representation type	Spatial representation type		
Data Quality Info: Hierarchy Level	Data Quality Info: Hierarchy Level		Data Quality Info: Hierarchy Level
			Service Name
			Service Version
			Spatial Data Service Type
			Service Contains Operations
Unique Resource Identifier	Unique Resource Identifier	Unique Resource Identifier	
USAGE/DISTRIBUTION			
Access constraints	Access constraints	Access constraints	Access constraints
Use constraints	Use constraints	Use constraints	Use constraints
Source	Source	Source	
sourceCitation	sourceCitation	sourceCitation	
Contact (author name)	Contact (author name)	Contact (author name)	Contact (author name)
Contact address	Contact address	Contact address	Contact address
Organization name	Organization name	Organization name	Organization name
OnLine Resource (GN dropdown menu, e.g. link to website, download link, etc..)	OnLine Resource (GN dropdown menu, e.g. link to website, download link, etc..)	OnLine Resource (GN dropdown menu, e.g. link to website, download link, etc..)	OnLine Resource (URL, protocol, name and description of resource)
Distribution format and version	Distribution format and version	Distribution format and version	
METADATA			
Metadata standard name & version	Metadata standard name & version	Metadata standard name & version	Metadata standard name & version
Metadata author contact details	Metadata author contact details	Metadata author contact details	Metadata author contact details
Date stamp	Date stamp	Date stamp	Date stamp

Table 6: New metadata standard sets according to four resource categories.

Table 6 gives an overview of the new metadata standard set. Element names and definitions are taken from ISO 19115 metadata standard. This guarantees seamless interoperability with external entities which are based on the same standards or this standard's derivates and profiles (e.g. INSPIRE directive). Further the table shows that elements are especially applicable for particular resource categories. ANNEX F comprises three metadata standard sets (vector, raster, geoservices and aspatial resources), including detailed element descriptions and examples. Moreover, mandatory conditions are listed.

ANNEX D (Table 2) lists the “left behinds”. These are metadata elements which are mandatory for ISO core metadata standard or INSPIRE metadata profile, but have been found to be disposable for the department’s new metadata standard set. This is true for elements providing information about metadata language, or the dataset character set of metadata. They are more suitable for distributed systems and international initiatives, than for the department’s local SDI node. New metadata standard set describes all attributes which are defined as important enough to be represented by a metadata element. As a consequence, this is the sum of information which the user is expected to provide when creating new metadata records. Accordingly, templates for creating metadata records have to be created and facilitated in the GeoNetwork geoportal.

E. No.	Elements (Red boxes indicate mandatory elements)	Expert votes (n=3)	INSPIRE profile of ISO 19115 & 19119	User votes (n=16)	GeoNetwork User Manual Reference
	RESOURCE				
1	TITLE	3	XX	16	XX
2	DATE	2		13	XX
3	DATE TYPE	2		14	XX
4	EDITION	1		9	
5	PRESENTATION FORM	3		7	x
6	ABSTRACT	2	XX	11	XX
7	STATUS	1		12	x
8	DESCR. KEYWORDS	3	XX	14	x
9	TOPIC CATEGORY	2	XX*	10	XX
10	TEMPORAL EXTENT -END DATE	2		12	x
11	TEMPORAL EXTENT -BEGIN DATE	2		12	x
12	SPATIAL EXTENT (bounding box)	2	XX*	10	x
13	LINEAGE	2	XX*	7	
14	REFERENCE SYSTEM	3		15	x
15	EQUIVALENT SCALE, DENOMINATOR	2	XX	10	XX

16	RESOLUTION **	3	XX	13	XX
17	SPATIAL REPRESENTATION TYPE	2		12	x
18	DATA QUALITY INFO	1	XX (if available)	10	x
19	SERVICE NAME***			-	
20	SERVICE VERSION***			-	
21	SPATIAL DATA SERVICE TYPE/SERVICE CONTAINS OPERATIONS***	-	XX	-	
22	UNIQUE RESOURCE IDENTIFIER	2	XX*	8	
	USAGE/DISTRIBUTION				
23	ACCESS CONSTRAINTS	3	XX	11	x
24	USE CONSTRAINTS	3	XX	11	x
25	SOURCE	2		14	
26	SOURCE CITATION	1		14	
27	POINT OF CONTACT	3		15	x
28	ONLINE RESOURCE	2	XX	10	x
29	DISTRIBUTION FORMAT AND VERSION	2		8	
	METADATA				
30	METADATA STANDARD NAME & VERSION	1		9	
31	METADATA AUTHOR CONTACT DETAILS	3	XX	11	XX
32	DATE STAMP	2		10	

Table 7: Factors used for definition of mandatory elements.
(XX = mandatory. x = recommended as being mandatory. Red boxes indicate mandatory elements. *for datasets and dataset series. **describing raster data. *** describing geospatial services).

Templates include the possibility to set a specific group of elements to “mandatory”. This helps users to understand which metadata information is absolutely necessary to create a valid metadata record. Elements in red boxes in Table 7 are classified as “mandatory”. Main determinants of this are expert vote and the INSPIRE profile reference. Moreover, Table 7 lists the results of user votes and the GeoNetwork user manual as additional references.

User and expert votes were assessed using the questionnaire on metadata standard sets (ANNEX E). This questionnaire concentrates on metadata element sets for vector and raster data. For the remaining two standard sets for aspatial resources and geospatial services, almost exactly the same elements were set to mandatory. An exception is the element called “Spatial Extent”, which was set to “mandatory for resources which are ‘locatable’ or for resources with an explicit geographic extent”. Further exceptions are elements which are not applicable to all four groups of resources. Elements which are only applicable for geospatial services (Table 7: element number 19, 20 and 21) were set to either optional or mandatory on the basis of INSPIRE's profile recommendations. ANNEX H lists detailed metadata sets and shows optional and mandatory metadata elements for each of the four resource categories.

5.3.2. GEOPORTAL DESIGN AND INTERFACE

Figure 24: Screenshot of geoportal prototype, basic search interface.

Design and conception of the geoportal concentrated on search interface and resource visualization interface. Figure 24 visualizes the prototypes' start screen, already mounted with the department's header and logo. This was done by simply editing GeoNetwork's HTML, CSS and XML configuration files. Start screen (= search interface) offers basic search functionalities within the left frame. This combination of keyword search ("what?") and geographic search ("where?") comes with standard GeoNetwork setup and remained unchanged for this prototype. Keyword search is a case insensitive, free text search and allows the user to search text in the entire record. Putting quotes around text lets the user search for exact matches of words. For geographic searches, GeoNetwork lets users either search for predefined regions in a dropdown menu, or for an “area of interest”, which can be drawn in the map window.

All inputs in search fields are combined to restrict search results. Moreover, resources can be discovered by exploring resource categories. Resources are allocated to categories in an automatic way by tapping the corresponding metadata element. These categories are listed at the lower left corner. The main frame to the right welcomes users and can be used to present recently added resources or news (e.g. a news feed). When the user performs a search, it serves as search result visualization frame.

El. No.	Rationale	Elements (Elements in red boxes are included in advanced search)	Experts (n=3)	Users (n=16)
1	expert+user vote	TITLE	3	15
2	expert+user vote	DATE	2	8
3		DATE TYPE	1	5
4		EDITION	0	4
5	expert+user vote	PRESENTATION FORM	2	8
6		ABSTRACT	1	6
7		STATUS	0	3
8	expert+user vote	DESCR. KEYWORDS	3	15
9	user vote	TOPIC CATEGORY	2	9
10	expert+user vote	TEMPORAL EXTENT -END DATE	1	7
11	expert+user vote	TEMPORAL EXTENT -BEGIN DATE	2	7
12	user vote, essential for basic search	SPATIAL EXTENT (bounding box)	2	11
13		LINEAGE	0	8
14		REFERENCE SYSTEM	0	7
15	user vote	EQUIVALENT SCALE, DENOMINATOR	2	9
16		RESOLUTION	1	6
17	user vote	SPATIAL REPRESENTATION TYPE	2	11
18		DATA QUALITY INFO	0	2
19		Service Name		
20		Service Version		
21		Service Contains Operations /Spatial Data Service Type		
22		UNIQUE RESOURCE IDENTIFIER	0	3
23		ACCESS CONSTRAINTS	0	4
24		USE CONSTRAINTS	0	4
25		SOURCE	1	9

26		SOURCE CITATION	0	4
27		POINT OF CONTACT	0	2
28		ONLINE RESOURCE	0	2
29		DISTRIBUTION FORMAT AND VERSION	0	5
30		METADATA STANDARD NAME & VERSION	0	2
31		METADATA AUTHOR CONTACT DETAILS	0	4
32		DATE STAMP	0	3

Table 8: Results of user questionnaire: advanced search interface design.

The advanced search offers a broader range of searchable attributes. To decide which attributes (or: which metadata elements) should appear in the advanced search interface, users and experts were asked to complete a questionnaire (ANNEX E). Table 8 lists these questionnaire results; elements in red boxes are selected by users or experts to be part of an advanced search interface. In the case of an ambiguous assessment result, a rationale for the decision is given in the corresponding column.

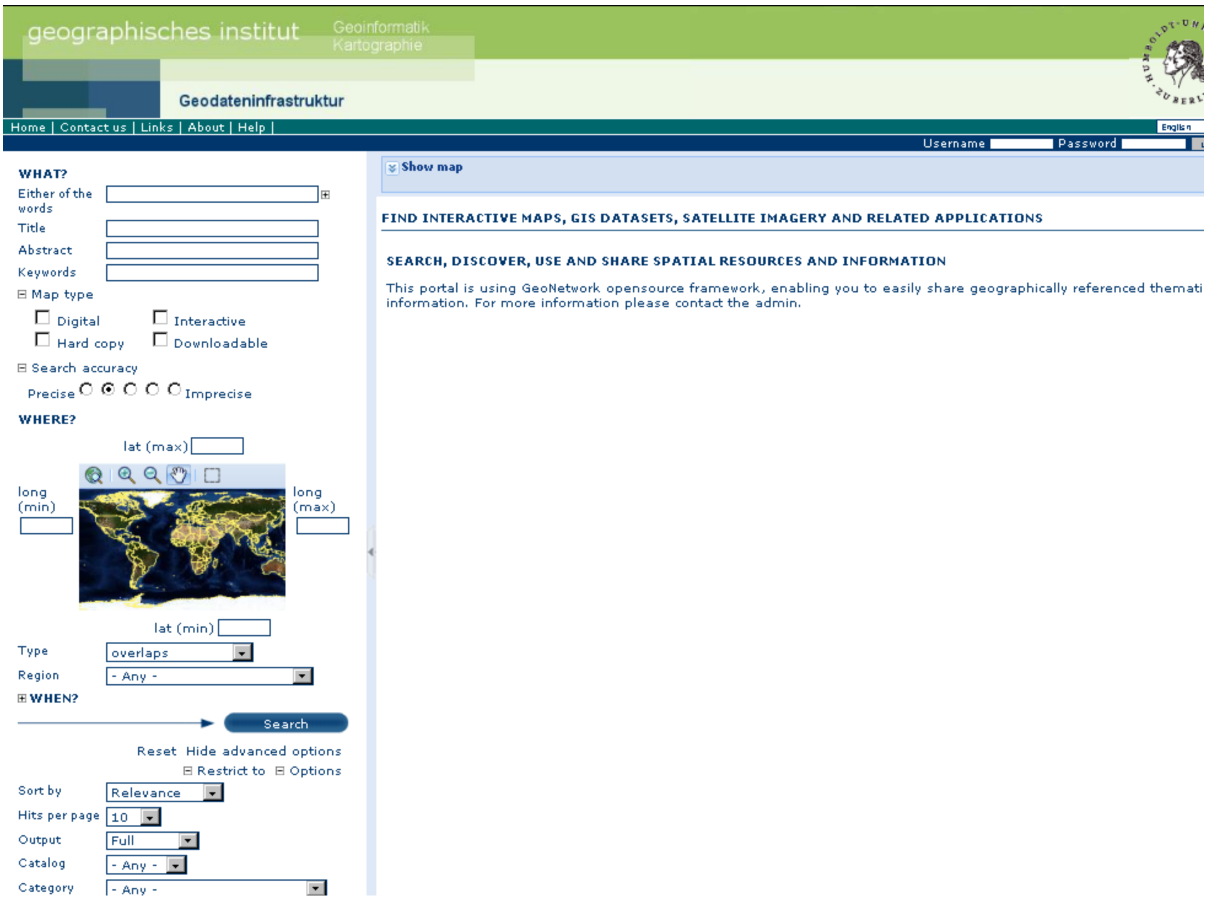

Figure 25: Screenshot of geoportal prototype, advanced search interface.

GeoNetwork's default advanced search frame (Figure 25) features pretty similar fields and would need only marginal adaptations. Moreover, it enables the user to personalize result visualization. Users can decide how many records to list per page and the degree of detail of result visualization. Further, the records found can be sorted by category (and by catalogue, which is only applicable in distributed infrastructures). GeoNetwork provides a number of additional search refinements and options which are available to both, basic and advanced searches. Those options are not the subject of the present work and can be explored in GeoNetwork documentation (GeoNetwork User Manual, 2011).
GeoNetwork visualizes search results in tabular format. Result presentation interface lists found records by showing the thumbnail, keywords and abstract, and source logo. From this basic overview, users can choose to retrieve additional information by viewing full metadata record, or to visualize the resource in an interactive map.

For the present work, requirements for the results presentation interface were adapted from an earlier investigation done by Aditya & Kraak (2009). In this reference, two types of tables were analyzed: on the one hand textual tables, giving an overview of the most important metadata (e.g. spatial, temporal, contextual information plus usage and accessibility), on the other hand thumbnail tables, which have been proven to increase the efficiency of search processes. To merge the benefits of both possibilities, additional interactivity was recommended to let the user choose between a rough overview and more detailed resource specifications. Not least this knowledge was based on Adytia & Kraak's user evaluation (2007) showing high user preferences for simple table displays compared to other visualization techniques. Results further indicated benefits of graphical previews such as thumbnails or metadata mapping. GeoNetwork's default set of services for result presentation and design of this interface as described above serves perfectly the prototype's requirements.
This work's thorough development process builds a reasonable basis for further development of the GeoNetwork prototype and its implementation in the department's SDI. The user requirements ascertained regarding technical specifications and functionality have been met without exception. A metadata standard set was compiled, combining both maximum interoperability with

international standards, and the possibility to merge all existing departmental metadata records with minimal effort possible. The special design of implementation process has brought about a number of dissemination activities which are contributing to the long-term success of the department's SDI node. These considerations are examined briefly in the final section.

6. DISCUSSION

The central achievement of the project at hand is a working prototype version of a new metadata management system for the Department of Geography's SDI node. This was done without changing the existing SDI's architecture and idea principle as a single, isolated SDI node. The system comprises a metadata catalogue for managing metadata and a geoportal for user access. It was developed based on a user-centric approach. With this prototype, the main project goals, which were to ensure a high level of user satisfaction and to contribute to long-term SDI success, could be met. These goals were achieved by special design of the implementation process, which was strongly shaped by user feedback and based on a preliminary assessment of user requirements, using a questionnaire (open question style). A Joint Application Development approach was used as a conceptual frame for the implementation process.

JAD proved a valuable choice for the present case study. Dividing possible future SDI beneficiaires into "experts" and "users" accounted for department's personnel structure. The expert group contains people who were already leading the existing SDI's development and people holding data and metadata custodianship. The main decisions regarding the technical setup and design of metadata catalogue and geoportal are based on expert advice. Collecting feedback from "users" generated additional input and essential suggestions from other perspectives. At the same time, user assessment meetings served as information dissemination forums where fundamental benefits of SDI were explained and the geoportal prototype was presented. This clearly contributes to both higher user satisfaction and long term SDI success since these experts are the driving forces of the department's SDI initiative.

The method of Rapid Prototyping was chosen to be able to start the feedback loop within a reasonable timeframe. The GeoNetwork software package accomodates this method, since a properly running prototype can be installed easily and many changes can be made in a manageable timeframe. Planning technical development and design of software prototypes in feedback loops is a good way to go, though it is time consuming. Having different kinds of feedback widens the perspective of the developer for user requirements. On the other hand, collected requests from different groups of users must be adequately analyzed and weighted up against each other. In this thesis, a quota based on points, extended by literature reviews, proofed to generate an arguable decision. Moreover, feedback from potentially unexperienced users proved critical; taken on without reflection it can potentially decrease usability and the SDI initiative's success.

Activities like presentation, publishing of questionnaires, collecting of feedback and organization of expert discussions raised awareness for SDI and its benefits. To incorporate user opinion and feedback is an appropriate way to reach high user satisfaction. As a side effect, it fosters the overall interest of users in SDI and its possible benefits. Dissemination activities and rasing of awareness for SDI and its benefits are the foundation of a successful development of effective collaboration relationships within an organization like the Department of Geography. This is essential for long-term SDI success since it is a sharing community, highly dependent on user numbers and user satisfaction (Thellufsen, Rajabifard, Enemark, & Williamson, 2009). Expert meetings serve the need to collect essential input. At the same time, this process fosters synergical effects like team building and communicates to the experts their important role in SDI development and maintenance. SDI experts are at the same time SDI stakeholders, holding responsibilites and custodianship for data and metadata. Therefore, they are essential for the success the department's SDI. Important tasks like collection and maintenance of metadata lie in their hands which represents a big hurdle on the way towards a fully deployed SDI node.

The software comparison revealed essential information and allowed an informed decision for the GeoNetwork according to assessed user needs. In accordance with Grill & Schneider (2009) the thesis at hand uses GeoNetwork as a very useful solution for direct support of research and education activities in an academic environment. GeoNetwork runs under free and open source licences and makes it easy to understand how to share spatial and aspatial resources and manage metadata centrally. This makes it relevant and practical subject in university curricula. Moreover, it follows international standards and was implemented respecting agreed SDI conventions and restrictions.

Further, GeoNetwork offers one central database for metadata and meets one central requirement as defined by experts. The prototype of a new metadata management system was developed in such a way that the Department of Geograpy SDI node's architecture does not have to be changed. GeoNetwork was migrated from running on top of a Jetty servlet (standard installation) to Apache Tomcat.

A collection of customized metadata standard sets was developed for new metadata catalogue and can be used as customized metadata standard templates. Metadata element sets for four classes of resources were put together in a process of repeated discussions with expert group members. As a result, the new standard set features compatibility with international standards (e.g. INSPIRE Profile of ISO 19115 and ISO 19119) and the highest possible conformity with the department's metadata repository. Expert participation emphasized the priority of seamless interoperability with European-wide accepted standards and the highest possible compability with existing metadata. In my estimation, the chosen method of joint development supported the process of compiling new metadata standard sets which contributed to seamless interoperability with remote nodes. It is a basic requirement for long-term plans to establish connections to remote SDI nodes.

6.1. DISCUSSION OF RESEARCH OBJECTIVES

-How can the implementation process be designed to respect the user-centric SDI concept?

The methods Joint Application Development and Rapid Prototyping proved very supportive and essential for the development of a user-centric SDI (node). During the whole implementation process, possible future users were offered very active roles. Instead of a data or service-driven development of SDI, user requirements and needs were collected continuously and built the basis for the design and implementation of new metadata management service.

- How can user satisfaction with the metadata management system be increased under the conditions of this case?

First, the Department of Geography SDI's user groups and their roles were identified. In the project at hand, possible future users were divided into "experts" and "users". This profed very supportive and corresponds with the JAD approach. The group of experts was consulted when it came to discussion of important

decisions and in order to identify central software requirements and project goals; the group of (possible future) users was invited to information dissemination sessions and to fill out a questionnaire regarding computer-user-interface design. This mixture of user participation, user information and dissemination activities are an important basis to generally increase user satisfaction.
Second, preliminary assessment of the user requirements questionnaire focused on special requirements for an academic institution's SDI. Comparable studies (e.g. Grill & Schneider, 2009) served as contributors. This special case's individual requirements for the new metadata management system built the basis for implementation design.

-Are the implementation strategy and methods applied adequate for the chosen software solution?
GeoNetwork proved very adaptive in terms of umproblematic and rapid generation of prototypes. This enabled feedback loops to take in a relatively short time. Due to the fast and easy installation of the available software bundle, the implementation process can be designed in a more efficient and transparent way. It enables continuous dissemination of working prototypes to users, keeping them informed and intrigued.
To have working prototypes disposable generally aids JAD and the development of user-centric SDI. Users can become more actively involved when they can try out software and working interfaces. Moreover, they can decide more easily about interface design because they can actually experience how requirements are attempted to be met and how solutions are implemented.

-Can the approach chosen ensure long-term SDI success?
In my opinion, an implementation design on the basis of user-centric SDI approach contributes to long term SDI success. In this special case, the methods chosen and architecture of GeoNetwork supports the central concept of user participation and active user contribution throughout whole SDI development. This concept aims at high user satisfaction, increased dissemination and user information activities and improved usability of the end product. SDI needs highly usable communication tools and a big community of well informed and satisfied users, since it is a network based on communication and cooperation.

6.2. OUTLOOK

The process undertaken in the present study represents a user-centric implementation process for a metadata management system. This process is not finished but has built a foundation and is ready to be continued. The department's SDI node is a living architecture, never finished and must always be open to improvement. The department's SDI should be developed on the basis of user and expert feedback, extending this thesis' efforts. The assessment of user requirements, the organization of feedback loops and dissemination activities and the discussion with the expert group should be continued to guarantee long-term success.

A short-term goal would be to actually implement the prototype in existing SDI node by replacing the old metadata catalogue and old geoportal. For that, the department's new PostgreSQL database cluster would need to be set up to have it ready to be connected with GeoNetwork. After establishing a connection beween the metadata catalogue and the database cluster, a technical framework would have to be set up to manage the department's metadata in one central database. Existing metadata needs to be imported to a new database after conversion into new metadata standards. GeoNetwork geoportal offers administrators and custodianship holders an online editor for creating a standardized metadata collection. In the work at hand the new metadata standards and design considerations described built the basis for the personalization process of interfaces and the creation of a set of metadata templates. For users, the geoportal will then be ready to be used to discover, visualize and use the department's resources.

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ANNEX A: SDI Stakeholder & Expert Questionnaire

Implementation of a Metadata Catalogue and a Geoportal
for the Spatial Data Infrastructure (SDI) of Dept. of Geomatics, Humboldt University Berlin
-in the frame of Peter Lanz's Master Thesis"Metadata Manangement Service for Spatial Data Infrastructure. Case Study User Centric Implementation Design for an Academic Institution

USER GROUP DEFINITION

(1)Who are the main users of existing SDI? (students, research -, educational -, organisational staff members, only intern versus extern people, partners and affiliates, project groups, ...)

(2)Who will be the main users of planned SDI in the future? (if others than in (1), please list)

SOFTWARE REQUIREMENTS

(3)SDI can be used to share various kinds of data called "resources". What kind of resources is currently covered? (spatial: raster, vector; aspatial: videos, documents (e.g. bachelor & master theses and results), services and applications (e.g. for mapping), digital and non digital resources...)

(4)What kind of resources are planned to share with SDI in the future? (if others than in (3), please list)

(5)Is SDI currently used to support typical activities of an academic institution? (as example and subject in curricula, for training purposes, as a data sharing tool for courses,...)

(6)Does existing SDI provide a security framework like user-management, user -roles and levels of access?

(7)Should future SDI offer user management, and if yes, which would be the main requirements?

(8)Is department's SDI set up as a node and is it connected to external, remote nodes, or is it only working with local databases?

(9)Is there a change in current SDI architecture as questioned in (8) planned, if yes what kind?

(10)Which functionalities, not supported so far, should be provided by department's SDI in the future?

(11)In the view of how department's resources are stored and maintained: can you think of special, additional requirements for future SDI?

(12)In the view of currently existing SDI: can you think of special, additional requirements for future SDI?

ANNEX B: Export Meeting 20.5. INFO

SDI Stakeholder & Expert Meeting 20.5., 10h - **INFOS**

Implementation of a Metadata Catalogue and a Geoportal
for the Spatial Data Infrastructure (SDI) of Dept. of Geomatics, Humboldt University Berlin
-in the frame of Peter Lanz's Master Thesis"Metadata Manangement Service for Spatial Data Infrastructure. Case Study User Centric Implementation Design for an Academic Institution

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Experts: Katja Janson, Gerd Schilling, Tobia Lakes
Moderation: Peter Lanz

Agenda:
I. Discussion about **Metadata Standards**,
+Decision about best-fitting standard for department's SDI
II. First considerations about design of **Geoportal**

I.Following Standards are incorporated in GeoNetwork as Templates:
Dublin Core (DCMES)[20],
FGDC[21],
ISO19110 (for feature classification) & ISO 19139 for raster, WMS, vector plus multilingual -> is used for XML encoding of ISO19115:2003[22]
(Additional test templates: Deegree22 Fragments Philosopher Database test template(for Web Feature Service WFS) , Geoserver Fragments Coutry Boundary test template(for WFS))
Additional templates can be added and edited

Dublin Core standards by Dublin Core Metadata Initiative (DCMI):
-intended to be used for **cross-domain information resource description**
-standard in the fields of library science and computer science
-typically makes use of XML
-*Resource Description Framework* based
- for resource description in a cross-disciplinary information environment

Dublin Core Metadata Element Set (DCMES):
15 Elements:
endorsed in the following standards:
ISO (Standard 15836), the
USA's National Information Standards Organization (NISO Standard Z39.85-2007), and the
USA based The Internet Engineering Task Force (IETF Standard RFC5013)

International Standardization Organization (ISO) Standards:
ISO19115 for geodata+geoapplications

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[20] http://www.dublincore.org/documents/dces/ (May 2011)
[21] http://www.fgdc.gov/metadata (May 2011)
[22] Description & German translation: http://www.gdi-de.org/thema2009/uebersetzungiso (May 2011)
[2,3] Metadata entries as in corresponding metadata templates from GeoNetwork

ISO19119 for geoservices (added content for ISO 19115 that supports the documentation of information services associated (coupled) with geospatial data including geospatial data portals, web mapping applications, data models and online data processing services)
ISO19139 (an XML document that specifies the format and general content of an ISO 19115 the metadata)
…and standards for feature classification and resource description
+ widely accepted, adopted by INSPIRE (regional European SDI initiative)

Federal Geographic Data Committee (FGDC) created the North American Profile (NAP) of ISO19115 (in collaboration with the American National Standards Institute's (ANSI) standards framework)
Moreover, the FGDC endorsed several ISO metadata standards, such as ISO19115, 19119 & 19139.

Comparison of "Historische Datensammlung" metadata entries and main standards.
(The table is unsorted, entries does not correspond linewise)
green: matching entries (DCMES:5, ISO core.: 8, FGDC: 8),
orange: partly matching entries (DMCES: 7, ISO core: 6, FGDC: 6)

Hist. Karten-sammlung des Instituts	DCMES	ISO minimum, extended by ISO core*	FGDC (minimum, extended*)
Signatur	Title	Title	Originator (Creator)
Titel	Creator	Date	Publication Date
Maßstab	Subject	Abstract	Publication Time
Bild (jpg)	Description	Descr. Keywords	Title
Standort	Publisher	Language	Edition
Autor/Bearbeiter	Contributor	Character set	Geospatial Representation Type (e.g.raster)
Stecher	Date	Topic category	Online Linkage*
Verlag	Type	Temportal Extend -Begin Date	Abstract
Herausgabeort	Format	Temportal Extend -End Date	Purpose
Herausgabejahr	Identifier	Spatial Extend (bounding box)	Temportal Extend - Begin Date
Auflage	Source	North	Temportal Extend - End Date
Größe	Language	East	Currentness Reference
Farbe	Relation	South	Progress (e.g. completed)
Nummer der Region	Coverage (north,	Metadata File Identifier	Maintenance+Updat

	south, east, west)		e Frequency
Nummer des Themas	Rights	Metadata language	Spatial domain (bounding box): west
Blattnummer		Contact (Author Name)	North
Bemerkungen		Organisation Name	East
		date stamp	South
		Spatial Representation Type (e.g.raster)*	Keyword Thesaurus
		Spatial resolution*	Theme Keyword
		Scope: (e.g. dataset)*	Access Constraints
		Lineage (info about events or sources used for data construction)*	Metadata Date
		Reference System (e.g.WGS84)*	Contact Person
		Distribution Format:Name (e.g. shapefile)*	Contact Address, Telephone
		Distribution Format: Version (e.g. ArcInfo 10)*	Metadata Standard Name
		OnLine Ressource: link to website*	Metadata Standard Version
		OnLine Ressource: download link*	Metadata Access Contraints
		OnLine Ressource: interactive map*	
		OnLine Ressource: view in google earth*	
		Contact Address*	
		Metadata Standard Name*	
		Metadata Standard Version*	

Resume:
ISO has specialized set of metadata standards for geodata, geoapplications and geoservices
FGDC endorsed ISO standards
DCMES is shortest and very basic,
ISO was chosen by INSPIRE and enjoys regional and international support

ANNEX C: Expert Meeting 20.5. Report

SDI Stakeholder & Expert Meeting 25.5., 10h - **REPORT**

Implementation of a Metadata Catalogue and a Geoportal
for the Spatial Data Infrastructure (SDI) of Dept. of Geomatics, Humboldt University Berlin
-in the frame of Peter Lanz's Master Thesis"Metadata Manangement Service for Spatial Data InfrastructureCase Study User Centric Implementation Design for an Academic Institution

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Decisions taken in expert group meeting on 25.5.:
1. Metadata standard set for department's SDI should base on ISO standards.
2. To increase usability, metadata standard templates are needed. There are four categories of resources defined (vector, raster, aspatial content and geoservices), each category must have its own metadata template

Roadmap to these four templates:
1. Comparison of metadata standards of „hist. Kartensammlung", vector metadata (DB "geodata"), raster geodata (department's file system) and K. Janson's draft (based on ESRI item description and FGDC) and INSPIRE profile of ISO 19115 and ISO 19119 (Table1) to
2. Develop a new "master" metadata standard set, based on ISO 19115/ ISO19119 (Table 1, left column)
3. From this "master" standard set, choose necessary metadata entries for each of the four resource categories (Table 2)

Table1: Comparison of Metadata Standard Sets

Proposed new Metadata set for Department's SDI (Based on ISO 19115/ISO19119)	Metadata used for Department's Collection of Historical Maps	Metadata used for Department's Vector Data (based on ESRI item description based on FGDC)	Metadata used for Department's Raster Data	Department's Draft Metadata Standard Set (April 2010, Katja Janson)	INSPIRE Profile of ISO 19115 and ISO 19119
RESOURCE					
Title	Titel Signatur	Description		Titel	Part B 1.1 ResourceTitle
Date	Herausgabe-jahr	Date and Time of pPublication Data Updated	Creation Time	(Lieferzeitpunkt)	Part B 5 Temporal Reference
Date Type e.g. creation or publication				Status/ Bearbei-tungsstand	
Edition				Stand der	

				Daten	
Presentation Form mode in which the resource is represented; e.g. digital map, hardcopy image, etc.				Ressourcen beschreibun g	
Abstract	Auflage Größe Farbe Nummer der Region Nummer des Themas Blattnummer Bemerkungen	Abstract		Inhalt der Daten	Part B 1.2 Resource Abstract
Descr. Keywords		Keywords Divided into theme, place and temporal		Descr. Keywords	Part B 3 Keyword
Topic Category Dataset's main theme					Part B 2.1 Topic Category
Temportal Extent - Begin Date		Beginning Date and Time		Stand der Daten	Part B 5.1 Temporal Extent
Temporal Rxtent - End Date Formatted as YYYY-MM-DDTHH:mm:ss		End Date and Time Time period for which the dataset is relevant		Stand der Daten	
Spatial Extent Bounding Box: north+west+east+south		Spatial Extent Bounding Box			Part B 4.1 Geographic Bounding Box
Lineage Statement on process history and/or overall quality of dataset e.g. Scene corresponds to the path1/row1 of Landsat orbit	Nummer der Region Nummer des Themas Blattnummer				Part B 6.1 Lineage
Reference System e.g.WGS84		Horizontal Coordinate System		Koordinaten system	
Equivalent Scale, Denominator					
Resolution Degree of detail in the grid dataset					Part B 6.2 Spa-tial Resolution
Status Completed, archive, ongoing, etc..		Status		Status/ Bearbei-tungsstand	
Spatial Repre-sentation Type Vector, raster, etc..		Type of Data		Datenformat	
Data Quality Info: Hierarchy Level E.g.: attribute, feature, service, dataset, etc..					Part B 1.3 Resource Type
Service Name E.g. OGC WMS, WFS, link, download, etc..)					Part B 2.2 Spatial Data Service Type
Service Version					
Service Contains Operations Supported operations (GetCapabilities, GetMap, etc..) with link and platform information					

(Java, SQL, etc..)					
USAGE/DISTRIBUTION					
Access Constraints Assure the protection of privacy or intellectual property, and any special restrictions or limitations on obtaining the resource or metadata		Access Constraints		Nutzungs-bedingungen	Part B 8.1 Conditions for Access and Use / Part B 8.2 Limitations on Public Access
Use Constraints Assure the protection of privacy or intellectual property, and any special restrictions or limitations or warnings on using the resource or metadata)		Use Constraints		Nutzungs-bedingungen	Part B 8.1 Conditions for Access and Use / Part B 8.2 Limitations on Public Access
Source Info about the source used in creating the data specified by the scope	Stecher	Who Created The Data			
Source Citation Recommended reference to be used for the source data				Zitations-hinweise bei Nutzung	
Contact Author name	Autor/ Bearbeiter	Publisher (incl. Place)		Ansprechpartner am Institut/ Da-tenlieferant/ Bearbeiter/ Bereitsteller	
Contact Address				Ansprech-partner Adresse	
Organisation Name		Organisation Name		Institut	Part B 9 Responsible Organisation
OnLine Resource E.g. link to website	Standort	File Name/ Data Location	Item Location		Part B 1.4 Re-source Locator
Distribution Format and Version: E.g. shapefile, ArcInfo10			ArcGIS Format		
Part B 1.5 Unique Resource Identifier Value uniquely iden-tifying an object within a namespace (e.g. http://image2000.jrc.it)			Item Location		
METADATA					
Metadata Standard Name & Version		Metadata Stan-dard Version			
Metadata Author Contact Details Name, organization, role		Metadata Author Contact Details			Part B 10.1 Metadata Point of Contact
Date stamp		Metadata Content last Updated			Part B 10.2 Metadata Date

(based on descriptions of FGDC standard (Federal Geographic Data Committee, 1998) and ISO standard (GDI-DE Koordinierungsstelle, 2008)

ANNEX D: Resource Specific Metadata Standard Sets

Table1 : Detailed list of records for Department's new metadata standard sets for four resource categories:
-vector data
-raster data
-aspatial content
-web services

Table 2: "Left behinds": Metadata elements from ISO 19115 core and INSPIRE profile of ISO 19115 and ISO 19119 which have not been chosen for department's metadata standard sets.

Table 1: Detailed metadata standard sets for different data formats

SPATIAL: VECTOR	SPATIAL: RASTER	ASPATIAL (TABLES, DOCS, PHOTOS, ETC..)	SPATIAL: SERVICES
RESOURCE			
Title	Title	Title	Title
Date	Date	Date	Date
Date Type (e.g. from GN template: dropdown menu: creation, publication or revision)	Date Type (e.g. from GN template: dropdown menu: creation, publication or revision)	Date Type (e.g. from GN template: dropdown menu: creation, publication or revision)	Date Type (e.g. from GN template: dropdown menu: creation, publication or revision)
Edition	Edition	Edition	
Presentation Form (mode in which the resource is represented; eg. GN template dropdown menu: digital map, digital video, hardcopy image, hardcopy table, etc..)	Presentation Form (mode in which the resource is represented; eg. GN template dropdown menu: digital map, digital video, hardcopy image, hardcopy table, etc..)	Presentation Form (mode in which the resource is represented; eg. GN template dropdown menu: digital map, digital video, hardcopy image, hardcopy table, etc..)	
Abstract	Abstract	Abstract	Abstract
Status (e.g. from GN template: dropdown menu: completed, obsolete, required, under development, archive, ongoing, etc..)	Status (e.g. from GN template: dropdown menu: completed, obsolete, required, under development, archive, ongoing, etc..)	Status (e.g. from GN template: dropdown menu: completed, obsolete, required, under development, archive, ongoing, etc..)	Status (e.g. from GN template: dropdown menu: completed, obsolete, required, under development, archive, ongoing, etc..)
Descr. Keywords	Descr. Keywords	Descr. Keywords	Descr. Keywords
Topic Category (main theme of the dataset)	Topic Category (main theme of the dataset)	Topic Category (main theme of the dataset)	Topic Category (main theme of the dataset)
Temportal Extent -Begin Date (information on the temporal dimension of the data)	Temportal Extent -Begin Date (information on the temporal dimension of the data)	Temportal Extent -Begin Date (information on the temporal dimension of the data)	
Temporal Extent -End Date (Formatted as YYYY-MM-DDTHH:mm:ss)	Temporal Extent -End Date (Formatted as YYYY-MM-DDTHH:mm:ss)	Temporal Extent -End Date (Formatted as YYYY-MM-DDTHH:mm:ss)	
Spatial Extent (bounding box: north east south west coordinates	Spatial Extent (bounding box: north east south west coordinates	Spatial Extent (bounding box: north east south west coordinates	Spatial Extent (bounding box: north east south west coordinates

Lineage (This is a statement on process history and/or overall quality of the spatial data set e.g. Product 1 scenes correspond to the path/row of the Landsat orbit)	Lineage (This is a statement on process history and/or overall quality of the spatial data set e.g. Product 1 scenes correspond to the path/row of the Landsat orbit)		
Reference System (e.g.WGS84)	Reference System (e.g.WGS84)		
Equivalent Scale, Denominator	Equivalent Scale, Denominator		
Equivalent Scale, Denominator	Equivalent Scale, Denominator		
Spatial Representation Type (E.g.:vector, raster)	Spatial Representation Type (E.g.:vector, raster)		
Data Quality Info: Hierarchy Level (drop down: attribute, feature, service, dataset, etc.., incl. free text statement)	Data Quality Info: Hierarchy Level (drop down: attribute, feature, service, dataset, etc.., incl. free text statement)		Data Quality Info: Hierarchy Level (drop down: attribute, feature, service, dataset, etc.., incl. free text statement)
			Service Name e.g. GN dropdown menu: OGC WMS, WFS, WCS, link, download, etc..)
			Service Version
			Spatial Data Service Type
			Service Contains Operations (lists supported operations (GetCapabilities, GetMap, etc..) with link and platform (Java, SQL, etc..) information
Part B 1.5 Unique Resource Identifier (value uniquely identifying an object within a namespace e.g. http://image2000.jrc.it)	Part B 1.5 Unique Resource Identifier (value uniquely identifying an object within a namespace e.g. http://image2000.jrc.it)	Part B 1.5 Unique Resource Identifier (value uniquely identifying an object within a namespace e.g. http://image2000.jrc.it)	
USAGE/DISTRIBUTION			
Access Constraints (To assure the protection of privacy or intellectual property, and any special restrictions or limitations on obtaining the resource or metadata)	Access Constraints (To assure the protection of privacy or intellectual property, and any special restrictions or limitations on obtaining the resource or metadata)	Access Constraints (To assure the protection of privacy or intellectual property, and any special restrictions or limitations on obtaining the resource or metadata)	Access Constraints (To assure the protection of privacy or intellectual property, and any special restrictions or limitations on obtaining the resource or metadata)
Use Constraints (To assure the protection of privacy or intellectual property, and any special restrictions or limitations or warnings on using the resource or metadata)	Use Constraints (To assure the protection of privacy or intellectual property, and any special restrictions or limitations or warnings on using the resource or metadata)	Use Constraints (To assure the protection of privacy or intellectual property, and any special restrictions or limitations or warnings on using the resource or metadata)	Use Constraints (To assure the protection of privacy or intellectual property, and any special restrictions or limitations or warnings on using the resource or metadata)
Source (information about the source data used in creating the data specified by the scope)	Source (information about the source data used in creating the data specified by the scope)	Source (information about the source data used in creating the data specified by the scope)	
Source Citation (recommended reference to be used for the source data)	Source Citation (recommended reference to be used for the source data)	Source Citation (recommended reference to be used for the source data)	
Contact (author name)	Contact (author name)	Contact (author name)	Contact (author name)
Contact Address	Contact Address	Contact Address	Contact Address
Organisation Name	Organisation Name	Organisation Name	Organisation Name
OnLine Resource (Link to website, download link, etc..)	OnLine Resource (Link to website, download link, etc..)	OnLine Resource (Link to website, download link, etc..)	OnLine Resource (Link to website, download link, etc..)

Distribution Format and Version: (e.g. shapefile, ArcInfo 10)	Distribution Format and Version: (e.g. shapefile, ArcInfo 10)	Distribution Format and Version: (e.g. shapefile, ArcInfo 10)	
METADATA			
Metadata Standard Name & Version	Metadata Standard Name & Version	Metadata Standard Name & Version	Metadata Standard Name & Version
Metadata Author Contact Details (Name, organization, role)	Metadata Author Contact Details (Name, organization, role)	Metadata Author Contact Details (Name, organization, role)	Metadata Author Contact Details (Name, organization, role)
Date Stamp	Date Stamp	Date Stamp	Date Stamp

Table 2: "Left behinds"

INSPIRE PROFILE OF ISO 19115 AND ISO 19119	ISO 19115 CORE	COMMENT
Part B 1.7 Resource Language	Dataset Language (M)	Language used in resource
	Dataset Character Set (C)	E.g. UTF8: 8-bit variable size UCS Transfer Format, based on ISO/IEC 10646
Part B 10.3 Metadata Language	Metadata Language (C)	Language used in metadata
	Metadata File Identifier (O)	Unique identifier for this metadata file
Part B 7 Conformity		Provides information on the degree of conformity with the implementing rules provided in Art. 7-1. ISO 19115 provides a mechanism for reporting about the evaluation of the conformity of the resource against a given specification.
Part B 1.6 Coupled Resource		Provides information about the datasets that the service operates on. Not applicable to dataset and dataset series, Conditional to services: Mandatory if linkage to datasets on which the service operates are available e.g. http://image2000.jrc.it#image2000_1_nl2_multi

ANNEX E: User Feedback Questionnaire

User Survey: Metadata Standard Set for Geography Department's SDI for Master Thesis "Metadata Management Services in Spatial Data Infrastructures", Peter Lanz, 11.7.2011

PROPOSED METADATA SET FOR SPATIAL RESOURCES (VECTOR & RASTER)

SEARCH ABLE?	MANDA TORY?	METADATA ELEMENTS	EXAMPLES
		RESOURCE	
		TITLE	*Berlin Political Boundary*
		DATE	*2011-06-01T09:00:00*
		DATE TYPE	*Creation,*
		EDITION	*V1.0*
		PRESENTATION FORM (mode in which the resource is represented)	*Digital Map*
		ABSTRACT	*This dataset shows the political boundaries of Berlin.*
		STATUS	*Completed*
		DESCR. KEYWORDS (with option to specify keyword type, e.g. "place")	e.g. *Berlin, Political Boundary, Administrative Boundary,* etc.
		TOPIC CATEGORY (main theme of the dataset)	*Political Boundaries*
		TEMPORTAL EXTENT -BEGIN DATE (information on the temporal dimension of the data)	*2011-06-01T09:00:00*
		TEMPORAL EXTENT -END DATE (Formatted as YYYY-MM-DDTHH:mm:ss)	*2011-06-01T09:00:00*
		SPATIAL EXTENT (bounding box): north east south west coordinates	North bound latitude *53;* West bound longitude *13;* East bound longitude *14;* South bound latitude *52*
		LINEAGE (This is a statement on process history and/or overall quality of the spatial data set)	*This map is part of region X, its Blattnummer is Y or e.g. Product 1 scenes correspond to the path/row of the Landsat orbit*
		REFERENCE SYSTEM	*WGS 1984*
		EQUIVALENT SCALE, DENOMINATOR (denominator for an equivalent scale of a hard copy)	*1:250.000*
		RESOLUTION (Degree of detail in the grid dataset)	*1m pansharpened*
		SPATIAL REPRESENTATION TYPE	*Vecto*
		DATA QUALITY INFO: Hierarchy Level & Statement	*Dataset*
		UNIQUE RESOURCE IDENTIFIER (value uniquely identifying an object within a namespace)	*http://gdi.hu-berlin.de/image*
		USAGE/DISTRIBUTION	
		ACCESS CONSTRAINTS (access constraints applied to assure the protection of privacy or intellectual property,and any special restrict-tions/limitations on obtaining the resource/metadata)	*Can only be onbtained by members of the University of Berlin.*
		USE CONSTRAINTS (constraints applied to assure the protection of privacy or intellectual property,and any special restrictions or limitations/warnings on using the resource/metadata)	*Can only be used by members of the University of Berlin.*
		SOURCE (information about the source data used in creating the data specified by the scope)	*Statistical Office Berlin*
		SOURCE CITATION (recommended reference to be used for the source data)	*Statistical Office Berlin, 2010*
		POINT OF CONTACT	*Max Mustermann, HU Berlin, GIS Officer, Status: Author, mm@web.com*
		ONLINE RESOURCE (type and name of resource plus optional description)	*htLink to website http://www.hu-berlin.de/datasets/dataset.shp*
		DISTRIBUTION FORMAT AND VERSION	*Shapefile, ArcInfo 10*
		METADATA	
		METADATA STANDARD NAME & VERSION	*HUGeoGDI standard set V1.0 based on ISO 19115/119*
		METADATA AUTHOR CONTACT DETAILS (name, organization, role, mail) – dropdown menu to define role: e.g. author, user, point of contact ect...	*Max Mustermann, HU Berlin, GIS Officer, Author, mm@web.com*
		DATE STAMP (automatically)	*2011-06-02T09:00:00*

ANNEX F: Detailed Metadata Set Description

Detailed metadata standard set description for
-Spatial resources: vector & raster (Table1)
-Spatial resources: services (Table2)
-Aspatial resources: tables, docs, photos, etc.. (Table3)

The tables present the following information:

— the first column "Reference" reflect metadata element schema of GeoNetwork's *Metadata Template for Vector data/Raster data/WMS service in ISO19119*. Metadata elements are grouped according to 5 main categories. Most of the department's SDI proposed metadata standard set elements are from one of these 5 categories:

1. Identification Information
2. Distribution Information
3. Reference System Information
4. Data Quality Info
5. Metadata

— the second column contains the name of the metadata element or group of metadata elements,

— the third column specifies the multiplicity of a metadata element. The expression of the multiplicity follows the unified modelling language (UML) notation for multiplicity, in which:

> 1 means that there shall be only one instance of this metadata element in a result set,
>
> 1..* means that there shall be at least one instance of this element in a result set,
>
> 0..1 indicates that the presence of the metadata element in a result set is conditional but can occur only once,
>
> 0..* indicates that the presence of the metadata element in a result set is conditional but the metadata element may occur once or more,

when the multiplicity is 0..1 or 0..*, the condition defines when the metadata elements is mandatory,

— the fourth column contains a conditional statement if the multiplicity of the element does not apply to all types of resources. All elements are mandatory in other circumstances.

Table1 SPATIAL DATA: VECTOR & RASTER				★Mandatory
		RESOURCE		
REF.	METADATA ELEMENTS	MULTI-PLICITY	CONDITION	EXAMPLES
1.01	Title★	1		*Berlin Political Boundary*
1.02	Date ★	1		*2011-06-01T09:00:00*
1.03	Date Type ★	1		*Creation*, *Publication* or *Revision* (from GN template dropdown menu)
1.04	Edition	0..1		V1.0
1.05	Presentation Form ★ (mode in which the resource is represented)	1		*Digital Map*, *Hardcopy Image*, etc..(from GN template dropdown menu))
1.06	Abstract★	1		Free text describing resource
1.07	Status	0..1		*Completed, Obsolete, Required, Under Development, Archive, Ongoing*, etc.. (from GN template: dropdown menu)
1.09	Descr. Keywords ★ (with option to specify keyword type, e.g. "place" or "theme")	1..*		Free text entry, e.g. *Berlin, Political Boundary, Administrative Boundary*, etc..
1.14	Topic Category ★ (main theme of the dataset)	1..*		Depending on Catalogue's categories, e.g. *Political Boundaries*, or *Berlin*
1.15	Temportal Extent -Begin Date★ (information on the temporal dimension of the data)	1		*2011-06-01T09:00:00*
1.16	Temporal Extent -End Date★ (Formatted as YYYY-MM-DDTHH:mm:ss)	1		*2011-06-01T09:00:00*
1.17.01 – 1.17.04	Spatial Extent ★ (bounding box: north east south west coordinates) ★	1		North bound latitude *53* West bound longitude *13* East bound longitude *14* South bound latitude *52*
	Lineage (This is a statement on process history and/or overall quality of the spatial data set)	0..1		Free text entry, e.g. *this:map is part of region X, its Blattnummer is Y or e.g. Product 1 scenes correspond to the path/row of the Landsat orbit*
3	Reference System	1		*WGS 1984*
1.13	Equivalent Scale, denominator (Enter the denominator for an equivalent scale of a hard copy of the map)	0..1	Mandatory for data sets & series if an equivalent scale/ a resolution distance can be specified	*1:250.000* or *250.000*
	Resolution (Degree of detail in the grid dataset)	0..1	Mandatory for raster data	*1m pansharpened*
1.12	Spatial Representation Type	0..1		*Vector, TIN, text/table, video*, etc.. (from GN template dropdown menu)
4.01, 4.02	Data Quality Info: Hierarchy Level & Statement	0..1		*Dataset* (choose from GN template dropdown menu)
	Unique Resource Identifier (value uniquely identifying an object within a namespace)	0..1	Mandatory for resources which are organized in a file/folder system	*http://gdi.hu-berlin.de/image*

USAGE/DISTRIBUTION				
1.10	Access Constraints★ (access constraints applied to assure the protection of privacy or intellectual property, and any special restrictions or limitations on obtaining the resource or metadata)	1..*		Free text entry to protect privacy or intellectual property, and to publish any special restrictions or limitations or warnings on accessing the resource
1.11	Use Constraints★ (constraints applied to assure the protection of privacy or intellectual property, and any special restrictions or limitations or warnings on using the resource or metadata)	1..*		Free text entry to protect privacy or intellectual property, and to publish any special restrictions or limitations or warnings on using the resource
	Source (information about the source data used in creating the data specified by the scope)	0..*		*Statistical Office Berlin*
	Source Citation (recommended reference to be used for the source data)	0..*		*Statistical Office Berlin, 2010*
1.08.*	Point of Contact ★	1..*		*Max Mustermann, HU Berlin, GIS Officer, Author, mm@web.com*
2.*	OnLine Resource (type and name of resource plus optional description)	0..*	Mandatory if linkage to the service is available	*htLink to website, download link,* etc..(from GN dropdown menu) and *http://mysite.org*
	Distribution Format and Version	0..1		*Shapefile, ArcInfo 10*
METADATA				
5.05, 5.06	Metadata Standard Name & Version	0..1		*HUGeoGDI standard set V1.0 based on ISO 19115/119*
5.07.1 to 5.07.12	Metadata Author Contact Details ★ (name, organization, role, mail) – dropdown menu to define role: e.g. author, user, point of contact ect...	1		*Max Mustermann, HU Berlin, GIS Officer, Author, mm@web.com*
5.04	Date Stamp	0..1		*2011-06-02T09:00:00*

Table2: SPATIAL: SERVICES				★Mandatory
		RESOURCE		
REFERENCE	METADATA ELEMENTS	MULTI-PLI-CITY	CON-DITION	EXAMPLES
1.01	Title★	1		*Berlin Political Boundaries Interactive Map Service*
1.03	Date ★	1		*2011-06-01T09:00:00*
1.04	Date Type ★	1		*Creation*, *Publication* or *Revision* (from GN template dropdown menu)
1.05	Abstract★	1		Free text describing resource
1.06	Status	0..1		*Completed, Required, Under Development, Ongoing*, etc.. (from GN template: dropdown menu)
1.08	Descr. Keywords ★ (with option to specify keyword type, e.g. "place" or "theme")	1..*		Free text entry, e.g. *WMS, Berlin, Political Boundary, Administrative Boundary*, etc..
	Topic Category ★ (main theme of the dataset)	1..*		Depending on Catalogue's categories, e.g. *Political Boundaries*, or *WMS Berlin*
1.13.01 – 1.13.04	Spatial Extent (bounding box: north east south west coordinates)	0..1	Mandatory for services with explicit geographic extent	*North bound latitude 53 West bound longitude 13 East bound longitude 14 South bound latitude 52*
4.01 & 4.02	Data Quality Info: Hierarchy Level & Statement	0..1		*Service* (choose from GN template dropdown menu)
1.10	Service Name ★	1		*OGC WMS, WFS, WCS, Link, Download*, etc..
1.11	Service Version	0..1		Version 1.1.1
	Spatial Data Service Type	1		e.g. Discovery-, View-, Download-, Transformation- Service..
1.15.*	Service Contains Operations	0..*		*GetCapabilities, GetMap*, etc.. (incl. link and platform (Java, SQL, etc..) info
		USAGE/DISTRIBUTION		
-	Access Constraints★ (assure the protection of privacy or intellectual property, and any special restrictions or limitations on obtaining the resource or metadata)	1..*		Free text entry to protect privacy or intellectual property, and to publish any special restrictions,limitations or warnings on accessing the resource
-	Use Constraints (assure the protection of privacy or intellectual property, and any special restrictions or limitations or warnings on using the resource or metadata)	0..*		Free text entry to protect privacy or intellectual property, and to publish any special restrictions or limitations or warnings on using the resource
1.07.*	Point of Contact ★ (author name, address, organization, role, etc..)	1..*		*Max Mustermann, HU Berlin, GIS Officer, Author, mm@web.com*
2.03.*	OnLine Resource ★ (URL, protocol, name and description of resource)	0..*	Mandatory if linkage to the service is available	*http://localhost:8080/geoserver/wms ?SERVICE=WMS , OGC:WMS 1.1.1, gn:berlinBoundaries, Berlin Political Boundaries*
		METADATA		
5.06, 5.07	Metadata Standard Name & Version	0..1		*HUGeoGDI standard set V1.0 based on ISO 19115/119*
5.08.1 5.08.2	Metadata Author Contact Details★ (name, organization, role, mail)	1		*Max Mustermann, HU Berlin, GIS Officer, Author, mm@web.com*
5.05	Date Stamp	0..1		*2011-06-02T09:00:00*

Table3: ASPATIAL RESOURCES (TABLES, DOCS, PHOTOS, ETC..)				★Mandatory
RESOURCE				
REF.	METADATA ELEMENTS	MULTI-PLICITY	CONDITION	EXAMPLES
1.01	Title★	1		*Photos Berlin*
1.02	Date ★	1		*2011-06-01T09:00:00*
1.03	Date Type ★	1		*Creation*, *Publication* or *Revision* (from GN template dropdown menu)
1.04	Edition	0..1		V1.0
1.05	Presentation Form ★ (mode in which the resource is represented)	1		*Digital Map*, *Hardcopy Image*, etc..(from GN template dropdown menu))
1.06	Abstract★	1		Free text describing resource
1.07	Status	0..1		*Completed, Obsolete, Required, Under Development, Archive, Ongoing*, etc.. (from GN template: dropdown menu)
1.09	Descr. Keywords ★ (with option to specify keyword type, e.g. "place" or "theme")	1..*		Free text entry, e.g. *Photos, Berlin*, etc..
1.14	Topic Category ★ (main theme of the dataset)	1..*		Depending on Catalogue's categories, e.g. *Photos Berlin*
1.15	Temportal Extent -Begin Date★ (information on the temporal dimension of the data)	1		*2011-05-01T09:00:00*
1.16	Temporal Extent -End Date ★ (Formatted as YYYY-MM-DDTHH:mm:ss)	1		*2011-06-01T09:00:00*
1.17.01 – 1.17.04	Spatial Extent (bounding box: north east south west coordinates)	0..1	Mandatory for resources which are "locateable" or for resources with an explicit geographic extent	North bound latitude *53* West bound longitude *13* East bound longitude *14* South bound latitude *52*
	Unique Resource Identifier (value uniquely identifying an object within a namespace	0..1	Mandatory for resources which are organized in a file/folder system	*http://mysite.org/resource*
USAGE/DISTRIBUTION				
1.10	Access Constraints★ (access constraints applied to assure the protection of privacy or intellectual property, and any special restrictions or limitations on obtaining the resource or metadata)	1..*		Free text entry to protect privacy or intellectual property, and to publish any special restrictions or limitations or warnings on accessing the resource
1.11	Use Constraints★ (constraints applied to assure the protection of privacy or intellectual property, and any special restrictions or limitations or warnings on using the resource or metadata)	1..*		Free text entry to protect privacy or intellectual property, and to publish any special restrictions or limitations or warnings on using the resource
	Source (information about the source data used in creating the data specified by the scope)	0..*		*Statistical Office Berlin*
	Source Citation (recommended reference to be used for the source data)	0..*		*Statistical Office Berlin, 2010*

1.08.*	Point of Contact ★ (author name, address, organization, role, etc..)	1..*		*Max Mustermann, HU Berlin, GIS Officer, Author, mm@web.com*
2.*	OnLine Resource (type and name of resource plus optional description)	0..*	Mandatory if linkage to the service is available	*Link to website, download link,* etc..(from GN dropdown menu) and *http://mysite.org*
	Distribution format and version	0..1		*JPG*
METADATA				
5.05, 5.06	Metadata Standard Name & Version	0..1		*HUGeoGDI standard set V1.0 based on ISO 19115/119*
5.07.1 - 5.07.12	Metadata Author Contact Details ★ (name, organization, role, mail) – dropdown menu to define role: e.g. author, user, point of contact ect...	1		*Max Mustermann, HU Berlin, GIS Officer, Author, mm@web.com*
5.04	Date Stamp	0..1		*2011-06-02T09:00:00*

Based on Implementing Directive 2007/2/EC of the European Parliament and of the Council (European Commission, 2008), GeoNetwork's metadata templates and INSPIRE Metadata Implementing Rules (JRC, 2007).

ANNEX G: SDI Stakeholder & Expert Questionnaire: Results

Question	TL	KJ	GS	OG
1 Main users now?	Students, research INTERN	Students, staff	Students, staff, extern experts	Students (intern), research (intern/extern), and organisational staff members (intern)
2 Main users future?	See 1	See 1	See 1	See 1
3 What kind of resources are supported now?	Spatial data (vector – digital; raster – analogue +partly digital; metadata)	Spatial (raster, vector) and aspatial (e.g. tables)	Analogue maps, digital raster and vector data, aspatial resources (photo collection: landscapes, people; petrographic collection data)	Spatial (vector, raster)
4 What kind of resources to support future?	See 3	Aspatial (documents), services & applications	See 3	See 3
5 Support for activities, typical for an academic institution now?	For introductive seminar "Processing Geoinformation"	data discovery tool for educational purposes, as an example for teaching SDI, data discovery tool for research projects		For educational training (GIS 1 classes), for data sharing in project collaborations (intern/extern)
6 Working Security framework, user-management (user roles and levels of access) now?	limited	No. unlimited access for every user		No
7 Security framework, user management required future?	Level of access for specific user groups	User groups with specific levels of access for specific data		User roles and access restrictions should be implemented (reading/writing)
8 Local or distributed catalogue now?	Local	Local	Local	Local
9 Distribution and connection to remote SDI nodes, other changes to SDI architecture planned future?	Maybe, middle term link to a university SDI	No	Long term vision	Migration to PostgreSQL Database, storage of raster data in a file system (SAN)
10 New SDI-functionalities needed in the future?	Professional metadata management, access to raster data and web services, project-wise SDI	Metadata management via a geoportal, services, access to data beyond geodatabase	Spatial search by drawing an "area of interest" in map, improved map for spatial search (more levels of detail, topographic and chorographic)	User friendly web service to easy discover and visualize data; one central metadatabase
11 Special requirements for future SDI in respect to department's data(base)?	access to raster data (beyond geodatabase)	Geoportal should be central access gateway to distributed and diverse databases and data storages		One person needs to be responsible and Gerd Schilling has agreed to do so. All data which is newly acquired or processed (at least vector or non-spatial data) and which could be of interest for others should be stored in the DB.

ANNEX H: Four Resource Categories' Metadata Standard Sets: Optional and Mandatory Elements

El. No.	SPATIAL:VECTOR	SPATIAL:RASTER	ASPATIAL(TABLES, MEDIA ,ETC.)	SPATIAL: WEB SERVICES
1	TITLE	TITLE	TITLE	TITLE
2	DATE	DATE	DATE	DATE
3	DATE TYPE	DATE TYPE	DATE TYPE	DATE TYPE
4	EDITION	EDITION	EDITION	
5	PRESENTATION FORM	PRESENTATION FORM	PRESENTATION FORM	
6	ABSTRACT	ABSTRACT	ABSTRACT	ABSTRACT
7	STATUS	STATUS	STATUS	STATUS
8	DESCR. KEYWORDS	DESCR. KEYWORDS	DESCR. KEYWORDS	DESCR. KEYWORDS
9	TOPIC CATEGORY	TOPIC CATEGORY	TOPIC CATEGORY	TOPIC CATEGORY
10	TEMPORAL EXTENT -END DATE	TEMPORAL EXTENT -END DATE	TEMPORAL EXTENT -END DATE	
11	TEMPORAL EXTENT - BEGIN DATE	TEMPORAL EXTENT - BEGIN DATE	TEMPORAL EXTENT -BEGIN DATE	
12	SPATIAL EXTENT (bounding box)	SPATIAL EXTENT (bounding box)	SPATIAL EXTENT (bounding box)	SPATIAL EXTENT (bounding box)
13	LINEAGE	LINEAGE		
14	REFERENCE SYSTEM	REFERENCE SYSTEM		
15	EQUIVALENT SCALE, DENOMINATOR	EQUIVALENT SCALE, DENOMINATOR		
16		RESOLUTION		
17	SPATIAL REPRESENTATION TYPE	SPATIAL REPRESENTATION TYPE		
18	DATA QUALITY INFO	DATA QUALITY INFO		DATA QUALITY INFO
19				Service Name
20				Service Version
21				Service Contains Operations /Spatial Data Service Type
22	UNIQUE RESOURCE IDENTIFIER	UNIQUE RESOURCE IDENTIFIER	UNIQUE RESOURCE IDENTIFIER	
23	ACCESS CONSTRAINTS	ACCESS CONSTRAINTS	ACCESS CONSTRAINTS	ACCESS CONSTRAINTS
24	USE CONSTRAINTS	USE CONSTRAINTS	USE CONSTRAINTS	USE CONSTRAINTS
25	SOURCE	SOURCE	SOURCE	
26	SOURCE CITATION	SOURCE CITATION	SOURCE CITATION	
27	POINT OF CONTACT	POINT OF CONTACT	POINT OF CONTACT	POINT OF CONTACT / Responsible Organization
28	ONLINE RESOURCE	ONLINE RESOURCE	ONLINE RESOURCE	ONLINE RESOURCE / Resource locator
29	DISTRIBUTION FORMAT AND VERSION	DISTRIBUTION FORMAT AND VERSION	DISTRIBUTION FORMAT AND VERSION	
30	METADATA STANDARD NAME & VERSION	METADATA STANDARD NAME & VERSION	METADATA STANDARD NAME & VERSION	METADATA STANDARD NAME & VERSION
31	METADATA AUTHOR CONTACT DETAILS	METADATA AUTHOR CONTACT DETAILS	METADATA AUTHOR CONTACT DETAILS	METADATA AUTHOR CONTACT DETAILS
32	DATE STAMP	DATE STAMP	DATE STAMP	DATE STAMP

(Red boxes indicate mandatory elements)

DECLARATION

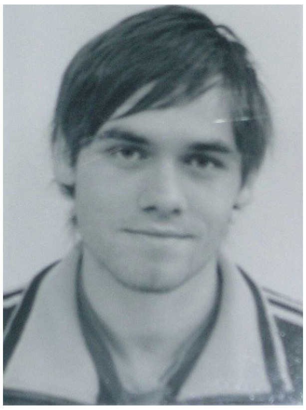
Ich versichere:

- dass ich die Diplomarbeit selbstständig verfasst, andere als die angegebenen Quellen und Hilfsmittel nicht benutzt und mich auch sonst keiner unerlaubten Hilfe bedient habe.
- dass ich dieses Diplomarbeitsthema bisher weder im In- noch im Ausland (einer Beurteilerin/ einem Beurteiler zur Begutachtung) in irgendeiner Form als Prüfungsarbeit vorgelegt habe.
- dass diese Arbeit mit der vom Begutachter beurteilten Arbeit übereinstimmt.

Berlin, 27.9.2011 Peter Lanz

CURRICULUM VITAE

Mag. Peter Lanz



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Born 11.08.1980 in Steyr, Austria
Driving Licenses: A, B (1999)
Civil Service: Red Cross Steyr (2000/01)

Education / Qualification

Magister Geography/Social Ecology (Univ. of Vienna, Univ. of Klagenfurt) 2001-2009
Diploma Thesis: “Material Flow Analysis of India 1960-2004”

Master program Cartography and Geocommunication at Univ. of Vienna 2009-2011
Exchange programmes at Univ. of Melbourne and Humboldt Universität zu Berlin
Master Thesis: “Metadata Management Services for Spatial Data Infrastructure -
A Case Study of a User-centric Implementation Strategy for an Academic Institution”

Languages: German (mother tongue), English (good), Spanish (fair)

Software skills:
Cartography: ESRI ArcGIS 10, ERDAS IMAGINE 8.5, GeoNetwork 2.6, QGIS, Arcview;
Graphics & Design: Adobe CS4 Suite, Macromedia Freehand, VR Worx;
Application development & 3D graphics: Director, Flash CS4; Swift 3D, Cinema 4D;
Scripting and Coding: Flash AS2&3, Python, PHP, HTML, GML(XML), JavaScript, CSS.

Working Experience

Student Staff Employee. Humboldt Universität zu of Berlin.
Computer and Media Services. Web development and programming, organisation of dissemination campaigns; 2011

Casual Employee. Department of Primary Industries Melbourne, Victoria.
Visualization of spatial data and development of interactive web applications with Adobe Flash and Google Earth, Adobe Flash employee trainings; 2009/2010

Research Assistant. University of Melbourne, Department of Geomatics.
Spatial data editing and processing supporting Prof. Ian Bishop, 2009

Web- and Flash Developer. Red-Hot Vienna.
Interactive (Flash) web applications and web design; 2008-2010

Research Assistant. Club of Rome Vienna.
Analysis and monitoring of biodiversity in the EU and associated networks; 2008/2009

Internship. UN Office Vienna - Office for Outer Space Affairs.
Development of Flash web applications and project assistance (UNSPIDER disaster management and emergency response programme); 2009

Web- and Flash Developer. ECM Consulting & ACE Group Vienna.
Interactive web applications, web design and websites; 2006 - 2008

Research Assistant. ACE Group Vienna.
Compilation of project proposals for the EU's 7thFP and for the IEE-call 2007 (solar cooling systems for southern and eastern European countries); 2007

On-site IT-Trainer. ECM Consulting Vienna.
Provision of software trainings; 2006

Research Assistant. Univ. of Natural Resources and Applied Life Sciences Vienna.
Qualitative data assessment; 2005

Tutor. Univ. of Vienna, Department for Cartography and Geoinformation.
GIS trainings for students; 2004/05

Application Developer. Univ. of Vienna, Department of Cartography and Geoinformation.
Development of an interactive web application for the visualization of flood scenarios in Townsville (Queensland, Australia) with integrated 360° panoramas; 2004

Casual Employee. Freytag & Berndt (Vienna) and Gisdat, Linz.
Editing and processing of spatial data; 2003-2005

Casual Employee Karmasin, IGF, Convalexius and AC Nielsen (all Vienna).
On-site qualitative data assessment and project assistance; 2000 - 2011

Berlin, 29th September 2011