Bridging Geospatial Metadata Standards towards Distributed Metadata Information Systems

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ABSTRACT

Within the last few years, more and more metadata information systems (MIS) have been offered in the WWW basing, however, upon quite a number of different standards and formats. This also applies to geodata systems. Therefore, it is often impossible for a user to get comparable information from different MIS. To harmonize the access to different systems and make more information available, it is necessary to bridge the different metadata standards / models.

This paper deals with aspects influencing the development of a geospatial metadata infrastructure and metadata information systems/catalogue systems (MIS/CS). Different approaches to solve problems caused by different overlapping metadata standards are examined.

With a focus on the European region and Germany it describes the current situation in the field of geospatial metadata in comparison with the USA and points out the need of connecting existing MIS and metadata bases. Several metadata standards / models are compared with reference to a practical example.

Central topics of discussion are the determination of a suitable metadata model and method as well as proposals for architectures which are apt to bridge metadata information systems (MIS) following different metadata models.

Keywords: Metadata standard, geospatial data, metadata information system, catalogue system

1 - INTRODUCTION

Within the last few years, an increasing number of distributed MIS/CS for geospatial data have been developed and presented on a regional, national and international level . These systems, however, show great differences in extent and thematic spectrum of covered information (including different terms and keywords), applied metadata standards and protocols (including attribute sets).
In order to find the data model appropriate for the description of the envisaged geodata the following questions, among others, must be taken into consideration.

- Which thematic spectrum has to be covered and how likely are changes and extensions of it?
- Are there any existing MIS/CS and meta-databases/servers addressing these topics? Is collaboration desirable or even necessary?
- If so, which standards/formats do these MIS or other significant systems use?
- Which metadata format shall be used for the new system: an existing standard format, an existing customized format, or a new one?
- If an existing standard shall be used: Which metadata standard (and format) should be taken into account?

In the following, possible general answers as well as an exemplary answer referring to a practical example of establishing a MIS are presented.
Chapter 2 will provide a short overview of general influences on the development of MIS. Chapter 3 first outlines the current situation in the field of geospatial metadata on a European and German level. Furtheron, some aspects for the selection of a convenient metadata model are discussed and three existing metadata standards / models are compared. Chapter 4 presents concepts for building and connecting MIS considering the problems of bridging the gap between different metadata models.

2 - GENERAL INFLUENCES ON THE DEVELOPMENT OF A NEW MIS

The development of a new MIS is influenced by quite a number of different factors. Figure 1 presents an overview of some of those aspects referring to a MIS on a national (German) level, the InGeo-MIS (InGeoForum-MIS) [1].

Those aspects can be classified into pure technical aspects, semantic aspects and several aspects with regard to user requirements and user-friendliness.

- Typical technical problems are the access to remote databases and the localization of (meta-)datasets. Obstacles may be firewalls or different query languages / mechanisms. The establishment of distributed MIS requires a suitable scenario for connecting the involved systems (client/server technology, middleware, RMI, etc.) as well as fitting data transfer protocols including profiles and attribute sets.
  The National Spatial Data Infrastructure (NSDI) in the USA for instance uses the Z39.50 protocol [2] with the GEO profile [3], whereas in Europe the CIP profile [4] and RMI are widely used within the Earth Observation (EO) community. HTTP and TCP/IP may also be used as data transfer protocols as for example the German library system DBV-OSI II [5] that uses TCP/IP and an ISO-OSI layer 7 protocol. Finally,

XML as a subset of SGML allows the exchange of structured data and will, in future, be supported by WWW browsers as well.

- The organizational and political environment of the target community (e.g. for environmental data) has to be considered. Most countries do not have an *'Executive Order'* (as in the USA, see 3.1) that regulates the market of geographic data. So it has to be evaluated which governmental regulations do exist as well as which metadata models and MIS are important due to their existing market impact.
  Distributed systems which incorporate subsystems in different fields of geo-applications (e.g., EO and geology) will have problems with semantic diversity because it is rather likely that different metadata models are used. A harmonization is required before query results of those systems can be compared in an integrated manner.
  Semantic problems for instance caused by homonyms and synonyms do also occur along with the use of multiple thesauri, even more in a multilingual environment European systems have to face. Multilingual thesauri are helpful but very complex to develop and inconsistencies will remain if different thesauri are used which do not belong to the same field of application.
- It is important to realize that a good technical solution alone does not necessarily imply a good - that means useful and used - MIS. Users take the system only as a means for their specific goals (to find geodata, marketing support etc.). Therefore, the needs of the target user groups as to contents and usability have to be included in the developing process of the MIS.

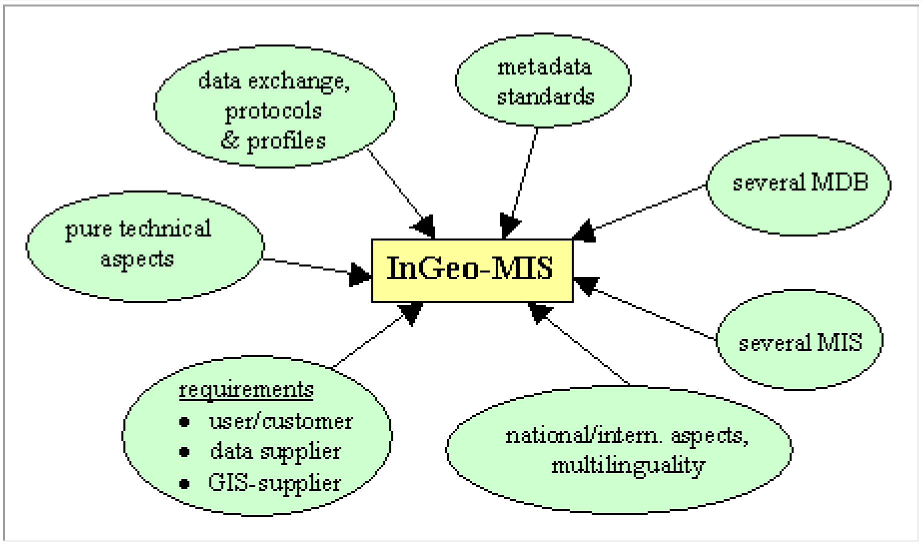

Figure 1: Aspects referring to the development of a MIS

3 - METADATA MODEL

To establish a new MIS, a first and basic technical step is to supply a metadata model. This chapter discusses how to obtain a suitable metadata model and exemplarily presents the decision process for the InGeo-MIS.

3.1 - OVERVIEW OF THE SITUATION IN THE USA, EUROPE AND GERMANY

On April 11, 1994, President Clinton signed the *'Executive Order 12906, Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure'* ([6]) in order to coordinate data acquisition and access to geospatial data in the USA. This executive order instructs federal agencies to document new geospatial data using the metadata standard under development by the **FGDC** (Federal Geographic Data Committee, [7]), and to make these metadata available to the public through the National Geospatial Clearinghouse. On June 8, 1994, the first version of the *'Content Standards for Digital Geospatial Metadata'* (FGDC/CSDGM, [8]) was approved, in June 1998 version 2.
The CSDGM Version 1 has also been the initial draft for the development of **ISO** (International Organization for Standardization, [9]) metadata standard 15046-15, carried out by the Technical Committee 211, which is scheduled to be approved in spring 2000.
Among others also the **OGC** (Open GIS Consortium, [10]) contributes the results of its endeavor to ISO/TC 211. Furtermore there is a so-called Class A Liaison between ISO and OGC, which aims to harmonize the plans of OGC and TC211 in the field of geoprocessing standards and guarantees the mutual use of experience / results.

Neither on a European level nor on a national (German) level there is a comparable regulating law or an executive order as in the USA. A lot of different metadata formats and information systems are emerging all over Europe. But there is as well a remarkable trend to harmonize the efforts. Some current initiatives shall be mentioned.
MEGRIN (Multipurpose European Ground Related Information Network) as an organisation representing and owned by 19 European NMAs established the Geographic Data Description Directory (GDDD, [11]), in order to help users of geographic information by simplifying access to digital map data of NMAs (National Mapping Agencies). MEGRIN itself is an initiative of CERCO (Comite Europeen des Responsables de la Cartographie Officielle), the forum for heads of European NMAs.
The GDDD is based upon the European standard **CEN**/ENV 12657 - Data Description - Metadata [12], which has been approved in October 1998 and is also part of the ESMI project (European Spatial Metadata Infrastructure, [13]).
ESMI is partly funded by the European Commission as a project of the INFO2000 program. The origin of the initiative is settled in the goal of several public and private organizations in Europe to establish a framework in form of a universal metadata service for geographic information. Existing MIS should be linked and future MIS should be easily integratable in this universal MIS, too.

For Germany, in particular, mapping and landsurvey is the business of the federal states. Thus, the single states developed individual approaches to the metadata problem. On a national level (in Germany) the **UDK** (Umweltadatenkatalog -catalogue of environmental data- [14]) has to be mentioned. The development of the UDK was funded by the German federal government. The main focus of the UDK is to register information related to environmental topics. Close cooperation between federal and state levels resulted in a common metadata model even if it is not an approved standard. It is currently widely used in Germany as well as in Austria. The UDK is also intended as the basic system to be used for delivering federal and state metainformation to the Catalogue of Data Sources (**CDS**). Further description of CDS and examples for MIS/CS using this data model for environmental data you can find in [15], [16].

3.2 - DETERMINATION OF THE METADATA MODEL

To supply a suitable metadata model for a new MIS three strategies can be followed:

- Development of a completely new model exactly fitting special needs
- Adoption of an existing model
- Adjusting / extending an existing model in regard to individual requirements

Considering the first option it is important to keep the major goal of MIS for geodata in mind particularly in the federally organized Europe: to achieve more market transparency of data sources and to enable potential customers to find just the data they need. As stated before, a lot of effort is spent at present to integrate and network existing metadata solutions. New metadata models bring in new incompatibilities and impede transparency. In addition, the process of modeling is rather time-intensive and therefore expensive. All in all, this is a less productive option and should be avoided if possible.
Using an existing metadata model can be appropriate if the user demands are not too specialized. But it is more likely that there will be some specific demands.
Therefore it is reasonable to determine the user requirements and to establish a set of criteria for the decision process of which existing model may be suitable for application or, if necessary, adjustment.
In the case of the InGeo-MIS the subsequent parameters have been used :

General purpose: The core topic of the model shall be the description of geographic data (not for example the description of related literature).

Depth of detail: The metadata model has to ensure a minimum metadata quality (means a set of well-defined mandatory elements). However, a precise description of geodata should also be possible if needed by the user. To cover different degrees of description the concept of several description levels is helpful. A possible higher level of detail can further support the mapping of other metadata models, because it is easier to relate precisely defined attributes with a smaller thematic scope than vaguely defined descriptive "free-text" sections.

Unambiguousity: Attributes of geospatial data shall be described only once within the model.

Consistency: With regard to mandatory / optional / conditional attributes as well as possible multilevel solutions it is important to have a contradiction-free model.

Extensibility: In the context of the InGeo-MIS one main requirement of users is to get information about geodata belonging to a variety of application fields. It is unlikely that one existing data model will cover all those possible topics and their related attributes. Therefore, it is important that there is a defined way to generate topic-related extensions when needed.

In short, to use an existing metadata model and - if necessary - fit it to the special needs is a reasonable and effective approach.

3.3 - THE DECISION PROCESS - AN EXAMPLE

Considering the requirements (see above) the decision process for the InGeo-MDF (MetaData Format) has taken into account metadata models on International, European and German level. This section will state and compare the three approaches which have been considered to be the most important ones for the German situation.

- ISO/TC211 CD 15046-15: Its process of standardization is supported by a lot of countries and organizations. It can be assumed to play an important role on international level after approval.
- CEN ENV12657 Geographic information - Data description - Metadata: It is an European standard and already used in several European metadata approaches.
- UDK: It is a national solution with a high degree of acceptance and usage.

3.3.1 - Comparison of Metadata Models

ISO/TC211 CD 15046-15

The objective of ISO standard 15046 part 15 is to provide a metadata model and procedures for describing digital geographic datasets. The total number of its metadata elements is about 400, structured into mandatory / optional / conditional metadata sections (see figure 2), metadata entities and elements. Many elements are based on fixed lists with alphanumeric value domains.

Metadata Sections of ISO/CD 15046-15
Identification
Data Quality
Lineage
Spatial Data Representation
Reference System
Feature Catalogue
Distribution
Metadata Reference

Figure 2

At present the standard defines two levels of conformance. Level 2 encloses the complete metadata model. Level 1 is a defined subset containing 53 metadata elements and is the minimum metadata required to uniquely identify a dataset. It is recommended to be used only for the purposes of cataloguing and to support data clearinghouse activities facilitating data discovery.
It has to be emphasized in particular that the ISO standard provides a method for extending the metadata with user-defined elements and to specify these within the metadata.

CEN ENV12657 Geographic information - Data description - Metadata

This European standard for geospatial metadata has been formally approved in October, 1998 and is already being used as part of the MEGRIN project. The general structure of ENV12657 (Metadata) corresponds with ISO 15046-15 (see figure 3) as well as many of the metadata elements. It has been one basic input into the ISO standardization process.

Nevertheless, with a total number of about 115 elements the description of geographic data is less detailed. Furthermore, most elements are defined as "free text". In comparison with ISO 15046-15 there are some limitations:

- Data sets / data collections cannot be effectively described regarding their hierarchy.
- Besides mandatory / optional / conditional metadata elements and sections, no levels of compliance are defined.
- There is no defined methodology to extend the original metadata model, extensions cannot be described within the metadata model.

Metadata Sections of CEN ENV 12657 Data Description Metadata
Dataset Identification
Dataset Overview
Dataset Quality Elements
Metadata Reference
Spatial Reference System
Extent
Data Definition
Classification
Administrative Metadata

Figure 3

UDK 4.0
The development of the UDK was funded by the German federal government and is used in Germany as well as in Austria. Originally, the purpose of the UDK was to describe environmental data, but not the complete spectrum of geodata. In spite of the initial purpose, the UDK is currently also used by some mapping agencies to describe their geodata.

Metadata Sections of UDK 4.0
"Feldgruppen"
Identification
Additional Information
Availability
Keywords
References
Space-related Contents
Time-related Contents
Topic-related Contents • Organizational Unit / Responsibility • Data collection / Database • Service / Application / Information System • Document / Report / Literature • Geographic Information / Map • Project / Programme
UDK Addresses

Figure 4

Although the total number of metadata elements is about 110, the description of geodata takes only a small part of it (see figure 4) because a wide information spectrum is described (data collection, applications, literature, geographic information, projects etc.).
Thus, there are some strong restrictions using the UDK for describing geodata:

- Some mandatory descriptors do not correspond well with geodata.
- Description of geodata is imprecise.
- Besides mandatory / optional / conditional metadata elements and sections, no levels of compliance are defined.
- There is no defined methodology to extend the original metadata model, extensions cannot be described within the metadata.

3.3.2 - Conclusion

The short comparison has shown some basic similarities, for instance structuring in sections and sub-sections, or mandatory / conditional / optional metadata elements, as well as specific strengths and weaknesses of the different metadata models.
Regarding the requirements listed in chapter 3.2 it finally has been decided in favour of ISO/CD 15046-15. Figure 5 presents the simplified decision matrix.
Despite this basic decision it is important to state that, due to the organizational and political prerequisites in Germany / Europe as well as the actual use none of the three mentioned metadata models can be disregarded.

	UDK 4.0	ENV12657	CD15046-15
General purpose	o	+	+
Depth of detail	o	+	++
Concept of Levels	-	-	+
Extensibility	-	-	+

Figure 5: Decision matrix regarding the requirements

4 - CONCEPTS FOR BUILDING MIS

This chapter will discuss two approaches how to build a distributed / networked MIS that can bridge - to some extent - different metadata models.
As said before, the authors follow a pragmatic approach. No generic search-engine shall be developed able to deal with whatever metainformation it finds, nor a generic metadata model that can incorporate all existing ones. The aims which are followed here for bridging different MIS / metadata standards are:

- To enable access to other but designated geographic metadata sources and to yield comparable search results between different metadata models, well-knowing that there remain more or less strong restrictions.
- Granting access to the own metadata resources and providing support for designated other metadata models - again with restrictions.

The focus of the subsequent discussion will be on the logical approach to bridging. The technical aspects especially of accessing distributed databases / MIS will only be shortly considered.

4.1 - LOGICAL CONCEPTS AND ARCHITECTURE

4.1.1 - Correlating Metadata Models and Query Results

As seen in the example of the decision process current metadata models show similarities and correspondences. These can be exploited to correlate / map the chosen metadata model to the designated other metadata models which are of special interest for the application field of the new MIS.

Mapping is a time-consuming process and has to be done in both directions for a pair of regarded metadata models. Whereas mapping the more detailed model to one with lower granularity may be quite successful, the extraction of needed information out of more general metadata elements can be complex or even impossible. In general the mapping will not be complete in neither direction. The quality of the result depends on the degree of similarity between the models. Nevertheless, mapping enables comparable query results within the set of identified concurring fields.

Metadata (Sub-)Section		Metadata Element ENV 12657		Identifier CD 15046-15	Metadata Element CD 15046-15
Dataset identification		Dataset title		10.08.01	Title
Dataset overview		Summary		10.03	Abstract
		Producer organization name		10.08.03.02 10.08.03.04	Responsible party organization name Responsible party role code
		Spatial schema type		40.02.03	Level of topology code
		Dataset language		10.01	Language of dataset code
		Dataset character set		10.02	Dataset character code set
Dataset quality elements		Lineage	C1	30.02.04.01	Lineage statement
		Quality parameters	C1	20.01.04.02.01	Qualitative narrative report
		Usage	C1	30.01.02	Use
		Homogenity	C1	20.01.04	?
Metadata reference		Entry date		80.04.01	Metadata date
		Last check date		80.04.02	Metadata review date
		Last update date		80.04.01	Metadata date
Extent (Currency / Completeness)		Extent status		10.11.01	Progress Code
		Extent date			
Planar extent	C2	Bounding quadrangle		10.12.01.01-04	West, east, north, south bounding coordinate
		Bounding area		10.12.03.01	Bounding polygon
		Geographic area: Name of the area covered by the geographic dataset		10.12.02.01	Geographic extent name
Vertical extent	C2	Minimum height value		10.12.03.02.02	Minimum elevation value
		Maximum height value		10.12.03.02.03	Maximum elevation value
Temporal extent	C2	Description of temporal extent		10.11.02.01	Maintenance & update frequency code
		Period range details		10.12.03.03.03	Temporal extent date/time description code
		Period start date		10.12.03.03.01	Temporal extent date/time
		Period end date		10.12.03.03.01	Temporal extent date/time

Metadata section

Conditional metadata (subsection) - at least one of these shall be supported

Mapping is incomplete or impossible

Figure 6: Mapping of mandatory metadata elements from CEN ENV 12657 to ISO/CD 15046-15

Figure 6 presents an overview of a mapping from the mandatory elements of the European standard CEN ENV 12657 to the current version of ISO CD 15046-15. It can be seen that the majority of elements can be correlated (even if type conversions and sometimes parsing may be necessary). A minority of elements remains uncorrelated. In this situation it may be acceptable to enhance the chosen metadata model (in this case the CD 15046-15) with the small number of missing elements to at least offer compliance on mandatory level.

Comparison and visualization of query results is a separated topic. Only two aspects shall be mentioned in this context. In existing MIS, queries based on the desired spatial extent and topic-related keywords are of highest importance. Topic-related keyword domains require the integration of referring thesauri. To support comparison / visualization of differing extent descriptions (coordinates, bounding box or area, geographic extent names, etc.) modules for coordinate transformation as well as extensive, geo-referenced gazetteers (may be even multilingual) are necessary.

4.1.2 - Architecture

Figure 7 and figure 8 are presenting two possible logical architectures to implement the access of external MIS.

Architecture 1 provides input and output facilites for queries / query results. The user interface shall be easy-to-use and especially may not require any knowledge of query languages. The query engine takes this part and translates the user's query into an appropriate dialect (e.g. SQL), based on the proper MetaData Format (here: InGeo-MDF). The technical access to other, remote MIS (with their respective metadata format) is symbolized by interfaces IF. They are facilitating the transmission of the query and the results in the appropriate manner (depending on technical aspects of the target system). The visualization engine will present the query results, i.e. the different metadata descriptions which satisfy the query. The user can change or refine his query during evaluation.
The logical access is done by mapping the output of the query engine to the target metadata format. In other words: the remote databases will only be asked for the metadata elements which are matching the query and which are in correspondence with the proper MDF. Thus, the set of query results encloses (after mapping, type conversions, etc. in reverse direction) only metadata elements of one semantic domain. The problems of visualizing are now "standard problems": for example, how to present consistently result-sets with different degrees of completeness.

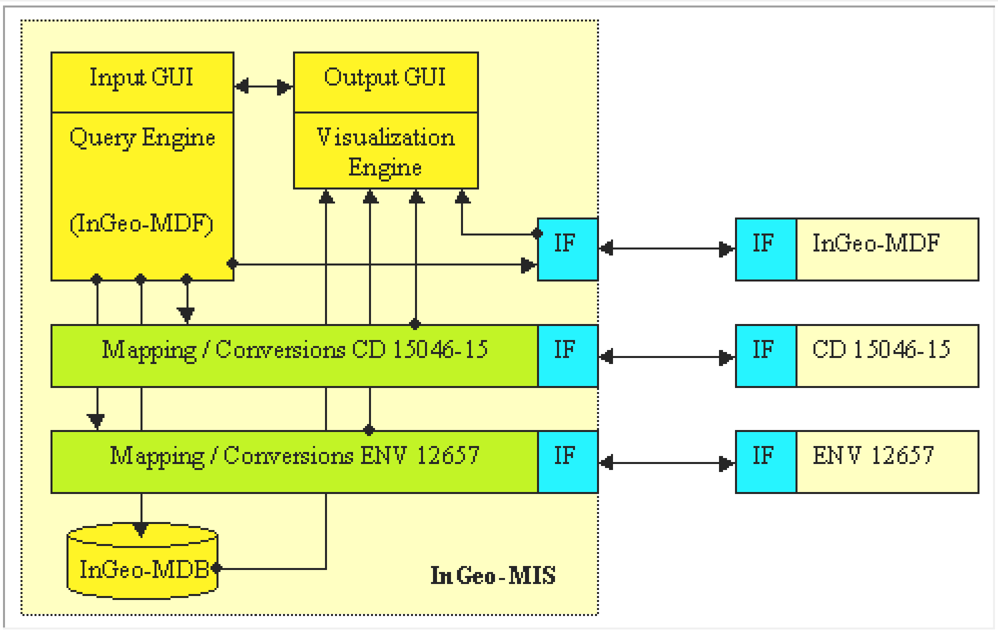

Figure 7: Architecture 1

Architecture 2 provides as well input and output facilites for queries / query results, as described above. But unlike the first solution a query is translated into the semantic domains of several target systems, including the proper one (InGeo-MIS). Accordingly, the results will consist of different metadata formats, but they will be unfiltered and include the complete set of information available. The user may access the results via different, simple visualization engines which do not provide any integration of the query results. A result integration is accomplished, as in the first architecture, by means of mapping, conversions etc. with the respective loss of information details.

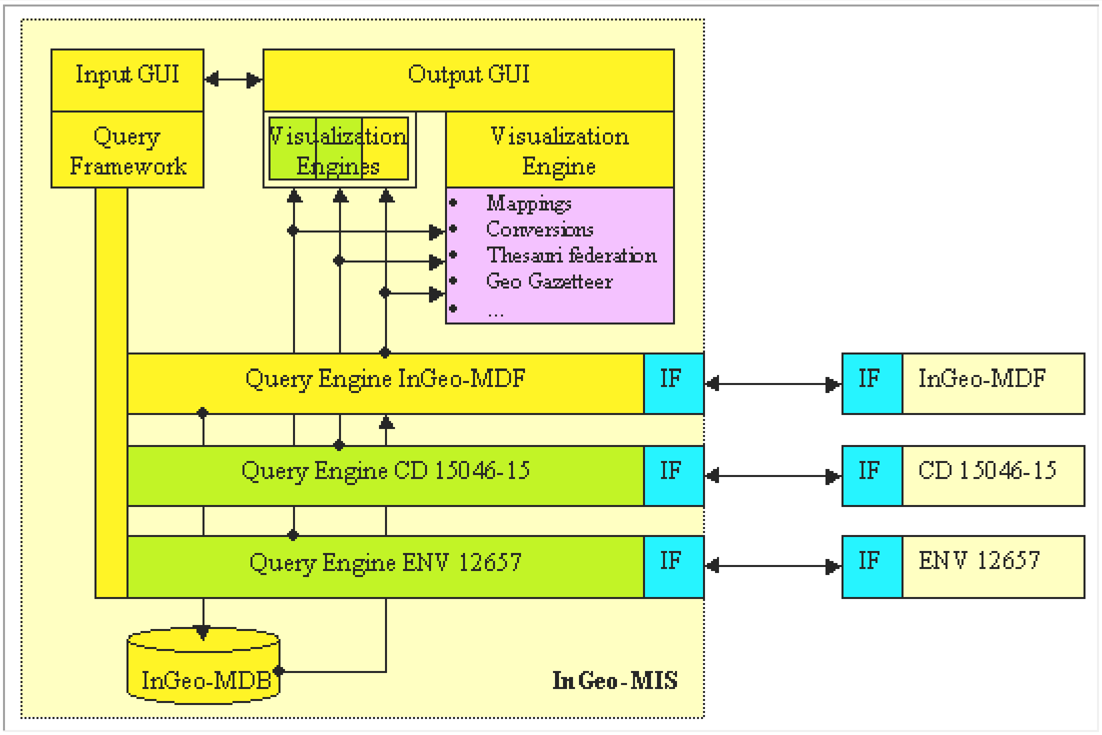

Figure 8: Architecture 2

In comparison, architecture 1 has the advantage of fewer modules and thereby less complexity. The multiple query engine along with the respective visualization engines leads to high implementation expenses for architecture 2.
On the other side, architecture 2 collects the maximum set of information. The user can decide if he wants to browse the query results in detail or if he prefers an integrated view on the result set. In addition, this solution offers more flexibility for mapping and the integration of collected information. Besause the set of original results is available interdependencies between several metadata elements can be exploited. Finally, the integrating module can be updated more easily, if new methods for analysis are developed. All in all, architecture 2 has crucial advantages.

4.2 - IT-CONCEPT OF THE InGeo-MIS

Based on the discussion of the general aspects influencing the development of new MIS (such as InGeo-MIS) the following IT-concept has been chosen:

- Basically, the InGeo-MDF is used as metadata model resp. format. It is strongly based on the ISO 15046-15 common draft (scheduled for approval in 2000). InGeo-MDF will at least be level 1 compliant to ISO.
- Due to the fact that CEN ENV 12657 is widely spread in Germany and Europe, it will be considered both in the system architecture (as described above) and in metadata extensions. On a national level, we intend to do the same with other - explicitly topic-oriented - metadata formats such as UDK in the field of environmental data.
- The local meta database (InGeo-MDB) will be a relational ORACLE database which is connected via JDBC to the InGeo-Browser (consisting of an input GUI, query

engine and output GUI, see figure 8). Queries are translated into SQL statements, result sets are presented via the visualization engine as part of the output GUI of the browser.

- For connecting external meta databases aside from the local InGeo-MDB, basically a http/XML interface will be provided. Data provider can store their metadata directly as XML sites on their webserver or in any kind of database using an additional interface, e.g. CGI. In the first line, project partners who will follow the InGeo-MDF are integrated into the InGeo-MIS network. Designated other systems (e.g. UDK) will come next, using the proposed approach (see figure 8). The interfaces (data/metadata server access mechanisms, protocols, profiles, etc.) will depend on the involved system. For instance, it is intended to support a CIP version (for the field of earth observation). In that case a Z39.50 server in combination with the GEO profile will be necessary.

5 - SUMMARY AND OUTLOOK

The paper gives an overview of different factors influencing the establishment of a new Metadata Information System. As an example, considerations and solutions concerning the development of the InGeo-MIS is presented.
In particular it is pointed out that, compared to the USA, the situation in Europe and Germany is less regulated and, therefore, demands the consideration of a diversity of meta formats and metadata information systems. To overcome this diversity for integration purposes a method of bridging is required.
A pragmatic approach has been developed and is presented which basically builds upon the choice of an existing metadata model in combination with a limited extension of it and a mapping of designated other metadata models.

In Europe, the acceptance of internet-based solutions and applications is evolving fast. The next steps in establishing geospatial MIS will be the integration of online access to real geodata and the connection of already existing MIS in a kind of "Supranet". The approaches described in this paper will contribute to this scenario. In the near future this development will continuously be restrained by the fact that the political awareness of the problems on the geo-market in Europe and especially in Germany is just awaking and that important standards (as the ISO 15046) are still under development. For the time being, pragmatic solutions are demanded to improve the situation.

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