Facilitating the Exchange of Marine Geospatial Data through the Marine Data Infrastructure for Germany (MDI-DE)

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Abstract. Spatial information on the sea and the coastal areas of Germany is an important base for a wide range of applications such as marine environmental protection, marine nature conservation, coastal engineering and regional planning. In order to facilitate the exchange of marine geospatial data ten federal and state agencies have decided to establish the Marine Data Infrastructure for Germany (MDI-DE). Built upon the concept of a spatial data infrastructure (SDI) and the orchestration of distributed geodata services, geospatial data of different domains are brought together. Results are consolidated within a joint portal that acts as a gateway to the manifold data. However, harmonization is needed in order to bring the data together and to achieve a uniform presentation. For this purpose, several specifications have to be agreed to by the partners of the MDI-DE regarding a) the content of the data (e.g. measurement units and temporal aggregation), b) technical conformity (i.e. a joint data model based on INSPIRE and OGC specifications) and c) cartographic aspects (e.g. symbolization and classification).

Keywords: coastal and marine data, marine data infrastructure, reporting obligations, spatial data infrastructures (SDI), spatial data integration

1. Introduction

The Marine Data Infrastructure Germany (MDI-DE) has the aim to facilitate the exchange of spatial information on the sea and the coastal areas of Germany. Thematic fields covered include coastal engineering, the protection of coastal waters, marine environmental protection, marine nature conservation and related topics. The MDI-DE comprises ten federal and state agencies at the level of partners and seven further cooperating partners, all of which provide and/or use marine spatial data (see Rüh & Bill 2012). Accompanying scientific-technical research is provided by the University of Rostock (Rüh et al. 2012).

The establishment of an infrastructure for marine geodata across multiple public authorities was considered necessary for two main reasons. Firstly, reporting obligations resulting from pan-European directives and regional conventions require the composition of data maintained at different sources. Lately, geodata have more and more become an integral part of such obligations. Especially with the conclusion of the Marine Strategy Framework Directive (MSFD, 2008/56/EG) these requirements have significantly increased in scope as well as complexity (cf. Krause et al. 2011). Secondly, also other tasks to be completed by the agencies have become more complex and thus require inter-disciplinary collaboration, also and especially at the level of geodata. Fields affected include e.g. intervention regulations and regional planning.

Due to the federal system of Germany, marine data of the same topic is maintained at several sources, i.e. at distinct federal and state agencies. The structure of these data is rarely homogeneous and data is thus not *per se* interoperable. As a result the urgently needed exchange of data is hindered. In order to facilitate the exchange of marine geospatial data the approach of a spatial data infrastructure (SDI) is considered especially suitable. MDI-DE uses the concept of a SDI to organize the harmonization of marine geodata at the level of Web services and by following international standards such as INSPIRE. In a second step, the data is brought together by using an orchestration of the individual Web services. The results are then presented via a Web-based information portal and can be forwarded to target systems that are responsible for the reporting of data to, for example, the European Commission. Data that is maintained at different sources can thus be exchanged easily.

In addition to the above mentioned reasons for the establishment of the MDI-DE, European directives as well as federal and state laws require the making available of geodata to the general public. These include the European INSPIRE directive (2007/2/EC), the national law on access to spatial data (GeoZG of 2009, 2129-52), the Environmental Information Act (UIG of 1994, 2129-42) as well as according state laws. Here, the approach developed in the context of MDI-DE can be used for the fulfillment of these requirements.

2. Harmonization of Marine Geodata

A lead scenario for the MDI-DE stipulates the facilitation of national reporting obligations resulting from the MSFD. As a prerequisite for nationally coherent monitoring data sets, the relevant data held and maintained at different sources needs to be harmonized in order to allow a bringing together. The harmonization is here suggested to be located at the level of Web services in order to prevent interference with existing database structures.

For measurement data belonging to the topic of eutrophication an exemplary workflow was established for the process of harmonization. The harmonization comprises multiple steps that can be grouped into three categories (Binder & Reimers in print): a) specifications concerning the content, b) technical specifications, and c) cartographic specifications.

2.1 Specifications Concerning the Content

For the analysis of eutrophication processes multiple measurement parameters are relevant such as the concentration of different nutrients, the concentration of chlorophyll-a, the oxygen content at sea bed level, the *secchi* depth, data on macrophytes, and the coverage of seaweeds. Measurement values for these parameters are sometimes stored in different units requiring a conversion into common units and the definition of according conversion rules. Special attention was also paid to the temporal aggregation of the data as well as the calculation of the mean value. For example, for the aggregation of total nitrogen measures the mean value was calculated using all measures throughout the year while for ammonium, nitrite, and nitrate only winter values measured between November and February were considered for calculating the mean value (ibid.). For other parameters such as chlorophyll-a the 90^{th} percentile was used for aggregation in accordance with common practice.

2.2 Technical Specifications

A joint data model was developed in order to order exchange the eutrophication data between the partners of MDI-DE. The model was designed in accordance to the INSPIRE Consolidated UML Model (INSPIRE 2012a). Measurements of eutrophication parameters are modeled with the feature types ‘EnvironmentalMonitoringFacility’ (INSPIRE data specification on Environmental Monitoring Facilities, INSPIRE 2012b), ‘Bio-geographical-Region’ (INSPIRE data specification on Bio-geographical Regions, INSPIRE 2012c) as well as the feature types ‘OM_Observation’ and ‘GFI_Feature’ (ISO-Standard Observation and Measurements, ISO 19156) (*see figure 1*). Code lists from INSPIRE and MSFD models were used to describe classification schemas, measurement regimes, parameter names, acquisition sources, units and media values. A code list for responsible parties in the MDI-DE was defined by the project.

The INSPIRE models are by their very nature object oriented. However, the software installed at the individual infrastructure nodes that provides the data as Web feature services (WFS) needs to work with simple application schemas. Also, most of the common GIS software packages do not (yet) support the use of such complex data models. Therefore, the complex feature types were flattened to attributes with simple types and foreign keys are used to map relationships of the objects belonging to different classes. With this relational model it is easier to combine the WFS in the central data portal without object relational mapping between the existing relational databases and an object oriented transfer schema. Nevertheless the elements in the WFS application schema supports all INSPIRE and MSFD requirements. It is delegated to the central data portal to create fully INSPIRE compatible Web services and to provide appropriated services for MSFD requirements.

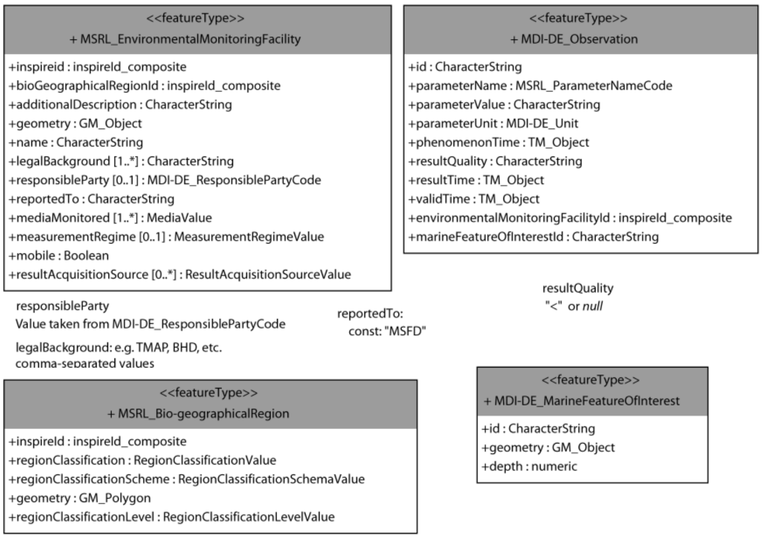

Figure 1. Outline of the model used for specifying eutrophication data in the MDI-DE indicating relational feature types for the WFS transfer schema.

2.3 Cartographic Specifications

In order to guarantee a coherent cartographic visualisation, again several specifications are required. These specifications result into a set of common structured layer descriptors (SLD) that are centrally maintained by MDI-DE. For the eutrophication data this procedure was exemplarily implemented (cf. Binder & Reimers in print).

As a first prerequisite the number of classes to be used and their break values have to be defined. Here, using frequency distribution graphs in combination with established threshold values used in assessments turned out to be a valuable approach for the determination of break values. For most parameters, six classes were chosen because they can still be easily distinguished when varying the signature's brightness only (cf. Buziek et al. 2000). For the visualisation in Web Services alternative versions of signatures were established, three for point signatures (variations in a) size only, b) brightness only, c) size and brightness) and two for area signatures (variations in a) brightness, b) the hash symbol). In addition, the overall size of point symbols was adapted to the map scale selected in such a way that in large scale representations signatures appear larger. Like this the appearance of the map is optimized. For distinguishing 18 different eutrophication parameters colour was used as variable. The different colours were defined by applying the HIS colour space and using 'hue' as variable. A differentiation of eutrophication parameters based on the variable colour is not crucial because only a limited number of parameters is displayed at once.

3. Orchestration of Distributed Geodata Services

Following the concept of a SDI, the MDI-DE is based on a service-oriented architecture (SOA). This approach is realized via spatially distributed infrastructure nodes that are connected via the internet (Lübker et al. in print). An MDI-DE infrastructure node is defined as the hardware and software of a local server architecture used for the management of (geo)data and metadata as well as for the making available of the data via standardized Web services (Helbing et al. 2012). Such a data node can be operated by a single institution or used in cooperation between multiple institutions. In contrast to a centralized database system, this concept has the advantage that the data is kept and maintained at the source and tailored applications can be developed upon the distributed geodata.

As described in more detail by Lübker et al. (in print), the components of a data node comprise an operating system, a database management system, a Web map and Web feature server, and a metadata information system (*see figure 2*). This architecture enables the following functionality: a) the provision of geodata via Web services, b) the provision of metadata, c) the visualisation on geodata, and d) the query of attribute data. For the exchange of data standardized Web services are used that are conforming to the specifications of the Open Geospatial Consortium (OGC). Associated metadata simplify the discovery of the data significantly.

Such standardized services are necessary to comply with the reporting obligations of European directives such as MSFD as well as with the requirements of INSPIRE. As already outlined above the architecture of the MDI-DE uses nodes which in turn use Web services that enable the infrastructure to fulfill or at least ease the compliance of the reporting obligations. Cartographic representations of the data are transmitted to the MDI-DE portal (see section 4) through Web map services (WMS) with SLDs and the data itself through Geography Markup Language (GML) documents via Web feature services (WFS; in version 1.0) to the portal. The cascaded services which have to be harmonized beforehand (see section 2) can be composed in the viewer of the portal. Here, the visualised data can be accessed and used for assessments. The individual layers of the Web services are presented in a fixed structure consisting of layer groups requiring coordination between the project partners. The use of these fixed relations in contrast to *ad-hoc* integration and the use of an outdated version of WFS instead of newer versions ensure that the system works more stable.

As already described above, the portal cascades the services of the data nodes and presents them in a harmonized way through the use of centrally provided SLDs and a central WMS inside the portal. This facilitates a consistent legend and appearance.

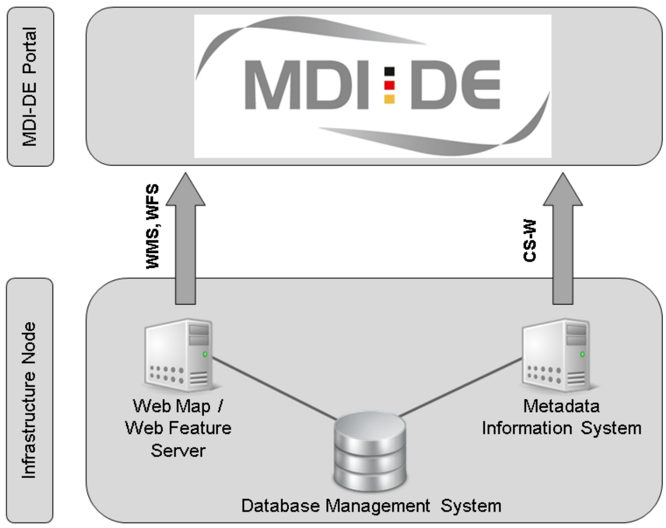

Figure 2. Model illustrating the architecture of an infrastructure node and its communication with the MDI-DE.

4. Access to and Presentation of Marine Geodata

As an important component of the Marine Data Infrastructure an internet portal was established (www.mdi-de.org) that serves as central access point to the marine geospatial data and visualises them.

The access to data is realized via two points of entry. Firstly, via a set of topics that guides the user to predefined map views with all layers displayed that are relevant to the topic (*see figure 3, top*). Secondly, via a detailed form that allows to search the metadata (*see figure 3, bottom*). In this context, the MDI-DE portal works according to the publish-find-bind principal: while the infrastructure nodes function as service providers and publish their metadata via the catalogue service Web (CS-W) gateway, the portal functions as broker that harvests the metadata and enables distributed search queries sent by a client. The harvesting mechanism was chosen instead of cascading queries to the individual nodes in favour of shorter respond times. Harvesting intervals can be scheduled according to the demand of an infrastructure node.

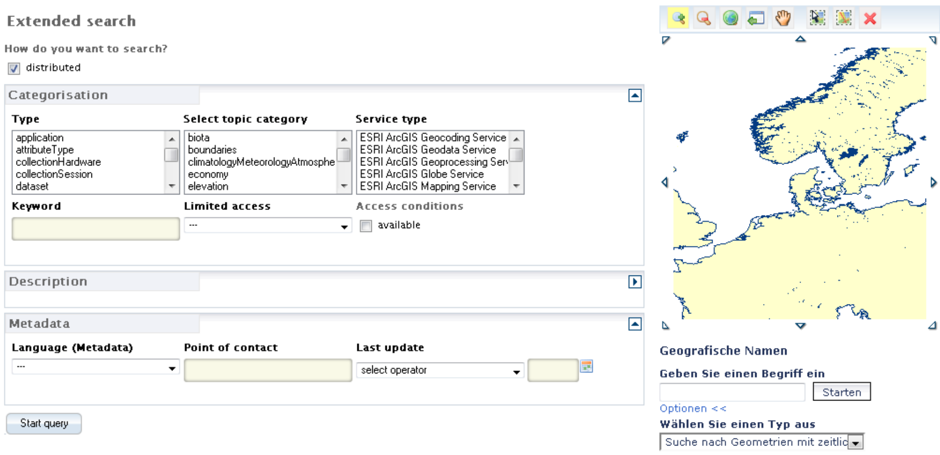

Figure 3. Screenshots of the MDI-DE portal: set of pre-defined topics (top) and metadata query form (bottom).

Since the partners have agreed to use standardized OGC-compliant Web services, the metadata query results as well as all WMS layers can directly be visualised in the map viewer (see figure 4 of Lübker et al. in this book). A coherent cartographic visualisation of the data is enabled by using centrally maintained SLDs (see section 2.3).

From a user's point of view, the data of different federal and state agencies is seamlessly integrated into a common interface. The harmonized Web services can now be used for the meeting of reporting obligations as well as to complete tasks that require inter-disciplinary collaboration between the partners at the level of geodata.

5. Conclusions

With the establishment of the Marine Data Infrastructure Germany the exchange of spatial information on the sea and the coastal areas is facilitated considerably, not least because standardized Web services are used. Geodata of distinct fields are made available via independently operated infrastructure nodes in an interoperable way thus allowing an easy access to the data. As entry point to the manifold marine data serves the MDI-DE portal. Using the service oriented approach of a SDI data of the partners are brought together. The data can be explored via a set of predefined compositions of layers belonging to one topic or via metadata queries the data is visualised in a map viewer.

Harmonization is an important prerequisite for a coherent cartographic visualisation of the data originating from different agencies. Such a harmonization requires different kinds of specifications: content-related, technical as well as cartographic specifications. For the topic of eutrophication such harmonization steps have been realized exemplary. This approach will now be extended to other data relevant to the MSFD. By agreeing to these specifications 'national' Web services can be realized which are required for the meeting of reporting obligations. The establishment of such harmonized Web services presents a case study for a successful application of Germany's Marine Data Infrastructure and an example of use for SDIs in general.

Acknowledgements

The authors would like to acknowledge Germany's Federal Ministry of Education and Research (BMBF) for funding the MDI-DE project (project number: 03KIS089/090/091/092).

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