An Interoperable Geodata Infrastructure for Precision Agriculture

Peter Korduan, Ralf Bill
Institute for Geodesy and Geoinformatics, University of Rostock
peter.korduan@auf.uni-rostock.de, ralf.bill@auf.uni-rostock.de
and Sebastian Bölling
Department of Geography, Humboldt University Berlin
sebastian.boelling@rz.hu-berlin.de

INTRODUCTION

Geo-Information (GI) are an essential component of the public, economical and private life. The importance of Geo-Information is increasingly recognized within all ranges of the society. A high economical potential is assumed when using GI systematically and wherever possible. Nevertheless the market for GI has not developed as strong as expected, may be because of organizational, juridical and technical limitations. A solution to overcome these type of problems is the establishment of spatial data infrastructures (SDI).

In agriculture, and especially in Precision Agriculture, the importance of Geo-Information is rising up, too. Precision Agriculture is dealing with the assimilation of agricultural applications to the natural heterogeneity outside in the fields. Using such technologies the total yield should increase, the means of production should decrease and the environment should be conserved. The assimilation to the spatial variability requires spatial data about the soil, the crop, the terrain, the land machinery, and the applications. Special analyses must be executed with GIS and many different data sets have to be collected and managed. Farmers spend much time in the data management, they usually are not that interested in the procurement and evaluation of data. By using of different devices, which support different data formats, and improperly spatial reference systems the farmer has to transform the data between proprietary GIS and coordinate systems. The low economical potential for the reduction of means of production enforce to save time and cost in data management. In addition the demands on traceability, sustainability and a transparent crop production are increasing. A solution from the farmers perspective will be the relocation of the tasks for data management to service providers, which are able to establish a comprehensive SDI. The introduction of interoperability and a web-service based SDI in agriculture has many advantages and is related to many actual GI-related research themes, expressed also on the AGILE conferences. An operational SDI in agriculture may support governmental issues such as the European integrated management and controlling system (InVeKoS) as well as consolidation of farming. If Geo-Information from agriculture will become a wider accessibility through a SDI it may be easily used in other communities and for other purposes, like disaster management to evaluate the diseases or the damages in crop through natural disasters like dryness or flood. In Precision Agriculture also digital terrain models, soil data or detailed data about the water flows are often used. This information can also be of interest for other environmental purposes. With the development of an operational SDI the semantic interoperability will be improved. The building of semantic homogeneous data models as well as standardized metadata belongs to the development of an interoperable Geo-spatial technology. The implementation of spatial services as web services is matching the idea of the OpenGIS Consortium (OGC).

The paper will describe the concept and the implementation of the SDI for Precision Agriculture on the example of a use case. The next section gives an overview about the common aims of OGC and the functions of later used specifications. This should promote a better understanding of the next sections. On one hand the concept of the SDI for Precision Agriculture will be described and on the other hand its implementation is shown. For the special use case the following questions were examined:

- Which actors appear in which roles in the use case?
- Which GI should be transferred and for what should they be used?
- Which storage components were necessary for GI?
- Which services were necessary to exchange GI and services between members of the SDI?
- Which functionality does a client need?

Spatial Data Infrastructure and Open GIS

The problems of interoperability inspired us to carry out research related to an interoperable SDI for Precision Farming. Vckovski (1999) defines the interoperability simply as "ability to exchange and integrate information", pp. 32. Bishr (1998) divides it in semantical, schematical and syntactical heterogeneity. He stated that the semantic depends on the subject area. The heterogeneity in names has to be solved by standardization. The cognitive heterogeneity can be solved by using the concept of Extensible Markup Language (XML) name spaces. Syntactical heterogeneity as the third form means, for example, that geometry can be coded by vector or raster structure. To describe the geometry in a uniform structure, the Geography Markup Language (GML) was established and is coming more and more into use. In former days data conversion was used to realize the interoperability. To convert the data from one system to the data format of another system, look up tables were used (Sondheim et al., 1999). In this strategy errors, redundancy and inconsistency can occur. To minimize the loss of information a semantically all-embracing model was introduced. The form of conversation is known as "smart translation" or "semantic translation". In the newer age special transfer formats, e.g. XML or the Spatial Data Transfer Format (SDTS), were used. They separate between data model and data format. Today the term of interoperability is not restricted to the data exchange rather it is extended also to the transfer of functionality between different systems. This might be realized by interfaces. Currently many manufacturer dependent interfaces are known. The communication between these proprietary interfaces is often a problem, like in the case of Precision Agriculture. To become independent of those interfaces manufacturer neutral interfaces were developed. One well-known interface is the Structured Query Language (SQL). To realize the communication between different clients and data base systems in a distributed client server architecture middleware was integrated.

The development of such manufacturer independent interfaces for Geo-Information is one of the primary targets of the Open GIS Consortium (OGC). All the investigations of the last years move along to there initiatives and flow into abstract and implementation specifications. Whether the implementation specification can be used for the purposes of a SDI in Precision Agriculture is one of the first aims of our research. We would like to find answers to the questions: Which standards can be used and what has to be standardized? We would like to implement a SDI concept for Precision Agriculture based on a concrete use case. The development of a metadata standard for Precision Agriculture data was investigated by Korduan (2003). This was a prerequisite to establish a SDI prototype. The main components of our concept are the data, the data storage, the OGC Web Services and an OGC Client.

The authors worked from 1999 to 2003 in the German research and development project *preagro* to establish a management information system (cf. Korduan (2003) and *www.preagro.de*). In this project many different and heterogeneous data sets were collected. The data pool build from practical farms was an ideal basis for the development of data models and a data storage system with real characteristics for Precision Agriculture. The data pool was also used for the extraction of important Precision Agriculture related metadata to describe the data and to realize the data archiving and retrieval in a catalogue system. A metadata profile based on the Content Standard for Digital Geospatial Metadata (CSDGM) was developed by Korduan, 2003.

In the mean time services have been specified by the OGC to realize a SDI and frame works are available to implement it. The decision about the service, which should be used, depends on the kind of the GI as well as on the data format and the functionality which should be provided.

The use case ‘Soil sampling’ and its implementation

In the use case of soil sampling we identified the following actors: the farmer, a geological federal state office (GLA), a cadastre government office (KVA), a service provider for soil analysis (LUFA), and a service provider for data management. The actors can be divided into the groups data providers or data consumers. The farmer is the only consumer, all others are providers. The provider for the data management plays the role of the data broker as he has to pass through the data from other providers. The government offices provide only maps, the analysis service provider must read maps, analyse soil samplings and provide the results, the farmer read maps, plans the soil sampling and reads the result of the analysis and finally he provides the data manager all maps which might be of interest for him. The cadastre governmental office provides data like topographic map and soil rate map, the geological office provides geological maps and the service provider, carrying out the analysis, provides nutrient maps of the soil. The data service provider manages the geometry data together with the alphanumeric and metadata as features in a special branch database system (SBDBS). The geometry and alphanumeric data was coded as simple feature in GML. The metadata describe geometry and attributes. The implementation of the SBDBS was realized in the relational database management system MySQL without special Geo-Data types and functions. Alternatively PostgreSQL with its special extensions for Geo-data types, Geo-operators and the Generalized Search Tree was tested. The geometry and alphanumeric data stored in ESRI-shape files was not integrated GML-coded, but as data type “GEOMETRY” based on OGC Simple Feature Specification.

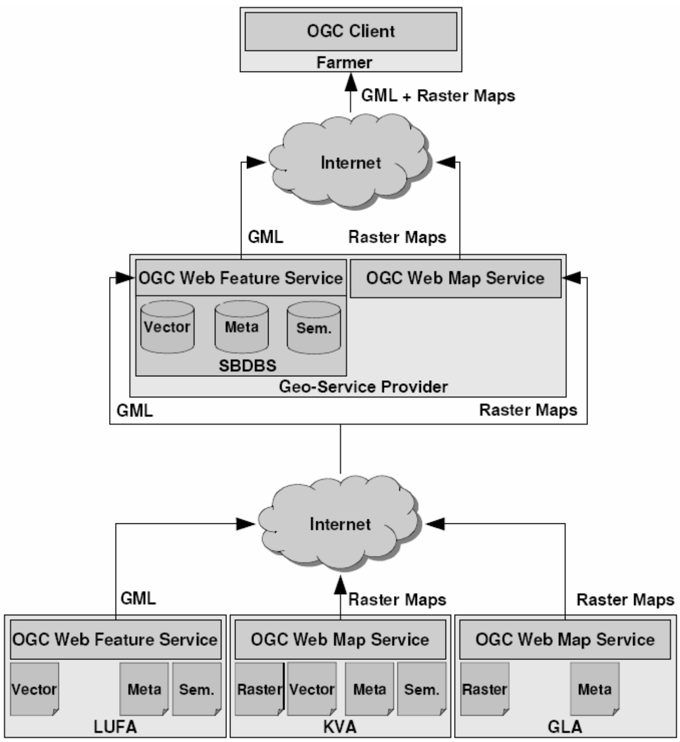

Figure 1: OGC Web Service Architecture for the use case ‘Precision Farming’

The Web service architecture is shown in Figure 1. The implementation of the spatial Geo-data infrastructure was realized with the framework deegree[61]. Deegree is free software under GNU (General Public Licence Model). The framework supports the OGC specifications. Beside the OGC Web Map Service and Web Feature Service also the Coverage, Catalogue, Gazetteer, Terrain and Coordinate Transformation Service may be implemented. Deegree support the Geography Markup Language, the Filter Encoding Specification and the Styled Layer Descriptor Specification. The framework seamed to be able for the implementation of the use case Precision Agriculture, because all required services were supported, the software is free, source code open, the realization of the services good documented and it is running already successful in other SDIs. For the prototype the OGC Web Feature Service was build in the Jakarta Apache Tomcat Server as Web application and configured by the deployment descriptor. After that the capabilities and data storage component was configured and build in the OGC WFS. For the Web application a directory structure was created, consisting of a root directory and directories for the deployment descriptor, Java-Libraries and classes. Further configurations for the Filter Service (interface to the data storage component), the DEG (Display Element Generator, combine the Filter Service with rules for visualization) and the Render Service (generate raster data based on the DEG) must be done. The front end of the services (see figure 2) was realized with a Mozilla Scalable Vector Graphic Browser as thick client. The user interface was created with XHTML-pages which were requested from a Apache HTTP server. The display consists of a map window, a list of used layer, the possible feature types and the functions for spatial and temporal navigation.

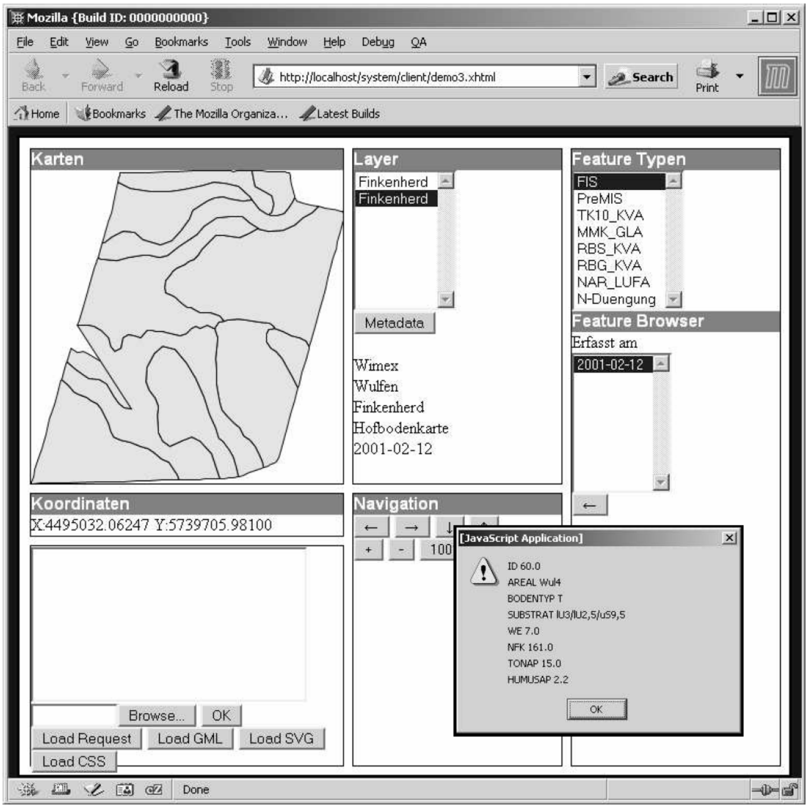

Figure 2: User Interface of the OGC clients

[61] http://deegree.sourceforge.net

SUMMARY

The paper describes how to use the OGC WMS and WFS to implement a SDI for Precision Agriculture. The different actors in our scenario would benefit from such a solution at several places: less data redundancy, less data transformation and communication effort, better workflow etc. In addition the example shows that the service provider becomes the key person in this workflow, thus reducing the IT workload from the farmer and offering new job possibilities for service providers.

For a completely working SDI more OGC web-services need to be included, for example, transformation and authentification services. For some of these useful services implementation specifications exist, but others have to be developed. In the developed prototype data sets for field plots were used. In the future also map sheet free storage must be taken into account.

However, to implement a basic infrastructure for Precision Agriculture the OGC WMS and WFS are sufficient in the moment to show the potential of an SDI according to the OGC specification for Precision Agriculture.

BIBLIOGRAPHY

Bishr, Y. (1998): Overcoming the semantic and other barriers to GIS interoperability. In. International Journal of Geographical Information Science. Vol. 12. No. 4. P. 299-314. Taylor and Francis London.

Korduan, P. (2003): Standardization in data management to increase interoperability of spatial precision agriculture data, in: Proceedings of the 4th European Conference on Precision Agriculture in Berlin, Wageningen Academic Publishers, P. 323-328

Sondheim, M., Gardels, K., Buehler, K. (1999): GIS interoperability. In: Longley, A., Goodchild, M., Maguire, D.J. (Ed.): Geographical Information Systems. Vol. 1. P. 347-358. John Wiley and Sons Inc. New York.

Vckovski, A. (1999): Interoperability and Spatial Information Theory. In: Goodchild, M., Egenhofer, F., Fegeas, R., Kottman, C. (Ed.): Interoperating Geographical Information Systems. Kluwer Academic Publishers. P. 31-38.