Interoperable Services for Web-Based Spatial Decision Support

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SUMMARY

A growing number of spatial decision support systems are available through the Internet. This paper introduces an approach based on GI services and SDIs, the specifications of the OGC and the upcoming 'OGC Web Services 2' initiative, the ISO and the INSPIRE framework. It ends with a roadmap for the development of a web based SDSS and a use case to illustrate the strategy.

KEYWORDS: *Internet, Web Services, Spatial Decision Support, OGC, Spatial Data Infrastructure, ISO, INSPIRE Service Chaining*

INTRODUCTION

The Internet could become one of the most important instruments for the process of spatial decision making because of its distributed, time-independent and license free nature, by providing decision makers with the opportunity to gather information and take an individual or even a group decision without facing the usual temporal and local restrictions of public hearings or group meetings. But while a growing number of web-based decision support systems are available, many of them do not take advantage of the Internet's distributed nature by sharing resources in terms of spatial data and geoprocessing software, which requires standardization and interoperability (see (Rinner 2003) for an overview).

This paper discusses an approach for spatial decision support techniques on the internet based on the specifications of the Open GIS Consortium (OGC), standards prepared by the International Organization of Standardisation (ISO) and the INSPIRE (Infrastructure for Spatial Information in Europe) framework. The approach focuses on a framework for building web-based SDSS for analyzing and processing spatial data for spatial decision support utilizing Multi-Criteria Decision Analysis (MCDA). The ideas are based on an earlier paper of (Bernard, Ostländer et al. 2003) for web-based Multi-Criteria Decision Analysis.

SPATIAL DECISION SUPPORT SYSTEMS AND MULTI-CRITERIA DECISION ANALYSIS

Research in the fields of GIS and Decision Support Systems (DSS) leaded to the development of Spatial Decision Support Systems (SDSS), as interactive, computerbased systems designed to support user(groups) in achieving a higher effectiveness of decision making while solving a semi-structured spatial decision problem. (Malczewski 1999: 281); (Densham 1991; Casey and Austin 2002). Though generally designed for a certain problem domain, they should allow a flexible exchange of underlying data sources to accommodate changes in the environment, a flexible exchange of analyze functions to allow changes in the decision making approach of a user identified within his preferences, and an extendable set of underlying tools to include new functionalities (Sprague 1986).

While the existing decision support techniques realized in a range of SDSS are various, this paper is concentrating on MCDA. It involves a decision maker with a certain goal (e.g. side selection for a certain activity) that is translated into criteria that may help the decision maker to evaluate a certain number of decision alternatives. Each criterion is specified within a *criterion map* prepared with the help of GIS-based data analysis and processing including standardization to a common scale. Criterion maps get preferences of the decision maker generally in form of *criterion weights* and several techniques exist to combine criterion maps using decision rules in form of logical operations and map algebra to aggregate attribute values and allow a ranking of decision alternatives (Malczewski 1999).

SDSS APPROACH USING INTEROPERABLE WEB-SERVICES

To ensure flexibility for *web-based* SDSS using MCDA techniques, this approach goes back to Spragues's common generic framework for developing DSS (Sprague 1986). He introduced the concept of three technological levels: DSS-Toolbox, DSS-Generator and specific DSS (***figure 1***, see (Densham 1991) for a transfer of this framework to the domain of spatial decision making).

- *Specific DSS* (top and most specialized level) as an application or group of applications, that allows a specific decision maker or group of decision makers to deal with an explicit set of related problems.
- *DSS-Generator* (intermediate level) as a "package" of related software, which provides a set of capabilities to quickly and easily build a Specific SDSS from the tools provided by the bottom level.
- *DSS-Toolbox* (bottom and most fundamental level) as an unspecified number of software elements which facilitate the development of a specific SDSS or a SDSS-Generator by providing a number of basic tools.

The following paragraphs transfer the technological framework bearing the three technological levels (henceforth renamed to SDSS Toolbox, SDSS generator and specific SDSS), to geographic web-services and place them in relation to current and future developments of the OGC and the INPIRE initiative (see also ***Figure 1***).

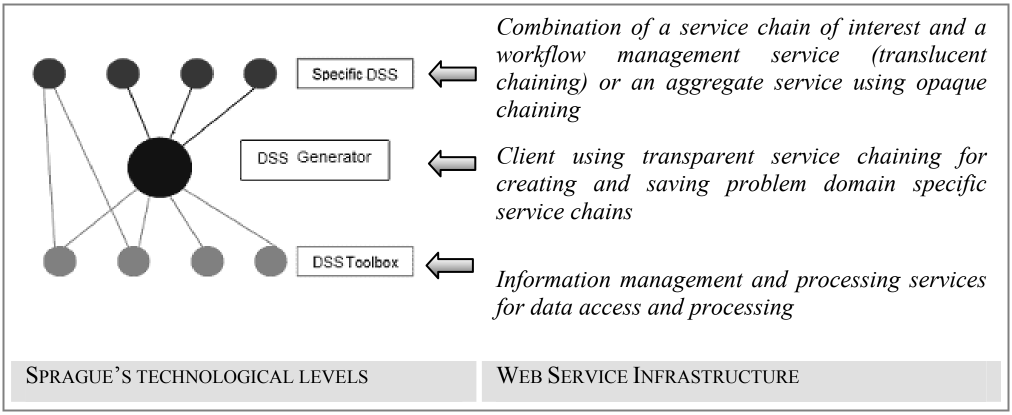

Figure 1: technology levels and roles by (Sprague 1986) transferred into an SDI approach

Web-based SDSS Toolbox

The SDSS tools building the toolbox shall be information management services and geoprocessing services (ISO/TC-211&OGC 2002) for storing and processing spatial data and applying decision specific rules within a service infrastructure by providing basic techniques for data processing like buffering, intersection and re-sampling (for the creation of criterion maps) as well as advanced MCDA techniques like attribute normalization and map algebra for weighted aggregation. As past OGC based GDI efforts concentrated on dissemination of geographic information (Groot and McLaughin 2000; Bernard, Einspanier et al. 2001; Bernard 2002) existing services do not yet provide the techniques mentioned above. Also the OGC Web Services 2 (OWS2) does not cover MCDA, but nevertheless the proposed deliverables in the Request for Quotation (RFQ) include *Interoperability Program Report for specification of Image classification* and *Web Coverage Transformation Service (OGC 2003a)*; if delivered these will be valuable input for the concept of this approach, as it provides important data resp. information input and a crucial transformation tool.

Web-based SDSS Generator

The SDSS generator shall be a client that enables SDSS developers to search and choose spatial data and geoprocessing services, which offer a range of decision rules and functionalities, and build and save a service chain using transparent chaining (ISO/TC-211&OGC 2002). A successful approach for such a generator relies upon a powerful Spatial Data Infrastructure and (future) developments in the field of service chaining: The SDI and data policies to be utilized are part of the INSPIRE initiative launched by the European Commission to build a European Spatial Data Infrastructure (ESDI) upon a network of National Spatial Data Infrastructures (INSPIRE 2002). In the field of Service Chaining the OWS2 RFQ focused on the Business Process Execution Language for Web Services (BPEL4WS or BPEL short) to orchestrate OWS services (OGC 2003a) and therefore the OWS2 outcome will be of great interest.

Web-based specific SDSS

A specific SDSS shall be a combination of a service chain of interest for a SDSS User (provided by a SDSS generator) and a workflow management service using translucent chaining or an aggregate service using opaque chaining, in both cases the SDSS user interacts with the aggregate/ workflow management service by providing parameters, e.g. user specific preferences concerning a certain criterion in form of weights, for executing the service chain (ISO/TC-211&OGC 2002). (Bernard, Ostländer et al. 2003) provide a first architecture example of the latter approach for MCDA using *Weighted Linear Combination* (Malczewski 1999) covering the problem domain of climate change vulnerability.

TOWARDS A SERVICE-BASED SDSS: ROADMAP

To be able to conceptualize a service-based architecture for the framework discussed, a preliminary roadmap for organizing further research has been developed. It includes 4 steps to be undertaken:

(I) Mandatory and optional elements of a toolbox and a generator for spatial decision support using MCDA will be identified based on SDSS Use Cases (to be described). The Use Cases shall also help to border the field of spatial decision making discussed within this approach.

(II) In an actual/target analysis existing and planned OGC web services and service chaining approaches have to be evaluated in the light of the elements identified with the help of the Use Cases.

(III) Concepts for missing OGC services and service chaining have to be developed considering the INSPIRE framework and the outcomes of the OWS2.

(IV) A proof of concept through a prototypic implementation covering elements of all three levels (SDSS Toolbox, SDSS Generator and specific SDSS) developed for a certain Use Case.

The should cover the different types of spatial decision tasks *Side selection, Land Use Selection, Location Allocation* and *Land Use Allocation* and show different levels of complexity. The Use Cases will be developed within the context of the research project BALANCE, which focuses on the integrated analysis and assessment of impacts on the Barent Sea Region's environment and society caused by climate change. Steps of the MCDA process considered for the Use Cases are: identification of alternatives and criteria, criterion scores, criterion weights, aggregation function, sensitivity analysis and final recommendation (though maybe not all within one Use Case) (see (Malczewski 1999)). With a growing number of Use Cases a core for SDSS service tools shall be understood and a strategy for web-based SDSS shall be developed. The following short example Use Case belonging to the task of side selection illustrates the strategy for step I and II of the roadmap.

EXAMPLE USE CASE

An investor looks for sides with potential for development within the tourism sector, to build a ski hotel and skiing facilities. To get a broad overview and limit the number of possible sides, he picks three different criteria: the selected side should A) lie close to a public road (maximum 30 Kilometers away), B) have a high number of days per year with snow cover and C) not lie within a protected area. The decision alternatives are represented by grid cells and the chosen decision rule is Weighted Linear Combination (WLC). The investor has a slight preference for the amount of snow and therefore gives this criterion a weight of 0.6 while accessibility (closeness to road) gets a 0.4. The following preconditions are given: Available data sources are a coverage dataset showing the snow cover (days/year), a vector dataset with streets and a coverage dataset with protected areas. The datasets are part of the INSPIRE framework and therefore share a common Spatial Reference System (SRS). The two coverage datasets are based on the same grid.

- Data preparation: The existing road dataset is buffered with a total of 6 buffers (one buffer per 5 kilometers). Each buffer zone gets the distance of kilometers to the street as an attribute. The buffers are rasterized to the grid of the two coverages and form the data source for criterion A).
- Criterion map production: The data sources for criterion A) and B) are normalized to a scale from 0 to 1 using score range transformation, where the range of values (minimum and maximum score) of each data source is used. The data source for criterion C) is recoded to 0 for protected areas and to 1 for all other areas to form a Boolean constraint.
- The aggregation function is formed as a mathematical expression, where the normalized criteria A) and B) are multiplied by their weights and added up. The result is multiplied by the Boolean constraint C): $(A \times 0.6 + B \times 0.4) \times C$.
- The resulting map shows possible sides as grid cells. The higher the value of the grid cell is, the more suitable is the location.

This Use Case shows the necessity for a variety of geoprocessing activities making up elements of toolbox and generator (step I): Creating new features through buffering, rasterizing vector data, attribute normalization, map algebra and the orchestration of data preparation, criterion map production and applying of the aggregation function.

For this exemplary Use Case to be transferred into a web service infrastructure, the following ideas could be considered (step II, a fraction):

- The functions to buffer and intersect a feature (OGC 1999) are specified within the simple feature specification upon which the Geography Markup Language (GML) (OGC 2003b) is based. As the Web Feature Service Implementation Specification (OGC 2002) uses GML to express features within the interface, the existing interface of the Web Feature Service could be extended with a buffer function.
- In case the score ranges are known, the normalization could take place when performing map algebra for the decision rule without producing special criterion maps.

A large number of Use Cases is needed in order to identify the core elements of toolbox and generator. An agreement on this core is needed, before step II, i.e. the extension of existing or the specification of additional web services can be addressed.

DISCUSSION

A major advantage of this approach is the amount of flexibility, as whatever might be specified and even implemented as part of the to be build service architecture, the nature of SDSS toolbox and SDSS generator should remain flexible and allow the extension with other tools covering different or more specific decision problems. But nevertheless within the future work it will have to be discussed if it is feasible to draw a clear line between SDSS tools and generator and possible to create a core of tools for MCDA.

The Use Case described above is rather easy and therefore when extended the problems will multiply: The preconditions currently prevent the need for coordinate transformation and resampling to a common Grid, which shows that a framework like INSPIRE with it's specifications and policies can be a major advantage concerning the number of beneficial preconditions. Interesting, though also very demanding, are topological conditions beyond the used buffer, e.g. the amount of connected grid cells should exceeding a certain threshold value.

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BIBLIOGRAPHY

Bernard, L. (2002). Experiences from an implementation testbed to set up a national GDI. 5th AGILE Conference on Geographic Information Science, Palma (Balearic Islands), Spain, AGILE: 315-321.

Bernard, L., U. Einspanier, et al. (2001). Developing OpenGIS Catalog Services For a GDI: Lessons Learned. 4th AGILE Conference on Geographic Science 2001, Brno: 355-361.

Bernard, L., N. Ostländer, et al. (2003). Impact Assessment for the Barent Sea Region: A Geodata Infrastructure Approach. 6th AGILE Conference April 24-26 in Lyon, France: 653-661.

Casey, M. J. and M. A. Austin (2002). Semantic Web Methodologies for Spatial Decision Support. International Conference on Decision Making and Decision Support in the Internet Age, 4th of July, 2002 - U.C.C, Ireland, Oak Tree Press: 453-463.

Densham, P. J. (1991). Spatial Decision Support Systems. Geographical Information Systems: Principles and Applications, vol.1. D. J. Maguire, M. F. Goodchild and D. W. Rhind. London, Longman: 403-412.

Groot, R. and J. McLaughin, Eds. (2000). Geospatial data infrastructure - Concepts, cases, and good practice. Oxford, Oxford University Press.

INSPIRE (2002). Data Policy & Legal Issues Position Paper, Environment Agency for England and Wales: 45.

ISO/TC-211&OGC (2002). Geogaphic information Services Draft ISO/DIS 19119, International Organization for Standardization & OpenGIS Consortium.

Malczewski, J. (1999). GIS and Multicriteria Decision Analysis. New York, John Wiley & Sons.

OGC (1999). Open GIS Simple Features Specification for SQL, OGC (Open GIS Consortium Inc.).

OGC (2002). Web Feature Service Implementation Specification, OGC (Open GIS Consortium Inc.).

OGC. OGC Web Services, Phase 2 RFQ, http://portal.opengis.org/files/?artifact_id=3554. last access: 2003-12-022003.

OGC (2003b). Open GIS Geography Markup Language (GML) Implementation Specification, OGC (Open GIS Consortium Inc.).

Rinner, C. (2003). "Web-basierte räumliche Entscheidungsunterstützung - Ein Überblick." geoinformatik_online 2003(1).

Sprague, R. H. (1986). A Framework for the Development of Decision Support Systems. DECISION SUPPORT SYSTEMS - Putting Theory Into Practise. J. a. H. J. W. Edited By Ralph H. Sprague: 1-26.