Landscape Editing for Planning Support in River Basin Management - FLUMAGIS

Jörn Möltgen & Karina Rinke

Institut for Geoinformatics, University of Muenster, Robert-Koch-Str. 28, 48149 Münster, Germany, joern.moeltgen@uni-muenster.de

Abstract: FLUMAGIS aims at the interdisciplinary development of methods and data processing data processing tools in support of the planning and management of river basins. The focus will be laid on the development of an interactive tool facilitating the evaluation and (3D) visualisation of river basin environments. This comprises the representation of current inshore water and landscape ecological aspects as well as the water balance and substance balances. Editing virtual environments makes it possible to elaborate future planning and management scenarios based on interdisciplinary data and knowledge platform in accordance with the water frame directive (WFD). Possible alternatives and effects of various planning scenarios become transparent, can be discussed and experienced in a participatory process. Furthermore the integration of GIS services, micro- and meso-scale simulation models and the derivation of ontology based measures support the decision finding. The ontologies are developed in co-operation of experts in the domains limnology, landscape ecology, hydraulic engineering, hydrology, geoinformatics and socio-economy. The effects caused by the implementation of proposed measures can be estimated with the help of simulation models. Standards and methodologies are used to enable interoperability of software components.

***Keywords**:* planning support, water framework directive, environmental modeling, ecological assessment, scale changing

1. INTRODUCTION

Upcoming environmental planning philosophies in juridical frameworks of the EU require better integration of those, who are affected by planning measures. As a consequence more and interdisciplinary information must be offered to citizens. For this reason, the role of planners will change from a technical engineering side towards a more process oriented moderator, coordinating planning steps and contributions of different involved institutions. In consequence, this coordination role requires quick and comprehensive data and information availability, supported by spatial planning and decision support systems.

The FLUMAGIS-project aims at the interdisciplinary development of methods and data processing tools for measure planning and effect assessment in river basin management. This includes the integration of techniques from visualisation, scale-specific modeling, knowledge processing and methods for ecological and socio-economical assessment and prediction of planning measures. It comprises the representation of current inshore water and landscape ecological aspects as well as the modelling of aspects of water balance and substance balances.

The basis for the landscape editing process of ‘virtual’ measures builds the (3D) visualisation of river basin environments in a virtual environment. Therefore some special requirements for the 3D environment had to be combined in FLUMAGIS: the use of suitable Virtual Reality (VR) environments, the organisation as real time capable component, the creation of suitable interaction tools and the direct reference to geo-objects. The interaction enables the actual editing process, which means to alter conditions of geo-objects. In that manner users can ‘plan’ measures and management scenarios (in accordance with the EC water framework directive) and continue with an investigation of their ecological and socio-economic effects. The prediction module enables the simulation and representation of measures effects. Therefore it interacts with ontology based knowledge processing techniques and simulation models.

The paper presents the implementation concept of FLUMAGIS for the integration of multi-disciplinary models (hydrological, biological, socio-economical), knowledge-processing modules, GIS and (3D) visualisation techniques and defines planning support functions. All implemented software modules are prototypes. Their data bases and content (e.g. of knowledge base) relate to spatial (the river Ems) and thematical use cases from the WFD. In principle all functions and modules can be applied to user river basins. Therefore adjustments and extensions to the specific geographical conditions are necessary.

2. EXPECTATION ON PLANNING SUPPORT FOR THE WFD

For effective support within complex spatial decision processes tools for the generation and evaluation of alternative planning scenarios are needed beside support in problem analysis. This aspect is not considered adequately by spatial decision support systems (SDSS) that designed in order to assist decision makers to address ill-defined spatial planning tasks (Densham 1991). Decision support is already given once decision makers possess tools that enable a systematic and informative data processing (eg. tables, graphics, etc.) For spatial analysis geographic information systems (GIS) are implemented (Armstrong and Densham 1990). Based on various approaches from artificial intelligence expert knowledge is implemented in order to diagnose environmental stages and to evaluate planning scenarios.

The major task for planning disciplines is the development of acceptable planning solutions. Spatial planning processes include:

- problem definition
- definition of planning objectives
- elaboration of planning alternatives
- selection/rejection of planning alternatives,
- realisation of measures.

This aspect is neglected in many SDSS. When the actual planning of scenarios (beside decision support) is the central part of a SDSS, we consider it as a planning support system (PSS). However, there is much equality between SDSS and PSS (Klostermann 2001). PSS supports collective planning, social interaction, communication, and discussion. The expansion of functionality should lead to an enlargement of the user group (Hopkins 1999).

Almost all steps of a planning process can be supported by PSS. However, in order to serve as a tool for the development of planning processes und coordination platform, PSS require access to relevant spatial conditions and their relations to multidisciplinary information.

The European water frame directive requires transparent and participatory planning processes. The time and effort for information retrieval increase with the growing need of transparency. But the enabling of more actors (all actors affected by planning measures) to explore planning scenarios could help to promote the acceptance of planning scenarios. Even the role of planners is not reduced to the preparation and presentation of planning alternatives anymore. Their function changes more and more towards a moderator role.

One vision of the FLUMAGIS project is the enhancement of transparent and participatory planning. In order to support planning, assessment, evaluation, simulation and prognosis, we want to couple various existing techniques and methodologies from visualisation, knowledge engineering and processing, modelling and simulation. The resulting software and information services are prototypical tools for river basin management. By adapting the models of FLUMAGIS to other river basins these tools can also be used in other regions.

In order to meet real practical requirements on such a tool, a task and requirement analysis is necessary. In the FLUMAGIS project this has been done in a close liaison with the German planning administration. Essential specifications resulted from interviews, questionnaires, best planning practise rules, etc. The following summary of 'overall goals' set up the basis for the FLUMAGIS-PSS to support the implementation of the WFD:

- tools for analysis and assessment (referring to defined ecological goals of WFD),
- tools for deficit detection in the river-ecosystem,
- participation support and tools that support measure and scenario planning,
- and prognosis and analysis of effects of planning measures.

From that we derived technical requirements to be fulfilled that are presented in the following paragraphs.

3. VIRTUAL ENVIRONMENT

The early information and participation of affected actors is essential for the quality of planning. Visualisation and interaction within the context of spatial planning represents an appropriate tool for information transfer and data processing. Since interdisciplinary projects like FLUMAGIS demand the integration of different technical aspects for communication of persons from various domains, the way of information transfer plays an important role. Particularly the 3D visualisation of landscapes and flooding situations enables the user to imagine how the environment look like. Furthermore the information should be coded in a suitable way so it can be easily and intuitively decoded and understood by recipients. Therefore it is necessary to combine the more abstract 2D and close-to-reality 3D visualisation for river basin management in a suitable way.

Some specific demands for the 3D environment have been combined in FLUMAGIS:

- the use of suitable VR environments,
- the organisation as real time capable component,
- the creation of suitable interaction tools
- and the direct reference to geo-objects.

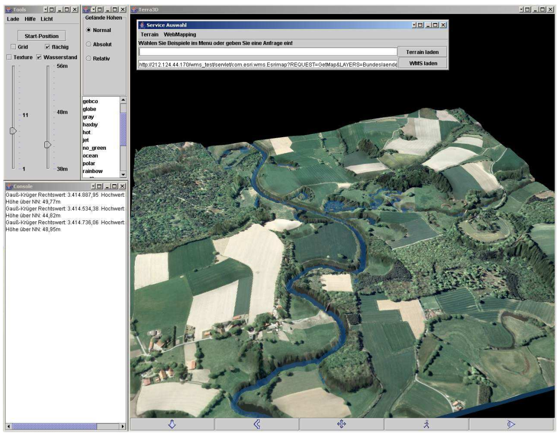

Figure 1. Prototypical part of the 2D user interface

The process of scenario or measure planning in virtual landscape editing is enabled by the interaction tools. Within the virtual river landscape the user (planners or planning affected people) can alter the objects of the virtual landscape (add, change geometry, change attributes, delete). For typical spatial and non-spatial interaction types for various entity classes see Möltgen et al. (1999).

The virtual environment is real time capable and is able to display the results of analysis directly. As environments of visualisation a desktop PC and a semi-immersive workbench environment have been chosen. The different characters and technical possibilities of both environments cause the implementation of different interaction tools.

Figure 1 shows the FLUMAGIS desktop PC user-interface. Figure 2 shows the workbench environment. One actor uses a data glove to interact in the virtual world.

Figure 2. Workbench environment with clipped 3D-river landscape

4. FLUMAGIS ARCHITECTURE

Tasks like determination of ecological deficits, suggestion of measures and prognosis of effects by measures on the landscape claim high demands for the software architecture and its components. Particularly because of the interdisciplinary functions it's necessary to combine different expert components. To avoid the development of a monolithic system and to ensure interoperability the single components of FLUMAGIS are extensively encapsulated connected to the system.

4.1 Overview

The prototypical FLUMAGIS software implements a server-client-structure so the visualisation (clients) and analysis components (server) are separated (see figure 3).

Functionalities like visualisation, exploration and manipulation of data are located on the client. The user can initialise the processes on the server through the user interface.

Data and knowledge management, more GIS-functionalities and simulation models are part of the server. Geodata and semantic data are kept strictly separated by connecting both a geodata base and a knowledge base.

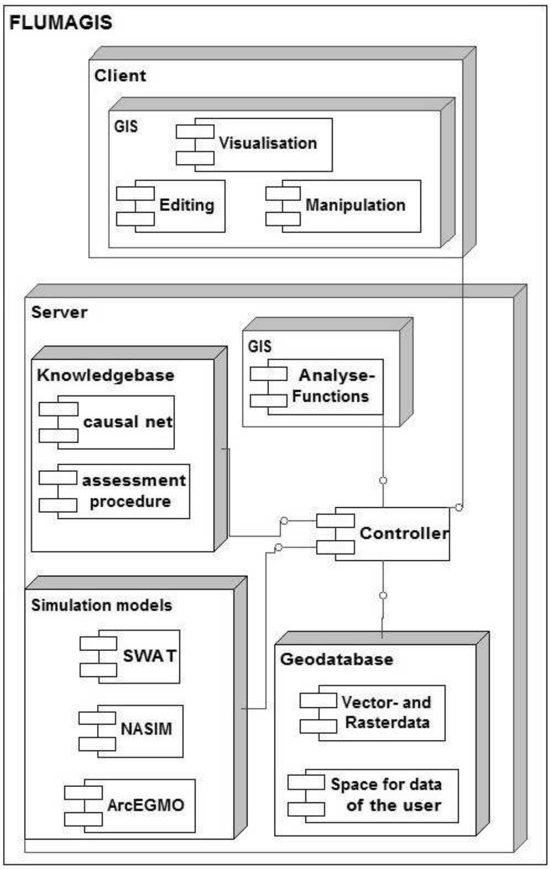

Figure 3. FLUMAGIS system architecture.

The purpose of the knowledge base is not limited to the providence of semantic data. Primarily it serves as a causal network that allows deduction of knowledge for analyse functions like deficit and causal analysis as well as assessment.

Geodata selection, spatial analysis and generation of data for visualisation are typical functions of the GIS components on the server. Science analysis are made by integrated calculation and simulation models that are initialised by the controller. The controller plays a main role due to the fact that he organises and coordinates the components and processes. The communication between the components is supported by XML-based interfaces that are significant important for the interoperability of the system.

The following passages describe some selected components.

4.2 Knowledge base

Causal analysis as well as prognosis and prediction of planning effects are the most important tasks of the knowledge base. Thus we have developed a causal net that includes three basic components (Borchert 2004):

- Ontologies represent taxonomies and categorizations of certain domains,
- A Bayesian Belief Network as the underlying concept of the causal net. It deals with causal relationships and probabilities of discrete states.
- Actions and processes are described by Coloured Petri Nets, a well known model to visualise and prove proceedings and events.

The ontology component delivers the basic node and net concepts to the causal network. It introduces the fundamental relationships “is cause of” and “is effect of” between nodes. For special tasks several subtypes of the basic node concept are created. Fig. 4 shows the concept of the causal net.

The inference machine of our knowledge base can take any status node as starting node in order to analyse object attributes in the database. Deficits for example can be detected and also their potential causes. In case of incomplete or uncertain data probabilities are invoked if possible.

The knowledge bases enable analysis like:

- Causal analysis checks object attributes to identify objects fitting the state described by a starting node, and it uses the “is cause of” relation of status nodes to find causing nodes.
- Prognosis goes the opposite direction: it estimates the effects of states and actions using the “is effect of” relation. It can also calculate probabilities if the database does not provide certainty (what is the normal case).

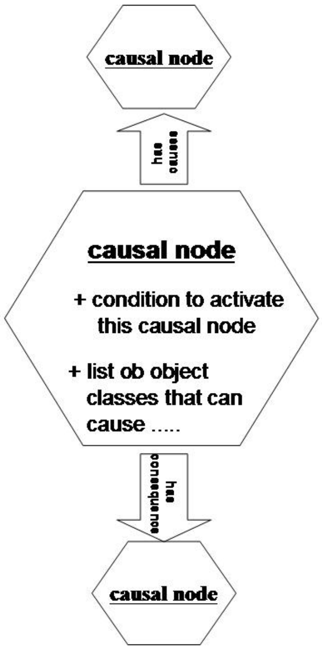

Figure 4. Concept of the causal net

The knowledge base platform Protégé has been integrated to FLUMAGIS due to its extensive functionality and expandability as an Open Source Project. Basically it serves as a frame logic based knowledge editor for domain ontologies [Noy et al., 2000]. By developing extensions (plug-ins) we can apply special evaluation methods and manage the communication with other system components [Borchert, 2003].

4.3 Interfaces

The communication between the internal components of the system is implemented by employing XML-syntax (Extensible Markup Language). It's specified by XML-schemes so the technical implementation of an interface is extensively automated. The only exception is the request of the geodatabase because the appropriate interfaces are not open to the public and a new implementation of their complex functionalities would cause to much effort. Therefore a proprietary API (Application Programming Interface) is used.

The communication concept that is implemented in FLUMAGIS offers some advantages compared to conventional implementation of interfaces. Due to the open XML-standards by the World Wide Web Consortium (W3C) the usage is not restricted by the producer. XML supports all established text encodings and can be used on different platforms.

The hierarchical file structure provides the possibility to interleave requests so that they are more than just usual "attribute-attribute value-requests". Extensions or changes to interfaces can easily be made in the XML-schema whereby the adaptation of the parser is automated.

4.4 Simulation models – scales and modeling

Different simulation models will be integrated in FLUMAGIS to deduce measures for river basin management and to give prognosis of the effects of those measures to the water quality, habitat conditions in rivers and vegetation changes. Furthermore cost of measures can be estimated by socio-economical models (e.g. BEMO). According to the specific measure types for river management and the interdisciplinary relevance, particular scale levels have been defined comprising the micro-, meso- and macro scale. Thus, for the description of the water balance and matter fluxes within the landscape the models NASIM (micro- and meso scale), ArcEGMO (micro- to macro scale), SWAT (meso to macro scale) and ABIMO (macro scale) will be applied.

The integration of the models became quite complicated because e.g. the models are not based on XML-interfaces and the simulation is usually initialised by input from the user interface and not like in FLUMAGIS automatically by the controller from the server.

5. EXEMPLARY PROCESS SEQUENCE

FLUMAGIS offers three main functions: the state visualisation, measure planning and prognosis (see figure 5).

The user starts the program by the 2D- or 3D-visualisation of a state and can choose between various functions of exploration. For example assessment data or background information about typical landscape vegetation can be added. Furthermore manipulation and generation of data is supported by different tools.

The subsequent measure planning consists of three analysis steps: the deficit determination, causal analyse and the measure suggestion. These steps can either be automatically run by the system, be managed manually by the user or be organised by a combination of both. Completing the measure planning, the sequence of measures that will be delivered to the prognosis is suggested by the system. The sequence depends on the kind of measures that are selected whether they're hydrological, structural etc.

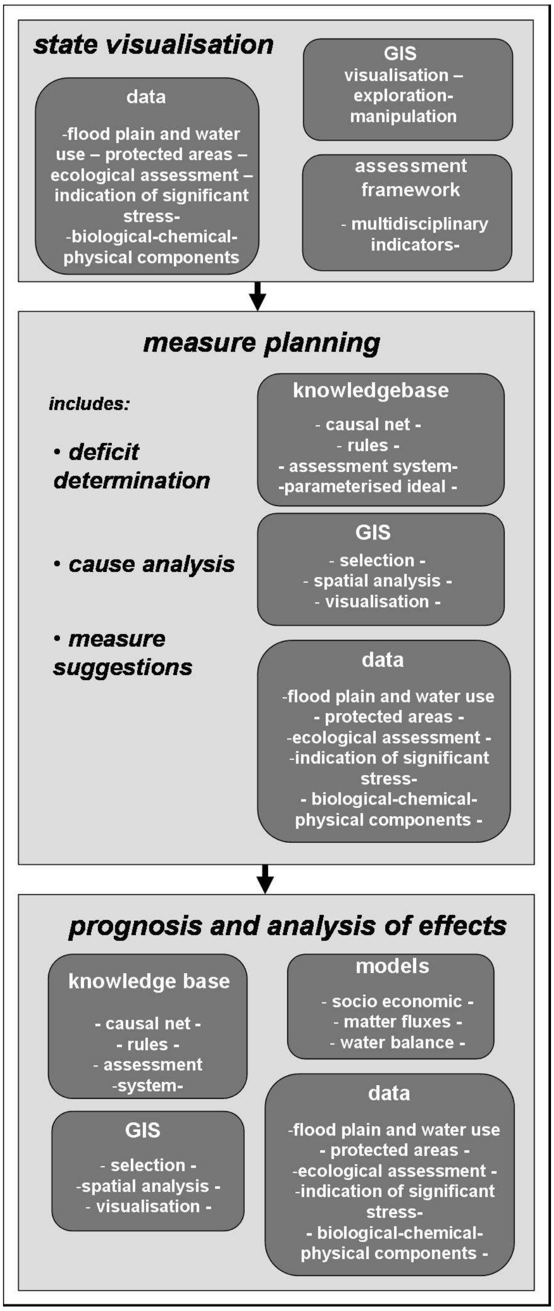

Figure 5. Process sequence and relating software components (dark boxes).

Every measure can cause diverse effects and can influence other measures and their effects. Therefore the measures are sequentional processed by the prognosis expect measure packets which must be processed in once. The states which are generated during the prognosis and the final forecasted state can be visualised.

The measure planning is mainly based on the interactions of the knowledge base and the GIS-functions. E.g. the knowledge base identifies possible deficits, so geoobjects can be search by GIS-components. The prognosis utilises different simulation models additionally. The operational sequence of the system is mainly coordinated by the controller. The controller receives information of other components and can determine the following steps.

Beside these three main functions there are two more ones: the effect analyse and the trend-assessment. The effect analyse provides the relative values of the measure effects. The assessments of the final forecasted state of e.g. hydrology, vegetation, water quality are realised as trend indications. These trend indications point out how far the conditions of the aimed ecological state could be prepared and initialised by the measures.

6. CONCLUSION

The presented approaches for planning and decision support are ongoing work. In a final implementation user are able to analyse the status quo, to perform diverse ecological assessment, to detect concrete deficits according to the goals of the WFD, to ‘edit’ measures in a virtual world and finally to investigate the effects of these edited measures. This editing and assessment approaches can improve the opportunities of participatory planning enormously. Core applications are the interactive visualisation, ecological and socio-economic models and the knowledge-processor. Most indicators and methods are already included in the knowledge base. Modelling measures and processes by Petri Nets and refinement of the causal network will be the next step.

7. REFERENCES

Armstrong, M. P. and P. J. Densham (1990). "Database Organization Strategies for Spatial Decision Support Systems." In: International Journal of Geographical Information Systems 4/1990 (1): 3-20.

Borchert, R. (2003): How can a knowledge base run executables on the frame level?, Sixth International Protégé Workshop, Manchester, England, July, 2003.

Borchert, R. (2004): Das Kausalnetz als Kern eines DSS. In: Möltgen J. und D. Petry (Hrsg.) Interdisziplinäre Methoden des Flussgebietsmanagements. Tagungsband Münster 15. u. 16. März 2004.

Densham, P. J. (1991). Spatial Decision Support Systems. In: D. W. Rhind (Hrsg.): Geographical Information Systems: Principles and Applications. Essex. Longman Scientific & Technical. 1: 403-4l2.

Geertman, S. & Stillwell, J. (editor) (2003): Planning Support Systems in Practice. Springer Verlag, Berlin.

Hopkins, L. D. (1999). Structure of a Planning Support System for Urban Development. In: Environment and Planning B: Planning and Design, 26: 321-331.

Klostermann, R. (2001). Planning Support Systems: A New Perspective on Computer-Aided Planning. In: R. Klostermann (Hrsg.): Planning Support Systems. Integrating Gis, Models, and Visualizations Tools. Redlands. ESRI Press: 1-24.

Kuhn, W., and M. Raubal, Implementing Semantic Reference Systems, AGILE 2003, Lyon, 2003.

Marcot, B. G., R. S. Holthausen, et al. (2001). Using Bayesian belief networks to evaluate fish and wildlife population viability under land management alternatives from an environmental impact statement. Forest Ecology and Management 153(1-3): 29-42.

Möltgen, J., B. Schmidt & W. Kuhn (1999): Landscape Editing with Knowledge-Based Measure Deductions for Ecological Planning. In P. Agouris & A. Stefanidis, eds.: ISD'99 - Integrated Spatial Databases. Lecture Notes in Computer Science 1737, Berlin: Springer.

Noy, N.F, R.W. Fergerson, et al., The knowledge model of Protégé-2000: combining interoperability and flexibility, 2th International Conference on Knowledge Engineering and Knowledge Management (EKAW'2000), Juan-les-Pins, France, http://protege.stanford.edu/, 2000.

Sowa, J.F., Knowledge representation: logical, philosophical, and computational foundation, Brooks/Cole, Pacific Grove, CA, 2000.

ACKNOWLEDGEMENTS

The FLUMAGIS research project is funded by the Ministry of Education and Science (BMBF) in Germany in its research program ‘Flusseinzugsgebietsmanagement’. The project will be conducted by the following partners in close co-operation: Institute for Geoinformatics, Institute of Landscape Ecology, Department of Limnology (all University of Münster), Labor of water resources management (University of Applied Science Münster), Institute for Ecological Economy Research (Berlin) and Centre for environmental research, Leipzig.

The authors wish to thank all project partners for their kind collaboration and providing us with current project results.