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Towards the Development of a Documentation Structure for Modelling Spatial Processes

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Abstract

This paper describes issues relating to the formation of a documentation structure for modelling spatial processes. The limitations and desirable attributes of such a structure are discussed with particular reference to the requirements of model designers and implementers. The definition of their structure is regarded as pivotal to the continued research and implementation of technology for modelling spatial processes previously conducted and published, in which extensive benefits were identified. In this paper, particular reference is made to highlight existing research in the area of model documentation that although requiring adaptation, may satisfy the specified criteria for the development of a generic system for modelling spatial processes.

1. INTRODUCTION

In the last 5 years there has been dramatic changes in the development, design, and implementation of systems for advanced spatial analysis and modelling. Rapid advances in processing power, developments in software, and increased availability of digital data have allowed diverse applications and the execution of complex geocomputational analysis. While this analysis varies greatly in form and application, environmental models are among the most frequent uses (Parks, 1993).

There has been a large amount of research into systems for modelling spatial processes. Potentially, these systems can facilitate complex modelling analysis and promote greater understanding of the relationships between environmental variables. Marr *et al.* (1997) argue that spatial process modelling is the procedure of outlining how geographic data (textual and non-textual) are manipulated in order to achieve desired results. In the traditional GIS setting, this is similar in concept to standard cartographic modelling, but with the facility to design, construct, test, and execute spatial models.

As an example of such a system, the SPMS (spatial process modelling system) software developed by Mann (1996) was tested by environmental decision makers and shown to enhance understanding of complex environmental relationships, and foster improved decisions.

A key feature of the SPMS software is the intuitive and interactive white-board style graphical user interface (Figure 1). With conventional software engineering, typically little consideration is made of the user interface, often until the development process is almost complete. With the SPMS software, the prime focus was on the drag and drop interface style, since this was particularly useful when portraying model elements and their relationships. With this system, model computation and the display of results are initiated based on the model constructed by the user, using the interface. Due to the relative significance of this interface, further development has focused on the enhancement of this system where limitations were identified (Marr *et al.* 1998).

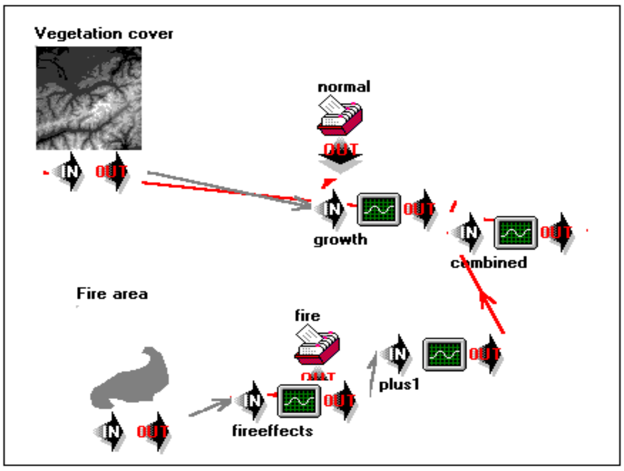

Figure 1. Screen Shot Model of SPMS Tutorial (Mann 1996)

SPMS is a software environment that facilitates the modelling of complex spatial and non-spatial operations. The aim of SPMS is to enhance user involvement in model design, and to assist in model execution and analysis. The use of SPMS with the associated powerful drag and drop toolbox user interface provides many potential benefits.

In summary, these benefits are first, that it graphically presents to the user the manipulation functions being utilised on each dataset and the order in which they are performed. This greatly assists the user to fully understand the processes involved and how they relate to the outcomes. The second benefit is that this method of modelling promotes the development of a toolbox approach for the representation of spatial functionality. The result of this is that the user is presented with a very powerful tool in which customised functions and models can be easily developed. A third and related benefit is that spatial process modelling using this method potentially provides a suitable mechanism to facilitate integration between GIS and additional functionality packages such as expert systems and specialised environmental modelling. The fourth benefit is that a system such as this, potentially facilitates the exchange of complex reusable process model components between researchers.

There are many other significant research issues yet to be resolved before fully integrated - and perhaps interoperable - spatial process modelling can take place. The development of a modelling design file that will adequately define and describe the structure of a spatial process model, and detail the model lineage and meta-data is one such issue. Such a structure must be platform independent and be able to be incorporated as a sub-component to an existing process model. The design must also handle mainstream GIS functionality and non-spatial modelling functionality, while also facilitating user-defined operations.

2. CONCEPTUAL SYSTEM FOR MODELLING SPATIAL PROCESSES

Marr *et al.* (1998) describes the conceptual development of a generic system for modelling spatial processes. This research examined the SPMS software, identifying deficiencies and highlighting desirable features of such a system based on the relevant literature. The research reports the formation of a series of conceptual services (Figure 2), that are designed to solve the issues previously identified and is principally based on the logical breakdown of the required features of the system.

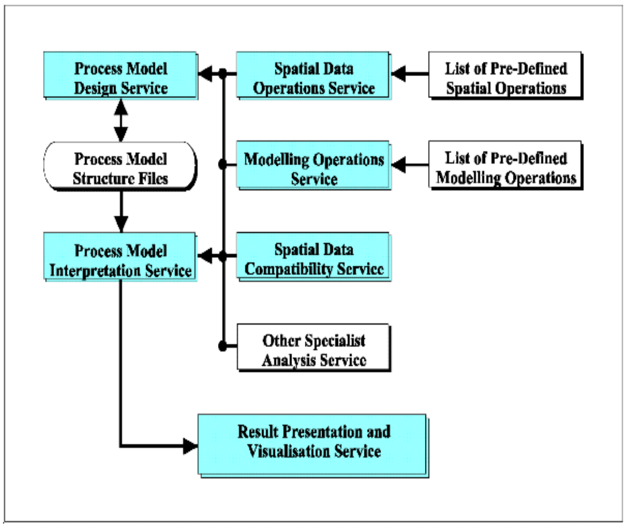

Figure 2. Conceptual Framework: System for Modelling Spatial Processes

The definition of a model (via the *Process Model Structure File* component) is regarded as pivotal to the continued research and implementation of technology for modelling spatial processes. This rest of this paper focuses on issues relating to the conceptual documentation of a structure for modelling spatial processes, suitable for implementation.

"During the past decades a sizeable number of mathematical models addressing questions in ecology and environmental protection have been developed. These models represent a large repository of scientific knowledge and experience about structures and function of ecosystems"   Benz et al. (1997, p1)

Benz *et al*. (1997) argues that seldom has this proliferation of numerical formula and structure been properly documented or properly disclosed in the form of publicly accessible and scrutinised scientific journals. Further, where this documentation has taken place, confusion of terminology is common, models have differing layouts and degrees of detail, and often lack proper discussion on their appropriateness and validity. Benz *et al*. (1997) further reasons, that the consequence of this is first, existing knowledge is only partially available and second, ecological modelling is inefficient because considerable resources are wasted on redundant work.

3. ISSUES OF MODEL STRUCTURE DESIGN AND IMPLEMENTATION

While there are extensive technical difficulties in designing a documentation structure for modelling spatial processes, there are many other considerable issues relating to the use of such a system within an organisation and beyond.

3.1. Open and Closed Sharing

The potential benefits of sharing models and numerical formulae are widely recognised. Bennett (1997) argues that modelbase management systems (MBMS) can be used to store, manipulate, and retrieve models in much the same way as a conventional database. Bennett concludes that by managing models like data, model redundancy is reduced and model consistency is enhanced. There is an obvious benefit to the scientific community in being able to share these models in an open and unrestricted research setting. While complete sharing of accumulated distributed model resources is a desirable goal, the specialization and complexity of some models may suggest a preference for limited sharing among a select group of individuals with intimate knowledge and familiarity with the subject area. It is probably also inevitable that commercial pressure will prevent some open sharing of research.

It could be argued that it is impossible to document environmental models in such a way as to be beneficial to others particularly in an open environment where the designer and user are physically detached. With the user not in direct communication with the designer, it is impossible to easily convey initial assumptions and model basis and allow the designer to ensure the full comprehension of the user. This supports the design criteria that a model structure must incorporate as much written documentation as possible.

Ultimately, as with many other areas of technical software use, the user is responsible for ensuring the validity of research outcomes however they were computed.

3.2. Model Complexity

Environmental models have a tendency to portray very complex theoretical concepts. It could be argued that this complexity is beyond the capabilities of any one system of modeling or documentation structure. Maxwell & Costanza (1995) argue that a widely recognized method for reducing program complexity involves structuring the model as a set of distinct modules with well-defined interfaces. They further argue that modular design facilitates collaborative model construction, since teams of specialists can work independently on different modules with minimal risk of interference.

Marr *et al*.(1998) argue that in addition to modular model construction techniques, the complexity of model development and testing could be reduced further. This is achieved by the adoption of software interfaces that incorporate an interactive toolbox approach to modeling functionality. With an illustrated white-board design, the relationships between environmental variables are clearly identified and model assumptions and results can be tested in a step-wise fashion.

Step-wise development, is a widely accepted programming style in software engineering, facilitating the construction of complex code step-by-step from proven foundations. This design process has a high degree of relevance to environmental modeling. The SPMS software system developed by Mann (1996) utilized this approach to environmental modeling. Analysis of SPMS use by environmental decision-makers clearly demonstrated enhanced problem understanding and improved solution development. In particular, the system facilitated the identification of conflicting issues between different sides in applications for the use of environmental resources. The system enabled sophisticated scenario development and what-if analysis.

4. EXAMPLE OF MODEL DOCUMENTATION: REM AND ECOBAS

In an attempt to solve the problem of model documentation and retrieval, Benz *et al.* (1997), produced a system (Figure 3) that is based on two principal components which form a hierarchy of model documentation (Register of Ecological Models and ECOBAS). "The objective of this system is to produce a model documentation which is easily accessible, complete, standardised, comparable and transferable to different applications" Benz *et al.* (1997, p2).

4.1. Register of Ecological Models

According to Benz *et al.* (1997) the Register of Ecological Models (REM) is a meta-database that stores generalised information about each model, that is in a suitable form for initial model identification. Such search criteria can include model name or some aspect of model content (e.g. keywords, main subject, main medium, type of model, level of organisation, free text string). Currently the REM has been implemented in freely accessible WWW searchable form at http://dino.wiz.uni-kassel.de/ecobas.html.

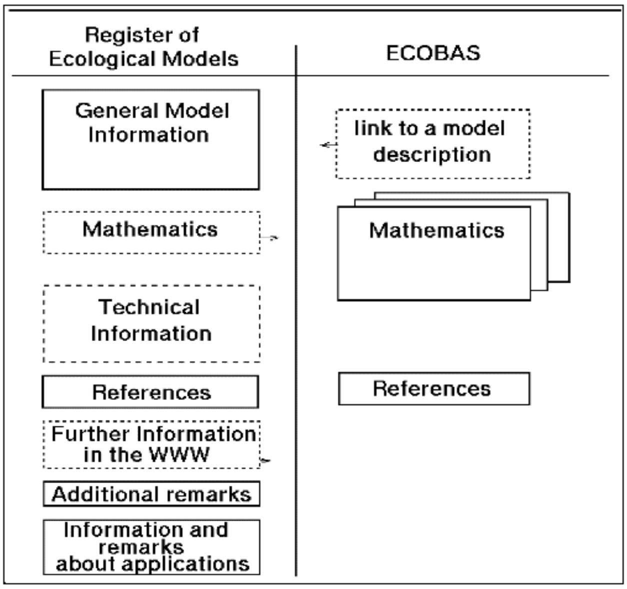

Figure 3. Hierarchy of model documentation in REM and ECOBAS

4.2. ECOBAS

Benz *et al*. (1997) describe ECOBAS as complementary to REM providing the "...detailed and complete declarations of the mathematics of ecological objects or processes" (p3). Aspects of the ECOBAS system include the declaration of all ecological objects, their attributes/quantities, using a consistent and complete format, and in a suitable framework for assessment of model validity in other areas of application.

Benz and Hoch (1997) describe an ECOBAS document as having a fixed basic structure (Figure 4). The model interchange format is ASCII based for maximum portability and hardware independence. Some of the sections listed below contain one or several subsections as required by the model being described.

One of the major problems of the system developed by Benz *et al*. (1997) is an incomplete consideration of numerical modelling, environmental or otherwise, that requires the use of spatial data, as detailed in the description of ECOBAS. The need for systems that utilise spatial data is clearly identified by Mann (1996) in his consideration of needs environmental decision-makers. Along with the proper consideration of spatial data, there is also a need to embrace functions and operations, which act on the spatial data that require inclusion in the model documentation. The SPMS software did not document model design in a way that it could be applied to future use. The software did however, execute the model designed by the user, in an iterative fashion when required. The ECOBAS system is designed to document model design in a logical and consistent manor for ease of understanding and cross model comparison. It does not however, facilitate an interactive style of model design or permit direct model execution.

```
[ECOBAS_MIF Version 1.1 ]
%%Last modification: Tue Apr 08 15:13:15 1997
%%Creator: ECOBAS-Documentation
%%User: nobody@wiz.uni-kassel.de
GENERAL_INFORMATION:
        :
DECLARATION_OF_VARIABLES:
        :
LIST_OF_EQUATIONS:
        :
LIST_OF_FUNCTIONS:
        :
LIST_OF_CONSTRAINTS:
        :
LIST_OF_CONDITIONS:
        :
CLASSIFICATION_OF_ENVIRONMENT
        :
DESCRIPTION:
        :
LIST_OF_REFERENCES
        :
LOCAL_TECHNICAL_EXTENSIONS:
        :
```

Figure 4. Basic structure of a ECOBAS_MIF document (Benz and Hoch, 1997)

Another aspect not covered by the ECOBAS specification is the facility to develop models with sub-components in keeping with the identified need for modular based, model construction. ECOBAS is developed around the definition of inputs and outputs which would tend to suggest that this functionality could potentially be incorporated.

5. CONCLUSION

This paper describes some of the issues relating to the formation of a documentation structure for modelling spatial processes. Future initiatives are expected to promote the development of a documentation structure for modelling spatial processes capable of being created, tested, and executed using a dynamic user interface. In addition, such a documentation structure must cater for modular construction, and other considerations relating to the wide distribution and use of designs among the research community.

In terms of existing research into the development of a generic system for modelling spatial processes, the construction of a documentation structure is regarded as pivotal for design of the process model structure file. Existing work in this area is regarded as promising, but there is a need to consider issues beyond the construction of basic model repositories.

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