DEVELOPMENT OF A SPATIALLY BASED DECISION-MAKING CONSTRUCT WITH APPLICATION TO RURAL LAND MANAGEMENT.

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Introduction

The main aim of this paper is to present the stages involved in the development of a spatially based decision making construct that has application to rural land management. The primary focus being the discussion and analysis of the main limitations associated with modelling the features on the surface of the earth using computer-assisted techniques.

The nature of spatial modelling

For this research project the many forms of modelling were considered and a sequence of modelling tasks, suitable for spatial modelling, were identified. These were:

The conceptual model - where the real world system is defined
The data model - consisting of the framework for the storage of the data
The logical model - for the determination of the processing steps for the data
The analytical model - dealing with the mathematical manipulation of the data
The cartographic model - for the graphical representation of the model of the earth
The cognitive model - the users interpretation of the cartographic model

It was acknowledged that there is never just one problem, neither is there just one solution when modelling the complex physical world. The modelling project needs to have a clearly defined purpose and the limitations in the data need to be acknowledged.

The more specific the outcomes from the model, the narrower will be its application. It may be possible to successfully model only one component of a physical system while the structure and interactions in the rest of the system remain undefined.

Modelling the features on the surface of the earth requires that a sample of features is selected and processed in the model. The data processing is designed to recreate aspects of our physical world. The limitations in the data must be taken into account before the user can utilise the model effectively. The limitations in the data can be discovered by investigating issues related to the data error, uncertainty, precision and accuracy.

Data error, uncertainty, precision and accuracy

There is a need to view a problem from a number of different perspective's. The reason being that our learning effects not only how we see a problem but also what we see in a problem. For this reason alone it is best to define a problem after discussion occurs among experts from related disciplines that are associated with a particular land management issue. The modeller is then required to make decisions in relation to assumptions, inclusions, sampling, uncertainty, allowable error levels, precision and accuracy in the context of the problem definition. It is then the responsibility of the modeller to provide an appropriate spatial model of the real world situation. The appropriateness of the model is influenced by the quality of the spatial data used in the modelling.

There are many issues relating to data quality. Some of the issues are:

1. The age of the data
2. The season the data was collected
3. The configuration of the data
4. The intermittent nature of data availability
5. The presence of irrelevant data
6. Undetected random errors
7. Unresolved systematic errors
8. Differences in data format
9. Incomplete sets of data
10. A lack of detail on nature of the data (no metadata)
11. Inappropriate precision or accuracy of the data
12. Excess data points that require removal.
13. When the amount of data exceeds the storage capacity of the computer
14. A lack of calibration of the data
15. When data are already pre-processed (eg. data transformed to Transverse Mercator map projection)
16. When the data medium is out of date (eg. 9 track CCT)
17. If the data storage medium is not compatible/accessible by the computer system

18. If a data origin shift, rotation or scaling is required
19. When data lacks topology
20. Lack of geographical reference
21. If the sampling method is unknown or inappropriate for the type of analysis
22. If there is a lack of suitable independent data for validation of the results of the modelling.
23. Copyright restrictions
24. The initial cost of the data
25. When inappropriate data generalisation occurs
26. When data required by the model is not available

Data stored in a spatial database is often stripped of its map scale information and hence unsuitable data combinations may be generated. Output products should be plotted at, or smaller than, the scale of compilation of the most generalised data. The user often overlooks this fact. This need becomes self evident when field data are combined with secondary digitised data. And finally conclusions from an analysis at one scale may not match conclusions from an analysis at another scale.

A digital spatial database, if developed as a general-purpose database, provides the user with a system that must be moulded to suit a specific purpose. If a user adds knowledge related to a specific topic (for example, land use) and delineates a specific study area, then this knowledge and project area definition create a knowledge domain. The cognitive input from an expert or group of experts is necessary if quality outcomes are to come from a study that relies heavily on the modelling of digital data. The knowledge domain allows a subset of the original database to be defined that is relevant to a specific problem. In the rural context the knowledge domain is built around the specific rural mapping task which is to be undertaken.

Rural case study

A rural case study was used for this study to illustrate many of the issues identified in the theory. There were issues associated with the case studies conceptualisation, data quality and limitations in the outcomes. The case study showed quite clearly that there is a need to have some structured way of identifying the data that is required for a project and also some way of identifying the limitations that should be placed on the use of digital spatial data.

The develop of a spatially based decision making construct

The proposed decision making construct would be made available to inform the user as to the capability of using a digital spatial database for a particular rural land mapping task.

The general concepts, underlying the development of the proposed decision making construct used for digital spatial database capability assessment, relate to the characteristics of a typical user of a digital spatial database and the need that exists for expert knowledge to be used as one of the inputs into a model. Data layer availability along with the quality of the data on the layer is considered. Data standards provide a means of systematically analysing the characteristics of the spatial data. Standards that defined a spatial data transfer standard, land use codes and metadata elements, were identified. It was noted that if data is built to a standard then it easier to compare databases or data layer quality and therefore ascertain its fitness for use.

The conceptual model

The main outcome from the research is a database capability model that assesses the suitability of a database for a specific rural mapping task.

In practice the model (***See Figure 1***) is designed to analyse an existing database **(1)** that a member of the rural community intends using for a chosen rural mapping task **(2)**. The layers and features on each layer of the database under investigation are compared with a list of the required layers and features for a specific rural mapping task to determine any mismatch. The database is given one of five capability grades from most suitable to most unsuitable **(3)**. Once the initial grading is established, further interrogation of the database is undertaken to determine the quality of the database by analysing any metadata associated with the database **(4)**. A final assessment of the database capability is then provided as a report to the user **(5)**.

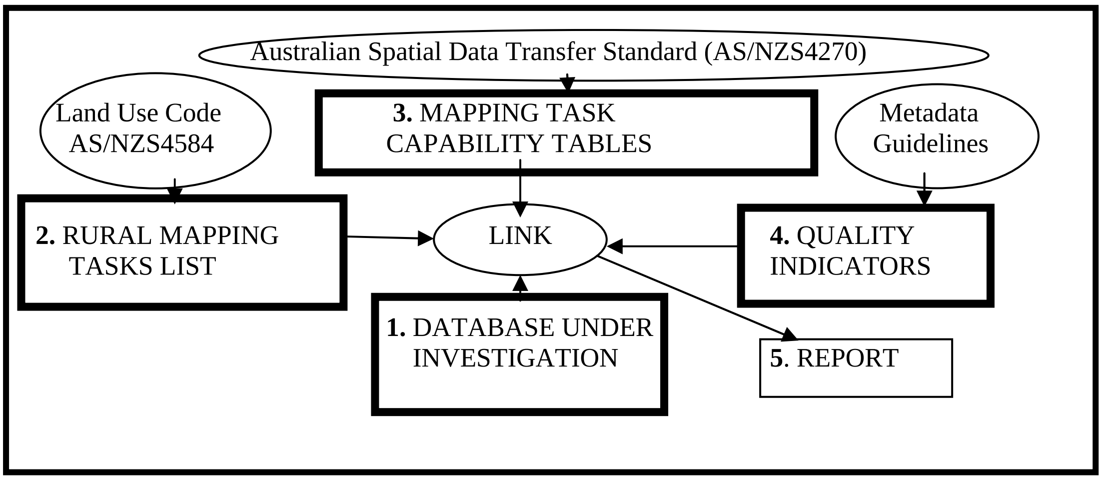

Figure 1 Spatial Database Capability Model components

The list of rural mapping themes is a central part of the model. This list provides a simple point of entry for the user to the capability model. Once the rural mapping theme, along with study area definitions, is entered into the computer, the capability model retrieves a computer file that contains specific requirements for the mapping task. The specific requirements relate to the data layers and features that are needed for mapping at one of four specified map scales. The requirements have been defined by a group of land management experts who specialise in this particular aspect of the rural environment. Identification of specific requirements is required for every rural mapping task in the list.

The model also establishes a link between the established requirements of any spatial database when applied to a specific mapping task and the database under investigation. This allows a comparison to be made between the required data layers and features, and the available data layers and features. This satisfies one part of the capability assessment. The database under investigation can now be given one of five capability grades from "most suitable" through to "most unsuitable".

The capability model also considers the essential nature of the data layer for the mapping task, with each layer being tagged with an attribute that indicates whether it is essential, desirable, valuable, suitable or useful. If an essential data layer is not present then this will mean that the database would be given a lower capability grade that if the data layer was only considered useful.

If all the required layers were present in the database then to this point the database would be given the highest capability grading but the capability model must also determine the capability of the database based on the data quality. To achieve this the metadata associated with each data layer is interrogated.

The final capability class that the database is placed into is determined from the capability grades based on the availability of the required data and on the quality of the data ***(See figure 2).***

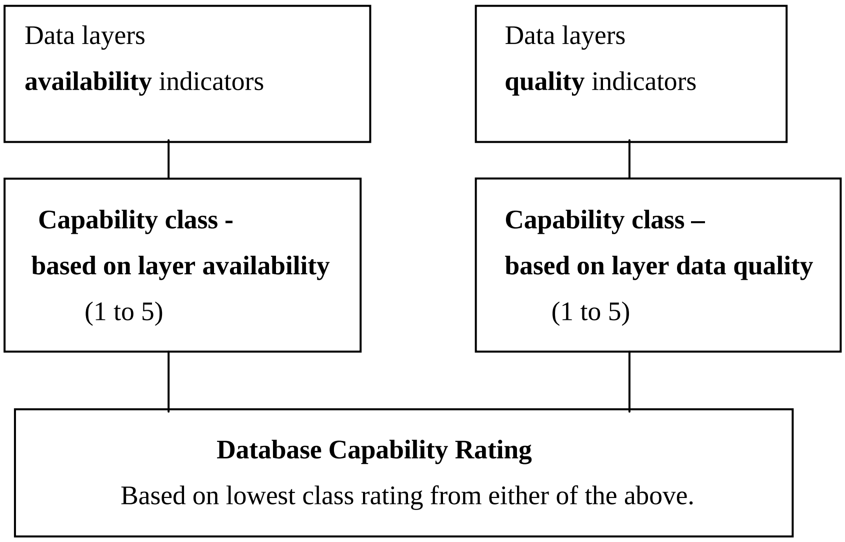

Figure 2 Components of the database capability rating determination

The spatial database capability model is designed to be equipped with controls and "intelligence" so that inappropriate use of the model is minimised. The database capability assessment is built around cartographic theory that acts as a guard against inappropriate output being created.

A spatial data directory can be interrogated to determine whether there exists suitable data that could be added and that would improve the capability of the existing database.

The spatial database capability model aims to control the level of decision making for which an output product may be used and provides one way of addressing the issue that a lot of the data collected, relating to the physical condition of natural resources, lacks comparability and uniformity.

Concluding comments

The paper gives a brief outline of a research project that addressed the following questions:
What are the stages involved in modelling geographical reality and how are they linked?
What effect does each stage of the modelling process have on the representation of the features on the surface of the earth?
What are the limitations inherent in each stage of the modelling process?
How can the user be made aware of the limits of a digital spatial database?

The primary outcome from the research is a conceptual model. The model outlines how a user of a digital spatial database can be provided with information that allows them to understand some of the uncertainty, errors, precision and accuracy issues associated with the use of a database for a particular rural mapping task. The main output from the model is a report that states the capability class that a digital spatial database has been placed into. It also outlines the reason why this class has been allocated to the database.

The theoretical study associated with this research identified many issues relating to the identification of errors and uncertainties in digital spatial databases. The author considers that the main issues have been accounted for in the conceptual model. The conceptual model that would form the basis of a fully interactive production model.