A NEW METHOD OF BUILDING GIS APPLICATION MODEL BASED ON GRAPHICAL VARIABLES

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ABSTRACT

Geographic information system (GIS) has become a very important tool used to implement the integration of complex application system and to complete various complex graphic processing. In general, GIS application is mainly relevant to a lot of complex graphic processing, so that how to develop an effective method to fast build GIS application model with the help of the graphic processing ability for guiding GIS application system implementation has been being a challenge problem in GIS application and research area. In the paper, we present a new method for the design and implementation of a graphic-oriented GIS application model. This method is based on a new design principle of GIS application model, which uses a graphic variable to construct various complex GIS application model. The model makes use of GIS graphic processing functions, graphic variable properties and relationships among those variables to implement the design of complex application system. Otherwise, we discuss also a typical example for showing how to construct a practical GIS application system based on graphic variable, which was used to implement scientific management of stored grain. Finally, this paper discusses the general method for designing graphic variable model and some key techniques.

1. INTRODUCTION

Geographic information systems(GIS) are computer-based systems designed to store, analyze and display spatially referenced data(ESRI,1994) and have emerged as an useful tool for natural and other resource management. Thus, the most important feature of GIS is its excellent ability to process, store analyze the spatial information. Otherwise, GIS is usually used as a general tool or framework for integrating many other commercial software packages to build more complex and efficient application systems. However, how to use these GIS functions to design and build a successful and satisfactory GIS application system model becomes one key of successful GIS application system construction in most cases. Unfortunately, most of existent methods for building GIS application models are mainly based on a numeric analysis method where data analysis model in one dimension space is used as 2D or 3D space model, so that the difference between model design space and its operation or implementation space makes it much difficult to efficiently use advantages of GIS information processing in 2D or 3D space. Thus, the quality or performance of GIS application system implemented by the model based on traditional numeric method is usually unsatisfactory in most of more complex applications, which affects directly GIS application extent and increases total expenses of the system design, construction and management. In fact, the most important reason for using 1D rather than 2D or 3D method for building GIS application model is because of the lack of an efficient method directly based on graphic variable analysis in 2D or 3D space for designing and building the application model or system in the above situations. However, our recent research shown that, really, graphical variables in 2D or 3D space can be reasonably defined to construct one new method that not only is directly used for describing GIS application task and designing its GIS application model, but also overcomes many disadvantages of the traditional numeric method and obtains a very satisfactory success in some typical GIS applications. Those successes show that the shift from numeric model toward graphical variable model is a profound. Further, some major steps of the method application are as follows: scooping of an application development project, in which the project area, requirement and relevant graphical variables are defined by the application plan objective, based on the GIS application system user requirement and graphical variable operation rules; collecting data relevant to graphical variables in the application field, in which these data must be represented as graphical variable form or transformed into the form by the method for generating graphical variables; developing, evaluating and selecting all important logical relationships between the graphical variables, in which the relationships are used to build basic framework of GIS application model; integrating the relationships and the data relevant to graphical variables, in which final GIS application model is built; refining this model and improving its performance. In this paper, we discuss general principle of the new method, key techniques used to implement GIS application system based on the graphical variable model and a typical application example about the implementation of advanced management system of stored grain as well as some other relevant problems.

2. GENERAL PRINCIPLE

In general, this new method for designing GIS application model based on graphical variable has three important features such as generality, precision and reality. The fist of these features is that this method suits to various applications and GIS development environments, in which the applications can be much better described and modeled by graphical variables other than numeric method in GIS environments. Really, this method provides also an excellent environment for object-oriented (OO) system development due to using graphic variables(better objects). Further, the object-oriented paradigm offers a better approach and is viewed as a major improvement towards expressing a problem domain in a comprehensible fashion and in engineering a system that is reusable and extensible. The second is the better precision of this model information processing than that of numeric model in complex GIS applications. The last is very lower expenses of this model development and maintenance and practically easier implementation of GIS application systems based on this model than that of numeric model. The general method for building graphical variable model used to support design and implementation of GIS application system is shown in Fig. 1, which describes mainly 8 key modules

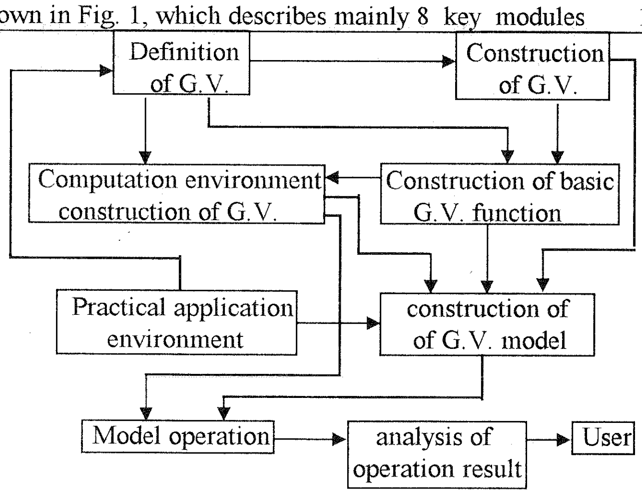

Fig.1 general Method for Constructing G.V. model

and relationships among them. Their major tasks or functions can be briefly discussed as follows.

--Practical application environment module: A formal method in it is used to describe some key features about practical application which can be further divided into several coverages about graphic processing. Otherwise, the input, output and precision requirement of designed application model are also described.

--Definition of graphical variable: This module makes use of some results from practical application environment module further define various necessary graphical variables for the application with the help of some heuristic rules(Barwise, 1985).

--Computation environment construction of graphical variable: This module selects and constructs suitable computing environment for defined graphical variables relevant to the application and GIS.

--Construction of graphical variable: This module makes use of defined coverages and relevant data further design or build practical normal graphical variables which can be processed in the above computing environment.

--Construction of basic graphical variable function: This module provides a basic set of graphic variable operation rules for the construction and makes use of the application requirement and the defined graphical variables further design or build various graphical variable functions with the help of the basic set of operation rules(Graver, 1977).

--Construction of graphical variable model: This module contains a basic set of model construction rules, and makes use of the application requirement, the defined graphical variables, the built graphical variable functions and the logical relationship among them further design or build the final application model based on graphical variable with the help of the model construction rules.

--Model operation: This module is responsible for providing the operation environment based on GIS computing environment about graphic processing for the final graphical variable application model with the help of a programming language provided by GIS(ESRI, 1990).

--Analysis of operation result: This module which contains several software packages is mainly used to further explain a number of operation results from the above module in order to provide as better as possible various services for users of the application system based on the graphical variable model.

3. KEY IMPLEMENTATION TECHNIQUES

One of most important problems about the key implementation techniques is how to create a satisfactory computing environment used to support the operation of graphical variable model on commercial GIS with the help of its Macro language(ESRI, 1989). Thus, a layered architecture model can be used to describe the relationship between GIS environment and various graphical variable processing and to guide the implementation of graphical variable computation, which is shown in Fig. 2. In the

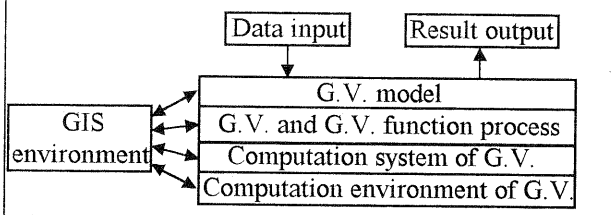

Fig.2 Implementation of G.V. Computation

model, the processing about graphical variables is divided into four logical layers. Each layer performs a related subset of the functions required to support the relevant graphical variable processing. However, it relies on the next lower layer to perform more primitive functions and to conceal details of those functions. Otherwise, it provides services to the next higher layer. Ideally, the layers should be defined so that changes in one layer do not require changes in the other layers. Thus, we have decomposed one complex problem about how to implement graphical variable computing into a number of more manageable subproblems. Our experiences shown that the architecture model under GIS environmental support makes the implementation of graphical variable computation become very simple. In fact, the GIS environment can be used as a real world model or a joining tool in integration of the above modules. The real world model can support very well the OO design(Filman, 1992) and implementation of application model based on graphical variable. Because the OO design does not allow some key modules to communicate directly, all communications must be governed by the real world model of the application domain. The advantage to this approach is that the application model would not be committed to or built around any specific type of modules, making the application model compatible with more application environments. Another important problem is how to generate various graphical variables used to describe the practical problems relevant to GIS application in order to construct the related coverages. A very good method for solving the problem is to apply suitable numeric simulation model for generating the required graphical variables. Otherwise, some images such as remote sensing images can also be used as graphical variables with the help of the suitable processing.

4. APPLICATION EXAMPLE

For showing practical application value and steps of this method, we discuss briefly a typical example relevant to GIS application model that is designed for implementing an optimal management system of stored grain in several geographic areas. The real project resulted in a prototype called 2D-SGMS. The primary consideration of 2D-SGMS design is to allow district level stored grain users to access and use all available relevant data and decision information provided by 2D-SGMS in order to optimally manage all stored grain through graphical variable processing in 2D-SGMS. The 2D-SGMS tasks include management of stored grain temperature(Chang, 1993), moisture(Chang, 1994) content, pest, and relevant physical and chemical control operation. The 2D-SGMS was developed on a PC-based system under the Microsoft windows system using the VISUAL BASIC 4.00, VISUAL C++ 2.0 and GIS packages. ARC/INFO and ARCVIEW(ESRI, 1994) form ESRI are the GIS tool

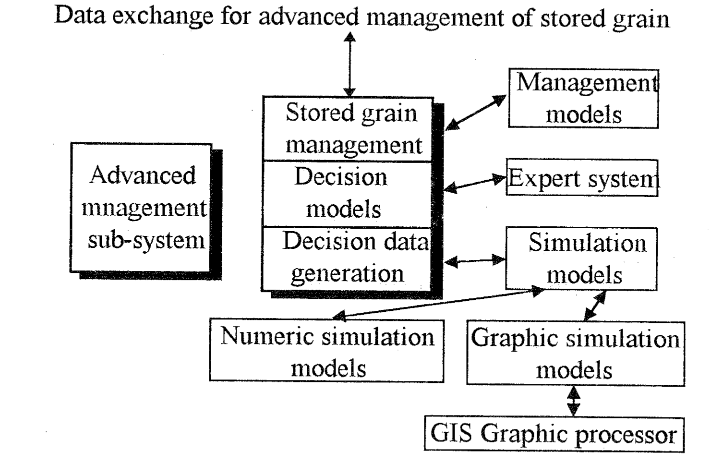

Fig.3 Advanced management sub-system and GIS

currently used in 2D-SGMS for managing and processing the spatial data and graphical variables. Advanced management subsystem of 2D-SGMS is shown in Fig. 3, which is based on an application model of graphical variable. This is a typically layered architecture model. The decision data layer makes mainly use of various simulation models further generate a number of key data that are used by decision models to provide optimal control and management decision for stored grain. Those models can further be divided into two classes such as numeric simulation models(Singh, 1993) and graphical variable simulation models in order to suite different requirements from various different decision models. In fact, the numeric models are very common and support mainly operation of numeric decision models. However, the graphical variable models are used to provide graphical decision data for new graphical variable decision models in the decision layer. The operation of graphical variable simulation model was implemented on GIS processor built from GIS environment with the help of complex operations among various graphical variable coverages from other subsystem. Otherwise, the decision layer consists of a number of basic numeric and graphical variable models to make basic optimal management decisions of stored grain. The management layer is used to define various different integrated management decisions(Chang, 1995) for different stored grain facilities in different geographic areas. Further, in the graphical variable model, a stored grain entity is usually considered as a closed entity, so that the temperature and moisture of the entity are influenced mainly by some factors as follows.

--Stored grain kind,

--Stored grain quality,

--Primary stored grain temperature and moisture,

--Environmental temperature and moisture in stored grain warehouses,

--Aeration equipment and its operation strategies,

--Basic stored grain facilities.

The graphical variable models can reasonably process the above 6 factors through using the graphical variable description and the operation of graphical variable models, and generate the temperature and moisture values of any point in stored grain entity and the related vector curves, in order to implement the precision prediction and control for the temperature and moisture of any point in the entity. When the graphical variable model finds any possible dangerous state in the entity, it takes at once some efficient means to control the state in order to force it to arrive at a normal state.

5. CONCLUSION

The work to develop more efficient graphical variable model to support GIS application will become an important research direction or future challenge in the domain. The work focus will change from the current 2D graphic into 3D space. Many current software tools will provide the powerful supports for the challenge or objective. However, the future major research works are to solve some key problems that include how to improve the architecture of graphical variable model, how to construct the operation rules used in the architecture, and how to design and implement those rules. On the other hand, when possible, using commercial software, instead of customizing code development, will increase the life of 2D-SGMS, since regular support can be expected from the commercial software product vendors. Prototyping is a strategy in development of GIS application system based on graphical variable model, by which a scaled-down system or portion of a system is constructed in a relatively short portion of time, tested, and improved through numerous iterations. Ultimately, the usefulness of such GIS application systems, and our ability to construct them, is limited not by computer technology but by our knowledge of the system dynamics and the effect of management practices upon them. It is that a model's dynamics may depend more on the manner in which its elements are described and linked(i.e., its connection topology) than on the form of its equation and subsystems. Thus, our new method based on graphical variables for designing GIS application system provides a very satisfactory answer to the above problems. Research results for the application example indicate that this new method has also many other advantages such as simple model construction process, easy correctness verification, management and maintenance of the model and easy integration with other software packages such as expert systems, machine learning systems, large database systems and special simulation systems. In summary, our successful experiences had shown that our current work and outcomes related to the research of graphical variable model provided a satisfactory ground and open a wider research domain for the future development of the model.

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