DESIGN OF AGRICULTURAL DISASTER EVALUATION SYSTEM BASED ON GIS, SIMULATION AND EXPERT-SYSTEM TECHNIQUES

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ABSTRACT

The agricultural industry is more complex, dynamic, and competitive. Agricultural disaster evaluation system(ADES) has become an important tool and technology in modern agricultural production. However, how to design such system has been being a very important and complex problem with the help of advanced information processing techniques such as GIS, simulation and expert system. In this paper, we present a new method for the design and implementation of ADES. this method is based on a new layered architecture model which is used to design and implement complex ADES. The model integrated reasonably GIS, simulation models and expert system in ADES and simplified its design and implementation. Otherwise, an excellent commercial GIS environment was used as a tool for the integration. ADES provides a number of important information and decisions for senior managers of agricultural production as well as plays a very important role in the production. Finally, we discuss a typical application of ADES in dangerous weather disaster warning of stored grain management.

1. INTRODUCTION

Today, the agricultural industry is more complex, dynamic and competitive. Many factors such as biology, weather, disaster, economics and market influence interactively this business(Liang, 1986). In recent years, Agricultural Disaster Evaluation System(ADES) has been being widely researched and fast developed, in which it not only is playing a more important role, but also has become a very important tool of production management in modern agricultural production. However, how to reasonably apply various existent information processing techniques for designing and implementing excellent performance ADES has been a very important and interesting problem in field of agricultural production management. Unfortunately, ADES design and implementation is also a very complex and difficult problem for most of agricultural applications. Major reason resulting in the situation is that ADES must process a lot of information relevant to agricultural disasters(especially including some random or undetermined information) and provide precise decision information for ADES users. Otherwise, another reason includes that the work to build ADES model for implementing satisfactory ADES is also very difficult. Thus, the number of existent ADES' not only is much limited, but those ADES function, quality and performance are usually unsatisfactory in many applications of agricultural disaster evaluation. However, our research on ADES shown that a new effective method for designing and implementing ADES that satisfies the performance required by user can be used to solve the above problems and overcome the relevant difficulties. Further, the new method provides really an approach to building excellent performance ADES model. Then, the model supports fast and reasonable implementation of ADES.

In this paper, we present this new method of building ADES model or ADES. This method includes three key information processing techniques such as geographic information system(GIS), simulation and expert system(ES) techniques. Really, they are also the most important techniques for implementing excellent performance ADES. The ADES based on this method not only makes use of advantages of those techniques as more as possible, but also has much better performance and more users than existent ADES.

2. ADES ARCHITECTURE MODEL

One of the most important tasks to design ADES is carefully to determine its various function parts and to build the logical relationship between those parts, so that those parts and relationship are used to construct ADES architecture model. However, in practical applications, ADES involves decision-making based on complex interactions between people, pests, lands, crops, natural disasters, and other natural resources relevant to agricultural disasters. Modeling these interactions and representing them in ADES for supporting decision have presented difficulties in its design and implementation when traditional design methods were used. Thus, during ADES design, a layered architecture model that includes both seven layers and relevant functions is used to guide the ADES design and implementation. Further, the ADES described in this paper utilizes a layered model of architecture which involves the seven different layers shown in Fig .1. The model is in practice a widely accepted structuring technique. The functions of ADES are partitioned into a vertical set of layers. Each layer performs a related subset of the functions required to exchange information with another similar system which has the architecture. On the other hand, the ability to exchange information can flexibly support the large size of distributed ADES design and implementation on a network environment. A layer relies on the next lower layer to perform more primitive functions and to conceal details of those functions. 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 construct ADES into a number of more manageable subproblems. The task of our research team was to define a set of layers and the services performed by each layer in order to make the design and implementation of ADES become more simple and easy. Further, the partitioning should group functions logically, should have enough layers to make each layer manageably small, but should not have so many layers that the processing overhead imposed by the collection of layer burdensome. Thus, we define carefully all functions of ADES according to the practical application requirements about ADES. Further, we discuss briefly each of the layer and the architecture model implementation.

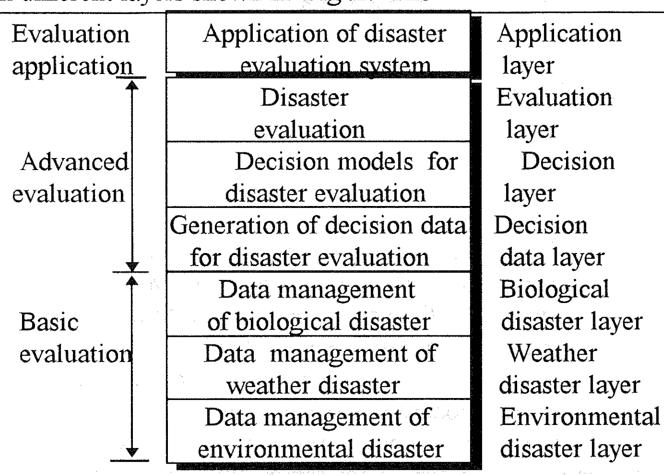

Fig.1 Layer model of Agricultural Disaster Evaluation System

3. ADES ARCHITECTURE IMPLEMENTATION

The environmental disaster layer(first layer) provides the mechanism for managing the environmental data about various disaster, which include mainly a number of natural disasters about flood, land, pollution and other natural factors about geographic environment. The second layer(weather disaster layer) attempts to make use of the services from the first layer and provides the means to mange the data about various weather disasters. The basic service of the biological disaster layer(the third layer) is to provide the management for data of biological disasters. The purpose of layer 4 (decision data layer) is to provide a mechanism to generate various data to support the decision and evaluation about agricultural disasters. The layer complexity depends on the type of service it can get from layer 3. The decision layer provides a mechanism for making various decisions for agricultural disaster evaluation with the help of a number of decision and evaluation models. The evaluation layer is concerned with the integrated evaluation decisions for a number of special groups of agricultural disasters. Its purpose is mainly to define various standard application-oriented evaluation decisions. Finally, the application layer which is relevant to ADES application provides a means for various users or application processes to access ADES. This layer contains management functions about the applications and some useful mechanisms to support local and remote applications. According to the description of various layers of the architecture model, ADES architecture model implementation can be divided into three subsystems. The first is basic evaluation subsystem shown in Fig 2, which encompasses the model's layers 1,

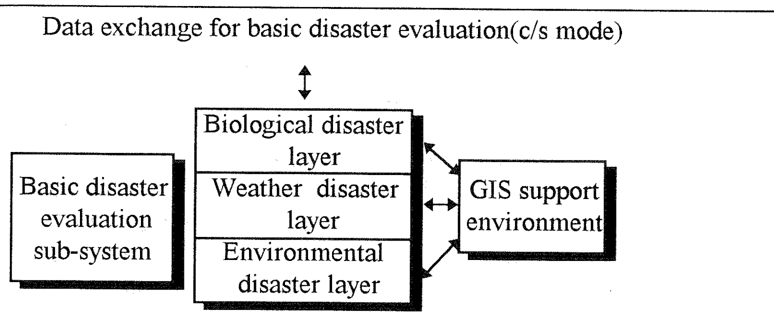

Fig.2 Relation between basic disaster evaluation sub-system and GIS

2 and 3. The subsystem is primarily intended to provide the "raw" evaluation service of agricultural disasters which is directly used by an end user and does not support further decisions based on raw evaluation. Two main components such as GIS support environment and Data base management system support its major operations. The second is advanced evaluation subsystem

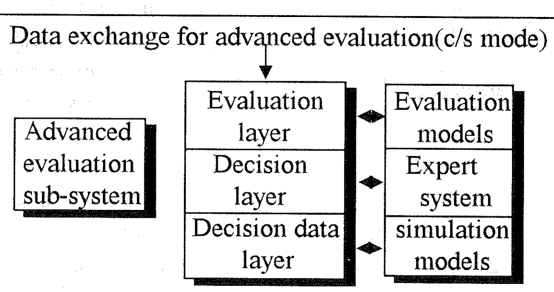

Fig.3 Advanced evaluation sub-system

show in Fig. 3, which is used to perform an analysis of basic evaluation data from the first subsystem and to recommend the best basic evaluation decisions or strategies for disaster evaluation application subsystem. The decision and evaluation a models, expert system(Davis, 1989), and simulation models are used support its major operation. The simulation models(Law, 1991) generate a complete data for each basic evaluation decision of the expert system. In general, the expert system is capable of integrating the knowledge of several disciplines about ADES evaluation into a single knowledge base system to support decisions about the evaluation(Coulson, 1987). The properly developed expert system(Edwards, 1991) is a powerful tool for providing managers or users of ADES with the day-to-day decision support need to evaluate various agricultural disasters and to make the relevant decisions. The evaluation models in the subsystem are some object-oriented programs(Booch, 1991) designed to analyze alternatives over both numeric and non-numeric evaluation criteria. According to various different application requirement, those programs form the final recommendation for the best disaster evaluation decision with an user's preferences and perceptions about the set of evaluation decisions. The third is disaster evaluation application subsystem shown in Fig. 4, which provides a means for application processes or users to access ADES. It is composed of three classes of models: local application models to handle various services for local users, remote application models to provide various services for remote users, and models for testing system functions, which provide for the testing of ADES components and assist in fault isolation and identification.

4. GIS INTEGRATION

The above subsystems can be regarded as collections of tools or methods that serve a special role in ADES. Thus, we can use a real world model based on GIS(ESRI, 1989, 1990) as the joining tool in ADES integration. However, our research shown that ESRI ARCVIEW 2.1(ESRI, 1994a) provides a very satisfactory GIS framework for the integration. The object-oriented model of ADES based on the above architecture and ARCVIEW 2.1 is shown in Fig. 5. The OO design does not allow subsystems to communicate directly(Folse, 1990). All communication is governed by the real world model or ARCVIEW 2.1 kernel. The advantage to this approach was that ADES would not be committed to or built around any specific type of subsystem, making ADES compatible with more

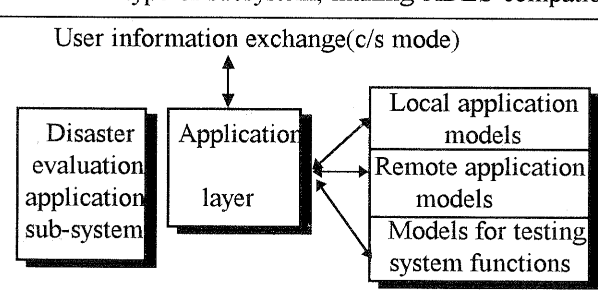

Fig.4 Disaster evaluation application sub-system

application environments (Henderson, 1990). In practical ADES implementation, the Microsoft's VISUAL BASIC 4.00 and VISUAL C++ 2.00 as well as ESRI's AVENUE(ESRI, 1994b) were used to implement the object-orient implementation model in ARCVIEW environment. Especially, a number of scripts were developed by AVENUE as a tool to complete complex integration, which make the design and implementation

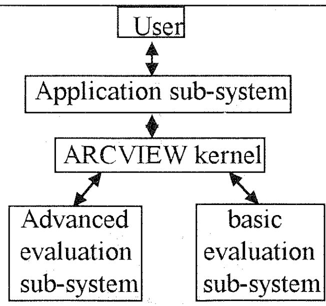

Fig.5 Interconnection of sub-systems

of some complex user interfaces become very simple. This integration process in shown in Fig. 6. A typical example of ADES application is to evaluate the influence

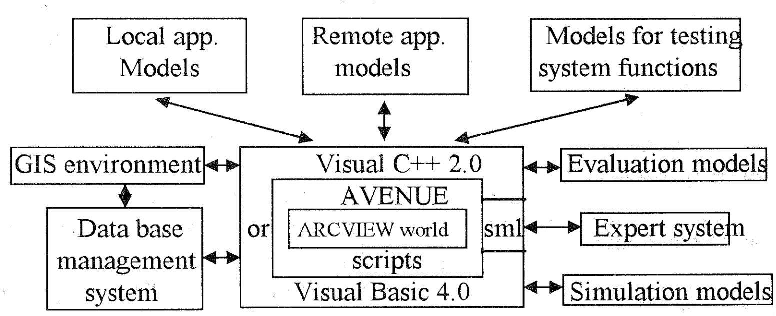

Fig.6 O-O model for system integration

of disaster weather on stored grain, so as to apply suitable means to improve dangerous stored grain environment to safety environment. Our experiences shown that the practical application of ADES reduces largely stored grain loss due to some disaster weather, which is equal to increase the grain yield. Further, the evaluation results from ADES are used to make or design various effective control strategies to maintain a very good ambient environment of a number of warehouses of stored grain distributed over a very large geographic area with the help of the remote models of ADES. For arriving at the objective, ADES used 10 years of weather data to evaluate various possible influence of current disaster weather on stored grain and provided satisfactory evaluation services for a number of managers of stored grain.

5. DISCUSSION

In summary, during ADES design and implementation, the object-oriented method that includes both analysis and design stages was used to build ADES implementation, integrate all its components such as classes and objects and implement it. The object-oriented analysis is a process of defining a model of some portion of the real agricultural disaster world in a manner that retains the representation of this world as viewed by those users who will use ADES. This analysis produces also a static model of the world's objects and relationships, plus a dynamic model showing activities that occur within and between these objects. Otherwise, the design process is used to organize objects into classes of a hierarchical structure, and defining associations, methods, data structures, and the user-ADES interface. In ADES, GIS has been used as major tool for natural resource management related to agricultural disasters. The GIS is also the most important module of ADES and is used as basic framework of overall ADES implementation. Further, major tasks of the module include the various ADES I/O and inter-ADES information processing and the information exchange (or communication) among GIS, simulation expert system modules. On the other hand, simulation module built by continuous and discrete simulation models is used to mainly generate a lot of data about agricultural disaster and process determent information relevant to agricultural disaster evaluation, including historical disaster, agricultural production planning, disaster geographic distribution and disaster type's information. The module uses a pseudo-random number generator to incorporate the disasters and losses risk faced by farmers or users of ADES, and provides them with numeric form of decision information with the help of other ADES function. Stochastic occurrence and influence of the disaster about crops and areas are draw at random each year from empirical probability distributions for these variables. Obviously, simulation technique here is mainly used for analyzing explicit relation between various variables relevant to the disasters and computing their values. Otherwise, expert system module is designed by the knowledge shop method. In this method, each component of the module is controlled by an independently running program. A rule-base manager is used for organizing the loading and execution of rule-base in the module. The rule-base consists of three components that are heuristic knowledge rules, computation rules and I/O protocol rules. Besides the heuristic knowledge rules, rule-base contains a set of rules to compute the combined weights of contributing factor relevant to the decision information of agricultural disaster evaluation. The module uses information from simulation module, GIS and data base system for reasoning and provides suggestion and decision information to GIS module. Generally, expert system technique here is mainly used for analyzing implicit relation between various variables effecting agricultural disaster evaluation and providing non-numeric decision information with ADES. Our experience shown that a rule-based expert system is really a useful approach in organizing relevant heuristic knowledge and analytic information for ADES. The major contribution of the study is in integration of GIS, simulation and expert system techniques with a layered architecture model for agricultural disaster evaluation.

6. ACKNOWLEDGMENTS

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