MVA'90 IAPR Workshop on Machine Vision Applications Nov. 28-30,1990, Tokyo

GEOGRAPHICAL FEATURE ANALYSIS USING AN INTEGRATED GRAPHIC INFORMATION PROCESSING SYSTEM

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ABSTRACT

For the effective use of a graphic information processing system, information-integration capabilities are important. Here, the information-integration is defined as an interactive execution of simulation tasks and a database management task. This concept as well as its practical methods are explained in this paper by the introduction of a geographical information system (GIS). The GIS consists of a database subsystem and application subsystems. The database subsystem executes a database management task, which systematically handles multimedia data including the analyzed results obtained by each application subsystem. The application subsystems execute simulation tasks of various geographical feature analyses using topographical map data stored in the database. The aim of information-integration is to extract new information by the "generation-and-aggregation" method using the above subsystems. As a preliminary experiment, a land route design is explained. The proposed method will be essential for advanced graphic information processing systems in the future.

INTRODUCTION

With the recent progress in graphic information processing technologies, a variety of geographical information systems (GIS) has been developed to date [1]-[3]. Many of these systems, however, seem to lack or be weak in sophisticated information-integration capabilities. One example of information-integration capabilities in the GIS is the effective storing of results from geographic feature analyses, which are executed using topographical map data, into a database in a well-structured form. These accumulated results can then be searched for, and new data can be obtained by simulations using the searched data. Then, the obtained new data are stored in the database. These procedures are repeated and new data are aggregated. The concept of this information-integration is important, especially when the utilization of large-scale data and the utilization of highly complicated information processing methods are intended.

In this paper, a GIS that can effectively perform this information-integration function is proposed. First, the concept of information-integration is introduced. Then, the basic structure and the elements of this GIS with the above information-integration capability are explained. Finally, the interactive use of a database subsystem and application subsystems is explained for route design as an example, by stressing the basic process of information-integration.

CONCEPT OF INFORMATION-INTEGRATION

Information-integration can be defined as an interactive execution of simulation tasks and a database management task. Execution of both tasks without the interaction limits their abilities. The simulation tasks can, in general, generate new information. However, it is almost impossible to store the results effectively, because these tasks are not usually facilitated to store the obtained data into the database. On the contrary, the database management task can store the data in a well-structured database. However, it is impossible to generate information, because the database is nothing more than a vessel for data registration. Therefore, the information-integration must be of a "generation-and-aggregation" type. "Generation" means to obtain non-trivial new information from information already obtained. "Aggregation" means to group the results of analyses.

The concept of information-integration is depicted schematically in FIG. 1 (a). In general, the information-integration procedures in the case of the GIS are as follows.

<u>Step1</u>: Several data are searched for from the database.

<u>Step2</u>: New data are generated by the execution of simulation functions.

<u>Step3</u>: Obtained new data are stored into the database. These data are aggregated with the data already stored and are utilized as the preceding data next time.

FIG 1 (b) is an example of information-integration for the route design. The detailed procedures for this example are explained in a later section.

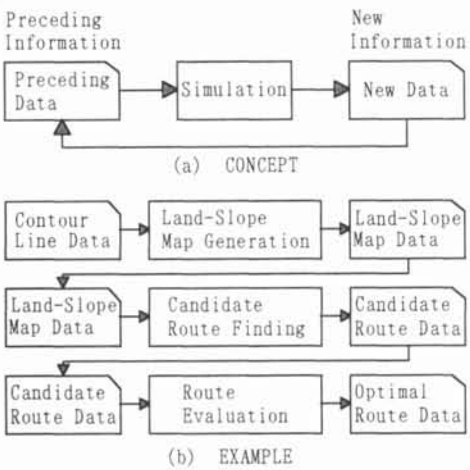


FIG. 1 BASIC ASPECT OF INFORMATION-INTEGRATION

BASIC STRUCTURE OF THE SYSTEM

In the GIS, simulation functions for various geographical feature analyses will be necessary and will be added into the application subsystems. Therefore, the application subsystems and the database subsystem must be separated physically and connected via an interface. The basic system structure of GIS is depicted in FIG. 2. The database subsystem manages data in its own format. However, the application subsystems usually manage data in various inherent formats. Thus, the interface must transform the data formats automatically. This basic configuration is based on the principle of data independence [4]. Characteristics necessary for information-integration in each subsystem are described in the following sections.

Database subsystem

The features of the database subsystem in the GIS are :

(1) to handle multimedia data [5],

(2) to manage large-scale data, and

(3) to reflect a user-defined conceptual design of the world.

The multimedia data include texts, figures, voices, images and relation-logic descriptors. Among the figures are contour lines, rivers, roads, symbols and so forth. Among the Images are still-pictures, movies, DTM (<u>D</u>igital <u>T</u>errain <u>M</u>odel) data and so forth. Each multimedia data can be managed not only in a separated manner but also in a mixed manner. In the mixed manner,

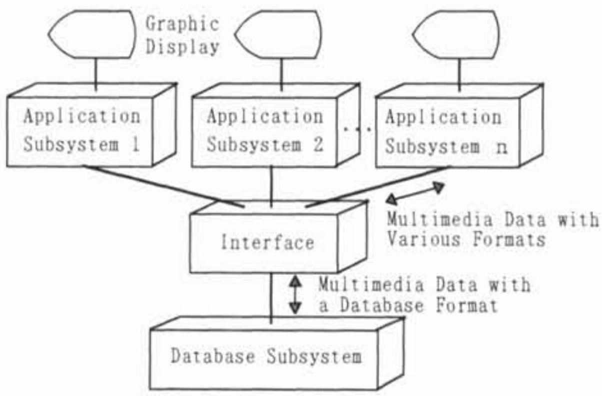


FIG.2 BASIC SYSTEM STRUCTURE

several types of multimedia data are merged as if they were just one data. Relation-logic descriptors are abstract data that do not have any display-forms, but define relations with other data. A data link model is depicted in FIG. 3, where (a) shows the relations among data. Objects and attributes can be any of the following : texts, figures, voices, images and their combination. They are linked either directly or indirectly to each other via relation-logic descriptors. A direct link forms a one-to-one relation and an indirect link forms a many-to-many relation. FIG 3s. (b) and (c) respectively show how to link data directly and indirectly. As for the link structure, it would be ideal if data could be linked to one another in a random manner; of course, a random network could be constructed by adequately using relation-logic descriptors. In this case, however, it seems to be difficult to manipulate the data and to maintain the consistency of the data structure, especially when the handling of large-scale data is required. Consequently, the regularity of the entire link structure is preferable from a practical viewpoint, and the link structure in which data are linked hierarchically is one advantageous structure.

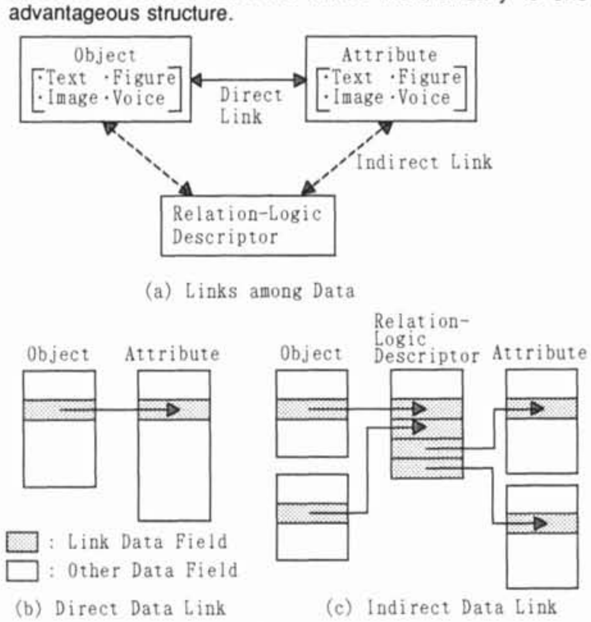


FIG.3 DATA LINK MODEL

The data link structure limitation is determined by the model of the world defined by the user. FIG. 4 shows one example of a link structure using a graph representation. The world is organized by "objects", "concepts", and "relations". Objects and concepts are represented by nodes, and relations are represented by lines. The objects are displayed on a screen as line drawings, symbols, pictures and so forth. These objects are classified into two types. One is called "independent objects" (IOBs). The IOBs (e.g. Lake Michigan) can exist in the database, even if they do not have links to any other data. The other is called "attribute objects" (AOBs). The AOBs are classified into two types. One is called "dependent objects" (DOBs) and the other is called "conceptional objects" (COBs). The DOBs (e.g. size of lake) are dependent on the IOB, and the COBs (e.g. the aerial photograph of the Great Lakes) are dependent on the concept (e.g. the Great Lakes). As opposed to the objects, the concepts themselves are not usually displayed on the screen. This is because they have the same format as the relation-logic descriptors. The concepts are the data that manage relations defined among IOBs. The relations are the links among data. These relations are defined between an IOB and DOBs, between a concept and IOBs, and between a concept and COBs. There exist several integrity restrictions among objects, concepts and relations. These restrictions are determined according to user-defined rules on how to construct the world.

The data stored in this database possess links, which represent relations between them to other data. The data have fields, called link fields, for storing relation names. These relation names are designated by the user. When new data with the same relation name as an existing group are to be stored in the database, the system automatically binds them to this existing group regardless of their data type. When a new relation name is assigned, the system creates a new group and adds a new link structure to the data. Thus, the data can be accumulated in the database systematically and successively.

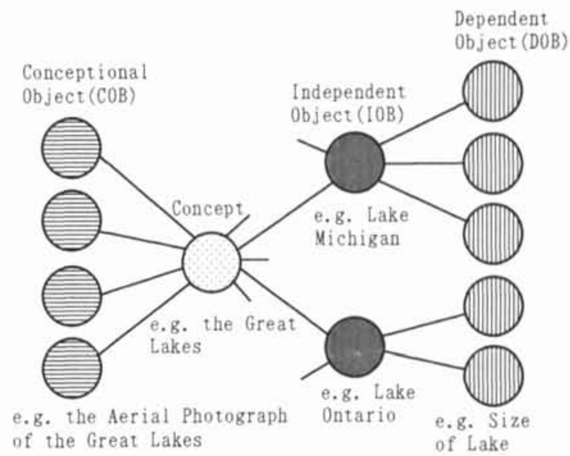


FIG.4 WORLD REPRESENTATION BY OBJECTS, CONCEPTS AND RELATIONS

Application subsystem

The characteristics of the application subsystems are :

(1) abundance of functions, and

(2) automatic execution through the use of skillful recognition functions.

As for item (1), application subsystems in the GIS have to execute the geographical feature analyses, which include the generation of :

* cross-sectional images,
* visual-range maps,
* 3D bird's-eye views, and
* land-slope maps.

These various analysis functions are required in order to obtain new views from various angles. These analyses can be effectively and accurately executed, using coordinate sequences of topographical map data. These analyses can also be executed by using mesh data. However, in this case, to obtain highly accurate results, it is necessary to prepare a large amount of mesh data whose mesh size is small enough, and thus, to develop effective handling methods.

There are several procedures to obtain coordinate sequence data from paper maps. The automatic method utilizing the drawing-recognition techniques [6] is an important one, and is explained here briefly. First, topographical maps are scanned optoelectronically with scanners, and stable and precise image data are obtained. Then, line segments in the images are detected as vector data. In this case, a sophisticated vector-detection algorithm traces the image of the line drawings. During the vector-detection procedure, the coordinate-detection algorithm finds the node positions of each line, and calculates their coordinates. The obtained coordinates are then stored in the figure data table successively, thus forming vector data. Next, these stored vectors are structured by inputting additional attributes such as a color code. Each contour line is given with its height value. The structure-addition algorithm is executed effectively by the cooperation of computer and user, rather than by fully automatic procedures.

As an example of the analysis using coordinate data, the algorithm for the cross-sectional image generation of a terrain is explained.

Step1: A line is automatically designated or manually drawn onto the screen.

Step2: Segments of contour lines, which intersect the designated line, are searched for from the figure data table. If intersected contour lines are obtained, their height information is selected from the contour line data. The pairs of height information and distance from the start point of the line to the intersection are stored in the analysis result table in the form of coordinate data. The process of searching for the intersecting contour lines is continued until the end point of the line is reached.

Step3: The cross-sectional image is displayed on the screen by transferring data stored in the analysis result data table to the display memory.

Other geographical features, such as visual-range maps, are calculated by applying the above algorithm repetitively.

As for item (2), new results are usually produced through the use of several results already obtained by the application subsystems. In this case, automatic recognition functions of the properties of the obtained data, such as the detection function of lower slope area in a land-slope map, are required for route finding. Actually, to manually indicate these properties is arduous work.

If the processing speed is a primary concern, a special data structure will be necessary for high speed data search. The structure called QND (Quasi N-Dimensional table) [7] is one such structure that exhibits high speed search. Here, it was reported that the searching process using the QND method is executed about 200 times faster than the process using an exhaustive search method. Other notable aspects of the QND method are described in the reference [7].

INFORMATION-INTEGRATION PROCEDURES

By the effective combination of a database subsystem and application subsystems, a conspicuous integrated GIS can be realized. Here, a preliminary experiment applied to a route design is explained. This experiment may, however, include the essence of information-integration capabilities. FIG. 5 shows steps for this route design. The steps are explained in the following.

Step1: Pre-analyses

The land-slope maps are generated by calculating the distances to neighboring contour line data.

Step2: Finding candidates

When searching for the route, there are usually many constraints to be met. Namely, the route must be such that :

- the distance of the route is nearly minimum,
- the slope of the route is less than a designated value,
- the cost of the route construction is almost minimum,
- the sceneries from the route are excellent.

There may be many alternative routes that satisfy the above constraints. After the candidate routes are obtained, these data are stored as IOBs into the database.

Step3: Detailed analysis

The system calculates the cross-sectional images along the designated route data, displays the results, and stores them as DOBs of IOBs (i.e. candidate routes) into the database. After the cross-sectional image generation, the user selects a command for symbol generation and puts symbols on a screen by indicating their positions. Positions of these symbols indicate the base points for the subsequent calculation of a visual-range map or a 3D bird's-eye view on the screen. The system stores these symbols as IOBs and automatically creates the concept that relates the candidate route data with symbol data. The user further selects commands for visual-range map

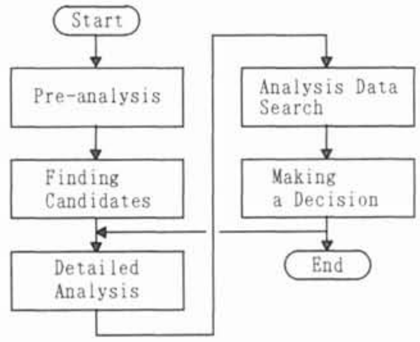


FIG. 5 INFORMATION-INTEGRATION PROCEDURES

generation and 3D bird's-eye view generation. The system then calculates these maps and views, and stores the results as DOBs of IOBs (i.e. symbols). Thus, results are stored into the database every time the simulations are executed.

Step4: Analysis Data Search

If several data are necessary to estimate and select the best route, application systems send commands of a data search to the database subsystem. Namely, when the user makes a decision for optimal route selection, the commands of the search for candidate routes, cross-sectional image, symbols relating to the candidate routes, visual-range maps, 3D bird's-eye views and so forth, are sent sequentially to the database subsystem. Then, the database subsystem searches for the required data from the database by finding the links among data.

Step5: Making a decision

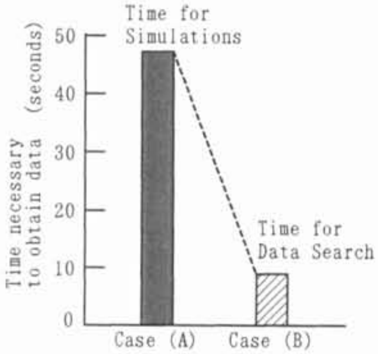
The user makes a decision and selects the best route using the above evaluation results. If necessary, further simulations are executed to improve the quality of the decision. After the decision-making, newly obtained data can also be stored into the database as COBs of the concept, which relates the candidate route data and symbol data.

FIG. 6 shows the entire results of the analyses displayed on the screen. The cross-sectional images are calculated along two candidate routes. The 3D bird's-eye view and the visual-range map are also calculated for the eye positions, each of which is represented by a symbol. The checkerboard-like pattern represents the land-slope map indicating steepness of the areas by gray-scale codes. Within this pattern, two alternatives (i.e. "Branch 1" and "Branch 2") of "Route 2" are indicated. The evaluation of each route is written in the text area. In this experiment, both the simulations of geographical feature analyses and the database handling are executed automatically. Thus, the interactive use of simulation subsystems and a database management subsystem are successfully confirmed. In this experiment, the candidate routes detection and the evaluation of the route in the application subsystems are carried out by manual operation. The next step is to generate and estimate the route automatically. For example, by adding a terrain navigation function with automatic geometric reasoning capabilities to the application subsystems, automatic optimal route finding will become feasible.

FIG. 7 shows an example of information-integration effect in the above route design experiment, and the time necessary to obtain data are compared. Case (A) corresponds to the utilization of a system without information-integration capabilities. Case (B) corresponds to the utilization of a system with information-integration capabilities. This graph shows that, if the database subsystem and application subsystems are not combined, lengthy simulations must be repeated to obtain data, thus resulting in an inefficient GIS system. However, if both subsystems are integrated, the data already obtained can be searched for from the database and can be re-used. Thus, the total speed can be much faster than the case of repetitive simulation execution.

CONCLUSIONS

A geographic information system (GIS) based on the concept of information-integration is proposed. The important feature of



Case (A) : Without Information-Integration
Case (B) : With Information-Integration

FIG. 7 EXAMPLE OF INFORMATION-INTEGRATION EFFECT (IN THE CASE OF ROUTE DESIGN)

the information-integration function is its generation-and-aggregation type strategy. This information-integration function is summarized as follows.
(1) Several data are obtained by the geographical feature analyses. These data are usually multimedia type and are stored in the database according to a user-defined link structure.
(2) To obtain new information, the necessary information are searched for from the database and new information is effectively obtained from the searched information through simulations. The obtained data can also be stored in the database.

In the experiment of route design, the concept of information-integration is explained as well as the methods that embody this concept. Furthermore, in the experiment, interactive execution of both a database task and plural application tasks is performed and the effectiveness of the information-integration strategy is confirmed. This concept is essential for and must be common in future systems, especially when large scale data and highly complicated information processing methods are to be utilized.

ACKNOWLEDGMENTS

The authors are grateful to Dr. Yoshito Tsunoda and Dr. Shigeo Nagashima of Hitachi Central Research Laboratory, and to Mr. Hitoshi Fushimi, Mr. Masayasu Katoh and Mr. Yoshizoh Itoh of Hitachi Omika Works, for their encouragement and cooperation during the course of the study.

REFERENCES

[1] H.Ebner, R.Hossler, and R.Wurlander : "Integration of an Efficient DTM Program Package into Geographical Information Systems", Proc. of the Symp. on Cartographic and Database Applications of Photogrammetry and Remote Sensing, Commission IV, Vol.28, No.4, pp.116-121, 1990, Tsukuba, Japan.
[2] G.Schreiev, W.Knoepfle, H.Cranbner, and H.Schumacher : "A Large Scale Database for Digital Elevation Models", ibid, pp.129-136.
[3] K.Cheng, and M.Idesawa : "A Simplified Conversion Method of Contour Line Surface", Proc. of the 1st Int. Symp. for Science of Form, pp.224-236, 1989, Tsukuba, Japan.
[4] S.Uemura : "Element of Database System" (in Japanese), Ohm Co. Ltd., 1979.
[5] Y.Masunaga : "Multimedia Database Management System" (in Japanese), Information Processing, Vol.28, No.6, pp.671-684, 1987.
[6] M.Ejiri, S.Kakumoto, T.Miyatake, S.Shimada, and K.Iwamura: "Automatic Recognition of Engineering Drawings and Maps", in Image Analysis Applications, edited by R.Kasturi, M.Trivedi, Marcel Dekker Inc., 1990.
[7] S.Kakumoto, K.Iwamura, and Y.Emura : "High Speed Analysis Method of Geographical Information Using a Quasi N-Dimensional Table", Proc. of the 4th Int. Symp. on Spatial Data Handling, Vol.2, pp.941-950, 1990, Zurich, Switzerland.

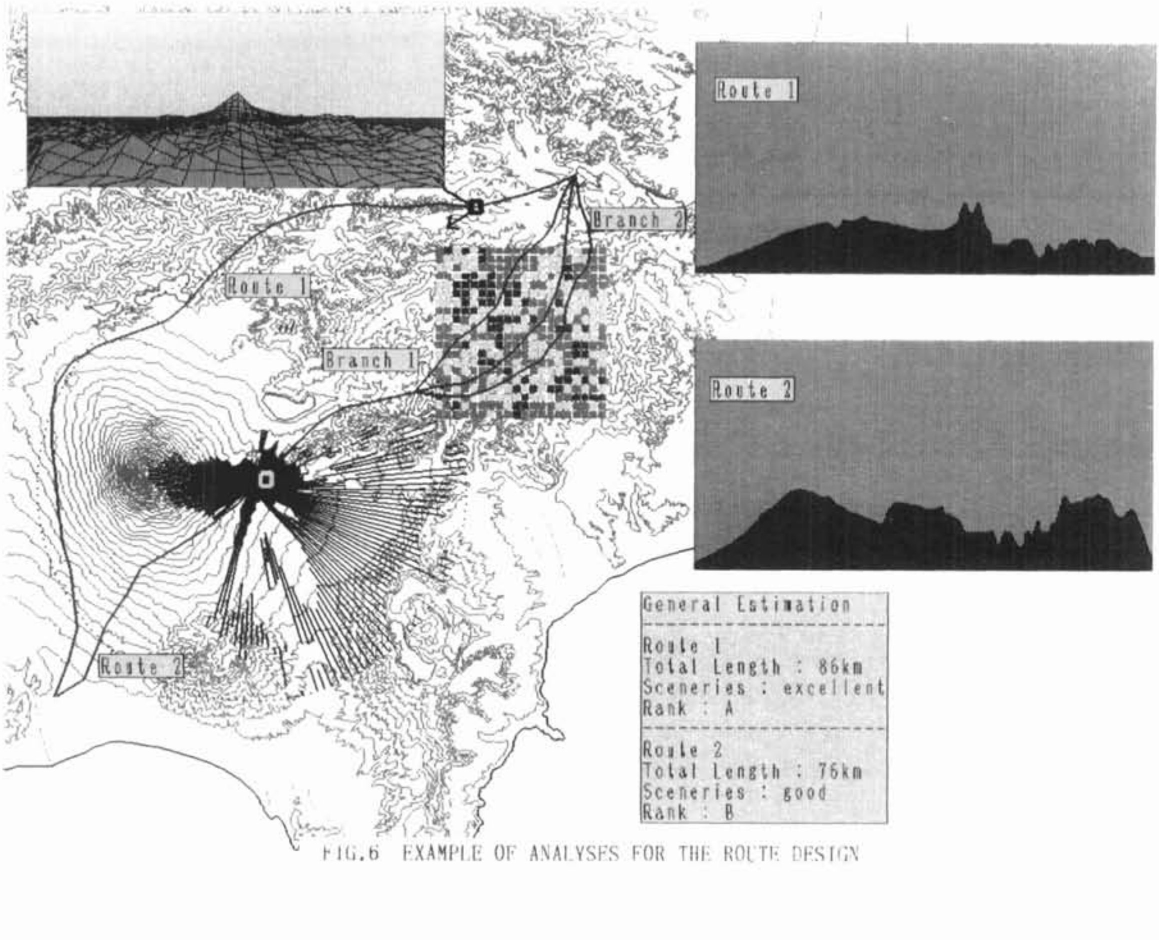


FIG. 6 EXAMPLE OF ANALYSES FOR THE ROUTE DESIGN