Establishment of the Spatial Information Infrastructure for the Scientific and Research Park in Kyushu University, Japan

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Abstract: The distributed spatial information system has been proposed as one of infrastructures for the development as a scientific research park in Kyushu University, Japan. The system is based on an autonomously-distributed database model with the geographical information system (GIS) technology. The GIS node, which is an important element of the system, is composed of spatial data storage, Web-based GIS, and a clearing-house. It makes it possible to share spatial data and promote campus-wide cooperation with scientist communities. In Kyushu University, the applications on this system have started based on the New Campus master plan 2001.

1. Introduction

A geographic information system (GIS) has recently attracted great attention. It is the system to capture, store, check, integrate, manipulate, analyze, and display data, which are spatially referenced to the Earth. The spatial data consist of the basic information of social, economic and cultural activity etc. The GIS technology is recognized as an important tool for the advanced information society of the 21st century. Using GIS makes it possible to process the great amount of spatial information dramatically fast and clarify various kinds of phenomenon. In addition, compared with manual works (mostly paper works), the objectivity, transparency and accuracy of the process will increase, and total cost including time and labor can greatly decrease. It is broadly adopted from national to organizational level, therefore.

The GIS technology was adopted mainly for constructing databases to automate traditional businesses in the past. Unfortunately, some of them were unsuccessful due to their poor system environments, which were unable to deal with problems, such as project-aid and risk-management etc. Lack of GIS standards also has made it difficult to integrate the GIS technology with an organization's other information systems, and sharing GIS data with scientist communities consumed much of their time and energy. To make an active use of the GIS, it is necessary to build the development environment for the cooperation and task-resolution with sharing and dispatching spatial data made by various disciplines.

In this paper, we propose the distributed spatial database system to establish a spatial information infrastructure strategically for the development of Kyushu University as a research park for the basis of environmental symbiosis and deconcentrate city planning. The system, which supports the Open GIS Consortium's open interface specifications for global use, will promote advanced utilization and campus-wide cooperation with information systems made by scientists with different discipline background.

2. Why does Kyushu University need GIS?

The master plan of innovations in Kyushu University, published in 1995, has declared, "independently innovations in accordance with the changes in the times to maintain our vitality, and establish an open research university" and "the vigorous adoption of the advanced information technology with a new conception, dispatching our information to the world, making sweeping reforms of educations, and building the electronic campus to operate and administrate the university efficiently". Based on this strategy, the New Campus master plan of the IT (Information Technology) -based research, education and campus administration in Kyushu University has been put forward in 2002.

The information technology, which can break off the distance limitation, has greatly improved the education and research environment on distributed campuses of Kyushu University. Some of departments in the university would make various information systems based on the New Campus master plan. However, there might be no concept about sharing data with scientist communities even if the system is managed by a relational database management system. It is indispensable for development of Kyushu University as a research park to discuss the significance of geographical index, active adoption of GIS, and strategy on how to use GIS in practice. It would clarify that an academic spatial information infrastructure is effective for inter-disciplinary, industrial-education, and international cooperation.

Our proposed system, which is quiet flexible for change of the university environment, has compatibility with other information systems, and advantage in problems such as project-aid, risk-management, and decision-making etc.

3. Development of the distributed spatial information system in Kyushu University

3.1 Characteristics of the proposed system

The proposed system is based on an autonomously-distributed database model with GIS technology. A distributed database system can be defined as a collection of multiple, logically interrelated database distributed over a computer network (Özsu & Valuriez, 1999). It is not a system where, despite the existence of a network, the database resides at only one node of the network. The data should be distributed among a number of sites (Figure 1). The each site is constructed as a spatial relational database, or related logically to a GIS portal site. A relational model of database can be characterized by relational data structures of two-dimensional tables, data consistency, and the set-oriented manipulation of relations. While, the GIS technology allows including geographical data (points, lines, and area) in the system, and each tuple of the relation is uniquely identified by the spatial index.

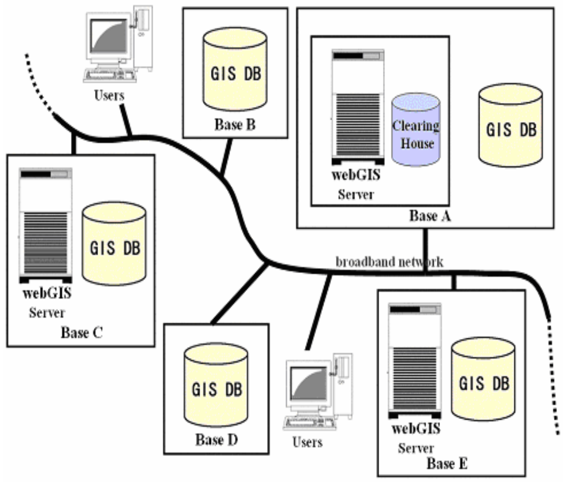

Fig. 1 Autonomously-distributed spatial database concept

One of our motivations behind the establish of this system is the desire to integrate the operational spatial data in Kyushu University and to provide centralized, thus controlled access to that data. The data sorted by spatial index can be easily overlaid on other spatial information without standardization efforts related to the key of a relation among a number of database sites.

A database information system is generally characterized with respect to the autonomy of local systems, its distribution, and its heterogeneity. The autonomy refers to distribution of control, while the distribution means locations of data. The heterogeneity indicates diversity of systems.

The developed system has the following characteristics.

(1) Autonomy

There are a lot of databases, which are connected physically to each other through a computer network, in Kyushu University. Some of them are constructed as information systems, like faculty, facility, and museum databases etc. The others, which might be majority, exist in personal computers, such as research tables, figures, and documents. The concept of the developed system is to integrate these databases, which are managed independently by each department or researcher. The data independence allows user applications to access the latest data constantly, and reduces damages due to failures of the computer network or the site.

(2) Distribution

The system is composed of databases and GIS platforms distributed through the computer network. Each database is connected logically or replicated fragmentally to a GIS node in the campus. It promises transparent management of distributed spatial data and reliability through distributed transaction. The transparent management is supported in the level of the database management system (DBMS). Distributed transactions execute at a lot of sites at which they access the local database. User applications can access a single logical image of the database and rely on distributed DBMS. They have no need to be concerned with coordinating their accesses to individual local databases or to worry about the possibility of site or communication link failures during the execution of their transactions. In a distributed environment, it is also easier and more economical to accommodate increasing database sizes. The expansion can be just handled by adding processing and storage power to the network.

(3) Heterogeneity

The heterogeneity dimension is generally referred to difference in computer hardware and network protocols. However, the proposed system is able to deal with geospatial information. The databases of Kyushu University have various types of data; 2-dementional tables, documents, maps, pictures and figures. The node GIS can correlate no-spatial data (documents, tables, etc.) with a spatial index, and share them as spatial information.

3.2 System Structure of the GIS node

The GIS node is composed of spatial data storages, web-based GIS, and a clearing-house (Fig. 2). It is constructed on campus LAN (KITE: Kyushu University Integrated Information Transmission Environment), which enables sharing of spatial data with another node. The shared spatial data are mainly commercial base maps and original thematic maps. These data are stored in the spatial data storage server. The system of data storage would be subject to amount of data and kind of GIS software, and would be managed by a database management system (DBMS: e.g.

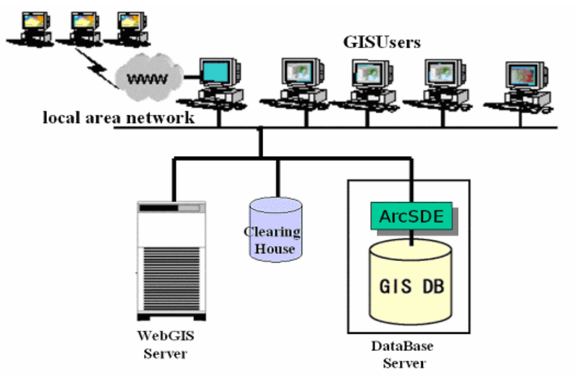

Fig. 2 System structure.

MS-Access, Oracle with ESRI ArcSDE, and PostgreSQL with PostGIS etc.).

The web-based GIS server, which consists of web server and web-based GIS software, can transmit the spatial data through Internet. A user can view the spatial data on a web browser even if they have no expensive GIS client software. The GIS software and web-based GIS, which support the Open GIS Consortium's open interface specifications, should be used. This makes it possible to share the spatial data with various GIS platforms.

The clearing-house server has metadata about identification, quality, organization, reference, entity, attribute, and distribution of the spatial data. Metadata makes search of sharing data possible. A user can get information about necessary spatial data from this server.

Our GIS node uses Oracle with ESRI ArcSDE as data storage, ESRI ArcIMS as web-based GIS, ESRI ArcGIS as GIS client software. Our laboratory has contracted with ESRI Co., United States for the special satellite license, so GIS software (ESRI ArcGIS) can be supplied cheaply in Kyushu University. The software can deal with various spatial data, and occupy a globally big market share. The clearing-house server uses the search engine proposed by the Center of Spatial Information Science (CSIS) at the University of Tokyo.

3.3 Operation of the GIS node

The GIS is originally based on synthesis of digital data, which are developed and provided by several organizations. It is very critical to set up the environment, in which scientists can easily share the data. However, it is difficult to share the spatial data with a different system because most of GIS software companies have developed the GIS software and data specifics uniquely and privately, so far. Our proposed system can provide the infrastructure needed to support sharing of data by scientists with different discipline background.

At first, a user accesses the clearing-house server (Fig. 3) and puts information (e.g. location, contents) about spatial data into a query form. This operation makes the user view metadata. The metadata show a location of the spatial data. Then, the user is able to obtain the data from the storage server shown in metadata. If the data are transmitted on a web-based GIS server, the user is allowed GIS operations on line (Fig. 4). The major GIS software (e.g. ArcGIS, SIS etc.) can take the spatial data through web-based GIS, and even without GIS software, the user can have the basic GIS operations (to zoom in, to zoom out, to move, to measure distance, to search under some conditions, buffering, and to show and close a layer) on a web browser.

Table 1 shows the spatial data prepared in our spatial database server to share with scientist communities. They are sorted by various terms (scale, area, coordinate system, and date etc.), and mainly digital maps of Geographical Survey Institute, which can be used in the wide fields from natural environment to social economy. Metadata of all data are also registered in the clearing-house server.

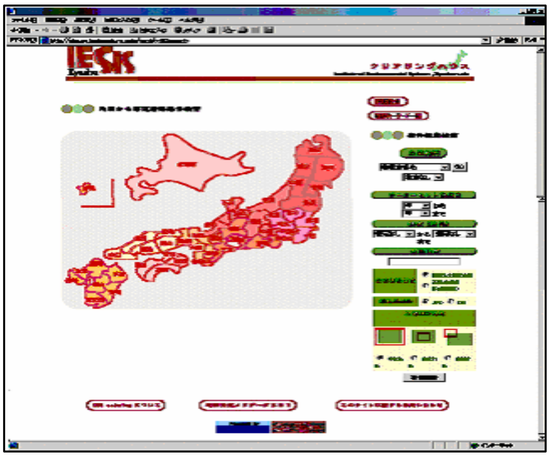

Fig. 3 Image of clearing house.

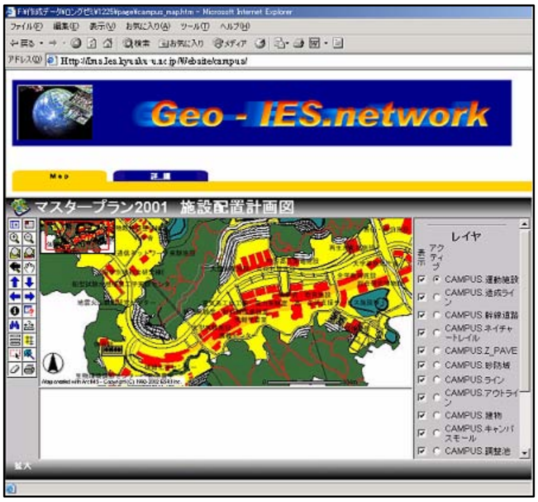

Fig. 4 Web-based GIS of new campus.

3.4 Security of the GIS node

The proposed system should be physically distributed in Kyushu University. Most of databases are not always connected with others, but some of them are integrated logically when the need arises. Because the database sites are managed by each department, securities of their data are dependent on their system. The GIS node has to care the only own data.

The users, which are supposed to use this system, are divided into tow types. One is a web user, and the other is a GIS user. The former, who has no GIS software, can browse open spatial data by a GIS viewer application, such as a HTML viewer of ESRI ArcIMS. The later, who has GIS software, can access spatial data service on Internet, such as web map service and web feature service. Some of GIS users can access spatial database servers with authorization. They can input and modify spatial data in database servers.

4. Applications on the distributed spatial information system in Kyushu University

4.1 Database of the New Campus

The Facility Management system (FM), which will use GIS and CAD data, is currently planned in Kyushu University. The flexible infrastructure, which can respond to the autonomous change of the university in the future and its peculiarity, is required in respects of the management, the education, and the research.

Based on the New Campus master plan in Kyushu University, various kinds of campus planning are executed with diverse investigations inside and outside the university. Since the planning began in 1990, a lot of data are

Table 1 Contents of spatial database.

Scale	Area	Scale	Date of data creation	Data name
Large (- 1/ 5000)	Fukuoka city			New Daikei Map
	Fukuoka city	1/ 1500	2001	Tel-Map
	Maebaru city	1/ 1500	2001	Tel-Map
	Shima town	1/ 1500	2001	Tel-Map
	Fukuoka city	1/ 2500	10/ 07/ 02	ME-MAP
	Itoshima Islands	1/ 2500	11/ 27/ 02	ME-MAP
	Kagoshima prefecture	1/ 2500	08/ 01/ 99	Digital map 2500 (Kagoshima)
	Okinawa prefecture	1/ 2500	08/ 01/ 99	Digital map 2500 (Okinawa)
Middle (- 1/ 50000)	Fukuoka prefecture	1/ 25000	01/ 01/ 01	Digital map 25000 (Administration line)
	Fukuoka prefecture	1/ 25000	01/ 01/ 01	Digital map 25000 (Map image)
	Fukuoka prefecture	1/ 25000	06/ 22/ 05	PDM
	Japan	-	07/ 01/ 97	Digital map 250 m mesh (Elevation)
Small (1/ 200000 -)	Fukuoka prefecture	1/ 200000	06/ 01/ 02	Digital map 200000 (Sea. Administaraion line)
	Fukuoka prefecture	1/ 200000	06/ 01/ 02	Digital map 200000 (Map image)
	West Japan	-	06/ 01/ 00	Digital map 50 m mesh (Elevation)
Aeria photograph				Aeria photograph

accumulating, such as maps, figures, forms, and documents. The transparency, fairness and opening of the information are also becoming very important. However, the format, scale, and media of the data are varicolored. The digital data have to be managed using a standard method to share easily with researcher communities. It should be useful for the general maintenance, the countermeasure against emergence conditions, and the decision-making of the New Campus in the future.

Our proposed system has been, therefore, installed for organization and management of the enormous data related to the New Campus planning. Based on "the Kyushu University New Campus master plan 2001" and "the basic design of Faculty of Engineering area in 2002", the data concerning the New Campus have been organized and stored in a spatial database. The details of them are shown as follows:

(1) The land use planning in the new campus

Altitude maps before and after development, development-planning maps (the first, the second, the third, and the final planning), a zoning map

(2) The equipment arrangement planning in the new campus

A map of building arrangement, land use maps (active land, slopes, erosion control barriers, farms, balancing reservoirs, sanctuary green space), traffic maps (campus malls, nature trails, a main road in construction area, a route of the bus, a route of car, a route of bike, future traffic planning), a map of sports facility, a parking map, a map of main equipment arrangement

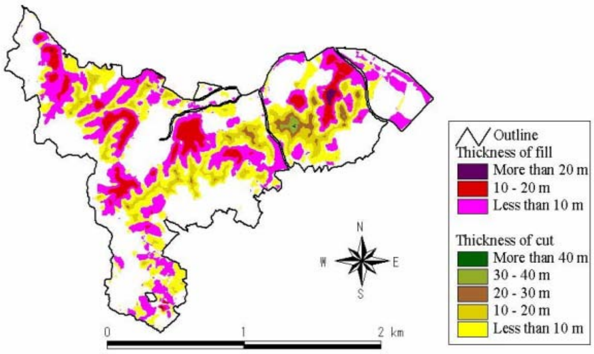

Fig. 5 Land cutting and filling condition in new campus.

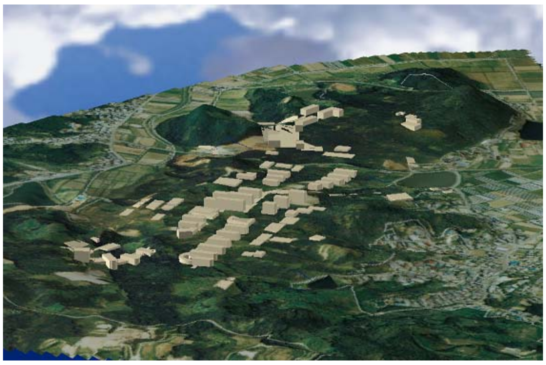

Fig. 6. 3D visualization of the new campus outline.

(3) The natural environment around the new campus

Contour maps before and after development, a map of topography classification, a geological map, a location map of boring, a map of meteorological data (precipitation, temperature, wind direction and velocity, humidity), AMeDAS (Automated Meteorological Data Acquisition System) data, a location map of water survey, groundwater level data, a location map of atmospheric survey, a location map of prospect and landscape, a distribution map of green space, a distribution map of farms, a map of rivers, a location map of storage reservoirs, a map of water system, a location map of dams, a location map of wells, a vegetation map, a map of noise level survey, a distribution map of life

(4) The social environment around the new campus

A boundary map of administration, maps of railway route and railroad station, a map of roads, a distribution map of villages, a distribution map of historic sites, various regulation maps, a map of public facilities

4.2 Applications of the data

All kinds of the data have been modified in a same coordinated system, and they can be displayed easily in GIS through a computer interface at the same time. These data are surely useful. The original data can be translated into new other data (secondary data) using the analytical tools of GIS. The application examples are listed as follows:

(1) Application for the development planning of Faculty of Engineering area

A terrain map is the most fundamental data for the planning of equipment arrangement. The terrain map before and after development are digitalized based on a contour map of 1 m intervals.

As an example of spatial analysis, the change of topography before and after development, in other words, the relationship between cutting and filling ground is shown in Figure 5. The cutting and filling ground condition are clarified by overlapping the contour maps before and after development. If this data is overlapped by other information, such as a geological map, it is also possible to know the ground condition for construction.

Figure 6 shows the 3D scenery of equipments in the New

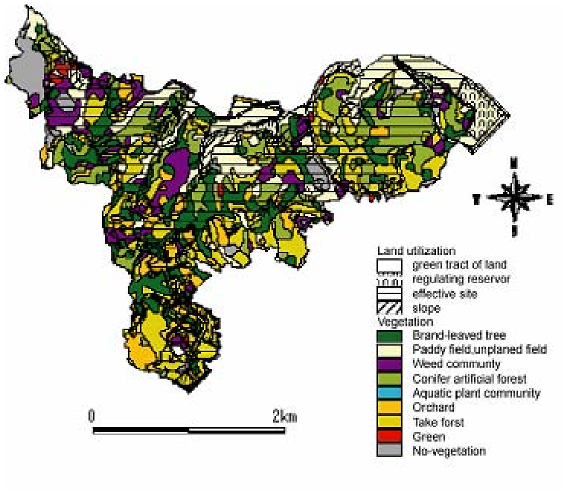

Fig. 7 Vegetation distribution changes.

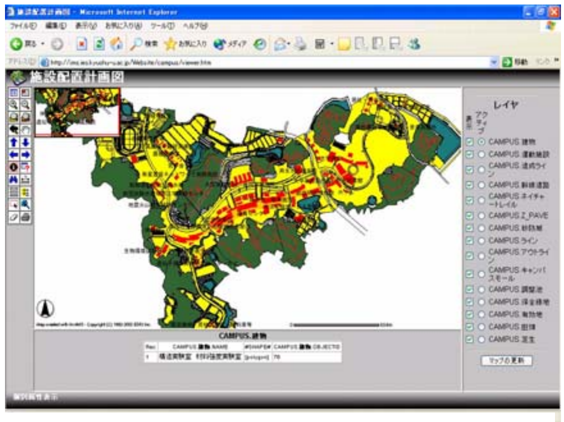

Fig. 8 Example of data open to public through

Campus. Integration of a 3D model with aerial photos or satellite imagery makes it possible to simulate a landscape, and demonstrate the compatibility with surroundings. A visual simulation enables a prompt countermeasure for problems like the revision of the planning etc.

(2) Discussion on an environmental assessment

Using GIS gives a quantitative assessment of an environment, which is very effective for the development planning, environmental conservation, and management of the New Campus. Figure 7 shows the overlay analysis of the land use planning with vegetation. About 64.5% (180.9 ha) of the total area (280.3 ha) has changed due to the development. 27.3 ha of the changed area are assumed as experimental farms, so the vegetation of 153.6 ha disappears actually. The ratios of disappearance in respective kinds of vegetation are calculated as 91.4% in garden and tree plantation fields with 3 in vegetation-authenticity, 86.8 % in aquatic plant communities with 10 in vegetation-authenticity, 83.6% in lowland, dry, and idle fields with 2 in vegetation-authenticity. The disappeared areas of the garden, tree plantation fields, and aquatic plant communities are small although their ratios of disappearance are relatively large. It depends on the initial area. The largest disappeared area is from the lowland, dry, and idle fields (49.3 ha).

(3) An application of spatial data with web-based GIS

The data referred in this paper are all reserved in our proposed autonomously-distributed database system. The data are shared, and presented publicly with the web-based GIS technology, as shown in Figure 8. Not only a specialist who engages in the New Campus master plan, but also a common user including a student, can view the spatial data on a web browser. The transparency, fairness, and opening of the data, then, can be assured. The web-based GIS server allows some GIS operations on the browser. The visualization with web-based GIS is very effective at understanding, and it supplies an environment to use GIS easily.

5. Conclusions

In this study, we have discussed about how Kyushu University should evolve as the digital campus in the future, and proposed the autonomously-distributed spatial information infrastructure system, by which a variety of GIS projects can be in cooperation with each other. We have designed the GIS node, which is an element of the system, and constructed it using commercial software.

The system should be embraced as the new social and intelligence infrastructure by Kyushu University to develop academic activities as an independent corporation with a global view. Generally, the GIS technique is concerned in limited cases and the technical level is still relatively low. It is most important to improve the technical level of instructors to popularize GIS more.

The features of our proposed system are as follows:

(1) The GIS node of this system, which is connected with a computer network, consists of a spatial database, a web-based GIS server, and a clearinghouse. It is easy to customize the GIS node upon request.

(2) Spatial data, which are normalized to a general format and coordinate system, are in situ inputted to the spatial database. The data can be shared with researcher communities. A user can search spatial data from metadata on a clearinghouse, and get them easily.

(3) The web-based GIS server provides the environment that a user can operate the spatial data even without GIS software.

As examples of using this system, some applications of spatial data in the New Campus (the development planning and the environmental assessment) have been demonstrated. If various kinds of GIS projects can be formed, and can cooperate with each other, the establishment of the spatial information infrastructure would develop Kyushu University as a scientific research park.

Reference

M. T. Özsu and P. Valuriez, Principles of distributed database systems 2nd edition, Prentice Hall, 1999.