Standardization of Geographic Information

Junichi KOSEKI
ASIA AIR SURVEY CO. LTD.
2-18, Shinjuku 4 Chome, Shinjuku-ku, Tokyo, Japan.

Abstract

The geographic data has been utilized worldwide with the advance of GIS technology now. In order to prepare interoperable datasets, geographic information is started to standardize in the technical committee 211 (TC211) of the International Organization for Standard (ISO). Therefore each country starts to make the profile of the Standards. In this chapter, basic concept and present condition of Standardization are discussed.

1. Necessity of the Standard

The most important problem to build GIS is prepared geographic dataset to be operated in GIS. The cost to acquire geographic dataset is estimated at 60 or 80 percents. A problem to be solved is to acquire low-cost and high-quality geographic data, however a cost to acquire geographic dataset is high. If dataset acquired once is used many times, the cost per an usage becomes relatively cheaper. Therefore, interoperable geographic dataset with common format is desired to prepare. The table 1 represents some formats of geographic dataset that were prepared by the recent developing studies in Japan International Cooperation Agency (JICA). Various kinds of format are used in GIS of many countries. The format of geographic dataset depends on the GIS applied in the system. We understand that datasets with the same format is needed, because many sets of GIS are already introduced in many countries.

Table 1 List of format to be prepared in the project of JICA

Nation	Format used	GIS applied
Angola	Coverage	ArcInfo, ArcView
Mali	DGN	Micro Station
Mozambique	DGN	Micro Station
Burkina Faso	DGN	Micro Station
Laos	Coverage	ArcInfo, ArcView
El Salvador	Coverage、SHP	ArcInfo, ArcView
Swaziland	DGN	Micro Station
Madagascar	DGN	Micro Station
Azerbaidian	DXF	ArcInfo, ArcView
East Timor	SHP	ArcView
Guatemala	RVC	TNTmips
Gambia	SHP	ArcView
Kazakhstan	TAB	MapInfo
Senegal	GCM、SHP、MIF	GeoConcept
Cambodia	Coverage	ArcInfo, ArcView

Of course, dataset acquired by each system is able to be converted to text files such as DXF by the system and is able to be imported by another system. But, the final datasets on CD-ROM represented by Table 1 may not be read directly and applied by user's GIS. It has to be confirmed in brochures of each GIS that these datasets can be imported in the GIS.

2. The trend of Standardization

In order to acquire interoperable geographic dataset, each country has planned to prepare the common format. The Digital Mapping Format (DM-format) was prepared in Japan for the purpose of making the common format. The SDTS in the United States of America, and the GDF in the United Kingdom were also prepared by the same reason. The SDTS was adopted in Australia, New Zealand and Republic of Korea at a later time. With advancing to apply GIS worldwide, it is difficult to analyze various data with these common formats developed by each country. And the standardization of geographic information to manage interoperable data has come to be required, in order to apply the distributed data management system, which system manages operations to query, relate to, classify, analyze and represent by using dataset stored in different systems separately, instead of using own dataset.

The discussion to make the standard for interoperable data, has started by government, academic and industrial experts in the Technical Committee of ISO.

3. ISO/TC211 Technical Committee: Geographic Information/Geomatics

The technical committee to examine the standardization of geographic information was established in 1994. Now, the Drafts of International Standard is examined by experts of 54 countries represented in Table 2.

The International Standard classified 20 work items, is discussed in 5 working groups. The work items increased 5 items or more later. After discussion and ballot by member's countries, these are coming to be enforced as the International Standard. The summery of work items are expressed as follow.

When we want to use existing geographic dataset to build GIS, we have to judge whether each dataset is usable or not. And we also want to know whether required geographic features are included in the dataset. We can confirm them in the Feature Catalogue (discussed in WI:10 Feature cataloguing methodology) which type of geographic features are included. The dataset should be composed of both data and Metadata (See Table 1). Information of Date of production (WI:8 Temporal schema), location of geographic features (WI:7 Spatial schema), quality of products (WI:13 Quality principles and WI:14 Quality Evaluation Procedures) and data structure of geographic features (WI:9 Rules for application schema) are included in Metadata(WI:15 Metadata).

In addition above information, the definition of location (WI:11 Spatial referencing by coordinates and WI:12 Spatial referencing by geographic identifiers), concepts and elements using in this standard (WI:1 Reference Model), language for definition of concepts(WI:3 Conceptual schema language) and definition of interface to another system which include definition of position exchange (WI:16 Positioning Services), procedures to describe maps (WI:17 Portrayal), Coding for data exchange (WI:18 Encoding) and other services (WI:19 Services).

And terminology for standardization (WI:4 Terminology), procedures and examination to conform to the Standard (WI:5 Conformance and Testing) and overview of overall standard items (WI:2 Overview). Description relating to exchange specifications between many countries (WI:20 Functional standards) and reference to International Standard to make the domestic Standard newly are also discussed in this committee.

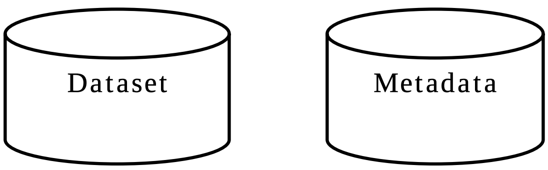

Fig. 1 Configuration of geographic data

We can understand these details of standard items, in order to exchange geographic dataset. The details of 409 items are defined in the Draft of Metadata, International Standard, and these are classified into Mandatory, Option and Conditional.

The international standard prepared in the ISO/TC211 is not unique specifications, that is the rules to make standard in each country and organization. If dataset is acquired based on the profile of the International standard, this dataset is interoperable.

4. Acquisition of geographic dataset up to the Standard

If the interoperable geographic dataset is acquired, the specifications to make interoperable dataset should be specified and the metadata specified details of the dataset should be prepared. During preparation of the geographic dataset, we have to pay attention following issues at least.

1) To use correct terminology.
2) To acquire dataset and a metadata which represent the summery of dataset.
3) To define surveying elements clearly.

Table 2 Examples of Surveying elements

Elements	Examples
Reference ellipsoid	Clarke1880
Plane origin	The origin of Adindan
Vertical origin	The origin of Dakar
Map projection	Universal Transverse Mercator
Size of map	15 ′ x 15 ′

Table 3 Sample of Metadata (part)

Items in metadata		Example	Condition
General information	Title	The national topographic mapping in Kita Area.	Mandatory
	Date of preparation	31.10.2001	Mandatory
	Country	Republic of Mali	Mandatory
	Language	French	Option
	Summary of project	1/50,000national base map	Mandatory
	Area of project	N12 ° ～14 ° 、 W9 ° ～11 °	Mandatory
	Contact point	Geographic Institute in Mali	Option
Lineage	Source of data	Photogrammetry using space images	Option
Information for data	Purpose	General map	Mandatory
	Scale	1/50,000	Mandatory
	Data items	Application rule for map symbols in Mali ↑	Mandatory
	Data structure	Application rule for map symbols in Mali. 2	Mandatory
	Quality	Surveying specifications of 1/50,000 map in Mali. 3	Mandatory
	Encoding	Micro/Station DGN file	Mandatory
Specific information	Survey elements	Separate sheet (ref. Table 4)	Mandatory
	Additional inform.	Separated in sheet 4	Option
Distribution	Distributor	Open to the public Geographic Institute in Mali	Mandatory

↑ Geographic feature catalogue has not been prepared.

2 Application schemata have not been prepared.

3 The procedure for quality evaluation has not been prepared.

4 Rules for numbering system of map have not been represented here.

Recent Trend of Web-Based GIS and Case Examples

Toshikazu Okuyama, Hirokazu Koike, Masanobu Hirano
Pasco Corporation
1-1-2 Higashiyama, Meguro-ku, Tokyo, 153-0043, Japan

Abstract

GIS is initially recognized as important because of its capability to integrate, analyze and visualize geographic information on different themes. Recently, especially in some western countries such as United States , geographic database become rich in types and volume, and more accessible, because these geographic information systems become interconnected with Internet. This unique combination of GIS and Internet will bring us a whole new vision for sharing of data, knowledge, and cooperation of people.

1. Characteristics of GIS and Internet

GIS was initially recognized as an important technology mainly because of its capability to integrate, analyze and visualize various geographic data. In order to serve various purposes such as planning e.g. urban planning, natural resource management, etc., various geographic databases have been developed and used in GIS. Whereas development of the geographic database has been advanced, the Internet becomes more and more accessible and different kinds of GIS have become connected with each other through the Internet. Consequently a new capability of multiple GIS has come to the fore. A unique basic function of GIS, i.e. being able to integrate different types of data, has been interconnected by networks, and as a result, people who previously worked in different fields and different organizations are beginning to communicate with each other on the Internet. This trend is further accelerated by the increase of communication speed of the Internet, improvement of protocol, wider availability of metadata service and dispersed functions of software. Now, GIS is expected to play a further important role in our social life.

In an economical sense, networking of GIS has a dramatic impact. In order to carry out their duties, the central and local governments produced various maps, which were intended to be used only in their respective sections. This occasionally resulted in producing redundant data. Offering geographic data in digital form via Internet connecting different sites plays a significant role in avoiding redundancies.

2. Case Examples of the United States

San Diego County in California has an area of approximately 4,200 square miles with population about 2.5 million. There are 18 cities including San Diego City, which is the sixth largest city in the United States. The County has been witnessing phenomena that surpass administrative units such as expansion of urban function, development of infrastructure and migration of daytime population. Under these circumstances, data production, data application and system development can be more economically carried out by cooperation of the local governments concerned, rather than by respective bodies. Therefore, they agreed on teaming up in a partnership, forming an association and carrying out common tasks such as GIS construction, regional planning, etc. SanGIS and SANDAG (San Diego Association of Governments) are some of these examples.

SanGIS and SANDAG

San Diego County has, so far, developed more than 200 layers of geographic data and been offering various services. Some of these data are available to the people via Internet. SanGIS and SANDAG are two of these sites and their URLs are:
http://www.sangis.org/index.html
http://www.sandag.cog.ca.us/data_services/gis/, respectively.

The services include data provision with or without charge and interactive mapping. For example, in the case of REDI (Regional Development Information System), which was developed to support regional development, data such as railroad, traffic network and traffic volume can be overlaid on the land use, land ownership information or aerial photographs. Conditional retrieval can be also performed. Services that are available in the Web are, in addition to mapping of demographic and economic statistics, Community Services that provide information about police stations, fire departments, schools, local service centers and parks, Disaster Hazard Map that shows inundated districts and geological characteristics, Natural Feature Map that shows vegetation and Utility Map that covers all of the social infrastructure such as water purification plants, water supply and sewerage systems, drainages and roads.

Other sites of San Diego County are ARJIS (http://www.arjis.org/mapping/help/disclaimer.html), which offers the information about crimes and (http://www.bandwidthbay.org/main.htm), which offers the information about the status of optical fiber laying.

These examples show that GIS has been firmly rooted as an information infrastructure in a local society and closely connected with daily life of people.

Besides San Diego County, many other local governments also have Web-based GIS service sites such as http://www.ci.portland.or.us/maps.htm of Portland City in Oregon and http://204.182.239.30/honolulu/ of Honolulu City in Hawaii. Anyone can freely access these sites from any place in the world, retrieve what one wishes from wide rage of geographic data including land use planning, land ownership, disasters, crimes, water supply and sewerage systems, parks, and so on, and produce a map in an interactive manner. As seen in these cases, GIS database that was initially created by local governments to carry out their administrative work including regional development, facility management, preservation of nature is open to the people. Now people can use it in such a way that they can manipulate the geographic data in the GIS database and produce maps in an interactive manner. The maps that people obtain are not those of the static images that have been prepared beforehand and stored in the database.

Figure 1 REDI, the local information system of SANDAG

Figure 2 Community Services of SanGIS

Figure 3 Utility of SanGIS

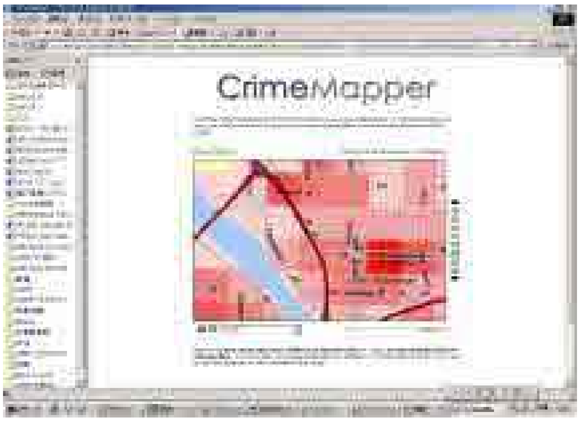

Figure 4 Crime Mapper of City of Portland

3. iPasCAL (Integrated GIS Web System for Supporting Public Administration)

Integrated GIS is an application that was developed with a view that the system should extensively cover map related fields in public administration such as property tax, water supply and sewage systems, roads, urban planning and so on, and the information that has been accumulated in each section should be shared by the entire organization. Its segments, which were designed on the basis of a unified concept, include users and data management, sharing system, and a system that supports individual office work. PasCAL is one of the examples. iPasCAL is a system which accommodates an integrated GIS that allows users to access and retrieve data centrally managed by the public administration supporting package system (PasCAL) by Web browsers in an environment connected with LAN.

The geographic data that iPasCAL deals with has been already stored in the organization, and the users access it via Web server and Map server. Therefore, iPasCAL doesn't need to have its own database. It is not wedded to particular clients' OS and accessible from PCs with small capacity or even from mobile PCs. By designating the data as open or closed, not only the staff of the organization but general public can have access to the data. In this way, the system can be used as a mean of opening of information to the public.

3.1 Outline of System Functions

(1) Screen Controlling Functions

- Addition and deletion of layers, setting of mapping scales, and displaying of legends
- Screen control (Magnification/Reduction), shifting, and displaying the whole area

(2) Editing Functions

- Drawing of a figure (broken lines, polygons, circles and characters) selected by a user
- Editing of a figure (copy, shift and deletion)

(3) Measurement

- Distance measurements and area measurements

(4) Retrieval

Retrieval of positions, figures and attributes

3.2 System Operation Environment

Following table shows operation environment of the system.

WWW Server

OS	Microsoft Windows NT 4.0 (Server/Workstation)
WWW server application	Microsoft Internet Information Server (NT Server)
	Microsoft Personal Web Server (NT Workstation)
Map cut out software	ESRI MO/IMS2.0

MAP Server

OS	Microsoft windows NT 4.0 (Server/Workstation)
GIS Engine	ESRI MapObjects2.0a
Map Management Software	Pasco PMMO.DLL

Data Base server

OS	Microsoft Windows NT 4.0 (Server/Workstation)
RDBMS	Microsoft SQL Server 7.0 SP1

3.3 Screen Image

The following figures show Screen images.(Fig.5,6)

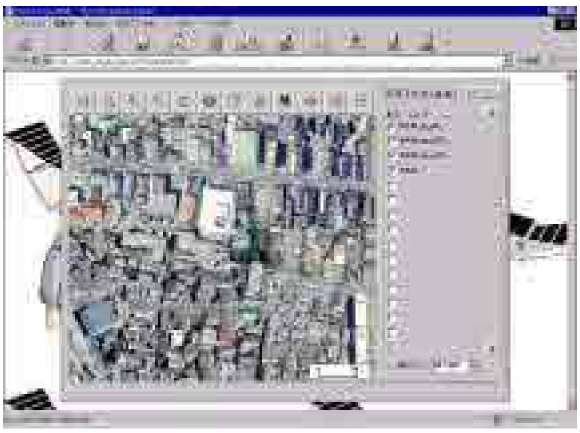

Fig. 5 Overlaying of an aerial photo and topographic map

Figure 6 Overlaying of land use map and topographic map

4. "River Information System" of the Ministry of Land, Infrastructure and Transport

This site (http://www.river.go.jp/) was created by the River Bureau of the Ministry of Land, Infrastructure and Transport. Objectives of the site are to minimize flood-related damages and to prevent drowning by providing real-time information about precipitation and water levels of Class A Rivers (109 rivers) across Japan on the Internet. Pasco Corporation took part in the site construction and was in charge of developing a program for producing map images used in GIS, provision of map data (Pasco Digital Map 25000) and designing of maps.

4.1 Outline of System Functions

The information provided on this site is as follows. The data offered to the people are classified into two categories, i.e. those that are "displayed overlaid on a map" and those that are "retrieved from a map and displayed on a new window."

(1) Those that are displayed overlaid on a map

- Radar precipitation (most up-to-date)
- Radar precipitation (record)

(2) Those that are displayed on a new window

- Information on water level
- Information on precipitation
- Information on water quality
- Information on snowfall
- Levee protection warning
- Flood prediction
- Notice of dam discharge

Four kinds of scales (whole Japan, 1:5,000,000, 1:1,000,000, and 1:300,000) are available to the users for displaying a map on a screen. First, a user selects the area from the initial screen of whole Japan. Then, a user selects the information that he/she wants to see. "MapObjects/Internet Map Server (MO/IMS)" of ESRI of the United States controls the displaying of maps and processes overlaying of various information.

4.2 System Composition

The followings are hardware compositions of operation system. As this site is "offering information on disaster prevention," a large number of simultaneous accesses were anticipated at the time of, for instance, typhoons. In order to cope with such a problem, server machines were multiplexed to enhance their processing capability.

(1) Load Balancer (Load Dispersing System)
This system is able to automatically allocate the processing load to an appropriate WWW server in response to the volume of requests from the Internet.

(2) WWW Server
This is a substantial gate to a WWW site. Unix machine (Solaris7) is used for this system.

(3) Map Server
This is a system to produce a map image in response to a request from WWW server.
A program developed by MO/IMS, Web-based GIS software of ESRI, runs here.

(4) DB (Data Base) Server
This is a file server to store all the data used in the system including map data, water level data and precipitation data.

(5) Image Producing Server
This is a server that receives the "on-line observation data" such as precipitation and water levels, and produces precipitation grids and water level graphs.

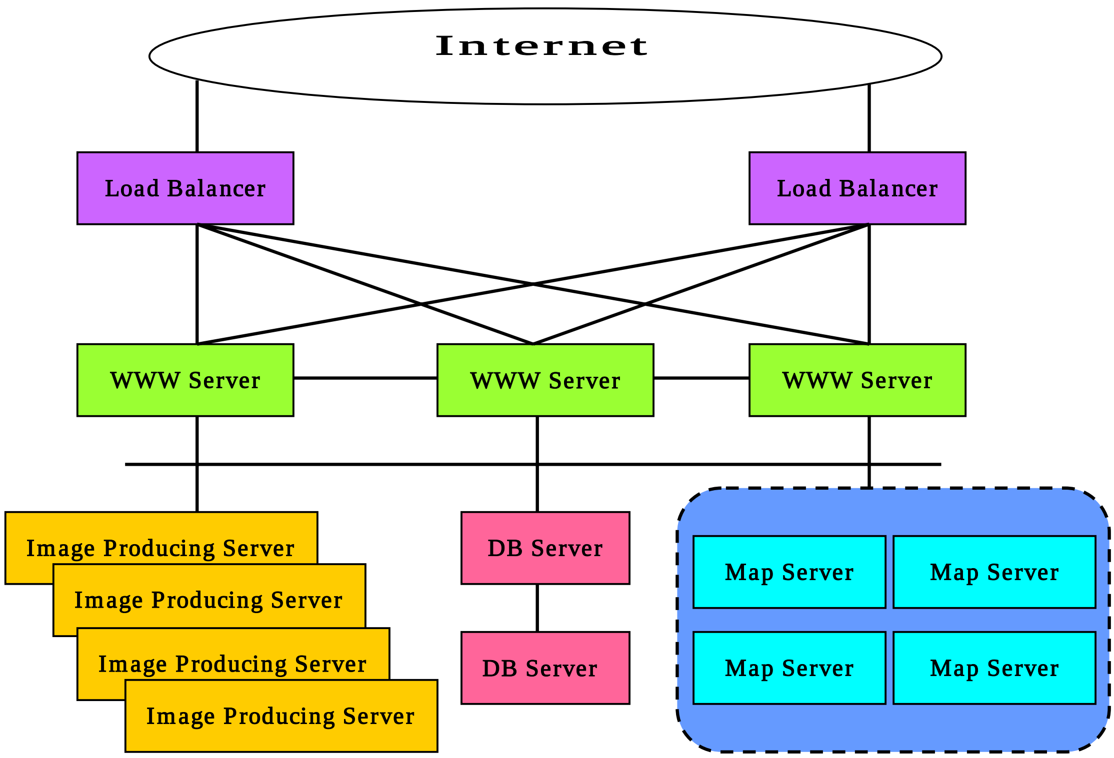

Figure 7 System composition
MO/IMS program within the dotted area

4.3 Operation Status of the Site

The site drew a huge number of accesses on June 1st, 2001, the day when the site opened. It was temporarily closed for adjusting the system and was reassumed on June 20th. As a result, the system could successfully accommodate the accesses with more than 60,000 page views per hour at the time of Typhoon No.15 in September 2001. The following are samples from the web site of the River Bureau, the Ministry of Land, Infrastructure and Transport. The graph below shows the status of access, which was release in the web page.
(http://www.mlit.go.jp/river/saigai/access/index.html)

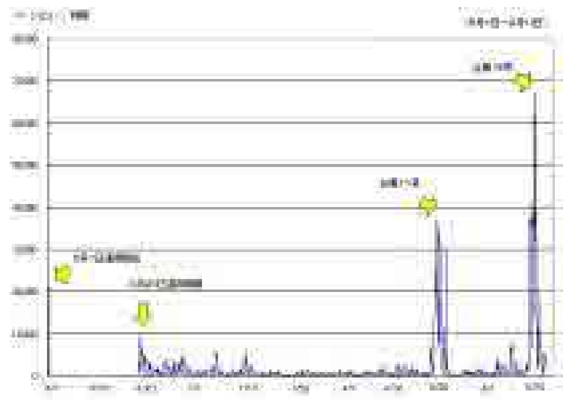

Figure 8. Access status to the site, which was released on the web site of River Bureau, the Ministry of Land, Infrastructure and Transport

Figure 9. Initial Screen for Retrieval

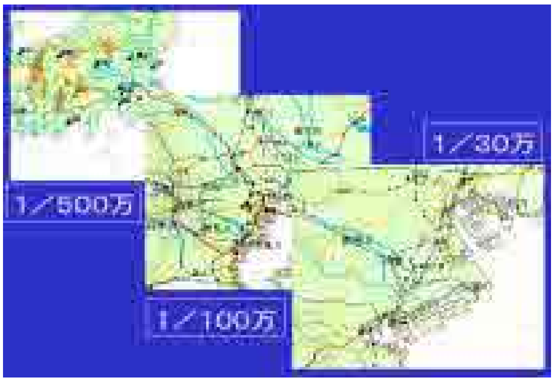

Figure 10 Zooming in

Figure 11. Radar precipitation Map (record) -past 4 hours

Figure 12 Telemeter Information
(Precipitation Graph, Water Quality List, Water Level Graph, Dam Discharge Information)

5. Conclusion

Due to the recent development of Web-based GIS, we are now able to distribute maps in the form of vector data through the Web. Moreover, Web-based GIS also enables each GIS site, which is connected each other with the Internet, to exchange data and provide services on equal and independent basis. This system is quite significant for developing countries mainly because that: 1) it can provide a technical basis to avoid redundant investments if these countries can firmly establish designing of geographic database and a system of operation. The fact that developing countries often do not have a system of map notation based on paper map system would be profitable rather than disadvantageous to them; 2) it can create a framework which allows organizations in developing countries, which often lacks human resources, to share data and knowledge and cooperates with other organizations in the policy making process such as regional development planning

Advent of the Web-based GIS ages is regarded as a dawn of a new era for developing countries that can expect much from an integrated GIS database and the management of human resources, albeit communication infrastructure poses a challenge to them. From a global point of view, we have entered a new age when all the people can share various data in the form of GIS via Web-based GIS as a social infrastructure in a true sense. (g.net:http://www.esri.com/news/arcnews/spring01articles/gnet.html).

Image Information Sources
— Optical Sensors, SAR and other Instruments —

Jun Sato
Geographical Survey Institute
Kitasato 1, Tsukuba-shi,
Ibaraki-ken, 305-0811 Japan

Summary
Remote sensing is a very effective method to quickly obtain spatial data on features and topography in a broad range of area. It uses images that are taken from an aircraft or satellite. In resent years, remarkable development has been witnessed in resolving power of satellite-mounted optical sensors. Also recent technical development in active sensors, which use laser and microwaves, is expected to contribute to acquiring high accuracy spatial data in near future. When selecting a method for acquiring spatial data or selecting proper images among various kinds of image information, characteristics of each method or means must be well considered along with the purposes and budgets of an operation.

1. Acquisition Technique of Spatial Data

Suppose you were assigned to investigate an unknown place and file a report on it. Since you've never been there, you have, at the start, no idea about where it is located, how to get there, how it looks like, etc. You may visit a library to check into books and maps to collect information about the place. However, if you are far away from the place, the information you collected may not be so detailed. You may call someone living there and ask about the place in detail. But if the place is located in a foreign country, you may face a language problem. In addition, you may feel uneasy about telephone bill. Thanks to a modern technology, the Internet may help you lead proper sites that give you necessary information. After taking pains with collecting information, you may visit the place to realize that you have missed much information. This analogy shows how collecting spatial data is for GIS.

In the following sections, methods to acquire spatial data are roughly classified into 3 categories for the sake of explanation.

1.1 Data Collection from Existing Maps

Collecting data from existing maps means using the information that our forerunners collected. Map may be used as it is, or whole or part of it may be processed for use. It is analogous to photocopying of literature in a library to use. For example, having a piece of map means having much more information than no map. Using a map, which has been converted into digital images after scanning, as simply a background map for GIS is often quite useful. When map is used in more sophisticated way, coordinates of every feature on a map have to be obtained so that a computer can identify positional information. They can be obtained through digitization process, which is called "map digitizing".

1.2 Data Collection from Images

"Images" here refer not only to aerial photographs taken from an aircraft or photographs taken from a satellite from several hundreds kilometers above, but also to the visualized reflection of microwaves such as radio waves, laser, etc., which are emitted from platform and reflected on the earth surface. This kind of method is analogous to collecting information by telephone as illustrated above. That is, whereas considerable amount of information can be obtained without actually visiting the place, certain degree of technical training is required to interpret and analyze the information on a photograph. Also cost required for interpretation and analysis must be taken into account.
Since image utilization is one of the themes in this paper, it will be explained in detail later along with the trends in new technology.

1.3 On-Site Data Collection

Spatial data dealt in GIS can be regarded as a huge collection of information, each piece of which consists of a pair of data, i.e. positional data and attribute data. In order to ensure high accuracy in obtaining spatial data, field investigation is the most powerful tool. Though it depends on the required accuracy, GPS receivers and other similar equipments make it possible, without much difficulty, to obtain positional data in the field. Much of attribute information, on the other hand, needs to be verified on the site. For example, names (such as geographic names) commonly used by local people often differ from those recorded in official documents. The fact that geographic names and administrative boundaries do not appear on a photograph is so obvious that it is often taken for granted and dropped out of one's mind. Field verification on these items must not be forgotten.
In general, field verification is costly. Furthermore, security measures, especially when verification is conducted in some quarters in foreign countries must be taken into consideration.

Thus, among various methods available, the one most suitable to the objectives of the operation should be selected. In an actual operation, therefore, advantages and disadvantages of each method should be carefully considered without adhering to a particular method.

2．Characteristics of Remote Sensing

A method to acquire information by means of images is generally called remote sensing, which literally means "to acquire information about objects while being away from them and without touching them".

In remote sensing photographs or images of a target area are taken from high above the sky, and the data is received and analyzed at a different place. In general, except for special cases such as disaster measures and military strategies in which data is processed in real time, data is recorded in some media for post processing, thus permitting some degree of freedom in time for analysis.

A device to take photographs or images is called sensor in a broad sense. A flight vehicle that mounts a sensor is called a platform, which is either an aircraft or satellite. An aircraft can be either a rotary-wing aircraft (helicopter) or a fixed wing aircraft. When selecting a sensor for an operation, the objectives of the operation and characteristics of each vehicle should be carefully considered since these platforms vary in flying speed and flight altitude. For example, an aircraft is operated in the atmosphere, i.e. generally several hundred or several thousand meters above the earth, whereas a satellite works in outer space of several hundred kilometers from the earth.

An aircraft has advantages of being very adaptable and therefore can easily accommodate the objectives of a planning agency. In case of an emergency such as disaster, its high mobility permits quick acquisition of the bearings of situation. On the other hand, it can be operated only in the atmospheric sphere and is, therefore, vulnerable to climatic conditions. Particularly clouds in an aerial photograph would pose a fatal obstacle in interpretation of the photographs. Scheduling of aerial photographing is the most bothersome part in the operation due to the vulnerability of aircrafts to the weather conditions. Moreover, in case of an incidence of a natural disaster such as volcanic eruption, data needed for analysis may not be always obtained because of risk involved in low-altitude flight.

The advantages of a satellite for acquiring image information are: 1. a satellite can cover a wide rage of area; 2. it can quickly cover a target area; and 3. it allows repeated observations. Since a platform exists in outer space and automatically operated, photographing of a disaster-hit area does not pose safety problems.

Whereas some satellites take a geosynchronous orbit (stationary orbit), as in the case of a meteorological satellite such as "Himawari" of Japan, a large number of earth observation satellites take a polar orbit, which is orthogonal to the axis of earth rotation. Therefore, photographic cycle of such satellites is fixed and, as a result, mobility is limited, which may result in delays in photographing at a time of disaster. Some commercial satellites is, in response to the requests of the customers, operated so as to quickly acquire images of a target area. Before making such a request, however, due consideration is necessary because an extra request charge is added.

3．Types of Sensors

A sensor that is mounted on a platform functions as "eyes in the air" and takes a view of the surface of the earth. A wide variety of sensors have been developed to serve various purposes. The following are general information about sensors that are commonly used.

3.1 Airborne Sensors

3.1.1 Optical Sensors

Among optical sensors a typical one is an optical camera, which is usually called an aerial camera. It is mounted on an aircraft, which flies along the planned course, and takes sequential photographs in such a way that one photograph overlaps with the next photograph in some degree. These two adjacent photographs can produce a three-dimensional image, when they are placed in a stereoplotter, and give positional information of geographic features or topography of an area in a photograph. When a digital plotter is used in this process, positional information can be obtained in a digital form and the data thus obtained is called spatial data. When an image that was taken by an aerial camera is used as a background image in GIS, distortion of an aerial photograph should be rectified through orthographic projection.

In recent years, a compact CCD camera is mounted on an aircraft to directly obtain images in digital form. At present, however, such a method still remains to be a complementary way of acquiring information because a CCD camera has not been proved accurate enough for surveying purposes. A "three-line scanner", a kind of a digital camera, has been developed and several kinds of them are available in the market. They are now under examination for their practical use.

3.1.2 Airborne Laser Scanner

An airborne laser scanner is a distance-measuring instrument. It emits weak laser beams and measures the time from their emission till their returning to the aircraft after reflecting on the objects on the earth surface. Using this time, distance between the aircraft and an object can be calculated. Laser beams are emitted several thousand to several ten thousand per second. Certain width of earth's surface can be scanned by swinging laser beams perpendicular to the traveling direction of a platform (refer to the figure). GPS and IMU (an advanced gyrocompass system) are used to monitor a posture of an aircraft, i.e. its position and inclination. Analyzing data of both the aircraft and the reflection laser permits quick and precise measurement of configuration of the earth's surface. Since information about the ground (topography) can be isolated from that of objects, which spread out on the ground such as vegetation, buildings and so on, they can be analyzed independently. Positional accuracy thus obtained is, in optimal conditions, reported to be 30 to 50 cm in horizontal direction and 15 cm in vertical direction, though it is affected by the conditions of topography and vegetation in a target area. It is not so hampered by the weather conditions as in the case of aerial photographing, but observations are not possible in rainy weather because raindrops cause absorption and scattering of laser beams.

In Japan, major aerial surveying companies started adopting this technique around 1997.

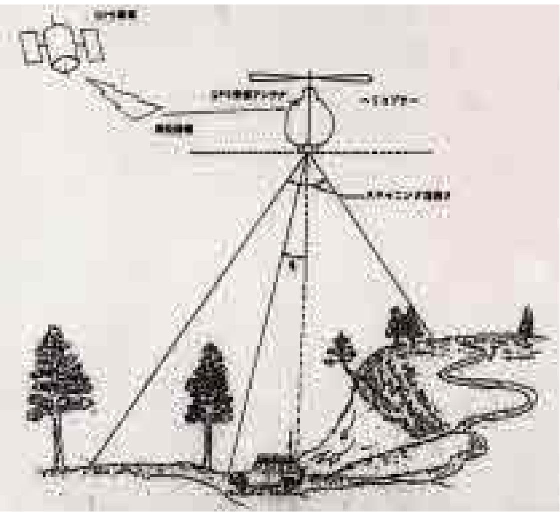

Figure 1. Schematic Illustration of Airborne Laser-mapping System
Geographical Survey Institute "Research Report on Application Technology of Laser Profiler to Topographic Surveying" (1999)

Though several technological issues such as whether accuracy can be constantly secured or not, etc. have to be solved, the technique is now beginning to be applied to topographical surveys under severe natural conditions such as erosion control sites in steep mountains or the investigations of volcanic eruptions.

3.1.3 Synthetic Aperture Radar (SAR)

In synthetic aperture radar (SAR) the condition of ground surface is grasped by analyzing reflection microwaves, which were emitted from an aircraft and returned to it after hitting the objects on the ground. Microwaves refer to the electromagnetic waves with wavelength of 1 to 1,000 mm. SAR has property of being able to acquire data under cloudy weather or even at night, so long as an aircraft is operated, because it uses not a visible light but electromagnetic waves that belong to a radio wave range. According to their wavelengths, microwaves are classified into several bands such as L, C, X, etc. A suitable band should be selected in consideration of the purposes of an operation because reflection property of objects on the ground, such as topography, vegetation and so on, show differences in wavelength.

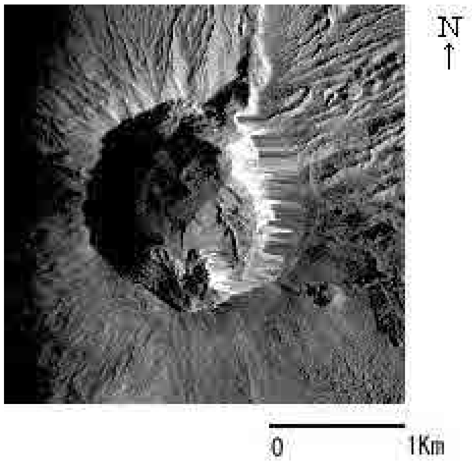

Figure 2. Orthophoto of Miyakejima by Airborne SAR (Geographic Survey Institute)
(Resolution: 10 meters, photographed in Sep. 2000)

For example, in case of analyzing forests by SAR, whereas X-band (wavelength about 30 mm) is more likely to be reflected on tree crowns (top of a forest), L-band (wavelength about 200 mm) prone to be reflected on tree trunks as well as the surface of earth. Accuracy of SAR in acquisition of topographic data is generally regarded to be around 10 to 20 meters, however, it is reported that its accuracy can be theoretically improved, if its power is raised, to scores of cm in both horizontal and vertical directions.

In Japan the Geographic Survey Institute (Ministry of Land, Infrastructure and Transport), Communication Research Laboratory, etc. own SAR and are presently carrying out various experimental data acquisitions (refer to the figure).

3.2 Satellite-mounted Sensors

3.2.1 Optical Sensors

Since the launch of LANDSAT-1 of the United States in 1970s, a number of optical sensors have been mounted on satellites and put into practical use for observation of earth surface. Still many new types are scheduled to be deployed. Present trends

Table 1. Principal Satellites Presently in Operation

Satellite Name (Country Name)	Type of a Sensor	Resolution	Observation Width	Altitude	Days for recurrence	Year of Launch
ERS-2 (European Space Agency)	SAR	30 m	80 km	785 km	35 days	1995
RADARSAT (Canada)	SAR	10-100 m	50-500 km	800 km	24 days	1995
IRS-1C (India)	Optical	5.8 m ~	70 km ~	900 km	5 days	1995
SPOT-4 (France)	Optical	10, 20 m	60 km	820 km	26 days	1998
LANDSAT-7 (USA)	Optical	15 m~	185 km	700 km	16 days	1999
IKONOS (USA)	Optical	0.8 m	11-110 km	680 km	3 days	1999
Terra (USA)	ASTER (Optical, Thermal Infrared, etc.)	15-90 m	60 km	700 km	16 days	1999
EROS-A1 (USA and Israel)	Optical	1.8 m	12.5 km	500 km	7 days	2000
QuickBird (USA)	Optical	0.6 m~	20 km ~	600 km	1.5 days	2001
(For reference) ALOS (Japan)	Optical SAR	2.5 m~ 10-100 m	35 km ~ 70-360 km	700 km	45 days	Scheduled in 2004

include: 1. higher resolution of sensors; 2. multi-national operation of a satellite; and 3. emergence of commercial satellites operated by a private sector.

French satellite, SPOT 1, launched in 1986 had panchromatic resolution of 10 meters, the highest resolution of the time for optical sensors for civilian use. As of 2001, some satellite-on-board sensors have resolution higher than 1 meter. High-resolution satellites in operation include India's IRS-1C (5.8 meters of maximum resolution), EROS-A1 co-developed by the USA and Israel (1.8 meters of maximum resolution), IKONOS of the USA (0.82 meter of maximum resolution) and so on. Further, QuickBird of the USA was successfully launched in October 2001, whose performance is now under examination. It is announced that, if things go well, QuickBird starts acquiring of images of 0.61-meter resolution by the beginning of 2002. The above-mentioned EROS-A1, IKONOS and QuickBird are all operated by private companies in the USA, which implies that acquiring and rendering of satellite images have become business targets. Japan, too, plans to launch a land-observation satellite, ALOS, with a 2.5 meter-resolution sensor in 2004.

Past performance proved that SPOT images of 10-meter class resolution were capable of providing information equivalent to 1:100,000 scale topographic map and actually its data has been already utilized for quick production of topographic maps in some developing countries in Africa. Furthermore, it is expected that high-resolution satellite images be utilized for acquiring even more precise spatial data, which will, in turn, permit producing larger scale topographic maps. However, questions about accuracy and cost remains. Yet, since a number of high-resolution satellites will be available in the future, benefits from completive market for the images obtained by these satellites may be expected. This is one of the fields that we should keep eye on.

3.2.2 SAR

SAR sensors explained in the former section are mounted not only on aircrafts but also on satellites, which keep transmitting data about earth surface. Satellite-on-board SAR has an advantage of easily permitting interference analysis based on the regular recurrence of a satellite. This means that micro-deformation of earth crust can be detected by analyzing phase difference, which can be obtained by interfering the data of the two different times at the same point. This kind of research is carried out at various agencies including the Geographical Survey Institute (GSI) of Japan. For example, GSI has successfully detected crustal deformation accompanied by Hyogoken- Nanbu Earthquake in Kobe city and Awajishima Island.

Shuttle Radar Topographic Mission (SRTM) can be regarded as a special example of satellite-on-board SAR. In 2000, the USA launched "Endeavor", a Space Shuttle, with instruments to emit radio waves. An objective of SRTM was to acquire digital data of topography of the whole earth. (Analysis of the data is still underway but the resolution of the final results would be 30 meters in horizontal direction and 16 meters in vertical direction.) SAR-mounting satellites presently in operation include RADASAT of Canada and ERS-2 of ESA (European Space Agency), both of which use C-band. Japan's JERS-1, which is no longer in operation, mounted SAR of L-band and the 1992-1998 observation data on the whole earth has been archived and is available whenever necessary. ALOS, which Japan will launch as mentioned before, will be equipped with a SAR sensor.

3.3 Other Sensors

Sensors for visible near-infrared region (wavelength around 0.7 μm), short-wavelength near-infrared region (wavelength around 2 μm) and thermal infrared region (wavelength around 10 μm) are sometimes used in exploration of underground resources. As in the case of SAR, a platform can be either an aircraft or a satellite.

4. Distribution Organizations

The following are the major organizations that distribute aerial photographs or satellite images. Note that aerial photographs and satellite images are also available at other organizations that are not listed here. For more detailed information such as price, forms of distribution, etc, please contact at each organization listed below.

- Aerial Photographs (which covers only Japan)
  - Aerial Photograph Department, Japan Map Center
    Kasuga 3-1-8, Tsukuba-shi, Ibaraki-ken, 305-0821
    Phone: 0298-51-6657
    http://www.jmc.or.jp

- Satellite Images (which include satellite SAR)
  - Earth Observation Research Center, National Space Development Agency of Japan
    Harumi 1-8-10, Chuo-ku, Tokyo, 104-6023
    Phone: 03-6221-9000
    http://www.eorc.nasda.go.jp/index_j.html
  - Remote Sensing Technology Center of Japan
    Roppongi 1-9-9, Minato-ku, Tokyo, 106-0032
    Phone: 03-5561-9771
    http://www.restec.or.jp
  - Earth Remote Sensing Data Analysis Center
    Kachidoki 3-12-1, Chuo-ku, Tokyo, 104-0054
    Phone: 03-3533-9310
    http://www.ersdac.or.jp
  - Japan Space Imaging Corporation. (IKONOS images)
    Yaesu 2-8-1, Chuo-ku, Tokyo, 104-0028
    Phone: 03-5204-2734
    http://www.spaceimaging.co.jp
  - Hitachi Software Engineering Co., Ltd. (QuickBird Images)
    Onoe-cho 6-81, Naka-ku, Yokohama-shi, Kanagawa-ken, 231-0015
    Phone: 045-681-2111
    http://w ww.hitachisk .co.jp/Products/Remosen/

Notes

The objective of the manual is to make guidelines for technical transfer concerning GIS. The method of use and functions of GIS technologies depend on the software and purpose of use. There are so many manuals and textbooks on GIS for experts.

Users of GIS for individual applications know well how it will benefit their work. However, without survey on the benefits of GIS applications, it is extremely difficult to know how beneficial GIS will be as a whole in a developing country. Before introducing a GIS in a developing country, an allocation of budget and/or personnel is required and the benefits of the GIS are need to be explained. One appropriate way is a survey on the benefits of GIS applications in other developing countries with similar condition.

As stated, the objective was to create a manual that concentrated on the fact that GIS is very useful in developing countries. Fortunately, the many authors understood and accepted the concept. In each section, technical words on GIS were explained as simply as possible to make the manual understandable for laymen. This was a difficult task but thanks to the great efforts of the authors and other related persons, the objectives of the manual was achieved.

Most of the application examples in the manual are taken from projects of JICA who implement technical cooperation of Japan. Applications of GIS are expanding and recently medical GIS applications are being implemented in assistance projects. Many GIS projects were not included in the manual because they are not finished yet. Because editing schedule was tight, GIS applications were not surveyed sufficiently. Please note that there would be many appropriate examples of GIS applications that have not been included here.

Finally, on behalf of authors, I express special thanks to kind allowance to the concerned departments of JICA, such as Social Development Study Department and Agriculture, Forestry and Fisheries Development Study Department, for kindly allowing JICA studies to be used in the manual.

Editor
Yoshikazu Fukushima
IDI