INTEGRATING REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS FOR REGIONAL PLANNING

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ABSTRACT

Remotely sensed satellite imagery are an important source of data for the development of a Geographic Information System (GIS) for applications in regional development planning. The level of data processing necessary determines the complexity and necessary level of interfacing of remote sensing and GIS. Advantages of integrating remote sensing and GIS are highlighted through illustrative examples in regional planning.

First, remotely sensed data like satellite imagery provide up to date cartographic information to augment outdated and infrequently revised printed maps. Second, maps that are printed at a variety of scales, projections and datum can be scanned or digitized, and then be fitted to known x, y and z control points using geometric control algorithms. Third, a GIS offers the most versatile, flexible and effective method for handling the storage and interrogation of remotely sensed data. GIS makes it possible to conduct spatial queries and create new thematic maps as a result of the queries. Last but not the least, integrating remote sensing and GIS systems helps in making better decision making by planners by realization of improved understanding, analysis and results presentation.

In conclusion, the full potential of remote sensing and GIS in regional planning will be achieved only when the two systems are fully intergrated.

RÉSUMÉ

Les images des satellites de télédétection sont une importante source de données pour le développement d'un SIG élaboré en vue de l'aménagement régional. Le degré de développement des données détermine la complexité et le niveau nécessaire pour l'interface entre la télédétection et le SIG. Les avantages de l'intégration télédétection-SIG apparaissent clairement à travers quelques exemples d'aménagement régional.

Tout d'abord, les données de télédétection telles que les images satellite permettent d'actualiser les informations cartographiques figurant sur des cartes périmées ou peu souvent révisées. Ensuite, des cartes qui sont imprimées à des échelles diverses, et avec des projections et des données variées peuvent être scannées ou numérisées puis ajustées sur des points connus en x, y, et z en utilisant des algorithmes de contrôle géométriques. Par ailleurs, un SIG offre la méthode la plus souple et la plus efficace pour le stockage et l'interrogation des données de télédétection. Un SIG permet de poser des questions concernant l'espace, et de créer de nouvelles cartes thématiques comme résultats de ces questions. Enfin, l'intégration télédétection-SIG permet de meilleures prises de décision par les aménageurs par le fait qu'elle améliore compréhension, analyse et présentation des résultats.

En conclusion, on ne profitera pleinement de la totalité du potentiel de la télédétection et des SIG dans l'aménagement régional que si ces deux systèmes sont parfaitement intégrés.

INTRODUCTION

The multi-sector nature of regional planning and overlap of data needs of various sectors along with the inherent spatial dimension of any planning activity, make the use of Geographic Information Systems (GIS) as a planning tool very attractive. The simultaneous use of GIS for the integrated planning of various sectors within the framework of a regional development master plan also results in the creation of a comprehensive database which is of immense value in the future for frequent updating of maps and attribute data and quick generation of planning alternatives and scenarios. Any development project in regional planning and management requires the handling of huge volumes of spatial data and extensive spatial analysis. The enormous amount of spatial data such as maps and drawings to represent natural resources information such as rivers, forest cover, and land use, and socio-economic information such as population, living conditions, employment and income levels can be efficiently input, stored and managed in an intelligent database.

Remote sensing data are also an important source of data for the development of a GIS for applications in regional planning. Nippon Koei (NK) has executed more than 630 projects in more than 57 countries in the world covering all fields of engineering and planning sectors. By the application of remote sensing and GIS planning tools for planning, NK has determined the possibilities for application of cost effective procedures for database formulation, preliminary analysis, selection of alternatives and monitoring to yield best results in projects. The present paper discusses the interrelationships between computer based Remote Sensing Systems(RSS) and GIS, and identifies specific advantages gained by their integration for applications in regional planning.

◆ GEOGRAPHIC INFORMATION SYSTEMS (GIS)

A GIS is a computer based system which provides for the acquisition, storage, and manipulation of geographic data, and its presentation in various forms, including maps, charts and tables.

A GIS links spatial data with geographic information about a particular feature on a map. The information is stored as attributes or characteristics of the geographically represented feature. The real world consists of many geographic features like hydrology, topography, land use, utilities, soils and roads, which are represented by a number of related data layers in a GIS. A GIS can also use the stored attributes to compute new information about map features. In short, a GIS does not just hold maps - it holds a database management system. This is the main difference between a GIS and a simple computer mapping system.

Some major analytical capabilities of GIS in terms of its geodata processing or spatial analysis capability, which can lead to better planning are as follows (ref. 1):

1. Thematic mapping: display of attributes of features using shades and patterns.
2. The selective retrieval of map units based on attribute searches.
3. Calculate proximity or distance based relationships: determine which features are within a given distance of a selective feature or group of features.
4. Calculate adjacency: determine which features are immediately adjacent to a selected feature or group of features.
5. Visual overlays: display attributes of two or more maps over top of one another for visual inspection.
6. Mathematical overlays: generate a new map by combining features of two or more maps, generating new polygons and attributes.
7. Easy quantification of map data e.g. in the form of tables.
8. Modeling: estimate attributes based on pre-determined methods, algorithms, and parameters.
9. Aggregation of features: combine features into larger aggregation of features.
10. Translate location referencing systems: convert coordinates from one unit to another.
11. Interface user coded routines: execute a program written and compiled outside of the software package and use the results of the program's calculations.

Table 1 (ref. 2) indicates the value of GIS in various dimensions. It is seen that GIS is extremely useful in regional planning studies. The GIS database creation process involves data input from various sources remote sensing satellite data, aerial photographs, paper maps, tabular data etc. These may be input using a tape reader, scanner, digitizer or by data entry. The data could be raster data, vector data or database records.

◆ REMOTE SENSING SYSTEMS (RSS)

Remote sensing data like digital imagery and maps made by computer processing of remote sensing data are very useful in regional planning applications. Even if little remotely sensed data exists for an area, the cost effectiveness of using such data in resource investigation and management may well make it worthwhile.

Benefits of using remote sensing data are:
(a) It may reveal features not visible on the ground.
(b) It facilitates morphological mapping, which therefore makes it easier, quicker and cheaper than ground survey.
(c) It can be used for several different purposes.
(d) It can be used as the basis for maps.
(e) It provides a record which can be compared with later surveys.

Applications of RSS are many (ref. 3):

(a) Hydrological applications: determination of evapotranspiration interception, soil moisture differences, determining size of lakes, marshes and swamps, determination of spring inflows, calibration of hydrological models of water balance, measure areas of drainage basins and map linear drainage networks, locating areas of recharge and discharge and inferring ground water conditions from surface water conditions and geological features, and flood mapping.

(b) Assessment of water pollution: remote sensing data can show where a pollutant is discharged into water, where that discharge goes and how it is dispersed, often more easily than it is possible on the ground. Generally, salt water intrusion, suspended solids, natural oil seeps, ship oil spills and general transport spills can be easily detected.

(c) Weather analysis and forecasting global climatology.

(d) Mapping of soil, land forms, rocks and mineral resources.

(e) Ecology, conservation and resource management: forest mapping and tree stand inventories, wild life studies.

(f) Crops and land use: multi-spectral sensing of crops and crop monitoring.

(g) The built environment: rural areas, urban areas, industrial complexes, air, land and water pollution, demography and social change interpretations, changes in the built environment.

(h) hazards and disasters: disaster assessment, hazard monitoring, insect infections.

◆ INTEGRATION OF RSS AND GIS

Remote sensing data are currently being extensively used in computer based GIS. GIS systems permit the synthesis and display of virtually unlimited sources and types of physical and socio-economic data as long as they can be computer coded with reference to a common geographic database. Remote sensing data are but one of the many forms of data typically incorporated in such systems.

The level of data processing necessary determines the complexity and necessary level of interfacing of RSS and GIS.

High level of data processing

A high level of data processing involves the use of digital tapes and image processing software. This computer assisted method for enhancing satellite images allows one to better interpret regional features such as land use, land cover and land form classifications. Most image processing systems offer the possibility to draw vectors and polygons over the image display on the screen. This feature can be used to trace road networks and to produce thematic maps such as land use maps. Another useful application in image processing is merging existing computerized digital maps with an image. This technique is used in cartography to create or update maps and for change detection when using time series data. High level data processing techniques can be incorporated with medium level techniques as well, particularly by adding additional data for analysis.

Medium level of data processing

A medium level of data processing involves the use of negative films or transparencies that can be reproduced as photographic prints at various scales. Satellite imagery data are visually interpreted from panchromatic or color prints. Land use and road maps are digitized directly from these prints at their scale. Using secondary sources other data such as topography, soil etc. can be superimposed on the base map. This can form the basis for a regional information system.

Low level of data processing

A low level of data processing involves using photographic prints made from films or transparencies. Satellite image data are visually interpreted and maps are manually traced from these prints.

The present paper focuses on the advantages gained by integration of RSS and GIS for high and medium level of data processing.

◆ APPLICATION CASE STUDIES

Urban and regional planners require continuous acquisition of data to formulate governmental policies and programs. These policies and programs may range from the social, economic and cultural domain to the context of environmental and natural resources planning. The role of planning agencies is becoming increasingly more complex and is extending to a wider range of activities. There is an increased need in these agencies to have timely, accurate and cost effective sources of data and data processing methods.

In the determination of land suitability for various crops in a national water resources master plan study in Kenya, NK used a GIS based procedure which used various kinds of data like soil, topography, isotherm, humidity, administrative and basin boundaries, and existing land use and vegetation. The land use and vegetation cover was determined by high level processing of Landsat and NOAA satellite data. Effective merging of the image data with other ancillary information was made possible by integrating it with the GIS database developed.

In a regional planning study in North East Thailand by NK, Landsat TM data was used in preparation of land use maps, which was combined with land use potential maps in a GIS for determining land use development zoning based on various land policies. In the same study, land use maps made from processing of satellite imagery were merged with land use potential maps and ground water potential maps (prepared by processing of remote sensing data in the form of satellite imagery and aerial photographs) to determine areas suitable for drip irrigation.

In another study (ref. 4) by Development Alternatives Inc. and Earth Satellite Corporation in the Helmand Arhandab valley in Southern Afghanistan, satellite imagery, GIS, and field surveys were used to assess changes that have occurred in a portion of the Helmand Arhandab irrigation system as a consequence of the war. Changes detected over time in the extent of vegetation were used as indicators of the current condition of the irrigation system.

In an ongoing regional development study of the Central Luzon region in the Philippines, NK is using high level remote sensing data processing methods in combination with a GIS to determine both the spatial and socio-economic development framework of a region devastated by the eruption of the Mount Pinatubo volcano in June, 1991. Remote sensing data remain the only mode of data source for the area where lahar flow and flooding pose a significant threat.

◆ ADVANTAGES

In summary, many advantages are to be gained by the integration of RSS and GIS for regional planning applications.

Remotely sensed data like satellite imagery provide up to date cartographic information to augment outdated and infrequently revised printed maps. Maps that are printed at a variety of scales, projections and datum an be scanned or digitized, and fitted to known x, y, and z control points using geometric correction algorithms. Ancillary data like soil data, elevation data, assessed property evaluation etc. can be merged with digital image processing data. Digital Elevation Model (DEM) data can be combined with image data for a number of different purposes like production of stereoscopic images. Merging topographic data with image data is often useful in image classification. For example, topographic information may serve as another «channel» of data in the classification directly or as a post classification basis upon which to discriminate between only the spectrally similar classes in a image. In either case, the key to improving the classification is being able to define and model the various associations between the cover types present in a scene and their habitats.

A GIS offers the most versatile, flexible and effective method for handling the storage and interrogation of remotely sensed data. Remote sensing data can be readily merged with other sources of geocoded information in a GIS. This permits the overlapping of several layers of information with the remotely sensed data, and the application of a virtually unlimited number of forms of data analysis. On the one hand, the data in a GIS might be used to aid in image classification. On the other hand, the land cover data generated in a classification might be used in subsequent queries and manipulation of the GIS database.

The utility of any image classification is ultimately dependent on the production of output products that effectively convey the interpreted information to its end user. Here the boundaries between remote sensing, computer graphics, digital cartography and GIS management become blurred. A virtually unlimited selection of output products may be generated. Three common forms that are commonly used include graphic map products, tables of area statistics, and digital data files.

CONCLUSION

It can be concluded that the full potential of RSS and GIS in regional planning applications will be achieved only when RSS and GIS systems instead of being interfaced as two independent systems, are actually fully integrated into one system. This will not only improve the ability to handle, analyze and interpret the data but also improve resource managers and planners to better understand and support decision making.

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Table 1 Value of GIS in Various Dimensions

COMPLEXITY IN SPATIAL ANALYSIS					SITUATIONS TO SELECT GIS BASED APPROACH (LEGEND: GIS: YES USE GIS, X: NO USE MANUAL) — EVALUATION CRITERIA TO JUSTIFY GIS				
Value of data (layers, area)		Detail of Information (scale, pixel size)		Complexity	Cost of Data preparation	Time & easiness of analysis	Value of final output	Cost of software	Cost of hardware
Small Area (~100 sq. km, ward)	1	Less (1:250,000)	1	1	X	X	X	X	X
	1	Medium (1:25,000)	2	2	X	X	GIS	X	X
	1	More (1:2,500)	4	4	GIS	GIS	GIS	GIS	X
Medium Area (~1,000 sq. km, city)	2	Less (1km grid)	1	2	X	GIS	X	X	X
	2	Medium (100m grid)	2	4	X	GIS	GIS	GIS	X
	2	More (10m grid)	4	16	GIS	GIS	GIS	GIS	GIS
Large Area (~100,000 sq. km, country)	3	Less Detail	1	3	X	GIS	X	GIS	GIS
	3	Medium Detail	2	6	GIS	GIS	GIS	GIS	GIS
	3	More Detail	4	36	GIS	GIS	GIS	GIS	GIS