GIS DATABASE REVISION --THE PROBLEMS AND SOLUTIONS

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ABSTRACT

GIS (Geographic Information System) is widely applied in many scientific domains. However, to keep the database "current" is still a "bottle-neck" which obstacles the application and promotion of GIS techniques and products. In this paper, we start with the analysis of why the updating of database is difficult and what kinds of the problems exist in GIS database updating. The problems are analyzed from following three of viewpoints: 1) data sources; 2) automatic object extraction; 3) change detection. The solutions by using automatic interpretation technique and integrated system are then proposed.

1 INTRODUCTION

As GIS is widely applied in many domains, the digital geographic products are increasing grammatically. People are suffering from how to keep their database "fresh" with low cost and high frequency. In fact, to keep a database "fresh" or "current" is one of the biggest "bottle-necks" that obstacles the application and promotion of GIS.

Indeed, a lot of concepts and methods have been proposed and/or developed for the purpose of digital product (database) revision, such as hybrid digital map revision system(Derenyi and Teng, 1992), geographic database revision method by merging old and new data(Jacobi, 1992), raster data-based topographic map revision method(Usery and Welch, 1989), dynamic updating concept(Shibasaki, 1994), automatic GIS database revision system(Shi and Shibasaki, 1996), and road database revision method(Gunst and Lemmens, 1992). In addition, the possibility of using non-survey data like municipal reconstruction plans, inspection reports, construction application and other types of administrative information to update GIS database was surveyed by Otsuka and Shibasaki(1995).

Nevertheless, while types of commercial software including manual, semi-automatic and automatic data acquisition or reconstruction systems are available, almost no practical commercial database revision systems can be found at moment. In this paper, we start with the analysis of why the updating of database is difficult and what kinds of the problems exist in GIS database updating. The problems are analyzed from following three of viewpoints: 1) data sources; 2) automatic object extraction; 3) change detection. The solutions by using automatic interpretation technique and integrated system for GIS database revision are then proposed.

2 GIS DATABASE REVISION – THE PROBLEMS AND DIFFICULTIES

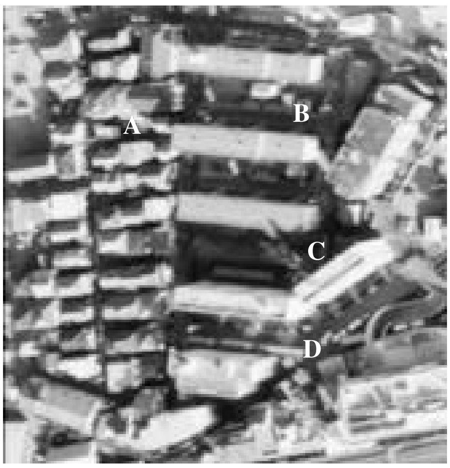
It is a general case that people may take great effort building his/her own Home Page (HP) but few of them are willing to update their Hp daily or even monthly. GIS database is facing the same problem. Many companies or agencies are taking great efforts to establish digital spatial database from papers and statistical data, but it seems that few of them are willing to spend much money for database revision. In this chapter, we try to find out the major problems and difficulties in database revision

2.1 Data Sources

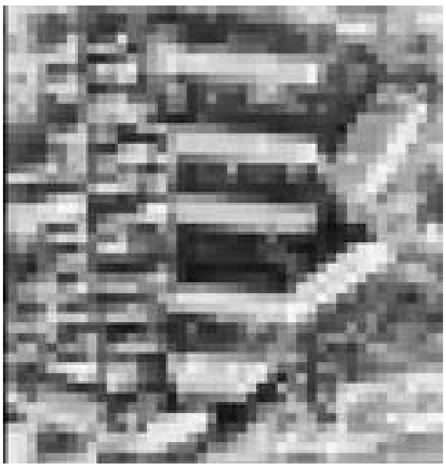
2.1.1 Aerial Photograph. Aerial photographs can provide data sets not only in high resolution (e.g. 10cm) but also with less geometric distortion (see Fig. 1). One can easy recognize the buildings (even small buildings, cars, and in some cases human beings). However, because of the limitations of weather condition and high flying and printing cost, aerial photographs can not be taken frequently (usually once every 3-5 years in the worldwide) with wide range. Thus, Aerial photographs are the suitable source for "LOCAL" GIS database, that is, urban and suburban GIS(including 3D GIS) construction and revision. However, because of the "snapshot" property, it is unreasonable to try to use aerial photograph for the purpose of so-called "dynamic" database revision.

Fig.1 Aerial photograph in urban area (resolution 10cm)

2.1.2 Remotely sensed imagery. It is well known that remotely sensed imagery can be received from satellites frequently (in days, hours, or faster) with a wide range of resolution from 1km to 1m in the time being. Satellite imagery has widely being applied for GLOBAL and REGIONAL GIS database construction and revision. People are now paying much attention to 1m IKONOS images. Fig 2 gives two images with resolution 1m and 3m respectively. One can easily find that it is almost impossible to try to extract buildings from an image with 3m resolution. On the other hand, in case of 1m image, it is possible to recognize the big buildings if the density is not high (e.g. buildings around B and C), but it is difficult to separate small buildings in high-density areas (e.g. buildings around A) even with our human eyes. Therefore, high-resolution satellite imagery itself may be insufficient for updating the GIS database in urban areas.



a) 1m image



b) 3m image

Fig. 2 Samples of high resolution satellite images.

2.1.3 Non-survey Data. A quantity of non-survey data like plans of municipal construction, inspection reports of fire service investigation, building construction application, and so on are collected by local and central government. A investigation upon H and N cities in Japan carried out by Otsuka and Shibasaki(1995) shows that more than 85 percent of the new-built buildings and about half of the disappeared buildings can be found their records in local government's administrative data. The problem is that most types of the administrative information at moment is in sheet base(non-digital).

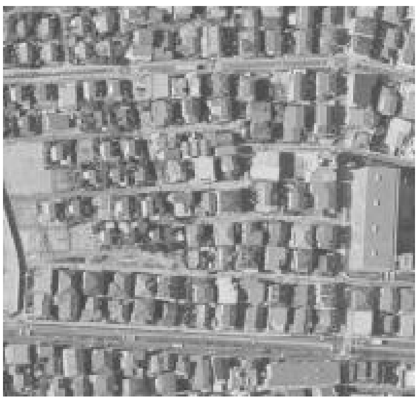
2.1.4 Other Data Sources. There are many types of other data and images from various sensors and cameras that can be used for GIS database revision, such as data from laser range finder, mobile interface(mobile GIS system), video or digital camera images and so on. Laser point data integrated with CCD camera data are thought to be one of the most useful candidates for updating road and its surroundings database. But the problem is that the speed of a laser range finder is still insufficient for practical uses in urban areas. On the other hand, mobile interface with GPS is also a potential method for catching geo-object changes. But, since GPS signal may not be available in many urban areas, improvement is required.

According to the analysis given above, we believe that single data source is generally insufficient for dynamic GIS database revision. That is, the integration or fusion of different data sets is needed. However, since each data set has its own special properties(e.g. resolution, accuracy etc.) and reference system, to integrate them is not a easy work.

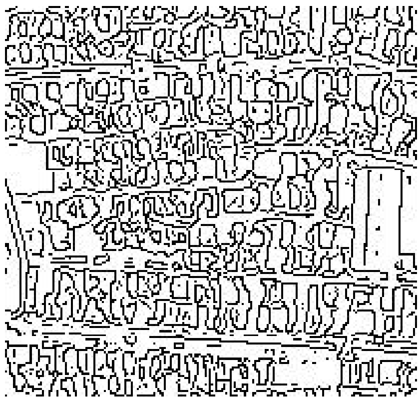
2.2 Man-made Object Extraction

2.2.1 Building Extraction. At the beginning of 1980's, Nagao and Matsuyama(1980) developed a fully automated system based on "structural analysis technique". After that, a lot of automatic and semi-automatic building extraction methods have been proposed and developed, such as stereo-matching based scheme(Herman and Kanade, 1986, Shi and Shibasaki, 1997), shadow analysis based algorithms(Huertas and Nevatia, 1988; Liow and Pavlidis, 1990) and fusion based systems(Mckeown, 1991; Haala, 1994). Most of them use DSM, DEM, or geometric hypotheses (e.g., a roof should have 90^o corners, the even edges of a roof should be parallel with one another) as inputs or/and assumptions for automatic building extraction. But as shown in Fig. 1, when there are no explicit or complete shadows in images or there exist very complex and irregular roofs, the density of buildings are high (in this case, high quality DSM and DEM is very difficult to be obtained) and occlusions, most of these systems may meet difficulties to work automatically and efficiently.

2.2.2 Road Extraction. On the other hand, a lot of road extraction methods are proposed(Fischler, 1994; Steger, *et al,* 1997; Gruen and Li, 1997). However, as Fig. 3 shows, trees, cars, occlusions, as well as other objects on roads or around roads destroy the homogeneity that let the automatic extraction very difficult.



a) Original image



b) Extracted edges from a)

Fig. 3 Road extraction in urban area

2.3 Change Detection

Change detection is generally carried out by overlaying images or features extracted from images with an existing database (digital maps etc.). But, since an image (central projection) and a map (ortho-projection) cannot be well overlapped directly, transformation is needed. In general, there exist two ways to solve such a problem. One is to transform an image from central projection to ortho-projection using DEM (Digital Elevation Model) and 3D information related to objects, while another is to perform a transformation such as affine transformation between an image and a map before overlapping. However, the former has being suffered from making accurate DEM and obtaining 3D information about objects like buildings in urban and suburban, while the latter has being suffered from the low efficiency of the operation since only a part of an image can be handled once a time.

In addition, according to Langran(1989), geo-objects in GIS database can be represented with "state" bounded by "events" in spatio-temporal space as shown in Fig.4(also refer to Shibasaki, 1994).

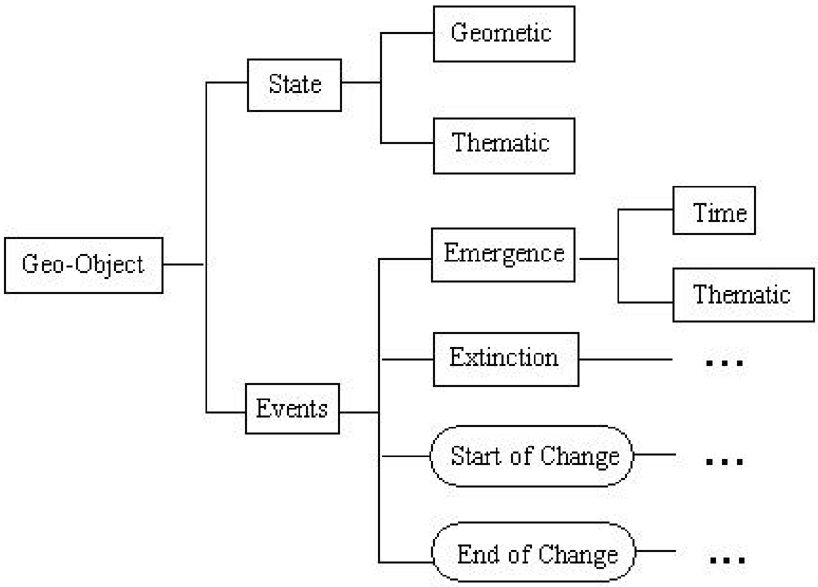


Fig.4 Geo-objects in GIS database

Thus, when we mention about geo-object dynamics, at least three aspects of changes, i.e., geometric change, thematic change, and combination of them, may be taken into account (Molenaar, 1991). Fig 5 shows six typical types of such changes:

i) A new object comes into the beginning of its life, i.e., new events occurred and a new state formulated as shown in Fig.5 (a).

ii) An object comes into the end of its life, i.e., new events happened but old state disappeared, e.g., object 2 in Fig.5 (b).

iii) Some thematic attributes of an object are changed. For instance, a building or a piece of land gets its new owner.

iv) Parts of the geometric aspects of an object are changed. Fig.5 (c) demonstrates three types of such changes.

v) The merge and/or split may occur among objects. For instance,
   1) Several old objects are merged into a new object;
   2) An old object is split into several new objects;
   3) More than two objects are merged and split into several objects.
   Corresponding samples are given in Fig.5 (d), (e), and (f), respectively.

vi) The merge and/or split may happen in inside an object. Different from 5), in this case, only the internal structures of an object change whereas the external relationships keep not changing. Examples are referred to Fig.5 (g), (h), as well as (i).

It is then easy to understand that to detect geo-changes, especially geo-changes iii) –vi) is still very difficult even after an image and a map are well overlapped.

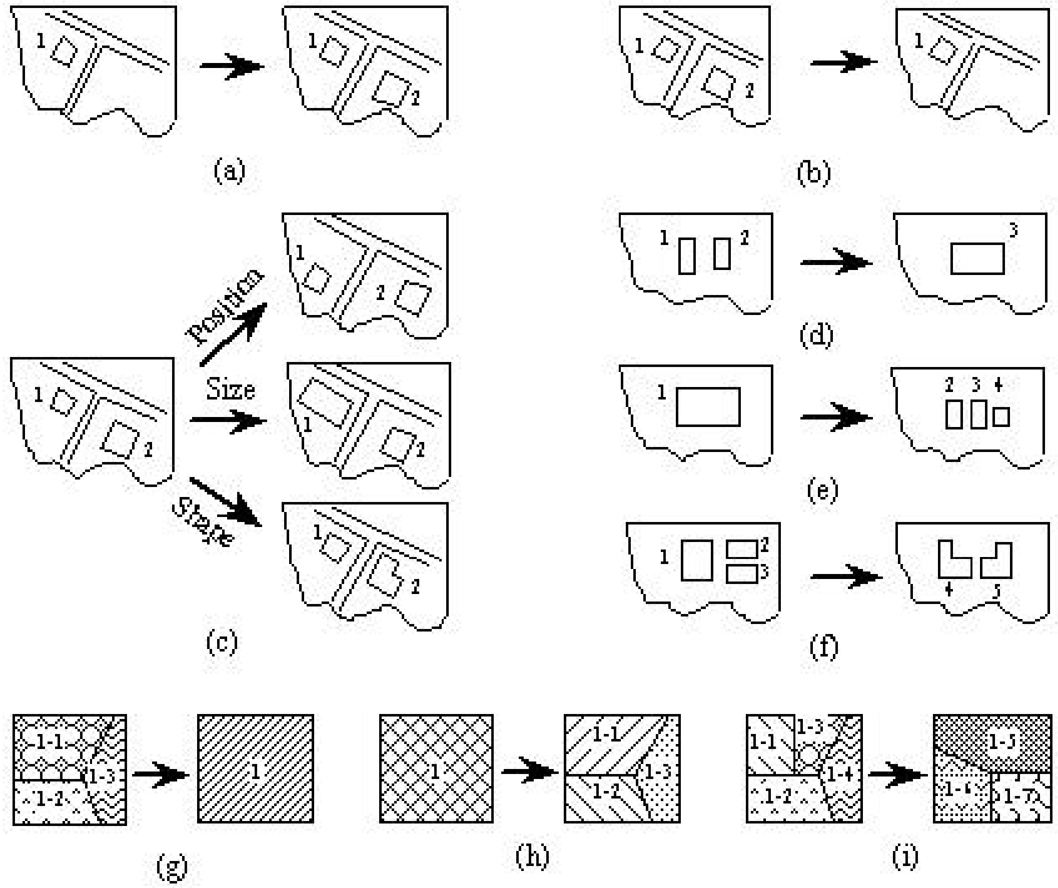


Fig. 5 Types of Geo-changes

3 TOWARDS DYNAMIC GIS DATABASE REVISION

Generally, GIS database can be simply classified into two big groups: global GIS and urban GIS. We will focus only on urban GIS revision in this paper because of the limitation of pages. Following data sets may be utilized for the purpose of urban database revision.

1) Aerial photograph : high accuracy, be suited for large-scale revision.
2) High-resolution satellite imagery : dynamic data set, low resolution, be suited for large-scale dynamic revision.
3) Laser range data integrated with TLS images : direct 3D-based operation, be suited for local and dynamic revision
4) Mobile interface : real time, be suited for local and dynamic revision.
5) Administrative information : dynamic data set, be suited for dynamic revision.

3.1 Large-Scale Revision

For the purpose of large scale urban GIS database revision, aerial photograph and high-resolution satellite imagery are, of course, the most useful data sources. The problem is the efficiency. The situation is that manual operation is now still the major method for finding out geo-changes by comparing photographs with existing map.

Authors proposed an automatic building extraction system (1997), which is able to extract buildings in high-density urban areas with high extraction rate. The system is now being improved for efficient urban GIS database revision. The system includes three major sub-systems: image processing sub-system, object extraction sub-system, and geo-change detection sub-system. We would like to give a brief summary about geo-change detection in this section, and the geo-changes will be limited in type i) and ii) 8see section 2.3). The other two sub-systems can be referred from Shi and Shibasaki(1997).

Fig. 6 shows a general case of "overlapping". In this figure, the black and regular polygons are buildings in digital map(old) while the gray and irregular polygons are polygons extracted(segmented) from a corresponding image(new). Here is an example about how to detect the disappeared buildings.

1) Let a building in GIS database be X.
2) To find out all the polygons extracted from corresponding image across and inside building X.
3) If no any polygons are searched, the building X may have disappeared. We then give a mark to building X as a candidate of disappeared building and then go back to step 1) for next building. Otherwise, process goes to next step.
4) To calculate the overlapped area between building X and the searched polygons.
5) If the overlapped area is smaller than 80 percent of building X's, building X is also taken as a candidate of disappeared building. Otherwise, building X is looked as unchanged. If all buildings in working area are checked, process goes to step 6). Otherwise, process return to step 1) for next building.
6) To confirm the marked candidates manually.
7) To update GIS database.

With the similar procedure, new-built buildings can also be detected.

Fig. 6 Geo-change detection with "overlapping"

3.2 Local and Dynamic Revision

Many types of data from ground-based sensors, digital camera, and administrative materials can be used for the purpose of dynamic database revision.

3.2.1 Administrative Data. As a useful data source, administrative data will be widely applied for database revision in future. It is because:

1) In order for quick response to disasters like fires and other emergency circumstances as well as efficient facility management (FM), more and more change information respect to man-made objects (e.g. buildings and roads etc.) will be collected by national and local governments.
2) Traditional sheet based management will be shifted to digital base.

3.2.3 Integrated Systems. Laser range data and TLS (Three Line Sensor) images are significant potential data source for database revision. One can easily derive 3D information from laser range data, while one can get high accurate texture images from three angles. With the integration of laser range data and TLS images, 3D city model (cyber city) can be easily reconstructed. In this case, to update database in 3D-base is also possible.

A TLS system with accuracy 10 cm on ground is now under developing in Japan. Fig. 7 gives a set of sample images of TLS taking from forward, middle and behind (provided by C-STAR Corp.). Because the ground resolution is very high, the TLS images integrated with laser range data may potentially be used for urban 3D city model reconstruction and revision, road database revision, urban facility management database revision, and other application domains.

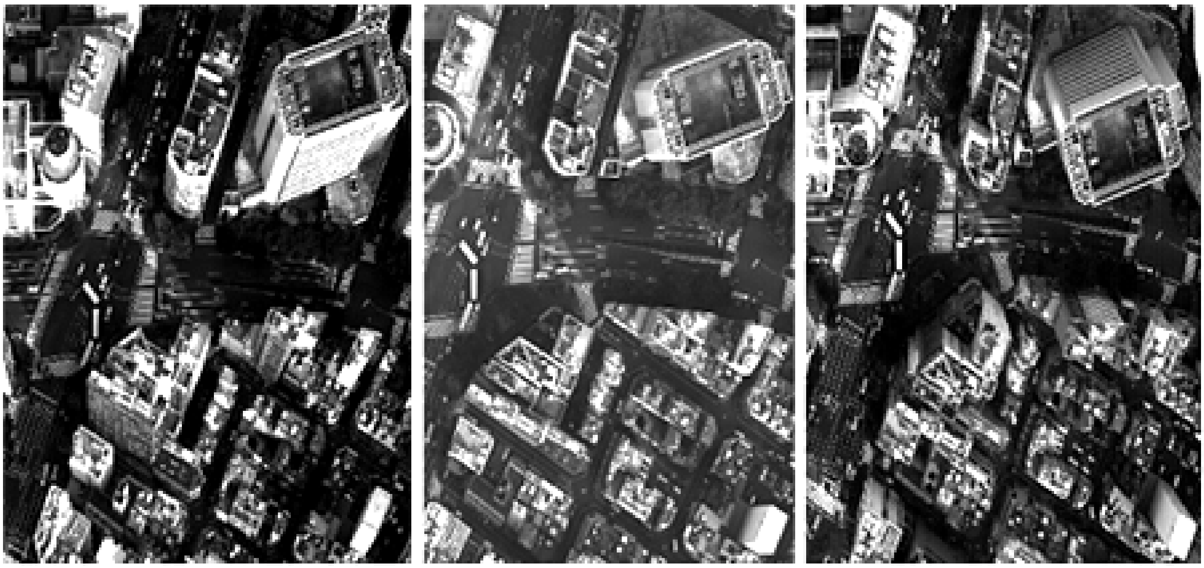


Fig.7 Sample of TLS images from three different view angles (left, middle, right)

4 CONCLUSIONS

In this paper, the difficulties and problems in GIS database revision were analyzed. We believe that types of data sets should be integrated in order for realizing so-called dynamic revision although there are still many unsolved problems in data fusion or data integration. In near future, besides the aerial photograph, laser range data, CCD images, TLS images and administrative information will be widely used for dynamic urban GIS database revision in local area. 1-meter level high-resolution satellite imagery may be a good candidate for road network database revision, but it is still not detailed enough for updating city database such as building database.

Anyway, as the increasing of digital products, database revision will be one of the most important topics in both scientific research and commercial software development in the next decade. Efforts will be focused on developing new devices like integrated TLS system and techniques like web-based on-line updating method.

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