INTEGRATED APPLICATION OF GEO-TECHNIQUES FOR DATABASE UPDATING STUDIES

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ABSTRACT

The main objective of this study was to develop an approach to make GIS and GPS integration available for database updating studies. Several issues were addressed in this paper. These include the review of concepts of GPS and GIS, data modelling, map updating and the analysis of the methods applied.
The rapid changes in topographic data within the development areas call for fast and precise method of updating the existing database for temporal study purposes. Continuous monitoring of these changes provides an opportunity for government/organisations to project the future demands of current data based on past trends and experiences.
The paper elaborates requirements on spatial data for database updating studies. The spatial data is viewed in the context of updating GIS technology Along with GIS, the integration with GPS has twofold tasks that were addressed: the conversion of output files from GPS format to GIS formats particularly ILWIS (pnt files); and conversion of attribute tables from GIS format to ILWIS attribute format (tbl).
In the practical observations, the use of GPS seems to be the most appropriate solution to quickly and efficiently survey map features. The use of this facility in carrier phase measurement mode has the potential to provide the continuos location of any point to an accuracy in the range of few millimetres. However, it is recognised that GPS alone is not a complete solution to the mapping task. The limitations of GPS in built up areas due to multi-path effects and other sources of errors require additional data acquisition methods.
Another aspect of this paper was to formulate procedures for a consistent automated updating of a database using GPS. In geoinformation production, it is important that the accuracy and currency of data should be reliable such that the purpose for setting up the database can be fulfilled with profitable cost recovery. GPS has proven to be potential in this respect.
Although geo-information updating includes change detection, data collection, and database updating, the focus in the paper was on automated database/map updating during data collection. Several techniques in GPS including stop and go method (semi-kinematic positioning) and real time method were applied. These methods indicate the possibility of automation of database updating during field observation or post processing.

1 ASPECTS OF UPDATING TOPOGRAPHIC DATABASES

Most developing countries witness a rapid expansion of their towns and cities due to population increase in those areas. Large impact comes especially from the change of features in unplanned areas. Entities appear, progress through various changes that can be sudden or gradual, and then may disappear over time (e.g. see for an elaboration on change and event types: Peuquet, 1999). This calls for rapid and efficient revision methods that assess the actuality of existing topographic databases and address updating procedures to include the changes in spatial objects in time.
This updating process should review all aspects of data quality - lineage, positional accuracy, attribute accuracy, completeness, and logical consistency - but the data currency, a subset of lineage, is the most important in this perspective: data currency information can help to deduce the actuality of a database. For instance, information on both the collection date and the date of the last database updating process can tell if the database should be regarded as up-to-date or needs updating. Lack of this information is emphasised by many authors as a serious cause of misinterpretation (e.g. Robinson et al., 1995). Since terrain objects represented by a topographic database do not have to be static in time, the actuality of the database is a very important aspect for the development of GIS-applications that use these data. New objects may appear, others may disappear, again other objects change their attribute labels (new function of buildings, new road class as a consequence of road improvement). A topographic database should respond to these object dynamics through consistent updating. It denotes operations that lead to:

- The insertion of new spatial objects into the database.
- The modification of existing attribute tables by incorporating temporal issues in the database.

- Storage issues of the old and the updated data – the old data have to be retrievable for historical referencing and facilitating temporal queries.

Updating of geo-information has evolved from simple graphic map revision using analogue methods and equipment through digital map revision with aid of computer hardware and software with intensive involvement of the human operator (Kufoniyi, 1995). Technological advancements have replaced most of purely human operations into computer-aided operations. An ambitious goal is to be able to update a structured database in GIS purely by automated processes, but at the moment full automation is confined to the research and development domain. Researchers on change detection have studied several methods, including superimposition techniques and image processing and analysis. Jensen (1996) outlined the general steps used to perform digital change detection using remote sensing data. Information about changes in the terrain can also be obtained from local knowledge i.e. from people and agencies involved in building constructions. The changes can be extracted manually or by means of photogrammetry (mono or stereo), image processing, screen digitising or field surveys. This paper will further elaborate on the updating process based on GPS-surveys.

2 DATABASE STRUCTURES

An appropriate database structure, or logical data model, is required to organise the data for storage and retrieval in the computer after developing (or selecting) the most appropriate data model. Three main kinds of database structures were commonly recognised (Burrough, 1986; Date, 1990). These are network, hierarchic, and relational database structure. The structure of the database describes how the data is organised for retrieval and storage.

2.1 Structure of Enschede database

The topographic and cadastral database from the Enschede municipality (The Netherlands) in the Data Exchange Format (DXF) was used in this study. The topographic data contained the green areas, trees, roads, buildings, boundary, and water layers representing topographic features. The Dutch cadastre is a parcel-based system. The cadastral data supplied by the municipality of Enschede consists of cadastral parcels and the attribute information. The attribute data consists of three files in Dbase IV format named Enskad.dbf, Building.dbf, and Kadbuild.dbf.

The Enschede database is available in vector and raster formats. It is a relational database. The oblique photograph of Enschede was used to compare the features that are missing in the vector database. The selected area of study was that around the ITC building. In the vector map, the features included are buildings, green, topography, water, and roads. Likewise in raster map, the features include buildings, roads, parking areas, streets, and contours. The vector map was used to update the missing features by importing the converted data to ILWIS format. The point and linear features were considered in the updating process. The attribute tables also were joined and linked with the point features

2.2 General remarks on the existing Enschede database

The existing database has some limitations for the relational database in entering temporal information. The updating of this database should focus on the three basic elements of time i.e. history/past, present, and future. The framework should retain past versions of data so that information is available for historical or process studies. Access to past versions is necessary to support historic thematic data that are registered to the framework and time-based studies essential in many applications. The storage of past and present database can be solved by:

- Store all data in one file, i.e. history/past, present, and future data. This will increase the data volume (because of redundant data) and decrease the system response/data access time.
- Store history/past data in a separate file and use join/mask (in ILWIS) functions to access the history data.

This strategy will improve the overall system performance in the long run. The join/mask functions are required to make queries about past and future.

The general procedure for geo-information updating is beyond the scope of this paper. In short, this includes applying several techniques in extracting new information and adding new semantic information. This should be done parallel with incorporating temporal information. However, the GPS technique has proved to be the faster and accurate to extract new information to update the database.

3 BASIC CONCEPTS OF GPS

GPS provides specially coded satellite signals that can be processed in a GPS receiver, enabling the receiver to compute position, velocity and time. Four GPS satellite signals are used to compute positions in three dimensions and the time offset in the receiver clock.

Space Segment consists of the GPS satellites. The nominal GPS Operational Constellation consists of 24 satellites that orbit the earth in 12 hours. There are six orbital planes equally spaced (60 degrees apart), and inclined at about fifty-five degrees with respect to the equatorial plane.

Control Segment consists of a system of tracking stations located around the world.

User Segment consists of the GPS receivers and the user community (military and civilian users). GPS receivers convert SV signals into position, velocity, and time estimates. Four satellites are required to compute the four dimensions of X, Y, Z (position) and Time. GPS receivers are used for navigation, positioning, time dissemination, and other research.

Position in XYZ is converted within the receiver to geodetic latitude, longitude and height above the ellipsoid. Conversion of Geodetic co-ordinates to ECEF XYZ Coordinate are usually provided in the geodetic datum on which GPS is based (WGS-84). Receivers can often be set to convert to other user-required datum. Time is computed in SV.

Transmitted signals are centred on two microwave radio frequencies 1575.42MHz, referred to as Link 1, or simply L1; and 1227.60 MHz, referred to as L2. The signals lie in the L-band which starts just above the frequencies used by cellular telephones (Sharif, 1998). There are receivers using the precision (P) code and/or coarse/acquisition (C/A) code. Most of the receivers used in high precision surveying measure the carrier phase of L1 and L2.

User Equivalent Range Error (UERE) or *User Range Error* (URE) is calculated as the root-mean-square error of the independent error sources contributing to the pseudo-range error. For C/A code receivers, this value is typically 25 metres. The total UERE is not the error in the position determination by GPS receiver; it is only a measure of the error in the distance to one of the GPS satellites.

Geometric Dilution of Precision (GDOP) is a mathematical function involving the co-ordinates of the GPS receiver and the satellites for an epoch. GDOP will change as the GPS satellites change position in the sky, the smaller the GDOP the better the certainty in the solution of the co-ordinates of the receiver. Typically, the GDOP is between 2 to 8, which is multiplied by URE, to define the accuracy of the positioning.

3.1 Observation techniques in GPS

The selection of the observation technique in a GPS survey depends upon the project's particular requirement; especially the desired accuracy plays a dominant role. When using a single receiver, only single point positioning with code pseudoranges makes sense. The C/A-code has unlimited access provided by the Standard Positioning Service (SPS) and that the accuracy can be deliberately degraded by turning on selective availability (SA). The Precise Positioning Service (PPS) offers access to both codes but is limited to authorized users when the system is declared operational and anti-spoofing (A-S) or encryption of the P-code will be invoked (Hofmann-Wellenhof, et al, 1993).

Static surveying method is the most commonly used since the only basic requirement is a relatively unobstructed view of the sky for the occupied point. Static surveys generally, require 60- to 120 minute observation periods (Hofmann-Wellenhof, 1993). However, this method also includes the shorter (e.g. 10-15 minute) observation wide-laning technique or rapid static surveying based on fast ambiguity resolution approach (cf Frei and Beutler, 1990).

Kinematic surveys require considerable reconnaissance since not only the occupied sites but also the route taken to travel between sites must be free of obstruction. This technique require that lock be maintained on four or more satellites throughout the entire survey (Hofmann-Wellenhof, 1993). The kinematic method is best suited for wide-open areas where there are few obstructions. The kinematic technique can be used to position a given receiver that is mounted on an all-terrain vehicle that travels across a given area in a series of cross section lines. It can also be used for most of traditional surveys such as topographic surveying and control surveying including the determination of photo-control points, detail surveying, engineering surveying, etc. (Tiberius, C., 1998).

Differential GPS (DGPS) requires two receivers. The first one is at a known location and is constantly recording the difference between its known position and the position received from each satellite. The data may be transmitted in real time or may be logged for post processing. These correction signals correct errors induced by SA, Satellite hardware, and ionospheric and tropospheric delays.
The second receiver is the mobile one, called the rover. It may use a separate data receiver to receive the corrections or it may log the data for post processing correction. Differential GPS can provide accuracy of better than a meter, but only if the corrections are made at a high enough rates.

Stop and go applications are simply based on two items. The first is to know the ambiguity and the second is to occupy the desired mark for a short while to take advantage of averaging. Lock is maintained between occupations to be able to use the already known ambiguity (Goad, 1996).

Real Time GPS Surveying is used to obtain the co-ordinates of points in the field as you survey. The term implies that the GPS data is being processed at the same time as it is being collected, albeit a fraction of time after the event. For this to take place, some reliable method of communication is required for transmitting and receiving the data between the control (reference) GPS receiver and the remote (roving) unit. A real time GPS reference station is set up comprising of a GPS receiver, Controller and radio modem. The reference station tracks the satellites computes its position, compares with the co-ordinates of the reference point, computes the corrections, and then transmits the correction data through the radio modem.
Any number of real-time rover units can use the reference station. A rover unit consists of a GPS receiver, Controller and radio modem. The rover unit receives data both from the GPS satellites directly and from the reference station through the radio modem. These two sets of data may then be processed together on the rover Controller giving a highly accurate position.
GPS surveying accuracy is affected by a number of errors, these are:
Selective Availability (SA), Ionosphere errors (upper atmospheric errors), Troposphere errors (lower atmospheric errors), Ephemeris errors (Satellite position errors), Satellite Clock errors, Multi-path errors (ghosts), Receiver errors

The accuracy requirements of GPS users are very different and vary between several hundred meters and centimetre level. A very large group of users is interested in real-time accuracy level of 1 – 10m (Hofmann-Wellenhof et al, 1994). This accuracy cannot be obtained in single point positioning mode, but can be achieved by DGPS. The accuracy of GPS positioning depends on two factors:
The accuracy of a single pseudorange measurement, expressed by the User Equivalent Range Error (UERE), or by the associated standard deviation. and The geometric configuration of the satellite (GDOP) used (Seeber)

4 GPS AS AN INFORMATION SOURCE OF DATA FOR GIS

For 20 years, the Global Positioning System has quietly changed the way the world looks at navigation, positioning and timing (GPS World, Dec., 1998). Many applications have been introduced in which GPS has become the prominent source of information. Following is the shortlist of applications;

- On farms, GPS guides agricultural equipment, helping farmers maximise yield by giving them the information they need to plant, grow and harvest crops. The same technology makes mining operations more productive, cutting down on needless excavation and minimises the impact on the environment.
- On roadways, railways and waterways, it pinpoints the precise location of trucks, trains and ships and their cargo, helping co-ordinate and verifies deliveries. In automobiles, GPS enables in-vehicle navigation systems to suggest alternative routes around traffic congestion.
- On shorelines throughout the world, differential GPS utilising marine radio beacons is rapidly setting the world's new standards for coastal and harbour navigation. On the open water, GPS performs a variety of functions, from finding the exact spot to locate an offshore oil platform to setting positions for new bridge piling to placing dredging barges precisely over an area to be deepened.
- In cities, GPS saves time and money on surveying and mapping projects, providing accurate, reliable information for customers in the public and private sectors. Time-consuming projects that once required surveying teams are now completed faster by just few people.

- In the skies, GPS guides a wide variety of aircraft. Space shuttle astronauts and commercial pilots alike use GPS systems to locate their position or determine the most efficient routes to their destinations saving time and money.
- All around us, in an increasingly wireless world, the timing signals from GPS satellites synchronise precise order in cellular, paging and broadcast network. Cellular telephone positioning using GPS time synchronisation is one of the techniques currently under development for vendors of personal communication services (Teunissen, 1998)
- Importance of GPS also in life serving. When seconds spell the difference between life and death, police and fire departments, as well as ambulance services, rely on GPS automatic vehicle location systems. GPS show dispatchers the precise, real-time location and status of their vehicle, allowing them to immediately send the closest available unit to an emergency (Trimble, GPS World, 1998).

5 GPS IN DATABASE UPDATING

The use of Global Positioning System (GPS) today is becoming widely accepted throughout the surveying community. Originally, the use of GPS evolved around control and high accuracy geodetic surveying. The adoption of GPS for various survey applications has followed. This type of use of GPS resulted from a number of fortuitous developments, of which differential GPS together with the application of the interferometric principle have probably been the most important. The civilian uses of the GPS are rapidly covering the whole spectrum of terrestrial, marine, aviation and space applications. The rate at which this is happening is breathtaking and hard to keep up with (in the early nineties, the ratio of military-civilian users was about 1:3, at the turn of the century it is estimated to be 1:17) (Teunissen, 1998).
Geography and GIS particularly, depend on the concept of location. Working with location seems to imply that one must organise and index space. GPS, then, gives people an easy method for both assigning and using absolute co-ordinates. Now, human can know their position (i.e. the co-ordinates that specify where they are); combined with map and/or GIS data they can know their locations (i.e. where they are with respect to objects around them) (Kennedy, 1996).
There are number of reasons that make GPS a primary source of data for GIS, namely;

Availability – In 1995, the U.S. Department of Defence (DoD), declared NAVSTAR to have final operational capability. DoD has committed itself to maintaining NAVSTAR's capability for civilians at a level specified by law for the foreseeable future at least in time of peace. Therefore, those with GPS receivers may locate their position anywhere on the Earth.

Accuracy – GPS allows the user to know position information with remarkable accuracy. GPS accuracy depends on equipment, time of observation, and position of satellites.

Easy to use – Anyone who can read co-ordinates and find the corresponding position on a map can use a GPS receiver. A single position so derived can be accurate according to the method applied.

6 GPS OBSERVATIONS

6.1 Data collection

Using satellite availability charts the data collection was carried out. The baseline used was very short and the initialization normally was 20 minutes and data collected at 1 second. In each day two sessions were observed followed by computations of the results.
As it has been mentioned earlier, the rapid changes in weather affected the planned observations even though each site was checked for satellite availability from sky plot. Also during the initialization, there was loss of satellites (being obstructed or below the cut off angle of 15 degrees) resulting into elongation of the duration of initialization.
In the Kinematic mode, the phase ambiguities were determined during initialization by different techniques. One was to start from a short known baseline, which allowed ambiguity resolution after a few observation epochs. Another was to perform static survey to determine the vector between the fixed point and the unknown starting point. For initialization in kinematics observations, the fixed receiver and the roving receiver were placed on fixed and known starting points for a few epochs of observation, Then the roving receiver was moved to different unknown points for which the co-ordinates were desired. In order to achieve a high degree of accuracy, both receivers continuously tracked four or more satellites (with low PDOP).

6.2 Data processing.

To transform the GPS solution (WGS84 co-ordinates) into the existing national grid co-ordinates, the 7 parameter transformation is used, and the transformation parameters were determined using four common points of the two systems located around the ITC building. Having determined the transformation parameters, the GPS co-ordinate system (ECEF X, Y, Z) were transformed to local system of Netherlands (Rijks Driehoeksmeting).

6.3 Conversion of output data

The conversion of output file in GPS observations after processing in the SKI software is the co-ordinates in the WGS84 which are earth centred earth fixed X,Y,Z. The predetermined transformation parameters are used to transform the output file into any local co-ordinate system.

6.4 Conversion of attribute table

Attribute table is created in the codelist manager before fieldwork. The attributes are associated with the points measured in the field. The conversion of attribute table is done from codelist manager by first extracting a codelist from the field and the conversion is done from codelist to IDEX. IDEX format defines the entire codes and attribute name as defined in the field and enables the table to be converted to any desired format. The attribute file in IDEX format and output file (point data) are then converted through an interface.

6.5 Conversion Program

This is an object-oriented language representing the attributes and operations of objects. The workbench is the visual interface for C++ compiler, linker, debugger, and other tools used to create, manage and maintain the programs. This program was used to convert both point data files and attributes tables from SKI software and codelist manager respectively to ILWIS format.

6.6 A Graphic User Interface

Establishing the graphic user interface (GUI) in this program provides the link between users and ILWIS. The GUI has two components:
To convert the attribute table using the menu CHANGEDATA and user can select the data file from any directory where the data is stored.
To convert the point data file using the LINKDATA menu and the user can select the data file from the directory it is stored.
The interface has elements including window- that separate the screen into distinct area; pull-down lists, each of which provide the user with a list of options.

6.7 Results

3 methods were used in data collection; these are static, semikinematic and real time. These methods can fix greater number of points in the least time when compared to other methods. These methods are only suitable to open areas with less/no obstruction to satellite signals.
In real time processing, the user desires improved accuracy at the time the equipment is being used. In real time differential correction, the base station calculates, and using the radios, immediately broadcasts a correction message for each satellite as it receives the GPS data. This correction is broadcasted to roving receiver, which applies the correction to the position it is computing.

6.8 Analysis of the results

In static technique, the positional can be computed as:

$\sigma_x = \sqrt{\sum v_x^2 / n-1}$ Where σ_x is the standard deviation in X, (or in Y, or in Z)

$$\sigma_{pos} = \sqrt{\sum \sigma_z^2 + \sigma_y^2 + \sigma_z^2} = \sqrt{\sum 0.00002195} = 0.00468\text{m} \sim 5\text{mm}$$

7 UPDATING A TOPOGRAPHIC DATABASE

In geo-information production, currency of data (a subset of quality) plays a very important role, together with data quality (lineage, positional accuracy, attribute accuracy, completeness, and logical consistency), in the reliability of the information. In the preceding chapters, the data modelling and conversions of data to GIS format was dealt with. This chapter focuses on the maintenance of data currency, i.e. updating part of Enschede database. The ILWIS package was used to update the database. Database updating is an important aspect of GIS development because the terrain objects represented in the database are generally not static in time; thus the database should also respond to such objects dynamics through consistent updating.

7.1 Object dynamics and updating in vector maps

Updating of geo-information has evolved from simple graphic map revision using analogue methods and equipment through digital map revision with aid of computer hardware and software with intensive involvement of the human operator (Kufoniyi, 1995). Technological advancements have replaced most of human operations into automation. The goal is to be able to update a structured database in GIS (using ILWIS package) with a high degree of automation, but the automation is very confined to the research and development domain. This study aimed at contributing towards achieving that goal by describing the complete process for updating with a limited set of features.

Researchers on change detection have studied several methods; these include superimposition techniques and image processing and analysis. Jensen, (1996) outlined the general steps used to perform digital change detection using remote sensor data. The changes can be extracted manually or by means of photogrammetry (mono or stereo), image processing, screen digitising, field surveys, etc.

For the Enschede case study, the oblique photograph s 1761_20 in ILWIS format was used to compare the changes by visual inspection to the topographic map *entop and ITCTOP* (segment maps) also in ILWIS format. The focus of this research was to address the issues of extracting new information using field survey (GPS measurements) and database updating.

7.2 Updating of the Enschede database

Database updating aspects involve topological editing and consistency enforcement. It denotes an operation that leads to the insertion of new data into the database, as well as the modification of some existing

Having detected the changed features (using oblique photograph), the GPS measurement was carried out. To this end two methods were applied, semikinematic and Stop 7 Go. The static method was applied for determination of transformation parameters. The adjustments and transformation of point data is done in SKI software and the output file is converted to ILWIS format. Point and linear features were considered, however, area features can be measured as well. After conversions of point data and attribute tables into ILWIS format, they were imported and linked together for display.

The cadastral map of Enschede was displayed with the new features (point features). The new ITC building does not appear in the map. The topographic map of Enschede (ITCTOP) when overlaid with the cadastral map (ITCKAD), the ITC building appears together with added point features.

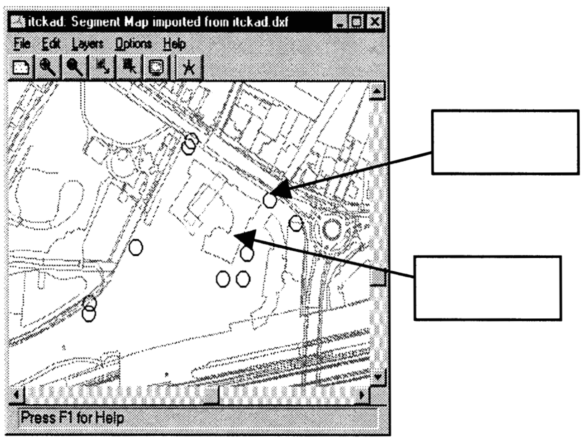

Figure 1 Cadastral map, point map, and topographic map overlay.

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