GIS Mapping with SiReNT Real-time Differential GPS

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ABSTRACT

Accurate and up-to-date GIS (Geographical Information System) data is essential for decision-making and resource management. To ensure the high reliability of the GIS data, a systematic GIS mapping process has to be implemented for spatial data capturing and updating. An effective and accurate mapping tool is the key to a good GIS system.

The GPS (Global Positioning System) is a worldwide satellite-based positioning (location determination) system. The system provides three-dimensional position, velocity and time information under all weather conditions 24-hours a day. The introduction of DGPS (Differential GPS) technique improves the positioning and mapping accuracy down to sub-meter.

The Singapore Land Authority (SLA) has launched a new GPS reference station network infrastructure in September 2006. The infrastructure, known as the Singapore Satellite Positioning Reference Network (SiReNT) is a nation-wide infrastructure developed to support various DGPS positioning techniques. The system serves as the national reference frame, provides homogeneous geographical coordinates system for land surveying, mapping, navigation and other positioning applications in Singapore. With SiReNT, the implementation of real-time DGPS for GIS mapping has become very simple and cost-effective.

This paper introduces the real-time DGPS technique using SiReNT and its application in GIS mapping.

BIOGRAPHY

Mr. Khoo is a Manager with the Survey Services of Singapore Land Authority (SLA). He received his Bachelor Degree in Surveying (Land) from the University Technology of Malaysia (UTM) and his Master of Engineering from the Nanyang Technological University (NTU). He is now working on his Ph.D. research on part-time basis in NTU. Prior to his appointment in SLA, he worked as an Associate Scientist in the Centre for Remote Imaging, Sensing and Processing (CRISP) and Research Associate in the School of Civil and Environmental Engineering, NTU.

INTRODUCTION

The Singapore Land Authority (SLA) has launched a new GPS reference station network infrastructure in September 2006. The infrastructure, known as the Singapore Satellite Positioning Reference Network (SiReNT) is a nation-wide infrastructure developed to support various DGPS positioning techniques. Besides the conventional usage of DGPS in surveying, mapping and GIS, SiReNT is designed as a fundamental infrastructure for all GPS positioning such as navigation, tracking, deformation monitoring etc.

The main objective of SiReNT is to support the new SVY21 cadastral survey system. Nevertheless, the system serves as the national reference frame, provides homogeneous geographical coordinates system for all land surveying, mapping, navigation and other positioning applications in Singapore. The homogeneous coordinate reference frame is essential in the development of National Spatial Data Infrastructure (NSDI) and ensures the accuracy and effectiveness of GIS analysis.

The tools available for GIS mapping were expensive, bulky in size and heavy in weight. The process of data collection was slow, difficult to learn and operate. But during the past few years, tremendous advances have taken place in GPS technology (receivers and reference station infrastructure), data collection hardware, and field data collection software. The hardware and software have become cheaper and easier to learn. In addition, for applications involving offsets, lower priced laser range finders have been become available. All of these advances have made the usage of GPS for GIS data collection tasks easier, faster and more economical.

Since the introduction of the SiReNT infrastructure, the DGPS technique was introduced as the tool for GIS data collection and general mapping work in SLA. The technique provides sub-meter positioning accuracy. A GIS mapping system using the integration of DGPS and laser ranging device was established to create a seamless workflow between the GPS field devices, GIS database and CAD drawings.

This paper is to outline the usage of SiReNT for GIS mapping and to highlight the integration of DGPS with laser ranging device and portable computer for field data collection. A simple field data collection test was carried out to illustrate the integration.

SiReNT CONFIGURATION

SiReNT network consists of 5 GPS reference stations, 4 located at the extreme corners and 1 in the centre of Singapore island. See Figure 1. The nucleus of the system is a Data Control Centre (DCC) located at the Singapore Government Data Centre; where the network reference station software and web servers are situated. The GPS data from the reference stations is transmitted directly to DCC for processing, archival and real-time dissemination. The network uses 256Kbps ADSL connection for communications link between reference stations to DCC. 56Kbps dial-up internet access is used as the back-up communications link. A remote access terminal was set up at the SLA for the administration and management of the DCC and all the GPS reference stations.

Each of the 5 GPS reference station is equipped with a set of dual-frequency GPS receiver and a choke-ring antenna that operates continuously. These GPS equipments are installed on the roof-top of buildings. The reference station also consists of other items such as batteries, temperature monitor, terminal server, cooling fans etc for communications and monitoring functions. All the other equipments and the GPS receivers are housed in weatherproof cabinet on the roof-top near the location of the antenna.

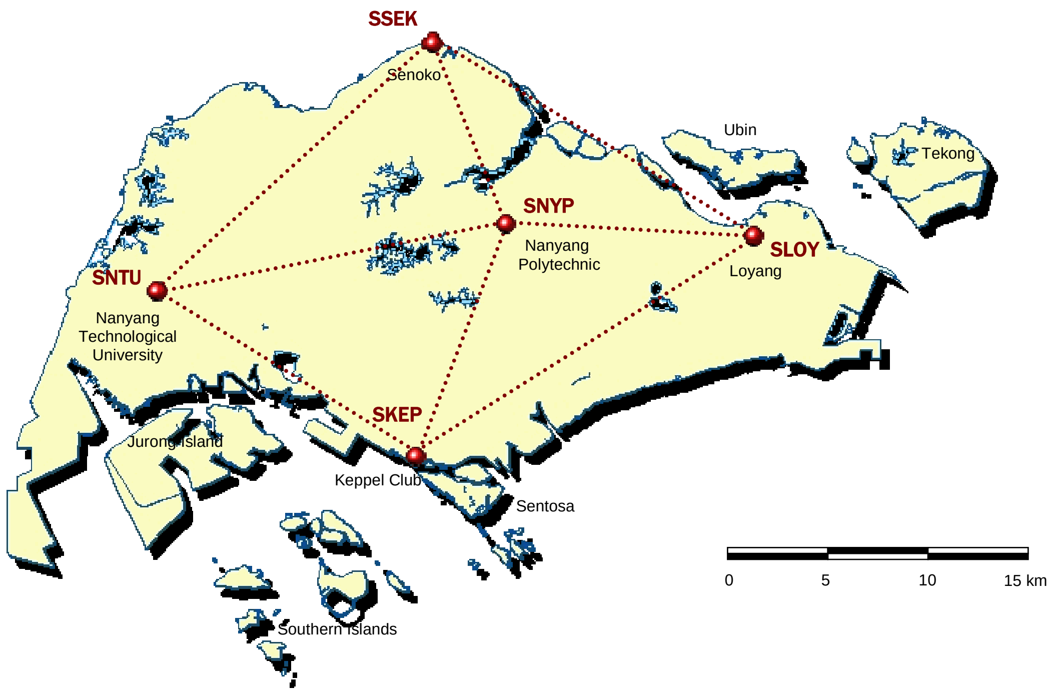

Figure 1: The 5 GPS reference station network configuration in SiReNT

SiReNT offers 3 standard services to meet various positioning needs and accuracy requirements:

- Post-processing (PP) service
- Real-time Kinematic (RTK) service (carrier phase)
- Differential GPS (DGPS) service (code)

For real-time applications of RTK and DGPS services, rover GPS receiver will be connected to SiReNT server via wireless Internet. The RTK service which provides centimetre-level accuracy is used by surveyor for engineering surveying. The DGPS service which provides sub-metre accuracy is suitable for GIS mapping and other kinematic positioning.

For Post-Processing (PP) service users generate and download RINEX (Receiver INdependent EXchange) data via SiReNT web site. The PP service is mainly used to establish survey control points for various purposes. Currently, the Integrated Survey Network (ISN) points used particularly for cadastral survey are established using PP method.

SiReNT system adopts the leading-edge technology of Network-DGPS (Differential GPS) both for Real-Time Kinematic (RTK) and code-based DGPS technique. Network-DGPS is an improvement over the conventional DGPS method based on single-reference-station. The principle of Network-DGPS is that a significant portion of ionospheric, troposheric and ephemeris errors are estimated over a region and this information is provided to rovers GPS receivers in the field. SiReNT makes use of the network software, GPSNet from Trimble Terrasat GmbH at the Data Control Centre (DCC) which supports the Virtual Reference Station (VRS) technique. The GPSNet software performs continuous computation of the following parameters by analyzing double difference carrier observations:

- Ionospheric errors
- Tropospheric errors
- Ephemeris errors
- Carrier phase ambiguities for L1 and L2.

Using these parameters GPSNet software will provide all GPS data and interpolate to an estimated position of the rover, which may be at any location within the reference station network. This estimated position of rover provides a very short baseline for the positioning solution, which reduces systematic errors for RTK considerably.

SiReNT also supports the conventional single-reference-station DGPS both for RTK and code-base DGPS techniques. The user has a choice to select the nearest reference station if he is working near to a reference station. Hence, it supports all types of GPS equipment including low-end DGPS receivers which is not network-DGPS ready.

Besides the standard services, SiReNT DGPS services can also be easily integrated into customised positioning products for other specialised applications such as land transportation, marine applications, structural monitoring, location base services etc.

Potential users can visit SiReNT web site at http://www.sirent.inlis.gov.sg to download the application form. Helpdesk is available to support users on technical issues related to SiReNT services and there is a customer handbook available for download to help the users get started.

SiReNT DGPS SERVICE

The DGPS service of SiReNT is provided via wireless internet using the NTRIP (Networked Transport of RTCM via Internet Protocol). NTRIP is based on Internet Radio technology for broadcasting of real-time DGPS correction data (RTCM) through IP. NTRIP is a generic, stateless protocol based on the Hypertext Transfer protocol HTTP/1.1. The NTRIP standard is meant to be an open none-proprietary protocol (bkg, 2007). Most of the GPS hardware and software developers (manufacturers) in the market have implemented NTRIP into their products. Table 1 shows some commercial software supporting NTRIP. The information is extracted from the BKG-NTRIP home page (Dammalage *et. al*, 2006).

Table 1: Some Commercial software supporting NTRIP protocol

ArcNTRIP	Galileo Sistemi, ArcPad GIS Data Collection Software, NTRIP Client
TerraSync Trimble	GIS Data Collection and Data Maintenance Software, NTRIP Client
SurveyController Trimble	Rover Control Software, NTRIPClient
GX1200 Leica	GPS Rover, NTRIPClient & Server
GSR2700 IS Sokkia	GPS Rover, NTRIPClient
TopSURV Topcon	Rover Control Software, NTRIPClient
EuroNet EuroNav	DGPS Network Processing Software, NTRIPClient & Server
EuroRef EuroNav	Reference Station Software, NTRIPClient

Once a user is connected to SiReNT DCC, the source table which consist of a list of available DGPS correction stream will be transmitted to the user. The user has a choice of 6 code-base DGPS data streams in RTCM 2.3 format; 1 correction stream from each reference station and 1 network-based DGPS stream from SiReNT.

A DGPS accuracy test was carried out to ascertain the accuracy of SiReNT. DGPS observations were carried out on 40 known points selected to be well spread evenly in the main island of Singapore. A total of 360 measurements were recorded. Taken together, anywhere in Singapore, SiReNT delivers DGPS positioning accuracy of 1m or better 90% of the time. The results are shown in Figure 2.

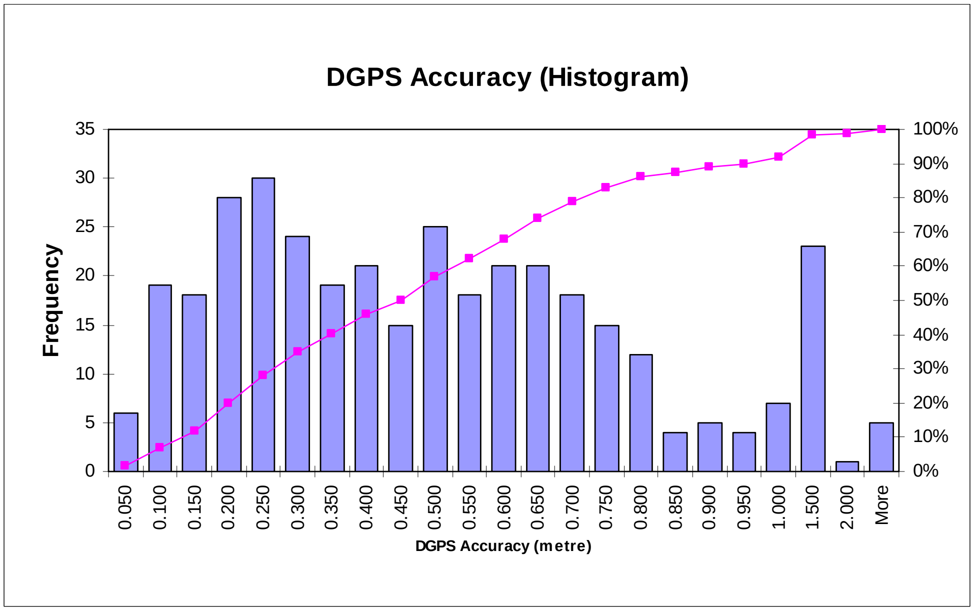

Figure 2: DGPS positioning accuracy achievable with SiReNT

GIS MAPING WITH SiReNT DGPS

In our urban environment, there are instances when the feature to be surveyed is located under trees, shelters or blocked by high-rise structures. Sometime, there is the need to occupy a point where it is difficult to reach due to various reasons such as high traffic volume etc. The performance of GPS is greatly affected in these conditions. In the worst case, positioning using only DGPS may not be possible at all. In some other cases, where many points are to be occupied, the requirement to occupy all points will slow down the process of mapping. In order to overcome these problems, a laser ranging device is integrated with the DGPS equipment for GIS mapping. The integrated system enables difficult to reach targets such as corners of buildings, trees with large canopy etc. to be easily pick up in the GIS mapping process.

The mapping grade laser ranging device provides an accuracy of about 5 cm to 1.5 meters. Maximum range varies from about 150 metre to 600 metre. It can be used in different ways depending on the application, for example, direct GPS integration, indirect GPS integration, or Independent Laser Mapping (Wadhwani, 2004).

The objective of this paper is to demonstrate the GIS mapping setup and procedures using SiReNT DGPS system in Singapore. The equipment and software used in the GIS mapping system are:

1. GPS Pathfinder ProXH receiver
2. Contour XLRic laser ranging device
3. Tablet PC

4. TerraSync software
5. GSM/GPRS card module

The GPS Pathfinder ProXH receiver is a GPS receiver designed specifically for GIS data collection. A GPS receiver, antenna, and all-day battery are integrated into one box. The all-in-one design of the ProXH receiver means it's simple to set up and easy to use. The Bluetooth wireless capability enables cable free connection between the ProXH receiver and field computer. The ProXH receiver is ready to be used with a variety of field computers, including laptops, tablet PCs and PDAs, and Trimble's own rugged handhelds, the Trimble Recon and Trimble Ranger handhelds. The receiver delivers sub-metre accuracy.

The Contour XLR is an integrated compass/inclinometer laser ranging device with the addition of Bluetooth wireless technology. With its integrated digital compass and inclinometer the Contour XLRic is the total package for mapping and rough surveying. The Class 1 eye safe laser range finder accurately measures the distance, bearing and inclination to the selected target without the need of using any reflectors. The built-in software functions can be used to calculate tree heights, slopes, areas, perimeters, missing line length, horizontal distances etc.

The TerraSync software is powerful field software, designed for fast and efficient data collection and maintenance to support mobile GIS. It accepts inputs and measurements from GPS receivers and laser ranging device. TerraSync has a few smart time-saving features such as pre-defined pick lists, waypoint navigation, map-centric operation, and graphical status display. It offers graphical navigation and real-time map display to help you navigate back to assets with ease. It is capable of displaying multiple background overlay images in the map screen; including satellite imagery, aerial photos etc. It works with various CAD and ESRI shapefiles.

All the devices communicate via Bluetooth connections that provide true wireless connectivity and simple data output flow from GPS equipment and laser ranging device to the tablet PC. Eliminating cables to Bluetooth enabled devices makes it less cumbersome to use and results in more productive fieldwork.

The process of field mapping starts with the connection to the SiReNT DCC to access DGPS corrections. First, the field surveyor logs on to the internet wirelessly using the GSM/GPRS card module attached to the PCMCIA slot of the tablet PC. After the internet connection is established, the TerraSync software that supports NTRIP is used to log into SiReNT server. The username and password for SiReNT access can be pre-configured in the software. The field surveyor can choose the correction streams available from any of the GPS reference stations. The choice of correction stream can also be pre-configured in the TerraSync. So, with a click of a button the connection can be enabled. The DGPS accuracy is achieved as soon as the SiReNT correction data is transmitted to the user. Figure 3 shows the TerraSync interface for NTRIP connection and the source table of SiReNT.

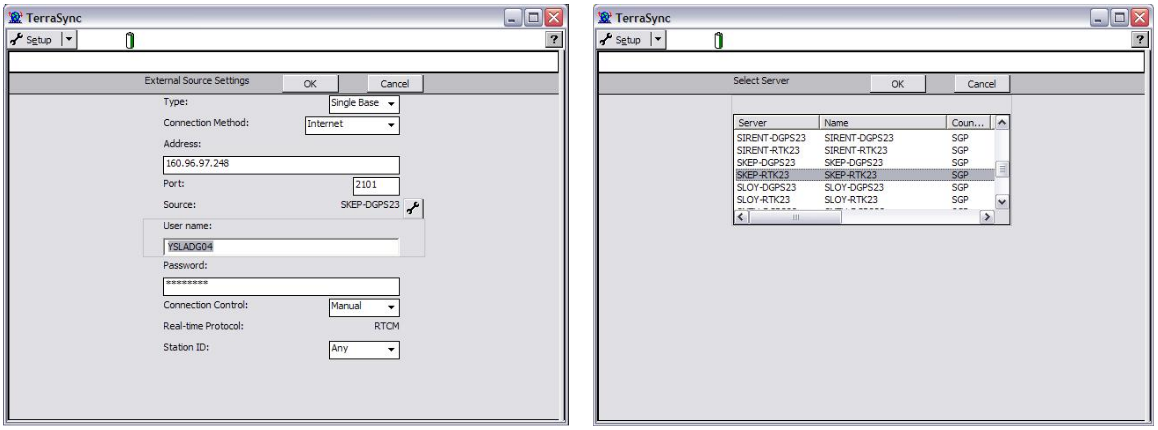

Figure 3: TerraSync interface for NTRIP connection and source table of SiReNT.

In the field mapping, the TerraSync software is also used in a tablet PC for the purpose of spatial and attributes data collection. The ProXH GPS receiver and the Contour XLRic laser ranging device are connected to the tablet PC via Bluetooth connections. The base map of the area under survey can be loaded in the tablet PC and displayed by TerraSync software. The base map helps the surveyor in the orientation of the site and provides a guide in the accuracy of the features mapped.

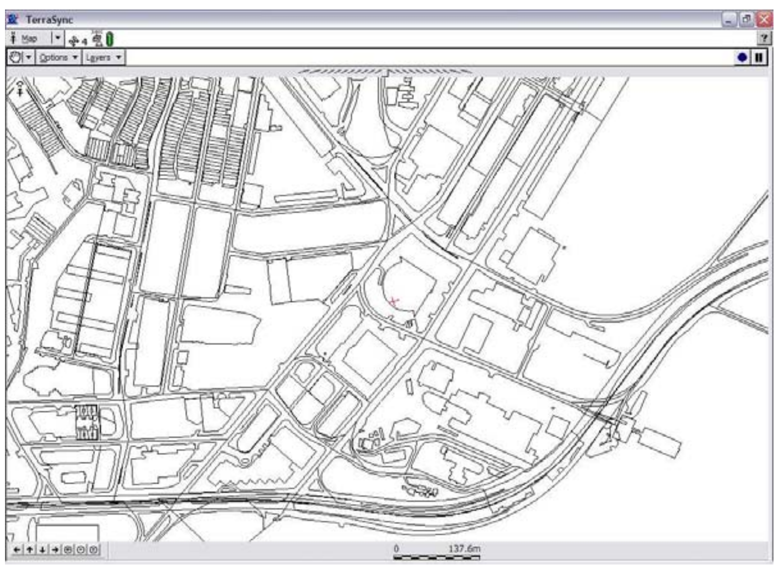

Figure 3: Base map supported by TerraSync.

The TerraSync supports a few offset techniques such as the distance-bearing, distance-distance, bearing-bearing etc. The DGPS provides the initial coordinates (control coordinates) and the laser ranging device measures the bearing and distance to the object of interest. The software derives the coordinates of the object and records the coordinates of the point. Lines and polygons is also supported by the software.

Figure 5: Surveyors conducting GIS mapping using the integrated method.

A field survey to demonstrate the integrated system was carried out in a HDB estate to illustrate the process of the GIS mapping. Features such as the sign boards, traffic lights, lamp posts, fire hydrant, post box, trees etc located at a road junction was mapped using this integrated system. Features which can be observed directly using the DGPS was surveyed directly. While those difficult to reach targets are surveyed using the combination of DGPS and the laser ranger. Figure 5 shows the surveyors conducting GIS mapping using the integrated method. The GIS data collected in TerraSync can be exported directly together with its attributes to shape file format. Figure 6 shows the features collected overlay on existing layers in ArcGIS.

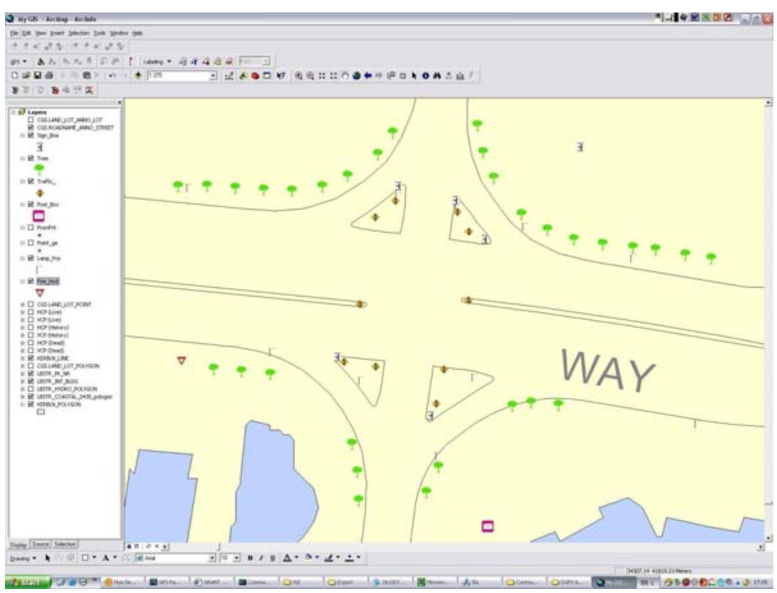

Figure 6: Features collected and overlay on existing layers in ArcGIS

CONCLUSIONS

The GIS mapping solution which combined the DGPS with the laser ranging device make GIS mapping possible in most conditions. DGPS with SiReNT increases the speed of GIS mapping, eliminating the need for surveyors to establish control marks and run traverses. With SiReNT, a user needs only one receiver to carry out DGPS positioning. It is estimated that the technique proposed is able to reduce 70% of the time needed for GIS mapping. The implementation of real-time DGPS for GIS mapping in Singapore has become very simple and cost-effective using SiReNT.

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