A PRELIMINARY STUDY ON THE PRACTICAL ISSUES IN USING RTK-GPS FOR 3D MAPPING

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SUMMARY

It is common that a geo-spatial model used for GIS analysis is a 2.5D model, i.e. a two-dimension base map plus a digital terrain model. However, with the introduction of 3D spatial analysis functions in many popular GIS software packages, such as line-of-sight analysis and visualization of 3D models, there is an increasing need of ground features contained in a base map be surveyed and stored in a 3D data format. In Hong Kong, the Survey and Mapping Office (SMO) of the Hong Kong Special Administrative Region Government, which is the base map provider in the territory, is aware of the need to produce 3D mapping data in future to cope with the demand from the GIS industry. SMO identifies that the Global Positioning System in Real Time Kinematic (RTK-GPS) is a suitable surveying method to capture 3D mapping data due to its proven accuracy and efficiency. Since this will be a new surveying activity in the office, it is necessary to review a number of practical issues before the official implementation of RTK-GPS for 3D mapping. The practical issues include accuracy requirements, operational procedures, quality checking methods and data format. Therefore, the writer made a preliminary study on these issues with reference to a topographic survey in which RTK-GPS was applied. The site surveyed had different common 3D features such as roads, buildings, open space and slopes. In this study, the survey data captured were processed and manipulated into a 3D format to form 3D models with a flythrough animation being an end product. Based on the results, the practical issues were reviewed to identify the critical aspects in 3D mapping. This paper will report the details of the study done.

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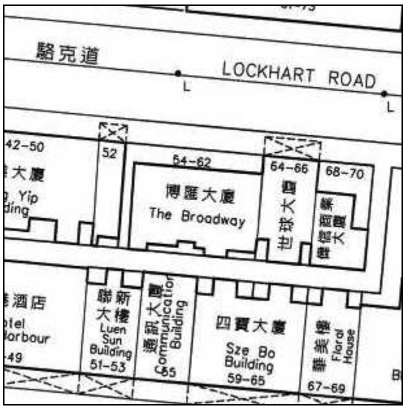
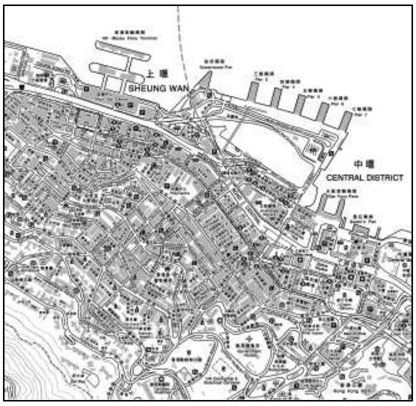
1. Introduction

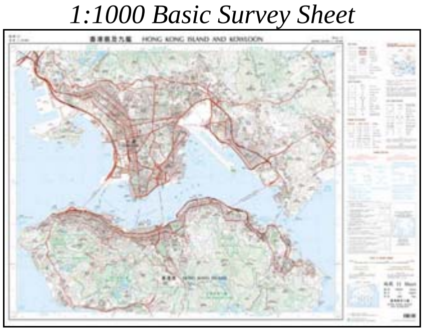
In Hong Kong, the Survey and Mapping Office (SMO) of the Hong Kong Special Administrative Region Government is the central authority for land surveying and all types of mapping in Hong Kong. One of the Office's major responsibilities is to maintain a comprehensive set of maps covering the whole Hong Kong in different scales in hard copy and digital form for land administration, town planning, engineering development, education, transportation, election, emergency and general use by the community. Some examples of SMO maps are shown in Diagram (1). The details of all the mapping products can be found at the SMO Homepage at http://www.landsd.gov.hk/mapping.



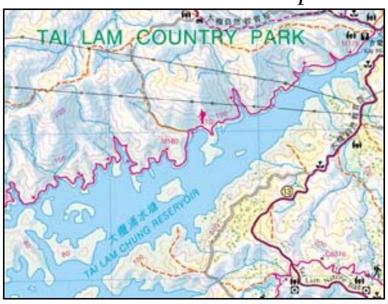
1:1000 Basic Survey Sheet



1:10000 Derived Map



1:20000 Topographic Map



1:20000 Country Side Map

Diagram (1): Examples of SMO Map Products

With the introduction of 3D spatial analysis functions, such as line-of-sight analysis and visualization of 3D models, in many popular GIS software packages, it is anticipated in SMO that there is an increasing need of 3D mapping data, i.e. the ground features contained in a base map are with X, Y, and Z coordinates. To capture 3D mapping data, use of Global

Positioning System in Real Time Kinematic mode, or so-called RTK-GPS, is identified to be a potential tool due to its proven accuracy and efficiency. Since this will be a new surveying activity in the office, it is required to review the practical issues before the official implementation of RTK-GPS for 3D mapping. In this connection, the writer has made a brief study on the practical issues, accuracy requirements, operational procedures, quality checking methods and data format and reported the findings in this paper.

2. Basic Mapping Data

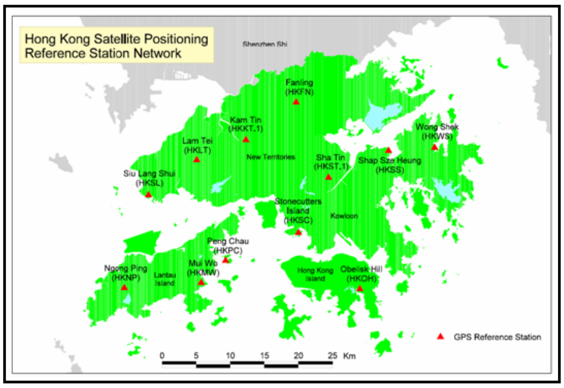
Out of the various map series, the 1:1000 basic survey sheet series is the largest scale topographic map widely used in the GIS community in Hong Kong. The ground features are mapped two dimensionally in the Hong Kong 1980 Grid coordinates and supplemented by spot heights and contours above the Hong Kong Principal Datum. The digital form of the 1:1000 basic survey sheets being used in GIS systems are available in the commonly used formats, namely ESRI E00, MicroStation DGN and AutoCAD DXF/DWG at UNIX and MS DOS platforms. However, since these sets of data are stored in a two-dimensional format, they do not support 3D GIS spatial analysis.

In SMO, there is a specification known as “1:1000 Basic Mapping Specifications” to promulgate the required survey and data standard. In general, the planimetric and vertical accuracy of these 1:1000 survey sheets are 0.2m and 0.3m respectively. Various surveying methods including photogrammetric surveying, tie measurements, total station and RTK-GPS are employed to survey the mapping data.

3. Use of RTK-GPS in SMO

An overview on the use of RTK-GPS for surveying in SMO is given as follows. SMO has employed the two well-known GPS modes, static GPS and Real Time Kinemaic (RTK-GPS), in land surveying work since 1993 and 1997 respectively. The former is used in establishment of survey controls and the latter is for picking up ground details. To enhance the GPS service, SMO has launched a GPS reference station network, so-called SatRef, in 2006. SatRef consists of 12 reference points located evenly in the Hong Kong territory such that there is at least one reference station within a 10 km range of distance from most places in Hong Kong. SatRef supports RTK-GPS by broadcasting RTK data to users via the GSM mobile telephone network. With the SatRef, a surveyor will save the effort in setting up a reference station near a site. Diagram (2) shows the locations of the 12 SatRef reference stations.

Using GPS for local measurements, it is required to convert measured WGS84 coordinates into the local coordinates (N, E, Ht.). A 7-P transformation model is available for Hong Kong. However, since the transformed height values have an error of 1 to 2 m due to lack of a precise local geoidal model, the transformation model is not acceptable for 1:1000 mapping. Recently, SMO has derived a two-step approach giving a height accuracy of about ±2 cm to fulfil the mapping applications. Simply speaking, it is to transform the WGS84 coordinates to the Hong Kong 1980 Grid coordinates for horizontal positions first; and then to interpolate the height value above the Hong Kong Principle Datum from the surrounding control points (with known height values in both systems). The project site should fall within the coverage of the control points to achieve a more reliable result. Diagram (3) shows the distribution of the available height control points in Hong Kong.



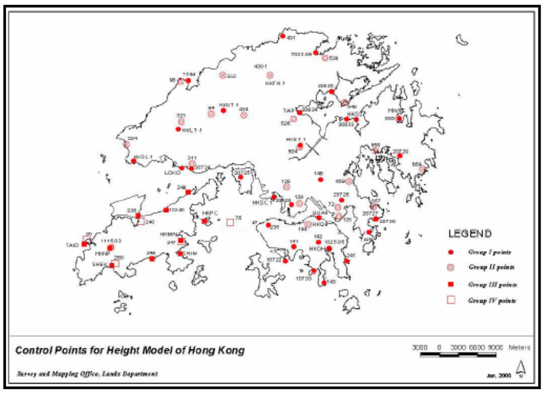


Diagram (2): Distribution of SatRef GPS Reference Station in Hong Kong (Left)
Diagram (3): Control Points for Height Model of Hong Kong (Right)

The field procedures of using RTK-GPS are very simple. With the SatRef, the surveyor will just need to bring a rover GPS equipment equipped with GSM modem and a measuring pole to the site. After connecting the rover GPS equipment to the SatRef via the GSM modem, the surveyor will use a measuring pole to pick up details. If the afore-mentioned transformation parameters for the 2-step approach have been input in the RTK-GPS equipment, the local coordinates can be obtained direct on site. As a quality measure to ensure that the GPS equipment is operating in order, the surveyor is required to pick up a point with known coordinates before and after the survey. Diagram (4) shows a surveyor working with a set of RTK-GPS equipment. The RTK-GPS equipment used in this study was Leica SR500 receivers.

Diagram (4): RTK-GPS Rover Equipment

The achievable survey accuracies of RTK-GPS are around ±3cm and ±10cm in horizontal and vertical positions respectively, which are obtained from the past studies done in SMO. Although they meet the required positional accuracies for the 1:1000 Basic Mapping Specifications, the surveyors are used to accept only the horizontal components of RTK-GPS measurements in a topographical survey. The spot levels are provided with an ordinary level or total station as an adopted practice. This practice should be changed in 3D mapping.

4. The Study

4.1. The Objectives

In this study, 3D mapping is defined as a survey activity to capture map features and store the surveyed data in a specified digital format for a 3D GIS system. 3D mapping data is in the form of (X,Y,Z) coordinates and thus RTK-GPS is identified as a potential tool. A topographic survey involving the use of RTK-GPS was selected for the study with the following objectives:

- To process survey data of mapping features into a 3D data format.
- To review the current operational procedures and data structures.
- To identify the practical issues requiring special attention in the implementation of 3D mapping

4.2. The Site

The site was situated near the Chek Lap Kok International Airport covering an extent of 400m * 500 m. It was a flat area with a carpark, buildings, flyovers and slopes in the site. Diagram (5) shows a panoramic view of the site.

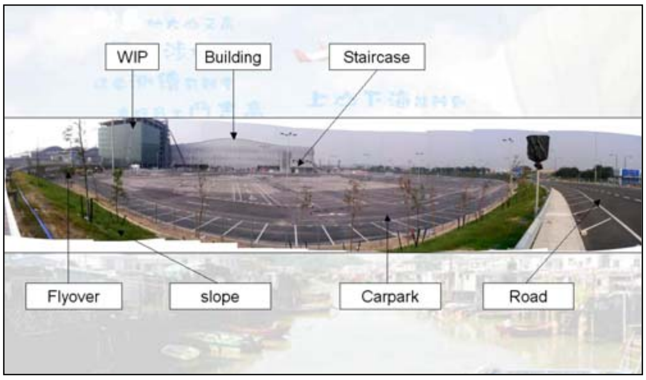


Diagram (5): Panoramic View of Project Site (Above)

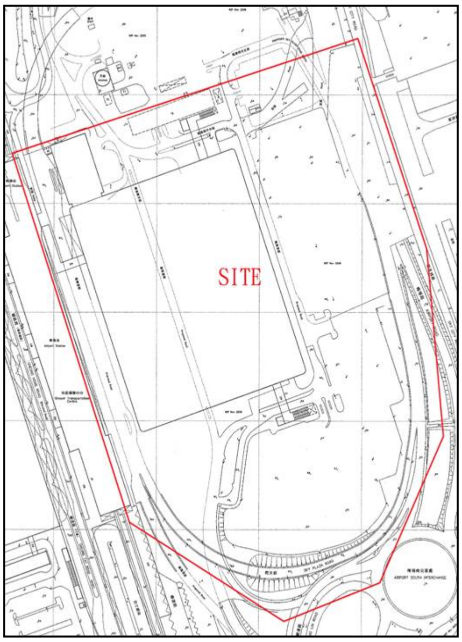


Diagram (6): Final Survey Plan of the Project Site (Right)

4.3. The Topographic Survey

The topographic survey was executed according to the Basic Mapping Specifications. The surveyor-in-charge selected both RTK-GPS and a total station to survey the required features. The former was for surveying the features with open-sky condition like the carpark, slopes and flyover. The latter was for establishing traverse stations and surveying spot levels and other obstructed features like buildings (roof top was not accessible) and roads under flyover. In summary, there were a total of 232 number of points surveyed by RTK-GPS, 402 number of points and 9 traverse stations by radiation method with total stations and the time spent was 5 days for field work and 4 days for office work. A survey plan produced is shown at Diagram (6).

4.4. Creating 3D Models

A number of 3D models of the mapping features were created using the survey data obtained from the topographic survey with 3D modelling software packages MicroStation and 3DS Viz.

Before creating 3D models, the survey data was processed to obtain the height values because they were required to be computed in the original survey. For RTK-GPS data, the 2-step transformation approach using existing height control points was applied; and a fixed signal height was assumed to reduce the height values to the ground point. For the data captured with a total station, the height values were assigned by adopting the nearby spot levels or other available height information. This method had introduced height errors, but it would not affect the study on the practical issues. Once the horizontal and height coordinates were available, the respective points were joined to form a polygon to represent a surface of the object. Then, the surfaces of the same object were merged to form a 3D model. For example, the house corners of a building were joined to form a polygon to represent a building façade and then the building facades were joined to form a 3D model to represent the building in the real world. This point-polygon-model approach for creating 3D models is a very time consuming process.

Afterward, the 3D models created were checked to ensure the quality. The items checked in this study were the positions, completeness, duplicating points, over/under-shooting points and face normal direction. They are the common items in checking GIS data. The existence of duplicating points or over/under-shootings will cause silver polygons. Diagram (7) shows examples of silver polygon and face normal errors.

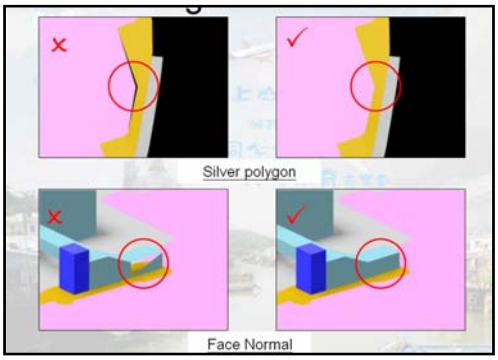


Diagram (7): Common 3D Model Errors

Finally, a flythrough animation for visualization purpose was produced with the 3D modelling software package as an end product in this study. In the flythrough animation, users could view the relative horizontal and vertical positions of the mapping features as they were on site. Some snap shots of the animation are shown in Diagram (8). Due to time constraint, the 3D data was not imported in other 3D GIS software for trial.

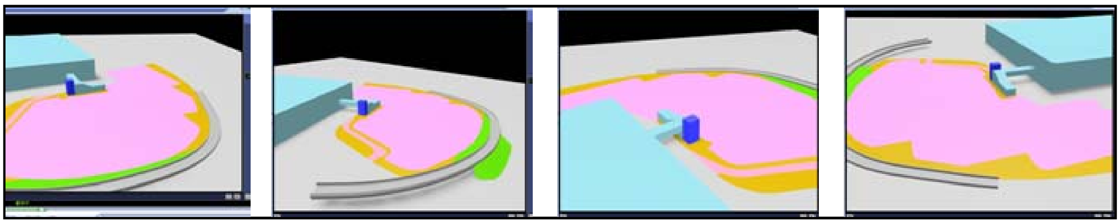


Diagram (8): Snapshots of Flythrough Animation

5. Observations on the Practical Issues for 3D Mapping

5.1. RTK-GPS

5.1.1. Accuracy

Four spot levels were adopted to check the height accuracy of RTK-GPS. The root-mean-square-error of the discrepancies was 8 cm, which achieved the expected vertical accuracy of ±10cm. The horizontal accuracy should be met due to its proven accuracy. It is believed that RTK-GPS can apply in 3D mapping for many local scale GIS projects.

5.1.2. Ease of Operation

RTK-GPS is an efficient and effective tool in capturing 3D mapping data with the support of SatRef due to its ease of operation. Other studies done in SMO also gave the same finding. However, users should note two limitations. The first one is the GPS signal obstruction problem. Other surveying methods should be used to supplement RTK-GPS when GPS signal is obstructed. The second one is the loss of GSM signal in some very remote areas. Under this situation, users will need to setup a reference station for the project site.

5.1.3. Transformation of Coordinates

The two-step approach should be adopted to transform WGS84 coordinates into local horizontal and height coordinates (N, E, Ht), which gives an error of about ±2cm. Users should note that height control points should surround the project site to achieve a more reliable result.

5.2. Field Survey for 3D Mapping

The existing 1:1000 Basic Mapping Specifications is required to be revised to tell the surveyor what types of vertical features to be surveyed and how to be surveyed. For example, the curved roof top of the building in Diagram (9) and the sloping surface of the footbridge in Diagram (10) are ignored in conventional 2D mapping, but they will be surveyed in 3D mapping. The density of points for an irregular shape such as the curved roof top should also be defined so that a realistic representation of an object will be given. In this study, this building was represented as a simple rectangular block due to lack of height information of the roof. Regarding the field procedures, the current practices are generally acceptable except that all height of signals should be recorded in 3D mapping.

Diagram (9): Representation of a Curved Roof Top
(Left: Survey Plan, Centre: Photo, Right: 3D model)

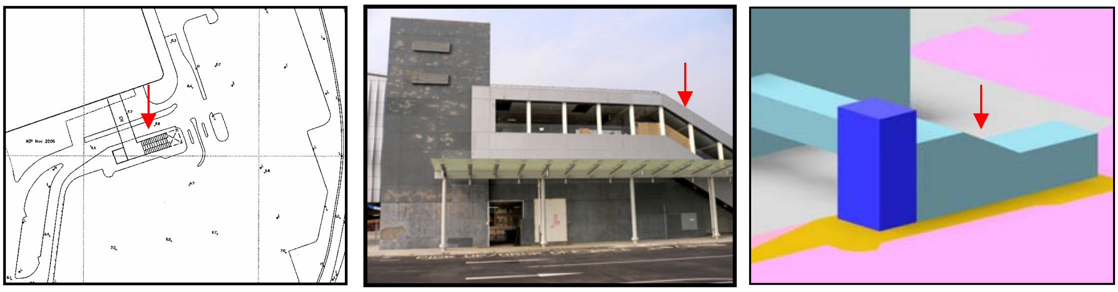


Diagram (10): Representation of a Sloping Surface of Footbridge
(Left: Survey Plan, Centre: Photo, Right: 3D model)

5.3. Creating 3D Models

5.3.1. <u>3D Data Format</u>

The existing format of the digital map data is designed for storing 2D data, so a new format is required. Besides, different 3D GIS software packages commonly have their propriety data formats. It means that the 3D model of a feature created in a software package will need to be re-manipulated and re-processed in another modelling software package before using it. The method for creating 3D model also depends on the software package in use. Thus, it is necessary for the office to select a suitable data format and software package to before the mass production of 3D model data.

5.3.2. <u>Quality Checking Mechanism</u>

Data quality checking is very important because the existence of errors will affect the accuracy of 3D spatial analysis. For example, an error existed in the height of buildings or a missing building will give a wrong answer in a line of sight analysis. The common checking items identified are position, completeness, duplicated points, point overshooting and face normal of 3D models. It is suggested that the first two items should be checked on site; and the others should be checked with a computer program to improve the efficiency and effectiveness.

5.3.3. 3D Model Products

Due to time constraint, only a flythrough animation was produced in this project for visualization purpose. It is found that flythrough is a quite impressive means to present a project to clients. However, other 3D GIS applications should also be explored in future.

5.3.4. Time Spent

Creating 3D models from the data points is a very labour intensive and time consuming process. It is noted that the time required depends on the complexity of objects, the number of feature points captured, the manpower, etc. The time and human resources are crucial factors to be considered in provision of 3D mapping for the GIS industry.

5.4. Staff Training

From the experience gained in this project, it is identified that the field operation procedures and the data manipulation processes for 3D mapping are new to the survey staff. Therefore, suitable training should be provided to let them familiarize with the details of the whole 3D mapping processes.

6. Conclusion

A brief study was carried out to investigate the practical issues in using RTK-GPS for 3D mapping and the objectives defined in paragraph 4.1 were achieved. It is found that RTK-GPS is a suitable surveying method in capturing 3D mapping data in terms of survey accuracy and effectiveness. It is also realized the surveyed data will need to be manipulated with a 2-step transformation for converting WGS84 coordinates into local coordinates and a point-polygon-model approach in creating 3D models. Furthermore, it is identified that a new survey specifications is required to standardize the accuracy, field survey operation, quality checking methods and data format. The time, human resources and training are crucial factors requiring attention in implementing a 3D mapping project. Since this is only a preliminary study, the above issues mentioned should be investigated in details before the implementation of 3D mapping.

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