Development of Land Based Mobile Mapping System using GPS and Close Range Photogrammetry Technique

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Abstract

The development of Mobile Mapping System (MMS) is still at initial stage in Malaysia. The research in MMS has been carried out quite awhile since the first prototype introduced by the Center of Mapping at The Ohio State University (Bossler et.al.,1991). This system integrates some navigation sensor such as Global Positioning System (GPS), inertial navigation system (INS) and mapping sensor such as Charge Coupled Device (CCD) camera. The strength of the MMS lays in their ability to directly georeferenced their mapping sensor by GPS. A mapping sensor is georeferenced when it is positioned and orientated relative to a known mapping coordinate frame. Once georeferenced, the mapping sensor can be used to determine the position of object points bases on the digital image in the same mapping coordinate frame. This research concentrates on georeferencing the geographic and topographic features and updating a GIS (*Geographic Information System*) base map using consumer digital camera and GPS positioning technique. The GPS provides the position of the camera and the images from the camera are used to determine the geodetic position of the object points using PhotoModeler software and developed program.

1.0 Introduction

The last two decades have shown an increased trend in the use of GPS technology in several applications in Malaysia which included land vehicles and automated car navigation, GPS-equipped KLIA limousines, land and marine survey job which currently applied in private sector and government sector such as the Department of Surveying and Mapping Malaysia, deformation monitoring and others.

The development of Mobile Mapping System (MMS) is still at initial stage in Malaysia. The research in MMS has been carried out quite awhile since the first prototype introduced by the Center of Mapping at The Ohio State University (Bossler et.al.,1991). This system integrates some navigation sensor such as Global Positioning System (GPS), inertial navigation system (INS) and mapping sensor such as Charge Coupled Device (CCD) camera.

The strength of the MMS lays in their ability to directly georeferenced their mapping sensor (i.e *digital camera*) by GPS. A mapping sensor is georeferenced when its position and orientation relative to a known mapping coordinate frame. Once georeferenced, the mapping sensor can be used to determine the positions of points external bases on the digital image in the same mapping coordinate frame.

This research is concentrates on mapping the geographic and topography features and updating map using a consumer digital camera and GPS positioning technique. The GPS provides the position of the digital camera and the images from the digital camera are used to determine the positions of the object of interest.

2.0 Literature Review

The mobile mapping technology has been developed since 1980's. The development of the mobile mapping system became possible due to the availability of GPS signal to the civilian community.

During the past year, tremendous advances have taken place in GPS technology especially the satellite receiver, data collection hardware and field data collection software. The autonomous GPS accuracy has been improved, the data collectors have become smaller, lighter, and less expensive. The GPS and GIS software has become cheaper and easier to learn. All of these advancements have made the GPS/GIS data collection tasks easier, faster and more economical.

Each GPS satellite transmits signal on two frequencies: L1 (1575.42 Mhz) and L2 (1227.60 Mhz). The L1 frequency contains the civilian Coarse Acquisition (C/A) Code as well as the military Precise (P) Code. The L2 frequency contains only P code. The P code is encrypted by the military- using a technique known as anti-spoofing and is only available to authorized personnel. The encrypted P code is referred to as the Y code. Civilian GPS receivers use the C/A code on the L1 frequency to compute positions, although high-end survey grade civilian receivers use the L1 and L2 frequencies' carrier waves directly. Military GPS receivers use the P (Y) Code on the both L1 and L2 frequencies to compute positions.

GPS receivers need at least three satellites for computation. Satellites position computation method is called triliteration. This position is accurate from about 10 to 15 meters. Now that selective availability, an intentional degradation of the satellites signals, has been turned off down to centimeters or less, depending on equipment and conditions.

It is important to understand that there are some amounts of uncertainties or errors, inherent in these positions. A number of factors that contribute to these errors, which included satellite clock drift, atmospheric conditions, measurement noise and multi-path. In addition, due to the satellite geometry, vertical accuracy (i.e elevation) is generally one and a half to three times worse than horizontal accuracy.

For close range photogrammetry, due to recent advances in micro-electronics and semiconductor technology, photogrammetry in general has received a substantial push forward towards the fully digital domain. The development of new sensors, such as solid state camera, and more powerful computer hardware has opened new technologies and fields of application. Hybrid and fully digital acquisition and processing system have triggered much interest among photogrammetrist since the 15th International Congress of Photogrammetry and Remote Sensing in Rio de Janeiro in 1984. Within ten years, digital close range photogrammetry has matured to the extent that it can now serve as a precise and reliable technique for non-contact three-dimensional measurement. The ease and speed of data acquisition, the inherent on-line and even real time capabilities, the high degree of automation and the adaptability to varying the requests have made it a viable measurement tool for a great number of different applications in science, art and industry. (Akinson,1996)

The position of a point in space is commonly defined by a three dimensional Cartesian coordinate system, the origin, scale and orientation of which can be arbitrarily defined. It is often necessary to convert between coordinates in systems having different origins, orientations and possibly scale (Akinson,1996). In other words, it is needed to define coordinate of points with reference to a coordinate datum related to features on the object itself, it may then necessary to define the points to a new datum.

MMS is capable of observing the objects at closer range, thus giving greater details. Land-based MMS uses digital cameras as imaging sensors. This was possible because of the much smaller camera-to-object distance in land-based MMS when compared to air-borne systems. The poor resolution of CCD chips meant that they could not used in aerial applications without noticeable accuracy degradation (El-Sheimy,1999). The use of digital camera is advantageous because they eliminate the requirement to scan photographs. Consequently they substantially reduce the period from raw data collection to extracted data dissemination.

MMS integrates navigation sensors and algorithms together with sensors that can be used to determine the positions of points remotely. All the sensors are rigidly mounted together on a platform. The navigation sensors are used to determine the position and orientation of the platform and the algorithms determine the position of points external to the platform. The sensors that are used for remote position determination are predominantly photographic sensors and thus they are typically referred to as imaging sensor (El-Shemy, 1999).

Land vehicle based mobile mapping systems result in, among others, a) close distances between the systems and the objects to be surveyed, b) no ground control and no triangulations across images exposed at different time, and c) completely digital processing. These systems are designed mainly for mapping purposes. Different approaches to the system design and implementation have been used. (R.Li,1999)

The strength of MMS lays in their ability to directly georeference their mapping sensors. A mapping sensor is georeference when its position and orientation relative to mapping coordinate frame is known. Once georeferenced, the mapping sensor can be used to determine the position of points external to the platform in the same mapping coordinate frame. The MMS is fundamentally different from the traditional indirect georeferencing where the position and orientation of the platform are determined using measurements made to control points. These control points are established through a field survey prior to or after the data acquisition. This is typically time consuming.(Joao Fernandos,C.Da Silva 2003)

The system operation can be divided into three components: raw data acquisition, georeferencing of the digital images, and 3D feature extraction. Data acquisition begins by supplying power to the system while it is stationary. The IMU uses this time to “warm up”, while the GPS receiver uses this time to resolve integer ambiguities. After this warm up period, which lasts several minutes, it’s then free to capture images of points or objects of interest - ensuring that each point or feature of interest is captured in at least two images.

Once the data collection is completed, the images and navigation data from the INS and GPS sensor are downloaded to a personal computer. Then the INS and GPS data is processed and the digital images are georeferenced using particular software. Finally, using photogrammetric principles, two or more georeferenced digital images, 2D and 3D positions of any point or object that is visible in two or more images can be determined.

3.0 System Configuration

The GPS antenna and camera are mounted on a roof rack of a van. The two GPS antenna are set parallel to 1 side of the vehicle to define the position and azimuth. The camera is located in the extension of the antenna. Figure 2 shows the system design.

In this study, the instrumentation used includes a digital camera (Kodak DC290) and Trimble GPS receiver. Also, a photogrammetry software for the close range photogrammetry known as PhotoModeler will be used. Matlab will be use for computer programming. Figure 3 shows the developed mobile mapping system in study area.

Figure 2: System Design

Figure 3: Developed Mobile Mapping System

3.1 Mapping sensor

Kodak DC290 zoom digital camera will be used in this research. The resolution of the camera is 1792 x 2100 mega pixels.

3.2 GPS Positioning

GPS Trimble 4800 is use in determine the position of the camera station. Stop And GO technique is applied to shorten the field measurement period. The data is process using TGO (Trimble Geomatic Office).

3.3 PhotoModeler

PhotoModeler is one of the close range photogrammetry software produces by Eos System. It is a windows program which is good in extract measurements and 3D models from photographs. By using a camera as an input device, the mapping scenes are captured. It then organizes the model building process as trace over photos on the screen.

To use PhotoModeler, one or more photographs of a scene or an object are taken. The photographs are displayed on screen and each photograph is mark with the mouse, tracing and tagging features of interest. PhotoModeler then combines the data and locates the marked features in three dimensions. The result is a 3D model that can be transferred to any graphics or CAD program. In this research, Photomodeler is used to determine the object position in local coordinate system.

3.4 Matlab

MATLAB is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numerical computation. It can also display information graphically. The photographs apply with photo coordinates are process using collinearity equation with MATLAB. The outputs of the program are object coordinates of the selected mapping object.

4.0 Camera Calibration

Before carrying out survey on sites, the camera calibration has to be performed. Camera calibration is the process of determining the characteristic of a camera so it can be used as a measurement device. Figure 4 shows the calibration grid provided in PhotoModeler which is projected on a blank wall. To obtain the required data of camera calibration, six or more photographs taken from different angles of a dense point grid are needed

Figure 4: Camera Calibration

6.0 Mathematical processing

Two GPS receivers provide the position for the cameras through some mathematical calculation.

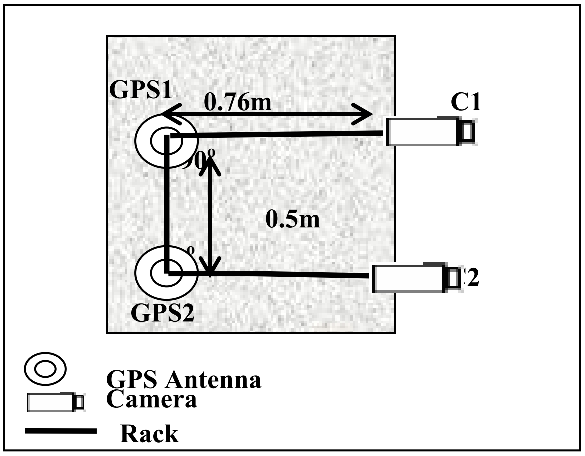

Figure 5: System Configuration

Figure 5 shows the derived GPS position for the cameras. Both cameras and GPS antenna are mounted on the roof rack of the vehicle. The cameras are set up perpendicular to the GPS antenna. The offset is 0.5meter apart. The positions of the GPS1 (N_{GPS1}, E_{GPS1}), GPS2 (N_{GPS2}, E_{GPS2}) are observed. The azimuth of the camera can be calculated as follows:

Azimuth C1 = Azimuth (GPS1 to GPS2) $- 90^0$ **(3.1)**
Azimuth C2 = Azimuth (GPS2 to GPS1) $+ 90^0$ **(3.2)**

The positions of the cameras can be calculated as:

Northing C1 = N_{GPS1}+ offset * cosine (Azimuth C1) **(3.3)**
Easting C1 = E_{GPS1}+ offset * sin (Azimuth C1) **(3.4)**
Northing C2 = N_{GPS2}+ offset * cosine (Azimuth C2) **(3.5)**
Easting C2 = E_{GPS2}+ offset * sin (Azimuth C2) **(3.6)**

7.0 Distance Test

A simulation test has been conducted on March, 2005, aiming to determine the effectiveness of PhotoModeler to provide accurate objects coordinate for longer distance. Two established known points were defined as control stations and the building are surveyed with total station. This simulation test was conducted at different distance of 5 meters, 10 meters, 15 meters and 20 meters between the cameras to the object (building).

Table 1: Accuracy Assessment of 10 meters

Check Point	Local Coordinate (Total Station) (m)		Local Coordinate (Integrate PhotoModeler and developed program) (m)		Different (m)		
	X	Y	X	Y	X	Y	X
P1	1000.31	1004.77	1000.51	1004.88	-0.14	-0.11	0.17
P2	1002.60	1004.44	1002.81	1004.48	-0.19	-0.05	0.24
P3	1001.23	1004.63	1001.42	1004.74	0.26	-0.10	0.27

Table 2: Accuracy Assessment of 15 meters

Check Point	Local Coordinate (Total Station) (m)		Local Coordinate (Integrate PhotoModeler and developed program) (m)		Different (m)		
	X	Y	X	Y	X	Y	X
P1	1000.31	1004.77	1000.17	1003.81	0.20	0.96	0.98
P2	1002.60	1004.44	1002.32	1003.50	0.29	0.96	0.97
P3	1001.23	1004.63	1001.01	1003.69	0.67	0.95	1.16

Table 3: Accuracy Assessment of 20 meters

Check Point	Local Coordinate (Total Station) (m)		Local Coordinate (Integrate PhotoModeler and developed program) (m)		Different (m)		
	X	Y	X	Y	X	Y	X
P1	1000.31	1004.77	1000.65	1005.95	-0.28	-1.18	1.21
P2	1002.60	1004.44	1003.07	1005.53	-0.66	-1.11	1.19
P3	1001.23	1004.63	1001.60	1005.79	-0.07	-1.05	1.15

The results showed that the greater the distance between the cameras to the object, the lower the accuracy can be obtained. The initial setup of this mobile mapping system was within 10 meters between the cameras to the object in order to obtain the accuracy below 1 meter for this mobile mapping system.

8.0 Updating Road Database

The data acquisition of study area was carried out on October, 2005. A road was chosen randomly in the study area, aiming to verify the accessible of the mobile mapping system in real world.The survey was carried out at Jalan Kebudayaan 26, Taman Universiti. The length of the road is approximately 40metres. The offset between the vehicle and the roadside is about 9 metres. Six GPS checkpoints were established along the road in order to verify the accuracy of the processed data. Figure 6 shows the image of the road. Table 4 shows the accuracy of the data set compared with the established checkpoints.

Figure 6: Image of Road Database Project

Table 4: Accuracy Assessment of Road Database

Check Point	Local Plane Coordinate (RSO)		Local Plane Coordinate (Integrate PhotoModeler and developed program) (RSO)		Different
	E (m)	N(m)	E (m)	N(m)	∆NE(m)
P1	625671.571	169997.453	625671.621	169997.459	0.05
P2	625674.363	169994.779	625674.413	169994.720	0.07
P3	625663.110	170005.525	625663.525	170005.439	0.42
P4	625665.969	170002.847	625666.399	170002.570	0.51
P5	625640.527	170027.063	625640.193	170027.405	0.47
P6	625643.346	170024.407	625643.210	170024.665	0.29

From Table 4, it was found that the accuracy of the mobile mapping system for updating the road network is within sub-meter. The factors that affect the non-stable accuracy might due to the tightness of the marked points during the processing, scale errors, resolution of the images, and others.After each successful processing, PhotoModeler generate a status report internally. The report includes various processing setting, overall status of the project, as well as specific information about significant 3D points. The report can be used to monitor various aspects of project's accuracy.

In this research, control point was not used and no sharp edges are available in the images for point marking on the objects. This may lead to the inconsistency in the accuracy for each set of processed images. Furthermore, the cameras were calibrated in the laboratory. Hence, the camera calibration parameters are not accurate compared to 'on-the job' camera calibration method.

9.0 Updating Infrastructure

The topographic details such as road network, lamp post, telephone booth, bus stop and road sign can be updated with the developed mobile mapping system.

Figure 7 shows the image of a road sign which is located in the study area. GPS checkpoints were established in the study area in order to verify the accuracy of the processed data. Table 5 shows the accuracy assessment of the road sign. The road sign was then plotted in the base map of the study area.

Figure 7: Image of Road Sign

Table 5: Accuracy Assessment of Road Sign

Check Point	Local Plane Coordinate (RSO)		Local Plane Coordinate (Integrate PhotoModeler and developed program) (RSO)		Different
	E (m)	N(m)	E (m)	N(m)	ΔNE(m)
CP1	626137.961	170085.374	626138.265	170086.272	0.94
CP2	626139.397	170086.870	626139.516	170087.881	0.94
CP3	626140.802	170085.648	626141.023	170086.747	1.12

Figure 8 shows the road sign that plotted in the base map. Figure 9 shows the comparison between the updated road sign and the existing road sign located in study area.

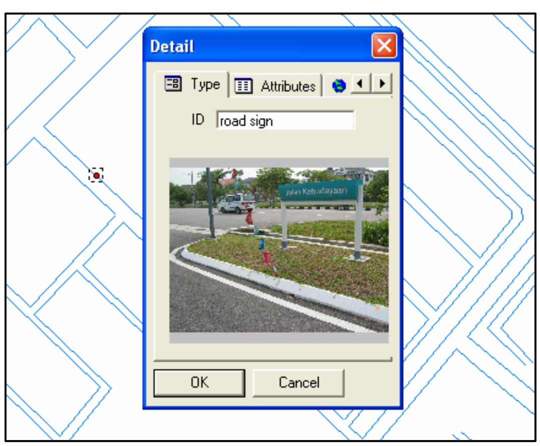

Figure 8: Road Sign in Base Map (scale 1:3900)

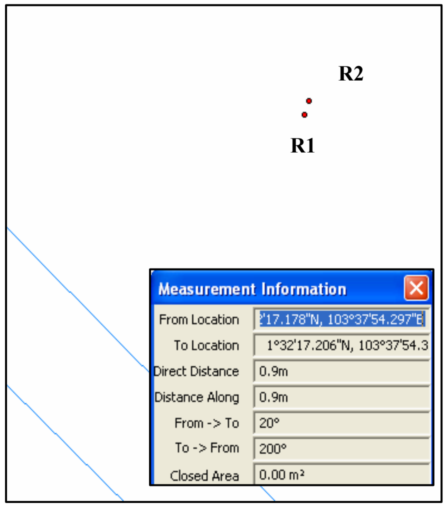

Figure 9: Qualitative Accuracy of Road Sign Project (scale 1:300)

Figure 9 shows the qualitative accuracy of road sign project. R1 is the observed coordinate using GPS. R2 is obtained from image processing. The distance between the two positions is measured. The distance is 0.9m.

10.0 Conclusion

Terrestrial photogammetry has become one of the standard technologies for mapping application. A mobile mapping system has been developed in this research. This system is comprises of a car, GPS receivers as navigation sensor and digital cameras as mapping sensor. In this research, the base map of study area – Taman Universiti was imported into ArcPad software. GPS checkpoints were established around the study area and plotted in the base map in order to verify the accuracy of the base map. The GPS check points are plotted accurately in the base map, and proved that the base map can be used in this research. The aim of this research is updating the GIS details in base map scale 1 in 10,000. The base map was altered for better view using zoom or pan function in ArcPad.

Data acquisition phase was carried out with the mapping vehicle and captured the images of the scene and object of interests. The Post-process Kinematic (PPK) observation technique was used. In this phase, the mapping vehicle is stopped for acquiring image of the object and position of the mapping vehicle is observed. Each stop is about 1 to 2 minutes. Additional image of the object was taken in different angle and position in order to have redundancy of images during processing. The image of features located in study area such as road, road sign, bus stop and building was captured and processed to identify the effectiveness of the developed mobile mapping system.

The digital images are processed using PhotoModeler software. PhotoModeler is good in modeling and generated the position of cameras and objects. The images of the object façade are imported to the software. Redundant images are needed in processing to get good accuracy. The object points are marked and referenced from images. Several step are needed to take care of the accuracy. The outputs generated from PhotoModeler are camera and object coordinates in local reference coordinate system. The results are export in text file (*.txt) format. There are three input files required for 2D transformation program. The input files are camera position from GPS, camera position and object position from PhotoModeler. The output of the program is the coordinates of the objects of interest. The coordinates of the features were plot in the base map for updating purpose.

In order to verify the effectiveness and accessibility of the developed MMS, some simulation tests have been carried out. The findings of the simulation test are as follows:

i. The camera-object distance need to be set within 10 meters to get high accuracy results (<1meter).
ii. The additional images are required at different angles and positions, in order to get redundant digital images during processing.
iii. Longer camera base line is required to determine accurate transformation parameter (refer to Chapter 5.3).
iv. Developed MMS can be used to update the topographic details such as building, road sign, lamp post, bus stop, road network and others.
v. The accuracy of the developed MMS is within 1meter.

These findings showcased the potential of the developed MMS in mapping and updating GIS base map. The accuracy of the developed system is within 1 meter which is acceptable for the base map of 1: 10,000 scale or larger scale. The scale 1: 10,000 means that 1mm in the map represents 10m on the ground. This research shows that the integration of the GPS, digital camera, PhotoModeler and 2D transformation program offer an efficient and economical solution for the developed mobile mapping system.

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