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Geographic Information System in Managing Flood Protection

Chugiat Wichiencharoen
Institute of Metropolitan Development
Navamindradhiraj University, Bangkok 10300, Thailand
E-mail : fsvcwc@gmail.com

Abstract

Geographic information system (GIS) is a very powerful tool in data preparation, management, manipulation, analysis and presentation. GIS is used in almost all applications. Quantum Geographic Information System or QGIS is free and open-source software. In this study, positions obtained from a mobile mapping system (MMS) were input to QGIS program to demonstrate how to manage flood protection. King Kaeo Road, a southern part of the King's Dyke in the east of Bangkok, was selected as an example for displaying the result of mobile mapping system (MMS) processing and analyzing the causes of inadequate satellite signals to compute the accurate (±5 centimeters) positions. Google map, Google satellite and OpenStreetMap were plug-in to QGIS program. From displayed map, points outside the King's dyke were eliminated and the gaps (of inaccurate positions) could be seen. To fill in small gaps caused by pedestrian overpasses, missing positions could be interpolated or approximated. Repeating MMS data collection at different satellite geometry could remedy the missing positions in some areas. The last recommendation to complete all needed positions along the dyke was to use a ground survey by differential and profile leveling. Using MMS to collect the data and QGIS to help analyzing the result was the most effective and rapid method to create the data base for managing flood protection.

Keywords : GIS; QGIS; Mobile mapping system; flood protection

Introduction

The event of 2011 Thailand flood in Chao Phraya basin caused severe damage to agriculture, industry, economy, society and impact to other regions. This event brought widely management plan for flood protection in the basin. Roads and their barriers were used as flood protecting dykes. Roads were resurfaced frequently, i.e. their heights changed. Wichiencharoen and Santitamnont (2020) [1] proposed to use a mobile mapping system (MMS) for collecting and processing such data, because MMS is the best system to easily and rapidly update the database whenever wanted.

Mobile Mapping System is a system to collect geo-information from mobile vehicles on ground, on water and in the air. System outputs include data for geographic information system (GIS), a digital map, geo-referencing images and videos. A system mainly consists of a Global Navigation Satellite System (GNSS) receiver and an inertial navigation system (INS) for geo-referencing positions of the vehicle [2, 3]. Other equipment on board includes photographic and video cameras, radar, laser, LiDAR and other remote sensing systems [4, 5] . Therefore, data collection and processing using MMS are suitable for flood protection planning because it is easy and fast to obtain heights and can be done at any time needed. The standard equipment installed in MMS is adequate to obtain high accurate heights.

Wichiencharoen and Santitamnont [1] used 3 areas for the study. These were (1) Uta-yarn Avenue in Taweewatana District, approximated 4 kilometers length, (2) Klong 10 to Klong 13 Roads in Patumtani, 30 km length, and (3) the King's Dyke in the east of Bangkok, 60 km length. The King's Dyke is the flood protection dyke of Bangkok. The study result was that it was possible to obtain heights at the accuracy level of ±5 centimeters, which was sufficiently accurate for planning flood protection. Guidelines to obtain heights as many points as possible at the required accuracy level were suggested at the end.

Geographic information system (GIS) is very powerful tool in data preparation, management, manipulation, analysis and presentation [6]. GIS is used in most applications including engineering, planning, management, transport and logistics, insurance, telecommunications, and business. GIS can be viewed as a digital map with details attached to coordinates/locations of interested features on the map.

Quantum Geographic Information System or QGIS is free and open-source software. Free means users do not pay any cost for using the software while they have to pay for commercial software. Open-source means computer coded languages are available so that users, who know the computer language such as C++, Python etc., can add-on or modify the program to their own needs. The first version: 1.0 Kore was posted in 2009. Since then users around the world have helped each other to develop new versions every day. QGIS version 3.10 A Coruna was used in this study, see [7] for a user's manual. Public information such as Google map, Google satellite, OpenStreetMap* can be plug-in to QGIS. Therefore, it is very convenient to the users because all of these data are up to date all the time. Google map and Google satellite are inserted as background of the map while OpenStreetMap can be considered as an attribute of a point.

Aims of this study were (1) a procedure to determine heights at the high accuracy as many points as possible and (2) using QGIS to manage

*OpenStreetMap is a collaborative project to create a free editable map of the world. The geodata underlying the map is considered the primary output of the project. Wikipedia data base systematically and analyze causes of inability to receive adequate GNSS signals.

Methodology

Research work flow can be classified as follows:

1. MMS data collection on King Kaeo Road (Route # 3256 is one part of the King's Dyke)

King Kaeo Road was selected for the reasons as follows: (a) the road being a southern part of the King's Dyke in the east of Bangkok which is actually used for flood protection planning, (b) surrounding buildings being densest part along the dyke, and (c) having data from Wichiencharoen and Santitamnont [1] for the result comparison.

Recommendation from Wichiencharoen and Santitamnont [1] for data collection was as follows: (a) collected points should be within 20 kilometers from a base station for kinematic surveying, (b) at the beginning of data collection, the vehicle should stop at least one minute so that the initialization of satellite kinematic survey could be completed, (c) then the vehicle smoothly moved at the speed of 30 kilometers per hour (km/h). Data on both directions of the road were collected.

2. MMS data were processed by Inertial Explorer software of NovAtel's Waypoint® Product Group (2014) [8]. Result of the processing included Coordinated Universal Time (UTC), GPS Time, Location and Orientation of the vehicle with their standard deviations and Orientation of the camera. Headings of the said values were shown in **Figure 1**.

3. Data Analysis to get height accuracy and causes of inadequate satellites for positioning. Results shown in 2. was input to Microsoft Excel to compute roughly different positions at every one GPS second so that the speed of the vehicle in each direction could be checked. Then height difference between GNSS height and GNSS incorporated with IMU (GNSS+IMU) height at each GPS second was computed. If the value of the difference was high (e.g. larger than 10 centimeters), the epoch would be considered as no GNSS reception. The filtered positions were input to QGIS program and each position was shown as a dotted point. Either a Google satellite map or a Google street map could be selected as a background of the map. Then we could see where GNSS signal could not receive properly and where positions were not on the King's dyke. Such points were removed from the data base. Causes of improper GNSS receiving would be analyzed and explained. After analysis, recommendation would follow.

4. Conclusions and Discussion. Significant findings and analysis would be concluded.

Work flow of the methodology is shown in **Figure 2**.

UTCTime (HMS)	GPSTime (sec)	Latitude (deg)	Longitude (deg)	H-MSL (m)	H-Ell (m)	SDHoriz (m)	SDHeight (m)	Q	HzSpeed (km/h)	Pitch (deg)
PitchSD (deg)	Roll (deg)	RollSD (deg)	Heading (deg)	HdngSD (deg)	Omega (deg)	Phi (deg)	Kappa (deg)	HdngSep (deg)	PtchSep (deg)	RollSep (deg)

Figure 1 Headings of values resulted from Inertial Explorer software of Waypoint® Products Group

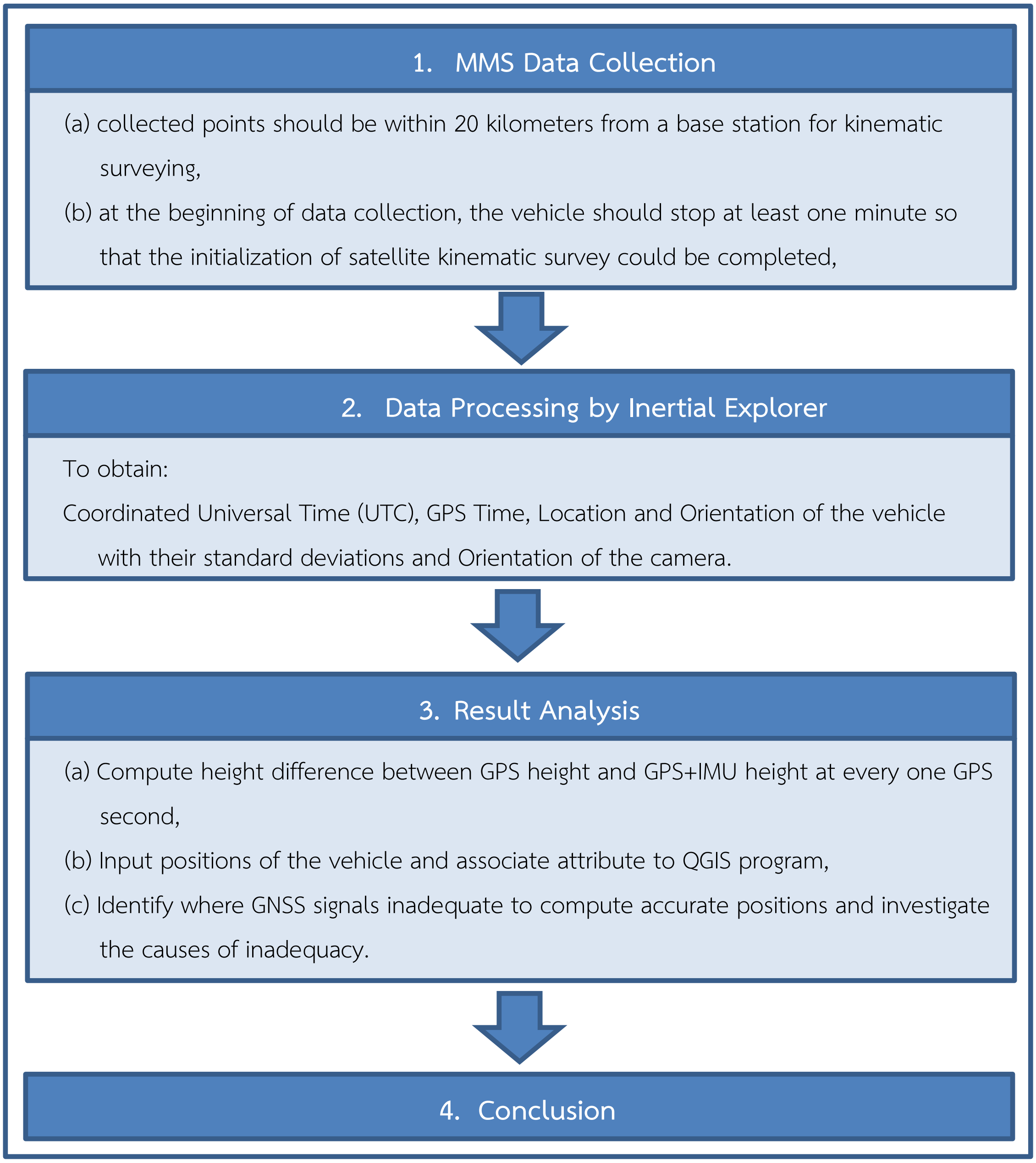

Figure 2 Work flow of the research methodology and step details

Results and Analysis

MMS data along King Kaeo Road were collected on May 21, 2019. The control point SBM.7301/53 of Department of Rural Roads, was used as the base station for the satellite survey. The vehicle speed was kept under 30 km/h. Time to collect of data on the west side of the road was 50 minutes and on the east side was 47 minutes. The route of collection processed at 1-second interval is shown in **Figure 3**.

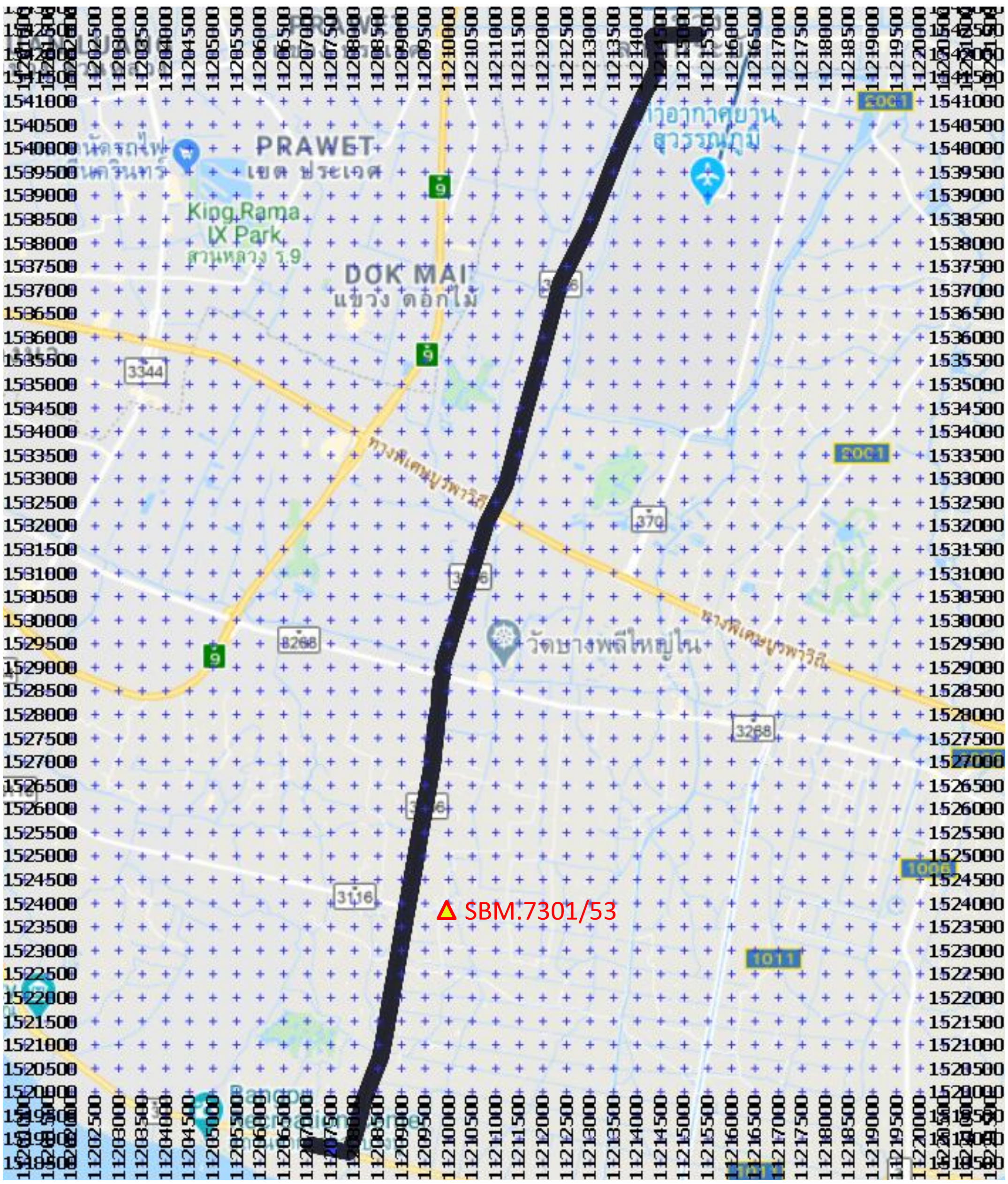

Figure 3 Showing the Route # 3256 where MMS data were collected. The map was plotted by QGIS program and Google Map (accessed on Feb.7, 2020) was plug-in as the background. Grids of 500 meters were shown as crosses

The map in QGIS could be enlarged until individual points were separately seen, e.g. the section shown in **Figure 4**. Missing points (seen as long gaps) were positions where satellite signals were inadequate to compute locations. When Google Satellite was plug-in to QGIS, the cause of signal lost could be seen. On the top of **Figure 4**, the pedestrian overpass appeared and satellite signals were lost just approaching the structure and then needed some seconds to initialize and get back the accurate positions again. The same patterns occurred every time the vehicle approaching the pedestrian overpasses. On the bottom of the figure, Bangna-Chon Buri Expressway could be seen and the same impact to position processing happened as above-said.

Sky plot during the time of data collection on May 21, 2019 can be seen in **Figure 5**. Normally, at least 4 satellites are needed for positioning. At the time of data collection, there were 9 GPS and 6 GLONASS satellites available for positioning. However, under the concrete structures the satellite signals could not pass through.

Figure 4 Showing a section of an enlarged map of **Figure 3**. The red dots were positions of the MMS processing result at every one GPS second. Google Satellite was plug-in as the background

Figure 5 Sky plots at 13.00 hrs. (local time) on May 21, 2019, using [9]. Lines were paths of satellites for the next 6 hours

There was an area that could not receive satellite signals for a long time i.e. when passing Thepharak Road. The vehicle ran along the on-ground road way to serve the purpose of flood protection. While there was an elevated road alongside, this caused inadequate satellites for positioning. There was another area where no overpass structures alongside the road, but the position differences between GNSS and GNSS+IMU were very large. This occurred when the vehicle was moving on the east side and while approaching Sukhumvit Road, see **Figure 6**. Google Satellite map did not show any obstruction around the area. Therefore OpenStreetMap was plug-in to QGIS. Street view was also shown in **Figure 6**. A lot of communication wires between the electric poles could be seen, and these wires obstructed the satellite signals coming from the east side of the sky. The sky plot in **Figure 5** shows that there were four GPS satellites in the eastern sky, so there were five satellites left to compute positions of the vehicles. However, the satellite geometry was not good enough to get accurate positions. This scenario did not happen when the vehicle moving along the west side (northern direction) of King Kaeo Road.

Now the question is what we can do to missing points on the King's dyke. The answer can be classified into three cases.

(a) The first case is points under the pedestrian overpass such as the top section of **Figure 4**. Normally the number of missing points was 5-6, therefore GNSS+IMU heights could be used, see for example **Table 1**. Secondly, linear interpolation between known points could be used. Thirdly, for this particular example, approximate values in centimeter level might be used. Consider the last column of **Table 1**, the heights of the road were almost horizontal, i.e. at 3.80 meters.

(b) The case of **Figure 6**, repeat MMS data collection when satellite geometry is difference or collecting the data at different time of the day, usually 3 hours difference. This choice was confirmed when result of data collected by Wichiencharoen and Santitamnont [1] was used, see **Figure 7**.

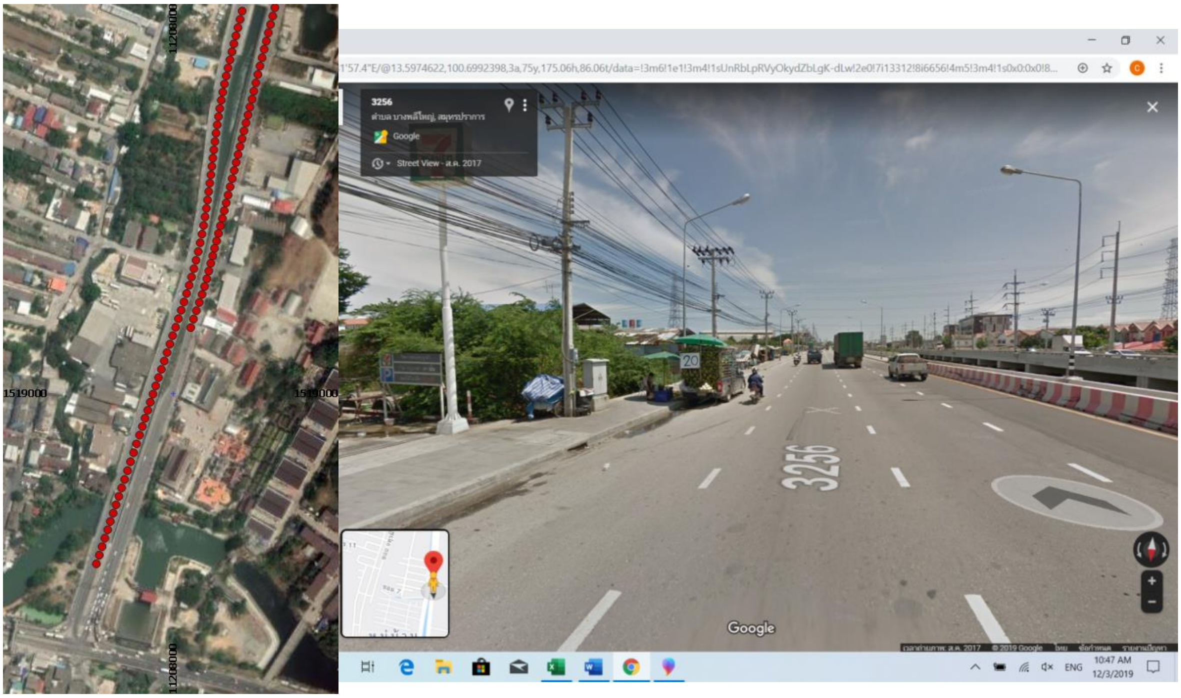

Figure 6 Picture on the left showing Google satellite with accurate positions (red dots) near Sukhumvit road. Moving northward could receive satellite signal better than moving southward. Picture on the right shows the street view (from OpenStreetMap) on the east side of King Kaeo Road (southern direction). A lot of communication wires between the electric poles can be seen. The street view on the opposite side (northern direction), only a few wires can be seen

Table 1 Example of result from Inertial Explorer. MMS data on May 21, 2019 was processed and some selected columns shown

Local Time (HMS)	GPS Time (sec)	GNSS only			GNSS+IMU		
		Latitude (deg)	Longitude (deg)	H-MSL (m)	Latitude (deg)	Longitude (deg)	H-MSL (m)
13:20:38	195656	13.6386	100.7116	3.787	13.6386	100.7116	3.814
13:20:39	195657	13.6386	100.7116	3.815	13.6386	100.7116	3.826
13:20:40	195658	13.6387	100.7117	3.826	13.6387	100.7117	3.821
13:20:41	195659	13.6388	100.7117	3.905	13.6388	100.7117	3.828
13:20:42	195660				13.6389	100.7117	3.789
13:20:43	195661				13.6389	100.7118	3.774
13:20:44	195662				13.6390	100.7118	3.764
13:20:45	195663				13.6391	100.7118	3.809
13:20:46	195664				13.6392	100.7119	3.810
13:20:47	195665	13.6392	100.7119	3.890	13.6392	100.7119	3.798
13:20:48	195666	13.6393	100.7119	3.883	13.6393	100.7119	3.811
13:20:49	195667	13.6394	100.7120	3.758	13.6394	100.7120	3.822
13:20:50	195668	13.6395	100.7120	3.749	13.6395	100.7120	3.804

Figure 7 Showing the same area as Figure 6. The green dots is the positions processed by Wichiencharoen and Santitamnont [1]. Continuous computed positions, when the vehicle was moving southward, can be seen. The result of the old data was different from the new data (in Figure 6)

(c) If the cases (a) and (b) do not work, the only choice left is to use a ground survey. The example of this case is when the vehicle passing Thepharak Road. The known heights of the points nearby can be pinpointed by satellite kinematic survey and used as reference. The method of differential and profile leveling is then performed to get the heights of the missing points, see for example [10]. This method had been used in Wichiencharoen and Santitamnont [1] to verify the accuracy of computed MMS data when satellite signals were insufficient for a long time.

Conclusions and Discussion

This paper demonstrates how to use QGIS in managing flood protection. The new work followed the work of Wichiencharoen and Santitamnont [1]. King Kaeo Road or Highway Route # 3256 (one part of the King's Dyke) was selected for MMS data collection. Inertial Explorer software of NovAtel's Waypoint® Product Group (2014) [8] was used to process the data and obtain the positions of the vehicle. Microsoft's Excel program was used to analyze the accuracy of the points by comparing positions from GNSS only and GNSS+IMU. The result from Excel was then put into QGIS program. The points outside King's dyke and those with inadequate satellite signals were cut off. When the map in QGIS was enlarged until computed points represented by dots were separated, the missing locations would be seen as gaps. The causes of missing were analyzed with the help of plugin Google Map, Google Satellite and OpenStreetMap. The points with inaccurate locations could be remedied and classified into three cases. First, the heights interpolated by using GNSS+IMU heights, linear interpolation or approximating from the surrounding point. Secondly, repeat data collection in the area when satellite geometry was different from the previous geometry, usually three hours difference. Thirdly, use differential and profile leveling to fill in the gaps, with the help of GNSS kinematic survey.

Now it can be seen that using MMS is the rapid and easy method to collect heights in order to create data base, and using QGIS to effectively manage flood protection planning.

Additional Comment

Photographic and/or video cameras are standard equipment of a mobile mapping system. This means that facilities and other information along the road can be geo-referenced and their locations are included in GIS. AN environmental engineer can use data in the system for wastewater management, air pollution control, etc.

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