Diverse Technologies in Surveying and Mapping to Update Building Map Information

Cheng-Yi Lin[1], Hung-Yu Liou, Po-Wen Wang, Ming-Chung Chen, Chin-Hui Shih
[1]Cheng-Yi Lin, NLSC
Email: wuliwuli@mail2000.com.tw

KEY WORDS: Simplified Unmanned Aerial Systems (UAS), Photographs Georeferencing, Change Points Detection,Feature Points Measuring, Field Land Survey

ABSTRACT: We selected one 1/1000 area topographic map in Taoyuan and Hsinchu respectively as well as a number of intensively populated areas as our research focus. Through suitable base data and PDMS update processing, we have established GIS building data, analyzed and verified the result of our research. According to our experiment, we proved the feasibility when using PDMS to update GIS building data with ideal accuracy coverage frequency. In addition to large-scale aerial surveys nationwide, we provide a more active and flexible way to establish GIS building data as well as support updating building map information.

1.Introduction

1.1 Motivation

Currently, the government agencies at various levels have produced and accumulated a large amount of spatial map data in actual, such as 1/1000 topographic maps, 1/2500 Taiwan e-Maps, aerial photography images, ground observation data. These various types of map data are stored in different forms (such as thematic maps, GIS layers, orthophoto images.) on different platforms for easy access and display.

Among the vast amount of spatial map data, buildings are always the focus of attention. It is often necessary to display the locations and attributes of buildings to assist in decision-making. However, building map data always are needed to be updated because of the temporal changes associated with the development of local areas. As a result, building map data are required to be updated in some areas while others remain unchanged. Therefore, effectively maintaining the usability of building map data becomes a significant issue.

1.2 Aims

To maintain the usability of building map data, this study chooses to use the original building map data as a foundation and integrates diverse surveying techniques as a method. It designs and proposes the method (PDMS) for updating building map data, with the hope of quickly, effectively, and flexibly identifying the changes in buildings and updating the building map data according to usage needs and maintain its usability.

Additionally, the feasibility of the PDMS for updating building map data will be examined through experiments. Consequently, the updated building map data results produced in this study will undergo confirmatory factor analysis to confirm that the PDMS can accurately and effectively update and reflect the changes of building map data.

2.Conceptual Framework

The research design will follow five main thematic frameworks, with each theme in the following sequence: 1. Research Direction, 2. Research Method, 3. Research Subjects, 4. Research Hypotheses, 5. Data Analysis.

The research process begins by confirming the overall research direction. It aligns with the requirements of the research direction to propose a systematic operational method (PDMS). Following the operational method, appropriate research subjects are selected for experimentation. Subsequently, testable research hypotheses are formulated, and the experimental data are organized. Finally, the experimental data are subjected to effective data analysis to draw conclusions.

The detailed descriptions of the thematic frameworks for each one:

2.1 Research direction

The PDMS for updating building map data is developed by integrating various measurement technologies, including unmanned aerial vehicles, image registration, eGNSS, ground surveying, and image processing. This plan is designed to facilitate the rapid production of updating building map data based on the original building map information.

2.2 Research method

The operational method is divided into four main components: Photo-simple UAS (Unmanned Aerial System) photography, Detect- changed point detection, Measure- feature point measurement, and Survey- field survey, referred to as PDMS (figure 1). After subjecting the research objects to recursive processing using PDMS, it can integrate the latest spatial data with the original building map data, allowing for the rapid updating and production of building map data. This approach ensures that the building map data are continuously updated to reflect the most current information.

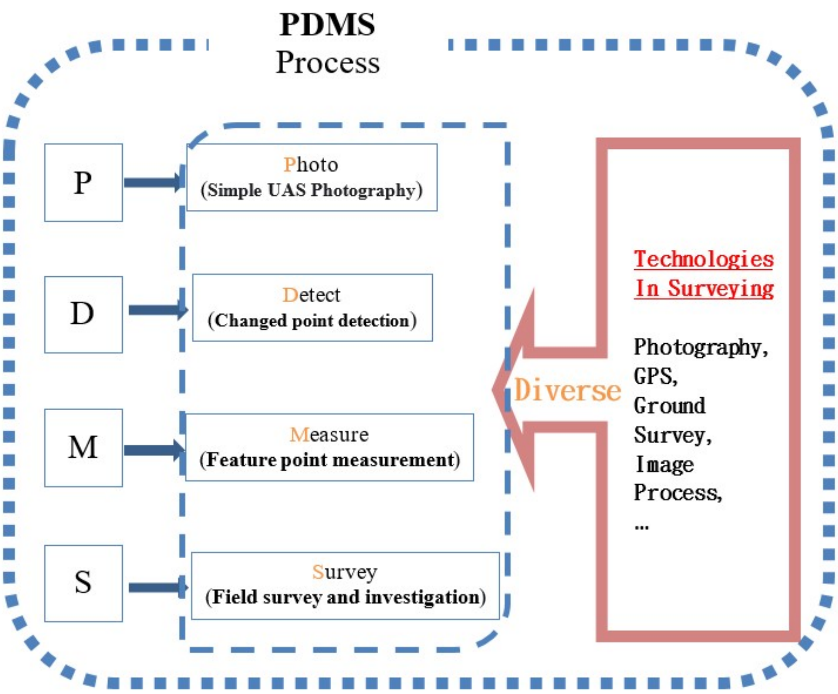

Fig.1 PDMS Process

2.3 Research object

The approach primarily relies on data from the Taiwan MAP Service (as shown in Figure 2). Within this platform, the map data includes 1/1000 topographic maps, 1/2500 Taiwan e-Maps, 1/5000 land use surveys, 1/25000 topographic maps, and other building-related map data.

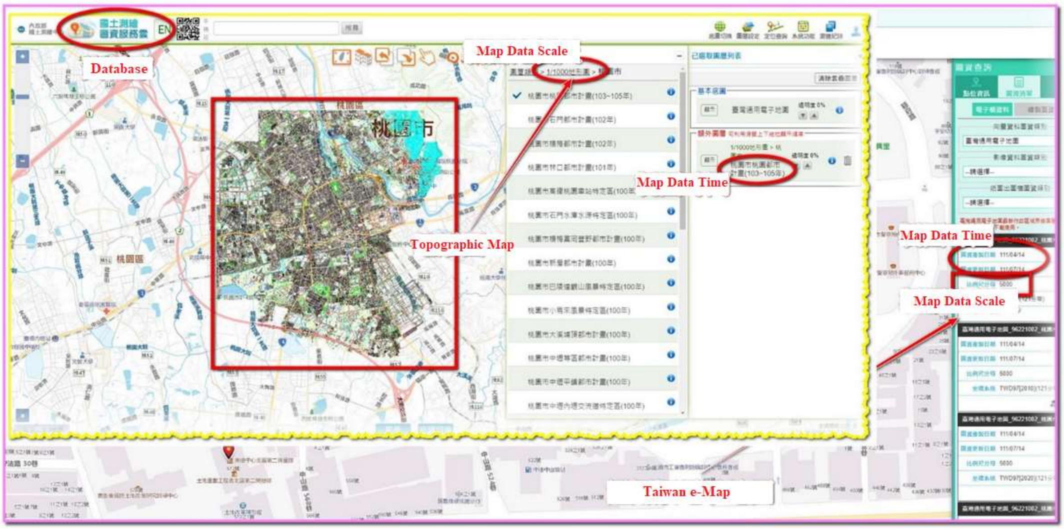

Fig.2 National Land Surveying and Map Data Service cloud - 1/1000 topographic maps and 1/2500 Taiwan e-Maps

Among this extensive building map data, the research focuses on the building map data with the largest map scale, which is the 1/1000 topographic map building map data available within the Taiwan MAP Service. This choice is made because building map data at the largest map scale typically exhibits the highest spatial geometric accuracy and precision, making it a suitable foundation for the research and updating process.

2.4 Research hypothesis

The research assumes that the operational method (PDMS) is effective and accurate in updating building map data. To validate this assumption, two tests are designed: an update rate measurement analysis and a spatial geometric accuracy measurement analysis. If the experimental results successfully pass these tests, it means that the updated building map data is practical and meets the criteria, confirming the feasibility of the PDMS for updating building map data. This ensures that the updated building map data is not only accurate but also usable for practical applications.

2.5 Data analysis

The research employs a data comparison method to conduct measurement analyses of update rates and spatial geometric accuracy on the experimental results. This approach is used to assess the completeness and reliability of updated building map data for the research.

Update Rate Measurement Analysis: This analysis involves comparing the research's updated building map data with the latest available building map data (1/2500 Taiwan e-Maps) as reference data. The assumption is that the research results are correct, and therefore, the building update rate relative to the reference data should be equal to or greater than 100%. If differences exist, it is essential to investigate whether the differences are due to demolitions or modifications in the buildings represented in the reference data. The calculation method is explained as illustrated in Figure 3.

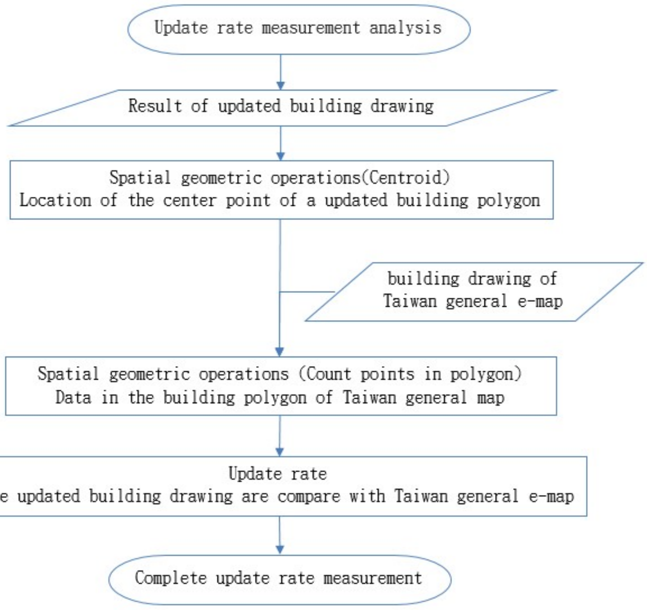

Fig.3 Update Rate Analysis Flowchart

Spatial Geometric Accuracy Measurement Analysis: In this analysis, the original building map data serves as the reference data for comparison. The assumption is that the experimental results are correct. In the updated building map data, the spatial geometric accuracy of the newly added buildings data should be equivalent to the reference data. The calculation method is explained as illustrated in Figure 4.

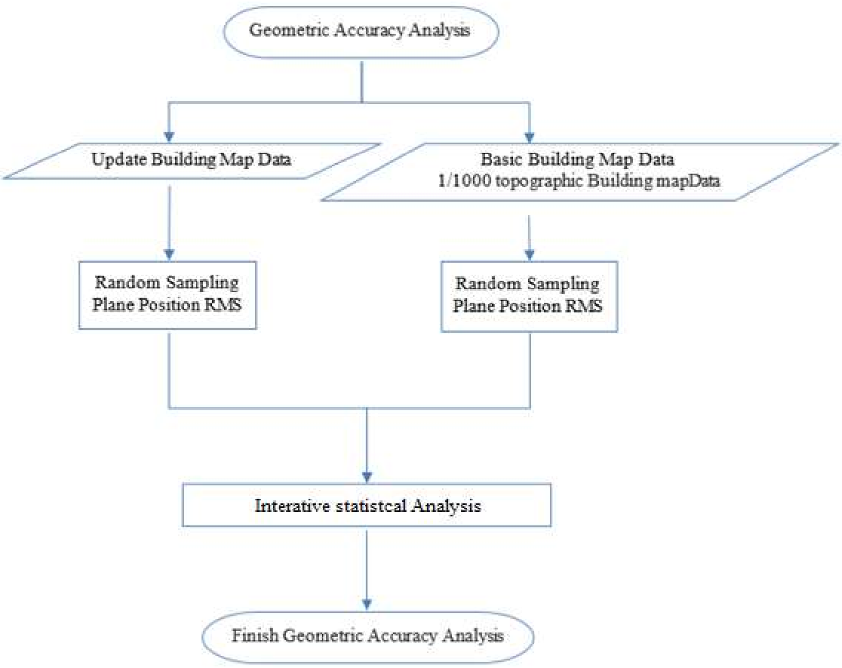

Fig.4 Geometric Accuracy Analysis Work Flow

3. Explanation of methods (PDMS)

After selecting the foundational building map data, enter the PDMS for updating building map data. Following the established workflow, data processing is conducted, resulting in the acquisition of the most up-to-date building map data. Subsequently, this updated data can be used for various GIS applications and analyses. Shown as Figure 5.

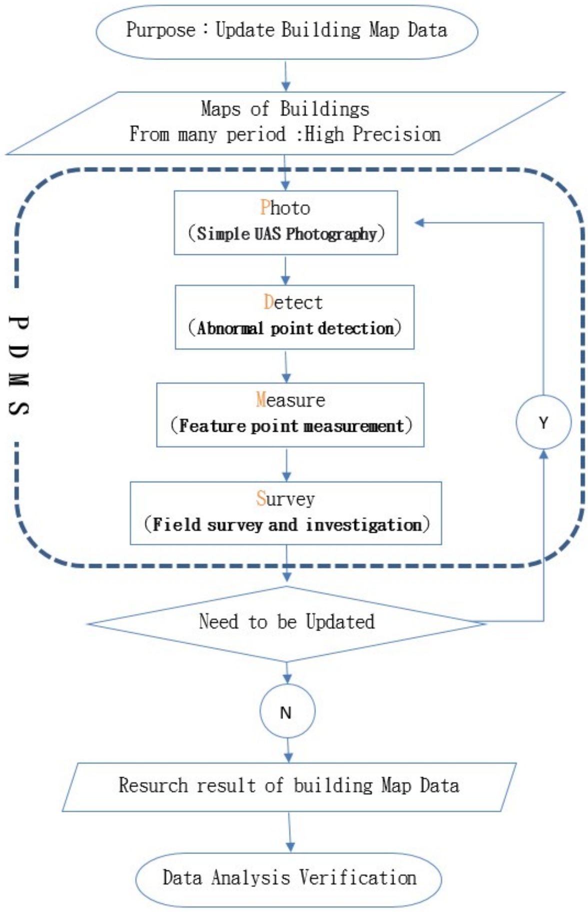

Fig.5 Work Process Diagram

The operational steps of the PDMS processing scheme are briefly explained as follows:

3.1 Simple UAS Photography (Photo)：

Simple UAS photography processing was carried out on the selected area with a primary focus on acquiring the latest building image data quickly and over a large area. Each aerial image is captured in a vertical photography mode, and spatial geometric alignment of the images is conducted. The resulting spatially aligned images can be directly overlaid onto the foundational building map data. This alignment facilitates the subsequent operation of change point detection, which aims to identify the locations of buildings within the foundational map data that require updating. Shown as Figure 6.

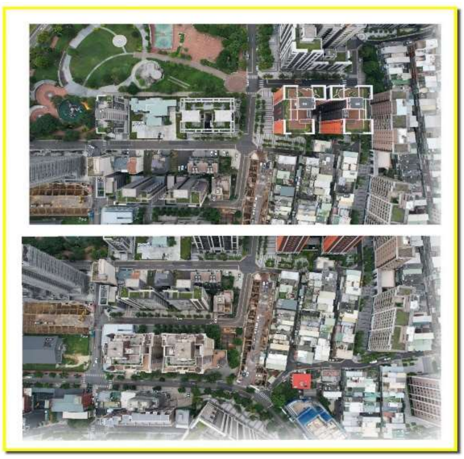

Fig.6 Simple UAS Photography

3.2 Changed point detection (Detect)：

The changed point detection process was performed on the building map data within the update range. The primary objective is to identify change points, with each change point location representing a position where building map data needs updating. Different spatial geometric measurement techniques can be employed at these change points to facilitate the subsequent operation of feature point measurement. This step involves collecting updated building map data for the identified changes in spatial locations. Shown as Figure 7.

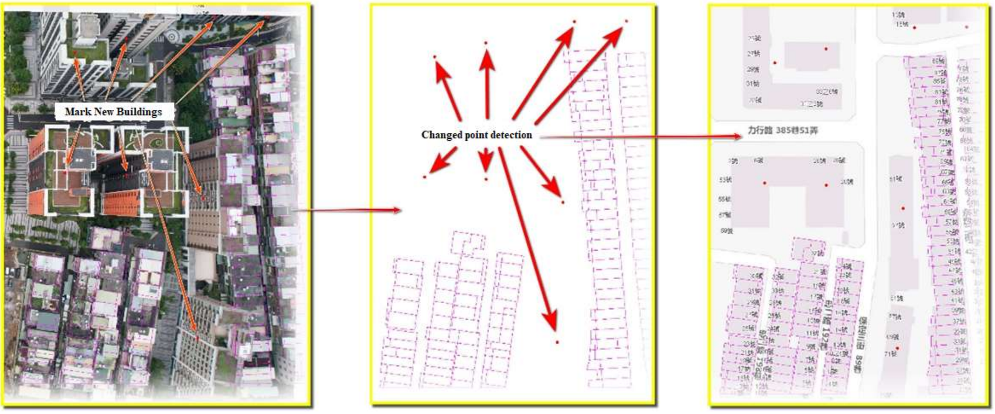

Fig.7 Abnormal Point Detection

3.3 Feature point measurement (Measure)：

The feature point measurement process involves measuring the spatial positions of building features within the location of changed points. The primary objective is to integrate various spatial geometric measurement techniques to gather the spatial positions of these building features. These feature points are used to create building boundaries and update the existing building map data. This prepares the data for the field surveys. During these surveys, attribute data is assigned to the building map data based on the current usage status of the buildings. Additionally, field survey is conducted to confirm if there are any other unaddressed updating requirements. Shown as Figure 8.

Fig.8 Building Polygon after Geometric Surveying

3.4 Field survey and investigation (Survey)：

The focus is on conducting field surveys within the spatial extents of the building map data. The objectives are to verify the attribute data of the building map data and confirm whether there are any pending changed points that require updating. The processing method includes the creation of street views on-site, followed by accessing a browsing platform to query the real-time conditions on-site and establish attribute data for building map data. Simultaneously, references are made to on-site usage conditions, and building map data are refined in coordination with other GIS data within the database, such as cadastral maps. Shown as Figure 9.

Fig.9 Data Adjustment on Newly Installed Building Story

Once the building map data are fully established, the research results employ a data comparison method for data analysis to examine the credibility and accuracy of the building map data.

4. Results

4.1 Update rate measurement analysis

This study follows the PDMS process to update the building map. To confirm whether the existing buildings were completely updated, we tried to compare the data with the newest building map data in 1/2500 Taiwan e-Maps in this study. Buildings updated in 1/2500 Taiwan e-Maps should be completely covered in study results when Update Rate Measurement Analysis was carried out. Shown as Figure 10-14.

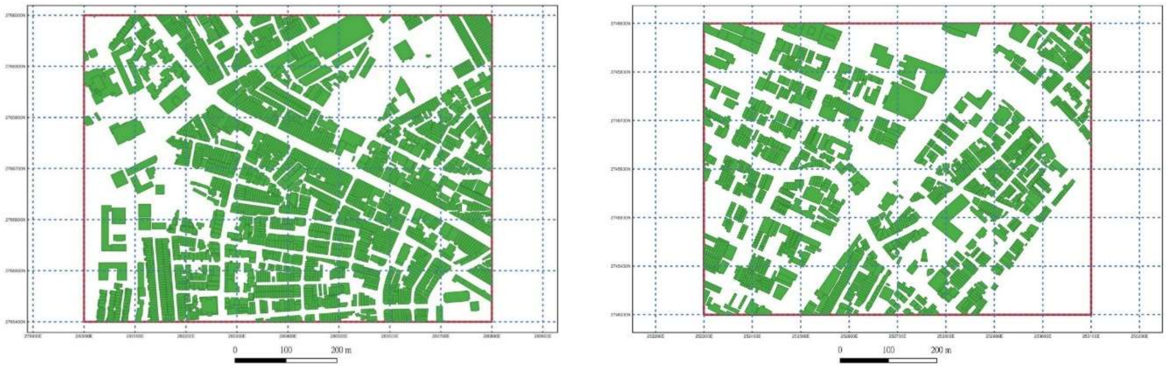

Fig.10 Taoyuan and Hsinchu Building Map Result

Fig 11 Taoyuan and Hsinchu – Calculation of the Center Point Position of Building Polygons

Fig. 12 Taoyuan and Hsinchu - Taiwan e-Maps of Buildings and Update

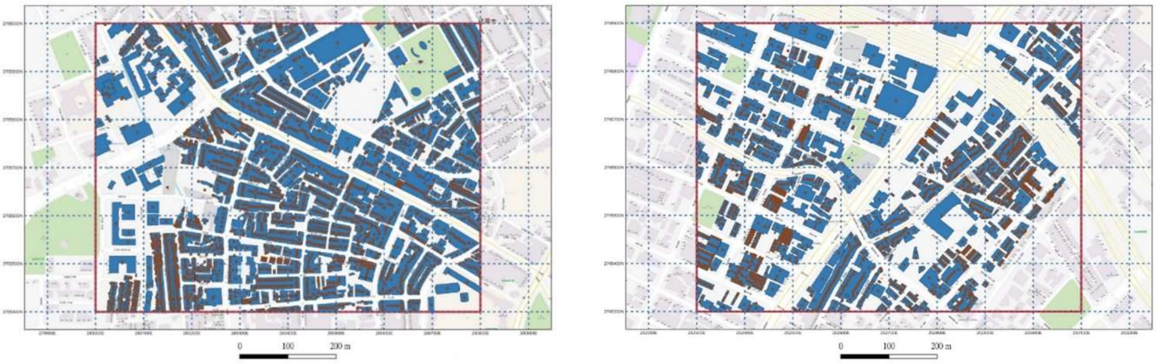

Fig. 13 Taoyuan and Hsinchu Research Result

Fig. 14 Taoyuan and Hsinchu Research Result (Update rate = 100%)

The update rate in the study area reveals that the method (PDMS) indeed could quickly and effectively update the building map data.

4.2 Spatial geometric accuracy metrological analysis

The research results of Taoyuan and Hsinchu are shown in Figure 15 respectively. The red solid line is the building map data of the research results (the building map data updated in this study) and the black solid line is the original building map data.

Fig. 15 Taoyuan and Hsinchu Target Area for Research

Based on the research results, the building map data and original building map data were independently and randomly sampled and tested on the spot to analyze the spatial geometric accuracy of the two maps. The spatial position of the building was measured on the spot and set as the true value, while the position of the building map data was set as the observation value. The square root error could assess the actual spatial geometric accuracy of the research results. Shown as Figure 16-17.

Fig. 16 Taoyuan and Hsinchu Research Result - New part of Building Map Data

Fig. 17 Taoyuan and Hsinchu Research Result - Original Building Map Data

The spatial geometric accuracy of the new building map data and the original building map data was compared through random sampling. The null hypothesis (H0) was set as follows: The spatial geometric accuracy of the building map data resulting from this research is equivalent to that of the original building map data. A t-test was conducted at the 95% confidence level, with a threshold p-value of 0.05.

Table 1 Geometric Accuracy Check Record Form

area	Taoyuan		Hsinchu	
Building statistics	New part of Building Map Data	Original Building Map Data	New part of Building Map Data	Original Building Map Data
RMS value	0.272	0.273	0.097	0.421
Number of samples	20	20	20	20
mean difference	0.177	0.172	0.082	0.382
Difference standard	0.211	0.219	0.053	0.181
t-test	p-value	0.918	p-value	0.000

The results of the random sampling test were computed, and for the Taoyuan area, the p-value was found to be 0.918. Since the p-value is greater than 0.05, the null hypothesis was accepted. Therefore, the research findings indicate that the building map data in the Taoyuan area shares the same level of accuracy as the original building maps data.

The results of the random sampling test were computed, and for the Hsinchu area, the p-value is less than 0.05, leading to the rejection of the null hypothesis. Therefore, the research findings indicate that the building map data in the Hsinchu area differs in accuracy compared to the original building map data. This difference in accuracy can be attributed to the extensive utilization of ground measurements in the Hsinchu study area. The overall geometric accuracy of the sampling test is presented in Table 1.

This study utilized two methods for obtaining the spatial geometric positions of building feature points in the building map data: ground measurement and image measurement. Despite their different approaches, the feature point measurement method employed in this study effectively and accurately updated the building map data.

5. Conclusions

This study used the building map data generated by the PDMS operation processing solution, combined with cadastral map auxiliary data to process the building polygons and obtain detailed results of the building polygons. Then we set the height of a single floor and added the building map attribute data to multiply the number of floors of a building by the height of a single floor to obtain the height of the building and generate a three-dimensional building model. It could be seen from the results of the example: the PDMS operation solution will indeed update the building graphics and assist in the updating of the 3D building model.

Under the same process, other thematic map data such as roads and water system layers, can be updated at the same time. Especially in terms of road map data, the general public has a high usage rate. Real-time and accurate road information as well as update frequency are even more important. With the method from our research, building and road maps will be able to get connected smoothly and updated together. This provide better benefits.

Through the update mechanism, with more flexibility and mobility, it is feasible and accurate to handle the update of building map data in a changing area. It can handle local map data in addition to the national map data update plan.

Automation will be implemented in abnormal point detection. The better automation, the more efficient the operation will be. This will also help save manpower and material resources. Looking for breakthroughs in the methods of pre- and post-imagery including aerial orthophoto, UAS image recognition and electronic map building frame comparison is a direction in the future.

References

Lin Yaozong, Que Wenlian, Yan Yihe, 2015, Discussion on the application of unmanned aerial vehicle (UAV) to conduct one-thousandth topographic map surveying and mapping case study, Chinese technology Issue 107.

NLSC, 2021, 2021 Study and formulate a commissioned research report on specifications for the measurement and production of 1/1000 topographic maps using small-format cameras.

NLSC, 2020, 2020 LOD2 three-dimensional approximate building model construction trial operation procurement project overall report.