Accuracy and effectiveness of 3D model reconstruction from UAV photogrammetry for physical road safety investigation

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ABSTRACT

Traffic accidents are one of a serious cause that pose a threat to human life and economic loss. In particular, road safety is one of the keys to help prevent traffic accident. Hence, the risk assessment of physical factors for roads is very important for road safety audits. This research attempts to employ UAV photogrammetry for the three-dimensional model reconstruction of the physical road in order to help reduce the process of data collection for road inspector in risk assessment of road safety. The study area in the research is the intersection of road in the Naresuan University, Phitsanulok province, Thailand. Image acquisition of UAV photogrammetric approach was taken using DJI Phantom4 Pro V2.0 at 50 and 70 m of the flight height above the ground. Next, 3D reconstruction from the UAV imagery was performed using WebODM opensource software and ContextCapture commercial software to generate a 3D model for evaluating the physical conditions of the road by visualization. The results show that the use of opensource software has many benefits for UAV photogrammetric processing almost as potential as commercial software. Accuracy assessment of 3D models of the road obtained from between 50 and 70 meters at the UAV flight height was insignificantly different. Both models could provide accuracy in decimeter-level. However, the completeness and details of 3D model obtained from an UAV flight height at 50 meters above the ground were better than at 70 meters. For the risk assessment of physical roads from the 3D model, the optimal speed limits on the curve should be 40 km/hr following a guiding advice of road safety. Therefore, UAV photogrammetry can be utilized for the primary investigation of physical road safety and offering the guidelines for improving road safety to the relevant agencies.

1. INTRODUCTION

The physical road conditions are one of the factors in traffic accidents that can lead to damages to human life and properties. In order to reduce the impacts of traffic accidents, the risk assessment of physical factors on roads is essential for road safety. It should provide the guidelines for reducing traffic accidents to relevant agencies, especially improving road safety. For the improvement of road safety, there are four main stages, as follows: (i) survey the risk areas of traffic accidents in the community; (ii) analyze to find the points of high-risk areas for traffic accidents; (iii) draft the high-risky points of traffic accidents on a map; (iv) review and design the improvement of the high-risky points of traffic accidents. Therefore, the survey and improvement of high-risk points for traffic accidents are crucial to help decrease the negative impacts of accidents (Zahran et al., 2021).

Traditionally, the inspection of the physical roads for assessing road safety can use many methods such as field surveying and the use of tape measurement. If a road safety audit needs to inspect a large area, it will be time-consuming and labor-intensive to survey in the field.

Also, it might be very costly compared to conventional survey. In the present, the UAV photogrammetry has an important role in the applications of topographic survey because it can help for time-saving methods and reducing the cost of survey (Ismael & Henari, 2019). In particular, the UAV approach has been widely used that is concerned with the study of the physical factors for roads. For example, the use of an unmanned aerial vehicle (UAV) can apply to provide the topographic data for road design and traffic accident investigation (Outay et al., 2020; Pérez et al., 2019; Zulkipli & Tahar, 2018). Thus, the application of UAV photogrammetry has enormous potential for surveying the physical road conditions in order to assess the road safety. As a result, the information of the road safety will be utilized for effectively improving the physical factors of road.

In this paper, we present the potential of UAV photogrammetry to facilitate the assessment of the road safety from the physical factors for roads. The study area focused on places that had experienced traffic accidents. The image acquisition was taken using the UAV platform at different altitudes in order to offer the suitable photogrammetric results. For the 3D reconstruction of road obtained from the UAV imagery, the use of open source/free software were compared to commercial software in order to evaluate the photogrammetric results from different software packages for photogrammetric processing. The assessment of the physical factors for this road was preformed through 3D visualization method from 3D model. The outcomes of assessed physical conditions and guidelines for improvement will offer to relevant agencies in the university for improving the road safety.

2. MATERIALS AND METHODS

2.1 Study area

The study site focused in the road of the researcher's workplace that had used traffic accidents. The study area was located at the intersection of road, near the King Naresuan Monument, in Naresuan University, Phitsanulok province, Thailand, as shown in Figure 1. The type of this intersection is the three-leg or T-intersection. Each leg of intersection comprising two lanes of concrete roads. The main roads of intersection are cruve and many vehicles often use over speed limits at 40 km/hr. That is one reason why traffic accident at this intersection.

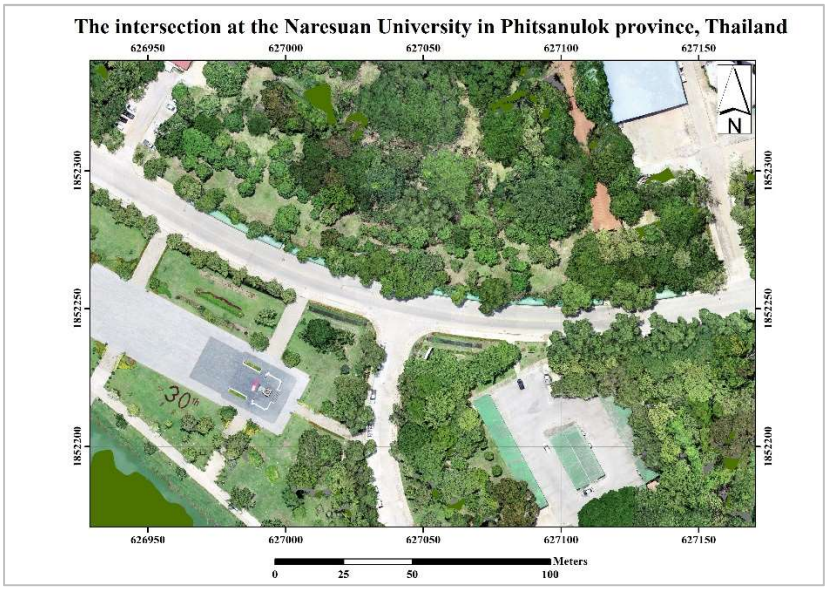

Figure 1. The intersection used in this study area.

2.2 Instruments and software packages

The UAV platform used for this study is the DJI Phantom 4 Pro V2.0 with 20MP of digital camera. The DJI GO 4 and the Pix4D capture mobile applications is used for setting up functions and flight plans for the DJI Phantom 4 UAV. For photogrammetric processing from the UAV imagery, the WebODM opensource/free software and the ContextCapture commercial software are utilized to generate a 3D model of the intersection and deliver photogrammetric results, such as orthophoto and Digital surface model (DSM). The visualization of 3D model for the intersection uses the CloudCompare opensource software Finally, the QGIS opensource software help for assessing the quality and accuracy of photogrammetric results and calculating the design of speed limits on the road.

2.3 Methodology

The purpose of study is the application of UAV photogrammetry in order to inspect the physical factors of the intersection for evaluating the road safety. Figure 2 illustrates the methodology used for this study.

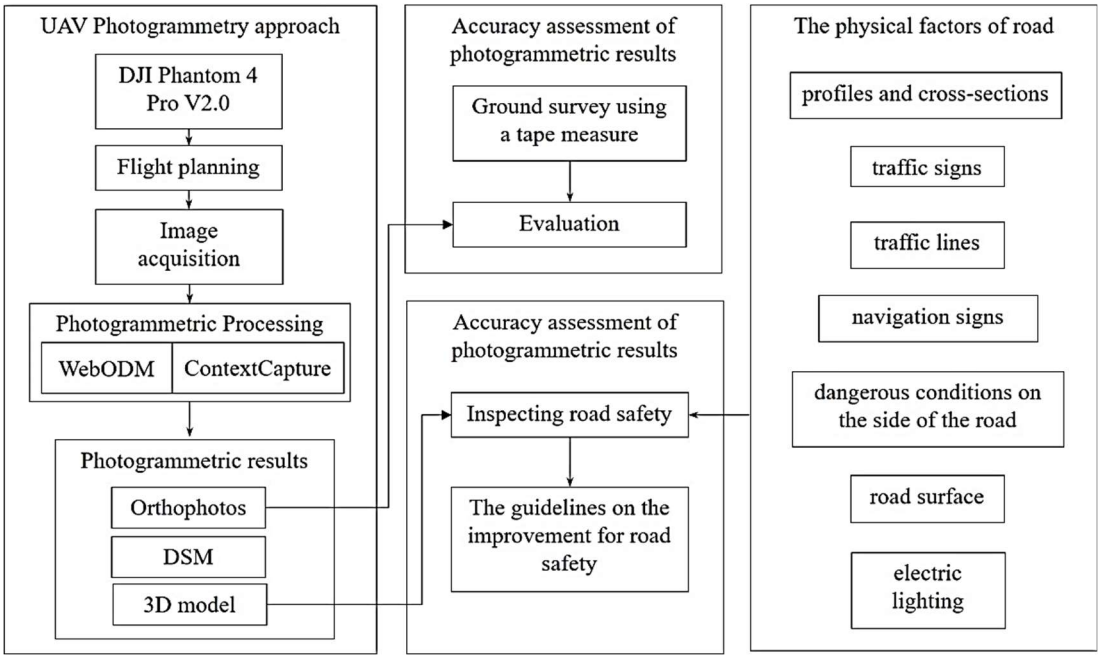

Figure 2. The methodology schema in this study.

2.3.1 *Data acquisition*

The flight planning for the UAV flying was designed using the Pix4D capture application on a mobile phone with the flying height at 50 meters and 70 meters above the ground, cross strips for flying direction and the 45 degrees of camera angle. As a result, there were two photosets, including: (i) 228 images for 50 meters of UAV flying height; (ii) 144 images for 70 meters of UAV flying height.

2.3.2 *Photogrammetric processing and assessing photogrammetric results*

After image acquisition, both photosets were processed using the WebODM software and the ContextCapture software for 3D reconstruction of the intersection. Georeferencing was based on the GNSS observation of UAV. The photogrammetric results obtained from the WebODM software were compared to the results of the ContextCapture software to evaluate

the potential of opensource/free software for photogrammetric processing. As the ContextCapture commercial software was able to provide high precision of photogrammetric measurement, that we assumed this software was used for a benchmark software in this study. To evaluate the accuracy of photogrammetric results, measuring the 30 widths of traffic lanes from the 3D models was compared to measuring the actual widths of roads in the field. The statistical errors such as Mean, Root Mean Squared Error (RMSE) from both photogrammetric software packages were calculated from the aforementioned comparison.

2.3.3 *The investigation of road safety*

Regarding the assessment of road safety for this intersection, the physical factors and characteristics of the road were analyzed following the principles for road safety of Department of Rural Roads (DRR), Thailand. To follow the recommendations for road safety, the roads should comprise physical factors or instruments on/alongside the road, such as profiles and cross-sections of the road, traffic signs, traffic lines, navigation signs, dangerous conditions on the side of the road, road surface, and electric lighting. The assessment of road safety was manually performed using 3D visualization on the CloudCompare software.

3. RESULTS AND DISCUSSION

Based on an UAV approach for the intersection of this study area, the results of 3D models obtained from the WebODM and ContextCapture photogrammetric software packages are presented in Figure 3.

Figure 3. The 3D models obtained from (a) WebODM, and (b) ContextCapture using the UAV flying height at (1) 50 meters, and (2) 70 meters above the ground.

Regarding the comparison of 3D modeling results, as shown in Figure 3, the completeness of 3D model obtained from WebODM software had noticeably lesser clarity than from ContextCapture software. However, using different altitudes for UAV flying, the generated 3D models of each software were insignificantly different. For assessing the photogrammetric accuracy from different software packages and different altitudes of UAV, the values of statistical errors from both photogrammetric software packages are showed in Table 1.

Table 1. The statistical errors for the assessment of photogrammetric accuracy.

Software	UAV flying height (m)	Errors	
		Mean (m)	RMSE(m)
WebODM	50	0.073	0.088
	70	0.095	0.104
ContextCapture	50	0.042	0.071
	70	0.054	0.082

From Table 1, the accuracy of photogrammetric results obtained from ContextCapture software was higher than from WebODM software. Moreover, the accuracy assessment of 3D models at different altitudes of the UAV flying obtained from the same software was slightly different.

For the risk assessment from the physical factors of the road, the orthophoto from UAV photogrammetric results was used to calculate the radius of the curve using QGIS software. As a result, the radius of this curve was approximately 250 meters. Normally, the speed limits of this designed curve should not more than 60 – 70 kilometers per hour. However, the suitable speed limits of the curve for all vehicles should not more than 40 kilometers per hour following a guideline for road safety. That is the reason why traffic accidents might happen easily at the intersection. Road safety is not guaranteed by road design and construction regulations (Huvarinen et al., 2017). Hence, this intersection should have improved to increase road safety, as illustrated in Figure 4.

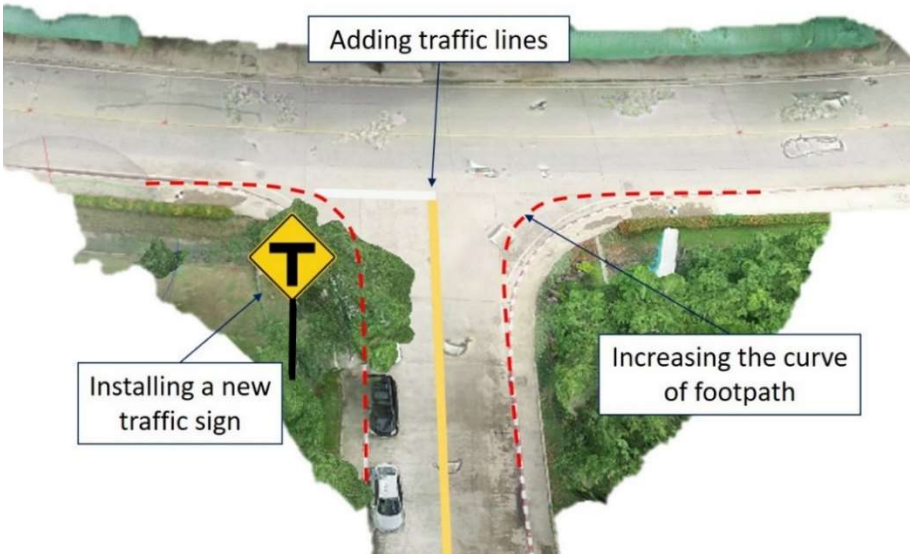

Figure 4. The guidelines on the improvement of the intersection for road safety.

4. CONCLUSIONS

The potential of the UAV photogrammetry has been utilized for inspecting preliminary road safety for this study. The application of UAV approach also helps decrease time-consuming and labor-intensive methods of road safety audits. Evaluating some physical factors of roads can identify on the 3D model reconstructed from the UAV imagery that facilitates extensively the assessment of the road safety. In this study, the photogrammetric accuracy from UAV approach depends on the photogrammetric software for processing. The WebODM opensource/free software can be potentially used for generating 3D models and photogrammetric results that provide accuracy at decimeter level. The outcomes of UAV photogrammetry (i.e. orthophotos) were used to analyze the causes of traffic accidents for decreasing human and economic loss. Moreover, a 3D model of the road was applied for offering guidelines on the improvement of road safety in the future.

5. REFERENCES

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