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A Review on the Usability of Mobile Phone-based Close-Range Photogrammetry, Terrestrial Laser Scanning and UAVs in Traffic Accident Modeling

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ABSTRACT

Fast, detailed and accurate three-dimensional (3D) documentation of traffic accident scenes are crucial since it provides data for traffic accident reconstruction which allows determining the vehicle speed, examining the nature of the collision, and affording evidence in court cases. There are various documentation techniques such as classical drawing techniques, photogrammetry, laser scanning etc. The modern methods have become more preferable compared with the classical drawing methods along with the developing technology. In this aspect, 3D models emerge as a solution for fast and detailed documentation of traffic accidents. In addition, deformations can be determined more accurately by using these models in comparison with the classical methods. In this study, three different models were produced by using mobile phone-based photogrammetry, UAV photogrammetry and terrestrial laser scanning. Then, each model was examined comparatively in terms of completeness, visual representation, time efficiency and metric accuracy. In addition, the usability of mobile-phones as a fast and low-cost tool for 3D modeling was also examined in terms of incident modeling.

1. INTRODUCTION

The number of fatal traffic accidents increases as a result of the rise in vehicle numbers and car speeds. This situation causes some challenges such as taking substantial time for officers to record the evidence and important scene characteristics after a traffic accident (Du et al., 2009). Today, spatial analysis of traffic accidents is mostly based on visual examinations. Hence, it highly depends on the observer (Sabel et al., 2005). Providing data for traffic accident reconstruction which allows determining the vehicle speed, examining the nature of the collision, and affording evidence in court cases are important. Hence having a fast and accurate examination method is necessary (Du et al., 2009). In addition to this; in terms of evaluating the performance of safety systems, determining the deformations on cars after traffic accidents is really crucial (Kullgren, Lie, & Tingvall, 1994).

Therefore, a fast examination of traffic accidents has been gained more attention along with the developing technology.

The developments in technology result in easy and fast data collecting along with the opportunity to store the collected data in computer systems. Incident reporting systems are started to be widely used by analysts due to its huge ability of data mine in addition to the aim of reducing the accident rate (Cassidy et al.,2003; Sabel et al., 2005).

In this case, close range photogrammetry, UAV photogrammetry and terrestrial laser scanning offer quick solutions for traffic accident documentation.

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Close range photogrammetry is a valuable tool for 3D modelling with its long history. In recent years, there have been many important changes and growth in the close range photogrammetric measurement area (Fraser & Hanley, 2004). In this aspect, mobile phones emerge as a tool for fast and low-cost data acquisition. However, the resulted 3D model needs to be examined whether it can provide sufficient models or not in traffic accident modeling.

On the other hand, UAV-based photogrammetry has gained popularity since the remotely controlled drones offer various capabilities for autonomous flying. UAV-based photogrammetry can be used in wide range of applications such as topographic mapping, environmental monitoring, archeological surveys, etc. In general, obtained images are processed by the use of SfM Software, which automatically produces point clouds (Luhmann, 2019).

In addition, 3D models obtained by using terrestrial laser scanners are useful for obtaining accurate, detailed and reliable information about the object to be scanned.

The laser scanners are capable of producing realistic models by using color information which can be obtained either from sensor or from a digital camera. On the other hand, the surface light is effective on the resulted data. In this case, the surface to be scanned plays an important role in the produced 3D model modeling (Godin et al., 2001).

In this study, usability of 3D models obtained by the use of mobile phone-based photogrammetry, UAV photogrammetry and terrestrial laser scanning were examined comparatively. The processes of the close range photogrammetric images were made in ContextCapture Software while UAV images were processed in Agisoft Photoscan Software. Faro Scene Software was used in order to generate 3D point cloud from terrestrial scans.

2. METHOD

Since the aim of the study was the production and comparison of close range photogrammetry, UAV-based photogrammetry and terrestrial laser scanning, different data acquisition techniques were carried out.

2.1. Close-Range Photogrammetric Survey

Close-range photogrammetric survey consists of two phases such as field work and office work. During the field work, photogrammetric images were captured in order to reconstruct the accident in 3D. Digital images of survey area (A test area closed to traffic at Mersin University Stadium) were acquired by using Apple Iphone 6s mobile phone during the field work. The mobile phone has a 12 Megapixel camera with a 1/3" sensor size and focal length of f/2.2, 29mm. 92 images at total were captured. As the next step of field work, 4 Ground Control Points (GCPs) were established on the ground and were measured with Topcon HiPer Sr GNSS receiver in ITRF-96 datum, UTM projection, GRS80 ellipsoid, 2005.0 epoch, 3-degree zone-33, in Continuously Operating GNSS Kinematic Reference Stations (CORS-TR) System. 31 detail points respectively consisting of targets pasted on the vehicles and specific points selected on the vehicles (corners etc.) were measured in reflectorless mode with Topcon GM series total station (Figure 1). In the office work phase, 3D coordinates of the detail points on the vehicles were computed on the Netcad software by the use of measured four GCPs and total station data. This process allowed to bring both close range photogrammetric and UAV model in common reference system. Thereby, integrating two models would be possible in case of some data is missing in other model. The 3D coordinates of the 15 of measured control points were used for geo-referencing the 3D model.

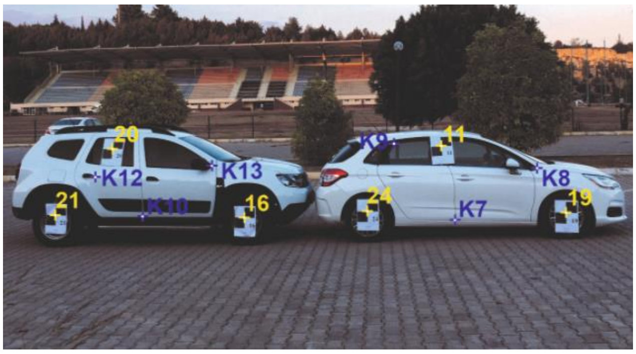

Figure 1. Details point on the one facade of the scene

During the office phase of the study, 73 of the images were processed in Bentley's Context Capture Software. Thus, point cloud and textured model were produced of the traffic accident scene (Figure 2).

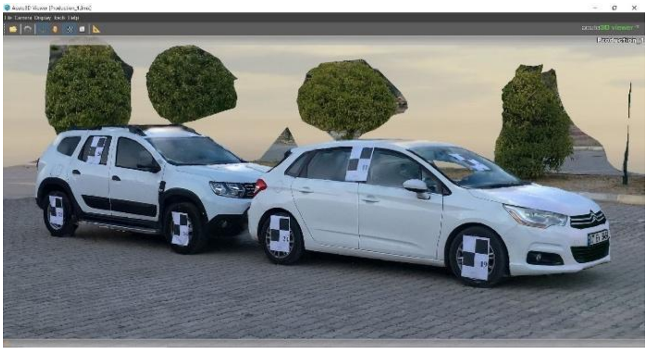

Figure 2. Textured model obtained by the use of close range photogrammetric images

2.2. UAV-Based Photogrammetric Survey

UAV-based photogrammetry is divided in two phases such as field and office work as well as the close-range photogrammetric survey. Parrot Anafi UAV was used for the UAV-based photogrammetric survey. It has a 4K HDR camera with a 180º inclined gimbal. The images were captured in two flight plans, one in circular and other in double grid mission by using Pix4DCapture. 168 images at total were captured in UAV-based photogrammetric survey. Then, the established four ground control points were measured in ITRF-96 datum, UTM projection, GRS80 ellipsoid, 2005.0 epoch, 3-degree zone-33 (Figure 3).

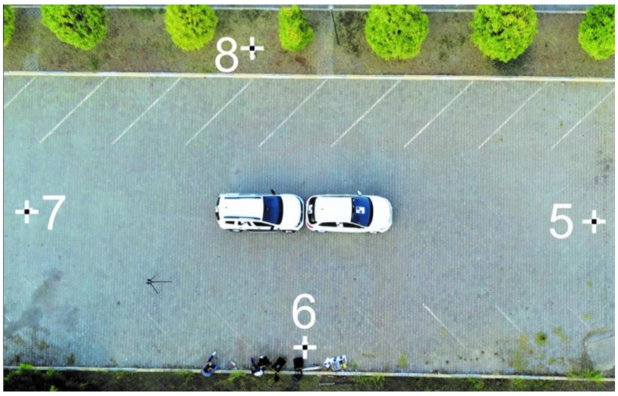

Figure 3. Established four GCPs

These GCPs were later used for geo-referencing the UAV-based point cloud in order to bring it in common reference system with the point cloud obtained by the use of close-range photogrammetry. During the office work, 164 images were processed in Agisoft Photoscan Software for producing 3D point cloud. Then, textured model of the traffic accident scene was obtained (Figure 4 & 5).

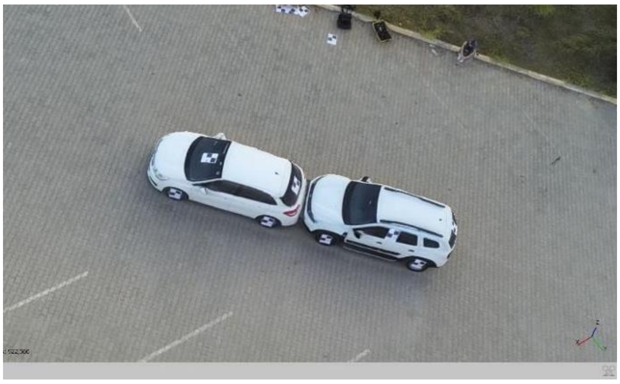

Figure 4. Textured model obtained by the use of UAV images

Figure 5. Textured model obtained by the use of UAV images

2.3. Terrestrial Laser Scanning

10 scans around the traffic accident scene were performed by using Faro Focus^S 350 scanner in the field. Then, the data acquired during the field work was processed in Faro Scene Software. Target based registration was performed in data processing phase. After registration; coloration, reflectance threshold and distance filter options were used in order to arrange the data. Thus, a meaningful point data set was obtained for 3D model production. Noise reduction was also performed in order to avoid redundant data. The resulted point cloud is shown in figure 6.

Figure 6. Point cloud obtained by terrestrial laser scanning

3. ACCURACY ASSESSMENT

In order to define the metric performance of each model; 10 distances between selected detail points were compared with the distances calculated by using the 3D coordinates obtained from GNSS and total station data (Figure 7, 8 & 9).

Close-Range Photogrammetry				
Points	Model Distance	Ground Truth	V	VV
	[m]	[m]	[cm]	[cm²]
(K1-K2)	1.327	1.378	5.13	26.30
(K2-K3)	1.036	1.138	10.12	102.36
(K3-K4)	1.285	1.372	8.66	75.05
(K4-K5)	1.183	1.285	10.16	103.19
(K5-K6)	0.484	0.522	3.74	13.99
(K10-K11)	0.904	0.970	6.67	44.48
(21-20)	1.111	1.175	6.41	41.15
(16-24)	1.593	1.687	9.44	89.05
(24-11)	1.278	1.357	7.82	61.11
(11-19)	1.719	1.824	10.54	111.00
			RMS = ± 8.61 cm	

Figure 7. Accuracy assessment of close range photogrammetric model

UAV Photogrammetry				
Points	Model Distance	Ground Truth	V	VV
	[m]	[m]	[cm]	[cm²]
(K1-K2)	1.361	1.378	1.71	2.92
(K2-K3)	1.173	1.138	3.53	12.43
(K3-K4)	1.361	1.372	1.08	1.16
(K4-K5)	1.243	1.285	4.19	17.56
(K5-K6)	0.532	0.522	1.02	1.05
(K10-K11)	0.991	0.970	2.07	4.31
(21-20)	1.172	1.175	0.27	0.07
(16-24)	1.674	1.687	1.25	1.56
(24-11)	1.336	1.357	2.09	4.38
(11-19)	1.805	1.824	1.93	3.72
			RMS = ± 2.34 cm	

Figure 8. Accuracy assessment of UAV-based photogrammetric model

Laser Scanning				
Points	Model Distance	Ground Truth	V	VV
	[m]	[m]	[cm]	[cm²]
(K1-K2)	1.305	1.378	7.26	52.77
(K2-K3)	1.079	1.138	5.84	34.14
(K3-K4)	1.341	1.372	3.10	9.60
(K4-K5)	1.273	1.285	1.16	1.35
(K5-K6)	0.540	0.522	1.84	3.38
(K10-K11)	0.981	0.970	1.08	1.18
(21-20)	1.220	1.175	4.52	20.47
(16-24)	1.679	1.687	0.81	0.65
(24-11)	1.396	1.357	3.96	15.68
(11-19)	1.776	1.824	4.81	23.12
			RMS = ± 4.25cm	

Figure 9. Accuracy assessment of laser scanning model

4. RESULTS

In this study, three point clouds obtained by using mobile-phone-based close range photogrammetry, UAV photogrammetry and terrestrial laser scanning were examined in terms of completeness, visual representation, time efficiency and metric accuracy. In terms of completeness and visual representation; terrestrial laser scanner point cloud and close-range photogrammetric point cloud may have some missing data at the roof of the vehicles since the view may not be seen clearly depending on the elevation which the data are acquired from. On the other hand, UAV-photogrammetry provides a complete 3D model since it can acquire data both from above and around the accident scene. However, the facades of the vehicles were more realistically reconstructed in close range photogrammetry. Based on the results, it is observed that; UAV photogrammetry is more suitable for obtaining a complete 3D model. In this case, the missing data in close-range photogrammetric point cloud and laser scanner point cloud can be completed by integrating the UAV point cloud since all models are in the same coordinate system. In terms of time efficiency, capturing images for close range photogrammetry and UAV photogrammetry both took approximately 15 minutes, while laser scanning process took approximately 1 hour in the field. Data processing time for all three methods was approximately 4 hours. Since acquiring data after a traffic accident in the fastest way possible is crucial, it is seen that; UAV-photogrammetry and close range photogrammetry are more time-efficient in comparison with the terrestrial laser scanning. On the other hand, metric accuracy of obtained models were also examined. In this term, 10 distances were compared with the ground truth data obtained by using total station and GNSS measurements. Mobile phone-based close range photogrammetry provides ± 8.61 cm accuracy model, while UAV photogrammetry is ± 2.34 cm accurate and terrestrial laser scanning is ± 4.25 cm accurate. However, the resolution of the camera plays an important role in geo-referencing the close range photogrammetric data. The results would be better if a higher resolution camera can be used.

5. CONCLUSION

There are various factors for evaluating the performance of obtained models in terms of traffic accident modeling. These factors can be listed as follows: completeness, visual representation, time efficiency and metric accuracy. It is seen that each method has its own advantages and disadvantages. Photogrammetric methods are more suitable for faster data acquisition in the field while data processing times are close to each other. On the other hand, UAV photogrammetry provides a complete model in a short time. In this context, there would be some missing data in the roof of the vehicles in use of close range photogrammetry and terrestrial laser scanning. But, both methods are successful in representing the facades of the vehicles. In terms of metric accuracy, the methods can be ranked in following order: UAV photogrammetry, laser scanning and close range photogrammetry.

In addition, it is seen that mobile phones can be used as a fast and low cost data acquisition tool for traffic accident modeling

In future studies, the usability of fusion models generated by using all methods can be investigated in terms of traffic accident modeling.

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