Extraction of As-Built Drawings Using Cell Phone Camera

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ABSTRACT

The objective of this study was to introduce a new method for extracting as-built drawings of road intersections using cell phone camera through Close Range Photogrammetry (CRP). Three different cell phones of different resolutions (5MP, 8MP and 20MP) were used in this study to capture images for road intersections in Jordan. Calibration of cell phone cameras was done before the captured images were processed using iWitness and Agisoft software. For the purpose of accuracy assessment and result verification, 68 points were collected from the study area using differential GPS. The resultant as-built drawings extracted by this method were tested and compared with the collected GCPs from the field. Euclidian distance for different linear features in the 3D model was computed and compared with the extracted as-built drawing linear features. The results revealed that using 20MP, root mean square error RMSE in the x, y and z directions was 0.472m, 0.514m and 0.462m, respectively, which shows the feasibility of using such method for extracting road network intersection drawings. As the cell phone's resolution increased, the potential accuracy of the as-build drawings increased. This method of extracting as-built drawings using cell phones will open the door for efficient and practical future applications.

KEYWORDS: Cell phone camera, Camera calibration, As-built drawings, Road intersections.

INTRODUCTION

Nowadays, most people have digital cameras or own a device which is capable of capturing digital images, like mobile phones with built-in cameras or webcams (Ebrahim, 2004). Digital close-range photogrammetry is an important branch of the science of photogrammetry that utilizes digital technology to make digital images of subjects. This new facility in the mobile phone generation could enable us to use it in the digital photogrammetric field. To use this tool, first we must find out its accuracy (Satchet, 2010). Using this handheld tool provides a low-cost method compared with the other conventional surveying methods which are available most of the time for everyone. This kind of device is considered more convenient for such kind of work, especially for its light weight and convergence.

For the investigation of this work, a study area was selected in Al-Balqa'a governorate in Jordan, representing an intersection in the Salt ring road near Al-Balqa'a Applied University as shown in Fig. 1. The main goal of this work was to study the potential of using cell phone stereo images to extract as-built drawings of the road intersection and its associated surface measurements.

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Figure (1): Study area on Salt ring road. Left: generated as-built drawing using total station. Right: image of the study area

Literature Review

Close-range photogrammetry has known remarkable developments, including the evolution from manual to automatic image orientation and from manual feature point measurement to automatic generation of dense 3D point clouds (Fraser, 2015). Close-range photogrammetry is mostly used for deformation measurement of structures, architectural mapping, modeling buildings, documentation of artifacts, reverse engineering purposes, remodeling traffic accidents and crime investigation (Mokhtar and Matori, 2013). Architectural and archaeological photogrammetry is an example of close-range photogrammetry application that is widely being used since the 1960s (Dallas, 1996). Close-range photogrammetric systems have been successfully used in recent times for measurements in fluid physics experiments in space (Maas et al., 2002), underwater archaeological surveying (Green et al., 2002), monitoring thermal deformation of steel beams (Fraser and Riedel, 2000), as well as for mapping low relief fluvial geomorphic features ranging from 10 to 100 m^2 (Heritage et al., 1998), surveying historical buildings (Mills and Barber, 2004) and modeling of moldboard plough surfaces (Aguilar et al., 2005).

Initial applications of (CRP) in accident reconstruction often involved scene documentation, but more recently, it is used to quantify vehicle dimensions and crush damage (Randles et al., 2010). So far, automated surface reconstruction methods, even if able to recover complete 3D geometry of an object, reported errors between 3% and 5% (Pollefeys et al., 1999), limiting their use to applications requiring only nice-looking 3D models (Remondino and Zhang, 2006). Bethmann et al. (2010) presented a least-squares' matching algorithm using the plane projective transformation model and polynomial transformations to handle geometric distortions between the images with coded targets.

Baltsavias and Zhang (2003) presented a practical system for automated 3D road network reconstruction from aerial images using knowledge-based image analysis. The system has been implemented as a stand-alone software package and has been tested on a large number of images with different landscape. Zhang et al. (2008) proposed an automated framework for road network extraction from high-resolution multi-spectral imagery. The pixels were classified by segmentation using a spectral clustering algorithm and then identified by a fuzzy logic classifier. Babu and Radhakrishnan (2016) presented a survey of various road extraction techniques which are used to extract road drawings from high-resolution images.

This work presented here will explore the usage of cell phone stereo images for the purpose of extracting as-built drawings of road intersections despite the lower field of view of the used cameras.

CAMERA SETUP AND ACQUISITION SYSTEM

Normal-base setup was used in this study to have a uniform image scale. During the acquisition of the images, the user maintained a constant distance from the object similar to that used for acquiring the chess board image during camera calibration. In order to acquire stereo images, a special stand was fabricated as shown in Fig. 2.

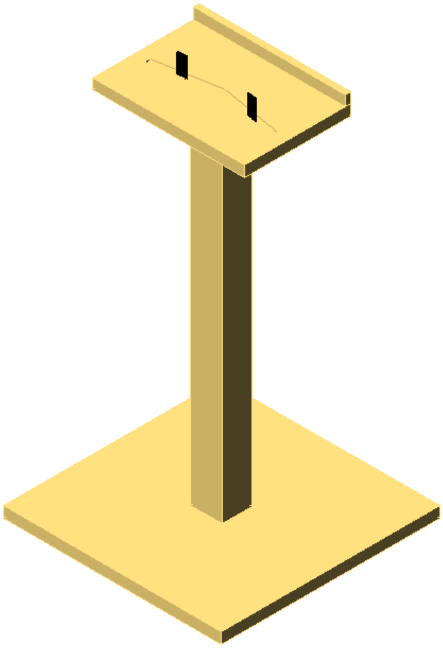

Figure (2): System setup consisting of a stand and two cameras to generate stereo paris

The stand allows the user to capture images with high overlap greater than 65%. For capturing stereo pairs, two cell phones of the same resolution should be fixed in the adjustable stand at once. In this study, different cell phones with different resolutions were used as shown in Table 1.

Table 1. Specifications of cell phone cameras used

Cell Phone	***Camera Specifications***
Cell Phone A	5 MP, f/2.2 camera
Cell Phone B	8 MP, f/2.2 camera
Cell Phone C	20.7 MP, f/2.0 camera

METHODOLOGY

The methodology used in this work consists of two main parts; (I) collecting points of high accuracy from the study area using differential Global Positioning System (GPS) and (II) acquiring images for the same area and comparing the coordinates of the acquired and collected points from these two methods. In order to carry out this methodology, the steps shown in Fig. 3 were followed.

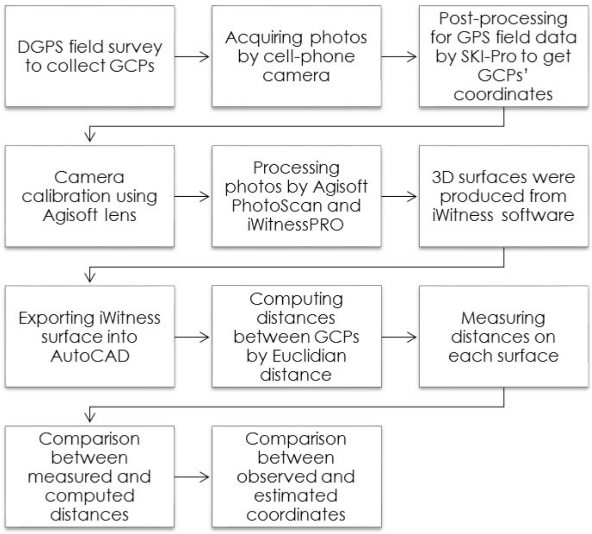

Figure (3): Flow chart showing the methodology used in this work

Field survey using GPS was carried out to collect 68 ground control points (GCPs) from the study area as shown in Fig. 4. These points were then processed using Ski-Pro software. This step is necessary for producing very accurate points which will be used as reference points for result verification. Photos from the field were then acquired using the fabricated stand shown in Fig. 2. In order to support the measurement from stereopair images, a set of well-distributed control points were measured using local surveying techniques in a local coordinate system.

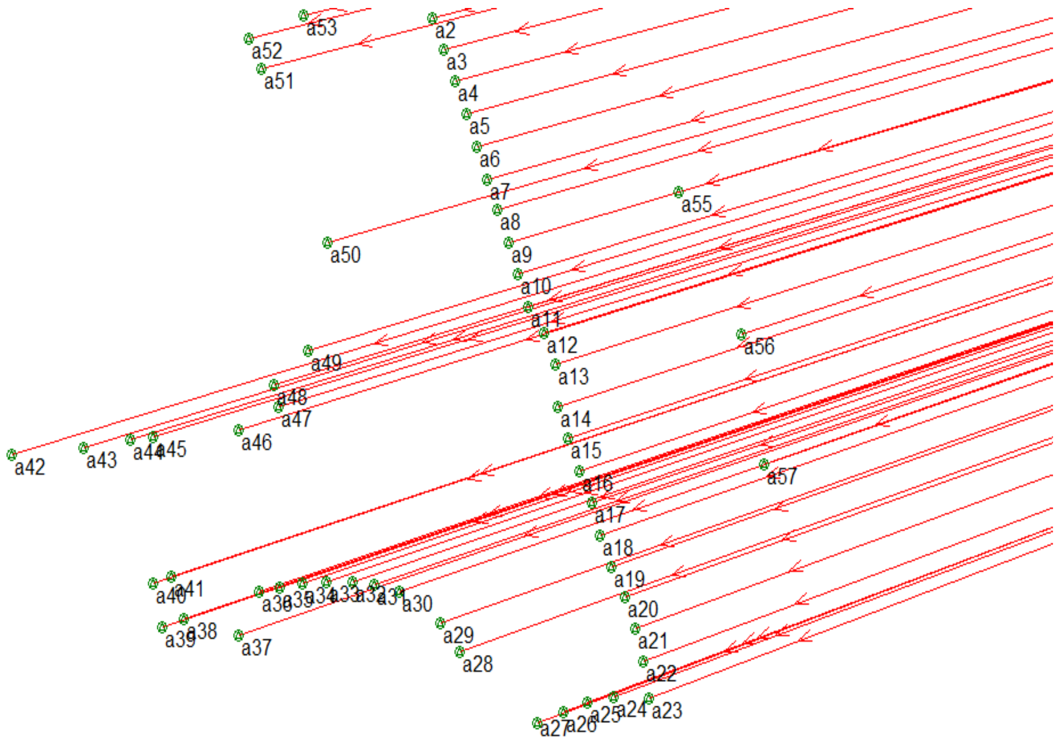

Figure (4): Sample of collected GCPs used in this study

Three different cell phones with different resolutions were used in this study to acquire photos. Each cell phone camera was calibrated using chessboard pattern and Agisoft software. This process is necessary for determining the internal camera geometric and optical characteristics (intrinsic parameters) and/or the 3D position and orientation of the camera frame relative to a certain world coordinate system (extrinsic parameters) (Tsai, 1987). However, poor camera calibration adds further uncertainty to camera measurements. If the image position of a point is inaccurate, the results depending on its image coordinates will be erroneous (Weng et al., 1992). Internal and external camera parameters of Cell Phone C -for example - are shown in Table 2.

3D surface of the study area was generated using iWitnessPRO software; different objects and points were determined and measured on this surface as shown in Fig. 5. The results were then compared with the actual coordinates and dimensions collected from the field by means of GPS system. In the final step, objects of the generated surface were exported into CAD format using iWitnessPRO software as shown in Fig. 6.

Table 2. Internal and external camera parameters of cell phone C

Parameter	*Value*	*Std. Error*
Image width	3840	
Image height	2160	
Focal length	2872.76	3.47976
Principal point (x)	-41.3263	4.14167
Principal point (y)	8.87329	3.80586
Affinity B1	4.87543	0.60349
Skew B2	-21.0904	0.624964
Radial k1	-0.0151229	0.0186795
Radial k2	0.597902	0.383132
Radial k3	-5.38716	2.92207
Radial k4	12.9905	53.7103
Tangential p1	-0.00746271	0.00046407
Tangential p2	0.00181057	0.000415156

Figure (5): Sample of measured points and objects from the generated surface using iWitnessPRO

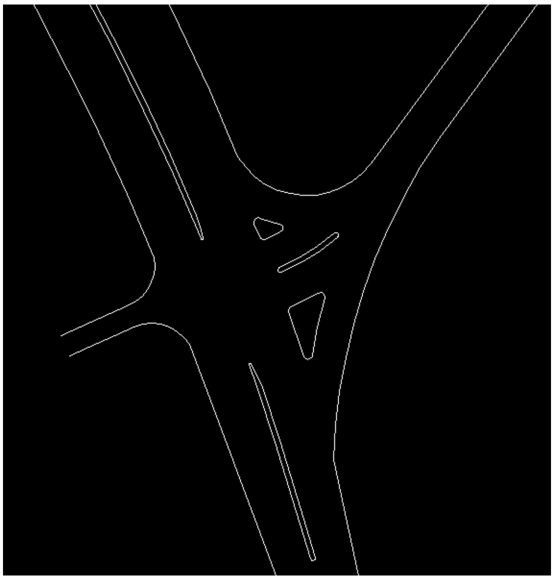

Figure (6): As-built CAD drawing of the study area using iWitnessPRO

RESULTS AND DISCUSSION

This study analyzed 3-dimensional locations for 68 check points by comparing those locations with coordinates determined by GPS. The coordinates of the 68 points were assessed using the mean value of the differences between measured and extracted points from the image. The results showed a clear trend; as the resolution of the cell phone increases, the mean differences decrease as shown in Table 3 and Fig. 7. The assessment mainly showed a difference of the image to be around 0.5 in all directions.

This study calculated geometric strength of the image using std. error of mean of image coordinates, which showed a standard error of mean around 0.035 in all directions.

Table 3. Statistical analysis of the extracted coordinates from the model

	Cell Phone A			***Cell Phone B***			***Cell Phone C***		
	Delta x	***Delta y***	***Delta z***	***Delta x***	***Delta y***	***Delta z***	***Delta x***	***Delta y***	***Delta z***
Mean	0.5414	0.5328	0.5455	0.487	0.5193	0.4943	0.4725	0.5144	0.4624
Std. error of mean	0.03784	0.0353	0.034	0.037	0.0382	0.0367	0.0331	0.0354	0.0357
Std. deviation	0.312	0.2912	0.2803	0.307	0.3151	0.3029	0.2727	0.2918	0.2942
Variance	0.09735	0.0848	0.0786	0.094	0.0993	0.0918	0.0744	0.0852	0.0865
Minimum	0.00483	0.0119	0.0197	0.006	0.0005	0.0004	0.0505	0.016	0.0062
Maximum	0.9987	0.9789	0.9969	0.969	0.9872	0.9844	0.9865	0.9865	0.9912
C.O.V.	0.57628	0.5465	0.5138	0.631	0.6068	0.6128	0.5771	0.5673	0.6362

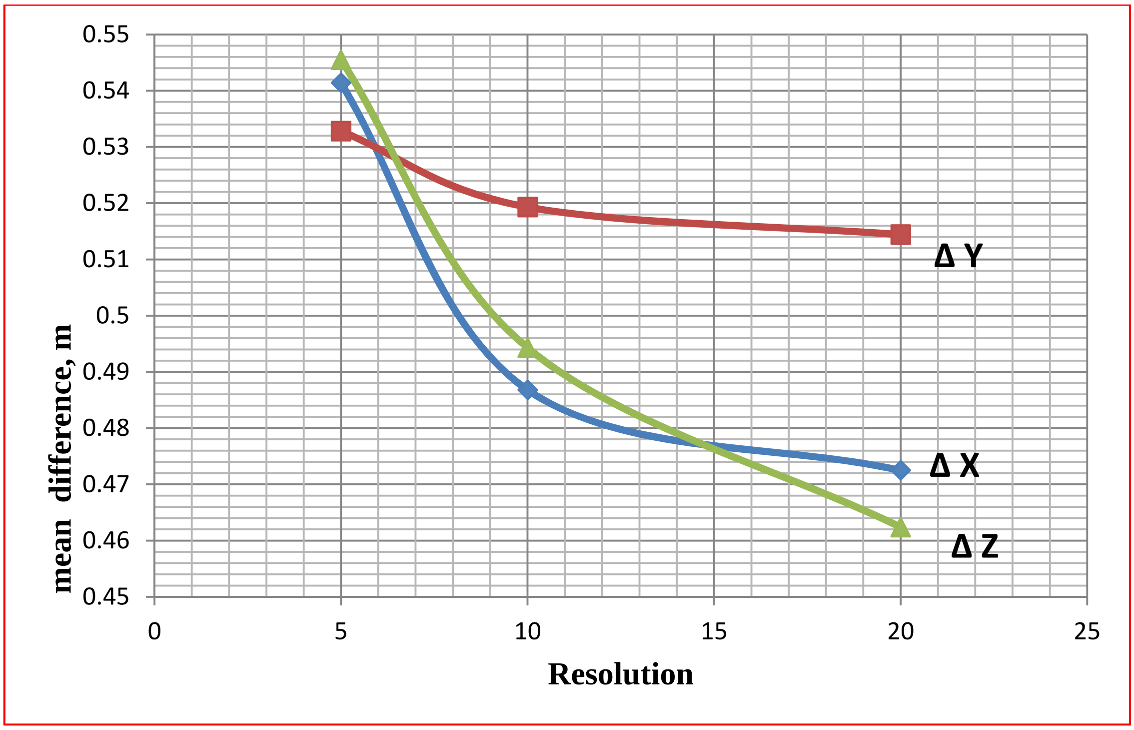

Figure (7): Relation between camera resolution and mean differences in coordinates

Different linear features were measured in the field and the extracted 3D model as well. The distances of these 10 features were computed using Euclidian distance, as shown in Table 4. The maximum difference of these measured features is 0.59 m, while mean of differences is 0.38, 0.29 and 0.19 for cell phones A, B and C, respectively, which shows the potential of using such method in extracting as- built drawings for roads intersections.

Table 4. Euclidian distance of different linear features from the study area

	GPS	***Cell Phone A***		***Cell Phone B***		***Cell Phone C***	
Point ID	***Distance (m)***	***Distance (m)***	***Difference***	***Distance (m)***	***Difference***	***Distance (m)***	***Difference***
(7-8)	2	2.23	0.23	1.89	0.11	2.07	0.07
(17-18)	1.36	1.82	0.46	1.39	0.03	1.68	0.32
(22-23)	1	0.76	0.24	0.76	0.24	1.05	0.05
(21-22)	2	1.87	0.13	1.77	0.23	2.34	0.34
(4-3)	1.89	2.25	0.36	1.54	0.35	2.07	0.18
(11-12)	1.39	1.05	0.34	1.08	0.31	1.66	0.27
(30-37)	6.27	5.72	0.55	5.68	0.59	6.17	0.09
(15-13)	2.1	2.56	0.46	2.36	0.26	2.02	0.07
(35-39)	1.3	0.83	0.47	1.55	0.25	1.39	0.09
(49-30)	5.65	6.17	0.52	6.19	0.54	6.06	0.41
Mean			0.38		0.29		0.19

CONCLUSIONS

To the authors' knowledge, the usage of cell phones for stereo image surface measurements is recent. It is facing many challenges, including the low field of view, resolution, image measurement accuracy and image configuration. However, mapping of intersection scenes showed a promising potential in this domain.

Results showed that the potential of extracting road intersection drawings was feasible. In fact, the accuracy of the extracted measurements was in the range of 0.4-0.5 m in all directions, which was equivalent to less than a pixel size in image domain. Moreover, the accuracy potential increased when using cell phones of higher resolution. Therefore, it is expected that the technology could be applicable in the near future with the yearly trend of increasing cell phone resolution.

It is expected that the proposed technology, setup configuration and procedure of extracting as-built drawings will open the door for other applications in the domain of transportation engineering, traffic engineering, road construction, among other domains. Moreover, we are looking forward to having hand-held cell phone applications of this technology on the smart phones themselves.

REFERENCES

Aguilar, M.A., Aguilar, F.J., Agüera, F., and Carvajal, F. (2005). "The evaluation of close-range photogrammetry for the modelling of moldboard plough surfaces". Bio-systems Engineering, 90 (4), 397-407.

Babu, R.S., and Radhakrishnan, B. (2016). "A survey on road extraction from satellite images". International Journal of Computer Science and Networks, 5 (1).

Baltsavias, Emmanuel P., and Zhang, Chunsun. (2003). "Automated updating of road databases from aerial imagery". ETH, Swiss Federal Institute of Technology Zurich, Institute of Geodesy and Photogrammetry.

Bethmann, F., and Luhmann, T. (2010). "Least-squares' matching with advanced geometric transformation models". ISPRS International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 38 (5), 57-69.

Dallas, R.W.A. (1996). "Architectural and archaeological photogrammetry". Chapter in: Close-Range Photogrammetry and Machine Vision, Edited by K.B. Atkinson, Wittles Publishing, Caithness, U.K., 283-302.

Ebrahim, M. A. (2004). "Using mobile phone cameras in digital close range photogrammetry". The Photogrammetric Journal of Finland, 19 (1), 11-22.

Fraser, C. (2015). "Advances in close-range photogrammetry". Presented to 55th Photogrammetric Week, Stuttgart, 7-11, 257-268.

Fraser, C.S., and Riedel, B. (2000). "Monitoring thermal deformation of steel beams *via* vision metrology". ISPRS Journal of Photogrammetry and Remote Sensing, 55 (4), 268-276.

Green, J., Matthews, S., and Turanli, T. (2002). "Underwater archaeological surveying using PhotoModeler, virtual mapper: different applications for different problems". International Journal of Nautical Archaeology, 31 (2), 283-292.

Heritage, G.L., Fuller, I.C., Charlton, M. E., Brewer, P.A., and Passmore, D.P. (1998). "CDW photogrammetry of low relief fluvial features: accuracy and implications for reach-scale sediment budgeting". Earth Surface Processes and Landforms, 23 (13), 1219-1233.

Maas, H.-G., Virant, M., Becker, J., Bösemann, W., Gatti, L., and Henrichs, A. (2002). "Photogrammetric methods for measurements in fluid physics experiments in space". Acta Astronautica, 50 (4), 225-231.

Mills, J.P., and Barber, D. (2004). "Geomatics techniques for structural surveying". ASCE Journal of Surveying Engineering, 130 (2), 56-64.

Mokhtar, M.B.R.M., and Matori A.N. (2013). "Close-range photogrammetry for landslide monitoring". International Journal of Civil Engineering and Geo-Environment, 4.

Pollefeys, M., Koch, R., and van Gool, L. (1999). "Self-calibration and metric reconstruction in spite of varying and unknown internal camera parameters". IJCV, 32 (1), 7-25.

Randles, B., Jones, B., Welcher, J., Szabo, T., Elliott, D., and Macadams, C. (2010). "The accuracy of photogrammetry *vs.* hands-on measurement techniques used in accident reconstruction". Society of Automotive Engineers, International, USA, 65-76.

Remondino, F., and Zhang, L. (2006). "Surface reconstruction algorithms for detailed close-range object modelling". ISPRS Commission III Symposium, Bonn, 20-22 Sept. 2006. IAPRS & SIS, 36 (3), 117-123.

Satchet, M.S. (2011). "Feasibility study of using mobile phone camera in digital close-range photogrammetry". Journal of Thi-Qar University, 7 (1), 61-70.

Tsai, R. Y. (1987). "A versatile camera calibration technique for 3D machine vision". IEEE J. of Robotics and Automation, RA- 3 (4), 323-344.

Weng, J., Cohen, P., and Herniou, M. (1992). "Camera calibration with distortion models and accuracy evaluation". IEEE Transations on Pattern Analysis and Machine Intelligence, 14 (10).

Yiting Wang, Xinliang Li, Liqiang Zhang, and Wuming Zhang. (2008). "Automatic road extraction of urban area from high spatial resolution remotely sensed imagery". The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 37 (B6b), Beijung.