Vision-based 2D map generation for monitoring construction sites using UAV Videos

Seongdeok Bang[a] Hongjo Kim[a] and Hyoungkwan Kim[a]

[a]Department of Civil and Environmental Engineering, Yonsei University, Seoul, South Korea
E-mail: bangdeok@yonsei.ac.kr, hongjo@yonsei.ac.kr, hyoungkwan@yonsei.ac.kr

Abstract –

This paper presents a system to generate a 2D map using unmanned aerial vehicles (UAV) videos. The system can process the collected images for lens distortion, unstable flight, and image redundancy. The system is demonstrated using an UAV video captured on road construction site in Namyangju city, Korea. The experimental result is a high-resolution 2D map of which resolution is 6010 by 9465. This study is expected to help site managers understand site conditions and make a decision timely in diverse construction sites.

Keywords –

Construction sites; UAV; Image Stitching; Computer Vision;

1 Introduction

Unmanned aerial vehicles (UAVs) equipped with a camera collect a large amount of images and videos in a short time from a variety of perspectives [1]. In the construction industry, UAVs have been investigated as the tool for monitoring infrastructures such as bridges, road, and plants [2]. UAV-based videos including as-built data of a construction site can be used for construction management applications, for example, work-in-process monitoring, safety management, and facility condition assessment. To name a few studies, Siebert and Teizer [3] researched 3D photogrammetric surveying for calculating earthwork volumes using a UAV system. Han et al. [4] proposed a formal process for construction progress monitoring using UAV images and 4D Building Information Model (BIM). González-Jorge et al. [5] experimented with camera-equipped UAVs to capture the geometric information of breakwaters for monitoring potential failures.

Image stitching is the method for integrating multiple images into one high-resolution image [6,7]. Recently, image stitching has been used in the field of construction management to monitor infrastructures [8,9]. These studies show that image stitching is suitable to cover the larger areas minimizing the loss of details. However, there are certain problems to be resolved for producing a map covering a large area such as a whole construction site using UAVs. Image capturing using UAVs is likely to obtain low quality images because of the vibration and immature control of aircrafts. Proper feature selection is another issue to be resolved for connecting multiple images.

To address the problem, this paper presents an automatic generation method of a 2D high-resolution map for monitoring construction sites using UAV videos. Figure 1 illustrates the system. The system performs a series of tasks, including (1) extracting key frame for UAV videos for reducing the size of an image dataset, (2) filtering out blurred images to obtain clear representation of the final map, (3) correcting camera lens distortion to rectify the curved effect on image boundaries, (4) matching images to unify each image coordinate into one global coordinate system, and (5) stitching and blending images to represent the whole construction site in a one integrated map. Details of the system and its validation are presented in the following sections.

2 System description

2.1 Frame selection

Similar scenes repeatedly appear in successive frames in a UAV video because of a high number of frame per seconds (fps) (at least 24 fps) [10,11]. Thus, key frame selection is required to reduce computational time for stitching images among nearly same visual information. The process to select key frames is based on the following Equation (1):

$$\text{frame per unit time} = \frac{\text{effective distance}}{\text{velocity of UAV}} = \frac{(1-\text{EO}) * {}^{1}/_{1-\alpha} * \tan\left(\frac{\text{FOV}}{2}\right) * \text{altitude of UAV per unit time}}{\text{velocity of UAV per unit time}} \quad (1)$$

in which EO and FOV are effective overlap ratio and the field of view of UAV, respectively, and α is the proportion of filtered images for blurring effect. Chaiyasarn et al. [12] and Zhu et al. [8] acquires images with at least 50% overlap between every two images for image stitching of tunnels. Considering these studies and empirical experiment, the value of EO and α are assumed to be 0.7 and 0.25 respectively. The calculated frame extraction rate per unit time will be accumulated until the total playback time of video.

2.2 Blur Filtering

Blurred images extracted from a blurred video have to be filtered for improving the quality of image stitching. Crete et al. [13] proposed the blur metric is able to quantify the occurrence of blur effect on each image. However, it is difficult to directly apply the value of blur metric which is ranging from 0 to 1 due to unclear criteria. In order to figure out the frame which are relatively more blurred than surrounding frames containing similar scenes, the blur value of each image is compared with the moving average.

2.3 Camera Correction

The curvature caused by the projection of straight lines of an image due to lens distortion degrades the performance of image stitching [7,14]. The camera with wide-angle lens is suitable for on-site monitoring, however, it has obvious radial distortion. Unless this distortion is considered, the result of proposed system will show blurring and edge dislocation. For compensating lens distortion, the intrinsic parameters of camera have to be calculated at first. Zhang [15] suggested the camera calibration technique to capture a planar pattern from different orientations, and the technique is used in this study for the correction of lens distortion.

2.4 Image alignment and blending

The process of this section is following the study of Szeliski [7]. Image stitching technique consists of two major processes: alignment and blending. Image alignment is finding geometric relationships between images through keypoint descriptor matching and unifying images with one geometric information. Image blending is the smooth integration of the color values between two images. Image stitching can be implemented using tools such as AutoStitch, ICE (Image Composite Editor) and Photostitch. In particular, ICE is a free software developed by Microsoft Research based on the research of Szeliski and has an advanced stitching capability. In this study, ICE was used to construct panorama image representing a construction site.

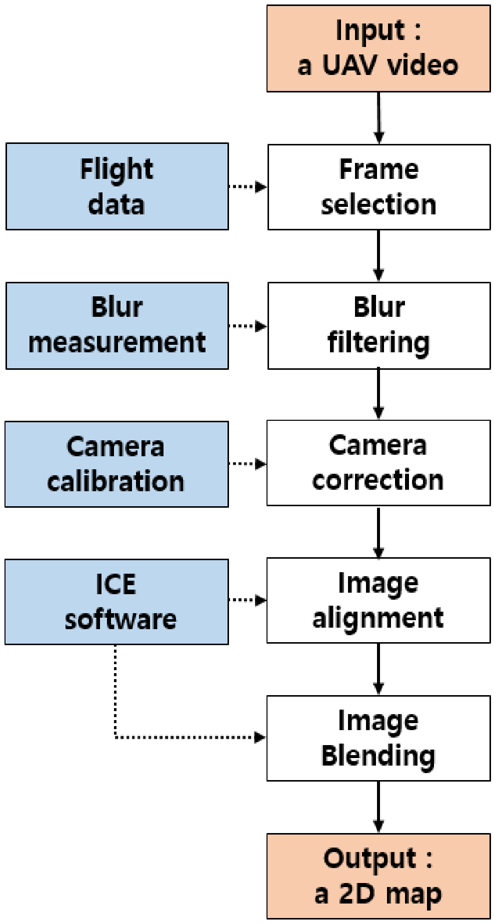

Figure 1. System for making a 2D high resolution map using UAV based images

3 Experiment and Discussion

UAV video captured in Namyangju city, Korea was used for validation of the proposed system. Frame selection, blur filtering, and camera lens correction were executed using the MATLAB programming language. In particular, the camera calibration was processed using the MATLAB cameraCalibration App. The model of UAV was DJI Phantom 3 Professional. The video used for the experiment had 42 seconds of playback time at 30fps. Thirty eight images were extracted by the frame selection function and 11 images of them were filtered out by the blur filtering function. The resolution of each image was 3840 by 2160 and the resolution of the resultant image was 6010 by 9465. Figure 2 shows the result–the visible map to perceive construction site at a glance.

4 Conclusion

This paper proposes a method to automatically generate a 2D high-resolution map for monitoring construction sites using UAV videos. The system enables the construction site to be recognized as a high-resolution map at a glance. Thanks to the error correction functions, a UAV video taken by a novice UAV pilot can be transformed into a map in a short time. Image stitching technique in computer vision is useful to represent a large-scale construction site. With future studies, the proposed system is expected to help site managers monitor the current construction status timely and frequently.

Acknowledgement

This work was supported by grants from the National Research Foundation of Korea (NRF), funded by the Korea government (MSIP) (NRF-2014R1A2A1A11052499 and No. 2011-0030040).

References

[1] P. Liu, A.Y. Chen, Y.-N. Huang, J. Han, J. Lai, S. Kang, T. Wu, M. Wen, M. Tsai, A review of rotorcraft Unmanned Aerial Vehicle (UAV) developments and applications in civil engineering, Smart Struct. Syst 13 (6) (2014) 1065-1094.

[2] Y. Ham, K.K. Han, J.J. Lin, M. Golparvar-Fard, Visual monitoring of civil infrastructure systems via camera-equipped Unmanned Aerial Vehicles (UAVs): a review of related works, Visualization in Engineering 4 (1) (2016) 1-8.

[3] S. Siebert, J. Teizer, Mobile 3D mapping for surveying earthwork projects using an Unmanned Aerial Vehicle (UAV) system, Automation in Construction 41 (2014) 1-14.

[4] K. Han, J. Lin, M. Golparvar-Fard, A formalism for utilization of autonomous vision-based systems and integrated project models for construction progress monitoring, 2015 Conference on Autonomous and Robotic Construction of Infrastructure, 2015, pp. 118-131.

[5] H. González-Jorge, I. Puente, D. Roca, J. Martínez-Sánchez, B. Conde, P. Arias, UAV photogrammetry application to the monitoring of rubble mound breakwaters, Journal of Performance of Constructed Facilities 30 (1) (2014) 04014194.

[6] M. Brown, D.G. Lowe, Automatic Panoramic Image Stitching using Invariant Features, International journal of computer vision 74 (1) (2007) 59-73.

[7] R. Szeliski, Computer Vision: Algorithms and Applications, Springer Science & Business Media, New York, 2010.

[8] Z.H. Zhu, J.Y. Fu, J.S. Yang, X.M. Zhang, Panoramic Image Stitching for Arbitrarily Shaped Tunnel Lining Inspection, Computer-Aided Civil and Infrastructure Engineering 31 (12) (2016) 936-953.

[9] R. Adhikari, O. Moselhi, A. Bagchi, Image-based retrieval of concrete crack properties for bridge inspection, Automation in Construction 39 (2014) 180-194.

[10] S. Nadarajah, K. Sundaraj, Vision in robot soccer: a review, Artificial Intelligence Review 44 (3) (2015) 289-310.

[11] K. Haase, N. Kröger-Lui, A. Pucci, A. Schönhals, W. Petrich, Real-time mid-infrared imaging of living microorganisms, Journal of Biophotonics 9 (1-2) (2016) 61-66.

[12] K. Chaiyasarn, T.-K. Kim, F. Viola, R. Cipolla, K. Soga, Distortion-Free Image Mosaicing for Tunnel Inspection Based on Robust Cylindrical Surface Estimation through Structure from Motion, Journal of Computing in Civil Engineering 30 (3) (2015) 04015045.

[13] F. Crete, T. Dolmiere, P. Ladret, M. Nicolas, The blur effect: perception and estimation with a new no-reference perceptual blur metric, Human Vision and Electronic Imaging Xll, 2007, Vol. 6492, International Society for Optics and Photonics 2007, pp. 1-11.

[14] H.S. Sawhney, R. Kumar, True multi-image alignment and its application to mosaicing and lens distortion correction, IEEE transactions on pattern analysis and machine intelligence 21 (3) (1999) 235-243.

[15] Z. Zhang, A flexible new technique for camera calibration, IEEE transactions on pattern analysis and machine intelligence 22 (11) (2000) 1330-1334.

Figure 2. The result of 2D high-resolution map using the UAV video of the road construction site