AUGMENTED REALITY VISUALIZATIOM OF FLOOD SITUATION IN UNDERGROUND SPACES

Makoto Hirose[1]. Kazuki Fujisato[1], Taira Ozaki[2], Satoshi Kubota[2], Hiroshige Dan[3], and Yoshihiro Yasumuro[4]

1) Master Course Student, Graduate School of Science and Engineering, Kansai University, Osaka, Japan. Email: {k466162, k434014}@kansai-u.ac.jp
2) Dr. Eng., Assoc. Prof., Faculty of Environmental and Urban Engineering, Kansai University, Osaka, Japan. Email: t_ozaki@kansai-u.ac.jp
3) Dr. Informatics, Assoc. Prof., Faculty of Environmental and Urban Engineering, Kansai University, Osaka, Japan. Email: dan@kansai-u.ac.jp
4) Dr. Eng., Prof., Faculty of Environmental and Urban Engineering, Kansai University, Osaka, Japan. Email: yasumuro@kansai-u.ac.jp

Abstract: Recently, risk of inundation in underground structures and malls have been increasing due to more and more frequent localized heavy rainfalls around the city in Japan. Existing hazard maps are difficult to understand the inundation situations predicted from the amount of rainfall and the notations of them also tend to be complexed. To enhance the expression of the predicted water levels in inundation, current technique of outdoor augmented reality (AR) systems depend on the location information by GPS, whose services are not available in underground and indoor spaces. This study proposes an intuitive AR visualization of estimated underground flood situations on mobile terminals, including smartphones, in order to contribute to inundation measures including refuge preparations. The proposed method acquires the three-dimensional coordinates of the natural features from prerecorded images by both structure from motion (SFM) technique and three-dimensional scanning by a laser scanner. The shooting viewpoint can be estimated by corresponding three-dimensional coordinates and natural features of the user photographed image, solving a Perspective-n-Point (PnP) problem. Then the water surfaces expressed by CG is superimposed on the photograph at the viewpoint of the user. The water surfaces are generated by using 3D models created based on both 3D data from scanned point cloud and SFM result. We implemented a prototype system using the proposed method and conducted an experiment in which the target place is located at underground structure in an actual railway station. The reproducibility of the user's viewpoints was verified and view-dependent AR representation was achieved. This method is expected to contribute to the flood measures in underground spaces where GPS does not work.

Keywords: Augmented Reality (AR), Flood Simulation, Underground Space, Structure from Motion (SFM), Laser Scan

1. INTRODUCTION

Recently, many cities meet heavy rainfalls, which often exceed drainage capacity of sewerage systems and lead to damage of inundation above and/or under the floor flooding. Some rainwater intrudes into underground spaces of center of the city, such as metro stations, parking spaces and shopping malls, and the people may face the danger of underground flooding all of sudden. Especially for the people who happen to be staying in underground facilities, it is hard to know the risk of short-time heavy rainfall, since they are isolated from outdoor weather conditions. Therefore, it is very important to have an emergency plan for flooding and systematic solution to notify the estimated hazardous risks according to realtime rain conditions. In order to estimate the underground flooding level caused by rainfalls relative to time and place, simulation of inflow discharges by different profiles of short-time high intensity rainfall can be conducted, by using 1D-2D urban flood model (Ishigaki et.al. 2011, 2013). It has been found that inflow volume, start time of inflow and velocity spread are quite different in the three cases, but location of inflow is almost same. Then, we have to move a quick response to the flush flood by high intensity rainfall. On the other hand, spread of hazard maps are promoted as flood control measures in many municipalities recently. However, existing hazard maps is sometimes difficult to read out the inundation situations predicted from the amount of rainfall. The notations for the maps also tend to be complicated. Eventually, the flood simulation results are hardly reflected to flood control measures. This study proposes an effective visualization method of expected flood risk by using AR representation. Based on our experiences at application development at cultural heritage site (Matsushita 2014, Yasumuro 2015), our method is designed to acquire information of the individual user's viewpoint at underground environment, where GPS does not function, in order to superimpose the flood surfaces expressed by CG on the photograph captured by the mobile terminal of the user.

2. METHOD

As depicted in Fig.1, we prepare a large photo collection of the target area and organize it within an identical 3D space. Using the principle of structure from motion (SFM) technique (Snavely N., et.al. 2006), extracted feature points on the images can be matched to each other and their 3D coordinates can be estimated. We also prepare a 3D model with real dimensions of the target area based on point cloud data captured by a laser scanner data, and calculate the transformation matrix between the space of SFM output and the 3D model. When a new photo comes in from the mobile user, its feature points are extracted and immediately used for searching for the most similar image in the pre-registered image set. The Perspective-n-Point (PnP) problem is solved, that is, 2D feature points on the input photo are associated with the corresponding 3D coordinates in the SFM space, and finally an extrinsic camera parameter of the mobile device can be estimated in the 3D model coordinates. The 3D model can be used for rendering a CG scene of the flooded situation, which is estimated by simulation assuming that the area has a particular heavy rain. Thus the visualized flooded water depth can be overlaid on the newly taken photo, taking into account consistency between the user's viewpoint and orientation and flood CG.

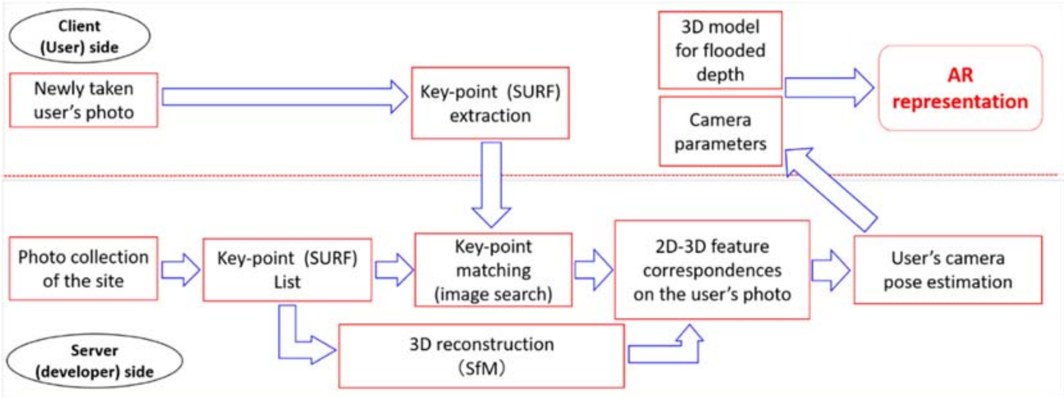

Figure 1. Process chain of the proposed method

3. IMPLEMENTATION

We chose a part of an actual railway station (Kandai-mae station on Hankyu Railway at Suita city in Japan) as the underground target area. We took 64 photos around the ticket gates where a typical high-foot traffic area at south part of the station underground, using a digital single-lens reflex camera, EOS kiss x7 (Canon corp.). As for a mobile user input, iPhone5 is used for the mobile terminal. We use SURF (Speeded up robust features) (Bay et.al. 2006) as the keypoint for feature extraction, considering the robustness and computational costs. Since the same feature points should be extracted from both of the input photo and newly taken by the on-site user, we use the same keypoint extraction implementation for on-site process as well. In order to quickly retrieve the most similar image to the input image out of the photo collection used for SFM process, we employ kd-Tree structure to accumulate the photo collection. All these processes are coded with C++ using OpenCV libraries.

SFM is performed by using Visual SFM (Wu, 2013). A part of the photo collection is shown in Figure 2 (left). Figure 2 (middle) shows the reconstructed point cloud (3D coordinates of the feature points) and estimated positions and the orientations of the cameras by SFM. The point cloud is colored by original photo information. The truncated pyramids depict the camera positions and the orientations. Then those 3D-reconstructed feature points have both 2D coordinates on the photo(s) and 3D coordinates which are spontaneously defined by SFM process. Figure 2 (right) shows dense mesh model generated by multi-view stereo method (Jancosek et al., 2011). Using a CG modeling free software, Blender, low-polygonal model of the station structure is prepared by manually tracing the point cloud data captured by a laser scanner, Focus3D X330 (FARO Inc.). Rendering the flooded water surface on the 3D model is done by OpenGL-based codes. Figure 3(left) shows the scanned point cloud by the laser scanner, based on which, a polygonal model shown in Figure 3

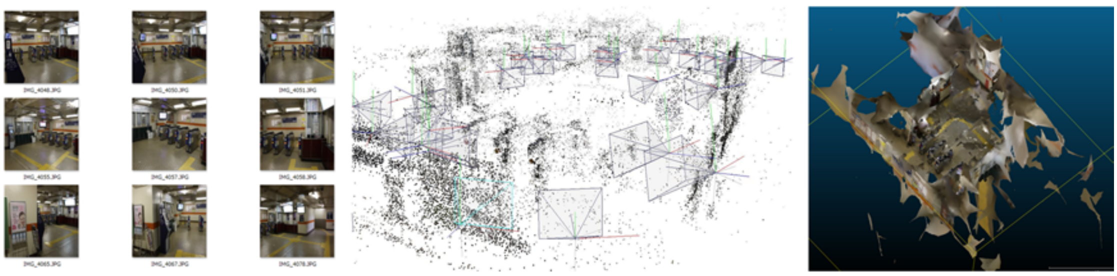

Figure 2. SFM process: photo collection (left) and reconstructed point cloud and camera positions (right)

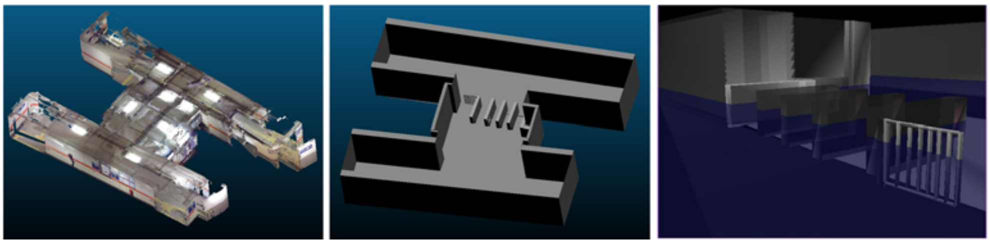

Figure 3. Point cloud acquired by laser scanner (left) and simplified polygon model (right)

(middle) is created. Using this model, additional flooded water surface is rendered with OpenGL as shown in Figure 3 (right). Only the water surface is extracted by stencil buffers with OpenGL and is used and overlaid on the mobile user's photo for AR visualization. We calculate a transformation matrix to register the SFM 3D coordinate into 3D CG model of the real scale coordinate by finding corresponding points between them, using a point cloud editing open source software, CloudCompare.

4. RESULTS AND DISCUSSION

Figures 4 shows an example of the visualized flooded situation in resultant AR representation. In the Figure, before flooded scene (left) and deeper flooded waters (middle to right-hand) are expressed, assuming that dark-colored water intrudes into around the ticket gates. Figure 5 (left) shows a failure case in which totally wrong direction of the view of the water surface is overlaid. Figure 5 (right) shows the SFM result of the similar part of the photo. Since the reconstructed 3D geometry is so fuzzy and reference 3D coordinates must be noisy, it is conceivable that the solution of the PnP problem of this view is affected by the noises. Even though we employ RANSAC (Random Sample Consensus) algorithm (Fischler and Bolles, 1981) to exclude outlier pairs of 2D keypoint and reconstructed 3D coordinates, SFM reconstruction contains unreliable parts. Enhancement of this 2D-3D mapping reliability by directly associating keypoints to laser scanner data is a part of our future work.

Figure 4. Result of AR representation: before flooded (left),

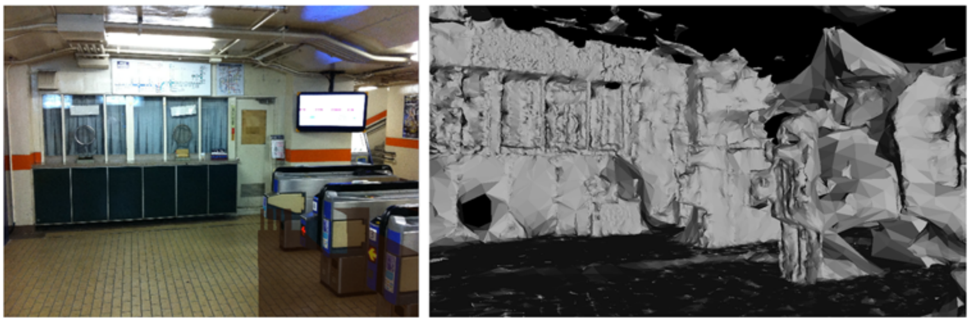

Figure 5. Failure case example

5. CONCLUSION

This paper described an AR system for visualizing expected flood condition at the underground construction on the spot, where GPS cannot be used. Especially, our method does not require any additional facilities or systems to install sensors and equipment on the site. Furthermore, wireless network communication is available in many underground facilities and indoor situation. The implemented system so far uses only single photo images as input, since the through put of the local network for data communication on the smartphone is sometimes not so high enough for realtime transmission of image data. Our next step is to minimize the displacements between the photo contents and CG water surface edges on AR representation, by giving more accurate 3D coordinates for solving PnP problems. Also applying this method for large scale underground area is our focus as well.

ACKNOWLEDGMENTS

We are grateful to Hankyu Corporation for helpful cooperation to collect the live data on site. This work was supported by Japan Society for Promotion of Science (JSPS) Grants-in-Aid for Scientific Research (15H02983, 15K02977, 16H05000).

REFERENCES

T. Ishigaki, T.Ozaki, T.Inoue, H. Shimada, K. Toda (2011) Drainage system, rainwater flooding and underground inundation in urban area, Proc. of 12th International Conference on Urban Drainage, Porto Alegre/Brazil, PAP005466. (on CD-ROM).

T. Ishigaki, N. Asano, M. Morikane, T. Ozaki, K. Toda (2013) Extreme Hazard of Pluvial and Tsunami Floods in a Dnesely Urbanized Area, International Conference on Flood Resilience: Experiences in Asia and Europe,(on USB)

N. Snavely, S. M. Seitz, and R. D. Szeliski. (2006) Photo tourism: Exploring photo collections in 3D, ACM Transactions on Graphics (SIGGRAPH Proceedings), 25 (3), 835-846.

R. Matsushita, T. Higo, H. Suita, Y. Yasumuro (2015) On-site An Interface with Web-Based 3D Archiving System for Archaeological Project. ISMAR 2015: 208-209

Y. Yasumuro; R. Matsushita; T. Higo; H. Suita: (2016) On-site AR Interface based on Web-based 3D Database for Cultural Heritage in Egypt, EUROGRAPHICS Workshop on Graphics and Cultural Heritage, pp. 183-186.

H. Bay, T. Tuytelaars, L. V. Gool (2006) Surf: Speeded up robust features. In In ECCV2006, pp. 404–417.

C. Wu (2013). Towards linear-time incremental structure from motion, International Conference on 3DTV, pp. 127-134.

M. Jancosek and T. Pajdla, (2011), Multi-View Recon-struction Preserving Weakly-Supported Surfaces, CVPR 2011, pp.3121-3128.

Blender: https://www.blender.org/

CloudCompare: http://www.danielgm.net/cc/

M. A. Fischler, R. C. Bolles (1981) Random Sample Consensus: A Paradigm for Model Fitting with Applications to Image Analysis and Automated Cartography. Comm. of the ACM, Vol 24, pp 381-395.