Efficient Mapping Technique under Various Spatial Changes for SLAM-based AR Services

Hyunwoo Cho*
Content Research Division, ETRI
Daejeon, South Korea
nonoriri@etri.re.kr

Sangheon Park
Content Research Division, ETRI
Daejeon, South Korea
shaprk12@etri.re.kr

Chanho Park
Content Research Division, ETRI
Daejeon, South Korea
chanho@etri.re.kr

Sung-Uk Jung
Content Research Division, ETRI
Daejeon, South Korea
brcastle@etri.re.kr

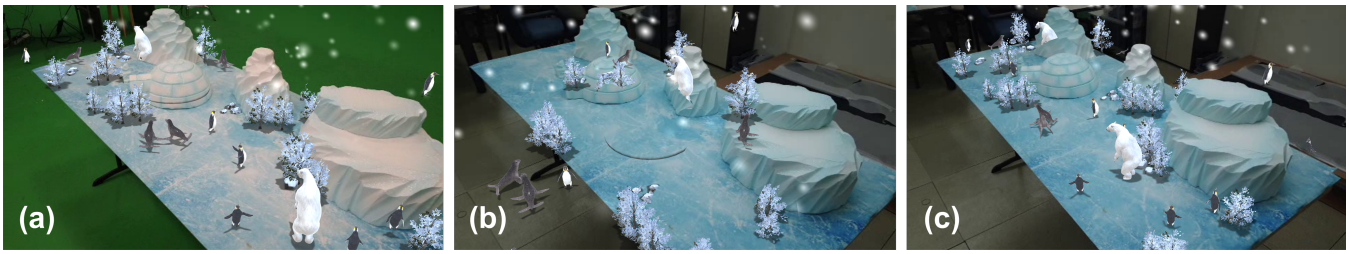

Figure 1: (a) AR content "Winter Village" played in space $P_{Control}$, (b) Virtual objects are positioned incorrectly due to a newly created map in another $P_{Location}$, (c) AR content applied to the map generated using the proposed method

ABSTRACT

Recently, many attempts have been made to apply real-time simultaneous localization and mapping (SLAM) technology to augmented reality (AR) applications. Such AR systems based on SLAM technology are generally implemented by augmenting virtual objects onto a diorama or three-dimensional sculpture. However, a new SLAM map needs to be generated if the space or lighting where the diorama is installed changes. This leads to the problem of updating the coordinate system each time a new SLAM map is generated. Updates to the coordinate system signify that the positions of the virtual objects placed in the AR space change as well. Therefore, we proposed a SLAM map regeneration technique in which the existing coordinate system is maintained even if a new map is generated.

CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**.

KEYWORDS

SLAM based AR, Diorama, Augmented Reality

VRST '21, December 8–10, 2021, Osaka, Japan

ACM ISBN 978-1-4503-9092-7/21/12.
https://doi.org/10.1145/3489849.3489916

ACM Reference Format:
Hyunwoo Cho, Sangheon Park, Chanho Park, and Sung-Uk Jung. 2021. Efficient Mapping Technique under Various Spatial Changes for SLAM-based AR Services. In *27th ACM Symposium on Virtual Reality Software and Technology (VRST '21), December 8–10, 2021, Osaka, Japan.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3489849.3489916

1 INTRODUCTION

Augmented reality (AR) is a technology that provides users with immersive visual effects and interactions in real time by overlaying virtual objects on real scenes. In the AR field, a method of estimating the camera pose using a plane marker or detecting feature points from a plane image and augmenting virtual objects is generally used. However, SLAM technology has recently made it possible to naturally augment virtual objects on complex-shaped three-dimensional objects such as a diorama. ORB-SLAM2 [1] and VINS [3] are representative real-time SLAM algorithms suitable for AR applications.

In general, SLAM-based AR systems work in the following two stages. First, a map of the target space or object is generated in advance. Next, the camera pose is tracked in real time using the previously generated map, and virtual objects are augmented. For SLAM-based AR systems in this environment, there are largely two problems. First, if the position of the diorama or sculpture for which the map was generated is altered or the lighting is changed, the generated feature points in the existing map are not detected in the new environment. SLAM mapping process can be performed even in the camera tracking stage, but the proportion of useless map points may increase, which cause overall tracking performance degradation. Second, if a map is generated again in this new envi-

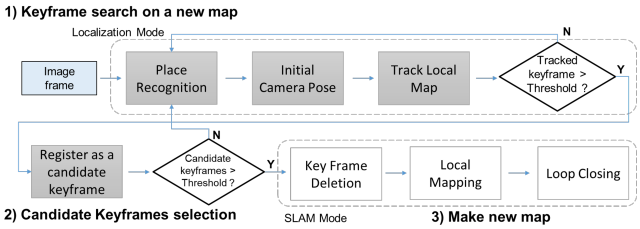

Figure 2: Specific process of the proposed method

ronment, a coordinate system different from that of the existing map is created. As a result, the positions of the virtual objects placed in the AR space are disarranged, as shown in Figure 1(b). To place these disarranged virtual objects accurately, additional time and effort are required.

In this study, we propose an efficient map regeneration technique that maintains the coordinate system of the existing map and augments virtual objects in their previous positions even when a new SLAM map is generated due to changes in the environment.

2 PROPOSED METHOD

Prior to explaining the proposed technique, the map regeneration scenario for AR services is explained as follows to provide background knowledge. The user creates an ORB-SLAM based map to augment virtual objects on a diorama similar to the one depicted in Figure 1. The user then places virtual objects on the coordinate system of the created map. To place the diorama in a different place and activate AR content as shown in Figure 1(b), a new map needs to be generated. If the proposed map regeneration technique is used in this process to create a new map with the same coordinate system, the same AR content can be activated without rearranging the content.

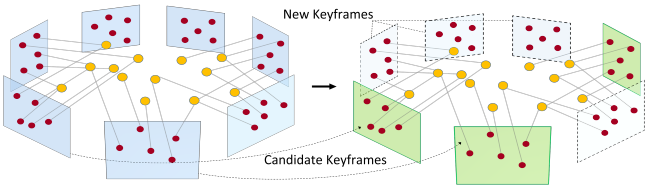

Figure 3: Map regeneration process

The proposed technique can be divided into three main stages, as shown in Figure 2. i) In the first stage, place recognition is performed for the diorama placed in a new location by referring to the previously generated map. Here, if the re-localization succeeds in finding the keyframe equivalent to the existing map, whether three or more consecutive keyframes can be tracked needs to be verified. The reason for tracking consecutive keyframes is to select a key frame with a relatively stable camera pose. ii) Subsequently, in the second stage, the keyframes selected in the previous stage are designated and saved as candidate keyframes. The first stage is performed until at least three candidate keyframes are selected. The reason for finding several candidate keyframes is to maintain the existing map coordinate system and scale as much as possible. iii) In the last stage, as shown in Figure 3, all remaining keyframes and map points other than the selected candidate key frames are removed from the map. Then, a new map including the candidate keyframes is generated through the local mapping process. The map generated in this manner regenerates most of the keyframes. Hence, the coordinate system of the existing map can be maintained without degrading the tracking performance.

3 EXPERIMENTAL RESULTS

In this work, we applied the proposed technique based on ORB-SLAM2 [1] (mono) and conducted a verification experiment. To verify the performance of our novel SLAM map regeneration technique, we changed the position and lighting environment of the target diorama to compare the camera tracking performance. In addition, to confirm whether the coordinate system remains the same, we applied the proposed method to the AR Room [2] system.

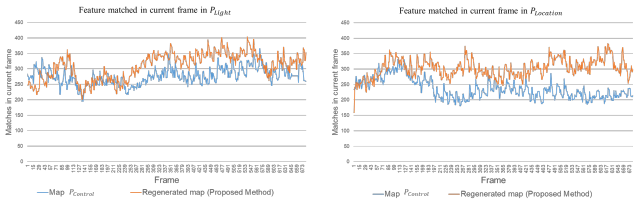

Figure 4: The number of matched keypoints in P_{Light} and $P_{Location}$

The experimental environment is shown in Figure 1; $P_{Control}$ is set as the control group, only the lighting conditions are changed in the same location for P_{Light}, and the location of the diorama is changed for $P_{Location}$. Maps were generated using the proposed method in P_{Light} and $P_{Location}$. We evaluated the tracking performance by measuring the number of matching features out of 1000 feature points extracted from each frame. If the generated map in $P_{Control}$ is used as is in P_{Light} and $P_{Location}$, as shown in Figure 4, the number of the matched keypoints is noticeably reduced. On the other hand, it is confirmed that the camera tracks robustly for the map generated using the proposed method. Also, it can be observed that the virtual objects in Figure 1(c) are arranged similarly to those in Figure 1(a) without a significant error.

4 CONCLUSIONS

In this study, we proposed a novel method that can generate a SLAM map in a new space while maintaining the existing coordinate system in a SLAM-based AR system. When the position of an object or lighting condition is changed in an AR service using a diorama, the SLAM map is generated based on the same coordinate system. Therefore, the AR content arranged on the map can be used as is without an additional authoring process.

ACKNOWLEDGMENTS

This work was supported by Institute of Information & communications Technology Planning & Evaluation (IITP) grant funded by the Korea government(MSIT) (No.2021-0-00230, 'Development of real·virtual environmental analysis based adaptive interaction technology')

REFERENCES

[1] Raúl Mur-Artal and Juan D. Tardós. 2017. ORB-SLAM2: An Open-Source SLAM System for Monocular, Stereo, and RGB-D Cameras. *IEEE Transactions on Robotics* 33, 5 (2017), 1255–1262. https://doi.org/10.1109/TRO.2017.2705103

[2] Sangheon Park, Hyunwoo Cho, Chanho Park, Young-Suk Yoon, and Sung-Uk Jung. 2020. AR Room: Real-Time Framework of Camera Location and Interaction for Augmented Reality Services. In *2020 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*. 736–737. https://doi.org/10.1109/VRW50115.2020.00219

[3] Tong Qin, Peiliang Li, and Shaojie Shen. 2018. VINS-Mono: A Robust and Versatile Monocular Visual-Inertial State Estimator. *IEEE Transactions on Robotics* 34, 4 (2018), 1004–1020. https://doi.org/10.1109/TRO.2018.2853729