Augmented Reality Approach For Position-based Service using Handheld Smartphone

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ABSTRACT

In this work, we present an augmented reality (AR) approach for position based service using a smartphone in an indoor environment. The AR method, combined with position estimation, provides a user with a smartphone with a service that is specific to a particular position without using a marker or any other hardware device. The position in an indoor environment is estimated using an IMU sensor only in the smartphone. The accuracy of the position and heading direction of the user is improved by integrating the values from the accelerometer and the gyro using Principal Component Analysis(PCA) and Extended Kalman Filter(EKF). Then, a drift noise of the estimated position is reduced by a registration step performed at a specific position. The estimated position is given to the position based service, which is provided to the user on the smartphone screen through AR. The concept of the proposed method is demonstrated with some examples.

CCS CONCEPTS

• **Computing methodologies → Mixed / augmented reality**.

KEYWORDS

Augmented reality, indoor position estimation, position-based service

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1 INTRODUCTION

The position-based service using AR is a popular topic these days as the hardware and software for a smartphone, and the network speed improve. More and more applications have been introduced for use in an indoor environment where the global positioning system is not available. The position-based AR requires the position and the orientation of the smartphone for a proper augmentation of virtual information onto the real environment. However, the robust estimation of the position and orientation of the device in the indoor environment is still a difficult problem. This situation even gets worse in an environment where GPS is not available, WiFi is not available, and a magnetometer is not working correctly due to various steel structures such as a construction site of an offshore structure. Therefore, a method of position and orientation estimation is required, and an AR service should be developed for use in such an environment. The potential of the position-based AR service has been well recognized in the industry. For example, a worker can check if a part has been correctly installed at the desired position. Moreover, they can retrieve necessary information for inspection and maintenance of a part or a machine at a specific position. However, in such an environment, the position and orientation of the device are hard to be estimated because of such an environment, as mentioned before. In this work, we present a method of the position-based AR framework to deal with such problems. The position of the smartphone (the user) is estimated using an IMU sensor only. The accuracy of the position and orientation is improved using a registration method. The estimated position and orientation are then combined with the AR method for a position-based service.

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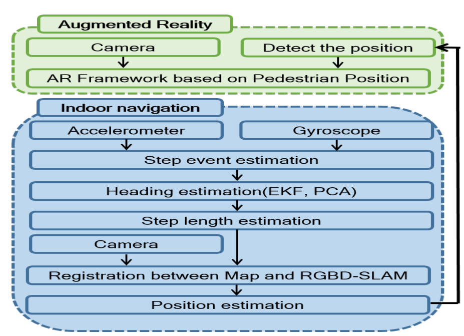

Figure 1: Block diagram of the proposed AR framework.

2 PROPOSED METHOD

Figure 1 shows the overall procedure of the proposed method. We assume that a user holds a smartphone nearly horizontally on his/her hand while moving, which is a condition different from the existing configuration that an IMU is attached to an ankle or a foot. Next, the 3D model of the indoor environment where the AR service is deployed is available. In this work, we created a 3D map of the space through the 3D scan and added position-specific information to the map. Under this setting, we developed a pedestrian dead reckoning based on the EKF and the PCA for improved position estimation. Motivated by the empirical model [Tian et al. 2014], we propose a step detection and heading estimation methods.

Based on the physical characteristics of a pedestrian, a waveform of the norm of acceleration follows the formation of cyclical changes. The steps are counted considering the range between the maximum acceleration value $A_{max,t}$ and the minimum acceleration value $A_{min,t}$ at Step t. We impose two conditions for a robust step detection from the acceleration values. The time interval between $A_{max,t}$ and $A_{max,t+1}$ should be larger than a threshold. Second, the time interval between $A_{max,t}$ and $A_{min,t}$ should be lower than a threshold. We use one second as the threshold. Next, the estimation of the user's heading is improved by combining the Extended Kalman Filter [Jiménez et al. 2010] and the principal component analysis (PCA) [Mohssen et al. 2014]. The EKF reduces the noise effect by minimizing the covariance of the accelerometer and gyroscope. For the EKF method, the heading angle for a short period time is reliable but the drift error accumulates over an extended period of time. On the other hand, the PCA based method tends to produce a stable heading angle for a long straight movement because it uses the acceleration values acquired for the past three steps. We combine these two methods as follows. When the heading directions by the two methods, denoted as EKF_t and PCA_t, are similar, we use the PCA based method to determine the heading direction. When $|EKF_t - EKF_{t+1}|$ is larger than 8 degrees, we determine that it is a corner and adjust the heading direction based on the difference. Otherwise, we estimate the amount of the heading angle change by $\omega_{EKF}(EKF_t - EKF_{t-1}) + \omega_{PCA}(PCA_t - PCA_{t-1})$, where $\omega_{EKF} = 0.1$ and $\omega_{PCA} = 0.9$ are the weights empirically determined in this work. The step length is computed by using the equation in [Tian et al. 2014]. Optionally, the position accuracy is further improved by the registration method. At a certain position such as a corner, the user may scan the environment around the position of the user using a SLAM method to obtain the 3D geometric shape of the environment. In this work, we used a smartphone with a depth sensor and an RGBD-SLAM [Labbé and Michaud 2018] for data acquisition. Then, the acquired points are registered to the 3D model of the space using an ICP algorithm to obtain a rigid body transformation. This transformation is used to adjust the error of the position estimation with respect to the reference and the orientation of the camera.

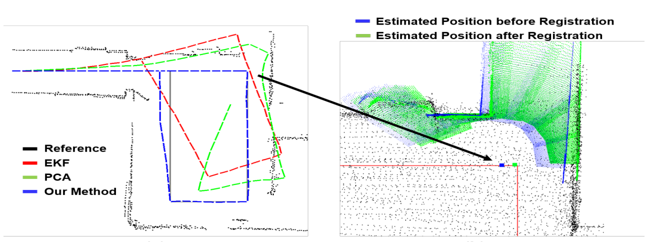

Figure 2: (a)Result estimated by Extended Kalman Filter(Red), Principal component analysis(Green), and our method(Blue). (b) Result of the estimated positions before and after registration

3 EXPERIMENTAL RESULT

Figure 2 shows the estimated results by EKF, PCA and our method, respectively. The RMSEs are calculated between the estimated position and the reference value. The RMSEs of the EKF and PCA are 0.97m and 0.929m. The EKF has a significant error on the straight route caused by drift. The result of the PCA method shows a heading problem around the corner. Our method estimates a better position compared to the others. The RMSE of the proposed method is 0.474m. After registration, the position error is reduced to the RMSE of the proposed method is 0.308m. Figure 3 shows examples of position-based service. When a user reaches a certain location, the information which is stored at that position is augmented on a mobile device as shown the figures.

Figure 3: The results of the Augmented Reality module in different places.

4 CONCLUSION

We present a position-based AR framework based on position estimation. The method is designed to operate in an indoor environment where GPS and WiFi are not available, and a magnetometer is severely compromised by the steel structures. It uses an IMU sensor only for position estimation, and no explicit marker is used. Therefore, the method is suitable for use in the fabrication site in the industry for inspection and maintenance. The proposed method needs to be further improved. First, the way to hold a smartphone should be generalized to handle various cases. Next, the orientation of the smartphone should be robustly estimated whenever required for robust augmentation. Third, the optional registration step needs to be eliminated for efficient operation. These topics are essential for the proposed system to be used in practice, which are recommended for future work.

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