SCAN: Indoor Navigation Interface on a User-Scanned Indoor Map

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ABSTRACT

We present an indoor navigation system, SCAN, which displays the user's current location on a user-scanned indoor map. Smartphones use the global positioning system (GPS) to determine their position on the earth, but it does not work in interior environments. SCAN uses indoor map images scanned by a smartphone camera and displays the user's position on the indoor map while they move around a floor. It tracks the user's position using an inertial measurement unit (IMU) on the smartphone. Camera calibration is required for precise navigation, but our system estimates the user's position based on a single landscape image. Results of our preliminary user study suggest that participants' experiences were similar to using outdoor GPS navigation systems.

CCS CONCEPTS

・Human-centered computing → Human computer interaction (HCI)

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KEYWORDS

Indoor navigation; camera calibration; activity-based navigation;

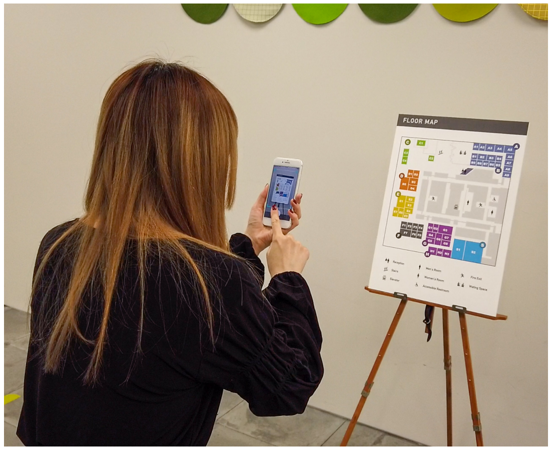

Figure 1: User taking an indoor map using SCAN.

INTRODUCTION

People use map applications on their smartphones to find their way to unknown destinations. Map applications use a satellite positioning system, such as GPS, to display where the user is on the map. However, it is difficult for satellite positioning systems to locate users inside buildings and underground, which makes it difficult to display their locations on maps. Map signs are often placed in commercial facilities or subways so that people can find their destinations. However, with this approach, people cannot move while viewing their position continuously. Furthermore, although a map of the facilities may be published on the website, in many cases, it is not possible to track the position of the user, like on a map application. Hence, we devised an indoor navigation system called SCAN, which shows and tracks the user's position on a picture of the indoor map taken by the user. When the user takes an indoor map with SCAN, the system displays the image, corrected such that it is viewed from the front. SCAN calculates the user's position and direction on the indoor map image and displays relevant markers. When the user starts moving, the system updates the marker position on the map using an IMU. When an error occurs in the value of the IMU, the position of the user can be corrected by photographing landmarks such as signboards and entrances. Using such a mechanism, it is possible to perform self-location tracking on map images, which do not require a special device indoors. In this study, we implemented a prototype on iOS to verify user interactions with SCAN. We carried out a preliminary experiment to observe user actions.

RELATED WORK

There have been many previous studies on indoor navigation. FootPath combines OpenStreetMap and a specially created facility map, and displays the user position and course on the map using an accelerometer and an electromagnetic compass mounted on the smartphone [1]. Mulloni et al. proposed a system in which a smartphone displays the 3D map and course of the facility by reading multiple markers placed in the facility [2]. Kim et al. estimated the user position based on the surrounding image input from the wireless camera, and superimposed the user position and direction on a small map displayed on a head mounted display (HMD) [3]. Although these methods support indoor navigation, it is necessary to create map data of the facility in advance.

Ozdenizci et al. proposed a system that displays a course when a user loads some NFCs placed in a facility [4]. Chang et al. read the geocodes from QR codes placed in the facility, communicated with the server, and displayed the course by text and images on a mobile device or personal digital assistant (PDA) [5]. These require us to place NFC transmitters or markers in the facility beforehand.

Werner et al. matched images taken by a user to feature points and calculated the distance between the user and the landmark [6]. SCAN can calculate both the distance from the landmark

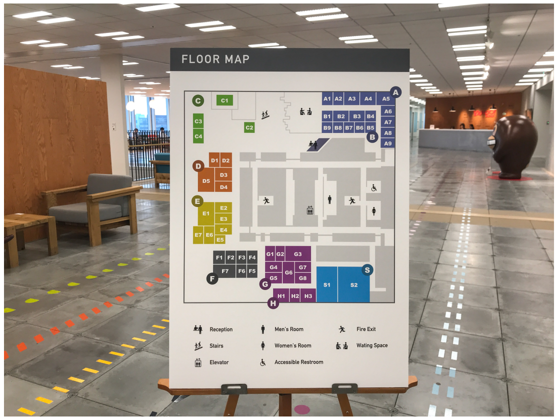

Figure 2: The indoor map

Figure 3: SCAN tracks the user's position and direction, and displays it on the user-scanned indoor map. The user can zoom in/out and move the map image. Light green dot displays user's current position.

and the user's position. It can track the user in real time because it uses an IMU. Betke et al. identified multiple landmarks in the spherical image and calculated the current location relative to these [7]. SCAN can be coupled with a camera mounted on a smartphone, so there is no need for a special camera.

Our approach is unique in that the position of the user is displayed on a picture of the indoor map taken by the user, without the need for advance the indoor map preparation. Furthermore, our approach can calculate the user's position based on readouts from hardware (camera, IMU) that is generally mounted on a smartphone, without requiring special devices inside the facility.

SCAN

The main concept of SCAN is that of displaying and tracking the user's position on an image of the indoor map taken by the user. Using this system, SCAN can determine the user's position and destination, even in environments where satellite positioning systems such as GPS cannot be used. The procedure and mechanism of the operation are described below.

User Interaction

First, the user takes an indoor map from any location using the SCAN application (Figure 1 and Figure 2). This indoor map image is adjusted by the system to be viewed from the front, and displayed on the screen. At this time, the system calculates the positional relationship between the user and the indoor map by camera calibration, and displays the user's position and direction on the image. As the user walks around, the system continuously updates their current position using the values obtained from the IMU (Figure 3). The user can zoom in / out or move the map image, and can look at their own position and destination. SCAN can recalibrate the user's position when errors occur in the IMU, and when the user finds a difference between their position and that shown on the map. The system activates the camera when the user presses the recalibration button on the screen (Figure 4). When the user takes pictures of their surroundings, the system determines which landmark the user is at and calculates the positional relationship between the landmark and the user. The system displays the map again when the positional relationship is calculated, showing the corrected user position and direction. It then resumes tracking the user.

Tracking

SCAN uses the IMU to calculate the distance and direction moved by the user. When the user activates SCAN to capture an indoor map, the center of the screen is used as a reference point for world coordinates, and the distance from this reference point is measured continuously. The distance is measured in meters. The scale of the corrected map image is known, and the distance moved in real space is converted into the distance moved on the map image.

Figure 4: SCAN can calibrate the user's position based on a picture of a landmark.

Calibration

A user takes a picture of the map that SCAN has registered as a target. For self-localization, it detects keypoints and computes the descriptors from the indoor map image taken by the user. We used scale-, rotation-, limited affine- invariant feature of the image generated by the AKAZE algorithm. SCAN matches features between this descriptor and the indoor map descriptors prepared in advance, detects the indoor map data with the highest matching rate, estimates the homography matrix using the feature matching results, and makes a projective transform of the image taken by the user into an ideal image, as viewed from the front. SCAN superimposes the user's position onto the ideal image. Furthermore, by calculating the position of the smartphone camera from the estimated homography matrix, a more accurate self-position is calculated, and the result is superimposed onto the ideal indoor map image.

As tracking is performed using an IMU, we assume that errors will accumulate. As errors accumulate, the user may feel uncomfortable with the position displayed in the application, in which case it is necessary to recalculate the user's position. When this is necessary, the user is prompted to photograph a predetermined landmark. For re-localization, the system detects keypoints and computes the descriptors from the landmark image taken by the user. SCAN matches features between this descriptor and landmark descriptors prepared in advance, which are close to the user's current position, then detects the landmark data with the highest matching rate. Based on the results, an essential matrix is calculated by a 5-point algorithm [8], and the relative positional relationship between the self-position and the landmark data is obtained. As the relationship between the position of the landmark in the real world and the position at which the correct data are collected is known, the positional relationship between the current self-position and the landmark can also be calculated. The sensor error is then corrected by camera calibration.

PRELIMINARY STUDY

We conduct a study to observe how users use SCAN application and how users understand navigation on the application to a destination.

Equipment

SCAN was implemented on an iPhone 7 with iOS 12.3, the display was a 4.7-in screen with 1,334 × 750 resolution.

Participants and Procedure

Four volunteers (two males and two females ranging in age from 24–41 years old; mean = 33.5; s.d.=7.14) participated in this experiment. All participants owned a smartphone, namely an iPhone (100.0%), and all had extensive previous experience with map navigation on a smartphone.

We briefly describe the procedure of the experiment. The participants received instructions about the SCAN interface. Next, they were verbally informed of the destination, and were asked to walk to the destination while looking at the indoor map taken by SCAN. When an error occurred in the user position on the indoor map image, we instructed the user to perform recalibration to correct their displayed position.

Result

All participants were able to reach their destination using SCAN. Likewise, when the participants detected an error in their position, displayed on the indoor map image, they could photograph a landmark and correct it. All participants were aware of their position and direction, and made their way to their destination confidently. One of the participants misrecognized the position of the entrance of the destination, and took a roundabout route, which we consider to be due to a problem with the photographed map itself.

DISCUSSION

All participants were able to reach their destination using SCAN, and also performed self-position correction on the facility map image. In a simple interview after the experiment, three of the participants commented that it was difficult to understand which landmarks are subject to camera calibration for position correction and, because they did not have previous experience of recalibration to correct their displayed position, they expressed the opinion that a more natural form of operation guidance is desired. As a next step, it is necessary to pre-validate such guidance for practical use, to facilitate a more natural form of positional error correction operation and automation.

CONCLUSIONS

We presented "SCAN", which navigates a user by displaying and tracking their position on a picture of an indoor map taken with a smartphone camera. SCAN tracks its own position based on the data obtained from the IMU, and the self-position error due to the accumulation of IMU errors is corrected by camera calibration. According to the results of our preliminary experiment, participants were able to reach the place described in the indoor map using SCAN. Our participant interviews showed that the experience was equivalent to that of using a map application with GPS.

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