Component Mapping Method for Indoor Localization System based on Mixed Reality

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***Abstract*—As the technology of the Internet of Things develops and spreads, the interest of the existing outdoor location information system is concentrated on the indoor information system. Recently, indoor localization has been actively researched, but signal-based method such as WiFi, BLE, UWB, and magnetic field have limitations in accuracy depending on the indoor propagation environment. In this paper, we propose an indoor localization method with high scalability and low computational complexity based on Component/Body abstracting indoor structure. To demonstrate the efficiency of this system, we experimented at 25 arbitrary indoor spaces and showed an 88 percent accuracy. We predict that this system will solve the problems of existing signal-based method and contribute to improving social stability.**

***Index Terms*—internet of things(IoT), Mixed Reality, Microsoft Hololens, Indoor Localization, Component Mapping Method**

I. Introduction

With the development and spread of smart devices and wearable devices such as the internet of things(IoT), the interest of the existing outdoor location information system is concentrated on the indoor information system. According to Technavio's 2017 Global LBS Market report, global indoor Location-Based Service(Indoor LBS) market sales were estimated at 4.8 billion dollars in 2018, an estimated increase of 47 percent to 7.13 billion dollars in 2019. Also, Global Indoor LBS market sales are projected to grow at an average annual rate of 47.3 percent, creating a 16.3 billion dollars market in 2021. Most of all, indoor localization method can be applied to various fields in the future. In addition, it can be applied to various fields such as indoor-based games and indoor facilities management[1]. In addition, indoor localization method has not been popularized in Korea, so it is unique and marketable.

In fact, The research on indoor localization has been done steadily since before. Recently, it has been actively researched using infrared technology, ultra wideband (UWB), Bluetooth low energy (BLE), and radio frequency identification (RFID)[2]. but the signal-based method such as WiFi, BLE, UWB have limitations in accuracy depending on the indoor propagation environment. One of the most representative indoor location estimation techniques is fingerprinting [3]. This technique estimates indoor location using Wi-fi signal, which is relatively high in positioning accuracy. However, if obstacles such as a wall exist between the mobile device and the access point (AP), signal attenuation may occur and the accuracy of the indoor positioning may deteriorate. And RFID has a very limited recognition distance. In addition, because hand-held devices are used, human factors cannot be considered and dangerous situations can occur[4].

Therefore, in this paper, to solve these signal-based problems, we propose Component mapping method for indoor localization based on Mixed Reality. We use Unity Engine and Microsoft Hololens which is Mixed Reality device. We define the Component/Body Set. Then we implement the indoor localization by the sequential search method of the generated structure set and the predefined instance DB based on this. To implement this system, Pixel block scan and array dimensions for the matching algorithm is used. To demonstrate the efficiency of this system, we experiment at 25 arbitrary locations in indoor space.

Recently, although similar studies have been conducted, the study is a level of mapping previously stored images to HMD images[5]. Thus, the image-based study is limited by the number and level of stored images and requires large computations. Therefore, we propose indoor localization technology with high scalability and low computational complexity based on Component/Body mapping method. Through this research, we predict that this system will solve the problems of existing signal-based method and contribute to improving social stability. Also, MR technology is in the early stage of development. So we can present a service model and contribute to improving the competitiveness of the fourth industry.

The rest of the paper is organized as follows. we present the motivation of this study and the introduction of this system in section I. In Section II we present related work of methods for indoor localization. In section III we propose Component/Body mapping method based on mixed reality device for indoor localization. In section IV, we present experiments and simulation results. Finally, In section V, we present conclusions and future work.

TABLE I
ADVANTAGES AND LIMITATIONS OF CURRENTLY AVAILABLE INDOOR LOCALIZATION APPROACHES

Approach Method	**Evaluation criteria**			
	Additional IT-infra required	***Data preparation effort***	***Continuous positioning***	***Accuracy***
Wireless LAN	- Specific infrastructure installation	O Signal measurement at reference points	+ Depends on signal coverage	- Building-specific disruptive factors
RFID/ NFC	- Specific infrastructure installation	O Signal measurement at reference points	+ Depends on signal coverage	- Building-specific disruptive factors
Indoor -GPS	- Specific infrastructure installation	++ None	+ Depends on signal coverage	- Building-specific disruptive factors
3D-Maps /SLAM	+ 3D Scanner for initial data creation	– Cleaning recorded point clouds	O Depends on point cloud quality	O Depends on point cloud quality
Component Method	++ No special infra-structure is required other than MR HMD	O Pre-trained Database	+ Depends on Mapping capacity	- Building-specific disruptive factors

** appraisal: ++ very good/positive; + good/positive; O average; - poor/negative; – very poor/negative

II. RELATED WORK

A. Current research efforts in indoor localization

Li and Becerik-Gerber [6] have presented a performance-based evaluation of RFID-based indoor location sensing solutions for the built environment[7]. They have concluded that no single solution meets all the criteria for successful implementation and that the adaptability of the evaluated solutions within the built environments is uncertain so that further research is needed.

Motamedi et al. [8] have investigated the use of RFID technology for indoor localization of RFID-equipped, fixed and moving assets during the operation phase of facilities. Apart from the asset location, the operators position can also be estimated using surrounding fixed tags and a handheld RFID reader [8]. However, the main disadvantage of signal-based technologies is the need for extra equipment installation and maintenance (both tags and readers), which still involves a considerable cost factor. Park and Hashimoto [9] have used passive RFID tags on the floor to enable a robot to successfully estimate the location and the orientation during navigation. The passive RFID tags offer a cost-effective alternative but require a large number of tags installed in a grid layout on the floor. Park and Hashimoto [9] have deployed 198 tags over an area of only 420 cm x 620 cm area.

Oskiper et al. [10] have introduced a camera tracking system for indoor and outdoor augmented reality applications using an integrated system of a monocular camera and an Inertial Measurement Unit (IMU). Since their approach does not use AR markers, they have to rely on robust visual feature tracking which is achieved through IMU supported feature matching. Available AR based indoor positioning methods usually requires artificial markers to estimate the camera position and orientation. For example, Park et al. [11] have presented an AR-based field inspection scenario using artificial 2D markers within the frame of a BIM-based construction defect management system. Kuo et al. [12] have proposed an outside-in tracking approach that uses an infrared invisible marker mounted on the head of a potential operator. This infrared marker is detected and tracked from the outside to estimate the position and viewing direction of the operator. However, this approach requires infrared tracking devices all over the facility to be both installed and maintained. Another AR based (optical) approach is the generation of 3D point maps via the camera or laser scanner [13], rather than using artificial 2D markers.

B. Previous work in augmented reality-based indoor localization

Simultaneous localization and mapping (SLAM) allow building point clouds of the building interior with relation to the camera position [14,15]. In the approach, the required 3D map must be created first, which is then linked to a virtual building model to calculate the position of the camera in a real-world coordinate system. Temporary bodies, e.g. poster banners or construction areas, can disturb the comparison of the currently detected with the previously scanned environment. Another example of comparing images from the users mobile device to a 3D point cloud model generated from a set of pre-collected site photographs can be found in [16].

These approaches require an unreasonably huge amount of data (videos or images) collected for every single facility prior to being able to support AR based indoor navigation and do not work in cases where the indoor scene has been changed by temporary bodies [16]. Moreover, they usually require additional IT infrastructures, like RFID sender or WLAN networks, and special calibration methods, as well as previous building scans and data preparation before navigation, can be realized.

Francis et al. [17] is an AR system for facility management is proposed by using image-based indoor localization method which estimates user 's indoor location and direction by comparing user' s view and building information modeling (BIM) based on learning calculation. The image retrieval method attempted to find the image closest to the captured image from the database image, and a two-dimensional BIM image was created for the image database in the 3D BIM model of the building. A pooling layer 4 of a pre-trained VGG network [18] was used to compare domains between BIM images and color images, and the weighting of pooling lasers was used for comparison after delivering images through the network. The advantage of this system is that it specializes in facility management and succeeded in localization at a relatively high speed. However, this system has a disadvantage that communication between server and client is very important because the server with GPU carries out many calculations.

III. Proposed method

A. Problem statement and objectives

- No special infrastructure installation
- No high computational complexity
- No low scalability

In this paper, to solve these problems, we propose indoor localization technology with high scalability and low computational complexity based on Component mapping method that abstracts indoor structure.

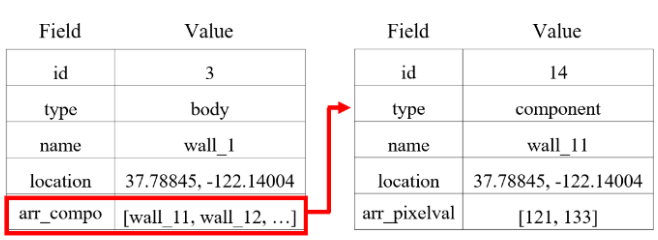
B. Development environment

TABLE II
Development environment

MR Device	Microsoft Hololens
SDK Versions	Windows 10.0.17763.132 SDK Unity Augmented Reality SDK
.NET version	Framework 4.7.2
Development Tools	Visual Studio 2017 Unity Engine 2017.4.17f1
Graphics card	Colorful GF GTX1060 OC DDR5 3G
Actual Indoor experimental space	the 9th floor of the Paldal Building (at Ajou University in Suwon-si, Korea)

To implement this localization system, we use Unity Engine and Microsoft Hololens which is the Mixed Reality device is used. Here, we used Unity 2017.4.17f1 version and Windows 10.0.17763.132 SDK version and Unity Augmented Reality SDK. Also, we used the .NET Framework 4.7.2 version. The development tools we used are Visual Studio 2017 version and Unity Engine 2017.4.17f1 version. Because in order to use the Microsoft hololens, we have to use together Unity 2017.4.17f1 version and Visual Studio 2017 version. The Graphics card used was the GF GTX1060 OC DDR5 3G. Unity engine needs a good GPU to run smoothly. The experiment indoor-space was located on the 9th floor of the Paldal Building (at Ajou University in Suwon-si, Gyeonggi-do, Republic of Korea)

C. Component/Body Mapping Method



Field	Value
id	3
type	body
name	wall_1
location	37.78845, -122.14004
arr_compo	[wall_11, wall_12, ...]

Field	Value
id	14
type	component
name	wall_11
location	37.78845, -122.14004
arr_pixelval	[121, 133]

Fig. 1. Define Component/Body Set

In this study, defining the Component and Body is very important. By defining Component and Body, MR Device can recognize Component and Body. At first, Component is a small base unit for representing a Body. And the Body is an integral unit for expressing a substance. In other words, as fig. 1, several Components form a single Body.

In detail, The Component consists of a total of five fields: id, type, name, location, and a set of arrays of the pixel value. The ID field is non-duplicate random numbers and is unique. The type field can distinguish between a Component and Body. The location field consists of an array of x-axis value and y-axis value that appear on the 2D map. And arr-pixelval is set of arrays of the pixel value. In the 2D map, if we generate 255 pixels with 3.14 x 1.96 pixels based on 800x500 pixels, Black data is all set to 1 and white space is set to 0. The fields of Component are constructed based on the pixel values thus obtained.

Next, The Body consists of a total of five fields: id, type, name, location, and a set of arrays of the Component. As we mentioned earlier, The ID field, type field, location field are the same as the above. And arr-compo is set of arrays of the Component. As we mentioned earlier, several Components form a single Body.

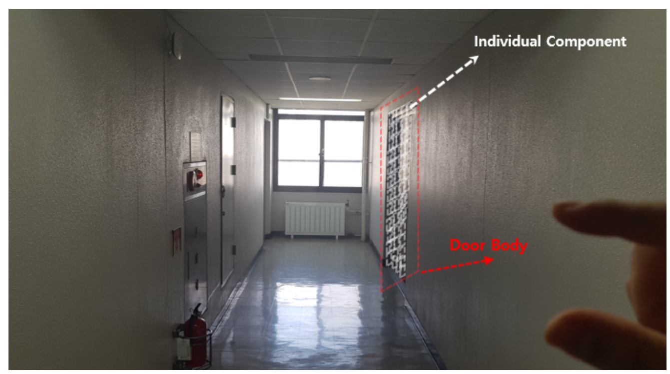


Fig. 2. Component/Body Recognition in Hololens

The actual screen of the Component/Body set recognized on hololens is as fig. 2. In this study, the system is Generate 255 pixels with 3.14 x 1.96 pixels based on 800x500 pixels and set Component for all pixels per unit pixel. When all Components are determined, create a Body. For example, As shown in fig. 2, A single Body can consist of a total of 48 instances.

D. Pixel block scan and array dimensions for the matching algorithm

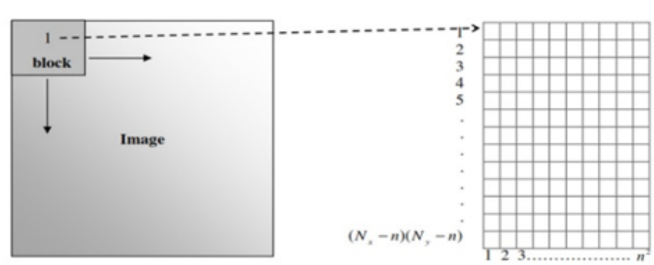


Fig. 3. Pixel block scan and array dimensions for the matching algorithm

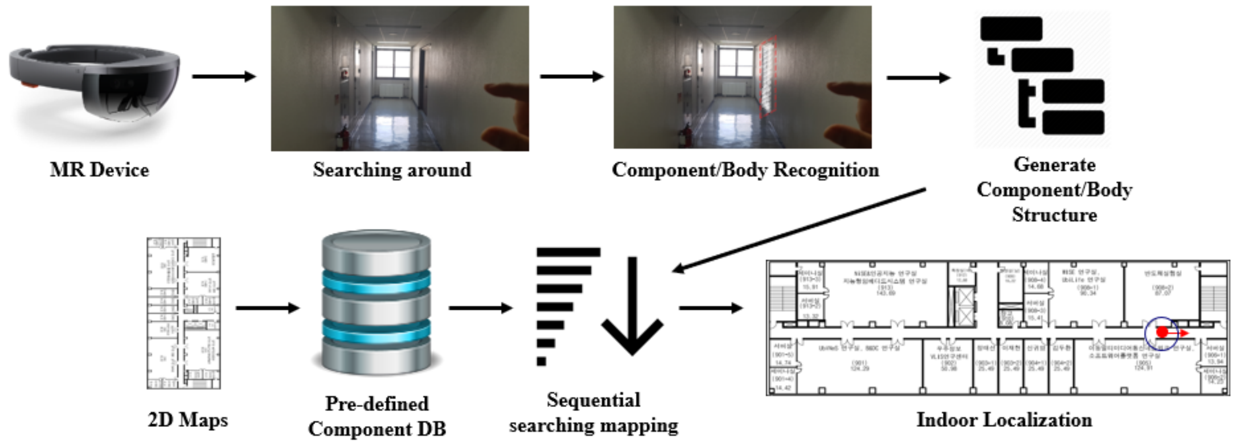


Fig. 4. the process of indoor localization

Next, the method of generating an instance at a unit pixel is [19]. Abhishek et al. [19] are tiling the image with overlapping grid or block method. The wavelet-decomposed image is being tiled by the block of R x R pixels. This block is horizontally slid by one pixel rightwards starting with the upper left corner and ending with the bottom right corner as shown in Fig. 3. Here the size of the duplicated regions is assumed to be larger than block size and the total number of overlapping blocks are (M - R + 1) x (N - R + 1) for an image size of (M x N) pixels.

As shown in the fig. 3, the image is tiled by Block method to create a Component in a unit pixel. So, create a set of Component/Body set through the structure of these pixel values. And the system sequentially compares the arbitrary data structure created based on the Component/Body set with the 2d map of the pre-defined component database. Finally, the indoor localization can be succeeded through the sequential search mapping with the predefined database. And successful indoor localization data is represented on MR HMD Device with 2D map.

IV. Experiment Result

In this study, to demonstrate the efficiency of this system, indoor localization was experimented at 25 arbitrary locations in indoor space as shown in fig. 5.

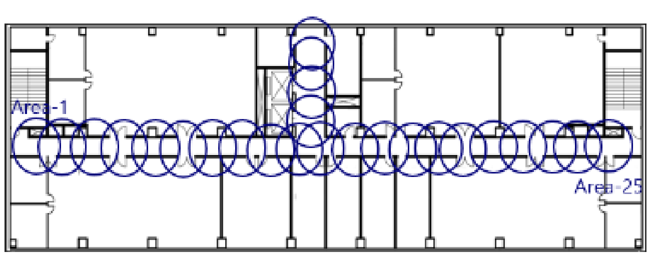


Fig. 5. the process of indoor localization

The experiment proceeded as follows. As we mentioned earlier, We create 25 arbitrary circles with a radius of 1.5 meters. When we operate the system in each radius, if the MR HMD Device is within the 1.5m radius, the experiment will be considered successful.

TABLE III
Experimental Results on Success/Fail in 25 area

Success/Fail	Area
Success area	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16 17, 18, 20, 21, 22, 23, 24
Fail	1, 19, 25

Fig. 6. Representative Experimental Results in four area

In the result, of the total of twenty-five experiments, twenty-two experiments were considered successful. The total success rate of the experiment is 88 percent. The fig. 6 is representative of the experimental results in 3, 14, 18, and 22 areas. And we were able to analyze three failed experiments(1, 19, and 25 areas). As you can see Fig. 6, in the failed experiments, the Component/Body set was not set well enough. That is, the condition of the failed area was insufficient becausve the information was scarce and the field of view was so narrow. In the general experimental environment, under the condition that the Component/Body set was set well, our experiment results in a high rate of success.

V. CONCLUSION

In this paper, we proposed indoor localization technology with high scalability and low computational complexity based on Component/Body that abstracts indoor structure. We used Unity Engine and Microsoft Hololens which is Mixed Reality device is used. We defined the Component/Body Set. To implement this system, Pixel block scan and array dimensions for the matching algorithm was used. And the system sequentially compares the arbitrary data structure created based on the Component/Body set with the 2d map of the pre-defined component database. Finally, the indoor localization can be succeeded through the sequential search mapping with the predefined database. And successful indoor localization data is represented on MR HMD Device with 2D map.

In this study, we solved the problems of signal attenuation caused by obstacles and special infrastructure installation in existing research. To demonstrate the efficiency of this system, indoor localization was experimented at twenty-five arbitrary locations in an indoor space and showed high accuracy of 88 percent. And we were able to analyze three failed experiments. The condition of the failed area was insufficient because the information was scarce and the field of view was so narrow. In the general experimental environment, under the condition that the Component/Body set was set well, our experiment results in a high rate of success.

Through this study, it is possible to quickly identify the location of the person in emergency situations such as a disaster. And we predict that it will contribute to the enhancement of social stability through the provision of stable and effective technology in the indoor environment. Also, mixed reality technology is still in the early stage of development, so it can present an application service model and contribute to improving the competitiveness of the 4th industry.

Finally, we expect that the system implemented in this study will be a more powerful and effective system if the indoor positioning accuracy is improved and the Component can be allocated dynamically. In addition, if the process of digitizing the 2D map is generalized, it will become a more universal and efficient system. In addition, the system can evolve into an indoor navigation system, which will be an additional extended version in this study.

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