2016 16th International Conference on Control, Automation and Systems (ICCAS 2016)
Oct. 16–19, 2016 in HICO, Gyeongju, Korea

Multi-floor Localization Method for Mobile Robots Using Elevator

Yu-Cheol Lee[1*] and Jaehong Kim[1]

[1]Intelligent Cognitive Technology Research Department, ETRI,
Daejeon, 305-700, Korea (yclee, jhkim504@etri.re.kr) * Corresponding author

Abstract: This paper proposes a new localization method for the mobile robots which should move to other floors using the elevators. The mobile robots use the various maps to obtain the spatial information, e.g. the floor numbers, the locations of waypoints, the structure shape of the spaces, etc. so that they can estimate the accurate position in the multi-floor buildings. As the maps in this paper, there are the grid-based map, the radio-based map, and the Point of Interest (POI) map. In addition, the mobile robots need to a localization framework to estimate their positions in the multi-floor spaces using the maps and the adequate sensors. As the sensors in this paper, the robot equipped with the laser range finder, the 3D depth sensor, and Wi-Fi receiver. The localization framework can find the positions of the robots by integrating the observations of sensors and the information of the map when the robots should move to the destination in other floor space. Finally, the experiments are performed to evaluate the proposed localization framework using the real robots. The experimental results showed the effectiveness of the proposed method that can be utilized as the multi-floor localization system for the mobile robots.

Keywords: Multi-floor Localization, Mobile Robot, Fingerprint Matching, Particle Filter

1. INTRODUCTION

This paper presents a localization framework to estimate the accurate positions of the mobile robots in the multi-floor buildings. It can expand the coverage of the services for the mobile robots by the multi-floor localization, e.g. the delivery, guidance, surveillance, monitoring, etc. comparing with the single-floor localization. A single robot can freely navigate between other floors, it requires the essential information such as the maps and the observations of the sensors to estimate the accurate positions. The map contains the static features of the spaces where the robots navigate, e.g. the shape of a structure, the radio signals, the locations of the major facilities, etc. In addition, the observations of the sensors include the current conditions of the spaces surrounding the robots, e.g. the scans of laser range finder (LRF), the point cloud data of 3D depth camera, etc.

The main function of the localization framework is to integrate the sensor measurements and the map data so that the mobile robot can find the current robot position in the multi-floor environments. In this paper, the mobile robots use the various maps including the grid-based map, the radio-based map, and the Point of Interest (POI) map. In addition, the robots equip the sensors such as the LRF, the 3D depth camera, and the Wi-Fi receiver. Each data of sensor and map is a principle information as the step by step according to the process of the localization framework.

The localization framework is divided into two places, the floor and the inter-floor spaces. In the floor space, the mobile robot should detect the initial position and track the moving trajectory. In the inter-floor space, the robot can take and get off the elevator safely. The floor localization can achieve the mission based on the Particle Filter (PF) using the Wi-Fi receiver and the LRF with the radio and grid-based maps. The inter-floor localization can accomplish the role to move other floor using the 3D depth camera.

This paper describes the multi-floor localization processes to estimate the robot positions when the robots should move to the destination in another floor in the building. For the practical approach, we focus on the explanations to implement the proposed localization framework with the real system in detail.

2. MULTI-FLOOR LOCALIZATION

2.1 Sensor

The sensors installed on the robots measure the current situations of the environments. Especially, the mobile robot used the various kinds of sensors to observe the specific target applications. The robotic sensors for the localization can be categorized the specially-designed sensors and the general domain sensors. The specially-designed sensors including the types of the UWB, WIFI, and RFID that are the high accuracy and the stable performance for the robot localization, but those are expensive with respect to the cost of the sensors [1][2]. Therefore, many researchers have developed the robot localization method only to use the general domain sensors such as the laser range finder, the infrared and the ultrasonic sensors that are low price comparing to the specially-designed sensors for the localization. The general sensors require the special algorithms to improve the accuracy of the localization using the maps. In this paper, the PF and the fingerprint matching algorithm as the floor localization method uses the odometer, the laser range finder, the Wi-Fi receiver to estimate the positions of the robots. In addition, the inter-floor localization utilizes the 3D depth sensor to find and detect the status of the elevator for moving to another floor in the building.

2.2 Map

The maps can provide the static features of the spaces to the mobile robots and help to perform the accurate localization. The representation formats of the maps are determined as the robot applications. Normally, the maps for the localization in a two-dimensional domain are divided into three types, the raster [3], the vector [4], and the topology [5]. The raster format can represent the shape of the structure with the multiple pixels similar to the bitmap images. It is suitable to express the complex shape of the objects or the structures with no specified geometry. However, there are drawbacks to increasing the storage space depending on the space size. The vector format oppositely holds pros and cons with respect to the raster one. Last, the topological format is defined as the connectivity of the nodes that can contain the meaning of the certain locations, e.g. the elevator, the entrance, etc. The limitations of the topological map cannot represent the geometric information of the space unlike other formats. In this paper, the grid-based map which is one of the raster formats are used for the PF to provide the static structure of the space. The radio-based and the POI maps as the topological format transmit the radio signal and the location of the elevator to the fingerprint matching and the inter-floor localization components respectively.

2.3 Localization

The localization framework in this paper is organized into two parts, the floor and inter-floor components. The floor localization consisted of two methods, the fingerprint matching and the PF algorithms [6][7]. The fingerprint matching step can find a broad region where the robots are using the Wi-Fi radio signals. The region is determined by selecting the best-matched locations into the radio-based map with the current radio signals of the Wi-Fi receiver. The region result of the fingerprint matching is delivered to the PF algorithm to estimate the initial position of the robot. The PF algorithm scatters the particles as the candidates of the robot position into the region found by the fingerprint matching and chooses the best-matched candidate using the grid-based map and the scan data of the LRF. In the case of moving to other floors, the robot obtains the elevator location from the POI map. And then, the PF can track the robot moving trajectory from the initial location and to the elevator location.

After the robot arrived at the elevator to move the other floors, the inter-floor localization component starts to recognize the status of the elevator using the 3D depth camera and proceeds the floor moving operation with four tasks. First, the robot moves to the center of the elevator when the robot recognizes the open status of the elevator. Second, the robot rotates in the opposite orientation easy to get off in an elevator. Third, the robot alights from the elevator when the elevator stops at the desired floor and opens the door. Last, the robot changes the maps belonging the destination and the inter-floor localization component transfers to the localization role to the floor localization module. The floor localization can continuously estimate the robot positions until the robot reaches the final destination safely.

3. EXPERIMENT

The multi-floor localization framework had been implemented as the real system for the mobile robot. As shown in Fig. 1, the proposed framework consisted of three modules, the fingerprint matching, the PF, and the inter-floor localization. In addition, each module necessarily includes three elements, the sensor, the map, and the localization. First, the fingerprint matching algorithm in the floor localization should find the coarse area where the robot is placed using the radio-based map and the Wi-Fi receiver. The Wi-Fi receiver can measure the received signal strength indication (RSSI) values and the MAC addresses of the Wi-Fi access points surrounding the robot. The fingerprint matching method extracts the node region with the lowest difference of RSSI values by matching between the current measurements of Wi-Fi receiver and the radio-based map.

Second, the PF algorithm in the floor localization can estimate the precise positions of the robots using the odometer, the LRF, and the grid-based map. The Pioneer 3DX platform made by Mobile Robots Co. would equip the odometer to measure the dead-reckoning data which contains the accumulated position errors due to the wheel slippery. The URG 04LX-UG001 as the LRF hardware can acquire the scan data to detect the shape of the structure surrounding the robot. In addition, the grid-based map provides the static structural feature points about the space to the robot. The PF algorithm can find the initial position of the robot in the region resulted from the fingerprint matching and estimate the exact trajectory of the moving robot by using the odometer, the LRF, and the grid-based map.

Third, the robot operates the inter-floor localization module when it receives the command to move to other floors. The inter-floor localization uses the POI map to perceive the locations of the elevator that is one of the waypoints to go to the destination in other floors. When the robot arrived in front of the elevator door, it should recognize the status of the elevators, e.g. the door opened or closed, using ASUS Xtion as a 3D depth camera. The inter-floor localization can guide the robot to move to the desired floor using the elevator. After the robot arrived at the target floor, the robot operates the floor localization again in order to succeed the mission arriving at the destination.

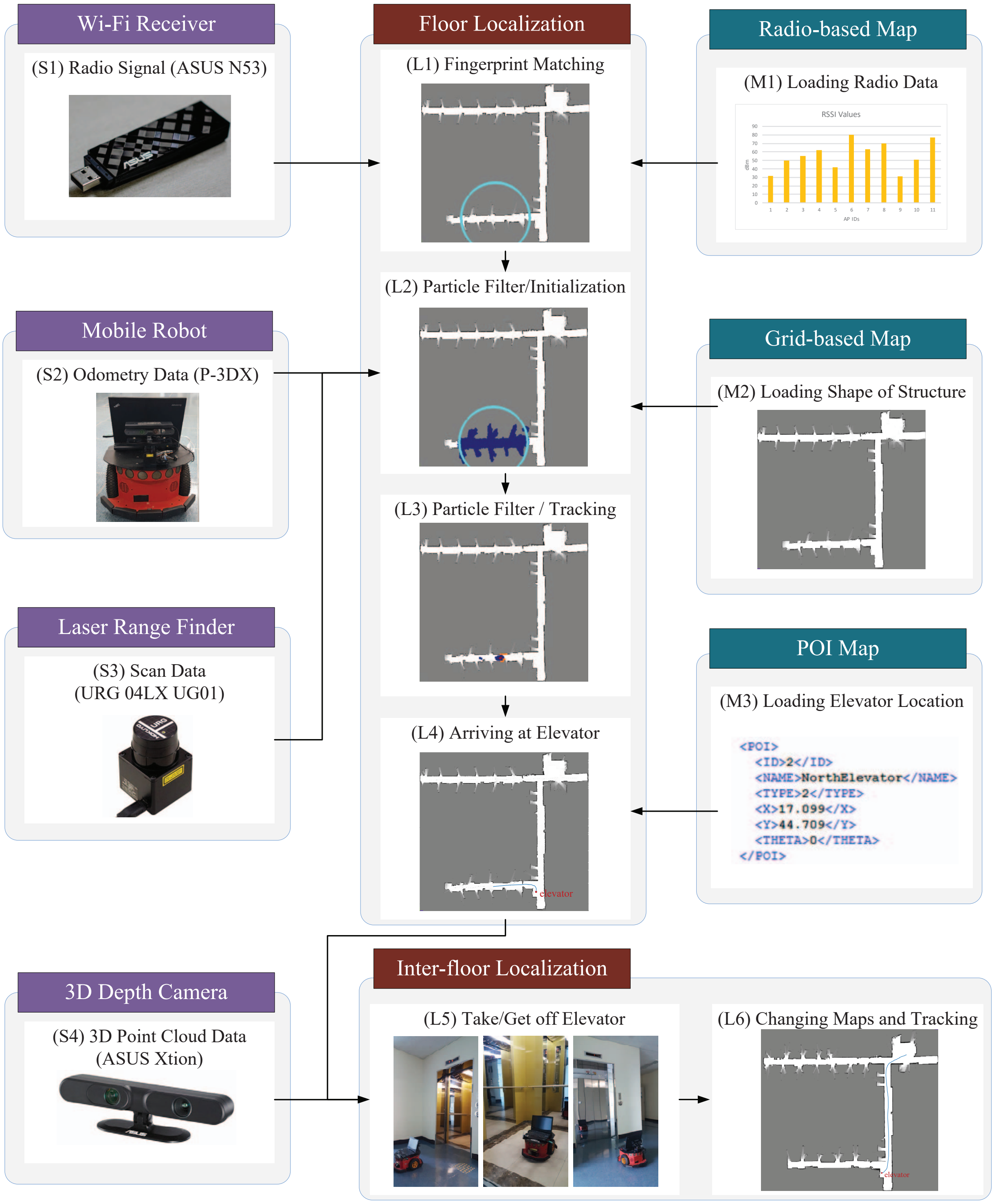

Fig. 1 The overview of the experiment to implement the proposed multi-floor localization: (S1 4) The sensors measures the observations of the spatial information surrounding the robot. (M1 3) The maps contain the static data about the robotic space, e.g. the radio signals, the shape of a structure, the locations of the elevator. (L1 4) The floor localization consisted of the fingerprint matching and the PF algorithm to proceed the estimation of the robot positions before the robot move to another floor. (L5 6) The inter-floor localization can assist the robot to take and get off the elevator, and then change the adequate maps about the target floor.

4. CONCLUSION AND FUTURE WORK

This paper developed the multi-floor location method for the mobile robot using the various sensors and maps. There are two major steps, the floor and the inter-floor localization. The floor localization is composed of the fingerprint matching and the PF algorithms. The fingerprint matching can find the coarse place where the robot is located using the Wi-Fi receiver and the radio-based map. And then, the PF algorithms can estimate the initial positions based on the result of the fingerprint matching and track the exact trajectory of a robot using the odometer, and the LRF, the grid-based map. The inter-floor localization can help the robot to safely move to the desired floor belonging the target destination using 3D depth camera and the grid-based map. The proposed localization method will enable the robot to estimate the accurate positions when it should move to another floor. Finally, we confirmed the usability of the proposed localization method for the multi-floor navigation by performing the experiments with the real robots.

In the future, we are going to integrate the automatic control module of the elevator that can reduce the manual operation to push the button of the elevator. We look forward to developing a better-refined technology for the multi-floor localization in terms of the autonomous robots.

ACKNOWLEDGEMENT

This work was supported by the Robot R&D program of MOTIE/KEIT. [10051155, The Development of Robot Based Logistics Systems Applicable to Hospital-wide Environment]

REFERENCES

[1] H. Liu, H. Darabi, P. Banerjee, and J. Liu, "Survey of wireless indoor positioning techniques and systems," *IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews*, vol. 37, no. 6, pp. 1067–1080, 2007.

[2] S. Y. Cho, "Hybrid linear closed-form solution in wireless localization," *ETRI Journal*, vol. 37, no. 3, pp. 533–540, 2015.

[3] A. Elfes, "Sonar-based real-world mapping and navigation," *Robotics and Automation, IEEE Journal of*, vol. 3, no. 3, pp. 249–265, 1987.

[4] S.-J. Lee, D.-W. Cho, W.-K. Chung, Y. Lee, J.-H. Lim, C.-U. Kang, and W.-S. Yun, "Evaluation of features through grid association for building a sonar map," *Proc. of IEEE International Conference on Robotics and Automation (ICRA)*, pp. 2615–2620, 2014.

[5] H. Choset and K. Nagatani, "Topological simultaneous localization and mapping (slam): toward exact localization without explicit localization," *IEEE Transactions on Robotics and Automation*, vol. 17, no. 2, pp. 125–137, 2001.

[6] Y.-C. Lee and S. Park, "Localization method for mobile robots moving on stairs in multi-floor environments," *Proc. of IEEE International Conference on Systems, Man, and Cybernetics (SMC)*, pp. 4014–4020, 2014.

[7] N. Al KhanbashI, N. Al Sindi, N. Ali, S. Al-Araji, and Z. Chaloupka, "Measurements and analysis of fingerprinting structures for wlan localization systems," *ETRI Journal*, vol. 38, no. 4, pp. 634–644, 2016.