

A Particle Filter-Based Indoor Positioning System using an RSSI Heatmap

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Abstract—With the advent of smartphones and increasing usage of Internet-of-Things (IoT) systems, many Indoor Positioning Systems (IPS) have been developed. Unfortunately, most of the systems require specific hardware and careful calibration. To tackle the issues, this paper proposes an IPS using a Received Signal Strength Indicator (RSSI) Heatmap. The usage of the RSSI Heatmap allows the IPS to function well in a partitioned environment where having the line of sight for beacons is difficult. Through the experiments, it shows that the Heatmap-based IPS can work to some extent, but having a low positioning accuracy. To further improve the positioning accuracy of the proposed IPS, the combination of a particle filter algorithm and a heatmap generation algorithm is studied.

Index Terms—Heatmap, Indoor Positioning System, Kalman Filter, Particle Filter, Bluetooth Low Energy, Received Signal Strength Indicator, Pedestrian Dead Reckoning.

I. INTRODUCTION

An Indoor Positioning System (IPS) can provide users or devices with a localization service indoors when a Global Positioning System (GPS) is unavailable, such as in parking lots and underground [1]. It continues to grow in various industries and has been applied to different service fields. It usually relies on different kinds of information to position a target, such as sensing information and wireless signal information. A wireless signal-based IPS usually can use the wireless signal strength to localize a target, which may require the deployment of several anchor points (APs) to collect the signal strength information.

However, one of the limitations in the existing wireless signal-based IPS using the received signal strength indicator (RSSI) is that if there are any obstacles between the target and the beacon receiver, the collected RSSI information may not reflect the actual relationship between the target and the beacon receiver. Another limitation is that the deployed APs can increase the installation cost, which can hinder the deployment of the IPS.

To tackle this problem, we propose a particle filter-based IPS using a simulated RSSI heatmap in reducing the installation cost of an IPS. The proposed RSSI Heatmap is a simulated map of RSSI that can efficiently reflect the wireless signal strength in an environment having a router. Since RSSI Heatmap simulates the RSSI signal, the line of sight (LoS) for the target is not required. In addition, the proposed IPS uses a particle filter (PF) to function in a partitioned environment where LoS is not provided.

The rest of this paper is organized as follows. Section II introduces the experiment for the proposed IPS. Section III describes the experiment results. Finally, in Section IV, we conclude this paper along with future work



Fig. 1. Gaussian Blurred RSSI Heatmap

II. EXPERIMENTS

This section describes the experiments of the proposed IPS using RSSI Heatmap. The IPS functions in three steps:

- 1) The initial environment logging
- 2) The heatmap generation
- 3) The particle filter-based IPS

During the initial logging process, the logged data holds the RSSI value and maps the coordinate of the source. The logging process was done manually, hence it is prone to error. This data is placed into an array with x and y used as coordinates to place the RSSI value into the array. The empty portions are filled up using [2], where n is calculated by using the closest

initial logged point and d represents the distance to the beacon where the beacon position is known.

$$RSSI = -30 - 10n \log d. \quad (1)$$

Fig. 1 shows the result of RSSI heatmap with Gaussian blur applied. We used a Raspberry Pi 3 that was set up to announce a BLE (Bluetooth Low Energy) signal as a beacon to be used in the experiment. Four Raspberry Pis were used to place in the environment, and in addition to the four Raspberry Pi beacons, a Wi-Fi router was also used as the fifth beacon to conduct this experiment.

We use an existing PF module to localize a target. Initially particles are randomly scattered, and each particle reads the corresponding value from the heatmap and compares it with the actual value. Since five beacons exist, five heatmaps are used. The weight of each particle is updated by (2) and normalized after all weights are calculated.

$$W_{t+1} = W_t \times e^{-0.005(Target-Ref)^2}. \quad (2)$$

Particles are re-sampled after a certain number of iterations. The re-sampling is done by weight and re-sampled particles are randomly scattered from the re-sampled coordinate [3]. The maximum radius of this random re-sampling is determined by the Noise in (3).

$$Noise = 800e^{-0.015 \times iteration} + 70. \quad (3)$$

III. EXPERIMENT RESULTS

This section describes the results of the experiment. The BLE signal was very unstable at the initial stage of the experiments and the general strength of the signal was also weak, resulting in particle sticking. However, this situation was alleviated after the application of Gaussian Blur in this experiment.

We also performed IPS tests to visually mark the particles. As seen in Fig. 2, red points display the particles and the blue point indicate the target location. Each location of the target is logged by hand as the user provides the current position and the RSSI value is sent to the server where the particles predict the location based on the reading. Certain areas of the map allowed the particles to converge quickly, however other places had some problems to converge. The converged localization and the movement tracking of the proposed IPS sometimes show a less accurate result.

IV. CONCLUSION

In this paper, we introduced a Particle Filter-Based Indoor Positioning System using RSSI Heatmap. We demonstrated the feasibility of IPS using PF, which predicts target locations by generating RSSI heatmaps instead of using RSSI values as distances. The current implementation lacks accuracy due to the manual implementation of the PF and the logging procedures, but improvements can be expected when we fine tune the PF and automate the logging procedures. In addition, it is possible to integrate a Pedestrian Dead Reckoning (PDR)



Fig. 2. Experiment with particles in the proposed IPS.

scheme into the proposed IPS. As shown in the results, the system can position a target to some extent but fail to track its movement. This issue can be mitigated by using a PDR scheme, which will be the future research work.

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