Fast Indoor Radio-Map Building for RSSI-based Localization Systems

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***Abstract*—Wireless Indoor localization systems based on RSSI-values typically consist of an offline training phase and online position determination phase. During the offline phase, geo-referenced RSSI measurements, called fingerprints, are recorded to build a *radiomap* of the building. This radiomap is then searched during the position determination phase to estimate another nodes' location. Usually the radiomap is build manually, either by users pin-pointing their location on a ready-made floorplan or by moving in pre-specified patterns while scanning the network for RSSI values. This cumbersome process leads to inaccuracies in the radiomap. Here, we propose a system to build the floorplan and radio-map simultaneously by employing a handheld laser mapping system in an IEEE802.15.4-compatible network. This makes indoor- and radio-mapping for wireless localization less cumbersome, faster, more reliable and delivers a new way to evaluate wireless localization systems.**

I. INTRODUCTION

Wireless Sensor Networks (WSNs) represent a rapidly growing area in computing and communications. In this scope, indoor localization techniques are used to estimate the position of devices by measuring the RSSI of surrounding WSN nodes. State-of-the-art indoor localization approaches employ different techniques for position estimation [1], [2]. While providing impressive results, these systems require significant effort and time for setup due to the manual nature of geo-referencing the network nodes. The focus of this demo paper is not to propose another localization algorithm, but to make the localization system less cumbersome to set up and deploy. One of the most promising techniques are RSSI fingerprint based methods [3][4]. These methods typically use an RSSI data collection phase on an existing, previously known map.

RSSI fingerprint based methods proceed in two steps: (i) an offline phase to collect reference RSSI measurements, and (ii) an online phase of real time localization. During the offline phase, RSSI values are measured at known positions, i.e. fingerprints, and combined to form a *radiomap*. This map is then used for localization during the online phase of real-time position determination. In this work we focused on the generation of this fingerprint radiomap. Usually, the radiomap is build manually through the cumbersome process of users pin-pointing their location on a ready-made map or by moving in pre-specified patterns while scanning the network for RSSI values. This manual and time-consuming offline phase is prone to introduce delays in the actual use of fingerprint-based localization as well as reduced accuracy due to human error.

Unlike most of the fingerprinting based approaches, we propose an automated offline phase for acquisition of radiomaps by using a handheld mapping system [5] in an IEEE802.15.4-compatible network. In our approach the delay for creating the radiomap is significantly reduced, since the measurement of positions is automated and very accurate. The rest of the paper is organized as follows. In Section II, we provide a system description, our approach for the automatic generation of a radiomap and an estimation of the possible accuracy of fingerprint-based localization systems in a sample environment. We conclude with future work in Section III.

II. SYSTEM DESCRIPTION

The handheld mapping device hardware uses a Hokuyo UTM-30LX LIDAR system, an Intel Atom based CPU board and a low-cost MEMS IMU system. USB ports can be used to connect peripheral devices. For this experiment we attached a WiFi stick to provide live data to a monitoring station and an IEEE802.15.4-compliant usb-stick to collect RSSI-fingerprints. Using the fast scan matching based SLAM approach described in [5], 2D occupancy grid maps of indoor environments can be built in realtime by walking through them with the system in hand. The SLAM software is open source and available online[1] as a stack for the ROS [6] middleware.

For the experiment shown in this paper, we used the wireless sensor network TUDμNet [7], which is deployed in the buildings of the Technische Universität Darmstadt. The TMote sky and Zolertia Z1 nodes were configured to run Contiki [8] and to answer ICMP ping requests. A Jennic-based sensor node attached to the mapping box periodically broadcasts those and collects the local RSSI values of the ICMP pong replies. These RSSI reference measurements were put into a database consisting of tuples $[id, x, y, rssi]$ (*fingerprints*), where id is the ipv6-address of each replying node, x and y is the current position returned by the mapping box and $rssi$ is the locally measured RSSI-value. Position estimates were returned at 40Hz, while RSSI-values were requested at 10Hz (the resulting sampling rate is higher since one broadcast request results in replies from multiple nodes at certain positions). The network consisted of 27-nodes (positions shown in Fig. 1) and

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[1] http://www.ros.org/wiki/hector_slam

978-1-4673-1786-3/12/$31.00

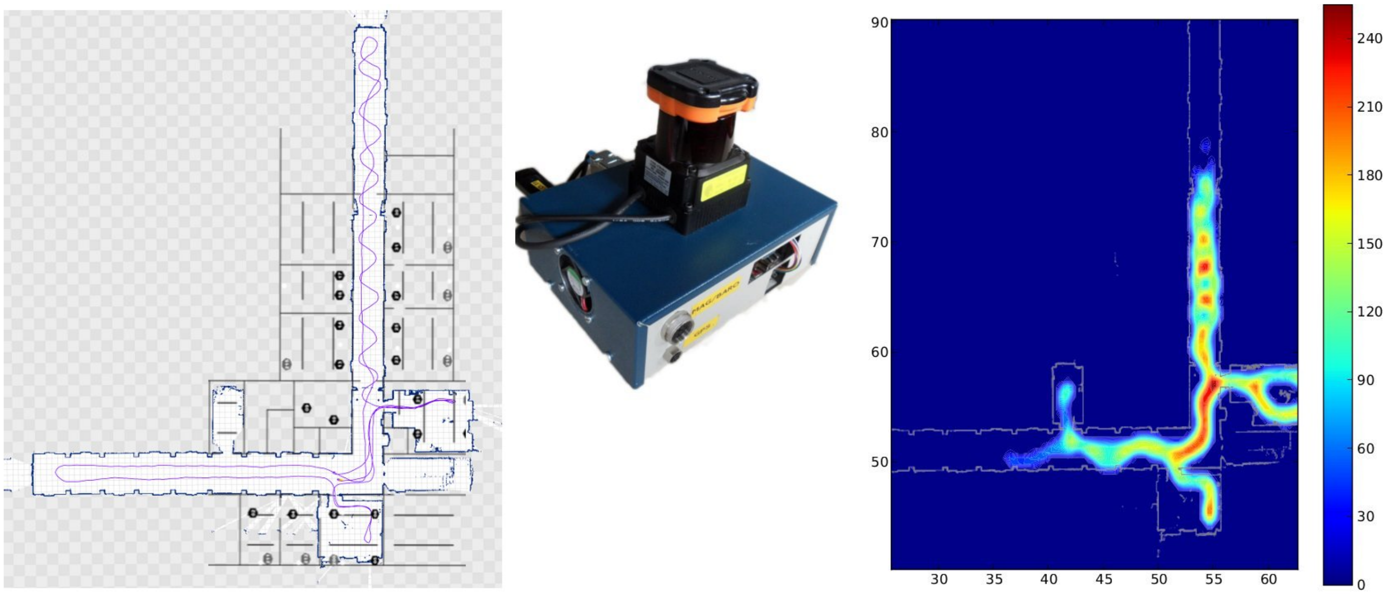

Fig. 1: The picture in the middle shows the handheld laser-scanner hardware, left is an overlay of the floorplan with positions of TUDµNet nodes (grey are Z1, black are tmote Sky). Together with the result of the laser-scan and path we took during data collection. To the right the collection of all RSSI-measurement vectors, in which the color stands for the similarity to all other measurements. The higher this value, the better this position can be distinguished from other positions via its RSSI-fingerprint.

a five-minute walk with the mapping box resulted in a total number of 12787 entries in the radiomap.

For estimating how well a possible localization algorithm based on our *radiomap* might work, we are interested in how distinguishable the measured RSSI-values are for each position in the map. For this we reinterpret the fingerprint map by regarding it as a collection of zero-padded (zeroes, where there is no measurement available due to limited reception range) measurement vectors $m_{x,y}$, which contains all (in our case 27) RSSI-values received at a certain positions x, y on a rectangular grid. Since we only have a sparse sampling of the area (we did not visit each possible position), we also zero-pad the grid. Resulting in a rectangular grid of measurement vectors spanning the whole area. We can then calculate the minimum euclidean distance between one measurement vector to all other measurement vectors on the grid, i.e. we express the similarity of each position regarding its RSSI-fingerprint by: $min(\forall i,j \in X,Y \ : \ \sqrt{m_{x,y}^2 - m_{i,j}^2})$. The higher this value, the more distinct the RSSI-measurement at position $[x, y]$ are compared to all other measurements. The result of this calculation in our sample environment is depicted in Fig1.

III. CONCLUSION AND FUTURE WORK

We believe that the approach of using a handheld laser scanner for simultaneously generating an indoor- and radio-map has a lot of advantages compared to the manual generation of a radio-map. There is no need for a floorplan, since this will be build during the offline phase, which makes this system applicable to environments where these might be hard to get, inaccurate, outdated, or not available. It is possible to build a more accurate radiomap because sampling positions and RSSI-values is done in an automated fashion, and the possibility of human errors is decreased. It also allows for a faster and more thorough evaluation of existing wireless localization algorithms.

Future work will include a direct integration of data collection in the ROS middleware to allow for easier experimentation. And existing wireless localization systems should be evaluated with this system to get an improved understanding of their localization performance.

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