Auto-Calibrated 2D Localization System Using RSSI

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***Abstract*—This project is a work in progress. It is an attempt to localize a laptop computer in two-dimensional space indoors using simple localization techniques and algorithms (RSSI and the min-max algorithm) as well as inexpensive and readily available hardware components (433 MHz RFM22B transceivers and Arduino devices). The system is composed of three anchor nodes and one mobile node, and goes through an automatic calibration phase before attempting to determine the coordinates of an ordinary laptop computer. The system achieves an overall average error of 0.59 m along the x-axis, and 0.76 m along the y-axis for selected test points.**

Keywords—localization, RSSI, min-max algorithm

I. INTRODUCTION

Indoor localization is a difficult and tedious task. It is no wonder systems which attempt to produce accurate measurements of the position of a target tend to make use of complicated techniques and infrastructures.

Figure 1. Sensor node prototype

This project attempts to show that accurate position determination can be achieved using simple localization techniques and readily available hardware components. Specifically, it aims to minimize the software and hardware complexity of the localization solution by making use of the wireless propagation model which utilizes the Received Signal Strength Indicator (RSSI) to determine the distance between nodes [1,2], and the min-max algorithm [3] to transform these distances to actual coordinates in a two-dimensional indoor space. The project also employs inexpensive hardware, with each sensor node costing around $50, each of them easily deployable with weight of approximately 200 g and with dimensions 12.5 cm x 10.8 cm x 3.5 cm, as shown in Fig. 1.

This paper presents the results of the use of this project in order to localize a mobile computer in a 3.5 m x 5.5 m typical laboratory room setting using 3 anchor nodes.

II. METHODOLOGY

A. System Architecture and Deployment

The system is composed of three anchor nodes and one target node attached to a mobile computer, as shown in Fig. 2. The mobile node is connected to the mobile computer via USB port. The anchor nodes are placed on the ceiling, each of them with known coordinates. These coordinates can be adjusted according to the user's preference. For the experimental setup, the anchor nodes were placed near the corners of the 3.5 m x 5.5 m area, with the room temperature set at 24 °C. Specifically, the anchor nodes were deployed at positions (3.5 m, 0 m), (3.5 m, 5.5 m), and (0 m, 5.5 m).

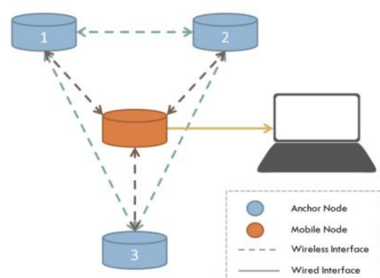

Figure 2. System architecture of the experimental setup

B. Automatic Calibration

In order for the localization technique to be able to adapt well in various environments without manual intervention, there is an automatic calibration of the wireless propagation model prior to acquiring RSSI samples from the anchor nodes. The automatic calibration phase, inspired from [4], is done by using information shared between anchor nodes, considering their known coordinates. The relationship between the obtained RSSI value of a signal sent from one node to another and the corresponding distance between these two nodes is given by (1) [3].

$$RSSI\ [dBm] = A - 10n\log_{10}\left(\frac{d}{d_0}\right) \qquad (1)$$

In (1), *n* is the path loss exponent which is dependent on the environment, *d* is the distance between transmitter and receiver in meters, d_o is a reference distance set to 1 meter, and *A* is the RSSI value when $d = d_o$ plus multipath and shadowing effects. The automatic calibration phase aims to calculate the values *n* and *A*. To do this, one of the anchor nodes acquires RSSI samples from all the other anchor nodes in the system, and sends these samples to the target node for processing. We note that the computer has knowledge of the distances between the anchor nodes, and can use (1) to compute for the average *n* and *A*.

C. Localization Algorithm

In order for the mobile node to localize itself, it acquires RSSI samples from all anchor nodes and uses (1) to calculate their respective distances to the mobile node. The Min-Max algorithm is then used to estimate its position, selected for its accuracy and computational simplicity [5,6]. The algorithm works by forming a theoretical box around each anchor node, a box whose corners are determined by the coordinates of the node and the measured distance between mobile and anchor node. The resulting intersection of all theoretical boxes is the box inside which the mobile node lies. For a detailed explanation of the algorithm, see [3]. However, it cannot be avoided that some RSSI samples yield distance estimates which would produce boxes that do not intersect at a single box. Thus, we have created a system which takes into account this occurrence.

This system effectively divides the localization area into two spaces; it determines whether the mobile node's position is nearer the anchor nodes or nearer the center of the area. By doing this, the system determines which space the mobile node is more likely to be located. A threshold is used to determine this division. Our system uses the original Min-Max algorithm in the area near the center, and a modified algorithm otherwise. This modified algorithm takes into account the circumstances when the box intersection calculated by the Min-Max algorithm is not the actual intersection, but is farther away from the true point. Through experimentation, we have determined that the Min-Max algorithm yields erroneous results when the mobile node is near the corners. The modified algorithm uses the conditions specified in (2) - (3). If at least one of these two conditions is not satisfied, the erroneous value is adjusted accordingly.

$$x_{min-max} > x_{max-min} \quad (2)$$
$$y_{min-max} > y_{max-min} \quad (3)$$

III. Results and Recommendations

The system was tested by obtaining the average Cartesian error at selected sample points. Specifically, points representative of smaller sections in the space were used in evaluation.

Fig. 3 is a sketch of the space localized. The dots in the figure represent the test points. As can be seen on the figure, the average error for all test points except (0, 0) range from -1 to 1 m. The overall average error is 0.59 m along the x-axis, and 0.76 m along the y-axis. The average error at point (0, 0) is much greater in magnitude than those of other points. This is because of the lack of anchor nodes in the area that covers (0, 0). It is, therefore, our recommendation to increase the number of anchor nodes to 4. In addition, to allow the obtained *A* and *n* to represent all the anchor nodes better, we recommend that all anchor nodes obtain RSSI samples from all other anchor nodes in the auto-calibration phase. Aside from those already mentioned, we recommend the increase of transmission power of each node to improve the granularity of the measured RSSI and therefore, the computed distances and coordinates, which could also prove useful for an indoor space of a larger area. Finally, we recommend the use of better antennas. All mentioned recommendations will be greatly considered when developing the next prototype of the system.

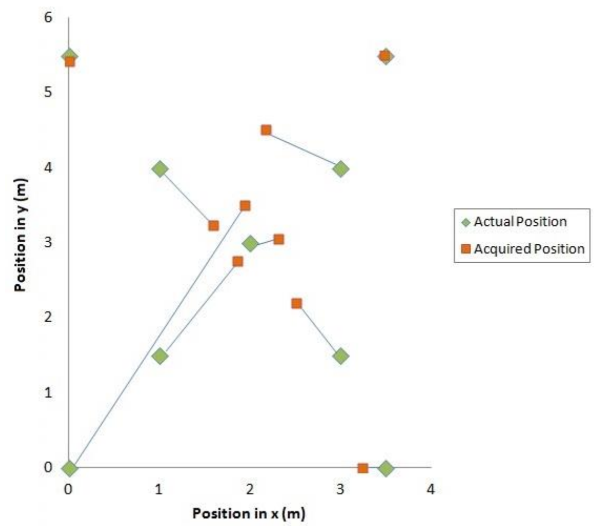

Figure 3. Actual vs. Acquired positions

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