THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY | DEPARTMENT OF ELECTRONIC & COMPUTER ENGINEERING

IoT-based Radio Tomographic Imaging System (MR02a-22)

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Overview

Indoor Positioning Systems are solutions that locate people and objects in an indoor environment where satellite technologies (such as GPS) lack precision. There are numerous applications for Indoor Positioning Systems. For instance, they can be used in Internet-of-Things products to automatically save electricity in areas that are unoccupied by tracking the movements in the area.

There are several other methods to implement an indoor positioning system, such as by using RFID tags, by installing video and/or thermal cameras, and by deploying a Bluetooth Fingerprinting system. However, the potential breach of privacy is a major concern when using video cameras. In addition, RFID tags require all targeted objects to be tagged, rendering it ineffective in locating untagged objects. Furthermore, WiFi signals operate at a frequency of 2.4GHz, implying that such signals can penetrate through physical barriers such as walls and glass panels and produce accurate imaging results.

Therefore, this project aims to build a Radio Tomographic Imaging system and ultimately, experiment with software-level and hardware-level optimizations to improve the imaging accuracy.

The Wireless Network

In this Radio Tomographic Imaging (RTI) system, WiFi signals are transmitted between every possible pair of nodes in the given wireless network. Each node measures the Received Signal Strength Indicators (RSSI) of the signals received from all the other nodes, which are then used in generating an image of the environment being monitored and detect objects.

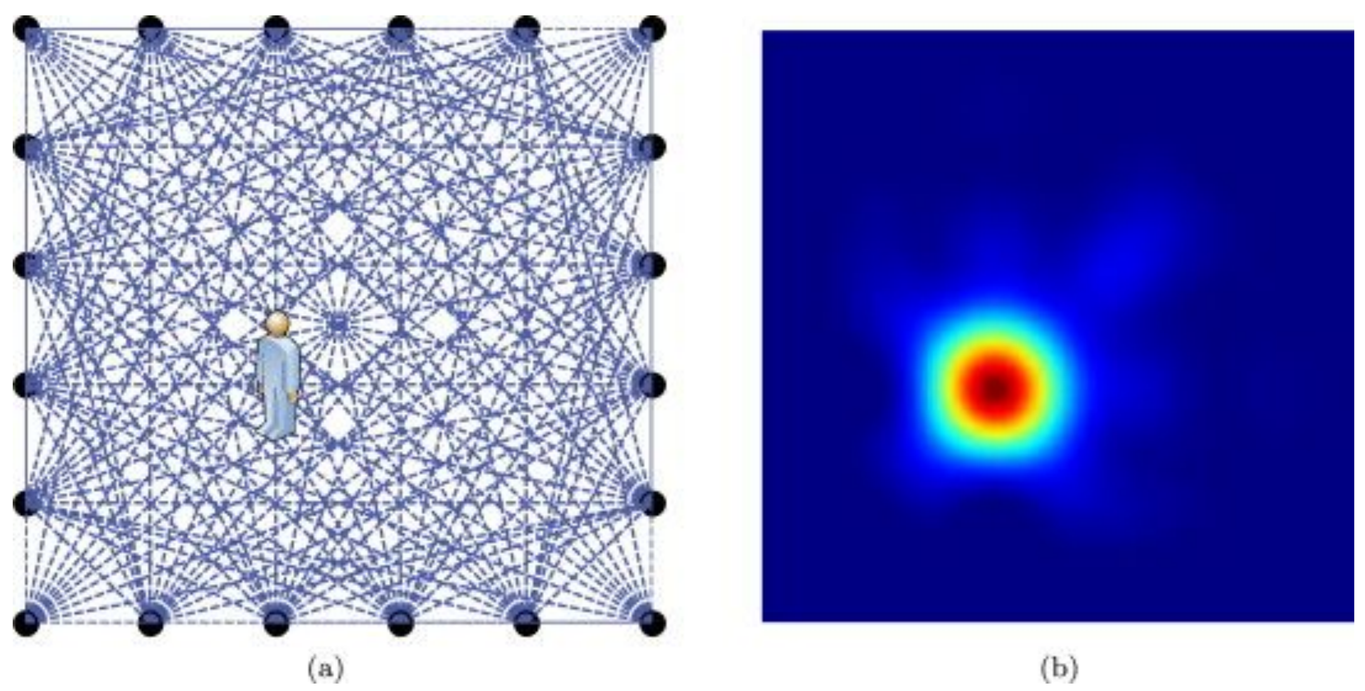

Figure 1a: Example of Links between Nodes in a Wireless Network
Figure 1b: Example of Imaging Result of Locating the Object

Methodology

There are two main aspects to building the Radio Tomographic Imaging System, namely the hardware within the wireless nodes that comprises a transceiver each to transmit and receive WiFi signals, and the image reconstruction software that collects the RSSI data from all of the wireless nodes and generates images.

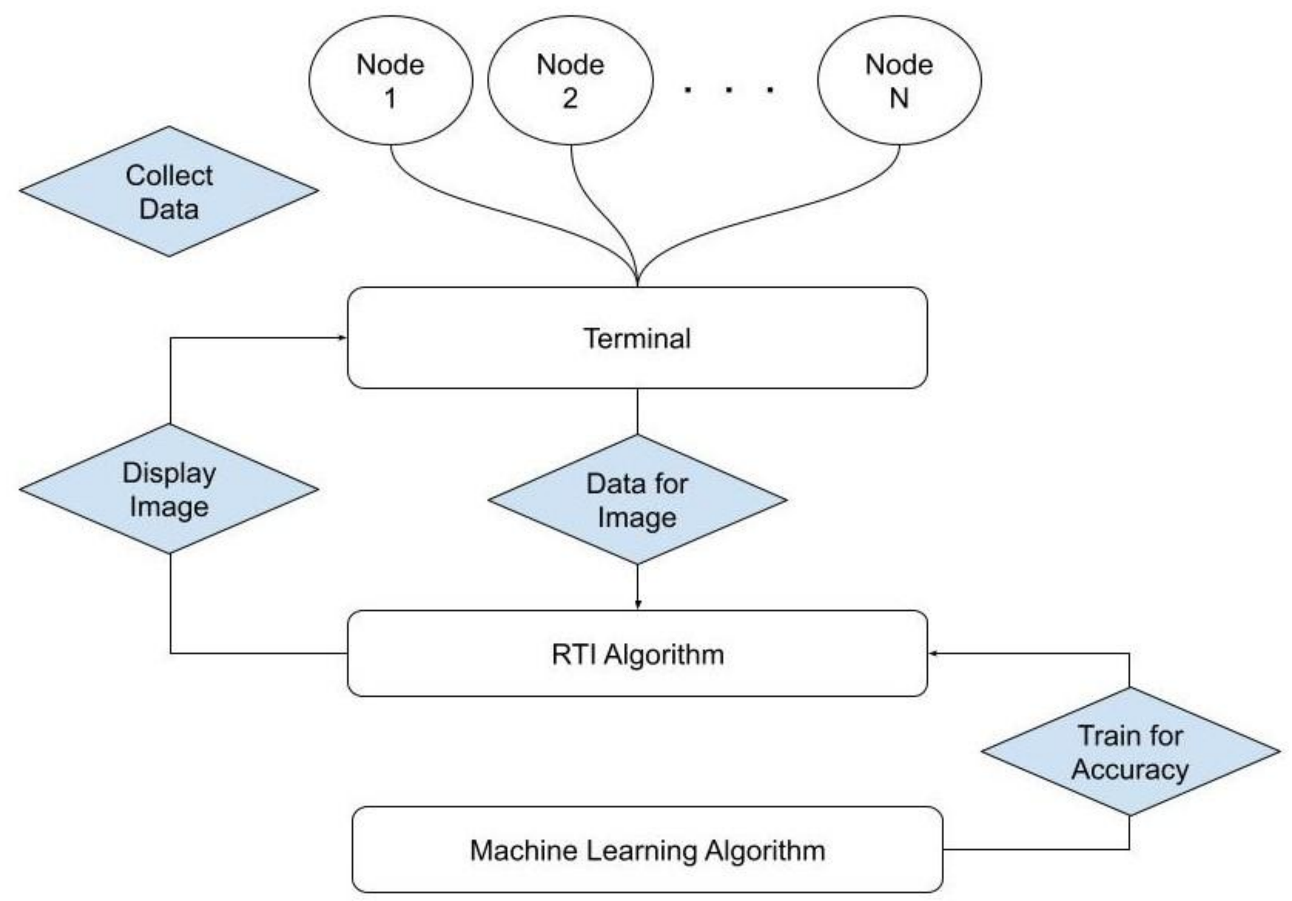

Figure 2: Block diagram for the proposed IOT-based Radio Tomographic Imaging system

An ESP32 development board is placed inside every wireless node to transmit signals and measure the RSSI values. ESP32 was chosen over various alternatives as the boards are relatively inexpensive and they have a built-in WiFi module. In every iteration, only one wireless node transmits a signal and the other nodes measure their respective RSSI values. After completing this procedure for all the nodes in the network, the RSSI values are all sent to the Image Reconstruction Software via a HTTP request.

Upon receiving the RSSI values, the image reconstruction algorithm is performed to compute the intensity of all the pixels in the image. An ill-posed inverse problem, the method solves the linear equation $x = W^{-1}y$, where x is the list of intensity values for all pixels in the image, y is the RSSI values, and W is the transfer matrix.

After building the Radio Tomographic Imaging system, the project aims to evaluate different machine learning algorithms to optimize the imaging accuracy while minimizing the system latency.

Progress

- As of now, the basic image reconstruction algorithm is complete. The system has been tested against simulation data and our method can successfully generate images of the obstacles based on the RSSI data provided from the simulation data. Moreover, our system latency is considerably lower as we have minimised the number of operations required for the imaging method. For instance, all the voxels in the Line of Sight of any pair of nodes in the network are determined in an initialisation procedure, after which the weight matrix is computed and stored in a JSON file. Therefore, the system simply runs the imaging algorithm to generate the images, instead of computing the weight matrix for every iteration.

- Moreover, our hardware set up is nearly ready - the wireless nodes can detect all nearby nodes and measure the RSSI values. Furthermore, the data pipeline in which all the RSSI values are transmitted to a terminal PC has also been completed. Currently, alternative methods are being evaluated to minimize the time needed to gather all the RSSI values needed for imaging.

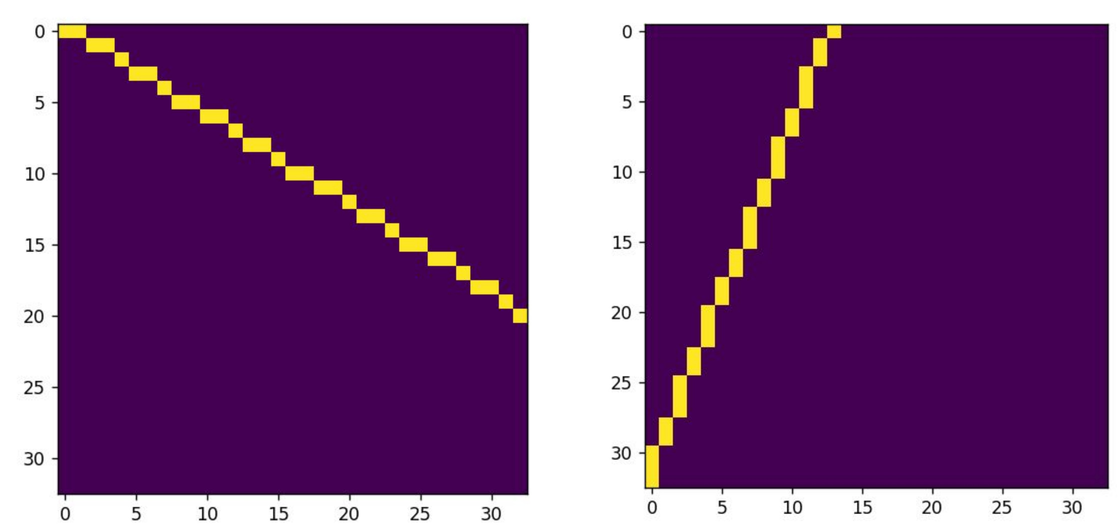

Figure 3 and 4: Defining the Line of Sight between two nodes in the WiFi network

- Our next objective to combine the data pipeline such that the RSSI values are transmitted directly to the image reconstruction method in JSON format via HTTP requests. After this achieving this objective, hardware-based and software-based optimizations will be evaluated to optimize the imaging accuracy and latency.

Conclusion

There is a considerable demand for Radio Tomographic Imaging solutions for Indoor Positioning as this method has several advantages over existing alternatives. In this project, we aim to build such a system, and improve the imaging accuracy and latency of the system to truly reach industrial standards for indoor positioning.