Using Robots and SLAM for Indoor Wi-Fi Mapping in Indoor Geolocation

[Extended Report]

A Major Qualifying Project Report

Submitted to the faculty of

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Degree of Bachelor of Science

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Abstract

Wi-Fi localization for indoor environments has been a successful field for research and development due to its increasing demand. Many companies like Google, Meridian, and Nokia collect Wi-Fi related databases for indoor environments which is used in millions of applications. For indoor environments that data is collected manually by war walking which is an extremely hectic and arduous progression. In this project we aimed to automate this process of collecting Wi-Fi related databases in indoor environments by introducing robots to perform the task. We also conducted a comprehensive performance evaluation of robot collected databases against the traditional human collected database and other commercially available systems (such as Wi-Fi Compass, Google Maps, etc.) to determine whether a human can be substituted with a robot for this kind of data collection.

Additional Notes:

This report is an extension of work that was initiated by three students, one of which, James Castro, submitted the first draft of the report at the end of D Term of 2012-13 academic year. This current report is the final and revised version of the formerly started report which is prepared by, Biao Zheng and Umair Rehman, who have continued work on the project for partial fulfillment of the requirements for the Degree of Bachelor of Science.

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1 Introduction

Localization has generally been done outdoors but as technology advances and as the need of consumers' changes there is an increased interest in indoor localization. For this kind of localization there are various tools that are available in order to localize. Localization can be done using a few different methods. Three of the most common methods are using RSS (received signal strength) from wireless access points to triangulate position and track movement, 2-D mapping is another in which a given map is used to navigate through with known obstacles and markers and another is 3-D mapping using some form of visual guidance that allows for dynamic adjustment as the position of the person, robot or object changes. Precise localization techniques have been the interest of study for decades. Until recently, Global Positioning System (GPS) has been developed and widely used in commercial applications. However, its performance in indoor area is significantly deteriorated due to path loss and other signal degenerating agents. Due to the inaccuracy of GPS in indoor applications, there is an increasing demand for precise localization inside buildings. Wi-Fi based localization technology makes use of Received Signal Strength (RSS) to determine the position of an object inside a building. One of the advantages of Wi-Fi localization is that it uses an existing infrastructure, which makes it an inexpensive sensor with extremely low power consumption. Lastly, since it is also a software-based sensor, it is far easier to debug, test, and modify as opposed to hardware-based sensors.

Traditionally, indoor localization algorithms were mainly developed for tracking people and assets. However, with the emergence of robotics, more and more applications involving automated tasks require precise localization of the robot. The main motivation behind robotic indoor localization is that such an application allows robots to be location aware. With modern software techniques, a robot can be automated to perform certain jobs inside a building as long as the location is known. The unpredictable variation of RSS in the indoor environment is the major technical challenge for the RSS-based WLAN positioning systems. There are four main reasons that lead to the variation of RSS. First, due to the structures of the indoor environment and the presence of different obstacles, such as walls and doors, etc. the WLAN signals experience severe multi-path and fading and the RSS varies over time even at the same location. Secondly, since the WLAN uses the licensed-free frequency band of 2.4GHz, the interference on this band can be very large.

After the release of Google Indoor Maps, Wi-Fi localization has had an increase in demand. Various companies have had an interest in indoor Wi-Fi localization such as Skyhook Wireless, Apple and Google. These companies are trying to map Wi-Fi access points by surveying inside buildings either by employees of their companies or by having the management of these building provide them with the necessary blueprints and locations of their wireless access points. We want to find an inexpensive and accurate method to map Wi-Fi access points inside buildings by using robots to do this task.

Depending on the necessary accuracy needed and limitations presented these methods can be used standalone or combined in various forms in order to produce a better mapping and an overall better tracking of position and guidance. One of the more common combinations is using Wi-Fi localization and a 2-D map in order to navigate. This creates a stable and accurate mapping that can be used although it does have some faults. A couple of its major faults are the inherent nature of wireless signals to dissipate at varying rates according to its surroundings and is further hindered by the number of access points available in the vicinity. Another major fault is since the map is static, any changes to the environment will have to be manually added and navigation will have to adjust to the change by going around, through or over the obstacle. The new method of using visual aids in order to navigate through an area and track movement has been increasing in popularity due to needing but a single sensor in order to perform its task. This method is currently being worked on at Worcester Polytechnic Institute.

1.1 Project Description

The structure of the entire project has been illustrated in **Figure 1**. According to the figure, the project has been divided into two main branches. The first branch deals with database collection and the second branch deals with performance evaluation of the collected databases. We first collected two kinds of reference databases: Database I was collected by hand using the program WirelessMon to accumulate the RSS values and their corresponding MAC addresses measured as the human walked through the third floor of Atwater Kent. The person's location was also manually tracked throughout the entire process. The other reference database was collected by Turtlebot using WirelessMon to collect the Wi-Fi information we needed while having SLAM algorithm running to navigate through the third floor and collecting its path using its odometry values. We received two databases because we independently tested two different SLAM algorithms. The databases were then designated as Database II and Database III respectively. With the collection of databases the first phase of the project was accomplished and we moved to the second phase which was the Performance Evaluation of these Databases.

Our aim was to see how much error does the robot collected database have compared to Human collected database. These databases were evaluated at first by performing position error by mere comparing the odometry values of the robot against human collected database in which we presupposed that the human collected database had no error. We then calculated the position error using the Nearest Neighbor Algorithm to further scrutinize the results. Lastly we compared the results with in use commercial applications like Wi-Fi Compass and Google Maps. We did an overall analysis and used error averages to conclude whether a robot would be suitable for such data collection

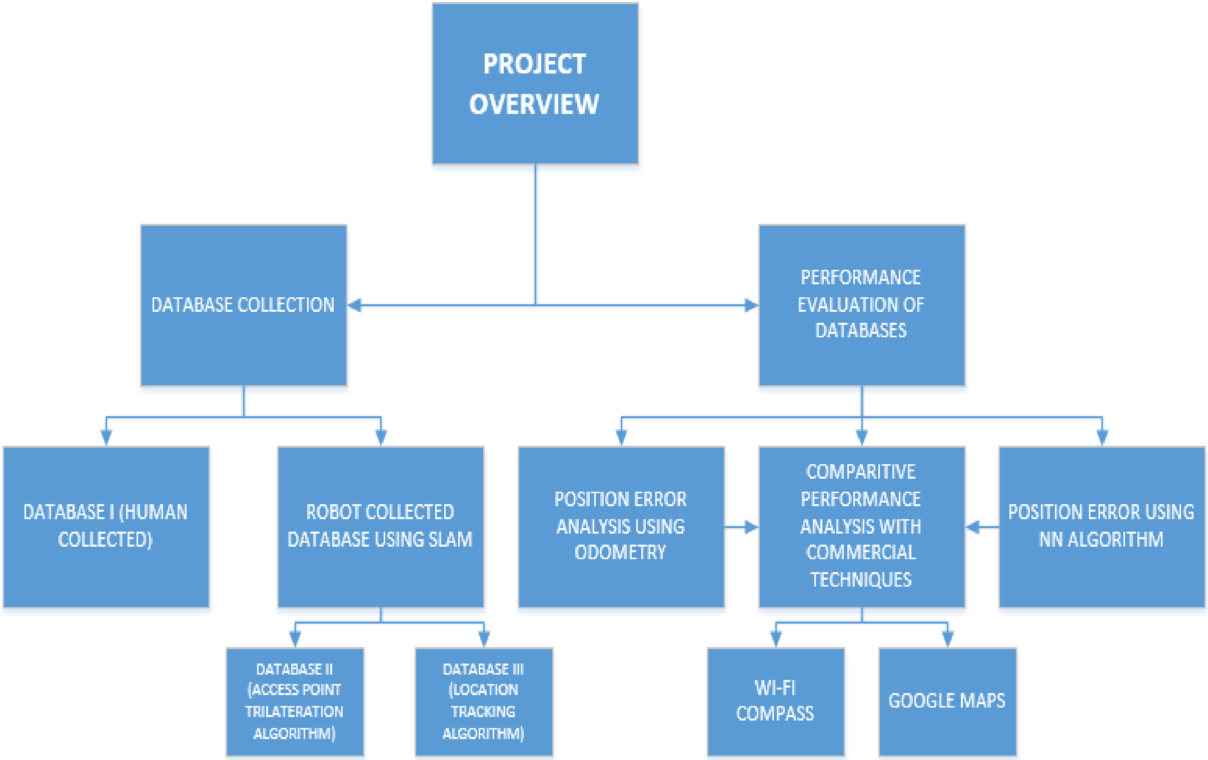


Figure 1 Entity Relationship Diagram showing Project Structure

1.2 Project Report Outline

In this report you will find an introduction stating the reasons behind choosing this project as well as section about current work being done in this field. Next, there is a chapter on the background of this technology, the current methods being used and the applications in which they are being used. The third chapter is the methodology. In it we describe in detail our procedures as well as any other work that was done either by a member of the team, a robot or some code (Matlab). The fourth chapter deals with the results we acquired as well as what the results mean to the project's validity and its worth. The fifth chapter is a section devoted to the conclusions that we have determined to be important and what they imply about our project, followed by a section that explains any future work that we perceive to be feasible and worthwhile for any future project teams or areas of research. In the very end of this report you will find appendices related to the various additional data acquired as well as any code that was developed or used in this project. There is also a reference section stating all the various references and sources used to complete this project and report.

2 Background

In this section, a comprehensive synopsis of Wi-Fi localization with respect to our project is provided. The main localization methods and their respective algorithms are discussed. An overview of Wi-Fi localization for indoor and outdoor applications is described and how everything is interrelated with the database and applied algorithm is also explicated. Later in the sections our motivation to choose indoor environments for this project is reasoned, traditional localization techniques like Wi-Fi Compass and Google Maps utilized in this project are also explained and the background of our applied Nearest Neighbor Algorithm (K-NN) in this project is given.

Localization refers to the process of determining an object's location in space. It helps people in so many fields such as locating a building or an object on the earth. The localization system is used in many areas, the best known is the Global Positioning System (GPS). Today GPS makes outdoor localization so easy. The system provides critical capabilities to military, civil and commercial users around the world. GPS is a space-based satellite navigation system that locates four or more of the GPS satellites, figure out the distance to each, and use this information to deduce the GPS's location; with the time information such as the speed of the object, it can navigate the object from one location to another. The accuracy of a position determined with GPS depends on the type of receiver. Most hand-held GPS units have about 1020 meter accuracy which is great for outdoor use. For indoor and even outdoor use we employ Wi-Fi localization techniques which are another big area of research and development. Wi-Fi localization is used in billions of smart devices and companies in Wi-Fi Localization receive several billions hits per day. Wi-Fi Localization according to many statistics is the 2nd most popular after GPS and more popular than cell tower localization. It is used in thousands of Smartphone Apps and current Wi-Fi localization which was traditionally being employed in outdoor Google Maps is also used in Google's recently released indoor maps.

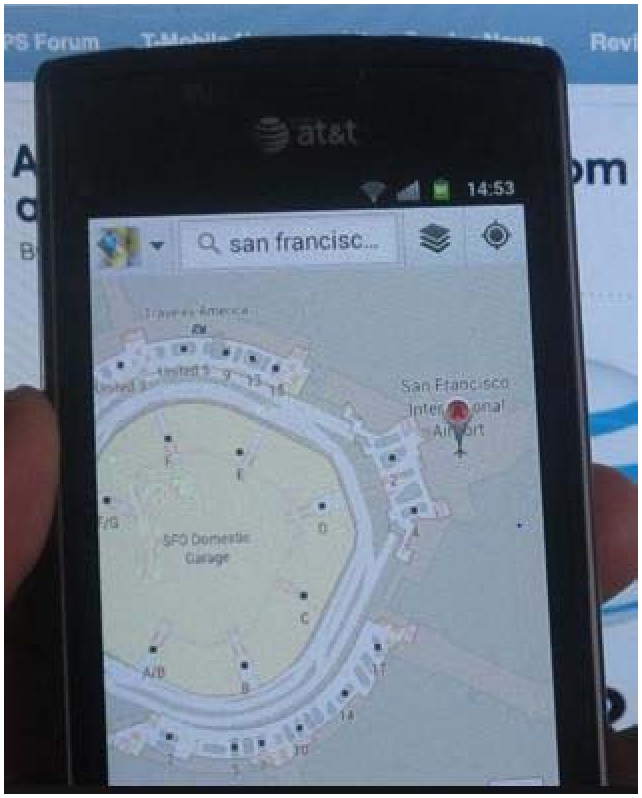


Figure 2 Google Indoor Map employing Wi-Fi Localization

(Shin, Wireless Communications, IEEE Transactions on 8 (10), 4906-4910 2006)

Indoor positioning technology is an important issue to be addressed for providing any kind of location based services. There were lot of approaches for this technology by the user of active sensors like active badge, active bat, etc. (Hightower and Borriello, 2001), and some approaches use the in-building Wi-Fi networks for indoor positioning. The use of Wi-Fi signals as a potential positioning system within buildings has opened doors for many applications. Lot of research is being undertaken in this domain to find a more viable solution of location positioning using the

Wi-Fi signals within the building with higher accuracy. This is because of the ubiquitous availability of Wi-Fi signals in almost all the buildings, so no additional hardware is required to install a positioning system in the buildings.

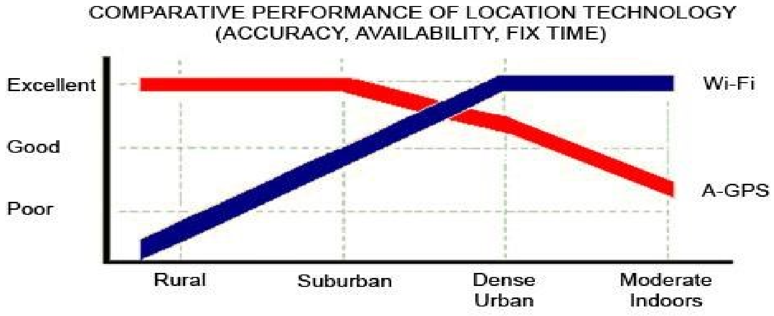


Figure 3 Wi-Fi vs. GPS in Indoor Environments

(Shin, A Ghosh, N Mangalvedhe, TA Thomas Communications Magazine, IEEE 50 (6), 54-642006)

2.1 Traditional Localization Techniques

In order to perform the localization, first we need to collect data as reference or use the data to compare with reference. The data collecting for outdoor and indoor have different method.

For the outdoor data collecting, we often see a Google car running around the city to collect data from Wi-Fi networks. While taking pictures for its Street View project, Google also recorded Internet traffic from open Wi-Fi networks in homes and businesses. To capture the images and the data, Google used cars equipped with roof-mounted cameras and computer hardware. There are 4 steps of this data collecting method.

Figure 4 Google Car Collecting Data using GPS Systems Mounted on a Fusion Car

(Mobile, HS Jo, P Xia, 2011 IEEE International Conference on, 1-52013)

The Google car's on-board computer listens for wireless routers, recording each router's unique hardware ID as well as its approximate GPS coordinates.

If a Wi-Fi network is not password- protected, the car's computer also saves any data transmitted across the network. That traffic can include e-mails and information from passwordprotected sites, which are not necessarily encrypted. If the network is password-protected, the computer does not save any of the network's traffic

The car's computer maintains a connection with a given network for only about one-fifth of a second, because the software cycles through 11 Wi-Fi channels every 2.2 seconds. A Wi-Fi router generally broadcasts on a single channel.

In the one-fifth of a second that the computer is connected to a network in each cycle, the amount of data collected could be as much as 250 kilobytes, equal to roughly 25 e-mails, or more. It is also possible that a car may connect with a network multiple times, if, for example, it is stopped at a red light.

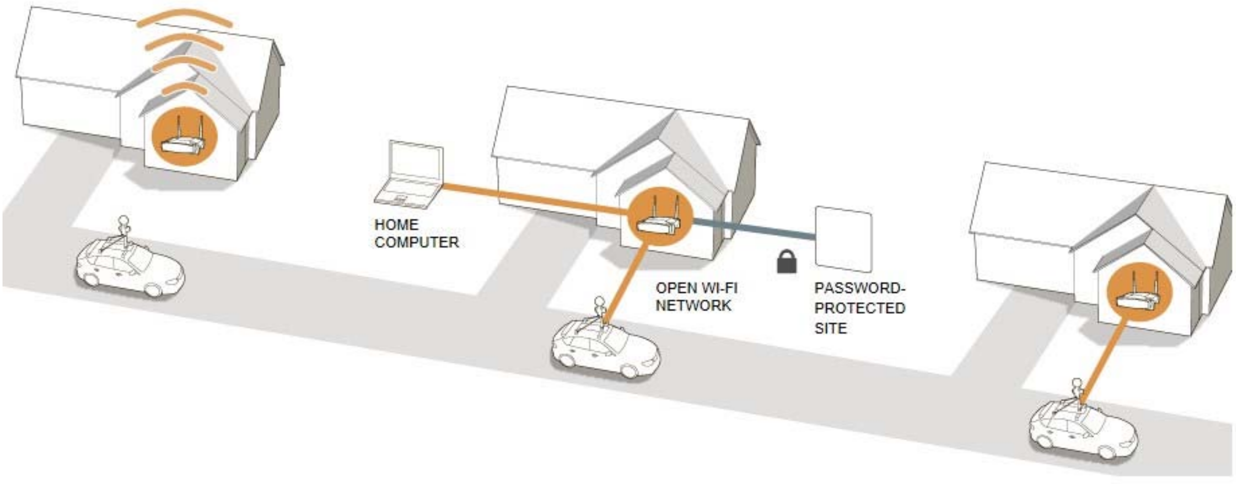


Figure 5 Google Cars Collecting Data using Wi-Fi Localization and Cell Tower Localization

(GRÖNDAHL, How Google Collected Data From Wi-Fi Networks, 2012)

2.2 Localization: Outdoor vs Indoor

Likewise, research location systems like RADAR and Cricket are limited to be functional in indoor environments and require a great amount of effort to use them in a greatly larger area. The systems in indoor environments can give accurate estimates of users' positions within about four meters. However the accuracy comes at the cost of much time spent on installation and calibration, thus the systems are deployed in limited areas.

Possibly for a large class of location-aware applications, ubiquitous availability of location information is important. However the main obstacle would be to control the cost of installation and calibration while deploying the system across an entire city for example.

With the increasing number of people using laptops and wireless Internet, the deployment of Wi-Fi access points is almost omnipresent in every major city. Ubiquity and a large number of Wi-Fi device users are two characteristics that make Wi-Fi localization viable.

So basically the process of RSS based Wi-Fi Localization employed in this project can be easily defined as the procedure of finding a user's location solely based on RSS readings. It involves two steps

- Collecting databases by surveying access point readings in known locations
- Comparing new RSS/MAC addresses while war driving with a known database and using an algorithm to approximate a user's location

Since its inception in the 1980s, Wi-Fi has become one of the wonders of the wireless revolution, nurturing ground-breaking innovations in popular applications. Always seeking higher data rates (now on the order of 100 Mbps), Wi-Fi users employ the technology for wireless Internet access and the ever-growing multimedia applications that it supports.

These Internet applications are commonly used in indoor areas, where extensive multipath conditions require robust methods to achieve high data rates. As a result, WLANs introduced the first popular commercial application of spread spectrum technology, orthogonal frequency division multiplexing (OFDM), and more recently multi-input multi-output (MIMO) antenna systems.

In the second half of 1990s the Defense Advanced Research Projects Agency (DARPA) launched its small unit operation situation awareness system (SUO/SAS) program aiming at onemeter accuracy for indoor geolocation in military and public safety operations.

About the same time, venture capitalists started funding startup companies such as PinPoint in Woburn, Massachusetts, and WhereNet, based in Santa Clara, California. Both were seeking to develop and implement indoor geolocation technologies with high accuracies.

The idea of Wi-Fi localization created substantial enthusiasm in the industry. Various companies filed numerous patents targeting TOA-based indoor geolocation, and the general idea of using a wireless networking infrastructure for associated applications spread to standardization activities such as IEEE 802.15.3 for UWB communications and IEEE 802.15.4 for sensor networks using ZigBee technology.

Although TOA-based Wi-Fi localization uses an existing infrastructure, designers still need to modify the mobile devices' hardware to extract the TOA estimate from a received Wi-Fi signal. Moreover, implementation of a precision TOA-based system faces the same multipath challenges encountered previously, demanding complex algorithms and solutions.

The first generation of RSS-based RTLS products were software programs running on laptops and palm-top computers equipped with Wi-Fi devices used for indoor tracking applications. The system included localization software and a graphical user interface (GUI). The localization software operated in two modes: *data collection*, in which the user builds up the reference database, and *localization*, when the software locates a terminal based on the relative strengths of RSS readings. The GUI in the mobile devices shows the map of building and estimated location of the terminal.

In metrowide Wi-Fi localization, a database is collected by wardriving the streets of a metropolitan area, using GPS to tag the location and time of measurements. Later, when a WPS mobile terminal reads the RSS of surrounding Wi-Fi access points, it sends a request to a server to calculate the terminal's location by comparing its RSS readings with the database and previous GPS readings using a pattern-recognition algorithm.

One of the fundamental advantages of WPS is that it can be used as a standalone software solution for netbooks and laptops when they are not equipped with GPS or cell phone chipsets. This solution is natural, because netbooks and laptops use Wi-Fi chipsets to establish Internet connections. When a Wi-Fi network is available, WPS works.

Smart phones have cellular network connections as well as Wi-Fi chipsets. Wi-Fi signals from hot spots, home routers, and public access and enterprise wireless networks cover most of the indoor and urban areas where Internet applications are commonly used. In locales such as interstate highways, where Wi-Fi signals may not be available all the time, less accurate celltower localization can complement this coverage.

The size of a Wi-Fi AP database can be huge compared to the database of a RTLS system in a single building. On a national basis, the collection procedure requires many wardrivers across many metropolitan areas. In general the distribution of the actual Wi-Fi access points in metropolitan areas forms a stochastic process with particular spatial and temporal characteristics, because the number of the access points and their locations are constantly changing. During any given time interval, new access points are installed and some old access points are re-located or even disestablished.

Wi-Fi localization is emerging as a new technology that complements GPS in coverage, time to fix, and power consumption. This began with the introduction of RTLS technology tailored for more precise indoor applications in specific buildings and then extended to WPS technology with less rigorous requirements for accuracy but a wider geographic coverage— i.e., a metropolitan area.

RTLS is currently combined with GPS to provide accurate indoor tracking and coarser outdoor tracking when the asset or personnel is moving between two specific building destinations. WPS is integrated with GPS to provide for a comprehensive coverage in numerous everyday consumer applications. To extend the Wi-Fi localization applications to the military and public safety, we need to understand the effects of electromagnetic and radio frequency interference in this technology to have an optimum solution for its integration with GPS techniques.

Due to the limited reliability of GPS in indoor environments, we must use other techniques in order to track our position indoors as well as record specific locations of interest for later use. For indoor mapping and localization many people turn to one of the most used methods available, SLAM. SLAM stands for Simultaneous Localization and Mapping in which a robot uses various sensors and actively tracks its position and creates a map of its surrounding environment at the same time. This effectively acts as a substitute for human manually tagging positions onto a database and can make a map for an environment that does not have one already. By keeping track of its odometry, the robot can then use its collected data to navigate through the now known map essentially using its own collected data as GPS.

2.3 Localization Algorithms

Wi-Fi localization has gained much popularity over the recent years. Many indoor localization applications have revolved around the notion of using received signal strength measurements. Although there are methods to implement Wi-Fi localization using TOA, AOA, and RSS, the most widely used algorithm involves using RSS. There are typically two basic WiFi localization techniques that are generally used in indoor localization. These two methods are the nearest neighbor method and the kernel method, as suggested by. The nearest neighbor method basically revolves around the notion of taking the measurements of many points inside of a building, and by using the RSS of the access points (AP), it estimates which point in the building the object is closest to simply by calculating the distance as shown in. The nearest neighbor method is an efficient method but is sometimes unpractical. The second method, Kernel method, is based on the idea of using a probability mass function and the Gaussian curve to estimate the position of the object.

Essential elements for Wi-Fi localization include MAC address and RSS. The MAC address can be used to identify surrounding APs and the RSS can be used to estimate the distance between specific AP and the terminal. Moreover, SSID and time stamps are usually recorded to provide a clear vision or the Wi-Fi localization process. System log are usually maintained and with a carefully trained database, real time Wi-Fi localization can be achieved.

Wi-Fi coverage analysis supports both open source software on laptop and application on Android phones for the RSS measurement. Since carrying a laptop is more difficult, in this project, we designed an Android application to measure and record the MAC address, and RSS of access points in close proximity as a provision for Wi-Fi localization. We used the same application for the android device and the robot so that comparison could be vindicated.

There are three major techniques to obtain the location estimate from the RSS.

Triangulation: The RSS can be translated into distance from the particular AP according to a theoretical or empirical signal propagation model. Then, with distance measurements from at least 3 APs with known positions, lateration can be performed to estimate the locations. This approach does not give accurate estimate, as the indoor radio propagation channel is highly unpredictable and thus the use of the propagation model is not reliable.

Proximity: This method finds the strongest RSS from a specific AP and determines the location to be the region covered by this AP. This method only gives a very rough position estimate but it is easy to be implemented.

Scene Analysis: This method first collects RSS readings at known positions, which are referred to as fingerprints, in the area of interest. Then, it estimates the locations by comparing the online measurements with the fingerprints through pattern recognition techniques. This method is used by most WLAN positioning systems, as it is able to compute accurate location estimates. This is the approach used by the positioning and tracking system proposed in this report.

2.4 SLAM Algorithms

There are many SLAM algorithms that are used for mapping. The main difference amongst them is the addition of various filters that allow for more accurate results. While adding more filters does provide with a clearer picture, the resulting map is generally created the same way. The major component of SLAM is the use of occupancy grids analysis portion of the SLAM algorithm. During this time the various readings that the ranging sensor, usually a camera or an IR sensor, in our case a Kinect camera, are put into a series of grids. These grids can be X number of pixels in size but typically take the shape of a square because they are easier to handle when generating a map. The size of these squares correlate to the resolution necessary for the robot to traverse through an environment avoiding the edges of objects. This “cushion” is then used as the resolution of these occupancy grids that will allow the robot to map an environment safely. These newly made squares have sub-squares inside that are assigned values to determine their existence in the physical world. By first predicting if there is an object present in the given square, the algorithm allows itself to adjust for any changes in the environment either from detecting a static object or an object that has crossed the path of the scan as it moves through an environment. Once these initial predictions are set any future scans will continuously update the probability of an object existing in a given grid until there is a high enough probability of an object existing, usually an average of 0.7, and this grid is replaced with an occupied grid that is denoted on a map by a solid line segment. At times there are grids that overlap and if their combined probabilities dictate that there is a high chance of an object being in there, they are combined and filled in as a series of solid line segments resulting in a solid line. This procedure is repeated over the course of the robot's navigation through an area. After there are no longer any areas that have not been exposed to the ranging sensor, the robot stops and saves the map. Generally the robot would return to its start location or another designated area on the map that it might have found. Below you can see a near finished map created by the Turtlebot using its SLAM algorithm.

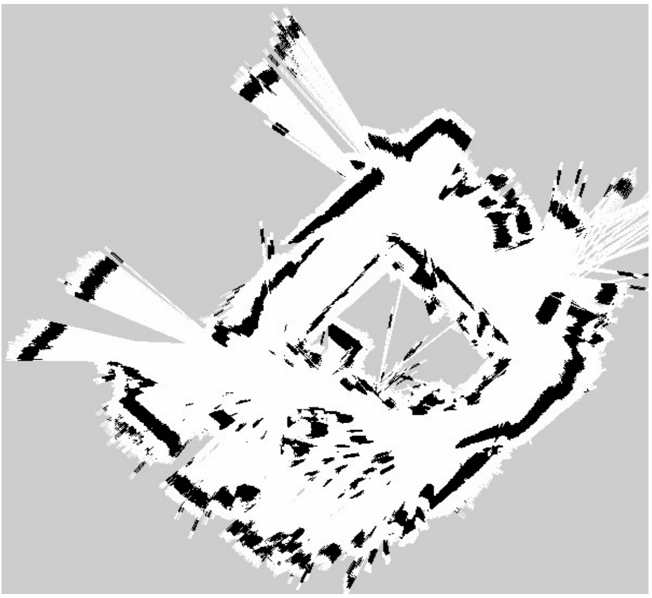
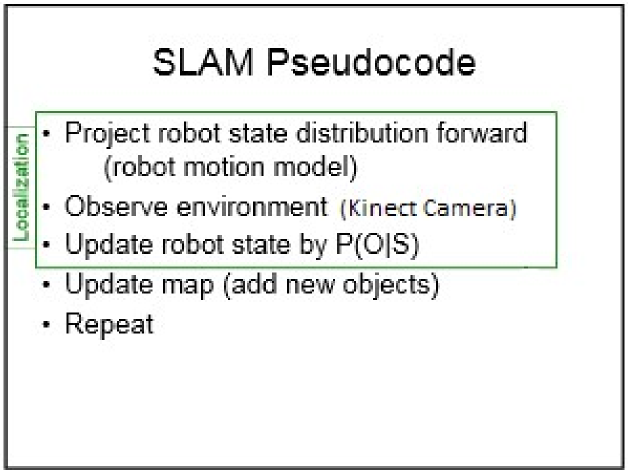


Figure 6 Slam Mapping using Kinect Camera on Hybrid Robots employing Inertial Capabilities

(SLAM, Antennas and Wireless Propagation Letters, Norick, 2002)

Below is a pseudo example of how the SLAM does its mapping. The procedure is repeated until there no longer is any empty space in the observed “world” of the robot.



SLAM Pseudocode

- Project robot state distribution forward (robot motion model)
- Observe environment (Kinect Camera)
- Update robot state by P(O|S)
- Update map (add new objects)
- Repeat

Figure 7 SLAM Iterations on Turtlebot Robot that Employs Kinect Camera

Path-loss characteristics in robotic applications at 2.65 GHz Microwave 48 (2), 383-386

3 Project Algorithm Development

3.1 Introduction

The key to development of an Indoor Positioning and tracking system is to first find individual methods to achieve accurate results by employing different algorithms. Our system works on mainly four different algorithms which are then put in comparison against SLAM algorithm as both are inertial systems and we want to conduct a comparative performance evaluation of the following various algorithms employed in this project.

1.) Access Point Trilateration Algorithm
    a. Step Detection Algorithm
    b. Weighted Centroid Algorithm
    c. Advanced Trilateration Algorithm
    d. The Local Strength Gradient Algorithm
2.) SLAM Algorithm
    a. Standard Iterate Closest Point Algorithm
    b. Extended Kalman Filtering
    c. Visual Odometry Algorithm

3.2 Step Detection Algorithm for Accelerometers

Step detection is the automatic determination of the moments in time at which footsteps occur, as it is performed by pedometers to generate step counts. Accelerometers are becoming increasingly ubiquitous in commercially sold devices, such as mobile phones like the Apple iPhone or the Nokia N95. While previous work is able to detect steps from foot-mounted accelerometers, we demonstrate step detection working reliably from hip-mounted accelerometers, a conceivable location for a device such as a mobile phone. In addition, the sensor platform used is no more powerful than many modern mobile phones. More than enabling pedometer functionality on mobile-phone-like devices, the step detection algorithm presented here could lead to more accurate automatic classification of bipedal human activities. Inferring human activities in real-time is a major goal of health applications. One general approach is to train a classifier to recognize activities. The input may be generated by sensors on an embedded device. The raw data are featured before being fed to the classifier. When inferring common human activities such as walking or running, features related to bipedal motion are especially useful in distinguishing classes.

Some accelerometer-based features are already used to aid activity recognition, such as the spectral distribution of the signal over a window. Using accelerometers to detect steps opens up not only some of the more obvious step features, such as step count and stride length, but also features that use steps to delimit sections of the signal. Features delimited by detected steps can be called intra-step features. One such feature might be the quality of a match between a time-normalized step and a template signal. The step detection algorithm is new, but simple. It uses an adaptive filtering technique to smooth the acceleration signal and locate steps. This technique is demonstrated to work while subjects walk or run at a range of paces from 1.9 to 2.8 Hz. Bicycling performance is not yet as reliable.

Steps can be detected by their characteristic change of acceleration. If a user moves forward, the device moves up and down in their hand. Experiments have shown that the amount of movement depends on the user and how they concentrate on holding the device still. One step is detected if the z-axis acceleration drops by at least $\Delta p = -0{,}7ms!!$ Within 5 samples. This drop must be within a window w = 5 samples, or 166ms. After one step is detected, a timeout $t = 400ms$ is applied to filter movements after a step. Figure shows the z-axis of an accelerometer and two detected steps. The parameters p, t, the lowpassfilter l and the step size $s = 0{,}7m$ can be calibrated. The initial values $\Delta p = -0{,}7ms!!$, $t = 400ms$, $l = 0{,}3$ are empiric values which proved as a good baseline.

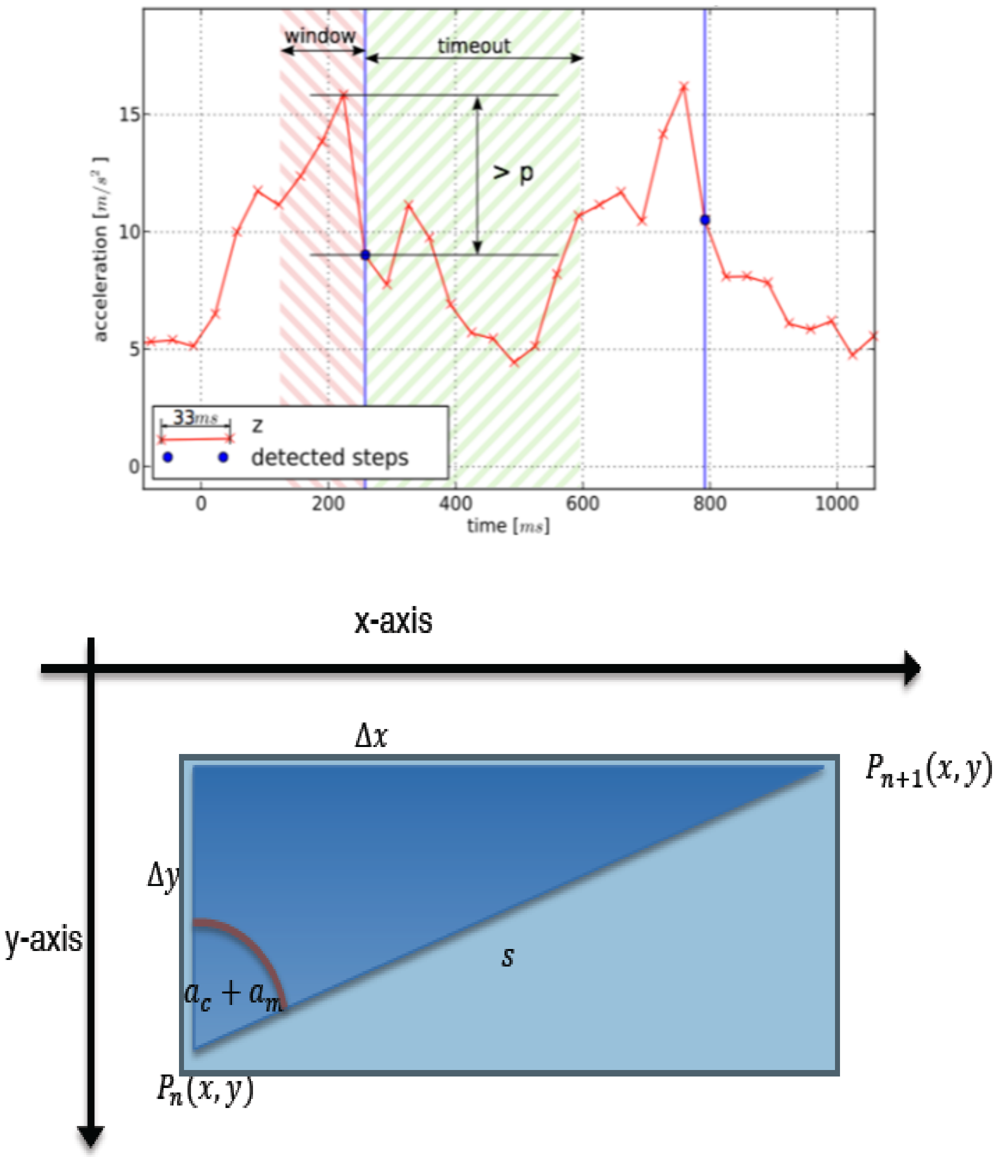
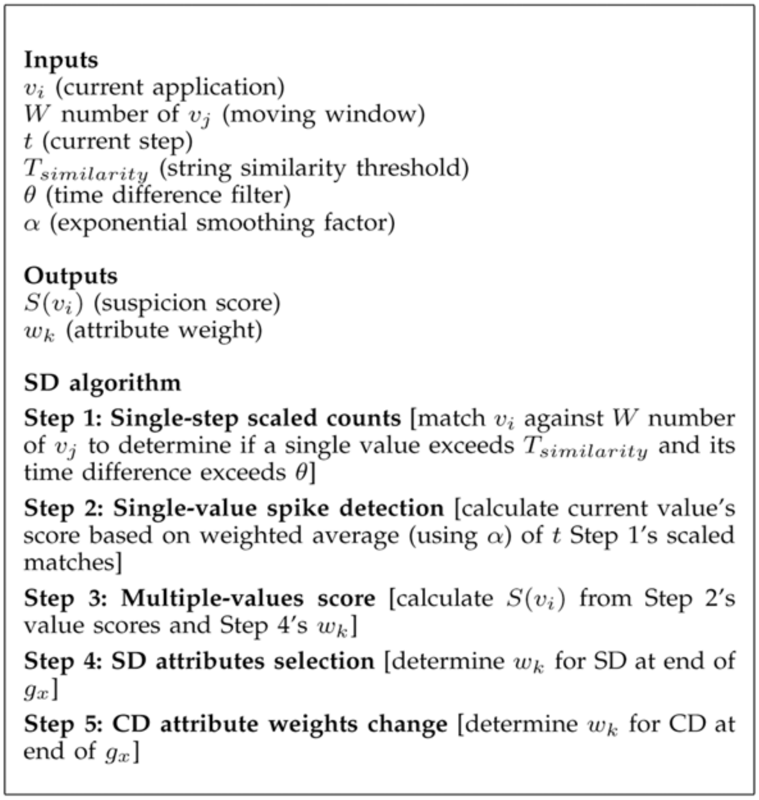


Figure 8 Filtered Accelerometer and Detected Steps used in Step detection Algorithms



Inputs
v_i (current application)
W number of v_j (moving window)
t (current step)
$T_{similarity}$ (string similarity threshold)
θ (time difference filter)
α (exponential smoothing factor)

Outputs
$S(v_i)$ (suspicion score)
w_k (attribute weight)

SD algorithm

Step 1: Single-step scaled counts [match v_i against W number of v_j to determine if a single value exceeds $T_{similarity}$ and its time difference exceeds θ]

Step 2: Single-value spike detection [calculate current value's score based on weighted average (using α) of t Step 1's scaled matches]

Step 3: Multiple-values score [calculate $S(v_i)$ from Step 2's value scores and Step 4's w_k]

Step 4: SD attributes selection [determine w_k for SD at end of g_x]

Step 5: CD attribute weights change [determine w_k for CD at end of g_x]

$$P_{n+1}(x,y) = P_n(x+\sin(a_c+a_m)*s*g, y+\cos(a_c+a_m)*s*g)$$

3.3 Weighted Centroid Algorithm

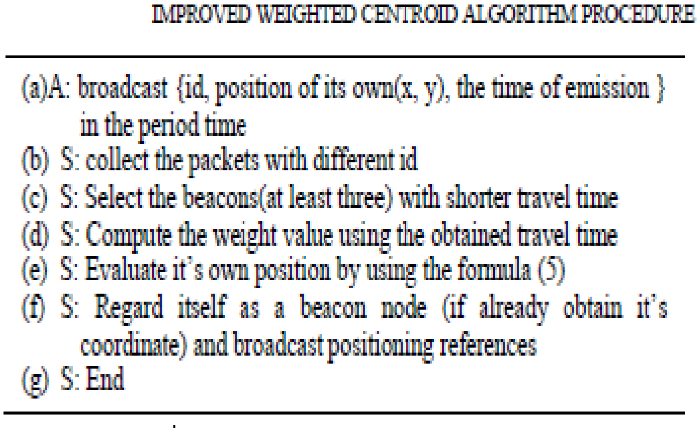
Information about primary transmitter location is crucial in enabling several key capabilities in cognitive radio networks, including improved spatio-temporal sensing, intelligent location aware routing, as well as aiding spectrum policy enforcement. Compared to other proposed non-interactive localization algorithms, the weighted centroid localization (WCL) scheme uses only the received signal strength information, which makes it simple to implement and robust to variations in the propagation environment. In this project we present the first theoretical framework for WCL performance analysis in terms of its localization error distribution parameterized by node density, node placement, shadowing variance, correlation distance and inaccuracy of sensor node positioning. Using this analysis, we quantify the robustness of WCL to various physical conditions and provide design guidelines, such as node placement and spacing, for the practical deployment of WCL. We also propose a power-efficient method for implementing WCL through a distributed cluster-based algorithm that achieves comparable accuracy with its centralized counterpart.

$$w_1 = \frac{1}{n}\left(\frac{t_1 + t_2 + \cdots t_n}{t_1}\right)$$

$$w_2 = \frac{1}{n}\left(\frac{t_1 + t_2 + \cdots t_n}{t_2}\right)$$

$$\vdots$$

$$w_n = \frac{1}{n}\left(\frac{t_1 + t_2 + \cdots t_n}{t_n}\right)$$

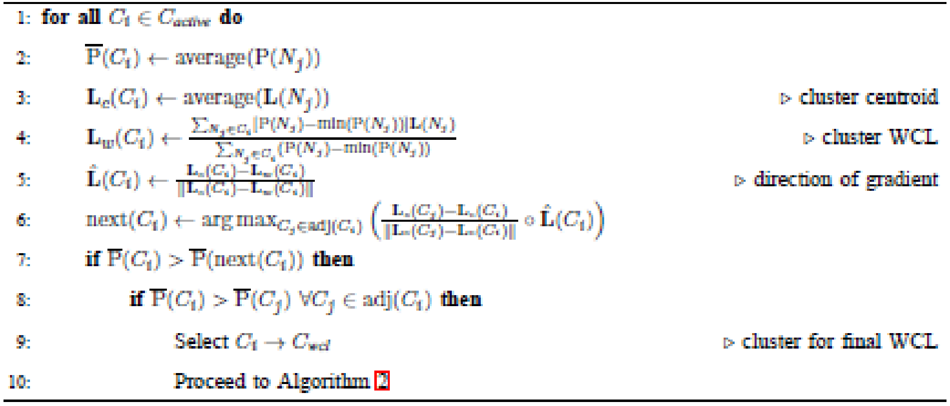


IMPROVED WEIGHTED CENTROID ALGORITHM PROCEDURE

(a)A: broadcast {id, position of its own(x, y), the time of emission } in the period time
(b) S: collect the packets with different id
(c) S: Select the beacons(at least three) with shorter travel time
(d) S: Compute the weight value using the obtained travel time
(e) S: Evaluate it's own position by using the formula (5)
(f) S: Regard itself as a beacon node (if already obtain it's coordinate) and broadcast positioning references
(g) S: End

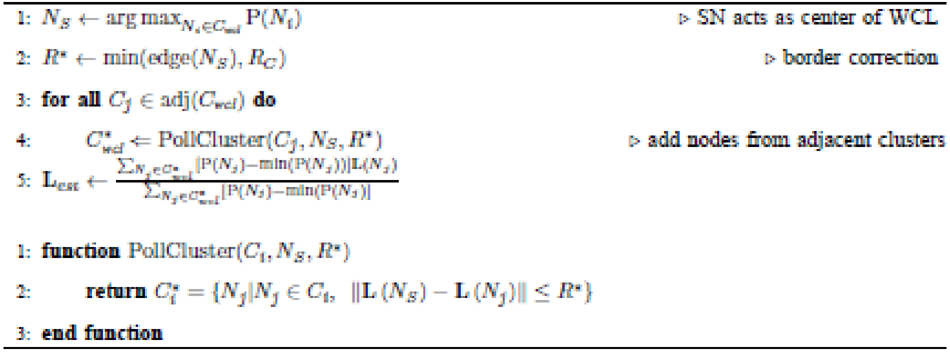
In the beginning, each beacon node propagates the localization reference to its neighbors. The transmitted information consists of the beacon's id, coordinate and the transmission power. Unknown node, then, received the packets that are sent out by different beacon nodes. Next, unknown node computes the weight of each beacon using the obtained travel time and uses it to determine its position. As soon as the unknown node obtains its own position, it will regard itself as a beacon node and take on the responsibility of beacon node.

Algorithm 1



```
for all $C_i \in C_{active}$ do
    $\overline{\mathrm{P}}(C_i) \leftarrow \mathrm{average}(\mathrm{P}(N_j))$
    $\mathbf{L}_c(C_i) \leftarrow \mathrm{average}(\mathbf{L}(N_j))$                ▷ cluster centroid
    $\mathbf{L}_w(C_i) \leftarrow \frac{\sum_{N_j \in C_i} |\mathrm{P}(N_j) - \min(\mathrm{P}(N_j))| \mathbf{L}(N_j)}{\sum_{N_j \in C_i} (\mathrm{P}(N_j) - \min(\mathrm{P}(N_j))}$                ▷ cluster WCL
    $\hat{\mathbf{L}}(C_i) \leftarrow \frac{\mathbf{L}_c(C_i) - \mathbf{L}_w(C_i)}{\|\mathbf{L}_c(C_i) - \mathbf{L}_w(C_i)\|}$                ▷ direction of gradient
    $\mathrm{next}(C_i) \leftarrow \arg\max_{C_j \in \mathrm{adj}(C_i)} \left( \frac{\mathbf{L}_c(C_j) - \mathbf{L}_c(C_i)}{\|\mathbf{L}_c(C_j) - \mathbf{L}_c(C_i)\|} \circ \hat{\mathbf{L}}(C_i) \right)$
    if $\overline{\mathrm{P}}(C_i) > \overline{\mathrm{P}}(\mathrm{next}(C_i))$ then
        if $\overline{\mathrm{P}}(C_i) > \overline{\mathrm{P}}(C_j)\ \forall C_j \in \mathrm{adj}(C_i)$ then
            Select $C_i \rightarrow C_{wcl}$                ▷ cluster for final WCL
            Proceed to Algorithm 2
```

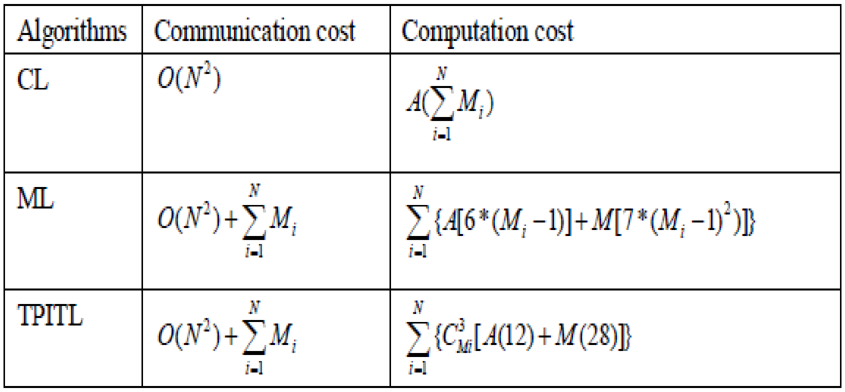
Algorithm 2



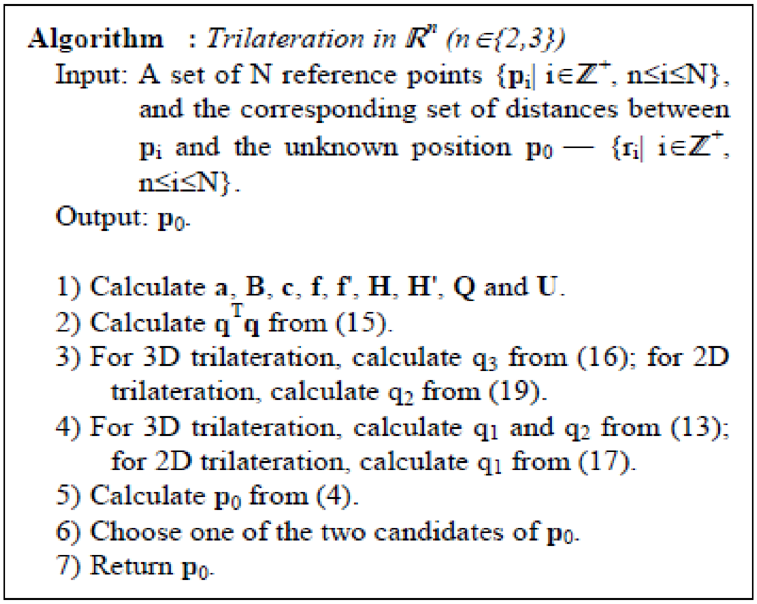
```
$N_S \leftarrow \arg\max_{N_i \in C_{wcl}} \mathrm{P}(N_i)$                ▷ SN acts as center of WCL
$R^* \leftarrow \min(\mathrm{edge}(N_S), R_C)$                ▷ border correction
for all $C_j \in \mathrm{adj}(C_{wcl})$ do
    $C^*_{wcl} \Leftarrow \mathrm{PollCluster}(C_j, N_S, R^*)$                ▷ add nodes from adjacent clusters
$\mathbf{L}_{est} \leftarrow \frac{\sum_{N_j \in C^*_{wcl}} |\mathrm{P}(N_j) - \min(\mathrm{P}(N_j))| \mathbf{L}(N_j)}{\sum_{N_j \in C^*_{wcl}} |\mathrm{P}(N_j) - \min(\mathrm{P}(N_j)|}$

function PollCluster$(C_i, N_S, R^*)$
    return $C_i^* = \{N_j | N_j \in C_i,\ \|\mathbf{L}(N_S) - \mathbf{L}(N_j)\| \le R^*\}$
end function
```

3.4 Advanced Trilateration Algorithm

Localization of sensor nodes is a key technology in Wireless Sensor Networks (WSNs). Trilateration is an important position determination strategy. To further improve the localization accuracy, a novel Trilateration based on Point in Triangle testing Localization (TPITL) algorithm is proposed in this section. Unlike the traditional trilateration localization algorithm which randomly selects three neighbor anchors, the proposed TPITL algorithm selects three special neighbor anchors of the unknown node for trilateration. The three anchors construct the smallest anchor triangle which encloses the unknown node. To choose the optimized anchors, we propose Point in Triangle testing based on Distance (PITD) method, which applies the estimated distances for trilateration to reduce the PIT testing errors



Algorithms	Communication cost	Computation cost
CL	$O(N^2)$	$A(\sum_{i=1}^{N} M_i)$
ML	$O(N^2)+\sum_{i=1}^{N} M_i$	$\sum_{i=1}^{N}\{A[6*(M_i-1)]+M[7*(M_i-1)^2)]\}$
TPITL	$O(N^2)+\sum_{i=1}^{N} M_i$	$\sum_{i=1}^{N}\{C_{Mi}^{3}[A(12)+M(28)]\}$



```
Algorithm : Trilateration in $\mathbb{R}^n$ ($n \in \{2,3\}$)
  Input: A set of N reference points {$p_i$| $i \in \mathbb{Z}^+$, n≤i≤N},
         and the corresponding set of distances between
         $p_i$ and the unknown position $p_0$ — {$r_i$| $i \in \mathbb{Z}^+$,
         n≤i≤N}.
  Output: $p_0$.

  1) Calculate a, B, c, f, f', H, H', Q and U.
  2) Calculate $q^T q$ from (15).
  3) For 3D trilateration, calculate $q_3$ from (16); for 2D
       trilateration, calculate $q_2$ from (19).
  4) For 3D trilateration, calculate $q_1$ and $q_2$ from (13);
       for 2D trilateration, calculate $q_1$ from (17).
  5) Calculate $p_0$ from (4).
  6) Choose one of the two candidates of $p_0$.
  7) Return $p_0$.
```

3.5 The Local Strength Gradient Algorithm

In this project we consider the combined problem of frontier exploration in a complex indoor environment while seeking a radio source. To do this in an efficient manner, we incorporate radio signal strength (RSS) information into the exploration algorithm by locally sampling the RSS and estimating the 2-D RSS gradient. The algorithm exploits the local motion to collect RSS samples for gradient estimation and seeks to explore in a way that brings the robot to the signal source. This strategy avoids random or exhaustive exploration. An indoor experiment demonstrates the exploration algorithm that uses this information to dynamically prioritize candidate frontiers and traverse to a radio source. Simulations, including radio propagation modeling with a ray-tracing algorithm, enable study of control algorithm tradeoffs and statistical performance.

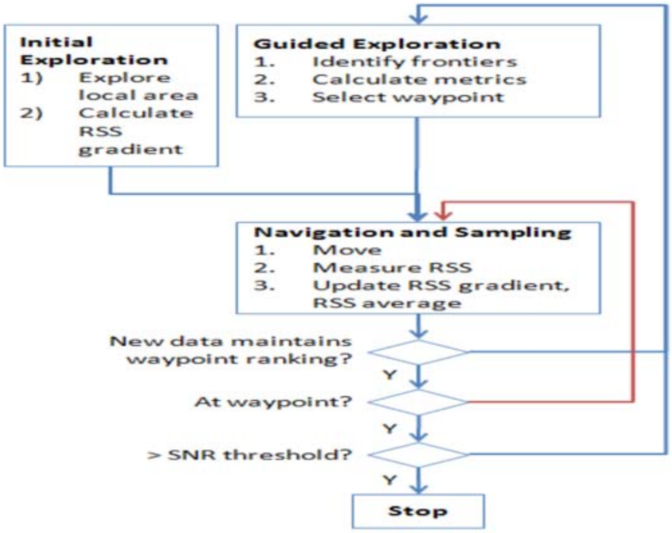


Figure 9 Flow Diagram for the Local Strength Gradient Algorithm

3.6 SLAM Algorithm

Localization and mapping are two of the most central tasks when it comes to autonomous robots. It has often been performed using expensive, accurate sensors but the fast development of consumer electronics has made similar sensors available at a more affordable price. A very imperative part of the project was to use a TurtleBot™ robot and a Microsoft Kinect™ camera to perform Simultaneous Localization And Mapping, SLAM. The project presents modifications to an already existing open source SLAM algorithm. The original algorithm, based on visual odometry, is extended so that it can also make use of measurements from wheel odometry and a single axis gyro. Measurements are fused using an Extended Kalman Filter, EKF, operating in a multirate fashion. Both the SLAM algorithm and the EKF are implemented using the framework Robot Operating System, ROS.

4 Database Collection Methodology

4.1 Introduction

This chapter basically deals with one of the most imperative parts of the project that is database collection. Since the main aim of the project is to check the accuracy and feasibility of a robot to accomplish this kind of data collection, we need to first study and select a hybrid robotic system.

We decided to select an existing platform that could collect the database. In this search we came across various different mobile platforms that ranged heavily in accuracy and in price. We decided to be cost-effective and decided to use a platform that was relatively cheap and that could be easily reprogrammed to do additional tasks, add extra features such as Wi-Fi localization and increase accuracy by manipulating the code all while being open source. This platform proved to be exactly what we needed since its given features were enough to perform the tasks necessary in our project.

Since Turtlebot is an off-the-shelf mobile platform, not much setup was required. The only setup needed was that of a workstation computer that would communicate with the Turtlebot while it performed its tasks and would relay information in the form of visual data, numerical data or graphical data. The other tool being used for this project is a laptop that can easily be mounted on top of the robot when necessary. Since it is a stand-alone device, a simple USB cable connection is needed to connect the laptop to the laptop that runs the operations of the Turtlebot. The actual parsing of data being collected needed to be done using software manipulation and implementation to allow the Turtlebot to actually send its Odometry to the laptop to be added to the database. After selecting turtlebot for such data collection we decided to implement two different SLAM algorithm for Database collection and later conduct a comparative performance evaluation.

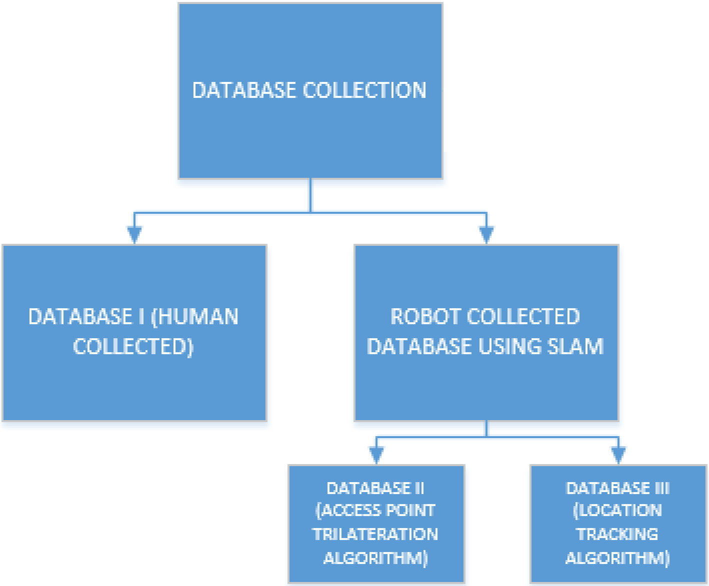


Figure 10 Entity Relationship Diagram illustrating our Database Collection Methodology

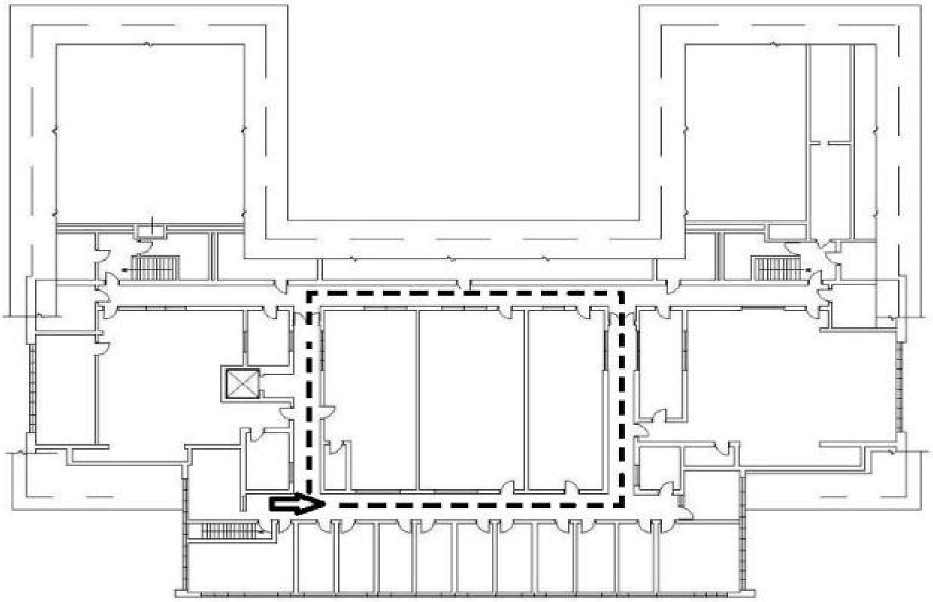


Figure 11 Desired Trajectory in the Third Floor of Atwater Kent Laboratories where all Experimentation was conducted

So our system produces three major databases for later comparative performance evaluation. We have designated the Database I, II and III. All data collection was carried out on the third floor of Atwater Kent Laboratories (Fig: 11).

4.2 Data Collecting Techniques

In this section we will discuss the various ways we collected the data and how we used them for later performance analysis. This is the first process done when trying to do any kind of localization.

4.2.1 Human Collected Database

Below you can see an overview of how we collected the database by hand which was designated as human collected database. This process was very time consuming and took 10 minutes to go through the designated path. Ten minutes may not sound like much time but the third floor of Atwater Kent is small compared to the whole building. The time taken to do this data collection is directly proportional to the size of the environment being mapped; it can take a couple of hours or more.

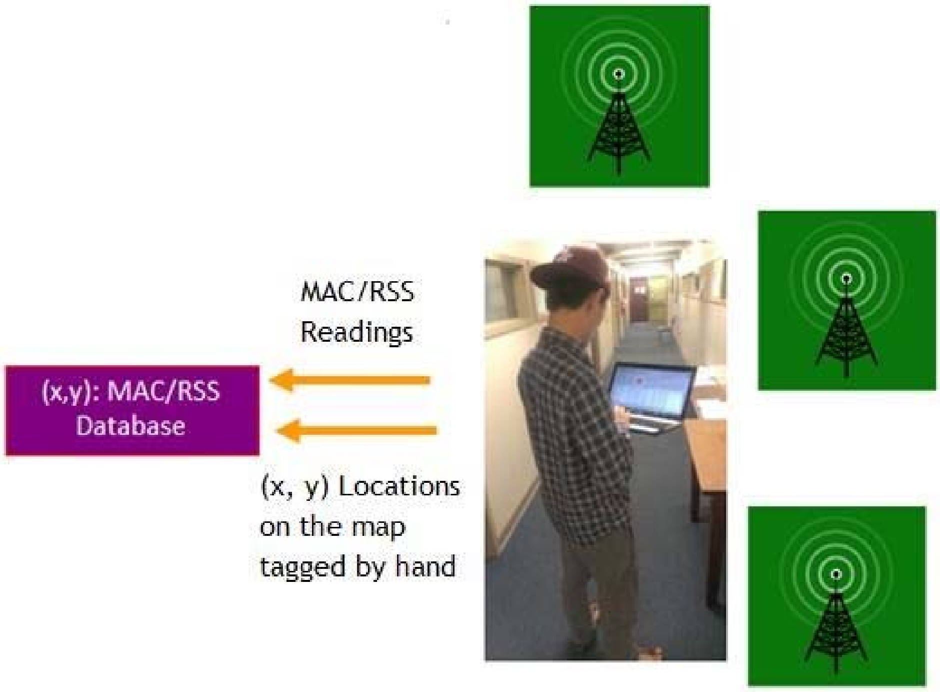


Figure 12 Human Collected Database collected by Project Partner Biao using WirelessMon on the Third Floor of Atwater Laboratories

The database created by going around the third floor by hand was accurate to say the least. It has many data points and can be used to compare various other instances of RSS values and MAC addresses effectively and reliably.

4.2.2 Robot Collected Database

Below you can see an overview of how we had our Turtlebot collect its own reference Database. The path it would collect and use to associate the RSS values and MAC addresses was recorded using its odometry which then could be converted into the same coordinate system that the other reference database used. Its odometry would later be used to map its trajectory through the third floor and see how off course the robot was compared to the human.

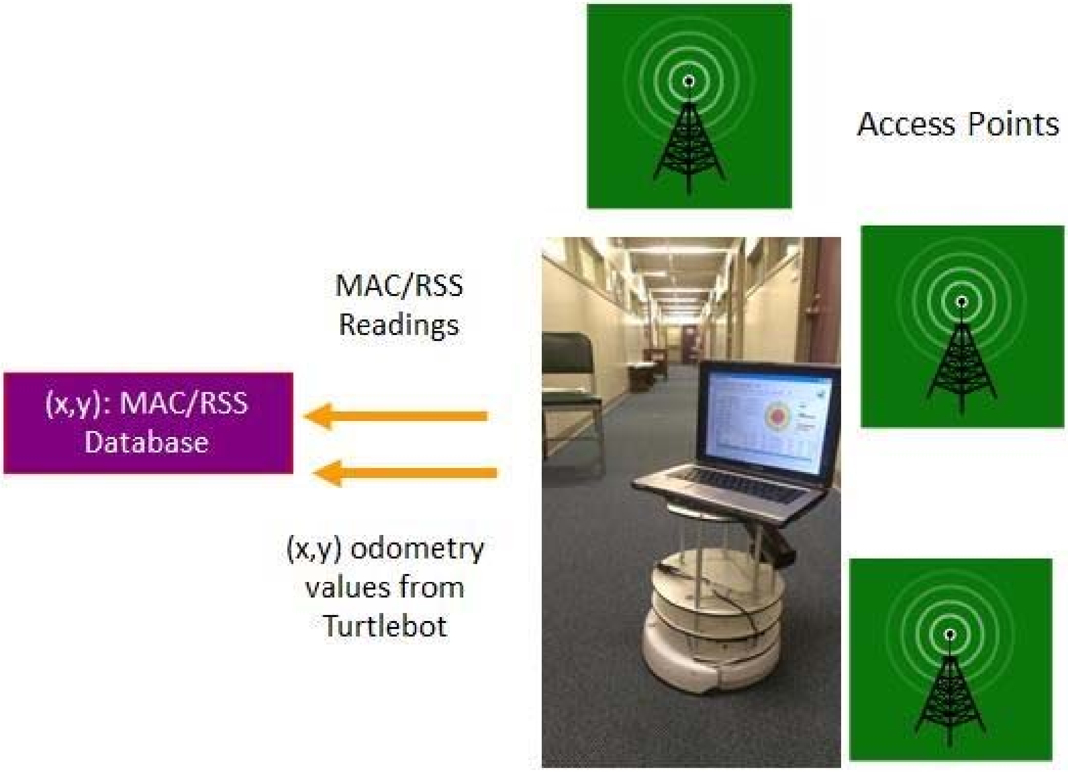
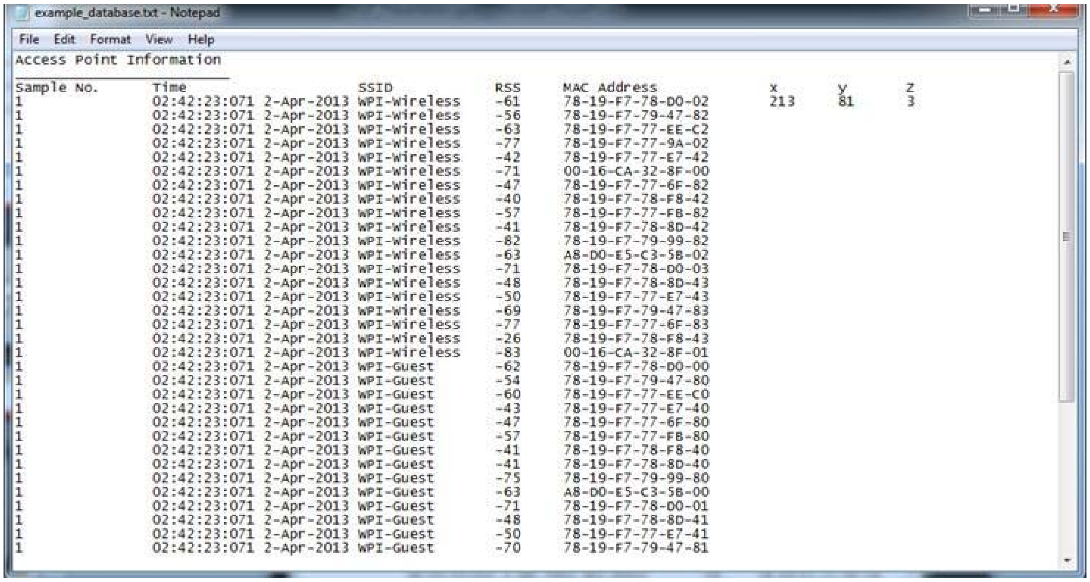


Figure 13 Robot Collecting Database using off-the-shelf robot called Turtlebot on the Third Floor of Atwater Laboratories



```
Access Point Information
_________________________
Sample No.         Time                     SSID              RSS       MAC Address            x        y        z
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -61       78-19-F7-78-D0-02      213      81       3
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -56       78-19-F7-79-47-82
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -63       78-19-F7-77-EE-C2
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -77       78-19-F7-77-9A-02
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -42       78-19-F7-77-E7-42
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -71       00-16-CA-32-8F-00
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -47       78-19-F7-77-6F-82
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -40       78-19-F7-78-F8-42
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -57       78-19-F7-77-FB-82
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -41       78-19-F7-78-8D-42
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -82       78-19-F7-79-99-82
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -63       A8-D0-E5-C3-5B-02
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -71       78-19-F7-78-D0-03
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -48       78-19-F7-78-8D-43
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -50       78-19-F7-77-E7-43
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -69       78-19-F7-79-47-83
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -77       78-19-F7-77-6F-83
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -26       78-19-F7-78-F8-43
1                  02:42:23:071 2-Apr-2013 WPI-Wireless      -83       00-16-CA-32-8F-01
1                  02:42:23:071 2-Apr-2013 WPI-Guest         -62       78-19-F7-78-D0-00
1                  02:42:23:071 2-Apr-2013 WPI-Guest         -54       78-19-F7-79-47-80
1                  02:42:23:071 2-Apr-2013 WPI-Guest         -60       78-19-F7-77-EE-C0
1                  02:42:23:071 2-Apr-2013 WPI-Guest         -43       78-19-F7-77-E7-40
1                  02:42:23:071 2-Apr-2013 WPI-Guest         -47       78-19-F7-77-6F-80
1                  02:42:23:071 2-Apr-2013 WPI-Guest         -57       78-19-F7-77-FB-80
1                  02:42:23:071 2-Apr-2013 WPI-Guest         -41       78-19-F7-78-F8-40
1                  02:42:23:071 2-Apr-2013 WPI-Guest         -41       78-19-F7-78-8D-40
1                  02:42:23:071 2-Apr-2013 WPI-Guest         -75       78-19-F7-79-99-80
1                  02:42:23:071 2-Apr-2013 WPI-Guest         -63       A8-D0-E5-C3-5B-00
1                  02:42:23:071 2-Apr-2013 WPI-Guest         -71       78-19-F7-78-D0-01
1                  02:42:23:071 2-Apr-2013 WPI-Guest         -48       78-19-F7-78-8D-41
1                  02:42:23:071 2-Apr-2013 WPI-Guest         -50       78-19-F7-77-E7-41
1                  02:42:23:071 2-Apr-2013 WPI-Guest         -70       78-19-F7-79-47-81
```

Figure 14 Sample Database designated as Human Collected Database which was Manually Collected

The database created by the Turtlebot while it was performing its SLAM algorithm was comparable to that of the human collected database. It generated a total of 56 data points. Although this database's position values are not the same as the designated path's position values, the difference between the two was minimal. Also that the database had a few less data points collected, it odometry provided us with an example to compare the two.

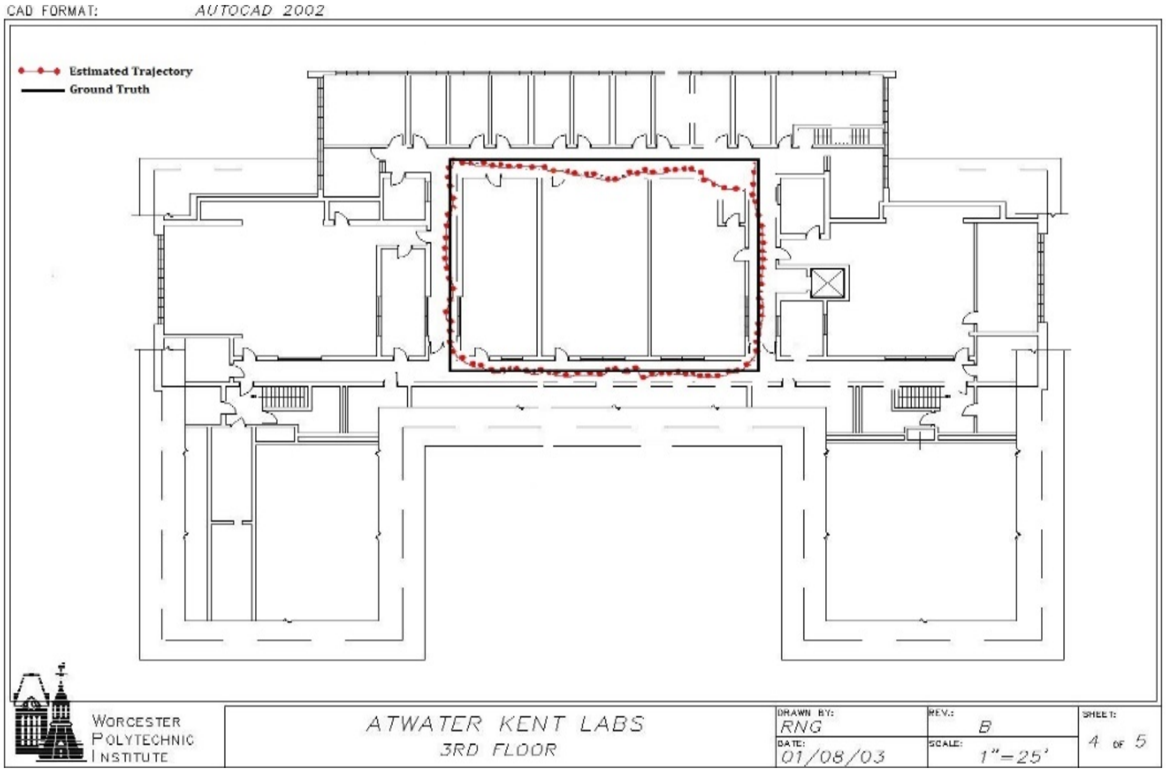


Figure 15 Trajectory Access Point Trilateration Algorithm-SLAM

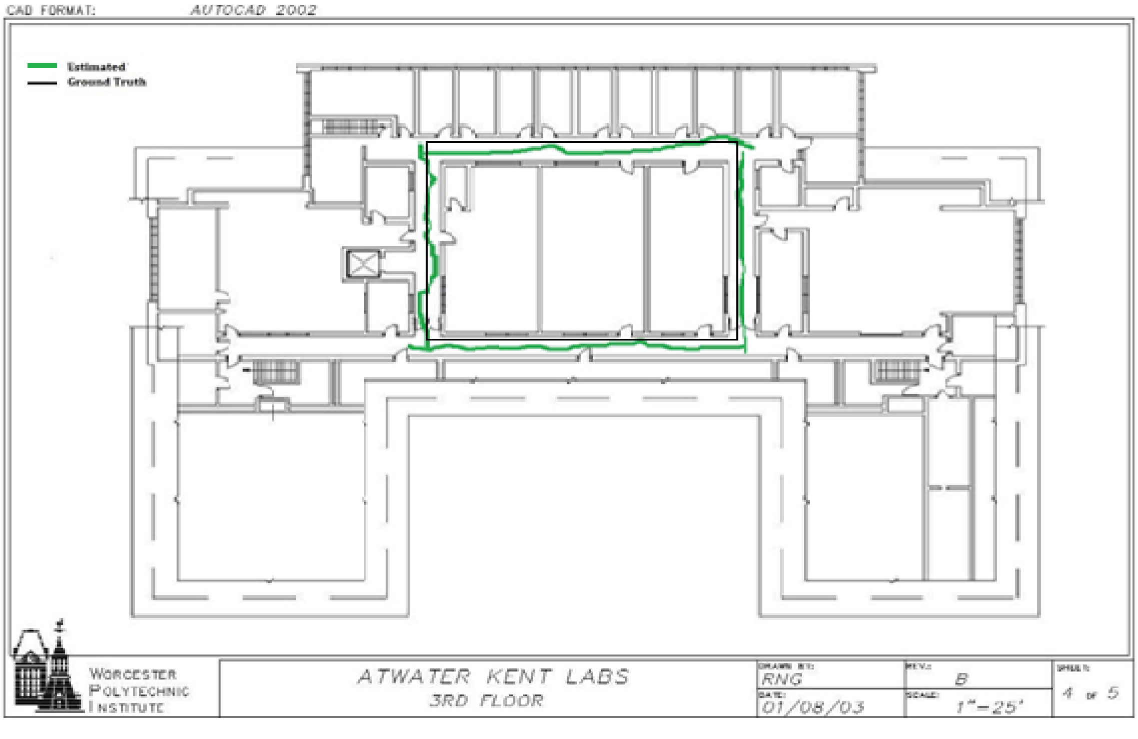
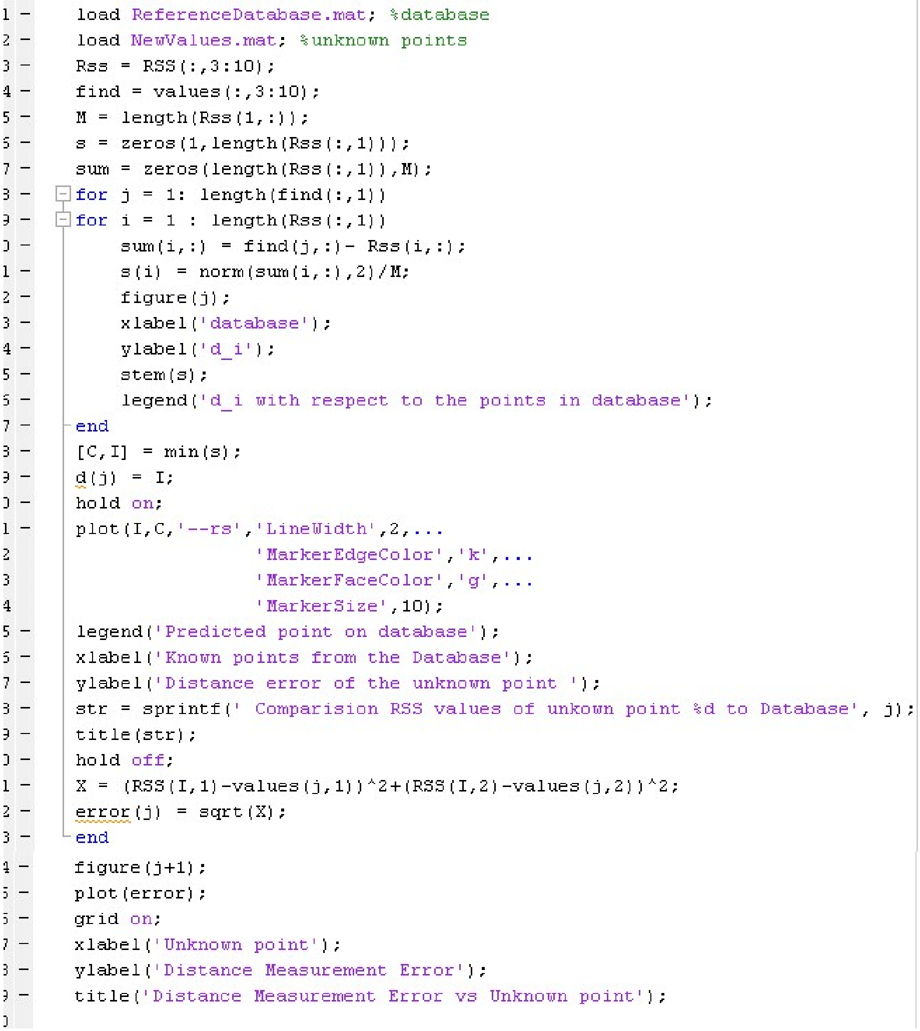


Figure 16 Trajectory Location Tracking Algorithm - SLAM

4.3 Algorithm Development and Implementation

For our project we chose to use the Nearest Neighbor Algorithm to calculate our position error. Using the pseudo code below, we develop a Matlab version of the code that would take in a reference database and a new database that did not contain any position information. The code would execute and produce a graph staying the position error between the measured location and the expected location. Each graph shows the eight points that were used for testing the performance of the databases when the algorithm was applied.



```matlab
load ReferenceDatabase.mat; %database
load NewValues.mat; %unknown points
Rss = RSS(:,3:10);
find = values(:,3:10);
M = length(Rss(1,:));
s = zeros(1,length(Rss(:,1)));
sum = zeros(length(Rss(:,1)),M);
for j = 1: length(find(:,1))
for i = 1 : length(Rss(:,1))
    sum(i,:) = find(j,:)- Rss(i,:);
    s(i) = norm(sum(i,:),2)/M;
    figure(j);
    xlabel('database');
    ylabel('d_i');
    stem(s);
    legend('d_i with respect to the points in database');
end
[C,I] = min(s);
d(j) = I;
hold on;
plot(I,C,'--rs','LineWidth',2,...
                'MarkerEdgeColor','k',...
                'MarkerFaceColor','g',...
                'MarkerSize',10);
legend('Predicted point on database');
xlabel('Known points from the Database');
ylabel('Distance error of the unknown point ');
str = sprintf(' Comparision RSS values of unkown point %d to Database', j);
title(str);
hold off;
X = (RSS(I,1)-values(j,1))^2+(RSS(I,2)-values(j,2))^2;
error(j) = sqrt(X);
end
figure(j+1);
plot(error);
grid on;
xlabel('Unknown point');
ylabel('Distance Measurement Error');
title('Distance Measurement Error vs Unknown point');
```

Figure 17 Matlab Implementation of Nearest Neighbor Algorithm

5 Performance Evaluation of Databases

5.1 Introduction

In this section we do a detailed performance evaluation of the three databases we have collected which included one from human (DB I) and two from turtlebot SLAM (DB II & DB III). The databases first undergo performance evaluation using the Odometry values. Then we apply the NN (Nearest Neighbor) Algorithm on the same database and conduct the position error analysis considering it as our second scenario for performance evaluation. The third scenario is to compare it with commercial techniques in market like WI-FI Compass and Google Maps to check for relative accuracy of our applied SLAM algorithms on the robot against currently in use market products. Details of data collection from the commercial techniques is also provided. Position Error Analysis of commercial techniques is also performed which is an imperative part of the chapter as it attests how outdoor localization methods fail for indoor environments. The first subsection, however, will explain how we set the scenario for performance evaluation.

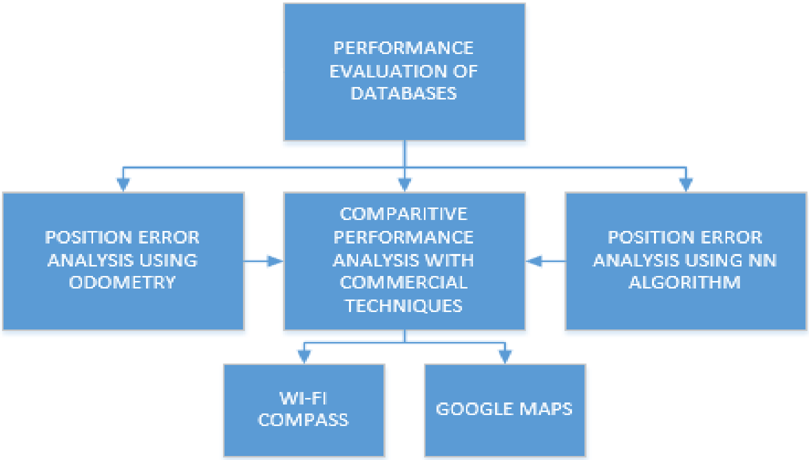


Figure 18 Entity Relationship Diagram illustrating our Performance Methodolgy

5.2 Scenario for Performance Evaluation

To make a performance analysis, we needed to designate specific locations on the third floor. Below, the sixteen locations selected are shown by red dots on the map. These points where employed later in the performance evaluation such that the data from these point was taken for conducting position error analysis.

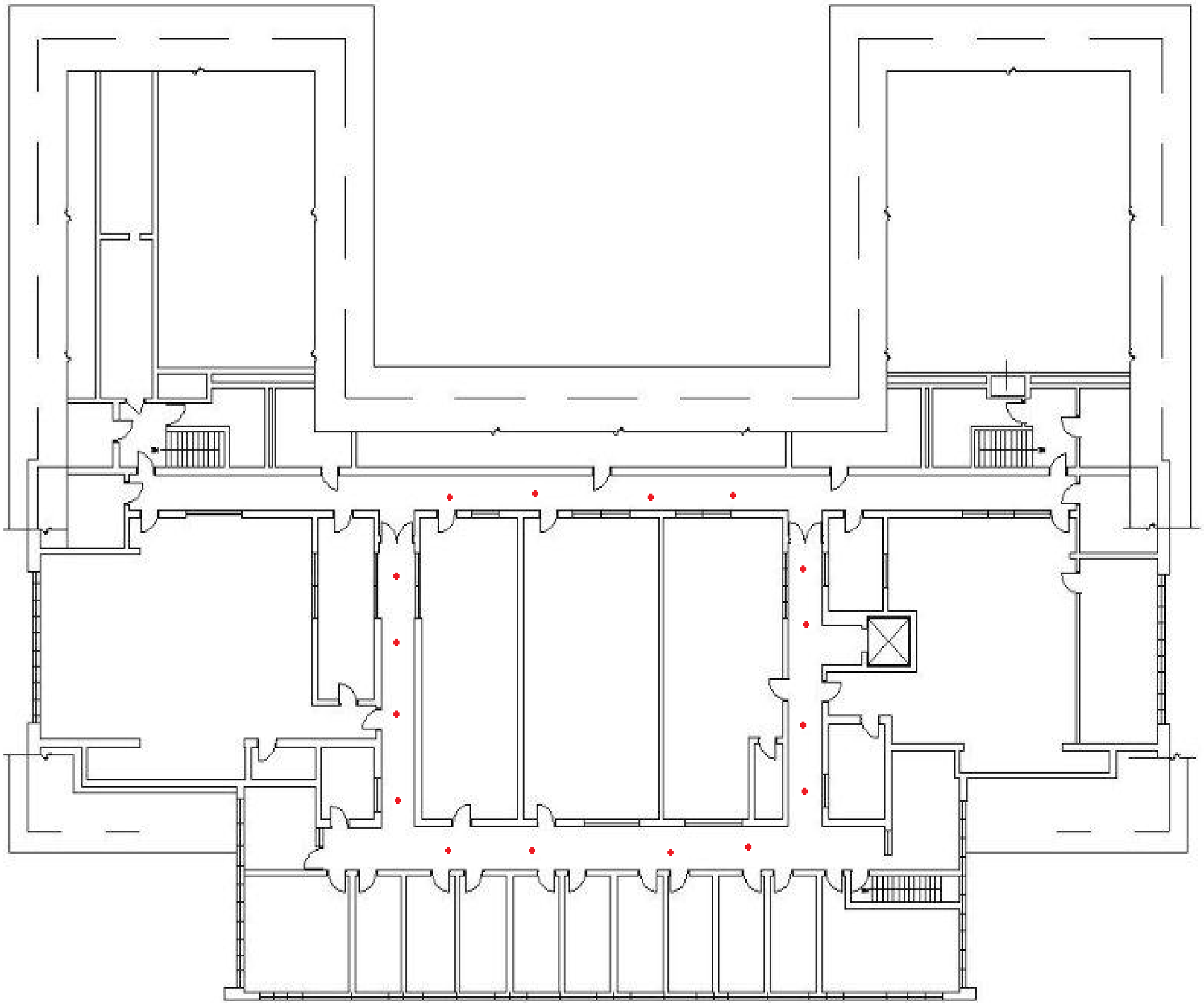


Figure 19 Shows our Data Collecting Points on the third floor; the data from these specific points were later used for Comparison.

5.3 Position Error Analysis Using Odometry

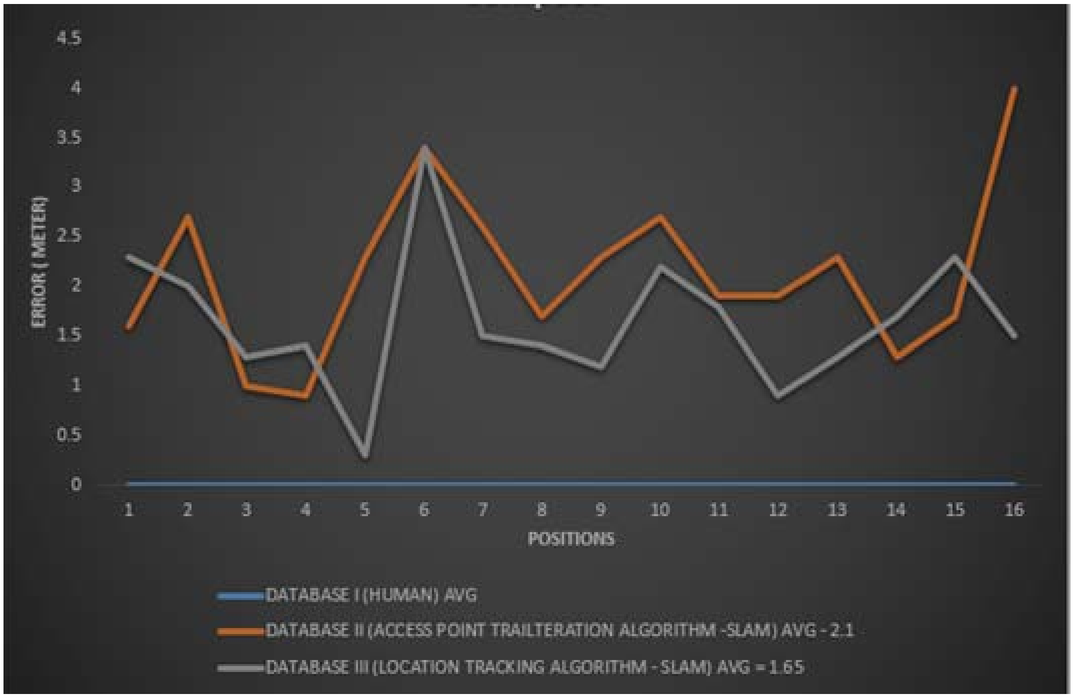


Figure 20 Position Error Analysis of Robot Collected Database vs. Human using Odometry

While performing this type of Position Error Analysis we have assumed that the human collected database would give us zero error because the database created by going around the third floor by hand was accurate to say the least. It had many data points but we choose the pre-selected sixteen point (Fig: Performance Evaluation) that were used to compare various other instances of RSS values and MAC addresses effectively and reliably. Database II was created by Access Point Trilateration Algorithm (SLAM) on turtlebot which gave us as even spread of error values with the highest at point 16 giving us an error of roughly 4m. Database III which was created by Location Tracking Algorithm (SLAM) on turtlebot gave us a relatively similar spread of error values with the highest at point 6 giving us an error of roughly 3.25m at point 6. It is surprising to know that Database II also has a significantly large error at this position. The two robot collected Databases when put under comparison with the human collected database do not show a very large amount of error difference and have almost similar plots where Database III performs better with an average error of 1.65m compared to Database II with an average of 2.10m error.

5.4 Position Error Analysis Using NN-Algorithm

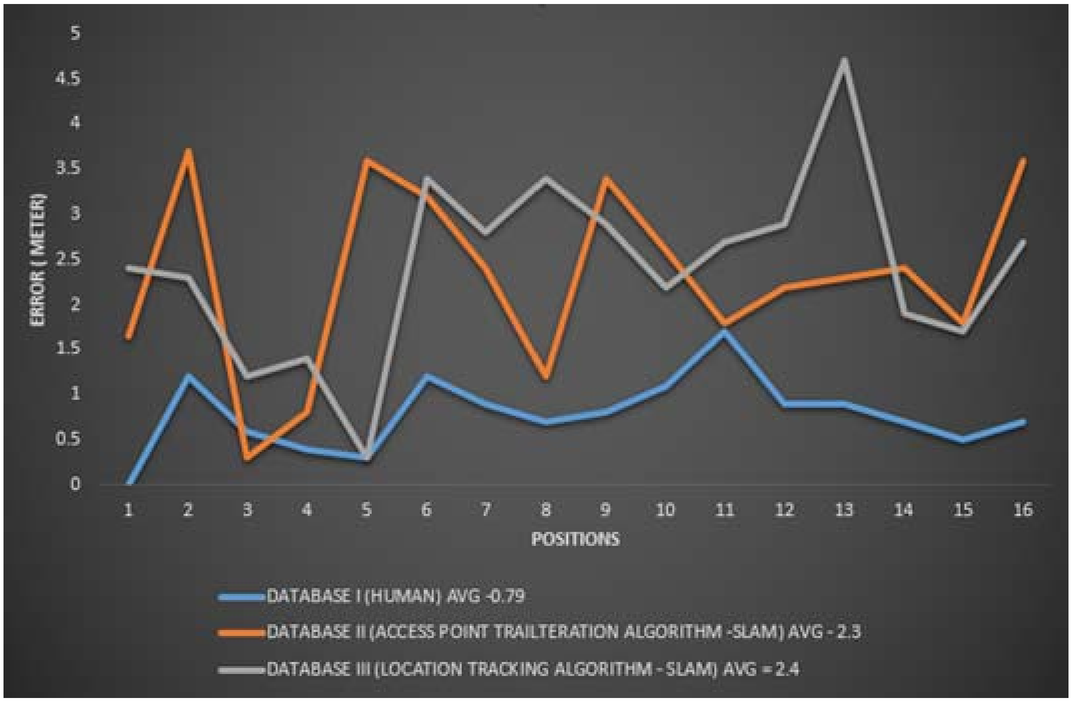


Figure 21 Position Error Analysis of Robot Collected Database vs. Human Collected Database using NN Algorithm

While performing this type of Position Error Analysis we have taken the previous database and applied the NN (Nearest Neighbor) Algorithm. When we apply the NN algorithm we see an overall increase in error as hypothetically established. This time the error difference was very little between Database II and Database III but unlike the previous analysis the Database II had a smaller overall average error compared to Database III. The human collected Database however was almost negligible with a mean error of only 0.79m.

The highest error of Database II was roughly 3.7m at point 4 whereas Database III had 4.7m of highest error at point 13. Again if we compare the two robot collected Databases against the human collected database we do not witness a very large amount of error difference which signifies to the fact that a robot is fully capable to accomplish such data collecting task with improved accuracy.

5.5 Comparative Performance Evaluation with Commercial Techniques

5.5.1 Wi-Fi Compass

We use WI-FI compass on the third floor of Atwater Kent Laboratories to compare our algorithmic results to it. Using Wi-Fi Compass's database containing the sixteen points, we performed a position error analysis, first with the human collected database (DB I) and then with the robot collected databases (DB II & III).

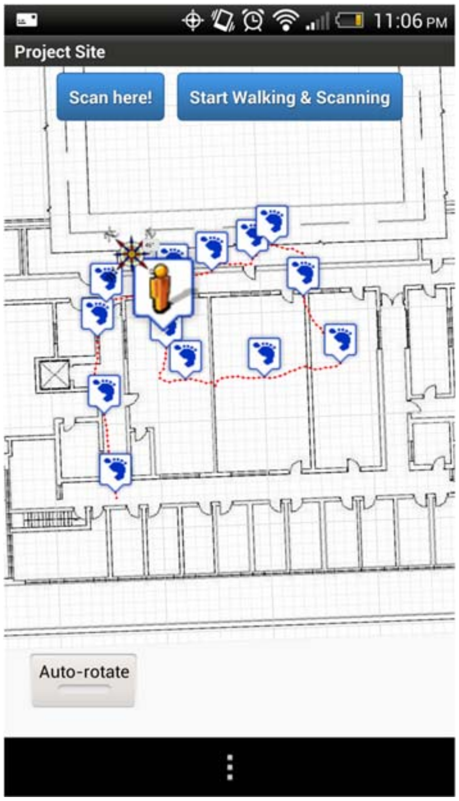


Figure 22 WiFi Compass Trajectory of Third Floor of Atwater Kent Laboratories implemented on Android Smartphone

As can be seen, the Android application works well up to a point. The point in which it makes a fatal error is where there is a metal structure that throws the Wi-Fi localization off and begins giving it false readings from the access points. The error is so great is because the two different sensors being used are both affected by the structure that the application keeps adding in more and more error values into its calculations. Even though the overall path seems to be accurate, the scaling is off and does not recover at any point after this disturbance is encountered.

```
WPI-Wireless 78:19:f7:78:f8:43 -58dBm 5180MHz [WPA2-EAP-
CCMP][ESS]
WPI-Wireless 78:19:f7:79:47:83 -74dBm 5785MHz [WPA2-EAP-
CCMP][ESS]
WPI-Wireless 78:19:f7:77:e7:42 -70dBm 2462MHz [WPA2-EAP-
CCMP][ESS]
PEDERSEN-PC_Network 20:aa:4b:4f:d3:d9 -57dBm 2462MHz
[WPA2-PSK-CCMP][WPS][ESS]
WPI-Wireless 78:19:f7:79:47:82 -61dBm 2462MHz [WPA2-EAP-
CCMP][ESS]
WPI-Guest 78:19:f7:78:f8:41  -57dBm 5180MHz [ESS]
WPI-Guest 78:19:f7:79:47:81  -76dBm 5785MHz [ESS]
WPI-Guest 78:19:f7:77:e7:40 -67dBm 2462MHz [ESS]
WPI-Guest 78:19:f7:79:47:80 -62dBm 2462MHz [ESS]
WPI-Wireless 78:19:f7:77:6f:83 -62dBm 5745MHz [WPA2-EAP-
CCMP][ESS]
WPI-Guest 78:19:f7:77:6f:81  -63dBm 5745MHz [ESS]
WPI-Wireless 78:19:f7:78:f8:42 -55dBm 2437MHz [WPA2-EAP-
CCMP][ESS]
WPI-Guest 78:19:f7:78:f8:40 -55dBm 2437MHz [ESS]
WPI-Wireless 78:19:f7:78:d0:02 -63dBm 2412MHz [WPA2-EAP-
CCMP][ESS]
WPI-Guest 78:19:f7:78:d0:00 -62dBm 2412MHz [ESS]
WPI-Wireless 78:19:f7:77:e7:43 -70dBm 5745MHz [WPA2-EAP-
CCMP][ESS]
```

Figure 23 Wi-Fi Compass generated Database collected from the SD card of the Android Phone

This database was generated at every foot step. Wi-Fi compass has a simple method of providing the RSS values and MAC addresses. At every step there is an option to scan which results in a generation of a similar database. The RSS values and MAC addresses of the chosen points are manually extracted for the K-NN algorithm application into a spreadsheet file.

5.5.2 Google Maps

The second commercial application used was Google Maps which was also being used as a comparative tool. Since Google Maps did not provide us with any RSS values we had to devise a different approach to test for accuracy. We first took the sixteen locations and gave them position vectors corresponding to their location. These position vectors are in our own coordinate system that we used to have all the position data easily interpreted through the various databases. We then proceeded to do the same with the locations that Google Maps showed us. We transposed them onto our coordinate system to create vectors for their individual locations. We then compared the two vectors and found the distance between them essentially telling us the difference between the actual location and the location shown by Google Maps. We generated graphs showing the disparity between the locations and compared them to the other databases.

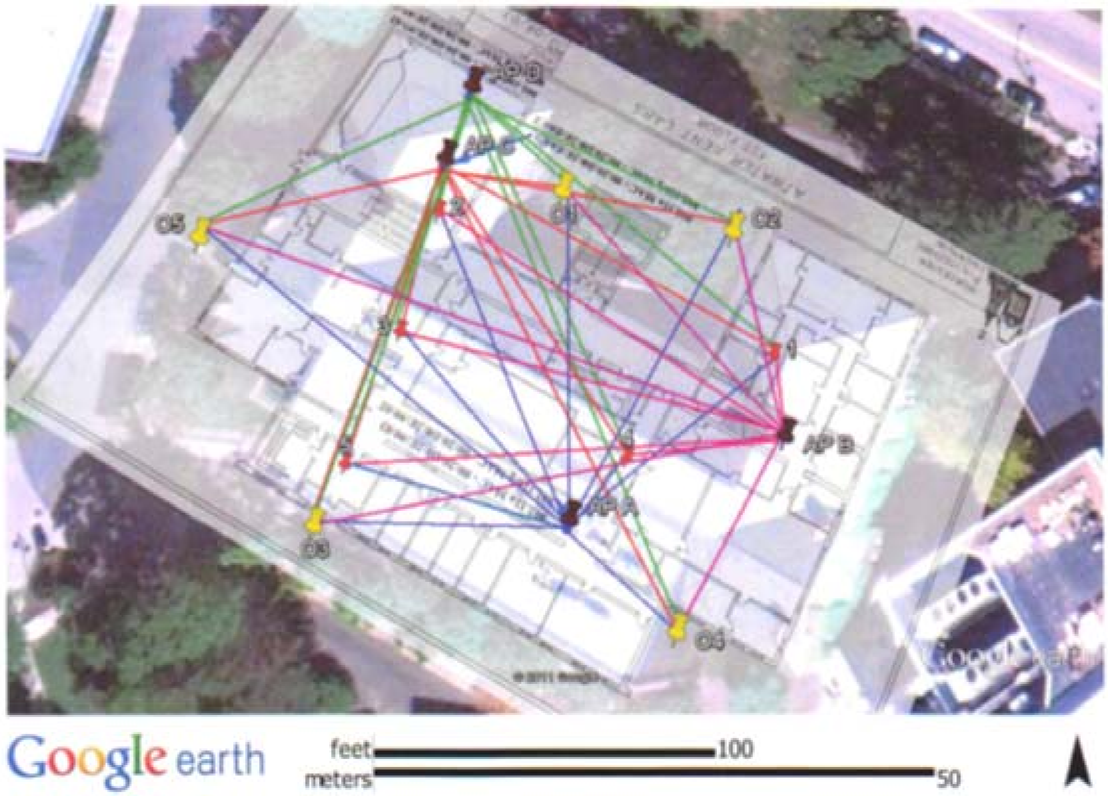


Figure 24 Google Map Testing Locations and Access Point Positioning

Figure 25 Localization using Google Maps using Map Editor

5.5.3 Position Error Analysis

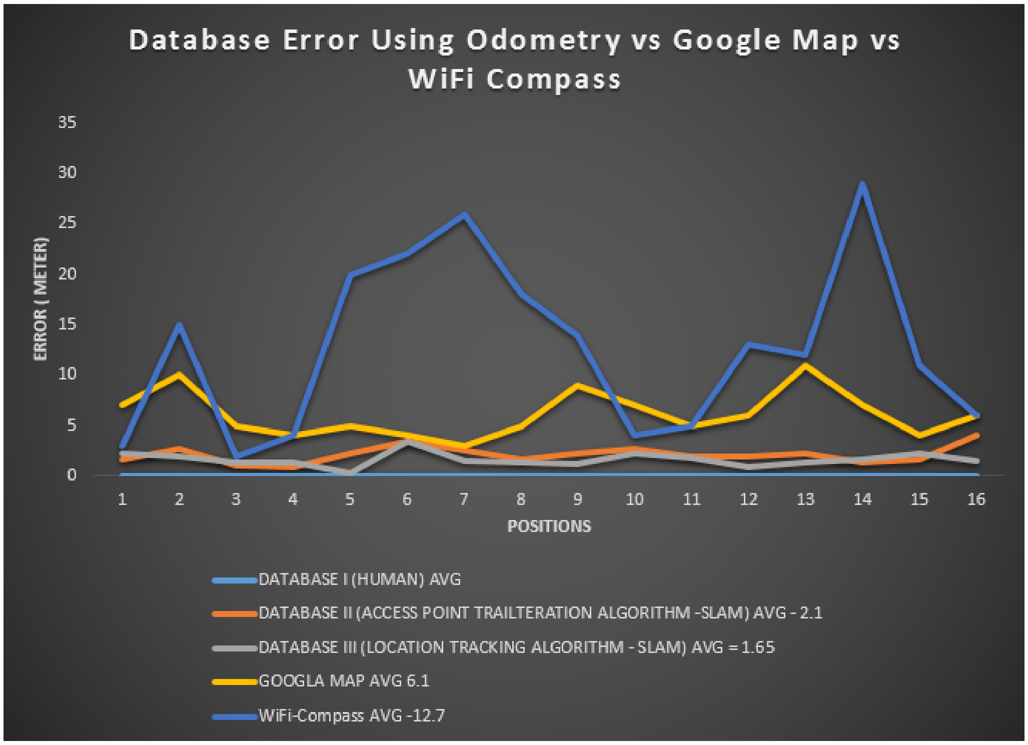


Figure 26 Position Error Analysis Graph using Odometry vs. Google Map vs. WiFi-Compass

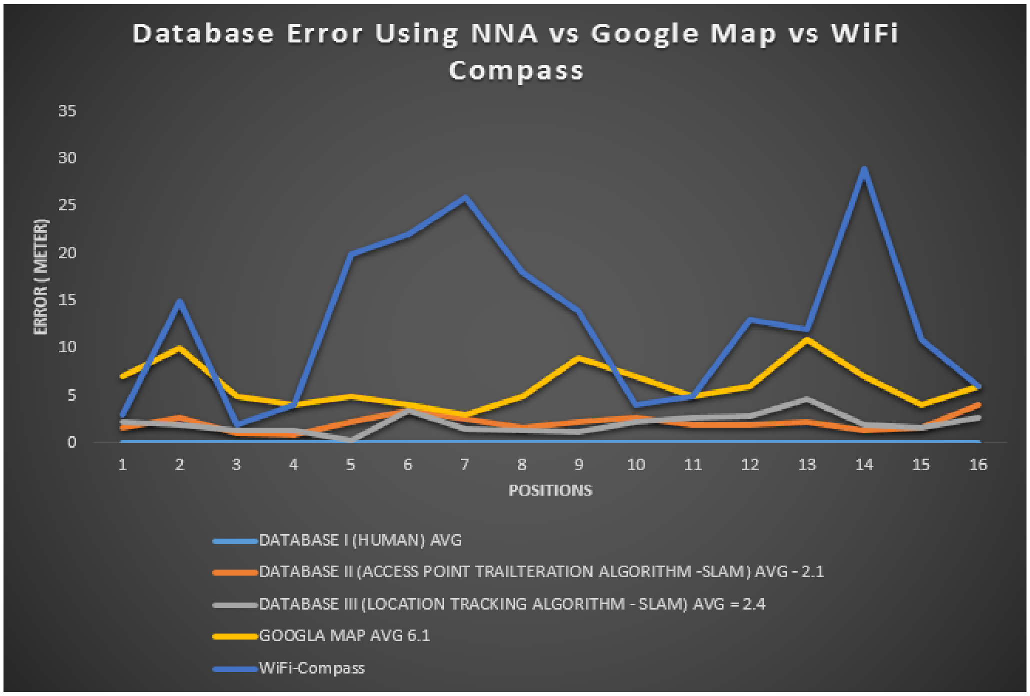


Figure 27 Position Error Analysis Graph using NNA vs. Googlel Map vs. WiFi-Compass

This position error analysis shows that Wi-Fi Compass can be very inaccurate. When we analyze this graph we see that the maximum error is roughly 25 meters which is huge. The average error is very large as well mounting up to approximately 13.5 meters. The error was low in reading points 2 and 3 where the Robot and Human almost produced negligible error. Wi-Fi compass probably had triangulation error and the scaling was probably off. It can be concluded that it gave us the most error and could be not totally suitable for indoor environments.

The above position error analysis also shows how inaccurate Google Maps is compared to the Robot and Human Collected Database. The main reason to justify such high inaccuracy is the fact that such user assisted localization techniques like Google Maps are basically employed for outdoor environments where an error of 8 meters or above is not considered considerable to cause any precision hitches but in indoor environments this is highly inexact. Analyzing the graph we see that the maximum error of Google Maps is roughly 9.3 meters and the average error around 6.1m. While we determined that the error difference between the Robot and Human was very little; after analyzing this graph we come to the conclusion that Google Maps produced a comparatively higher error difference and is also yet unsuitable for accurate indoor geolocation.

5.6 Overall Performance

After completing position error analysis on all different platforms, we came up with very precise results testifying that the error difference between a robot and a human for this type of data collection is present but not very significant. The NN algorithm we employed helped us further scrutinize the results by providing a better sketch of error points. We also observed that the two robot collected Databases showed very little individual error difference at the same points but had a slight difference in overall mean error. We also concluded that the human and robot produced better localization results than applications that do not do indoor surveying.

6 Conclusion and Future Work

In conclusion we designed, implemented and tested a system of Wi-Fi localization on robots and other wireless devices. We concluded that having a robot to do this kind of data collection is more efficient than having a paid employee do this kind of work because collecting data manually is hectic and time consuming for large complex indoor environments. While the results obtained by using a robot are not as precise as a human, they are accurate enough to be usable for indoor localization.

The main aim of the project was to come up with a solution for companies like Google, Skyworks, etc. which manually collect Wi-Fi related databases for Indoor Geolocation. Our aim was to computerize the process by allowing a robot to do it but we wanted to check whether a robot could efficiently accomplish this task. By performing comprehensive error analysis and gathering databases employing a robot we came to our conclusion that the difference was not that huge henceforth a robot had the capability to accomplish the task with satisfaction.

In the future, we can further improve the Nearest Neighbor Algorithm (NNA). We can test other indoor localization algorithms. Besides the NNA, there are some other widely used algorithms for indoor localization such as the Extended Kalman Filter Algorithm, Centroid Algorithm and the Particle Filter Algorithm. In order to process it, we have to implement the Extended Kalman Filter Algorithm, Centroid Algorithm and the Particle Filter Algorithm in Matlab, with the collected data from the previous data collecting to evaluate the performance of the different algorithms. The resulting locations could be compared back to the actual and empirical locations to see which of the four algorithms is best for indoor environment. Besides algorithm improvement, we can also develop both autonomous and manned movement applications using our multi-sensor location aware robot. Some of the autonomous applications that we can implement include guided tours to provide better tour experience. In our vision, such applications can be employed at museums, art galleries as well as universities. In terms of manned movement applications, telecommunication can be developed upon the algorithm we have already designed and these types of application can be used in factories and science lab to provide firsthand experience for those who are not able to travel. With the aid of location information, many indoor robotics services can be made possible.

References

Interference mitigation using uplink power control for two-tier femtocell networks HS Jo, C Mun, J Moon, JG Yook Wireless Communications, IEEE Transactions on 8 (10), 4906-4910	2009
Heterogeneous cellular networks: From theory to practice A Ghosh, N Mangalvedhe, R Ratasuk, B Mondal, M Cudak, E Visotsky, TA Thomas ... Communications Magazine, IEEE 50 (6), 54-64	2012
Self-optimized coverage coordination in femtocell networks HS Jo, C Mun, J Moon, JG Yook Wireless Communications, IEEE Transactions on 9 (10), 2977-2982	2010
Heterogeneous cellular networks with flexible cell association: A comprehensive downlink SINR analysis HS Jo, Y Sang, P Xia, J Andrews Wireless Communications, IEEE Transactions on 11 (10), 3484-3495	2012
A self-organized uplink power control for cross-tier interference management in femtocell networks HS Jo, JG Yook, C Mun, J Moon Military Communications Conference, 2008. MILCOM 2008. IEEE, 1-6	2008
Downlink femtocell networks: Open or closed? HS Jo, P Xia, JG Andrews Communications (ICC), 2011 IEEE International Conference on, 1-5	2011
The coexistence of OFDM-based systems beyond 3G with fixed service microwave systems HS Jo, H Yoon, J Lim, W Chung, J Yook, H Park Journal of Communications and Networks 8 (2), 187	2006
Outage probability for heterogeneous cellular networks with biased cell association HS Jo, YJ Sang, P Xia, JG Andrews Global Telecommunications Conference (GLOBECOM 2011), 2011 IEEE, 1-5	2011
Open, closed, and shared access femtocells in the downlink HS Jo, P Xia, JG Andrews EURASIP Journal on Wireless Communications and Networking	2012
Reverse-link interrogation range of a UHF MIMO-RFID system in nakagami-m fading channels DY Kim, HS Jo, H Yoon, C Mun, BJ Jang, JG Yook IEEE Transactions on Industrial Electronics 57 (4), 1468-1477	2010
Fundamentals of inter-cell overhead signaling in heterogeneous cellular networks P Xia, HS Jo, JG Andrews Selected Topics in Signal Processing, IEEE Journal of 6 (3), 257-269	2012

Appendices

Appendix A Human Collected Database

Access Point Information

Sample No.	Time	RSSI	MAC Address	First Seen Time	Last Seen Time
1	23:41:28:796 10-Apr-2013	-34	78-19-F7-78-F8-42	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-45	78-19-F7-78-8D-42	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-48	78-19-F7-77-6F-82	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-40	78-19-F7-77-E7-42	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-62	78-19-F7-77-FB-82	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-68	78-19-F7-78-D0-02	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-78	78-19-F7-79-96-C2	4/10/2013 23:30	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-77	78-19-F7-78-EE-82	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-76	78-19-F7-77-EE-C2	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-57	78-19-F7-77-E7-43	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-70	78-19-F7-78-D0-03	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-59	78-19-F7-77-6F-83	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-84	78-19-F7-79-47-83	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-74	78-19-F7-78-8D-43	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-32	78-19-F7-78-F8-43	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-34	78-19-F7-78-F8-42	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-45	78-19-F7-78-8D-42	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-48	78-19-F7-77-6F-82	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-40	78-19-F7-77-E7-42	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-62	78-19-F7-77-FB-82	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-68	78-19-F7-78-D0-02	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-78	78-19-F7-79-96-C2	4/10/2013 23:30	4/10/2013 23:41
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1	23:41:28:796 10-Apr-2013	-57	78-19-F7-77-E7-43	4/10/2013 23:29	4/10/2013 23:41
1	23:41:28:796 10-Apr-2013	-70	78-19-F7-78-D0-03	4/10/2013 23:29	4/10/2013 23:41
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1       23:41:28:796 10-Apr-2013                    -84          78-19-F7-79-47-83
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1       23:41:28:796 10-Apr-2013                    -74          78-19-F7-78-8D-43
        4/10/2013 23:29       4/10/2013 23:41
1       23:41:28:796 10-Apr-2013                    -32          78-19-F7-78-F8-43
        4/10/2013 23:29       4/10/2013 23:41
1       23:41:28:796 10-Apr-2013                    -46          78-19-F7-78-8D-40
        4/10/2013 23:29       4/10/2013 23:41
1       23:41:28:796 10                             -35          78-19-F7-78-F8-40
        4/10/2013 23:29
1       23:41:28:796 10                             -62          78-19-F7-77-FB-80
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1       23:41:28:796 10                             -78          78-19-F7-79-96-C0
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1       23:41:28:796 10                             -76          78-19-F7-78-EE-80
1       23:41:28:796 10                             -75          78-19-F7-77-EE-C0

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1       23:41:28:796 10                             -58          78-19-F7-77-E7-41

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1       23:41:28:796 10                             -70          78-19-F7-78-D0-01
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1       23:41:28:796 10                             -59          78-19-F7-77-6F-81
        4/10/2013 23:29       4/10/2013 23:41

1       23:41:28:796 10                             -84          78-19-F7-79-47-81
        4/10/2013 23:29       4/10/2013 23:41

1       23:41:28:796 10                             -73          78-19-F7-78-8D-41
        4/10/2013 23:29       4/10/2013 23:41

1       23:41:28:796 10                             -32          78-19-F7-78-F8-41
        4/10/2013 23:29       4/10/2013 23:41

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1       23:41:28:796 10-Apr-2013                    -68          74-DE-2B-8E-13-5A
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2       23:41:34:708 10-Apr-2013                    -34          78-19-F7-78-F8-42
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2       23:41:34:708 10-Apr-2013                    -45          78-19-F7-78-8D-42
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2       23:41:34:708 10-Apr-2013                    -48          78-19-F7-77-6F-82
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2       23:41:34:708 10-Apr-2013                            -77            78-19-F7-78-EE-82
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2       23:41:34:708 10                                     -32            78-19-F7-78-F8-43
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2       23:41:34:708 10                                     -46            78-19-F7-78-8D-40
2       23:41:34:708 10                                     -35            78-19-F7-78-F8-40
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2	23:41:34:708 10 4/10/2013 23:29	-76	78-19-F7-78-EE-80
2	23:41:34:708 10 4/10/2013 23:29	-75	78-19-F7-77-EE-C0
2	23:41:34:708 10 4/10/2013 23:29	-58	78-19-F7-77-E7-41
2	23:41:34:708 10 4/10/2013 23:29	-70	78-19-F7-78-D0-01
2	23:41:34:708 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-59	78-19-F7-77-6F-81
2	23:41:34:708 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-84	78-19-F7-79-47-81
2	23:41:34:708 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-73	78-19-F7-78-8D-41
2	23:41:34:708 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-32	78-19-F7-78-F8-41
2	23:41:34:708 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-57	20-AA-4B-4F-D3-D9
2	23:41:34:708 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-68	74-DE-2B-8E-13-5A
3	23:41:37:329 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-29	78-19-F7-78-F8-42
3	23:41:37:329 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-44	78-19-F7-78-8D-42
3	23:41:37:329 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-51	78-19-F7-77-6F-82
3	23:41:37:329 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-59	A8-D0-E5-C3-5B-02
3	23:41:37:329 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-43	78-19-F7-77-E7-42
3	23:41:37:329 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-72	78-19-F7-77-EE-C2
3	23:41:37:329 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-76	78-19-F7-79-47-82
3	23:41:37:329 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-56	78-19-F7-77-E7-43
3	23:41:37:329 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-68	78-19-F7-78-D0-03
3	23:41:37:329 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-59	78-19-F7-77-6F-83
3	23:41:37:329 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-81	A8-D0-E5-C3-5B-03
3	23:41:37:329 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-63	78-19-F7-78-8D-43
3	23:41:37:329 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-77	78-19-F7-79-47-83
3	23:41:37:329 10-Apr-2013 4/10/2013 23:29 4/10/2013 23:41	-26	78-19-F7-78-F8-43
3	23:41:37:329 10-Apr-2013 4/10/2013 23:31 4/10/2013 23:41	-82	78-19-F7-77-EE-C3
3	23:41:37:329 10-Apr-2013 4/10/2013 23:41	-29	78-19-F7-78-F8-42
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3	23:41:37:329	10-Apr-2013	-44	78-19-F7-78-8D-42
	4/10/2013 23:29	4/10/2013 23:41		
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7 23:41:54:458 10-Apr-2013 -79 78-19-F7-78-8D-41
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7 23:41:54:458 10-Apr-2013 -74 78-19-F7-79-47-81
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         4/10/2013 23:29         4/10/2013 23:41
7        23:41:54:458 10-Apr-2013                           -41          78-19-F7-77-E7-42
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8        23:42:00:370 10-Apr-2013                           -79          78-19-F7-78-D0-02
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8       23:42:00:370 10-Apr-2013                    -53         78-19-F7-77-E7-43
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8       23:42:00:370 10-Apr-2013                    -82         78-19-F7-77-FB-83
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8       23:42:00:370 10-Apr-2013                    -78         78-19-F7-78-8D-43
        4/10/2013 23:29         4/10/2013 23:42
8       23:42:00:370 10-Apr-2013                    -74         78-19-F7-79-47-83
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8       23:42:00:370 10-Apr-2013                    -40         78-19-F7-77-E7-40
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        4/10/2013 23:29         4/10/2013 23:42
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8       23:42:00:370 10                             -75         A8-D0-E5-C3-5B-02

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7	23:41:54:458 10		-78	78-19-F7-78-8D-43
8	23:42:00:370 10		-79	78-19-F7-78-D0-02
	4/10/2013 23:29	4/10/2013 23:42		
8	23:42:00:370 10-Apr-2013		-82	78-19-F7-77-FB-81
	4/10/2013 23:31	4/10/2013 23:42		
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	4/10/2013 23:29	4/10/2013 23:42		
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	4/10/2013 23:29	4/10/2013 23:42		
8	23:42:00:370 10-Apr-2013		-32	78-19-F7-78-F8-41
	4/10/2013 23:29	4/10/2013 23:42		
8	23:42:00:370 10-Apr-2013		-42	78-19-F7-77-6F-82
	4/10/2013 23:29	4/10/2013 23:42		
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	4/10/2013 23:29	4/10/2013 23:42		
8	23:42:00:370 10-Apr-2013		-76	78-19-F7-78-8D-42

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Appendix B Robot Collected Database

Access Point Information

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1	23:49:21:375 10-Apr-2013	-85	00-1B-BA-A5-D4-80	4/10/2013 23:31	4/10/2013 23:49
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7 23:49:46:991 10-Apr-2013 -39 78-19-F7-77-E7-42
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7 23:49:46:991 10-Apr-2013 -79 78-19-F7-78-D0-02
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7 23:49:46:991 10-Apr-2013 -77 A8-D0-E5-C3-5B-02

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7 23:49:46:991 10-Apr-2013 -65 78-19-F7-79-47-82
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7 23:49:46:991 10-Apr-2013 -66 78-19-F7-77-EE-C2
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7 23:49:46:991 10-Apr-2013 -50 78-19-F7-77-E7-43
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7 23:49:46:991 10-Apr-2013 -56 78-19-F7-77-6F-83
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7 23:49:46:991 10-Apr-2013 -84 78-19-F7-77-FB-83
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7 23:49:46:991 10-Apr-2013 -79 78-19-F7-78-8D-43
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7 23:49:46:991 10-Apr-2013 -74 78-19-F7-79-47-83
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7 23:49:46:991 10-Apr-2013 -50 74-DE-2B-8E-13-5A
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7 23:49:46:991 10-Apr-2013 -46 78-19-F7-77-6F-80
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7 23:49:46:991 10-Apr-2013 -35 78-19-F7-78-F8-40
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7 23:49:46:991 10-Apr-2013 -54 78-19-F7-78-8D-40

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7	23:49:46:991 10-Apr-2013		-67	78-19-F7-79-47-80
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7	23:49:46:991 10-Apr-2013		-51	78-19-F7-77-E7-41
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7	23:49:46:991 10-Apr-2013		-57	78-19-F7-77-6F-81
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7	23:49:46:991 10-Apr-2013		-83	78-19-F7-77-FB-81
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7	23:49:46:991 10-Apr-2013		-79	78-19-F7-78-8D-41
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7	23:49:46:991 10-Apr-2013		-75	78-19-F7-79-47-81
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7	23:49:46:991 10-Apr-2013		-43	78-19-F7-78-F8-41
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7	23:49:46:991 10		-75	20-AA-4B-2C-20-38
	4/10/2013 23:30	4/10/2013 23:49		
7	23:49:46:991 10		-51	20-AA-4B-4F-D3-D9
	4/10/2013 23:29	4/10/2013 23:49		
8	23:49:52:903 10		-75	20-AA-4B-2C-20-38
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8	23:49:52:903 10		-35	78-19-F7-78-F8-42
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8      23:49:52:903 10                                                  -53           78-19-F7-78-8D-42
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8      23:49:52:903 10-Apr-2013                                         -53           78-19-F7-77-FB-82
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8      23:49:52:903 10-Apr-2013                                         -39           78-19-F7-77-E7-42
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8      23:49:52:903 10-Apr-2013                                         -79           78-19-F7-78-D0-02
       4/10/2013 23:29             4/10/2013 23:49
8      23:49:52:903 10-Apr-2013                                         -77           A8-D0-E5-C3-5B-02
       4/10/2013 23:29             4/10/2013 23:49
8      23:49:52:903 10-Apr-2013                                         -65           78-19-F7-79-47-82
       4/10/2013 23:29             4/10/2013 23:49
8      23:49:52:903 10-Apr-2013                                         -66           78-19-F7-77-EE-C2
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8      23:49:52:903 10-Apr-2013                                         -50           78-19-F7-77-E7-43
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8      23:49:52:903 10-Apr-2013                                         -56           78-19-F7-77-6F-83
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8      23:49:52:903 10-Apr-2013                                         -84           78-19-F7-77-FB-83
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8      23:49:52:903 10-Apr-2013                                         -79           78-19-F7-78-8D-43
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8      23:49:52:903 10-Apr-2013                                         -74           78-19-F7-79-47-83
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8      23:49:52:903 10-Apr-2013                                         -42           78-19-F7-78-F8-43
       4/10/2013 23:29             4/10/2013 23:49
8      23:49:52:903 10-Apr-2013                                         -35           78-19-F7-78-F8-42
       4/10/2013 23:29             4/10/2013 23:49
8      23:49:52:903 10-Apr-2013                                         -47           78-19-F7-77-6F-82
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8      23:49:52:903 10-Apr-2013                                         -53           78-19-F7-78-8D-42
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8      23:49:52:903 10-Apr-2013                                         -53           78-19-F7-77-FB-82
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8      23:49:52:903 10-Apr-2013                                         -39           78-19-F7-77-E7-42
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8      23:49:52:903 10-Apr-2013                                         -79           78-19-F7-78-D0-02
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8      23:49:52:903 10-Apr-2013                                         -77           A8-D0-E5-C3-5B-02
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8      23:49:52:903 10-Apr-2013                                         -65           78-19-F7-79-47-82
       4/10/2013 23:29             4/10/2013 23:49
8      23:49:52:903 10-Apr-2013                                         -66           78-19-F7-77-EE-C2
       4/10/2013 23:29             4/10/2013 23:49
8      23:49:52:903 10-Apr-2013                                         -50           78-19-F7-77-E7-43
       4/10/2013 23:29             4/10/2013 23:49
8      23:49:52:903 10-Apr-2013                                         -56           78-19-F7-77-6F-83
       4/10/2013 23:29             4/10/2013 23:49
8      23:49:52:903 10-Apr-2013                                         -84           78-19-F7-77-FB-83
       4/10/2013 23:31             4/10/2013 23:49
8      23:49:52:903 10-Apr-2013                                         -79           78-19-F7-78-8D-43
       4/10/2013 23:29             4/10/2013 23:49
8      23:49:52:903 10-Apr-2013                                         -74           78-19-F7-79-47-83
       4/10/2013 23:29             4/10/2013 23:49
8      23:49:52:903 10-Apr-2013                                         -42           78-19-F7-78-F8-43
       4/10/2013 23:29             4/10/2013 23:49
8      23:49:52:903 10-Apr-2013                                         -50           74-DE-2B-8E-13-5A
       4/10/2013 23:29             4/10/2013 23:49
8      23:49:52:903 10-Apr-2013                                         -46           78-19-F7-77-6F-80
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8	23:49:52:903 10-Apr-2013		-35	78-19-F7-78-F8-40
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8	23:49:52:903 10-Apr-2013		-54	78-19-F7-78-8D-40
	4/10/2013 23:29	4/10/2013 23:49		

Appendix C Matlab Code

```
load RSS.mat; %database
load values.mat; %unknown points
Rss = RSS(:,3:10);
find = values(:,3:10);
M = length(Rss(1,:));
s = zeros(1,length(Rss(:,1)));
sum = zeros(length(Rss(:,1)),M);
for j = 1: length(find(:,1))
for i = 1 : length(Rss(:,1))
    sum(i,:) = find(j,:)- Rss(i,:);
    s(i) = norm(sum(i,:),2)/M;
    figure(j);
    xlabel('database');
    ylabel('d_i');
    stem(s);
    legend('d_i with respect to the points in database');
end
[C,I] = min(s);
d(j) = I;
hold on;
plot(I,C,'--rs','LineWidth',2,...
                'MarkerEdgeColor','k',...
                'MarkerFaceColor','g',...
                'MarkerSize',10);
legend('Predicted point on database');
xlabel('Known points from the Database');
ylabel('Distance error of the unknown point ');
str = sprintf(' Comparision RSS values of unkown point %d to Database', j);
title(str);
hold off;
X = (RSS(I,1)-values(j,1))^2+(RSS(I,2)-values(j,2))^2;
error(j) = sqrt(X);
end
figure(j+1);
plot(error);
grid on;
xlabel('Unknown point');
ylabel('Distance Measurement Error');
title('Distance Measurement Error vs Unknown point');
```

Appendix D Atwater Kent Sixteeen Locations Coordinates

---------------------- Page 1----------------------

xpixel	ypixel	x	y
260	81	184.1939547	58.27338129
321	81	227.4086902	58.27338129
390	81	276.290932	58.27338129
433	81	306.7537783	58.27338129
488	81	345.7178841	58.27338129
530	81	375.4722922	58.27338129
530	114	375.4722922	82.01438849

530	155	375.4722922	111.5107914
530	231	375.4722922	166.1870504
530	280	375.4722922	201.4388489
497	280	352.0938287	201.4388489
471	280	333.6744332	201.4388489
430	280	304.6284635	201.4388489
395	280	279.8331234	201.4388489
329	280	233.0761965	201.4388489
261	280	184.9023929	201.4388489
261	241	184.9023929	173.381295
261	199	184.9023929	143.1654676
261	171	184.9023929	123.0215827
261	117	184.9023929	84.17266187

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0.708438	0.719424