

# York University

Faculty of Science and Engineering

SC/ENG4000  
Engineering Design

**Report #1 – Group # 8**

## CampNav: Indoor Localization Using a Hybrid Probabilistic Approach

Date Submitted: January 22, 2014

Instructor: Professor Ebrahim Ghafar-Zadeh

Submitted By:

---

Phillip Robbins	209 286 824	phillipr@yorku.ca
Maninder Gill	209973744	gillman@yorku.ca
Alec Mantha	210770568	sloanm@yorku.ca
Patrick Eagan	208421398	patrick.eagan@gmail.com

---

## **Abstract**

Augment reality has the potential, through software, to take complex navigational data and make it easy to process for solving simple or complex positioning and navigational problems for the layman.

The proposed project will investigate the feasibility of applying augmented reality involving overlaid and selectable metadata onto a live video stream on a mobile device, and possible indoor positioning using radio signal mapping through existing Wi-Fi router infrastructure at York University.

The application will use a combination of GPS, and surface/image recognition techniques to georeference the user for position and orientation respectively, then provide the overlaid data onto the images being recorded, and later an investigation into the ability to use the Wi-Fi radio signals to replace the GPS positioning for indoor applications will be conducted.

The project will require the group to apply fundamental skills in georeferencing, photogrammetry, digital terrain modeling, and image processing taught in the 3<sup>rd</sup> and 4<sup>th</sup> years of the Geomatics Engineering program, as well as, develops new skills in software and mobile application development in order to meet the stakeholders' requirements.

The project will be supervised by Dr. Gunho Sohn, Chair of the Geomatics Engineering Program and Principle-Investigator, and in partnership with ESRI who will be providing some funding for the project.

## Contents

Abstract .....	2
Introduction .....	4
Objectives .....	4
Constraints .....	4
Deliverables.....	4
Deadlines.....	5
Group Members , Advisors and Mentors .....	5
Gantt Chart .....	6
Milestones.....	6
Budget.....	9
Expenses .....	9
Scope Management Plan .....	10
Project Scope .....	10
Scope Management .....	10
Roles and Responsibility.....	10
Risk Management Plan.....	12
Risk Identification .....	12
Risk Assessment .....	13
Eliminating risks.....	14
Design Implementation.....	15
General Algorithm Description .....	16
kNN approach:.....	16
WAF Modelling using the Log-Distance Path Loss (LDPL) Model .....	16
Preliminary (kNN only) Algorithm Results .....	17
Heat Maps.....	24
Conclusion.....	27

## Introduction

Position information is an important aspect of everyday life. GPS is globally used to provide positioning but indoors, GPS does not work well or at all. Wi-Fi network infrastructure is common in many places and can be used for indoor positioning. Indoor navigation uses a fingerprinting approach based on the Received Signal strength (RSS) transmitted by nearby Wi-Fi access points. Typically such an approach consists of a survey phase; a location related Wi-Fi RSS series of fingerprints that characterize each survey position. This report will give a brief introduction to the technology that is going to be used during the course of this project. This report also talks about the different sensors available in the market and their advantages and limitations.

## Objectives

The objective of this project was to create an indoor positioning and navigation system in a small subset of the York Campus, specifically a portion of Vari Hall. This project will be performed over the course of the school year with a budget of roughly \$1000 offered by the Lassonde School of Engineering. This system will be integrated with an indoor map in order to show real time position, orientation and directions. The goal of this project is for the team to develop leadership capabilities and a greater grasp of the Geomatics profession.

## Constraints

The constraints for the project were put in place by the Advisor to our Project Dr. Gunho Sohn, as well as the budget put in place by the Lassonde School of Engineering. Dr. Sohn has expectations for the project which must be met. These include the need for the positioning, orientation and directional results to be displayed real time on an Android Tablet device. These expectations are to be met before the final presentation deadline in May. There is also a budget constraint of \$1000 which must be maintained throughout the course of this project in order for it to be deemed a success.

## Deliverables

The Campnav project is to deliver the following parameters by the end of the project:

- An Android application capable of displaying real time positioning, orientation, and directions.
- Intermediate Progress Presentations
- Intermediate demonstrations
- Large Final Demonstration/ Presentation
- A series of reports; documenting everything which happens in the course of this project.

## Deadlines

- March 5<sup>th</sup>, 2014 Preliminary Demonstration #2
- March 5<sup>th</sup>, 2014 Report #2
- April 26<sup>th</sup>, 2014 Final Demonstration
- April 26<sup>th</sup>, 2014 Final Report
- April 26<sup>th</sup>, 2014 Final Assignment related to all lectures including Invited Talks.

## Group Members , Advisors and Mentors

Prof. Gunho Sohn, Director of GeoICT

- [gsohn@yorku.ca](mailto:gsohn@yorku.ca)

Solomon Chan, MSc.

- [solomonchan.is@gmail.com](mailto:solomonchan.is@gmail.com)

Alec Mantha

- 210770568
- [sloanm@yorku.ca](mailto:sloanm@yorku.ca)

Maninder Gill

- 209973744
- [gillman@yorku.ca](mailto:gillman@yorku.ca)

Phillip Robbins

- 209286824
- [phillipr@yorku.ca](mailto:phillipr@yorku.ca)

Patrick Eagan

- 208421398
- [patrick.eagan@gmail.com](mailto:patrick.eagan@gmail.com)

## Gantt Chart

A Gantt Chart assigns the time and duration for each task in the work breakdown structure. It clearly details when tasks and subtasks start and end for the project.

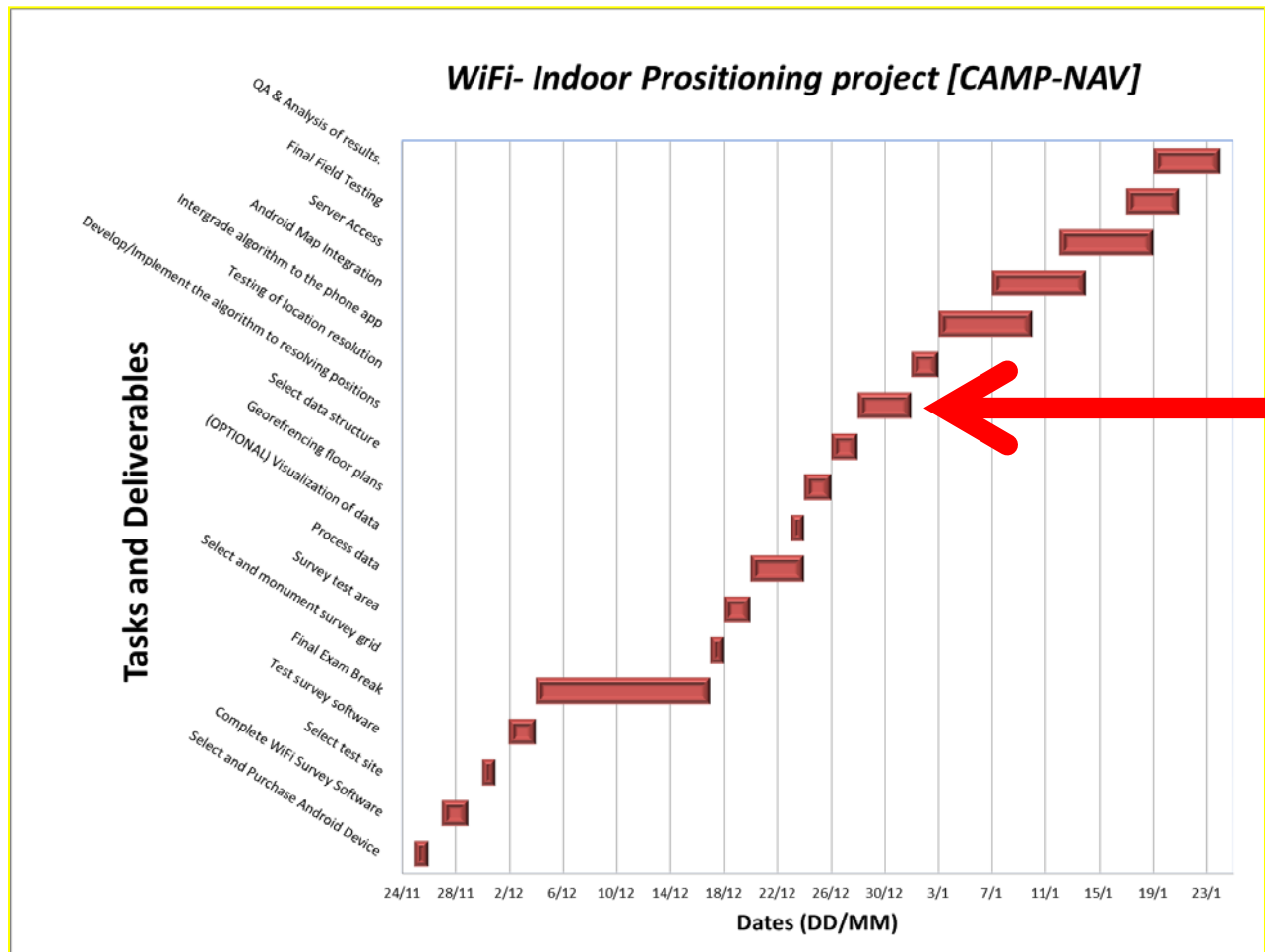


Figure The Gantt Chart of Milestones with an arrow depicting the current progress to date.

## Milestones

The Significant Events that must occur in the project are depicted above in the Gantt chart but will also be outlined below in their corresponding order of completion.

1. Select and Purchase Android device

In this step an Android Tablet device was chosen, the tablet which was chosen was the Galaxy Tab 3. This tablet was chosen because it possessed all the sensors of which we estimated to be required in the scope of this project. In addition the Galaxy Tab 3 has a large screen which is perfect for the final presentation. Two tablets were purchased costing roughly \$385 each.

2. Complete Wifi Survey Software

In this stage of the project an app was written in order to log the wifi signals and save them in a text file format. This app was capable of performing 1 scan, 10 scans, or a predetermined length of time for as many scans as possible.

3. Select Test Site

A 10 x 20m grid inside of the Vari Hall “Dome” was selected to be the test site area. This site was selected because this is where the final demonstrations will take place additionally it is a wide open area with large fluctuations in foot traffic making it perfect for testing.

4. Test Survey Software

The survey software was tested using different points names and scan times in order to find any bugs in the program before the survey of the large test grid.

5. Monumentation of Survey Grid

A relative coordinate system was created in the “Vari Hall dome” with the grid axis parallel to both the North and East wall faces. At each 1m grid interval a piece of masking tape was stuck to the ground. Each piece of tape would correspond to the coordinates of a point which were recorded.

6. Survey Test Area

A point was collected at each point in the North, East, South and West directions for roughly 60 seconds in each orientation. These points were recorded where the masking tape marked their locations on the ground or roughly once every 1m. This high density was done in order to access the accuracy of this method. The grid resolution can be modified in order to meet the accuracy set out by individual specifications. By lowering point resolution the survey time can be drastically reduced.

7. Processes Data

The points were processed by converting the dB signal to power ratios and averaging the power ratios of the matching BSSID’s as well as recording their corresponding standard deviations for each point’s orientation scan. This is done in order to have the data formatted properly by pre-processing as much of it as possible.

8. Visualization of Data

This step was performed by fitting a second order least squares surface to the intensities data of the grid. There was a different surface fit for each orientation which coupled with the known emitter’s position will help give a representation of the power distribution. In addition to these surfaces 4 long scans of an hour were taken at two locations in both a busy foot traffic time and a relatively quiet time of the day with little foot traffic.

#### 9. Georeferencing the Floor Plans

The group was given the floor plans to the Vari Hall building which can quickly be georeferenced by a simple rotation to the UTM frame using pre-established bench marks, such as Google Earth. This will allow a fluid integration with pre-designed mapping software such as ArcMaps and Google Maps.

#### 10. Selecting Data Structure

A data structure was selected for the project which would be able to hold the preprocessed data in order for quick inquiries into the database to be performed. The selected structure was a struct however the data structure is likely to change once the algorithm is finalized.

#### 11. Develop Positioning Algorithm

As of right now the basic algorithm implemented uses the following steps:

1. Pass a recorded WiFi scan into the algorithm
2. Compare the BSSID's with the fingerprints and take the fingerprints with the 5 highest matching numbers of AP's in order to limit search space.
3. Subtract the test signal's power from the matching fingerprints in order to get the residuals.
4. Take the Root Mean Square of the Residuals.
5. The result with the smallest RMS is taken as the calculated coordinate.

However the group is currently experimenting with an Algorithm called the K-NN hybrid based location estimate in order to better minimize the search space and remove corresponding outliers in the results. This algorithm consists of getting pseudoranges from the known AP locations in order to mix the trilateration approach with the fingerprint method.

The group is also hoping to add a wall attenuation factor in order to minimize the errors caused by obstructions such as walls.

#### 12. Testing of Grid Resolution

This step will be performed by testing the resulting accuracy of the algorithm. Judging by its accuracy the grid resolution may be reduced in order to save on the time it takes to survey future areas.

#### 13. Integrate Algorithm with Android Tablet

Currently the Algorithm is being tested using matlab, so the algorithm will have to be taken and reprogrammed into a Java format which can be run using the Galaxy Tab 3.

#### 14. Map Integration

At this stage the AutoCad files containing the building information will need to be converted into an ArcMap format which can easily be accessed as well as overlaid onto an existing mapping system such as Google Maps. These maps will include all of the Points of Interest which might be of importance to the user.



#### 15. Server Access

The group will need to devise a way to use a server to perform the grunt of the calculations, as well as hold the databases which will need to be queried. This will be done in order to minimize the battery usage of the app as well as quicken the calculations. The group was given permission to access YorkU servers for the scope of the project.

#### 16. Final Field Testing

This will consist of measuring the success of the application in the real world environment as well as checking for bugs and any modifications in the appearance which would benefit the user. Once this test is performed the Project will finally be ready for the final presentation.

#### 17. Final Analysis of Results

This stage will consist of analyzing what has been achieved in order to write an informative report on the topic which will be handed in and marked for our final mark in this course.

## Budget

The project has a budget which must be balanced throughout the course of the project. The Lassonde School of Engineering offers a budget of approximately \$1000 to each group throughout the course of the project. This budget will be well maintained at the project will be completed with a projected Budget surplus of approximately \$200.

There were two large purchases throughout the project of two tablets. They are both the Galaxy Tab 3 which was chosen because it contains all of the sensors necessary for the scope of this project, as well as a large 10" screen. A large screen is vital for the demonstrations needed for the final presentation. The group decided to purchase 2 in order to speed up the programming process as well as the surveying processes.

## Expenses

Galaxy Tab 3 10" **GT-P5210** (Black) Cost: \$385.32

Galaxy Tab 3 10" **GT-P5220** (White) Cost: \$385.32

## **Scope Management Plan**

### **Project Scope**

This research project designed to test the ability, reliability, and accuracy of an indoor positioning service in York University that implements the existing Wi-Fi access point (AP) infrastructure. The project aims to investigate the usability of the service for accessibility, safety, and fire services.

The project has an allocated budget of \$1000, and will include the design proposal, testing and programming of the android application and server algorithms, and a demonstration of the completed product.

### **Scope Management**

The scope management will entirely be the responsibility of the Project Manager. Any changes to the scope of the project can be proposed by the project manager, project sponsor or team members.

All change requests by sponsors, advisors, team members, or stakeholders will be submitted to the project manager whom is responsible for their approval and communication of changes to all stakeholders.

Before a change can be integrated into the project, approval of the Project Manager is required.

### **Roles and Responsibility**

For the project to be successful all team members and sponsors must be aware of their responsibilities. Table S1 outlines their roles and responsibilities.

Name	Role	Responsibility
Prof. Gunho Sohn	PI/ Advisor	-Approve or deny the changed project deliverables
Soloman Chan	Mentor	- Advise on changes to the project deliverables
Alec Mantha	Project Manager	-Measure and verify project scope -Facilitate scope change requests -Communicate outcomes of scope change requests -Update project documents upon approval of all scope changes
Phillip Robbins	Team Member	- Programmer in charge of Surveying, localization algorithm and android implementation.  - Evaluate the need for scope changes and communicate them to the project manager
Maninder Gill	Team Member	- Programmer in charge of final service with augmented reality implementation in android.  - Evaluate the need for scope changes and communicate them to the project manager
Patrick Eagan	Team Member	- Programmer in charge of final service with augmented reality implementation in android.  - Evaluate the need for scope changes and communicate them to the project manager -Scribe

Table S1 - Roles and Responsibilities

## Risk Management Plan

With every project there are inherited risks and it is the responsibility of the team members and the project manager to identify these risks and minimise their impact and cost on the project.

This document is to assist in identifying, assessing and minimising the impacts of apparent risks.

### Risk Identification

Risks can occur due to poor definition and planning of the project. The assumptions made for the timeline can be invalid as a task may take longer than anticipated. There can also be a risk to the timeline due to loss of a team member, which will also increase work load and time requirements of the remaining members. Furthermore there can be risk associated with the prototype as it may not behave in the desired manner. Moreover there can be hidden risks to the project, which will have to be assessed and resolved accordingly.

All the resulting risk will have an impact on the project, these impacts can be categorised into the following areas:

- Schedule
- Scope
- Budget
- Quality
- Privacy concerns.
  - Tracking people requires permission.
  - Getting access to floor plans and Router location also requires special permissions.
- Augmented reality features.

## Risk Assessment

In the risk identification, each risk has been identified which could occur during the course of the project. Each risk is given priority based on the chance for that event to occur and the consequences if that event occurs. In the table below each event of risk is carefully studied by the group members and assigned its priority according to its likelihood and consequences.

Table1: Risk assessment table based on identified risks

	<b>Negligible</b>	<b>Marginal</b>	<b>Critical</b>
<b>Likely</b>		Accuracy of results	
<b>Possible</b>	Augmented reality (additional features)		Permission to track people
<b>Unlikely</b>		Budget	Time constraint
<b>Rare</b>			Access to location of WIFI routers

In the Table above each identified risk is assigned a priority accordingly. It can be seen from the Table 1 that Privacy is the most critical risk identified by the group with high probability. Since the application requires the tracking of people in the building and it is very likely that people in certain cases may not give permission to track them.

One can also make out the Quality of the output has not given very high priority, since this technology is in the early development stage and because of the short time available for the development of the project it is very likely that cm level of accuracy will not be achieved. But accuracy will not have a high impact on the final outcome because this application is only developed for navigation and navigation does not require a cm level of accuracy.

Augmented reality (AR) is the feature that will allow user to get other information about the building e.g. name, features etc. It has been planned to have this feature in the end product but because of the shortage of time this objective may not be met at the end. Since the goal of project is to position and navigate people inside, so not having AR features will not have a huge impact on the final outcome.

Since it is mostly a software utility and does not require much of hardware which help group to work within allotted budget and to eliminate the consequences of running out of the budget.

At the moment group have a better understanding of risks associated with the various aspects of the project. By similar approach as followed above future risks will be evaluated and removed if the evolve in future stages of project.

### **Eliminating risks**

Because of the consequences of the risks the risks discussed above may not the completely removed. But their effect can be reduced or modeled to have less impact on the final solution. Certain algorithms have been developed to model the various consequences.

## Design Implementation

The general motivation behind the design is loosely based on the paper *Dynamic WiFi-based Indoor Positioning in 3D Virtual World* By; S. Chana , G. Sohn a, L. Wang a, W. Lee from the GeoICT at York University that was authored by both our Advisor and Mentor.

The paper aimed to show the feasibility of constructing a 3D virtual world that users can interact with in a virtual sense. The generalized localization approach used a hybrid probabilistic approach for indoor positioning involving the integration of kNN (k-Nearest-Neighbors) and probabilistic ranging based WAF (Wall Attenuation Factor) modeling using Log-Distance Path Loss (LDPL) Model, based on previously recorded Wi-Fi fingerprint database.

At the time of writing this report a finger print database was established in Vari-Hall at York University, and the preliminary kNN algorithm is complete, but the hybrid algorithm has not yet been implemented and will be further discussed below.

The figure below is an excerpt from the paper mentioned above [S. Chana]:

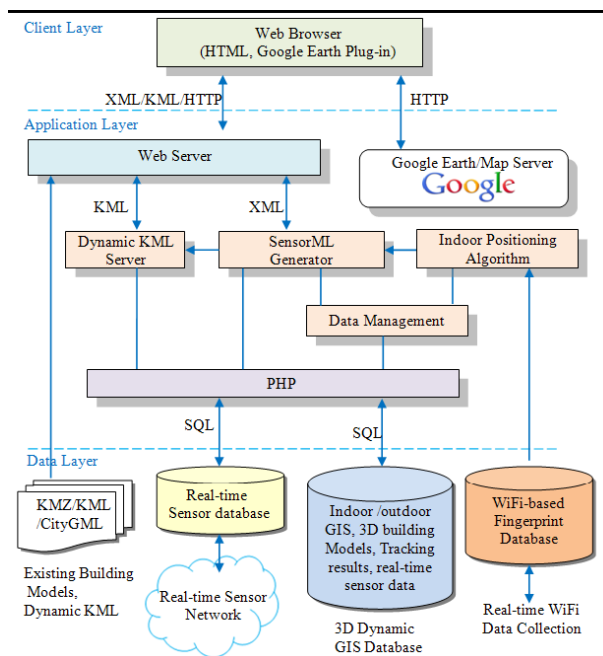


Figure: General system architecture for implementing dynamic 3D virtual world.

For the scope of this project we will be focusing only on position resolution and mapping (implemented in Android OS) using the dynamic KML servers, Wi-Fi finger data base and data collection, the data management and structures, webservers, and user-end visualization and server access.

## General Algorithm Description

### kNN approach:

Currently the algorithm implements the kNN approach to fingerprint resolution. The kNN algorithm produces the  $k$  best candidates that match the user inputted finger prints.

Currently the best candidate produced by this algorithm resolves positions anywhere from 2-15 meters from the target; these results are expected to improve with the implementation of the WAF modelling.

### WAF Modelling using the Log-Distance Path Loss (LDPL) Model

The log-distance path loss model is a well-established radio propagation model that predicts the path loss a signal encounters inside a building or densely populated areas over distance.

$$S = S_{1m} + 10n \cdot \log_{10} d \quad (\text{Equation 1})$$

Where:

$S$  = signal path loss between AP and receiver (dBm)

$S_{1m}$  = signal path loss at a distance of 1 meter away from AP (dBm)

$d$  = distance in meter between receiver and AP

$n$  = path loss exponent of the environment (obtained from AP calibration)

The model is used to solve the distance  $d$  (see Equation 1), between a person at an unknown position and the AP location

The Wall Attenuation Factor (WAF) is an extension to the LDPL model that attempts to account for

$$S = S_{1m} + 10n \cdot \log_{10} d + C \cdot WAF \quad (\text{Equation 2})$$



## Preliminary (kNN only) Algorithm Results

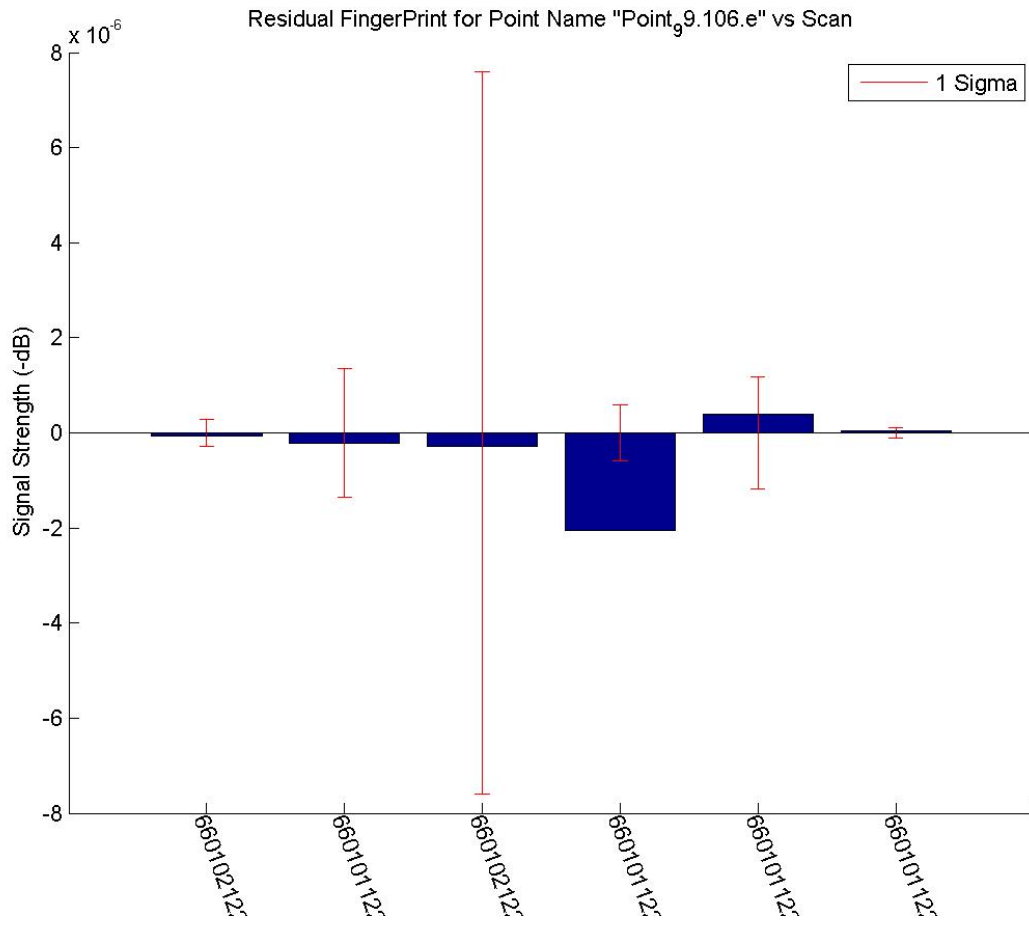
The following tables outline a selection of the preliminary results obtained from the k-NN algorithm. As mentioned above, the following results are not based on the Hybrid-Probabilistic-Model but only on the initial k-NN position resolution of the algorithm. With this in mind, one should view the current results as having only a minor significance, and are operating under the expectation producing of improved results once the WAF is added to the algorithm.

The following results are presented in tables where;

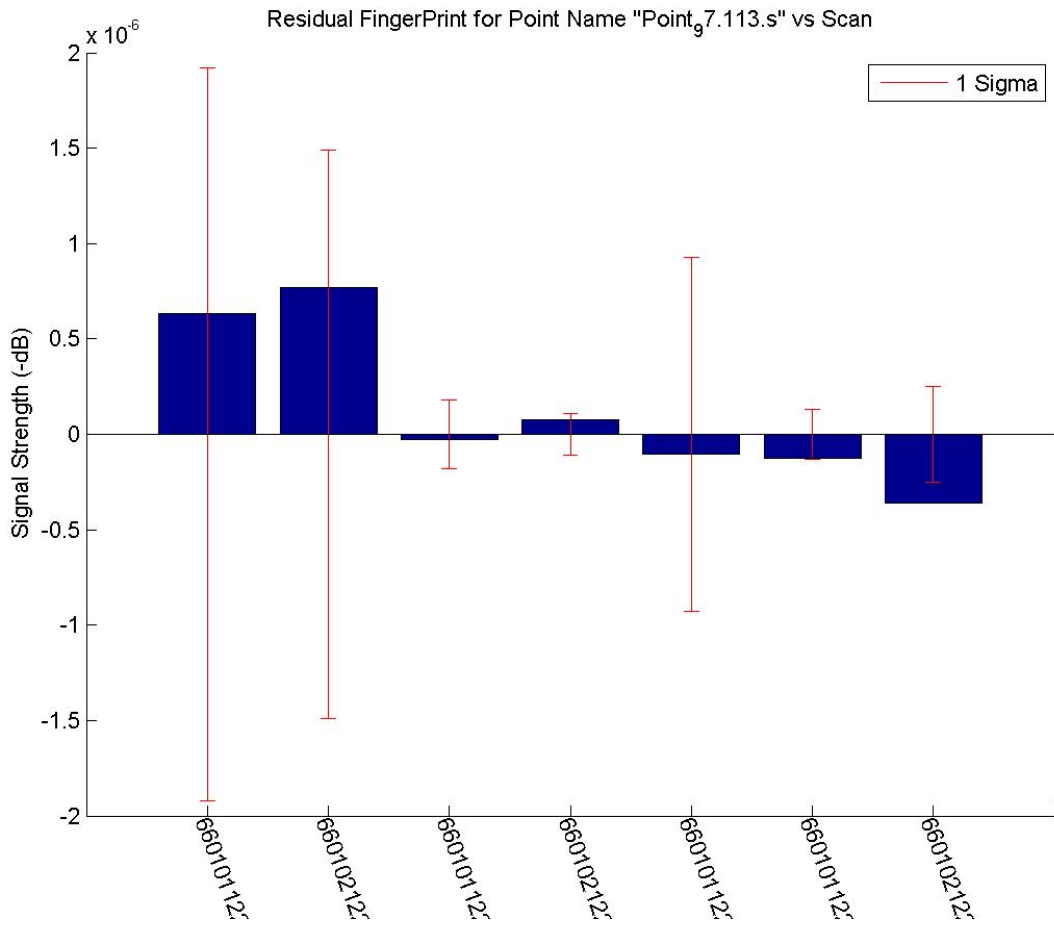
- “Test Case File” - are the pseudo-“user scanned” file.
- “Resolved Position” - are the Database Fingerprint the algorithm matched with.
- “Candidates” & “RMSe” - Next best candidates in ascending order of root-mean-square-error.
- “Num Matched Routers” -
- “Euclidean Distance Err (m)” - The magnitude of the error vector in meters.

The figures show the difference between the database values and the “user-scanned” values, with the database standard deviation ( $1\sigma$ ) in red.

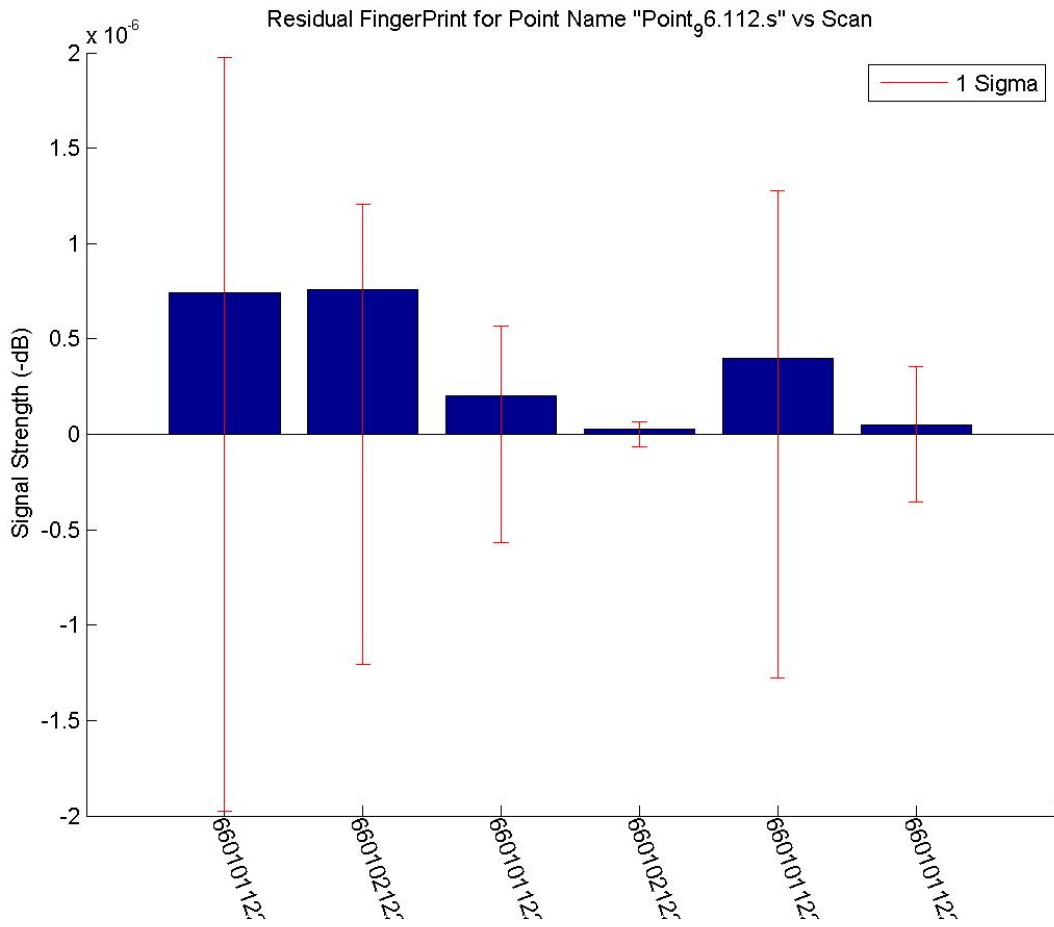
Test Case File	P_x-95.105.e			
Resolved Position	Point_99.106.e			
Canidates	Point_99.106.e	Point_97.102.e	Point_95.102.e	Point_96.103.e
RMSe	8.6177E-07	9.06528E-07	1.04919E-06	1.08665E-06
Num Matched Routers	6			
Euclidean Distance Err (m)	<b>4.123105626</b>			



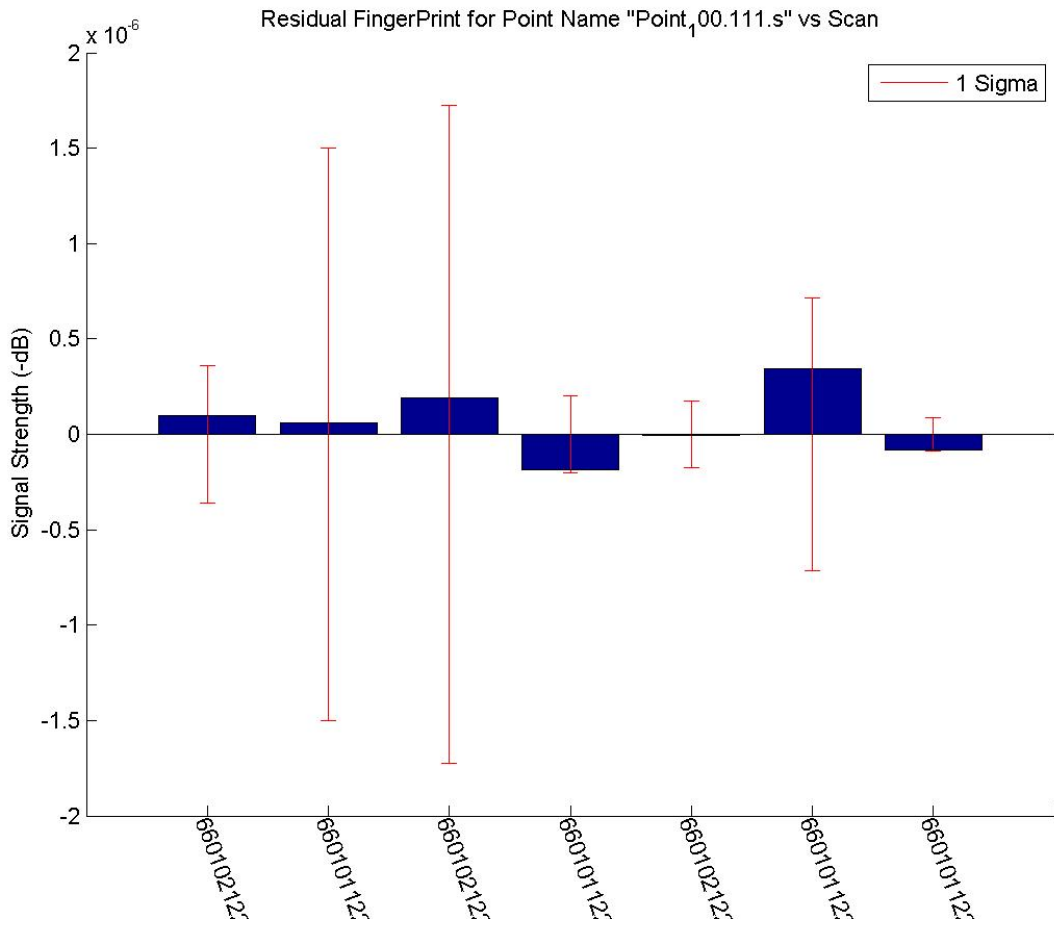
Test Case File	P_x-95.115.n			
Resolved Position	Point_97.113.s			
Canidates	Point_97.113.s	Point_100.111.e	Point_99.113.e	Point_99.116.e
RMSe	4.05738E-07	4.36367E-07	4.4631E-07	4.47395E-07
Num Matched Routers	7			
Euclidean Distance Err (m)	<b>2.828427125</b>			



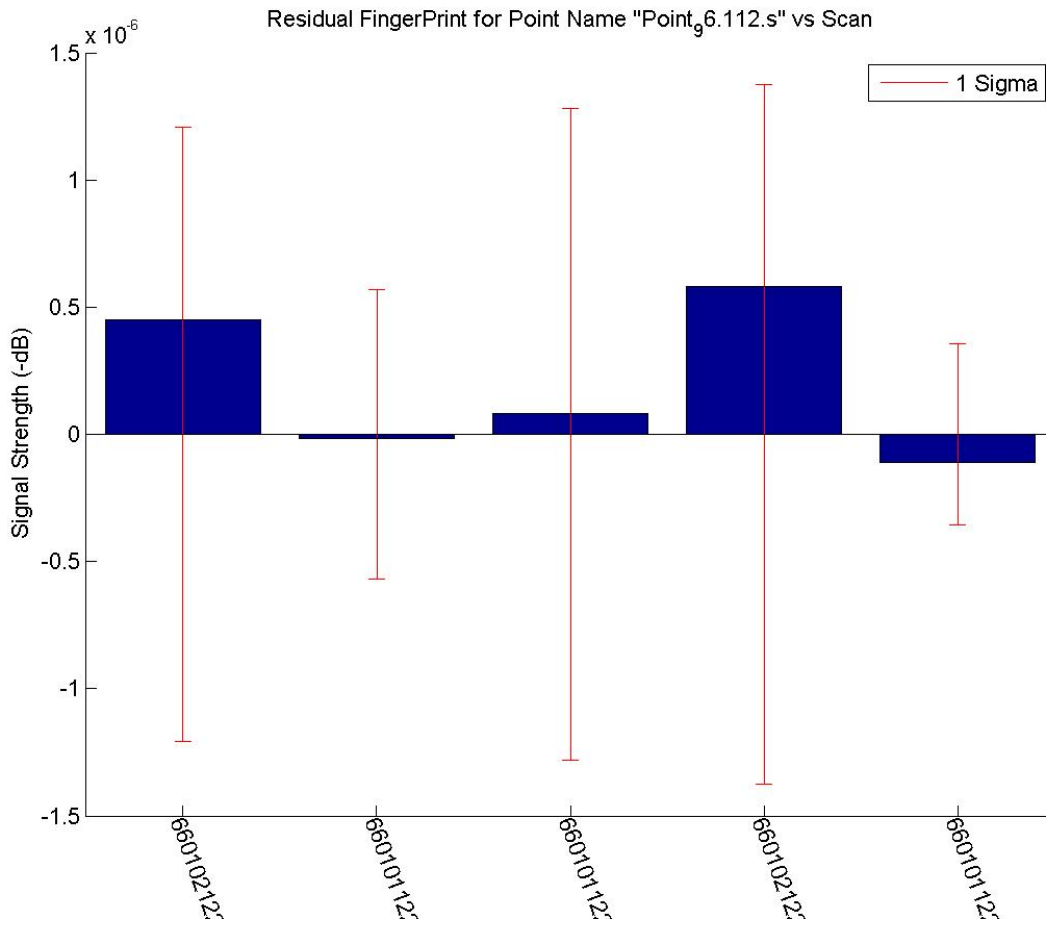
Test Case File	P_x-95.115.s			
Resolved Position	Point_96.112.s			
Canidates	Point_96.112.s	Point_99.110.w	Point_97.113.s	Point_100.111.s
RMSe	4.70564E-07	4.7652E-07	4.77938E-07	4.83708E-07
Num Matched Routers	6			
Euclidean Distance Err (m)	<b>3.16227766</b>			



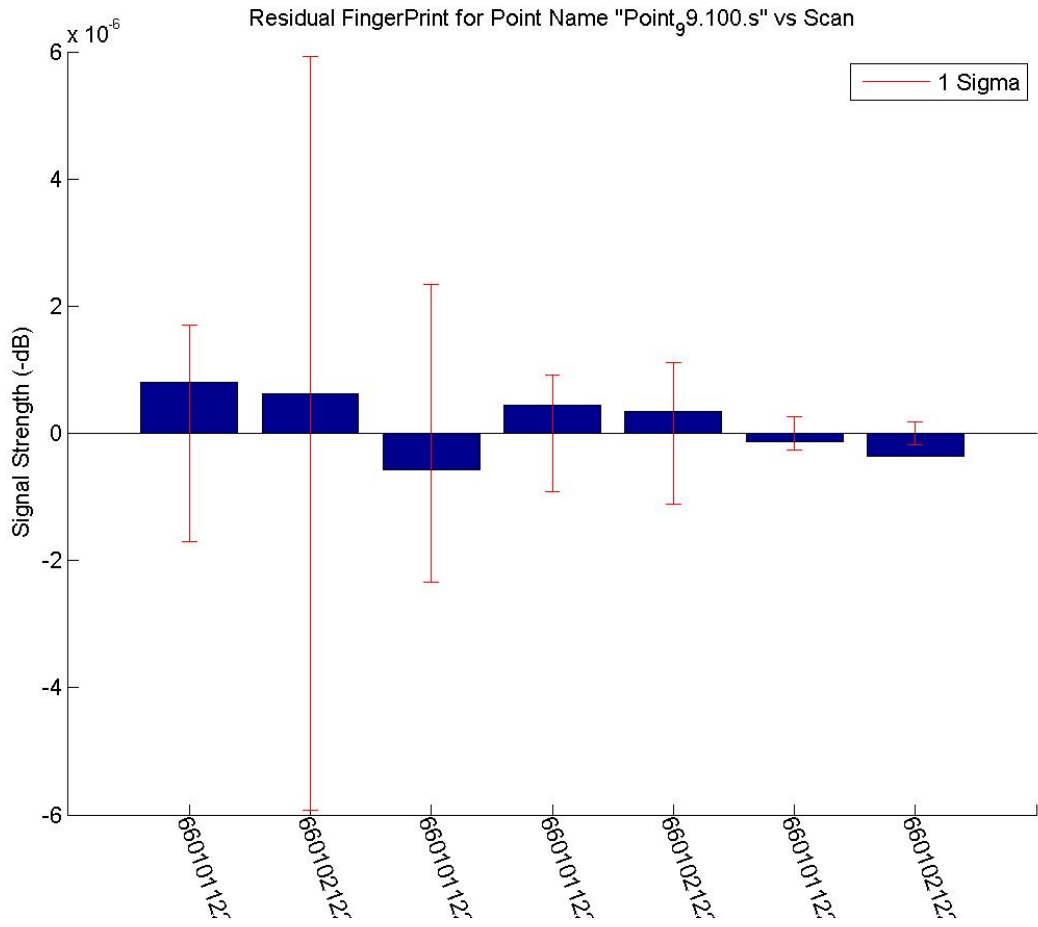
Test Case File	P_x-98.108.e			
Resolved Position	Point_100.111.s			
Canidates	Point_100.111.s	Point_99.110.e	Point_99.110.w	Point_97.113.s
RMSe	1.73323E-07	1.82532E-07	2.22027E-07	2.22642E-07
Num Matched Routers	7			
Euclidean Distance Err (m)	<b>3.605551275</b>			



Test Case File	P_x-98.108.n			
Resolved Position	Point_96.112.s			
Canidates	Point_96.112.s	Point_99.110.w	Point_99.108.s	Point_100.109.s
RMSe	3.34003E-07	3.43704E-07	3.66188E-07	3.69941E-07
Num Matched Routers	5			
Euclidean Distance Err (m)	<b>4.472135955</b>			



Test Case File	P_x-95.105.s			
Resolved Position	Point_99.100.s			
Canidates	Point_99.100.s	Point_99.101.e	Point_100.102.w	Point_98.103.e
RMSe	5.1232E-07	9.94734E-07	1.07515E-06	1.13911E-06
Num Matched Routers	7			
Euclidean Distance Err (m)	<b>6.403124237</b>			



## Heat Maps

Heat Maps of the data were calculated in order to show the distributions of the signals in the test area using select APs with approximate known coordinates. These Heat Maps were designed to show the areas with the highest and lowest signals and the distribution of the signal strengths throughout the test areas. These plots were also shown with the locations of the routers on them. What can be seen is that the higher signals will be found in the areas closer to the APs. Since some of the APs will have a wall blocking them the signal strength will be spread out in a lot less predictable manor. The Heat Maps were created using a second order Trend Surface Analysis technique, learned in 4<sup>th</sup> year Digital Terrain Modelling.

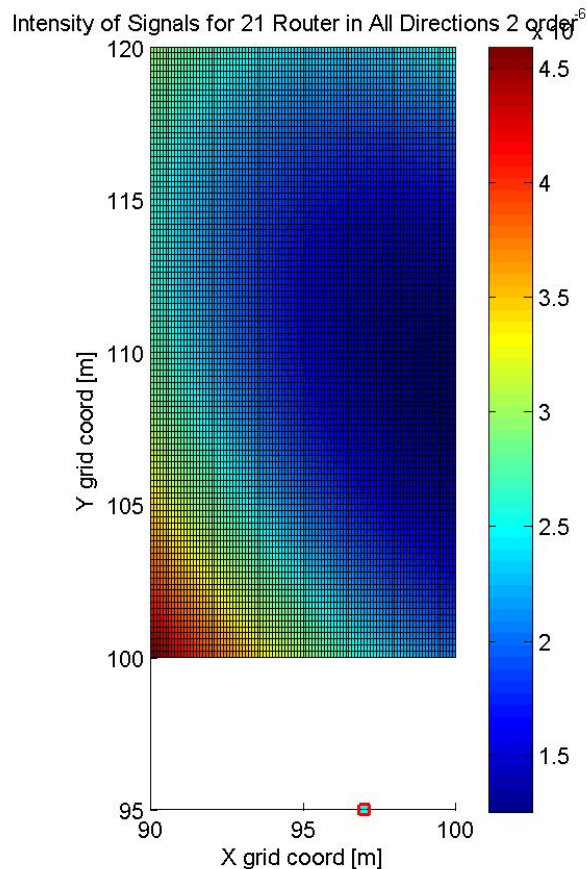
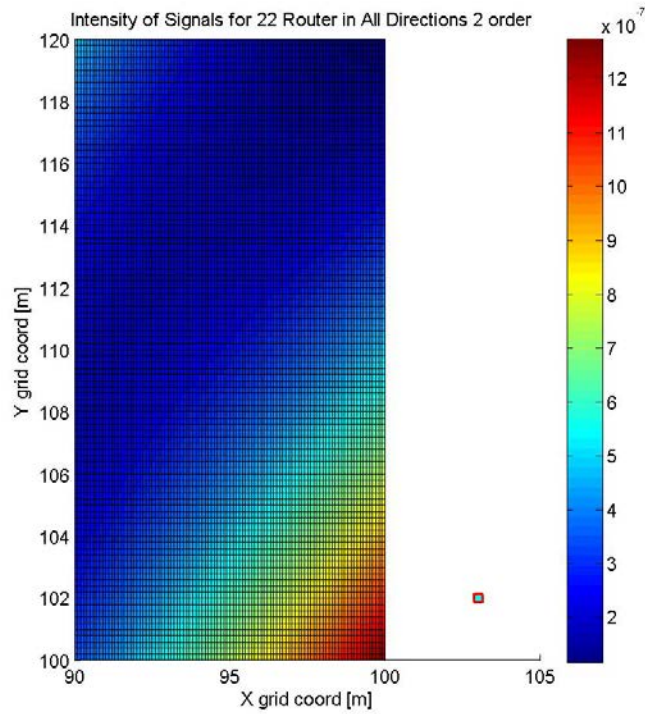


Figure Router #21 in all orientations

In the above image it appears that the highest signals are not the closest to the receiver's approximate location however this can be quickly fixed by going to measure the exact receiver's coordinates. The group believes that the higher signals will be closer to the APs actual location. The group also believes that Vari Hall's unique dome shape creates a situation where the signals will be carried along the walls with slightly higher signal strength.





**Figure Router #22 in all orientations**

In the above image it can be seen that the intensity is highest near the approximate location of Router number 22. As in stated before these are only approximate router locations which makes us believe that once the true coordinates are known the heat map will correspond more accurately. In addition to these heat maps there was one created for all routers with known locations and in all orientation which were omitted due to length of the report.

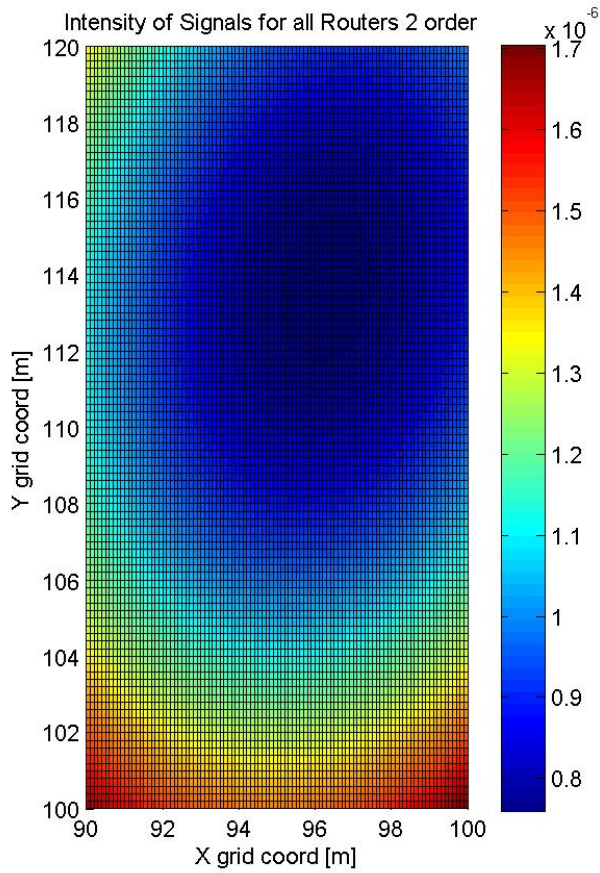


Figure Average Intensities over Whole grid

This final heat map is a second order TSA which will show the average intensities of all the measured signals. This final heat map shows that the largest concentration of APs is in the bottom portion of the grid. This makes sense with what would be expected by looking at the router locations plotted on the floor plans of Vari Hall where the vast majority of APs are below the grid.

## **Conclusion**

Indoor positioning is a relatively new field in Geomatics. This report illustrates the accomplishments we have made in data acquisition, in particular the mapping of the Vari Hall dome. The report details the accuracy of results to be a critical component to the success of this mission. Difficulties are expected and are considered by this group, to be challenges to be overcome. This is shown in the continued refinement of the positioning algorithm to the current k-NN method, with results between 3 to 6 meters of the true position.