Undergraduate Research Opportunity Program (Summer 2013/2014)
Final Report

Wireless Localization

Visualization Method of Wifi Signal in 3D space

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Abstract

Wifi is one of the most common technologies in humans' daily life. It is essential to find a suitable way of visualizing Wifi signals to understand how a Wifi network covers humans' working and living areas. This research project aims at exploring an easily understandable way of displaying Wifi signals in a 3D space. By analyzing Wifi signal strength (represented by RSSI) in several places in HKUST campus using specific software, the research team has successfully produced a set of visualized graph of Wifi signal strengths. The findings enable researchers to further study how humans interact with Wifi, for example, effect on health by exposure from Wifi, optimization of Wifi Access Point to maximize coverage, etc.

Keywords

Wifi, Wireless Localization, Data Visualization

I. Introduction

Wifi, as the most frequently used local area wireless technology, is widely adopted by people in both working and living areas, making it very influential on humans' life. However, studying the interactions between humans and indoor Wifi is not easy because the coverage of Wifi is relatively complex inside a building. Metal planes and concretes can block and reduce some of the Wifi signals such that the radio wave emitted by the Wifi Access Point is unevenly spread to the surrounding. Without visualization, it is

quite difficult analyze the coverage of Wifi. The goal of this project is to solve this problem by a software approach.

II. Methods

Generating a visualized Wifi signal graph requires a data model (see Figure 1 below) so that further editing and processing can be done easily

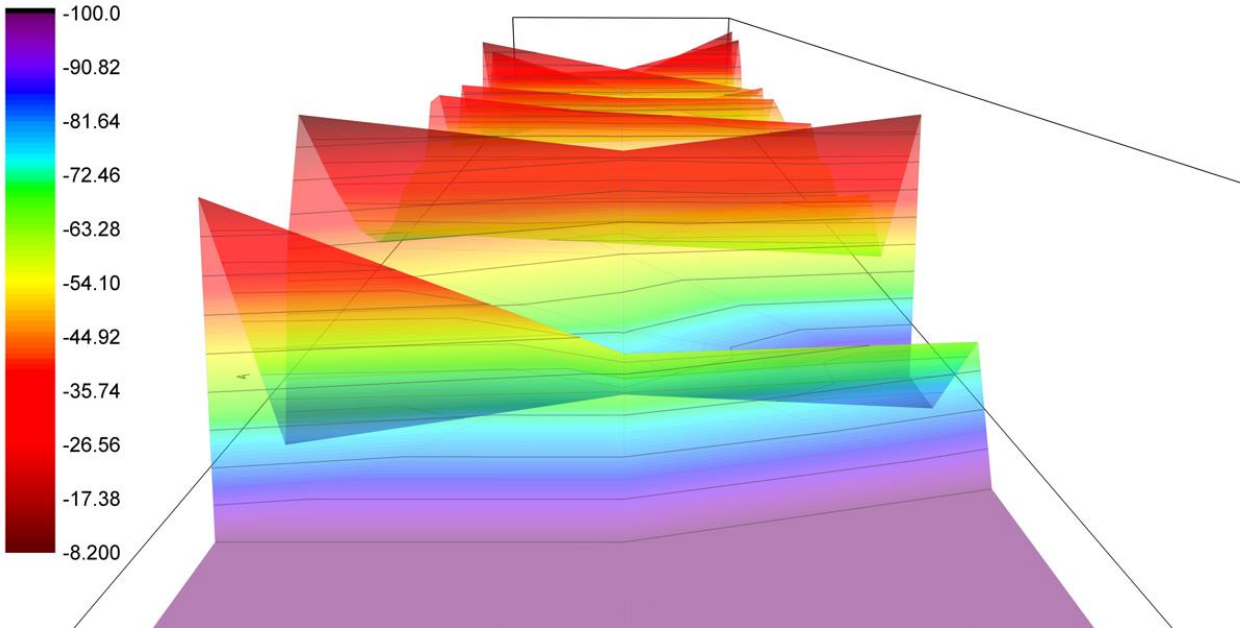

Figure 1 Example of data model

Before making a data model of Wifi coverage, we need to collect a set of data representing the Wifi signal strength first. As the project is in relatively small scale, the data collection process is done by ourselves. The whole data collection process was conducted in late June to early August, lasting for two weeks.

A. Variables

The signal strength at a point can be represented by Received Signal Strength Indication (RSSI), which can be used considered to be the power transferred in received radio wave. RSSI is a relatively reliable indicator of how good the Wifi reception is. Furthermore, RSSI is widely adopted by many operating systems like Android as the Wifi signal strength indicator. Using RSSI would be the most convenient way to collect the Wifi signal strength data.

B. Tools

We have used two devices to measure the RSSI value. One is a Google Nexus 4 running Android 4.4, in which an Android application is installed to collect the Wifi signals emitted by the surrounding Access Points. Another one is a Lenovo X220 laptop installed with Linux running a kernel for collecting Wifi Access Point data.

C. Venue

We have chosen two corridors in HKUST campus as the testing areas. One is near the laboratories on the 2nd floor in Academic Building and one is in the same position but on the 3rd floor. It is because corridor, which is similar to a rectangular prism, is a relatively simple structure to analyze. Moreover, there are no large obstacles along the corridor. The changes in Wifi signal strength are considered to be smoother.

D. Measurement

We have samples more than 180 points along the corridors on each floor. Each measuring point is 2 meters away from the adjacent points. Three points (left, middle and right) are taken for each cross-section area of the corridor. At each point, we sampled 100 connections to the Wifi Access Points and record the RSSI value and APs information for identification purpose.

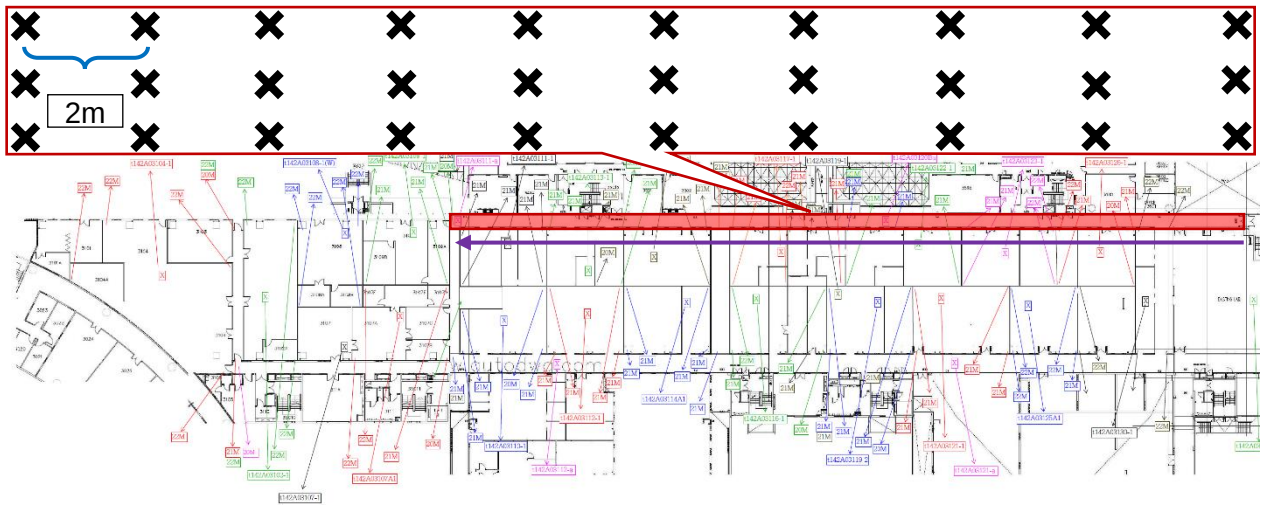

Figure 2 Area of data collection in the corridoor on the 3rd floor (Red area)

E. Generating a 3DModel Representing the Data

After collecting the data, five Wifi APs are chosen to analyze. For each AP on a floor, we can create 2.5D model representing the RSSI (a 3D object with single horizontal layer of surface). Moreover, after combining the data from the 2nd floor and the 3rd floor, a truly 3D model can be created.

The data will be processed by Excel for organization purpose. RSSI collected from every Access Points at a particular position will be taken average. After that, the data is output to Origin, a program used to generate 3D data model. The 3D model can be adjusted to a suitable viewpoint that matches the real photos. We produce the visualized graph by roughly adjusting the points of view of the 3D model and paste it to a corresponding photo of the building.

III. Results

After series of trials, we successfully visualize the Wifi signal. The figure below is some of the visualized graph created.

Figure 3Front view of the2rd floor corridor

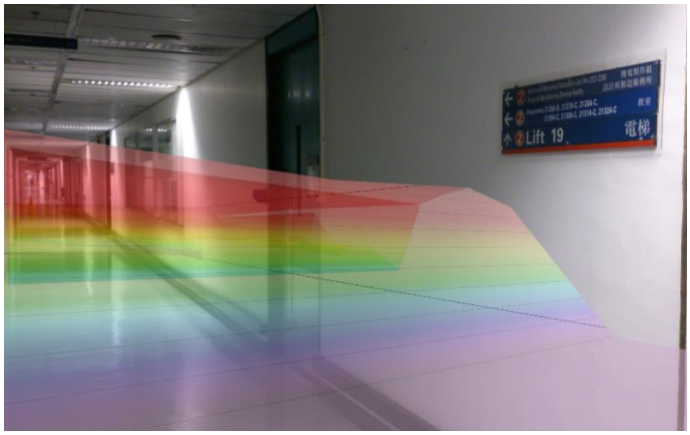

Figure 4Side view of the2nd floor corridor (left)

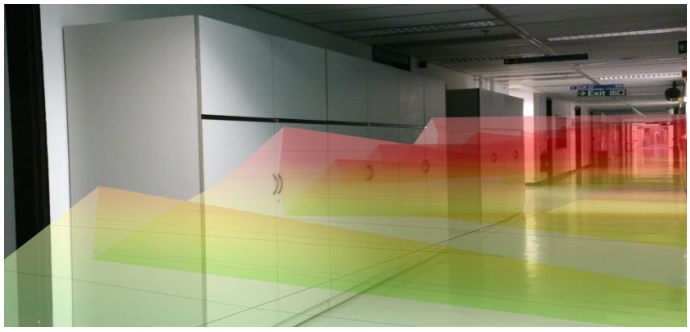

Figure 5Side view of the2nd floor corridor (right)

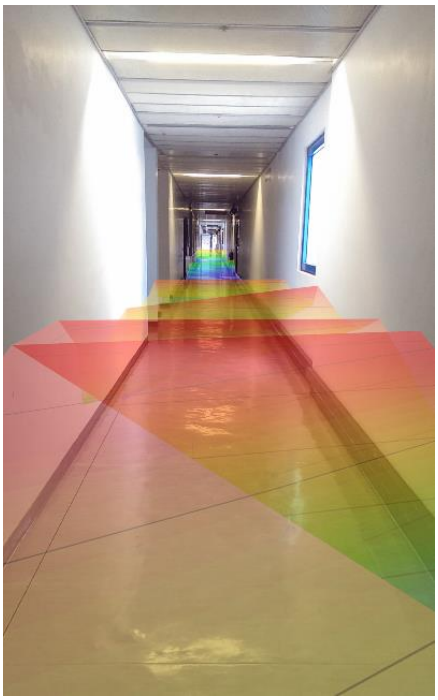

Figure 6 Front view of 3rd floor corridor

Figure 7 Side view of the 3rd floor corridor

IV. Discussion

A. Summary

Throughout the process of visualizing Wifi signal, we can foresee that visualizing wireless data is no longer a big challenge using modern computer visualization technology and the potentials of it can be very large.

With the growing popularity of Wifi, the way humans interact with it has actually been an important issue when designing a building and even establishing a community. However, from the image generated, we found that the distribution of Wifi signals actually does not match the way people live. Some strong Wifi signals are observed in a place people seldom stay but some places with a lot of human activities actually do not have strong signal strength. It is worth investigating in this meaningful aspect.

Also, the visualization of Wifi signal strength can also be used to let people find a place where the Wifi signal is the highest and give them information about the nearby Wifi Hotspots. Not only does this make people's life easier, but also utilize the network usage.

B. Limitations and Suggestions

The method that we use to generate visualized Wifi signal indeed has some limitations. We are looking forward to seeing someone can solve these problems.

1) Efficiency and Accuracy of Data Collection

Spending few weeks to collect Wifi data is time consuming. If someone needs to gather information of Wifi in every position of the campus, it would cost few months to do so. Some more efficient method of data collection should be used.

Also, RSSI is affected by a lot of factor including humidity of air, temperature of surrounding, reflection of building inner surfaces, gesture of holding the devices, design of device, allocation of Wifi Access Point, etc. The value measured during this project may not be the same when people actually use the Wifi network.

It is suggested that the Wifi strength can actually be collected by crowd sourcing Wifi data. Not only does this save efforts in data collection, but also gather the Wifi signal strength when people actually use.

2) Mapping

The way we map the points in photo to the model is relatively inaccurate because there is no existing solution to precisely change the perspective of 3D data model in Origin. If the model can be transferred to CAD software, more accurate operation can be done.

3) Visibility of 3D Space Model

Using color to distinguish different level of Wifi signal strength is a good way of presentation but when the original data set is a 3D space instead of a 2D plane, color may not be as clear as before. One alternative way would be using a 2.5D to present the data - only choose specific signal strengths to display as a close surface. This requires further research to find a way to create such image with appropriate quality.

C. Further Investigation

This project is just a start of visualization research on Wifi. There are some interesting directions of further investigation to explore.

One of the directions is exploring how to build a precise 3D model for the Wifi data collected. The method of mapping data into 2D image with an extra dimension of signal strength has been used in this project. However, another way is to directly build a 3D model of building and map the data into it. This may produce a much precise and editable result.

The second one is to analyze how Wifi affects humans based on the data generate by this project. With the help of visualized Wifi signal strength, researchers can know how the structure of a building blocks the Wifi signal, how the design of a building affects the Wifi network, how is the health of a person who stay in an environment with strong Wifi signal comparing with that with weak Wifi signal, etc.

Moreover, further investigation can be done for the application of Wifi visualization like real-time Wifi signal graph, Wifi Street Map, Wifi Hotspot finder, etc. This kinds of applications may help people getting access to the Internet and even reduce the waste of productivity in waiting for the web service to complete loading.

All in all, Wifi data visualization is still a relatively young area of wireless technology research. A lot of potentials and opportunities are waiting for people to explore. It is hoped that Wifi is no longer "invisible" someday in the future.

V. Reference

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VI. Tables and Figures

Data collected in HKUST campus

The 2nd floor corridor			
Access Points	00:23:eb:0a:c2:60	00:23:eb:3a:24:90	00:23:eb:3a:2a:80
The 3rd floor corridor			
Access Points	00:23:eb:3a:27:e0	00:23:eb:3a:28:b0	

Position	00:23:eb:0a:c2:60			00:23:eb:3a:24:90			00:23:eb:3a:2a:80			00:23:eb:3a:27:e0			00:23:eb:3a:28:b0		
(meter)	L	R	M	L	R	M	L	R	M	L	R	M	L	R	M
2	-64.4	-62.6	-63.5	-49.8	-12.3	-31.1	-58.4	-43.4	-50.9	-73.8	-79.3	-79.3	-69.1	-75.3	-75.3
4	-70	-22.4	-46.2	-5.05	-58.9	-32	-41.6	-63.1	-52.3	-61.7	-64.2	-64.2	-66	-66	-66
6	-40.6	-17.6	-29.1	-34.6	-71.4	-53	-49	-50.1	-49.5	-63.8	-67.8	-67.8	-66	-66	-66
8	-72.3	-73.7	-73	-75.9	-77	-76.4	-54.4	-50	-52.2	-62	-62	-62	-66.7	-68.8	-68.8
10	-14.1	-65.2	-39.7	-65.7	-1.93	-33.8	-48.1	-53.9	-51	-62	-62	-62	-71.4	-63.3	-63.3
12	-39.7	-62	-50.9	-200	-200	-200	-54.6	-51.3	-53	-62	-62	-62	-69.5	-67	-67
14	-36	-66.3	-51.1	-200	-200	-200	-33.4	-42.1	-37.7	-77.7	-62	-62	-75.3	-71.1	-71.1
16	-29.9	-72.2	-51	-200	-200	-200	-42.5	-65.4	-54	-62	-62	-62	-71.5	-69.4	-69.4
18	-12.6	-77.1	-44.9	-200	-200	-200	-23.6	-47.3	-35.5	-62	-62	-62	-66.9	-75.4	-75.4
20	-20.1	-200	-110	-200	-200	-200	-49.4	-43.5	-46.5	-62	-62	-62	-67.1	-72	-72
22	-200	-200	-200	-200	-200	-200	-51.7	-200	-126	-62	-62	-62	-72.7	-69.9	-69.9
24	-200	-200	-200	-200	-200	-200	-51.7	-67.2	-59.4	-62	-80.5	-80.5	-66.7	-75.3	-75.3
26	-200	-200	-200	-200	-200	-200	-57.3	-49.7	-53.5	-62	-62	-62	-68.9	-65.8	-65.8
28	-200	-200	-200	-200	-200	-200	-58.7	-67.1	-62.9	-62	-62	-62	-71.6	-69.1	-69.1
30	-200	-200	-200	-200	-200	-200	-56	-64.3	-60.2	-62	-62	-62	-70.4	-65.4	-65.4
32	-200	-200	-200	-200	-200	-200	-48	-8.4	-28.2	-62	-48.9	-48.9	-70.2	-68.3	-68.3
34	-200	-200	-200	-200	-200	-200	-8.3	-36.7	-22.5	-48	-48	-48	-74.8	-65.4	-65.4
36	-200	-200	-200	-200	-200	-200	-10.6	-34.2	-22.4	-78.3	-48	-48	-75.3	-76	-76
38	-200	-200	-200	-200	-200	-200	-23.2	-200	-112	-48	-49.4	-49.4	-67.5	-76.9	-76.9
40	-200	-200	-200	-200	-200	-200	-8.2	-200	-104	-52	-52	-52	-71.9	-79.5	-79.5
42	-200	-200	-200	-200	-200	-200	-200	-200	-200	-52	-52	-52	-62.8	-78.6	-78.6
44	-200	-200	-200	-200	-200	-200	-200	-200	-200	-52	-53.7	-53.7	-66.4	-73.5	-73.5
46	-200	-200	-200	-200	-200	-200	-200	-200	-200	-59	-79.1	-79.1	-70.2	-75.3	-75.3
48	-200	-200	-200	-200	-200	-200	-200	-200	-200	-59	-59	-59	-77.8	-68.1	-68.1
50	-200	-200	-200	-200	-200	-200	-200	-200	-200	-59	-59	-59	-80.2	-68.6	-68.6
52	-200	-200	-200	-200	-200	-200	-200	-200	-200	-60.5	-67	-67	-77.5	-72.3	-72.3
54	-200	-200	-200	-200	-200	-200	-200	-200	-200	-67	-55.7	-55.7	-75.6	-65	-65
56	-200	-200	-200	-200	-200	-200	-200	-200	-200	-57	-57	-57	-62.5	-73.2	-73.2
58	-200	-200	-200	-200	-200	-200	-200	-200	-200	-77.6	-57	-57	-75.3	-70.9	-70.9
60	-200	-200	-200	-200	-200	-200	-200	-200	-200	-59.3	-61	-61	-78.3	-71.2	-71.2
62	-200	-200	-200	-200	-200	-200	-200	-200	-200	-62.1	-68.4	-68.4	-77.4	-78.6	-78.6
64	-200	-200	-200	-200	-200	-200	-200	-200	-200	-62.3	-63	-63	-71.8	-69.5	-69.5
66	-200	-200	-200	-200	-200	-200	-200	-200	-200	-58.3	-61.6	-61.6	-73.8	-75.4	-75.4
68	-200	-200	-200	-200	-200	-200	-200	-200	-200	-63	-76	-76	-71.7	-75.3	-75.3
70	-200	-200	-200	-200	-200	-200	-200	-200	-200	-63	-63	-63	-75.8	-78.7	-78.7

72	-200	-200	-200	-200	-200	-200	-200	-200	-200	-63	-63	-63	-72.3	-76.2	-76.2
74	-200	-200	-200	-200	-200	-200	-200	-200	-200	-60.4	-60.3	-60.3	-75.8	-77.6	-77.6
76	-200	-200	-200	-200	-200	-200	-200	-200	-200	-61.8	-65.6	-65.6	-74.9	-76.3	-76.3
78	-200	-200	-200	-200	-200	-200	-200	-200	-200	-67.9	-64.2	-64.2	-78.8	-71.6	-71.6
80	-200	-200	-200	-200	-200	-200	-200	-200	-200	-78.6	-71.4	-71.4	-75.3	-76.9	-76.9
82	-200	-200	-200	-200	-200	-200	-200	-200	-200	-66.3	-72.4	-72.4	-74.9	-77.9	-77.9
84	-200	-200	-200	-200	-200	-200	-200	-200	-200	-65	-72.1	-72.1	-74.2	-79.3	-79.3
86	-200	-200	-200	-200	-200	-200	-200	-200	-200	-68.3	-67.3	-67.3	-73.5	-76.7	-76.7
88	-200	-200	-200	-200	-200	-200	-200	-200	-200	-77.9	-75.3	-75.3	-75.3	-75.3	-75.3
90	-200	-200	-200	-200	-200	-200	-200	-200	-200	-74.8	-77.8	-77.8	-69.1	-73	-73
92	-200	-200	-200	-200	-200	-200	-200	-200	-200	-75.8	-80	-80	-62.9	-62.9	-62.9
94	-200	-200	-200	-200	-200	-200	-200	-200	-200	-76.8	-76.9	-76.9	-62.9	-62.9	-62.9
96	-200	-200	-200	-200	-200	-200	-200	-200	-200	-75	-76.1	-76.1	-62.9	-62.9	-62.9
98	-200	-200	-200	-200	-200	-200	-200	-200	-200	-72	-74.9	-74.9	-62.9	-61.4	-61.4