Indoor Floorplan with WiFi Coverage Map Android Application

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Acknowledgement

To my beloved parents, for their love and supporting for so many years. I love you.

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By

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Abstract

Because of the emerging trend of mobile, developing applications on smartphone platform gathers more and more people's interests. Our capstone project is to build a mobile application on the Android platform that generates a house floor plan overlaid with Wi-Fi strength map. Right now in the market, there are plenty of mobile apps about measuring the floor plan or the WiFi signal strength, but there has not been an app that combines those two features. Since Wi-Fi is becoming the de facto standard for in-home wireless connectivity between devices inside the home, our industry partner, Qualcomm, thought this could be a great feature to be added to the floor plan app. We divided the whole product into two parts. One is the house floor plan, the other is the WiFi signal strength map. We finished those two separately then assembled them together. The whole developing process includes the selection of the main algorithms for the floor plan measurement and the WiFi signal strength, graphical user interface design as well as some marketing research. Finally we achieved that the error of the measurement result given by our application is within 10%. After the measurement process, the user can get the desired floorplan with the WiFi signal strength map.

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Introduction

The Capstone Project is to develop an Android app that generates a house floor plan overlaid with Wi-Fi strength map. This paper firstly gives a brief introduction to the implementation of the main algorithm and how we choose one over the other. Then it focuses on the development of graphical user interface design. Finally, it shows the final presentation of this application.

For evaluating such a product, besides the core functions it needs to realize, the graphical user interface (GUI) is probably the most explicit way to tell. Good user interface design facilitates finishing the task at hand without drawing unnecessary attention to the interface itself. Graphic design may be utilized to support its usability. The design process must balance technical functionality and visual elements, such as mental model, to create a system that is not only operational but also usable and adaptable to changing user needs. (1)

During this project, we were trying to develop and design a user-friendly GUI - not only because GUI is the first expression our product will leave to customers, but also it bears the task of delivering our excellent product ideas and accurate results to customers. First of all, the GUI provides branding, helping customers to identify our product from a lot of other apps with similar functions. The product's look and feel, including elements such as colors, shapes, layout, and typefaces (the "look"), as well

as the behavior of dynamic elements such as buttons, boxes, and menus (the "feel"), will make the product unique and very easily to be distinguished. (2) The importance of a well-developed and -designed user interface is that it may determine whether this product is acceptable to users or is a rejection. A good user interface means easy to understand and use, even more, since users will become familiar with how one product functions (looks, reads, etc.) , they will become loyal to this product. Second, user interface always serves an a media to convey the ideas of the product to users and transfer the command and information received from users to the main algorithm of the product behind the UI, in order to give the desired results. (3) Without a GUI, no matter how good the ideas are or how well the main algorightm of the app is developed, the customers can never see on the mobile screen what they are looking for.

For the development of GUI design part, this paper demonstrates how we explored to develop and design a good user interface based on academic research and marketing research. Also, it reflects the problems we encountered during the progress and how we tackled the difficulties. Finally, it shows the accomplishment of the GUI design of the Android app and states how it serves its functions.

Literature Review

Overview of AR Development

There are literally hundreds of examples of very cool augmented reality apps, tools and innovations out there. Both hardware and software have breakthroughs. The main hardware components for augmented reality are: processor, display, sensors and input devices. Modern mobile computing devices like smartphones and tablet computers contain these elements which often include a camera and MEMS sensors such as accelerometer, GPS, and solid state compass, making them suitable AR platforms. Not only with handheld devices as AR supporters, head-mounted, display, eye-glasses, and even contact lenses are all used as display devices to support AR. (4) Augmented reality has many applications, and many areas can benefit from the usage of AR technology. AR was initially used for military, industrial, and medical applications, but was soon applied to commercial and entertainment areas as well. (5) (6) All of these factors indicate AR has a very promising future.

Previous Research Effort

There are lots of efforts have been made in this research field. Artist, designer and computer scientist generate tons of ideas with new materials, new sensor or display technology. However, the most common framework for AR is still mainly camera based, with a software system deriving real world coordinates, independent from the camera, from camera images. (4) That process is called image registration, which

uses different methods of computer vision, mostly related to video tracking. This matches exactly what our Capstone Project product does. Our application tries to utilize camera to get information related with the house the user's in, and create a vision the user can see directly on screen. This is one kind of visual odometry.

Many computer vision methods of augmented reality are inherited from visual odometry. Usually those methods consist of two parts. The first stage is to detect interest points, or fiduciary markers, or optical flow in the camera images, which can be implemented by using feature detection methods, like corner detection, blob detection, edge detection or threshold or other image processing methods. The second stage restores a real world coordinate system from the data obtained in the first stage. (4)   Some methods assume objects with known geometry (or fiduciary markers) present in the scene. In some of those cases the scene 3D structure should be pre-calculated beforehand. If part of the scene is unknown, simultaneous localization and mapping (SLAM) can map relative positions. If no information about scene geometry is available, structure from motion methods like bundle adjustment are used. Mathematical methods used in the second stage include projective (Epipolar) geometry, geometric algebra, rotation representation with exponential map, Kalman and particle filters, nonlinear optimization, robust statistics.

Following the trend of mobile storm, mixed reality (MR) is a further developed idea for AR-referring to the merging of real and virtual worlds to produce new

environments and visualizations where physical and digital objects co-exist and interact in real time; a mix of reality, augmented reality, augmented virtuality and virtual reality (7) - from location- and context-aware systems through immersive augmented reality applications, which has been studied in research labs for more than two decades. With the advent of the modern smart phone, and the rapid adoption of wireless broadband technologies, this research is moving out of the lab and into the real world. Beyond just providing a platform for MR to reach a broad range of users, the capabilities and limitations of the smart phone provide a set of constraints on what kinds of applications can and cannot be delivered to consumers that have fundamentally changed how researchers think about MR, as a class of experiences occurring in an ecosystem consisting of the smart phone, the cloud, and the user.

Inspired Approaches

Among all those approaches to create an AR mobile app, we were inspired by an existing mobile app called Magic Plan. It measures the size of the room, draws the floor plan and creates a DXF file, PDF document, JPEG images and a web site with an interactive floor plan. This multi-award winning floor plan capture application has been improved by leveraging "MagicAR", a unique and proprietary technology that perfectly showcases how Augmented Reality can power a new breed of applications. MagicPlan is based on a multiple patent-pending technology that accurately localizes points in 3D thanks to the gyroscope. It is able to run on any device with a built-in

gyroscope and a camera. (8) The reason why they choose this approach is firstly because of the nature of the app. It is a mobile app, so the developers naturally came up with the idea that they should utilize some commonly existing functions of mobile phones. Secondly is because of the function of the app. It is suppose to be used by people who want to easily get the floorplan of a whole house by their own, instead of hiring expertise to do this time- and money-consuming work. So it should be easy to use.

Therefore we utilized its idea to use built-in sensors to get the measurement in our product. In our primitive version of product, the user can see on screen the surroundings in order to fix the points he/she wants to measure, then based on the data the sensors collected, such as angle and height, the main algorithm gets the measurement.

Methodology/Approach

A collaboration relationship has established among me and other three M.Eng students through this project. We decided to divide the project into three parts. One of the other three is responsible for the main algorithm, which serves the function of precise room measurement. The other student devotes himself to the API part-API is short for Application Programming Interface, which is a protocol intended to be used as an interface by software components to communicate with each other. Android system has its own API library, and for our application, we need to pick the right protocols to connect our codes with the hardware of the phone so that the hardware, such as the camera and the WiFi control, can be utilized by the app. I am in charge of the third part, which is the Graphical User Interface (GUI) design. Additionally, we are using Samsung Galaxy S3 as the product platform through our development.

For the main algorithm, we used two different approaches to get the floor plan. We first utilized the built-in sensors, such as gyroscope and accelerometer, to get the measurement result. Unfortunately, the very big noise caused by the poor precision of the built-in sensors, the measurement result differed a lot from the real situation. So we decided to abandon this method, instead, we decided to use simple geometry with the aid of some assumption and built-in sensors.

Figure 1. Geometry method to get the measurement

As the Figure 1 indicates, we assume the user has a certain height, and by using the angles decoupled by the smart phone's sensors, we can get the measured distance.

For the GUI part, there are mainly three tasks. One is to build a user interface so that the user can follow some steps to generate the floorplan and the WiFi coverage map. The other is to generate the measurement result on the screen, which means the user can see the shape and the proportional length and width of each room, and the colored Wifi coverage map, indicating the WiFi signal strength by using different colors. The third is to make it possible for users to move the "virtual rooms" on the screen and rearrange their positions according to the real house. For those last two tasks, I decided to take the "Divide and Conquer" way, that is, to implement the drawing and the dragging separately, then integrate these two parts together, which is easier to handle and debug.

Since I have no related experience or programming skills before, I started from gaining the basic Android app development training in the first semester. Setting up the development environment is an important step to start. The Eclipse IDE is used for building the project, writing and debugging the codes; The Android SDK, the ADT plugin for Eclipse, and the latest SDK tools and platforms using the SDK Manager are all used to support the code to use existing functions in an Android development library, and to make sure the code can be run in an emulator, which is a simulated Android system.

After setting up this, I started the learning curve. By studying a "Hello World" type of example code on the Android website, I learned some key concepts, such as how to create a Android project, how to build a simple user interface, how to change from one activity to another and how to manage the activity lifecycle. Also, I built my first Android App by the knowledge I learned, as Figure 2 shows.
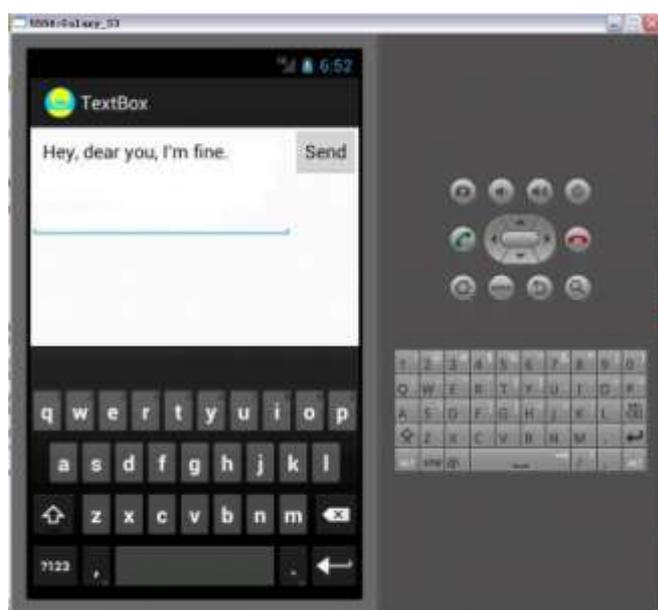

Figure 2. "Hello World" of Android App

At the beginning of the second semester, I got several breakthroughs. First, by using "onDraw Canvas" function, the room can be displayed with measured data on the screen. Second, a view called OnTouchListener, which is for a callback to be invoked when a touch event is dispatched to this view, is utilized to realize the function of dragging the displayed "room" on the screen. Then, in order to generate the colored WiFi coverage map, since we divided one room into multiple cells based on the width and the length and measured the WiFi signal strength at each cell, instead of using two integers as the width and the length to draw the room, we used an N*N matrix, of which the elements are the corresponding strength values of each cell, we coded those strength values to a range of colors, represented by RGB values, and mapped them to each cell, thus we got the WiFi coverage map. The colors ranges from red to green, meaning the WiFi signal strength from the weakest to the strongest.

Discussion

Graphical User Interface Design

Based on the marketing research, our target customers are those young adults who do not want to hire expensive experts to do the floor plan measurement and embrace innovative stuff and love DIY. So we decided to design the user interface simple but easy to understand and use, without superfluous instructions. Figure 3 (a) and (b)(c)(d)(e)(f) show the comparison between the graphical user interface between our application and MagicPlan. Figure 4 shows the floorplan of one single room with measured dimensions.

Figure 3 (a). The graphical user interface during measurement of MagicPlan

Figure 3 (b). The graphical user interface during measurement of our application (Pin on the first corner of the room)
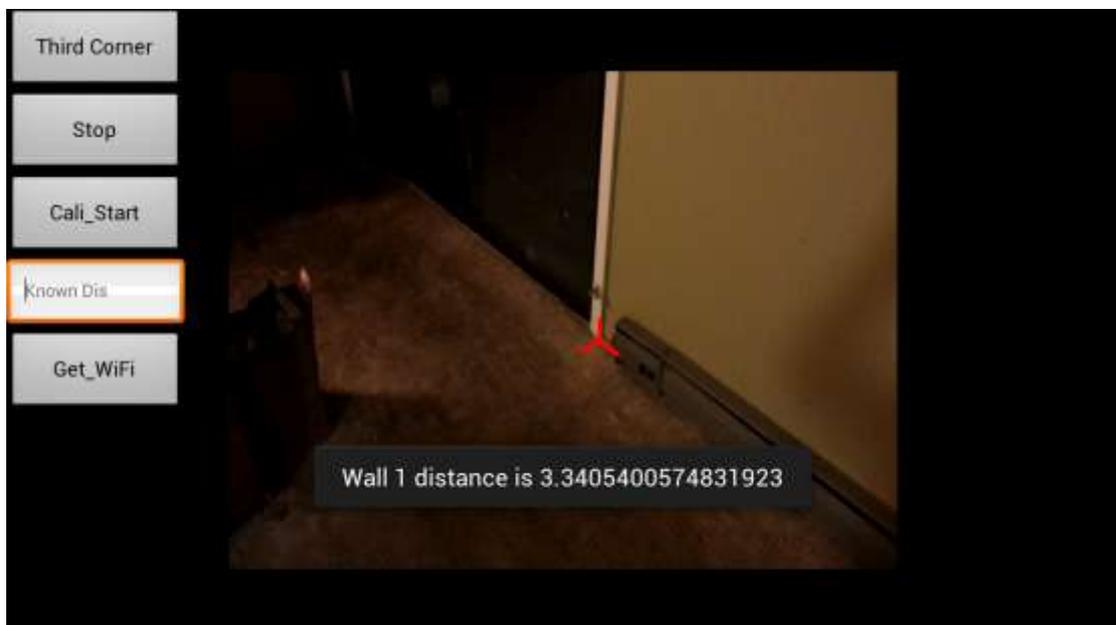

Figure 3 (c). The graphical user interface during measurement of our application (Pin on the second corner of the room and get the distance of the wall)
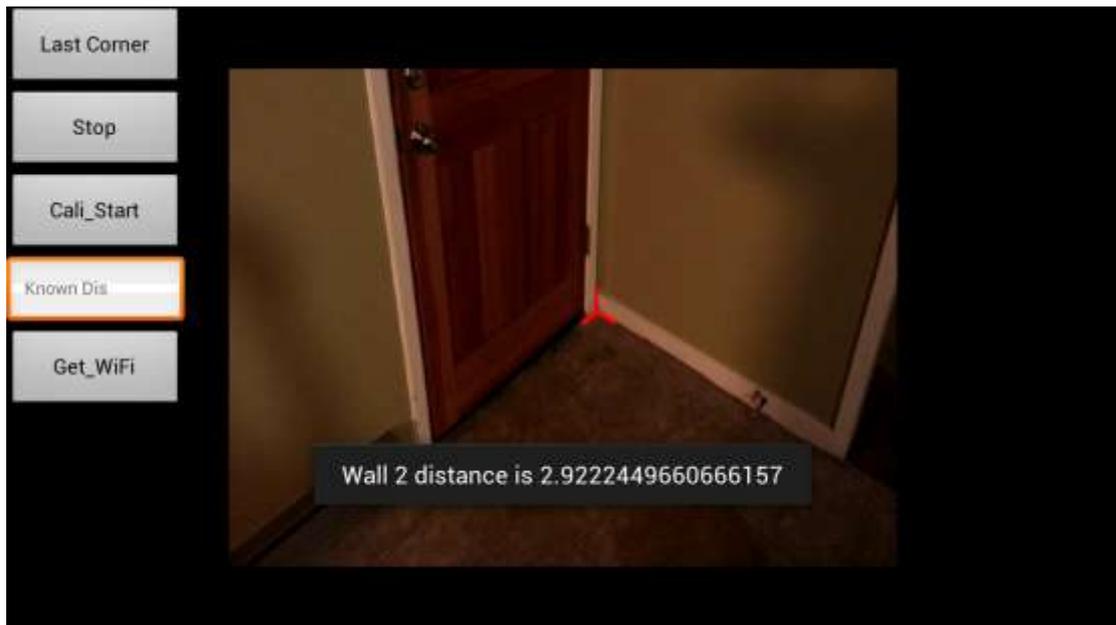
Figure 3 (d). The graphical user interface during measurement of our application (Pin on the third corner of the room and get the distance of the second wall)
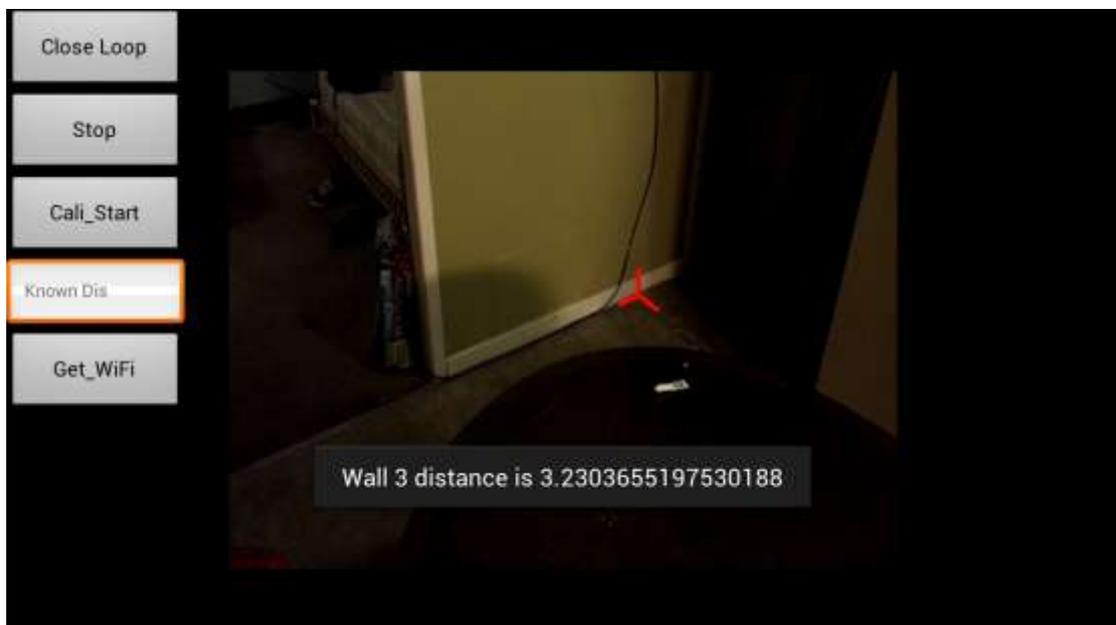

Figure 3 (e). The graphical user interface during measurement of our application (Pin on the fourth corner of the room and get the distance of the third wall)

Figure 3 (f). The graphical user interface during measurement of our application (Get

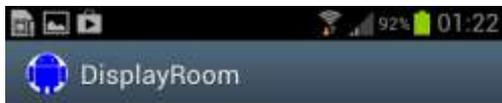back to the first corner of the room and get the distance of the fourth wall)

Figure 4. Floorplan of one single room with

measured dimensions.

WiFi Signal Strength Map

I explored several ways to make the color coding for the WiFi signal strength map. One is to assign existing colors in Android development library to the matrix cells mentioned in the previous section. Since there are only several very distinguishable colors in the library, such as red, green, yellow, blue, gray, cyan, magenta, white, black and so on, using this cannot achieve our goal of getting a relatively smooth-changing colored map to indicate the signal strength. Then I turned to a way called RGB coding. A color in the RGB color model is described by indicating how much of each of the red, green, and blue is included. The color is expressed as an RGB triplet (r,g,b), each component of which can vary from zero to a defined maximum value. (9) In computers, the component values are often stored as integer numbers in the range 0 to 255, and in JAVA, this number is represented as decimal number. For example, (0,0,0) represents black and (255,255,255) represents white. By changing the numbers, we can get a set of smoothly changed colors. However, because of two reasons, we still do not get a smooth colored map. On one hand, the set of points we got for the WiFi signal is not large enough, when they are constructed as a matrix, the value of each component in the matrix is quite different from each other, thus leads to not very evenly distributed colors. On the other hand, due to the time constraint, I did not delve into the RGB coding deeply. There should be a way to uniform each number in that matrix and then as changing the portions of

red, green and blue, assign a more smoothly changed RGB coding in the code itself, which can help us get a colored map as we expected. Figure 5 (a) and (b) show our expected map and the one I got when I run the code. One thing to notice is that when I run the code, I assigned some arbitrary numbers to the matrix, which does not represent the situation in the real measurement.
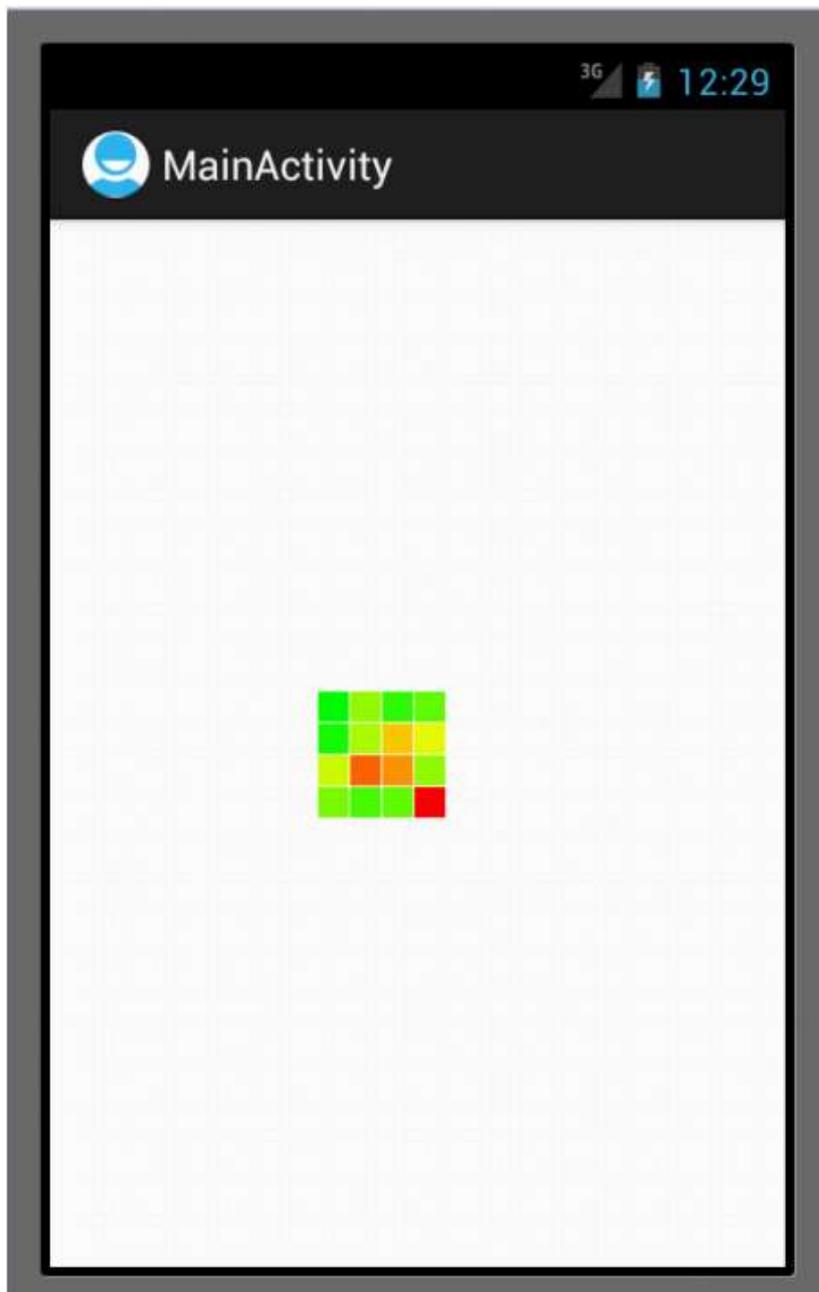

Figure 5(b). The map got from running the code

Conclusion

This paper illustrated and discussed how we developed the app of getting the floor plan and the WiFi signal strength map of a house, and showed both maps. The methodologies of main measuring algorithm, graphical user interface design, and displaying the drawing maps are discussed in this paper. During the year of development, my coding skills have been improved; more importantly, I have learned how to work in a team, how to make changes when we encountered problems, and how to study by ourselves when facing something totally new.

Although the accuracy of the measurement and the complexity of the user interface are still need to be improved, the product is already been able to implement the basic functions and meet the need of the market. It successfully combines the desired features of getting two maps using one single app, and can yield reasonable results. Further improvement can be done not only regarding to the technical side of the product, but also how to market it.

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