iDOCENT:

Indoor Digital Orientation Communication and Enabling Navigational Technology

Final Proposal

Team #2

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Executive Summary

iDOCENT is an indoor navigational smartphone application for the blind which utilizes already existing Wi-Fi access points to locate an individual and route the user to a desired location. This method avoids relying on a true GPS signal which may not always be available inside buildings. The algorithm works by surveying the current location for available Wi-Fi access points within range, assigns a factor based on signal strength, and performs an averaging calculation based on the previously documented locations of the access points. Step-by-step instructions can then navigate the user through the building while audible feedback assists every move.

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Introduction

The focus of the iDOCENT, or Indoor Digital Orientation Communication and Enabling Navigational Technology, includes prototyping a feasibly priced solution that will locate an individual inside of a building. Positioning accuracy is to be within four feet, and the location will be uploaded to Michigan State University's mobile website to ultimately guide a user throughout a building.

iDOCENT operates as a smartphone application, wirelessly calculating a user's specific location within a building. Its operation is akin to a GPS system found in today's cars. iDOCENT's focus end-user is the blind, allowing an individual to seamlessly locate himself by providing audible feedback and turn-by-turn instructions on how to reach a desired destination. Location results are given in real time and points of interests may be found on the move. The indoor guidance system is the collaborative effort between the Resource Center for Persons with Disabilities, the College of Engineering, Academic Technology Services, and the Libraries Computing Department.

Currently available technology for indoor navigation is limited and underdeveloped. However, methods do include the use of signal strength triangulation, radio frequency, and ultrasonic noise applications. There are several problems encountered when incorporating the different technologies into a final solution. The feasibility of many approaches declines for large scale implementations due to maintenance challenges. In addition, many of the buildings where iDOCENT will be deployed are constructed with steel, where GPS signal is weak or unavailable. The key functionality behind iDOCENT is its ability to operate without the use of a GPS signal. Instead, a modified version of signal strength triangulation will be implemented to determine a user's location on a smartphone within four feet accuracy.

Background

Research was initially performed on a variety of different methods for indoor navigation. Several of the early attempts included utilizing one of the following wireless technologies: Wi-Fi, Bluetooth, and RFID. Additionally, a group was discovered who determined location using a method called dead-reckoning, where no external wireless signals are used. All of the approaches were considered in the development of the iDOCENT application.

Bluetooth is an open standard wireless technology that is not defined by the Institute of Electrical and Electronics Engineers (IEEE), unlike other popular wireless standards such as Wi-Fi. Bluetooth is popular for the use of Personal Area Networks, or PANs where a master and slave relationship is created between two or more devices. The technology has been growing in popularity because of the power efficiency features and ease of use. Nearly all cell phones today contain Bluetooth functionality. Although the technology is widely available, manufacturers who use Bluetooth do not always stick the standard, because it is not regulated, and often modify functionality. Also, Bluetooth does not by default offer an easy method of signal strength calculation. When comparing to other existing wireless technologies, Bluetooth does not fit the criterion for indoor navigation applications.

Wi-Fi, or Wireless Fidelity, is a standard used today for broadcasting network connectivity. It is defined by IEEE under 802.11x. Most commonly, Wi-Fi is used for IP based networking equipment such as personal computers. The advantage of choosing Wi-Fi for a location based service is its high compatibility and frequency of availability. The majority of today's smartphones also have Wi-Fi connectivity. Newer revisions of Wi-Fi broadcast at the 2.4 Ghz frequency, allowing for signals to more easily travel through obstructions like doors and walls. Unlike other wireless technologies such as Bluetooth, Wi-Fi incorporates signal strength functions into all the firmware drivers and Application Programming Interfaces (APIs) which are defined by the manufacturers and backed by IEEE. This feature will provide a large benefit when using Wi-Fi to determine a location based on signal strength triangulation.

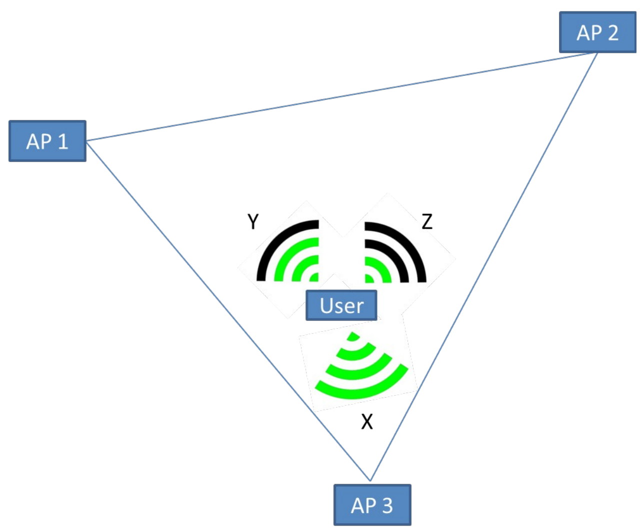
Dead-reckoning is a current method for determining location strictly based on three main factors: velocity, direction, and known initial location. Many of today's smartphones contain an accelerometer and digital compass hardware. Combining the sensor readings from both pieces of hardware, software can be used to track a user's movement throughout a building, without the need for wireless signals. The accelerometer can act as a pedometer, tracking steps taken, and the compass will determine the direction the user is walking. As long as the initial location is known, each new step taken can be recorded in the application. Error is evident in dead-reckoning due to compounding miscalculated steps and compass calibration issues. Additional algorithms may be incorporated to compensate for error but may require an excessive amount of trial-and-error based debugging.

While taking careful consideration into each technology, the most practical method for indoor navigation for iDOCENT's requirements will be met through Wi-Fi signal strength triangulation. It offers easily accessible and reliable hardware and the ability to use an existing smartphone to perform all necessary calculations. A combination of dead-reckoning and Wi-Fi positioning may be implemented in the future, time permitting.

Objectives

While concluding that Wi-Fi positioning would provide the best functionality to the iDOCENT proposal, a list of features was analyzed to see the project's complete potential. All buildings on Michigan State's campus are fully Wi-Fi capable so the need to purchase and install additional Wi-Fi access points (APs) is eliminated. An additional advantage is a unique identifier assigned to every access point called a MAC address. In this manner, individual information about each AP can be stored in a database. The database will be maintained alongside MSU's mobile website. In order to determine indoor positioning, an algorithm needs to be written and executed within a smartphone application. Two key factors in the calculation of positioning are the following: documented GPS location of all available access points and real time signal strength measurement. After the iDOCENT application is launched, location is obtained by first scanning for available APs, assigning a signal strength factor to each AP, and uploading one entry per factor to the database. Each entry will contain the known GPS longitude and latitude coordinates of that particular AP. The stronger the signal strength, the more entries will be uploaded, thus increasing the weight of a particular AP who the user is closer to. By averaging every entry in the database, a known location can be determined. This method has been referred to as triangulation and is illustrated in Figure 1.

Figure 1: Triangulation

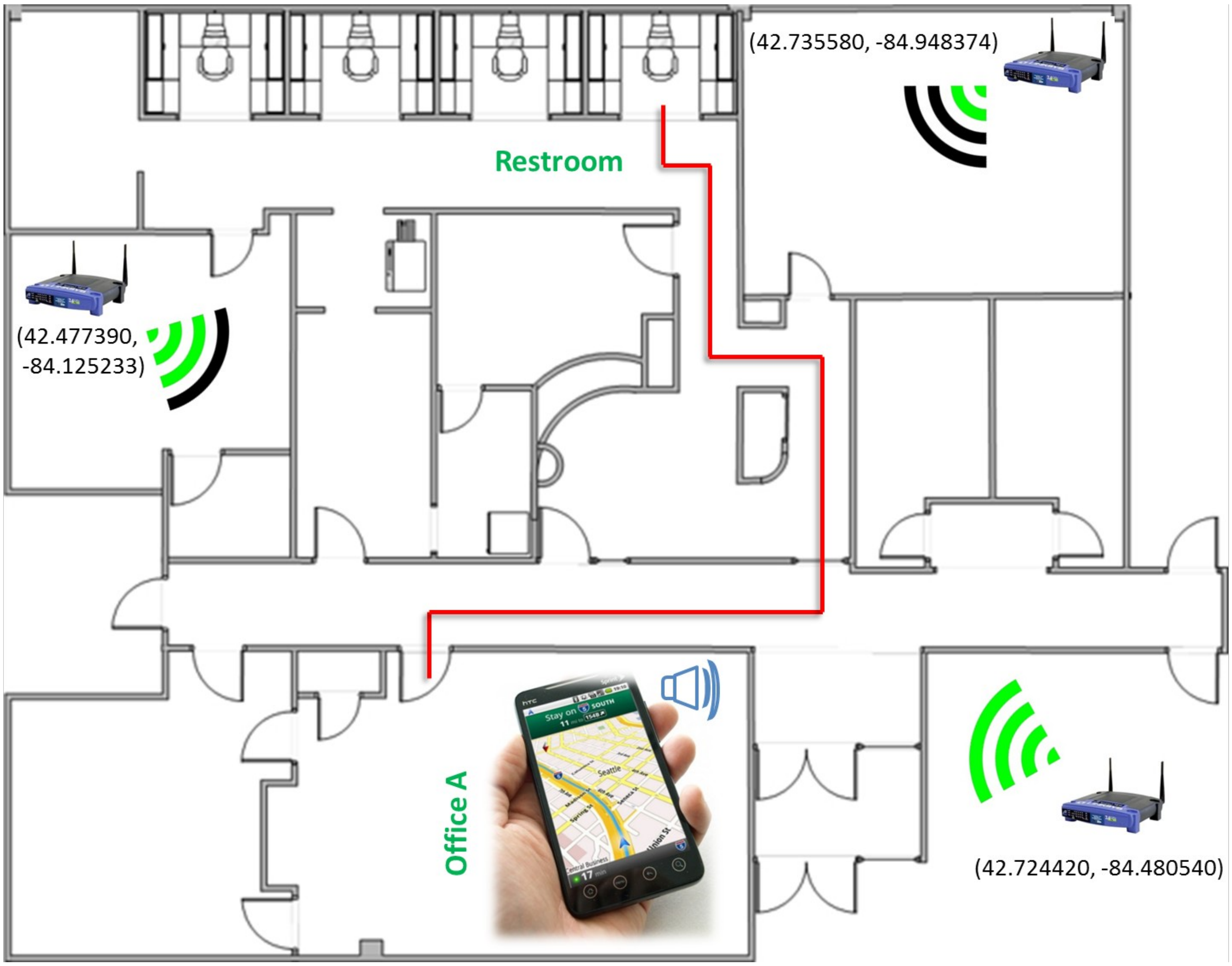


After location is determined, a navigation algorithm may be applied to route a user to a desired destination. This feature may be difficult to implement within the scope of the project but will see completion in the future.

FAST Diagram

Conceptual Design

Figure 2: Conceptual Design for iDOCENT Implementation


(42.735580, -84.948374)
Restroom
(42.477390,
-84.125233)
Office A
(42.724420, -84.480540)

Ranking of Conceptual Designs

Row Labels	Bluetooth Design	Wi-Fi Triangulation	Dead-Reckoning Design	Ultrasonic Receivers
Available Tools	3	2	2	4
Deployment	4	2	1	5
Ease of Use	2	1	3	3
Overall Cost	4	2	1	5
Precision	4	3	4	1
Previous Knowledge	3	1	2	4
Grand Total	**20**	**11**	**13**	**22**

Criteria Rank Legend	
1	Best
2	Good
3	OK
4	Not Good
5	Worst

Proposed Design Solution

It was decided that the most feasible solution for indoor navigation could be accomplished using the Android smartphone platform. The particular accessible smartphones available both featured Wi-Fi capabilities and the processing power to deliver accurate results. The smartphone will scan all access points that in range and determine the signal strength in dBm (or dBmW). The strength measurements are translated into a rating from one to twenty, and the access point's MAC address is compared against a database of known access point locations. All of the quantified location coordinates are uploaded to a separate database and averaging is applied to gain a location of the phone. The more available access points, the more accurate the location reading will be. The calculated position will be displayed on a downloaded map on the smartphone from the MSU mobile server. The map coupled with the calculated location will allow the application to give directions to a desired location.

Test Plan

The first step in testing this design will be to program an Android application to do all of the Wi-Fi scanning and location calculations. This will be done using the Eclipse IDE and the Android SDK libraries. The WifiManager class provides all the functionality to scan and rate WiFi signals.

The next requirement will be to acquire at least four Wi-Fi broadcasting devices and to place them in defined locations around an accurately measured room. These locations will need to be added to the program to calculate the position of the phone. Once the hardware and software are in place the calculated location will be monitored to see the accuracy of this system. If more Wi-Fi devices are available, the accuracy of the system can be tested using more or less access points.

Ultimately, this approach will be applied to a larger scale implementation, such as the Wi-Fi broadcasting devices already in place in the Engineering Building or MSU Union. This will require mapping the respective building and the wireless routers to GPS coordinates. Once this testing is refined to an acceptable tolerance of plus or minus three feet, the navigation aspect of the application can begin.

Once the building and access point GPS coordinates are tolerable, the navigation in and directions to and from a specific location can be determined by making use of Dijkstra's Algorithm. This algorithm will find the shortest path to and from specific points of interest. This can be easily tested by comparing the given path to the path known previously.

Evaluation Plan

The proposed design will be considered successful if it can be demonstrated that this technique can be used to estimate a person's location within several feet inside a room with well defined access point locations. The app should also be able to guide the user around this room to defined points of interest within several feet.

Risk Analysis

The risks assessed are based on the critical path shown in the following project management plan. The plan highlights the fact that the tasks involving Wi-Fi software development, navigation mapping and algorithms, and overall testing all have substantial impacts upon schedule and completion. The analysis of risk was assessed to three key events that pose future challenges and concerns.

Potential Pitfalls			
Task at Risk	Description	Number	Color
Cannot obtain the GPS locations of all access points in the designated building (i.e. Engineering Building, The Union)	Serious, Likely	12	Yellow
Wi-Fi algorithm cannot be refined to specified tolerance (±4 feet)	Major, Low Likelihood	5	Green
Navigation algorithm and specified paths cannot be determined	Serious, Low Likelihood	8	Yellow

Risk Analysis					
Likelihood					
Near Certainty	5	10	15	20	25
Highly Likely	4	8	12	16	20
Likely	3	6	9	12	15
Low Likelihood	2	4	5	8	10
Extremely Improbable	1	2	3	4	6
	Minimal	Minor	Major	Serious	Catastrophic
	Severity / Impact				

Risk Value Legend		
Low	< 5	Green
Medium	> 5 && < 12	Yellow
High	> 12	Red

Table 1: Risk Analysis

Project Management Plan

Task Name	Duration	Start
App Programming	**75.75 days?**	**Mon 2/14/11**
Refine WiFi Algorithm	4.38 days	Mon 2/14/11
Dead Reckoning Consideration	11.38 days	Mon 2/14/11
Navigation	**60.75 days?**	**Tue 3/1/11**
Algorithm	28.38 days?	Tue 3/1/11
Mapping	18 days?	Tue 3/29/11
Testing	14.38 days?	Sat 4/16/11
Audible Feedback	**4.38 days?**	**Mon 3/28/11**
Programming	4.38 days?	Mon 3/28/11
Meet with AI	1.38 days?	Mon 3/28/11
Interfacing with MSU Mobile	**53.38 days?**	**Fri 2/25/11**
Database	4.38 days?	Mon 2/28/11
Contact ATS	4.38 days?	Mon 2/28/11
Overall Testing	53.38 days?	Fri 2/25/11
Deliverables	**101.96 days?**	**Fri 2/4/11**
Pre-proposal	5.33 days	Fri 2/4/11
Final Proposal	21.33 days	Wed 2/9/11
Technology Showcase Poster	86 days	Sun 2/20/11
In-class Presentation	**7.38 days**	**Mon 2/21/11**
Prep	1 day	Sun 2/27/11
PowerPoint Slides	7.38 days	Mon 2/21/11
Website	27 days	Fri 4/1/11
Group Photo	1 day	Sun 2/20/11
FAST Diagram*	29.5 days	Mon 2/14/11
Progress Report	14.38 days	Mon 2/28/11
Notebook Photocopy	1.33 days	Sun 3/13/11
Demo for Facilitator	4 days	Sun 3/20/11
App Notes	29.5 days?	Mon 3/21/11
Technical Lecture	**3.38 days?**	**Sun 4/3/11**
Prep	3.38 days?	Sun 4/3/11
PowerPoint Slides	3.38 days?	Sun 4/3/11
Design Issues Paper	8.38 days?	Sun 4/3/11
Demo 2 for Facilitator	1.38 days?	Sun 4/10/11
Progress Report 2	7.38 days?	Mon 4/4/11
Professional Self-Assessment F	7.38 days?	Mon 4/11/11
Final Report	25.38 days?	Fri 4/1/11
Design Day	**21.38 days?**	**Fri 4/8/11**
Demo Prep	2.38 days?	Fri 4/8/11
Presentation Prep	21.38 days?	Fri 4/8/11
Faculty Invites	1 day?	Mon 4/18/11
Scope the Union	2.38 days?	Fri 4/8/11
Ordering	**4.38 days?**	**Sat 2/5/11**
Router Order from Newegg	4.38 days?	Sat 2/5/11
Meetings	**63.38 days?**	**Fri 2/11/11**
Sponsor Update 1	0.38 days?	Fri 2/11/11
Sponsor Update 2	0.38 days?	Fri 2/25/11
Sponsor Update 3	0.38 days?	Fri 3/25/11
Sponsor Update 4	0.38 days?	Fri 4/15/11

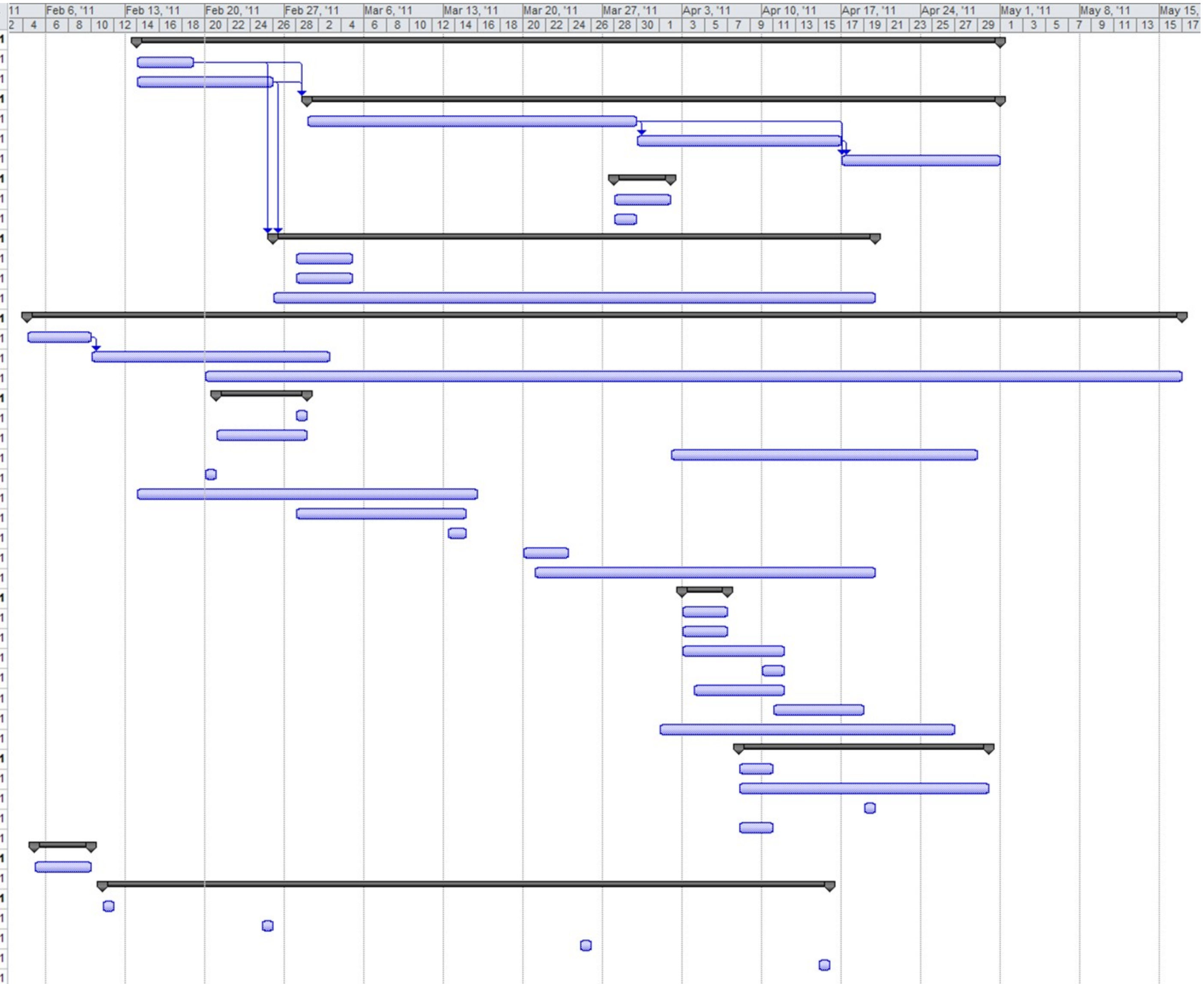


Figure 3: Gantt Chart with Task List

Budget

Row Labels	iDOCENT Costs Sum of Quantity	Sum of Cost	Sum of Total Cost
iDOCENT Hardware	**6**	**$24.99**	**$99.96**
Smartphone for testing	2	0	0
Wireless Routers for testing	4	$24.99	$99.96
iDOCENT Software	**2**	**0**	**0**
Smartphone app	1	0	0
Website Domain	1	0	0
Presentation	**2**	**$34.79**	**$34.79**
Mobile App Presentation Poster	1	$14.79	$14.79
Poster Supplies	1	$20	$20
Grand Total	**10**	**$59.78**	**$134.75**

Financial Analysis	
Description	Amount
Available Funds	$500.00
Enterprise Costs	-$134.75
Extra for Error	$365.25

Table 2: Budget

Bibliography

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