Indoor Navigation System for Vision-impaired Individual

An Application on Android Devices

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***Abstract*— The number of vision disability individuals has been increasing continuously, including those who are totally blind and have low vision. Technology has become a big part of aiding these people but most of the equipments do not provide enough utility and convenience. One of the major problems for those visually impaired individuals is to navigate through indoor buildings without having extra equipment or devices with them. Currently, there is technology for outdoor navigation, such as Google Maps, however navigating through indoor buildings requires further development. This research is developed an application on a mobile device, being used widely in this group of people, with available sensors provided on the devices. Therefore no extra equipment are needed for those visually impaired individuals. The application is a prototype and has been tested to navigate successfully in a single floor of a building.**

Keywords- Application on Android, Indoor navigator, Vision disability individua aid, Indooratlas, Voice command;

I. INTRODUCTION

With the increasing numbers of visually impaired individuals, not only blindness but also low-vision or night blindness, there are limited technology to support them. Even though, the technology has become more advance and provide more tools to aid this group of people, but it usually comes in high cost. Moreover, different tools are designed for different purposes; hence it is becoming difficult for those individuals to take all aiding devices with them all the time.

Smart phones are being used widely among those people with vision disability since they provide an all-in-one ability that can run different applications for many different purposes in a single device.

One of the obstacles in daily life for visually impaired people is to navigate from one place to another, especially in new places they have never been before. Even though, most smart phones provide many applications with GPS access for navigation. However GPS signal cannot be accessed inside the building and this becomes one of the problems for most visually impaired people to be able to navigate easily inside the building.

Additionally, mobile phones are now more capable with a special feature designed especially for them. The feature is called an "accessibility mode" that provides voice over for all texts and some icons on screen which allow the users to interact with the mobile phones.

This paper proposed a prototype application on Android mobile devices to navigation from one place to another inside the building.

II. LITERATURE REVIEW

A. Wi-Fi Positioning System

The Wi-Fi positioning system uses the strength of Wi-Fi signal (RSSI) from the wireless access point (AP) by measuring the intensity of the received signal [1]. The location of the indoor position will be calculated based on the intensity of the Wi-Fi and revert this intensity back to the distance of the location to the access point. The further the location to the Wi-Fi access point the lower the intensity will be. If the location can receive more than one signal, it can combine the intensity from all access points to calculate the location more precisely. The accuracy based on the number of accessed point collected in the database. However, this method needs the access to the MAC address of the access point which many building keeps the address private for security reasons [1].

B. Indoor Navigation with RFID

The radio frequency identification (RFID) is applied to differentiate the location of the object, using the RFID tags attached in the different locations [2] [3]. Each RFID tag will be attached to different objects on the way inside the building for navigation. The user will have stick with an RFID reader to navigate inside the building. If the RFID tag is detected the reader attached to the walking stick can tell where the location precisely with the proximity of 10-15 metres.

For navigation, the walking stick can communicate with the server to calculate the shortest path of the location to the destination easily with the shortest path [2].

This method, however, needs to install RFID tag to many different locations prior to the start of the navigation. It requires skill to properly locate the location to be able to precisely navigate without problems. Furthermore, RFID tags will require extra cost and the RFID reader device will be an extra object that the users have to carry.

The previous research has shown that extra devices and extra information are needed to be able to navigate. Our research will use only a single mobile device for navigation.

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Figure 1: Floor Plan in IndoorAtlas. The grey paths are collected data and the black dots are validated paths (ready for navigate)

III. Methodology

The application uses the third floor of Engineering building, Mahidol University as the prototype location. It can navigate from every location to all 22 rooms on that floor. The application uses a few methodologies to complete the application.

A. IndoorAtlas

IndoorAtlas uses the uniqe megnetic value found in each location to determine the position inside the map with great accuracy, without using external or extra accessories [4]. The location is stored on IndoorAtlas service database[4]. IndoorAtlas requires a graphical map provided by the user to the system. To create a map file, the users will need to have a simple picture with floor plans and uploaded to the system. The positioning is done by the map creater walking on predefined routes to record the megnetic fingerprint of the location. The map creaters will have to test and validate the fingerprint data to confirm the position.

After the positioning of the location is confirmed, the map is ready to use for navigation. Figure 1 hows the confirmed path that the system has recorded the magnetic fingerprint of all locations. Once the location is confirmed, the system can now locate the current position of the user.

B. Dijkstra's Algorithm

Dijkstra's algorithm [5][6] is invented by a computer scientist, named Edsger Dijkstra in 1959. The idea is to solve the shortest path problem to travel from one place to the others by iteratively search for the smallest distance found from neighboring nodes. Figure 2 shows the resulting example from calculating the shortest path with Dijkstra's algorithm from a node *a*. The shortest path from node *a* to node *d* has changed from 6 to 5 because node *d* is connecting to node *a* directly and the distance is 6. After finding that node *b* gives the shortest path to node *a* with the distance 3 and node *d* is the neighbor of node *b* with the distance 2. Therefore, the final shortest path from *a* to *d* is changed to 5, calculating from 3 + 2.

In this research, different nodes are marked in a map. All destination rooms will have a node located in front of them so that the Dijkstra's algorithm can be applied for searching for the shortest route from one place to the final destination.

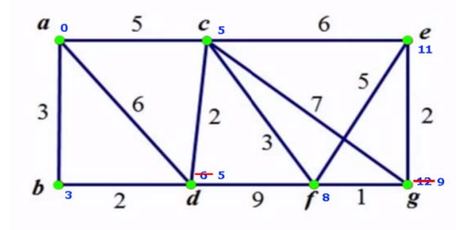

Figure 2: The example shortest path calculation of the Dijkstra's algorithm

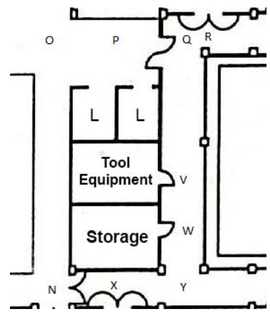

Figure 3 Example of nodes marked on the map, including corners, edges, and rooms

Additional nodes, rather than the ones in front of all 22 rooms, are at the corner and at edges of the map, ranging from the node labeled A to AP. The example of marked nodes that are used in the system is shown in Figure 3Figure 3.

C. Google Voice Recognition

The Google voice API is a free online service by Google [7] to translate the received voice to text. Further to its capability of translating voice from multiple languages into text messages; it also provides with overlay user interface which makes it very useful but does not disturb the main program. The service provides the ability to directly take the voice from the microphone and send to the online service, with a language parameter, and a translated 'text' is passed back to the sender, allowing our application to process the text received from the service to determine the designated location from the users.

IV. The Flow of the Application

The flowchart of the navigation is shown in Figure 4. The flow of the application is divided into 5 steps, A.-E.

A. Locate the current location

The application will communicate with IndoorAtlas to determine the current location and marked the location on the application screen, as show in Figure 5.

This process will take a slight amount of time to initialise the starting location. Once the location is confirmed it will notify the user with the command of the first move for navigation.

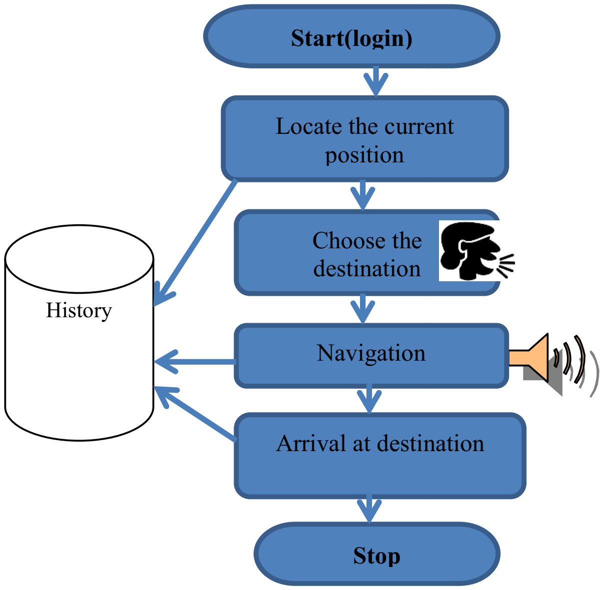

Figure 4: The application architecture.

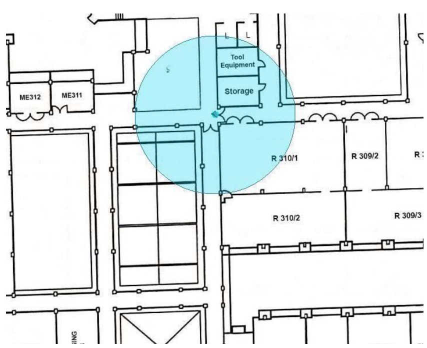

Figure 5: The blue dot inside the circle shows the current location determined by the IndoorAtlas

B. *Choose the destination*

To start navigating, users can select destination by tapping the “Room” button and the menu will popup, as shown in the left panel of Figure 6.

This menu allows the user to choose the destination from all 22 rooms provided on that floor.

This part is compatible with the accessibility mode provided in all Android devices to read out the text from the provided screen. After tapping on each room button, the room name will be read so that the user can choose the room from the screen directly.

Addition to the normal mode of navigation, the voice mode is also available in the application. The user can tap the “Voice” button then the Google Voice Recognition screen will be popuped. After the ready sound, “beep”, the users can start inputing the destination with their voice.

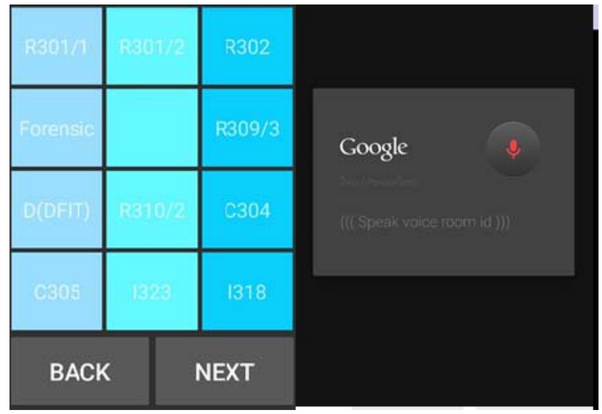

Figure 6 The choice of destination can be done by clicking the destination room on the screen(left) or use your vice to choose the destination(right)

Figure 7 The confirmed location after the voice command has translate to location into text.

For example, a user can say “R302” (in either English or Thai), the program will send the voice too the Google voice service. After the application received the translation the confirmation menu will bepromted, shown in Figure 7.

In the accessibility mode, the confirmed room number will be read and the voice will be alerted after the room number is found. So that users can reassured of the destination room.

C. Navigation

The system will determine the nearest node to the user's current location. When a user request a navigation, the Dijkstra's algorithm will be used to calculate the shortest path from that nearest node of the user to the destination node.

The application will use the compass of the mobile phone to determine the direction of the user therefore the proper adjustment for the direction for the user can be done. The adjustment of the direction is particularly important since visually impaired individual can never know that the location they are facing to. They can accidently face to the wall without knowing, the proper adjustment is very important to avoid any unexpected accidents.

When the navigation is active, the screen will show green arrows on the map pointing towards next upcoming nodes. The path showing in the application is always the shortest path since the program runs Dijisktra's algorithm for every movement of the user. Additionally the user will receive voice explaining of the next step they will have to do. For example, from node A to B is a straight line. The programs will play the voice of "Go straight for [distance] meter". The greens arrows will continue pointing until the destination is reached, as shown in Figure 8. The tipping point of the arrow is the location of the nodes that the users need to walk through. The important nodes are the node at the corner, which will give the sudden change of the direction. These nodes will determine from the direction of the user whether the right turn or the left turn will be made.

Even though, the navigation arrows cannot seen by the visually blind people, it could be used by people with normal vision but not used to the location inside the building.

However, the navigator for the blind could not be completed without voice navigation. In this step, the route will be explained in voice telling the user continuously how to move from that particular location to the next.

The voice used for navigation is separated into different formats as:

- <u>Straight line navigation</u>: The system will repeat voice navigation in every six steps. After the sixth step is reached, the program will recalculate the route and the give remaining distance in metres to the destination or to the next turning point.
- <u>Corner approching:</u> When the user is approaching the corner, the program will immediately tells the user to turn left or right without waiting for the step count.
- <u>Incorrect direction:</u> When the user walks in the incorrect direction 180 degrees compared to the calculated path, the voice "Wrong direction, please turn back" alarms.
- <u>End of the map:</u> When the user walks in to the end of the map, the voice "End of the map" will be warned.

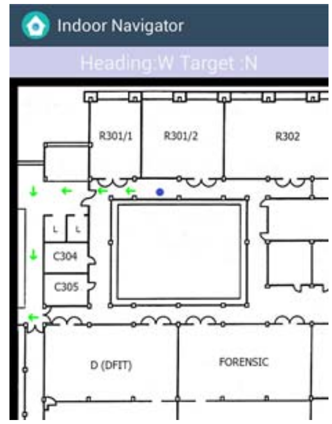

Figure 8:Navigation guideline shown on the screen.

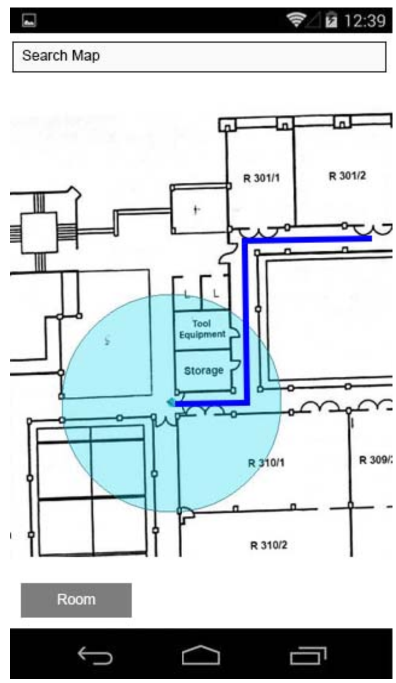

Figure 9 The complete navigation of a single route

D. Arrival to the destination

When the user is in the surrounding area to the destination node, the system will determine the user's direction and the destination. The system will give a voice command to either turn left or right to allow the user to face to the correct direction to the room. Figure 9Figure 9 shows the complete navigation of a single route to the final location.

After the complete navigation, the system will remove navigation system and the recommended path from the screen.

E. Login and history

The login system allow multiple users to login and view their navigation history with details. The login and the register page are shown in Figure 10. The register page allow a new user to fill in their name with user name and password to be able to store their navigation information in the database. Once the user asked to record the location, the application can keep their location and the time record.

Figure 11 shows two different users who have their history stored inside the application. The right of Figure11 shows the detailed record of user “new”.

Figure 11 shows the records of time and the location of the user have been to. The record of the location can be kept all the time either the user uses the navigation or not using. The symbol in the record is also shown as ‘O’ if the navigation system is on during the record. On the other hand, the ‘N’ symbol is used when the destination is not on or the navigation is off.

After implementing this system on a cloud service, it will allow rescue team to easily track and find lost vision-disability people who might have gone to wrong places or possibly ouside of provided map area.

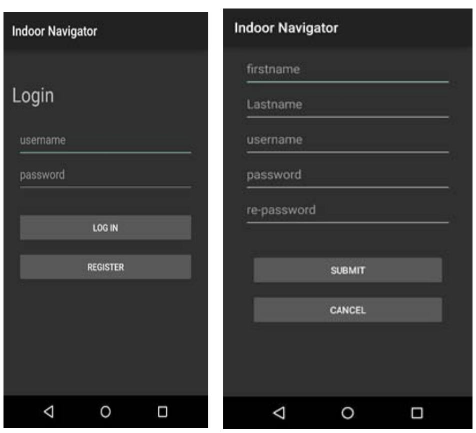

Figure 10: The login and the regis ter page

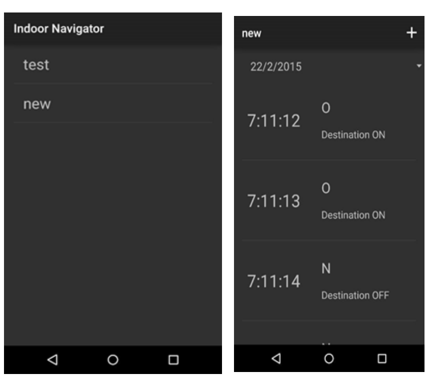

Figure 11 The history page. (Left) The name of recorded userrs in the sytem. (Right) The history of the use "new".

V. EVALUATIONS

To evaluate the application two experiments are designed to test both the efficiency of the program to aid the navigation of the users and the satisfaction of the user to the application. The first experiment is tested on subjects in two groups; people who are new to the location and the visual impaired people who are also new to the location. The experiment is tested repeatedly from the started location, R301/2 to 9 other different rooms, numbering with the alphabet ‘A’ –‘J’.

The navigation time of each person to all locations is recorded. The summary of the time record for the two groups is shown in Table 1 for those people who are not used to the route and Table 2 for those who are visually impaired people.

For the first group, the average time consumed when using the application is 1.62 minutes while those who did not use the application take in average 2.06 minutes. With the application the group used the application took 44 seconds or 21.77% lower on average.

TABLE 1: THE AVERAGE NAVIGATION TIME OF PEOPLE WITH NORMAL VISION BUT NOT USED TO THE BUILDING, COMPARED BETWEEN USING THE APPLICATION AND NOT USING THE APPLICATION.

Destination	**Not** using app. (min)	Using app. (min)
A	0.328	0.198
B	2.17	1.182
C	1.454	1.038
D	1.062	1.116
E	3.382	2.336
F	2.248	2.126
G	2.682	2.208
H	2.85	2.192
J	2.39	2.148
average	**2.06**	**1.62**

TABLE 2: THE AVERGE NAVIGATION TIME OF PEOPLE WITH LOW VISION AND NOT USED TO THE BUILDING, COMPARED BETWEEN USING THE APPLICATION AND NOT USING THE APPLICATION.

Destination	**Not** using app. (min)	Using app. (min)
A	0.306	0.246
B	2.118	1.378
C	1.364	1.108
D	1.212	1.232
E	3.336	3.128
F	3.268	2.198
G	3.262	2.322
H	3.078	2.368
J	2.488	2.296
average	**2.27**	**1.81**

For the other group, the low vision people who do know in the building structures. An average time consumed when walking with the application is 1.81 minutes while those who did not use the application took 2.27 minutes on average. To summarise, those who use the application took 46 seconds or 19.92% lower on average compared to the ones who did not use the application and even faster than the normal vision people who are not using the application. The result shows the usefulness of the application in navigating inside the building. The time consumed is less for all people when using

The other experiment uses a questionnaire to ask all subjects of their experiences to the use of the application. The questionnaire has been divided in 3 main topics. The first one is the convenience to evaluate the ease of use and ease of comprehension of the application. The second one is the accuracy to evaluate the accuracy based on the user understanding. Lastly, the effectiveness is to evaluate the effectiveness that users perceive from getting from the application. Table 3 shows the result form the normal vision people and Table 4 shows the answer from the visually impaired people. The answers are giving in the score, ranging from 0-5. The most satisfactory score will be 5 while the least satisfaction will be given 0.

The overall average satisfactory score from the two groups are 4.58 and 4.35 respectively. The score from visually impaired people is less than the normal vision people mainly in two topics. The first is the destination selection using button on the screen is difficult, which is solved by the use of voice command with high score of satisfaction. The other topic is the accuracy of voice command. If compared to the normal vision people who found the voice command to be more accurate, it may imply that the voice command is in fact accurate but the voice instruction can give a slight delay.

TABLE 3: THE AVERGE SCORE OF THE APPLICATION 1ANSWERED BY NAVIGATION TIME OF PEOPLE WITH NORMAL VISION AND NOT USED TO THE BUILDING. THE SCORES ARE RANGED FROM 0-5.

The convenience	**4.65**
User Interface is easy to understand	5
Choose Destination easily(With button)	4.8
Choose Destination easily(With voice command)	4.8
The navigation is easy to understand	4
The accuracy	**4.46**
The application can lead to the destination precisely	4.2
The voice command to choose the room is accuracy	5
The voice navigation is accurate	4.2
Effectiveness	**4.6**
The effectiveness of the application compared to not using the application.	4.6
Overall average	**4.58**

TABLE 4: THE AVERGE SCORE OF THE APPLICATION ANSWERED BY NAVIGATION TIME OF PEOPLE WITH IMPAIRED VISION AND NOT USED TO THE BUILDING. THE SCORES ARE RANGED FROM 0-5.

The convenience	**4.4**
User Interface is easy to understand	4
Choose Destination easily(With button)	4.2
Choose Destination easily(With voice command)	4.8
The navigation is easy to understand	4.6
The accuracy	**4.2**
The application can lead to the destination precisely	4
The voice command to choose the room is accuracy	4.8
The voice navigation is accurate	3.8
Effectiveness	**4.6**
The effectiveness of the application compared to not using the application.	4.6
Overall average	**4.35**

VI. CONCLUSION

From the results, we can conclude that our application can provide significant improvement to indoor navigating experiences. This application is helpful and can aid almost every group of vision disability individuals with great accuracy. However, there are still rooms for improvement for example; the voice instruction for navigation can be improved to make visually impaired individual more comfortable with indoor navigation or with additional features like navigation between floors or automatically detect when user arrives to the service area. Additionally, the application requires constant internet connection for the use of indoorAtlas service for positioning and Google voice recognition for voice translation. Furthermore, the application cannot detect abnormal object or some changes after the map in initially installed, the use of walking stick is highly recommended for those with visually impaired problem.

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