Indoor Navigation System: An Application on Android Devices

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***Abstract*— Visiting new building without knowing the location well can be very difficult to navigate from one room to the others. Currently, navigation system has been extensively developed for outdoor navigation, such as Google Maps, however not enough has been done for navigation indoor and still needs further development. This research uses magnetic fingerprint inside the building obtained by magnetic sensors embedded in most smart phones to identify the indoor location. The application can also be applied for visually impaired people to navigate freely inside the building without extra assistant. Smart devices are now becoming popular in the visually impaired people with the special mode of to read the screen out for those in need. The application has been tested by both people with normal eye sight and with those with visually impaired individual. As a prototype the application has been shown to be able to navigate successfully on an example floor of a certain building.**

***Index Terms*— Application on Android, Indoor navigator, Vision disability individual, Indoor atlas, Voice command.**

I. Introduction

With many mobile applications for outdoor navigation has been in used widely and successfully with devices with GPS access. However GPS signal cannot be accessed inside the building and it is now one of the biggest problems for identifying the position indoor precisely. This makes the indoor navigation extremely difficult. Furthermore indoor maps are needed to be regularly updated in order to locate all rooms and facilities inside the building correctly. This makes the application development become even more difficult.

Additionally, mobile phones are now become one of the tools for most people with either normal eye sight or the visually impaired vision. For visually impaired people, there is an accessibility mode that is designed especially for them. This mode provides voice for all the texts appear on screen which allow the users to interact with the system with screen reading and multiple special gestures. Smart phones are being popular among those people with vision disability since they provide an all-in-one device that can run different applications for many different purposes in one place.

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

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II. Literature Review

Many techniques have been used for identifying indoor positions. Wi-Fi signal by using the intensity of the signal strength received at each particular location has been used by calculating the possibility of the location to the access point [1]. If the location can receive more than one signal, it can use the intensity from all access point to calculate. The accuracy based on the number of accessed point collected in the database, the more access point the more accurate the position will be. However, this method is the access of the MAC address of the access point which many building kept the address private for security reasons. This can obstruct the application development process.

The radio frequency identification (RFID) can also be used to identify the location of the object [2, 3]. The RFID tag will need to be attached to different positions along the navigation route to be able to identify the location. The more tags are used the more precise navigation system will become. During navigation, the RFID reader will need to be carried in order to identify the current position. The reader can be attached to the walking sticks for the ease of navigation. With this technique, the location can be estimated with the proximity of 10-15 metres.

III. Methodology

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.

a. Magnetic Fingerprint

Inside building structures, there are many types steel and other material creating different deviation to the earth magnetic field. Each location will reveal a unique value of affected by the magnetic field, so-called magnetic fingerprint [4].

b. IndoorAtlas

IndoorAtlas uses the unique megnetic value found in each location together with other sensory devices found in smart phones 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.

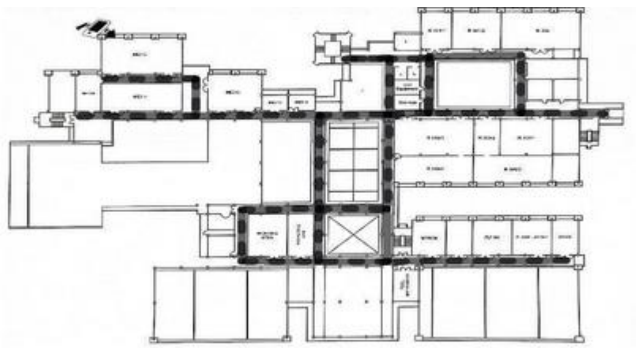

Fig. 1. Floor Plan in IndoorAtlas. The grey paths are collected data and the black dots are validated paths (ready for navigate)

After the positioning of the location is confirmed, the map is ready to use for navigation. Figure 1 shows 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.

c. Dijkstra's Algorithm

Dijkstra's algorithm [5,6] 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 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, calculated 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.

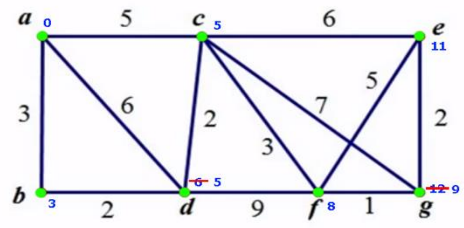

Fig. 2. The example shortest path calculation of the Dijkstra's algorithm

d. 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.

IV. Application Architecture

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.

The flowchart of the navigation is shown in Figure 3. The flow of the application is divided into 4 steps, (A)-(D).

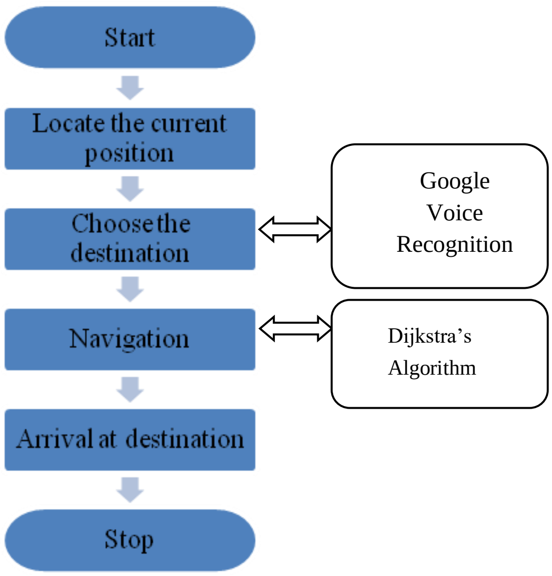

Fig. 3. The application architecture.

a. Locate the position

The application will communicate with IndoorAtlas to determine the current location and marked the location on the application screen. This process will take a few seconds to initialise the starting location. Once the location is confirmed it will notify the user with the command of to start the navigation.

b. Choose the destination

To start navigation, users can select destination by tapping the "Room" button and the menu will popup, as shown in Figure 4(a). 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 without looking at the screen.

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 shown, allowing the application to translate the location provided by voice from a user to text by using the service to determine the designated location. After the ready sound, "beep", the users can start inputing the destination with their voice.

Figure 4(a) Figure 4(b)

Fig. 4. (a)The choice of destination can be done by clicking the destination room on the screen (b) voice recognition service to choose the destination

c. Navigation

The application has predetermined the nodes in front of every room in the system and at the corner and at edges of the map with the labeled A to AP.

During 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 using Dijisktra's algorithm.

When the navigation is active, the screen will show green arrows on the map pointing towards next upcoming nodes. The shortest path will be calculated constantly in every movement of the user to ensure the best path is always provided despite incorrect movement has been made. Additionally the user will receive voice explaining of the next step they will have to do.

- Straight line navigation

The programs will play the voice of "Go straight for [distance] meter". The greens arrows will continue pointing until the destination or the turning point are reached. 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.

- Turning points

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. 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.

- Incorrect direction

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. When the user walks in the incorrect direction 180 degrees compared to the calculated path, the voice "Wrong direction, please turn back" is used.

- End of the map

When the user walks in to the edge of the map, no further position has been recorded previously, the voice "End of the map" will be warned.

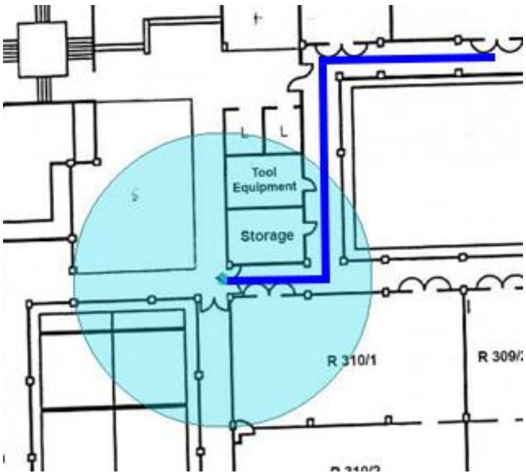

Fig. 5. The complete navigation of a single route

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 5 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.

V. Evaluation

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, a single location to 9 other different rooms, numbering with the alphabet 'A' –'J'.

The navigation time of each person to all locations is recorded. The efficiency of the application is calculated by equation (1).

$$\text{Efficiency} = \left(\frac{T_{without\_application} - T_{with\_application}}{T_{without\_application}}\right)*100\% \quad (1)$$

$T_{without\_application}$ is amount of time used when not using the application, while $T_{with\_application}$ is the time used when using the application. The efficiency shows the improvement in term of time when the application is used.

The efficiency of the two groups is used for those people who are not used to the route and for those who are visually impaired people. The results are shown in Table 1.

For the first group, the efficiency is 21.77% on lower on average. For the other group, the low vision people who do know in the building structures. An average efficiency is 18.92% on average compared to the ones who did not use the application. It can be implied that it is even better compared to 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 application. Only Destination 'D' gives less efficiency because the place is very close to the starting point, therefore time for initializing the program make the overhead of time become longer.

TABLE I

The Application Efficiency navigation time of people with normal vision but not used to the building, compared between using the application and not using the application.

Destination	**Normal vision**	**Visually impaired**
A	39.63%	19.6%
B	45.52%	34.94%
C	28.61%	18.77%
D	-5%	-1.65%
E	30.92%	6.24%
F	5.43%	32.74%
G	17.68%	28.82%
H	23.10%	23.10%
J	10.13%	7.72%
average	**21.77%**	**18.92%**

On the other experiment a questionnaire is used to ask all subjects of their experiences to the application. The questionnaire has been divided in 3 main topics, which are the convenience, accuracy and effectiveness. Table 2 shows the result form the normal vision people and 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 II

The average 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.

	Normal vision	**Visually impaired**
Convenience	**4.65**	**4.4**
User Interface is easy to understand	5	4
Choose Destination easily(With button)	4.8	4.2
Choose Destination easily(With voice command)	4.8	4.8
The navigation is easy to understand	4	4.6
Accuracy	**4.46**	**4.2**
The application can lead to the destination precisely	4.2	4
The voice command to choose the room is accuracy	5	4.8
The voice navigation is accurate	4.2	3.8
Effectiveness	**4.6**	**4.6**
The effectiveness of the application compared to not using the application.	4.6	4.6
Overall average	**4.58**	**4.35**

VI. Discussion

From the results, we can conclude that our application can provide significant improvement to indoor navigating experiences. This application is helpful and can aid not only normal vision people but also vision disability individuals with great accuracy. However, there are still rooms for improvement for example; 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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