An iPhone-Based Device to Give Surrounding Area Information for Guiding Tourist or Aiding Visually Impaired

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Abstract

The data from National Statistics Office (NSO) of Thailand show that 543,332 people in Thailand are blind or visually impaired (2007). Even though, many navigation devices are made for visually impaired people, the vast majority of the devices are expensive and available only in some country. Therefore, iPhone, which is one of the most popular GPS-enabled smart phones today is selected as a platform for the development of the navigation system for the blind and visually impaired.

The navigation map is limited to 500 acres of Mahidol University, Salaya Campus. This navigation devices is not only used by a visually impaired person, but can also be used for a self-guided audio campus tour. By pointing iPhone to any direction of interest, it can give information of the building in the nearby range and provides distance, direction and information of the building on screen and voice.

To identify a distance and a direction of a building to the user, a novel navigation algorithm for local area, where a building or place cannot be represented as a point, was developed. The algorithm includes two main parts. The first part is a marking process, in which multiple points are manually selected to represent corners of the area encloses a building or place. Then the centroid of the area is calculated and used as the center of the building to determine the location of the building with respect to the user. The second part is a navigation algorithm, which determines a nearby building in each direction by splitting the area around the user into 4 sections with an X shape. In case that an area of a building fall into multiple sections, the algorithm can determine the direction of the building or inform that the user is already inside the building correctly.

Key Words: GPS Navigation, Visually Impaired, Blind, iPhone-Based, Visual Aids

1. Introduction

The data from National Statistics Office (NSO)[3] of Thailand that Thailand has 1.9 million people with disabilities from the total population 65.6 million people or 2.9%.Among those disabilities, 543,332 people are visually impaired. People with visual impaired have inconvenient living in most activities such as walking, finding places, communication, etc. In Thailand, there are organizations and associations to help those people. There are a lot of city infrastructure and supporting systems waiting to be improved to make their living easier.

In term of navigation, good-eye people use eyes to avoid obstacles, to read, to identify locations and direction to a destination. To aid the visually impaired people with the needs above, there are many supporting devices available such as an audible book, DAISY (Digital Accessible Information System). In 2006 T.Ueda et al.[9] designed and developed a sensor for creating 3D images of the surrounding obstacles to alert its user for walking safety. In 2006, A.Cassinelli et al.[8] researched and designed a device to alert its user with vibration from a headband when there is an object proximity, so that the user can avoid crashing accident. In 1997, J.Borenstein and I.Urich[4] designed an electronic guiding cane that can navigate by using a sonar sensor for detecting nearby objects or obstacles. In Europe, European Space Agency is an important agency, which is the center for research and development of navigation devices for people with visually impaired by using maps to navigate[1].

The above data suggest that many people try to develop the navigation devices to increase convenience and safety for visually impaired people. But these navigation devices are tailor-made designed for a small group of people and specific applications, which make them expensive and inaccessible. However, there are many consumer navigation devices available in the market, but they cannot be used for visually impaired due to the following limitations:

- Most devices are made for car navigation, not suitable for walking.
- It cannot give surrounding area information that the user need for self-orientation.
- Only manufacturers can develop program.

The development of navigation system on iPhone will be even more widely used because it is a consumer electronic product. This allows developers to implement their idea into practice and publish to end users in very short time and little cost.

2. Methodology

This research developed the navigation system by using iPhone because iPhone is a common smart phone that has many built-in sensors needed for navigation such as a global positioning system (GPS), an electronic compass, and accelerometer, and a gyroscope (only available in iPhone 4 for better orientation measurement). To develop a navigation system from iPhone, the following tasks were performed.

- Creating maps of Mahidol University, Salaya Campus.
- Programming to communicate with sensors on iPhone to define and identify the current phone's location and orientation.
- Developing an algorithm to determine the surrounding buildings in the key directions, and testing the result with users.
- Programming to display locations of surrounding places and buildings by both on-screen display and screen reading.

3. System Design

This developed navigation system, once completed, can inform its user names and direction of surrounding buildings and places. The system design, therefore, is developed according to such requirements. From the Fig. 1, the programming is divided into three parts, the user interface, data processing and information display. The system must be able to display both on-screen information and sound to facilitate the use of visually impaired persons.

Fig.1 System Design

The user interface is divided into two modes. The first mode, a simple on-screen display with large buttons and screen reader is designed for visually impaired users. The second mode for good-eye (maybe tourist) users, the screen shows pictures of surrounding buildings for self-guided tour application. Once the user interacts with the device, by pressing or moving around, data processing is taken place. The system updates distance and direction of surrounding buildings from the sensors and map, and makes decision of which buildings to be displayed to the user. Once the user clicks on a building shown on-screen, the system displays the building information in two modes with respect to the selected user interface. In good-eye mode, the information and image can be shown in multiple pages for more information. In visually impaired mode, the information will be shown both on the screen and sound, which allows visually impaired persons to understand the information.

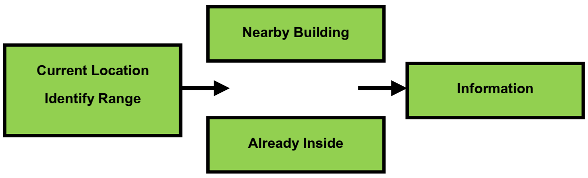


Fig. 2 Steps of Data Processing

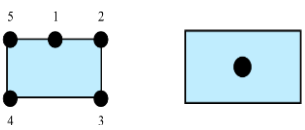
Fig. 2 shows the detail steps inside data processing. From the Fig. 2, when the program starts the device will identify the current location and the building in range. The algorithm is determines building in key directions (front, rear, left, and right) and whether the user is inside any building already. The device calculates and updates the distance, direction and information of the building.

4. Algorithms for Data Processing

Coordination system and algorithms are the key factors that will make navigation more efficient. In this part, algorithms to identify surrounding buildings and display only selected information to users will be described.

4.1 Marking Building Coordinates

Coordinates are manually selected from the important points to represent a building. Selections of marked coordinates were compared by a test that which model can determine directions of a building correctly. From the Fig. 3(a), a building is represented by a square. The first point is the first main entrance of the building. The second through the fifth coordinates are set in clockwise order to all four corners of the building. In the Fig. 3(b), the centroid of the building is computed.



(a) (b)

Fig. 3 Coordinates Marking

4.2 Obtaining Distance and Direction toward Buildings

Aviation formulary used in the calculation to determine the distance and direction of the coordinates at different positions. Aviation formulary is one of the equations relating to the great circle, which is used in the calculation of the coordinates on the surface of a sphere. Calculating the distance between two points in short is the different between the coordinates, but the surface of the earth is not flat, it must be a great circle by following equations.

Great circle distance between two points

$$d=\arccos(\sin(lat_1)\sin(lat_2)+\cos(lat_1)\cos(lat_2)\cos(lon_1-lon_2)) \quad \text{Eq. (1)}$$

Great circle from A to B at A

if

$\sin(lon_2-lon_1)<0$

$$tc1=acos\frac{((\sin(lat_2)-\sin(lat_1)\cos(d))}{(\sin(d)\cos(lat_1)))} \quad \text{Eq. (2)}$$

else

$$tc1=2\pi-acos\frac{((\sin(lat_2)-\sin(lat_1)\cos(d))}{(\sin(d)\cos(lat_1)))} \quad \text{Eq. (3)}$$

for

d	Distance of the coordinates(rad)
lat1	First latitude coordinate
lat2	Second latitude coordinate
lon1	First longitude coordinate
lon2	Second longitude coordinate
tc1	Course out of First Coordinate(rad)

Calculating the distance between two coordinates can be done to know the current coordinates and destination coordinates by substituting values into the Eq. (1)

The direction of the target coordinates relative to the current coordinates can be calculated from the Eq. (2) or Eq. (3). Directions between two coordinates are in degrees. Comparing bearing of building B with building A is shown in the Fig. 4.

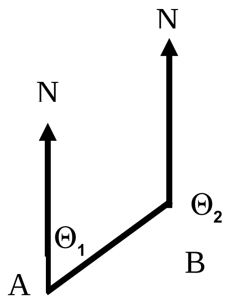


Fig. 4 Bearing Angle

4.3 Determining Which Buildings are in the Key Direction.

By applying an “x”-shape mask on top of the map, we can identify buildings in the key direction: that is front, rear, left and right. In the Fig. 5, the top view of the key directions around the user will be divided into four angles in 360°. The first angle started from 315° to 359.9° and 0° to less than 45°. The second angle started from 45° to less than 135°. The third angle started from 135° to less than 225°. And the fourth angle started from 225° to less than 315°.

In the Fig. 6, if the dashed arrow represents the direction of the user or pointing device. Forward direction is defined as the first angle. Rightward direction is defined as the second angle. Backward direction is defined as the third angle. And leftward direction is defined as the fourth angle.

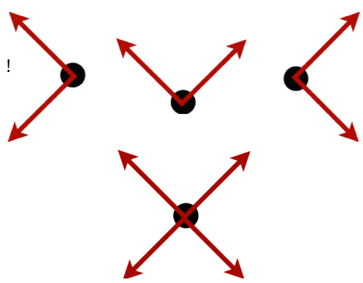


Fig. 5 Orientation Marking

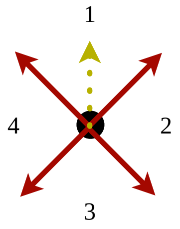


Fig. 6 Top View User

In the Fig. 7, when user moves or turns in different directions, the mask is translated or rotated. Surrounding buildings on each direction must be re-computed.

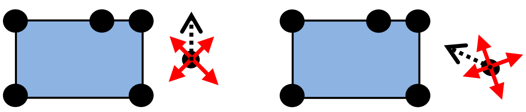


Fig. 7 Mask Rotation

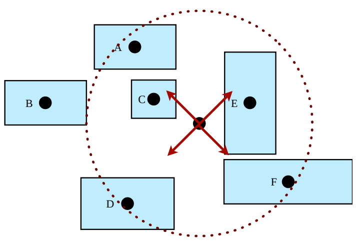


Fig. 8 Calculation Range

An only building within a certain range from the center of the most is considered to reduce burden of calculation. For example, the scenario In the Fig. 8, the program selected on buildings A, C, D, E and F.

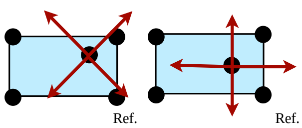


Fig. 9 Rotation Mask

4.4 Determining Whether the User is Inside a Building

Not only for the building in each direction around the user the algorithm will determine the building or inform that user is already inside the building correctly. In the Fig. 9, by rotating the mask with respect to the map, the direction of the mask will be parallel to the building of interest. If four corners of the building are in each angle, the program will show that the user already inside on the user interface.

4.5 User Interface

Interface of the program are created by tool in xcode developer. Interface is divided into two modes. In the Fig. 10, the visually impaired mode was designed with large buttons and easy to use for the visually impaired. When the user touches a button, the program will provide information by voice. In the Fig. 11, the good-eye mode can show more buildings which are not limited to the nearest buildings. When the user clicks on the building, the information will be shown in multiple pages in the Fig. 12.

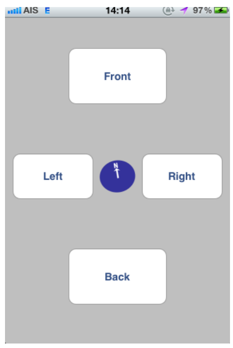


Fig. 10 Interface for Visually Impaired

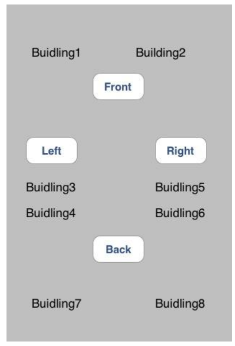


Fig .11 Interface for Good-eye User

Fig. 12 Interface for More Information for Good-eye User

5. Testing Result

The test is divided into two parts. The first part is tested to determine the distance and direction of surrounding buildings. The test based on the different marking coordinates. The second part is a testing to check whether user already inside the building.

5.1 Testing Algorithms to Determine Which Buildings are in the Marking

Four cases of coordination systems that are used to represent buildings are compared. The first case uses five points that consist of one point at a main entrance of the building, and the other four points at four corners of the building. The second case uses four points at the four corners of the building. The third case is determined by one point at the main entrance of the building. The last case is determined by only point at the centroid the building area.

Case 1: 5 points, first point is entrance, second-fifth points is corners

Case 2: 4 points, first-fourth points is corners

Case 3: 1 point is entrance

Case 4: 1 point is centroid

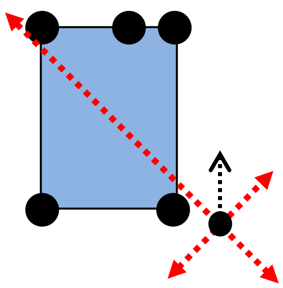


Fig. 13 Case 1 Testing

Result of Case 1: The program will check the direction of building with five points marking. Algorithm will identify the points on each angle of the mask. Algorithm will also identify the direction of the building from the angle on the mask with the most points. In the Fig. 13, algorithm will determine that the building in the forward direction.

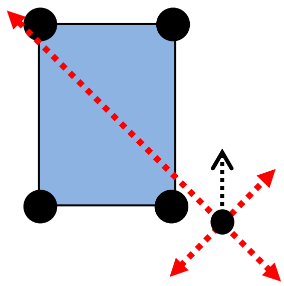


Fig. 14 Case 2 Testing

Result of Case 2: The program will check the direction of the building with four points marking. The building will be made on four corner of the building. Algorithm cannot identify the direction of the building, because there are the same numbers (two) of points on each angle of the mask as shown in the Fig. 14.

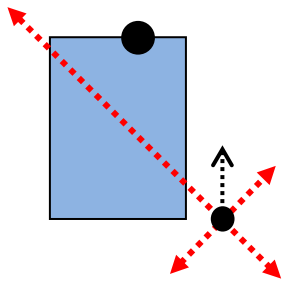


Fig. 15 Case 3 Testing

Result of Case 3: The program will check the direction of building with entrance point marking. It is easy to use a single point to determine the direction of the building on the mask. In the Fig. 15, algorithm will determine the building located in forward direction.

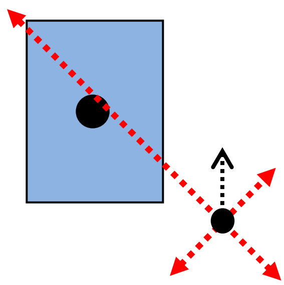


Fig. 16 Case 4 Testing

Result of Case 4: The program will check the direction of building with centroid point marking. It is easy to use a single point to determine the direction of the building on the mask. In the Fig. 16, algorithm will determine the building located in leftward direction. By using a centroid point to indicate direction of the building with respect to the user, it gives the most accurate result when compared with other methods. In the Fig. 17, program shows that the building is on the left, where the area of the building is represented by the yellow shade on the left side of the mask. Most of the building area is on the left side as well.

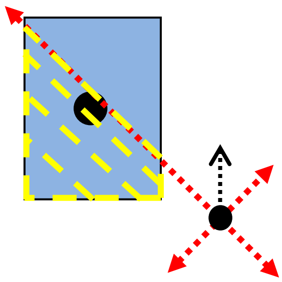


Fig. 17 Case 4 Comparison of the Area

5.2 Testing Algorithms to Determine Which the User is Inside a Building

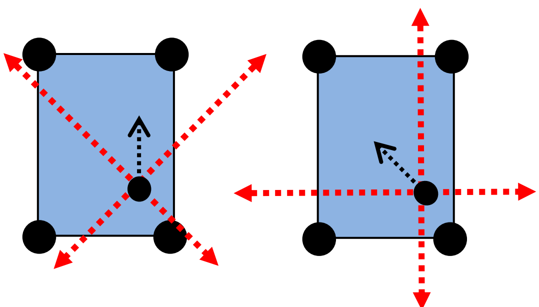


Fig. 18 User is Inside Building Test

The algorithm can inform that the user is already inside a building. This Information will reduce confusion from keep telling the user direction even though the user is already inside but not aware. In the Fig 18, the algorithms apply a "+"-shape mask on top of the map. If the user is inside a building, each of the four points at the corners of a building must fall on each quadrant.

6. Conclusion

The device cans correctly determine the direction of the surrounding buildings by using centroid point of the building areas. Good-eye (tourist) mode will provide names, pictures and information of buildings surrounding the user. Visually impaired mode provides only one selected the building name for each direction on screen and voice. Once inside a building, the user will be alert. The surrounding area information given by the device allows visually impaired persons to be self-supported in familiar places, and allows tourists to self guide and learns about new places and surrounding areas.

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