NavTU: Android Navigation App for Thai People with Visual Impairments

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Abstract—**This paper introduces a new Android navigation app called NavTU for Thai people with visual impairments. Our NavTU app is designed to promote safe and independent travel for Thai people who are blind or have low vision. It is the integration of the GPS-based and camera-based technologies that not only helps the blind pedestrians navigate outdoors from place to place but also locates obstacles such as concrete electric poles, so that the visually impaired can avoid walking into them. The main advantage of NavTU is that the users are allowed to record their own walking paths to the preferred locations. This enables the blind users to walk through any local roads that might not be shown on Google Maps. The blind pedestrians can plan any outdoor path that is convenient and safe to them. The proposed app has Thai as the natural language interface, so it is easy for Thai people with visual impairments to use.**

Keywords—Android apps; blind navigation; GPS devices; mobile phones; obstacle detection

I. INTRODUCTION

The Thai Ministry of Social Development and Human Security reports that the number of visually impaired persons in Thailand has increased from 112,615 in 2010 to 188,050 in 2017 [1]. This number is expected to grow significantly in the near future. A large number of the visually impaired cannot live their daily lives independently and depend on people with normal vision for navigation. Thus, there is an urgent need for assistive technology to help the blind or the visually impaired overcome these challenges and maintain their independence.

Current navigational technologies for people who are blind and visually impaired [2] can be roughly categorized into sonar-based, vision-based, and GPS (global positioning system)-based. Each technology has its strengths and weaknesses. For instance, sonar-based devices [3], [4] can perform well in the dark and rain but are unreliable for use in crowded places. Vision-based devices (using cameras or lasers) [5], on the other hand, capture and interpret environmental information including signs and obstacles and provide navigation based on specific landmarks. They operate well both indoors and outdoors but fail under low luminance. GPS devices [6], [7] can retrieve location information in all weather conditions but is subject to poor satellite signal conditions. Thus, they cannot work indoors. Due to the shortcomings of each technology, effective blind navigation needs the combination of several technologies. In addition, these navigational devices for the blind are rather expensive, ranging from $800 to $2,199.

This work proposes using smartphones as tools in blind navigation, since most smartphones include many navigational devices, such as compasses, digital cameras, GPS trackers, and maps. Furthermore, the portability and price of a smartphone make it very attractive for daily life activities of the blind. Mobile navigation apps for people with visual impairments often rely on a GPS device to give turn-by-turn directions to the destination. Popular commercial GPS navigation apps for the blind and visually impaired include Nearby Explorer [8], The Seeing Eye GPS [9], and BlindSquare [10]. Nearby Explorer is a GPS app that installs onboard maps for the United States and Canada on the phone, so a data connection is not required. It lets the users select from several different locations on the map and provides navigation including street name and address. The Seeing Eye GPS uses Google Maps for navigation and employs the local search-and-discovery service Foursquare to show points of interest. The users need a data connection to access most features on the Seeing Eye GPS. BlindSquare uses the free third-party navigation apps including Apple Maps and Google Maps to provide turn-by-turn directions. It is thus less expensive than the other two apps. We note that these apps are not available for sale in Thailand, for they have no Thai language or Thailand maps. Thus, there is a need for a Thai navigation app for the blind and visually impaired.

This paper introduces a new Android navigation app called NavTU for Thai people with visual impairments. The proposed app is the integration of GPS-based and vision-based technologies for blind navigation. It utilizes the compass, the accelerometers, and the GPS tracker to provide turn-by-turn outdoor navigation and uses the primary camera to detect the presence of obstacles such as concrete electric poles and walls. Since the GPS devices can provide positional information on the order of up to 10 m accuracy, our app should be used with a cane for guidance. The app has Thai as the natural language interface. To the best of our knowledge, our app is the first of its kind available for Thai blind users. Our main goal is to improve quality of life for Thai people who are blind or have low vision.

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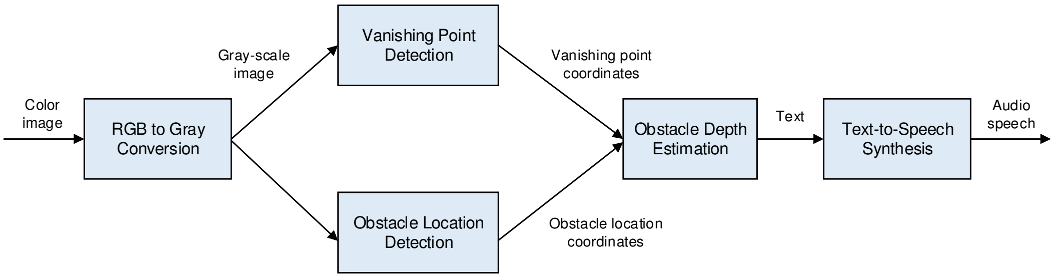

Figure 1. An example of detection of the vanishing point and the pole location on the ground using digital image processing techniques.

The paper is organized as follows. In Section II, we review digital image processing techniques used to locate obstacles for blind pedestrians. Section III describes our NavTU app for blind navigation. Experimental results and conclusions are discussed in Section IV and Section V, respectively.

II. Obstacle Detection Techniques

As noted earlier, our NavTU app uses the primary camera (vision-based device) of the smartphone to capture environmental information during navigation. Locating obstacles such as concrete electric poles generally found in sidewalks in Thailand is important, so that the blind can avoid walking into them. Fig. 1 shows the block diagram of the obstacle (pole) depth estimation system from a single outdoor image. First, a color image captured by the smartphone camera is converted into a gray-scale image *Im*. This image *Im* is used to detect a vanishing point and pole location coordinates on the image. These coordinates are needed for calculating the depth information of obstacles in the world coordinates. The depth information are then converted into audio speech for the blind navigators. The following subsections discuss the digital image processing techniques used to locate the concrete poles in the sidewalks from an image in detail.

A. Vanishing Point Detection

First, the gray-scale image *Im* is smoothed for noise reduction [11]. We detect all edges in the resultant image using the Canny edge detection [12] to obtain the edge image *Ed*. The Canny edge detection is a well-known method that provides accurate and strong edge detection. Next, we locate dominant straight lines in the edge image *Ed* by using the Hough transform [13], [14]. These straight lines that are not horizontal or vertical tend to intersect at a point called a vanishing point [15], which is often found in city scenes. An example of a detected vanishing point is shown on Fig. 2.

B. Obstacle Location Detection

The gray-scale image *Im* is used to detect concrete electric poles in sidewalks. We perform global thresholding to segment the poles from the background. The threshold value is chosen ad hoc. The resultant binary image is then morphologically processed to remove any false alarms. The image

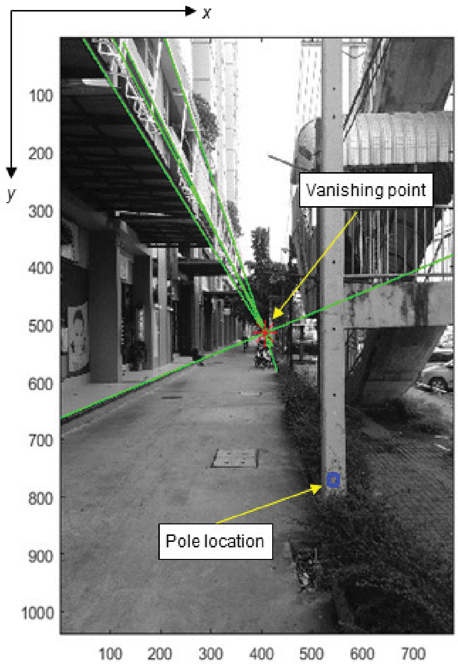

Figure 2. An example of detection of the vanishing point and the pole location on the ground using digital image processing techniques.

coordinates of the electric poles on the ground plane are then located (see Fig. 2).

C. Estimating the Depth of Obstacles

To understand the depth information of obstacles, we construct a plan view of the ground plane. Assume that the vanishing point and the pole location on the ground level are at the image coordinates (x_{vp}, y_{vp}) and (x_{pl}, y_{pl}), respectively. The depth Z in the scene in the world coordinates can be found in terms of the image coordinates as follows [16]:

$$Z = \frac{Hf}{y} \tag{1}$$

where H is the height of the camera above the ground and f is the focal length of the camera lens. Here, the distance y in the image plane in (1) is equal to $(y_{pl} - y_{vp}) \times \mu$, where μ is the pixel size of the camera. The lateral distance X in the world coordinates is given by:

$$X = \frac{Hx}{y} \tag{2}$$

Similarly, the distance x in the image plane in (2) is equal to $(x_{pl} - x_{vp}) \times \mu$. Given the distances Z and X, we can easily calculate the distance and direction between the concrete pole and the visually impaired. Audio cues can thus be given, so blind pedestrians can determine which paths are suitable for travel.

III. THE NAVTU APP

In this section, we describe in detail the components of the NavTU app that are designed to assist the visually impaired for navigation.

A. *System Requirements*

NavTU runs on the Android smartphones version 4.0 or later. The Android mobile operating system includes Google TalkBack that helps people with visual impairments interact with their phones. NavTU requires approximately 70 MB for installation, and 1 GB of RAM is recommended. The smartphones must have GPS devices, accelerometers, compasses, and primary cameras used for navigation. In addition, internet connection is required if the users choose to use voice commands.

B. *Functional Descriptions*

The main page of NavTU provides four modes of operation, Navigation, Path Recording, Deletion, and Setting, as shown in Fig. 3. These modes operate as follows.

1) Path Recording: Before the NavTU app can provide navigation, the users are asked to record walking paths to their destinations. The blind or visually impaired are expected to commute to the same nearby places in their daily lives. Thus, our app requires the users to enter the name of the destination by typing or speaking though voice command (see Fig. 4). After the location name is entered, NavTU starts recording the walking path from the current location to the destination. In order to perform path recording, a person with normal vision is needed to help the blind record and walk to the destination. An example of a walking path recorded via GPS locations is shown in Fig. 5. As seen in Fig. 5, when the users arrive at the destination, the system asks the person with normal vision to confirm whether or not the walking path shown is acceptable. The advantage of Path Recording is that the users are able to walk through any local roads that might not be shown on Google Maps. The blind pedestrians can plan any outdoor path that is convenient and safe to them. NavTU is thus different from prior blind navigation apps in this aspect. The customized walking paths are stored in the database for use in navigation.

Figure 3. The main page of NavTU shows four modes of operation, Navigation, Path Recording, Deletion, and Setting in Thai.

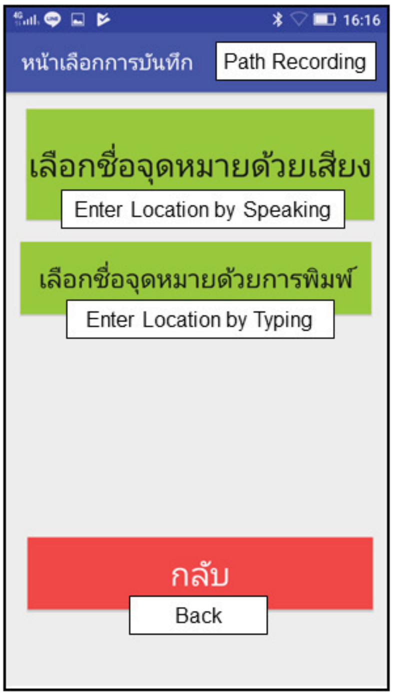

Figure 4. The Path Recording mode allows the users to enter the destination name by either speaking or typing. After the name is entered, the system starts recording the walking path to the destination via GPS locations.

Figure 5. An example of the walking path recorded from an academic building at Thammasat University to a nearby dormitory in Pathumthani, Thailand. The system askes the user to confirm the path before storing it to the database.

Figure 6. The Navigation page shows the destination name, the walking direction, the remaining distance, the nearby places, and the locations of detected obstacles.

2) Navigation: When the users select their preferred location, the system finds the current location of the users and checks whether or not there is a walking path from the current location to the destination stored in the database. If there is no stored path, the request is denied. If the walking path to the destination is found, the system uses the GPS-based and vision-based technologies to provide direction commands for the blind users. During navigation, the blind users are advised to hold smartphones on their one hands and canes on the other hands for their safety. With the GPS coordinates of the phone location and the walking path to the destination stored on Google Maps, the app uses the compass and accelerometers to find the directions that need to be taken. The directional audio cues such as "move forward 50 meters", "turn around", and "turn left at 30°" are then given to guide the blind pedestrians to the chosen location. In addition, the primary camera of the smartphone is used to capture environmental information, and the obstacle detection techniques (see Section II) is employed to locate obstacles during navigation. Fig. 6 shows an example of the Navigation page of NavTU. As seen, the Navigation page provides turn-by-turn walking directions for the blind pedestrians to walk to the selected destination. The users are informed when they are near known locations, and the remaining distance is also shown.

3) Deletion: The Deletion operation is used to discard any locations that are no longer needed. In other words, the users will never go to the selected locations in the future. This allows the users to efficiently manage their databases.

4) Setting: The Setting operation contains options for the users' preferences. For example, to improve the accuracy of the global position information, one may combine position information from both the GPS and GLONASS satellite constellations. The Setting operation is used to wirelessly pair the smartphone with a GPS/GLONASS receiver device using Bluetooth technology.

IV. Experimental Results

To measure the performance of NavTU, we recorded the accuracy of the GPS device and the obstacle location detection system. Using the same smartphone, we recorded the latitude and longitude coordinates of the same locations at different times. We found that for the same locations, the coordinate differences were between one and five meters. This is expected, since the GPS accuracy is sometimes not precise when the users are walking under dense foliage or between tall buildings. Furthermore, the GPS accuracy strongly depends on the GPS receiver in each smartphone.

The accuracy of the pole location detection system can be easily measured. We compared the estimated distances to the pole locations of 10 poles by our system with the actual distances measured by a tape measure. We found that our estimated distances were off by less than one meter. The errors occurred because the vanishing point and pole location detections were not accurate due to noise and varying illumination in the images.

V. CONCLUSION

NavTU designed to promote safe and independent travel for Thai people with visual impairments is currently available for free download at http://nawin.ece.engr.tu.ac.th/navtu/#download/.

The main contributions of NavTU are briefly summarized as follows:

- NavTU is for Thai people with visual impairments. Its natural language interface is Thai.
- The users are allowed to customize their own walking paths in the Path Recording mode. These paths might not be found by Google Maps Navigation.
- NavTU is an Android app that combines the GPS-based and camera-based technologies for blind navigation. There is plenty of room for improvement in NavTU using the camera-based technology for navigation.

NavTU is currently being tested by students with visual impairments at the Bangkok School for the Blind, Bangkok. The limitations of NavTU include failures to detect stairs, steps, or any moving objects such as motorbikes and cars. Furthermore, our obstacle detection techniques fail under low luminance. Thus, a blind user is advised to navigate with caution and to use a cane for his/her safety.

Our future work will improve upon the vision-based techniques to detect more objects such as steps on the sidewalks and pedestrian overpasses. This should ensure safe travel for Thai people with visual impairments.

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