GPS Navigator for Blind Walking in a Campus

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***Abstract*—**We developed a GPS-based navigation device for the blind, with audio guidance in Thai language. The device is composed of simple and inexpensive hardware components. Its user interface is quite simple. It determines optimal routes to various landmarks in our university campus by using heuristic search for the next waypoints. We tested the device and made note of its limitations and possible extensions.

***Keywords*—**Blind, global positioning system (GPS), navigation

I. INTRODUCTION

FOR the blind to travel safely and independently, two levels of navigation, macro-navigation and micro-navigation, are essentially performed [1]. *Macro-navigation* or *wayfinding* is broadly explained as the process of knowing the current position and orientation, finding a route to the destination, and maintaining a heading toward that destination [2]. On the other hand, *micro-navigation* or *mobility* is concerned with detecting and avoiding obstacles while walking through immediate environment. In order to accomplish the tasks in both levels, navigation aid devices are required. Wayfinding devices use global positioning system (GPS) to locate places, whereas mobility aid devices use sensors to detect obstacles. A few examples of are briefly reviewed as follows:

Holland *et al.* [3] developed AudioGPS, a GPS-based audio navigator that used continuous non-speech tones to indicate the bearing of the next waypoint (a reference point along the journey route) and whether the user was moving closer to or farther from that waypoint. But without electronic compass or head tracker, it could not tell which way the user was facing. Hence the device could calculate the direction only as soon as the user started moving. Holland *et al.* reported that it took about 10–15 seconds or 20–m walking distance for the device to detect direction change, which was rather slow for practical use. Marston *et al.* [4] solved this by mounting an electronic compass on a GPS receiver. Their navigator emitted unique beeps when the user was heading in the right direction, i.e. within 10° of the next waypoint, and when she was within 2.1–m radius of that waypoint. Similar devices were proposed by Ross and Blasch [5], Kowalik and Kwasniewski [6], Pressl and Wieser [7], and Sanchez *et al.* [8] among others.

Handheld device and audio guidance are impractical if the user has to carry things and there are too many surrounding noises. Although headphone helps block out these noises, it leaves the user with no auditory cue (such as traffic noise) for hazard avoidance. Heuten *et al.* [2] proposed a tactile belt mounted with small vibrators and a personal digital assistant (PDA) that runs a wayfinding program. It conveyed path information to the user by inducing vibration on different parts of the user's hip. However, its accuracy was moderate because some users had difficulty in sensing the vibration.

In addition to GPS, other wayfinding systems such as [9]–[11] employ radio frequency identification (RFID). These systems typically require the set-up of RFID information grid, by attaching passive RFID tags to various reference points. As a result, they are more suitable for navigation within small localized areas, or indoor where the GPS signal is blocked.

Mobility aid devices commonly use ultrasonic sensors to detect obstacles. For instance, Boubia-Salah and Fezari [12] developed a mobility aid system consisting of an ultrasonic cane, a speech synthesizer, and an accelerometer for the calculation of travelled distance. Kim and Song [13] attached ultrasonic sensors to a vest and used stereo bone conduction to alarm the blind walkers of any obstacle. Bellik and Farcy [14] used a laser telemeter to detect how far ahead an obstacle is. Their distance information was conveyed to the walker via many interfaces such as auditive interface, tactile interface, or force-feedback interface.

In Thailand, blind persons usually walk with white canes or human guides, but their travelling is limited to familiar routes or within familiar places. Because electronic devices have not been widely available and affordable, when they want to go to unfamiliar place, they have to rely on human guides [15] (note that travelling by vehicles is outside the scope of our study). To encourage the use of electronic devices, a few requirements should be met as follows. First, the devices should have simple user interface with audio instructions in Thai. They should be portable and do not interfere with the blind's normal activities. In addition, their prices should be moderate.

Our project focuses on GPS-based wayfinding devices, thus "navigation" in this paper refers to macro-navigation. The rest of the paper is organized as follows. In Section II, we review related studies about blind navigation in order to understand what information is necessary to guide them. In Section III, we present system development and report some testing results. Finally, Section IV concludes the paper.

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II. BLIND NAVIGATION

A journey route usually consists of a sequence of waypoints. Guiding a blind person to walk from one waypoint to another requires at least two pieces of information: which direction she has to take, and how far she has to walk. Information about landmarks and surrounding environment helps the walker pick up sensory cues to improve her navigation [16]. In this project, we initially focus on direction and distance, but our device also offers short description about the landmarks.

A. Distance

In general, distance information can be expressed *in length* such as “walk for 50 m”, *in time* such as “walk for 5 minutes”, or *in steps* such as “walk for 50 steps”. According to Andre and Rogers [17], by using length expression, blind pedestrians could walk accurately for the distance up to 22 m. But when the distance was longer, they tended to undershoot the target.

In order to use step and time expressions, we need to know conversion constants such as average step length (m/step) and average speed (m/second) of blind walkers, respectively. An empirical study by Mason *et al.* [18] gave us a few figures as follows. First, the mean step length and step-length variability of normally sighted and visually impaired people were not significantly different. The mean step length increased with walking pace, that is, the faster they walked the longer their steps were. At walkers’ preferred pace, the mean step length ranged from 0.55 to 0.88 m. The overall mean and standard deviation were 0.74 m and 2%, respectively. This finding agreed with Wada [19] who also found that step expression significantly outperformed length expression. However, when a blind pedestrian concentrates on counting steps, she may be less aware of her surrounding environment and thus prone to accidents.

B. Direction

In general, direction can be specified by using *cardinal expression* (north, south, east, west); *relative expression* (left, right, front, back) [4], [5], [7]; or *clock expression* [5], [8]. Cardinal expression is difficult to follow even for a sighted person. Relative expression is much more comprehensible and widely used, but it limits the movement to only orthogonal directions. Marston *et al.* [4] added angle information to the relative direction, telling the user to turn by a certain degree, e.g. “turn 45° right”. Finally, when using clock expression, the user initially faces 12 o’clock and then turns to the specified hour position.

C. Veering

Veering or deviation from an intended path is one of main problems for the blind. Veering occurs even when the blind initially face the right direction and there is no obstacle along the path. Kallie *et al.* [20] studied how blind and blindfolded walkers veered from their straight-line paths. Their individual steps were awry with a standard deviation of 1.3°. Over a long distance, i.e. over 9.14 m, the accumulated effect of these awry steps could lead to severe misorientation. The veering was reduced if the distance was covered by fewer but longer steps.

III. SYSTEM DEVELOPMENT

A. Hardware

Our navigation device is based on GPS and audio guidance. A navigation program, written in C, runs on a 32-bit ARM Cortex-M3 microcontroller (ET-STM32F103) connected with a GPS receiver (Holux GR-82) and a MP3 audio decoder (VS1011e), as shown in Fig. 1. The communication between GPS receiver and the microcontroller is in UART (universal asynchronous receiver transmitter) mode. The device requires one 9V battery and four 1.5V batteries for power, which lasts about 45 minutes. The total cost of the hardware is about 4,300 THB or 135 USD.

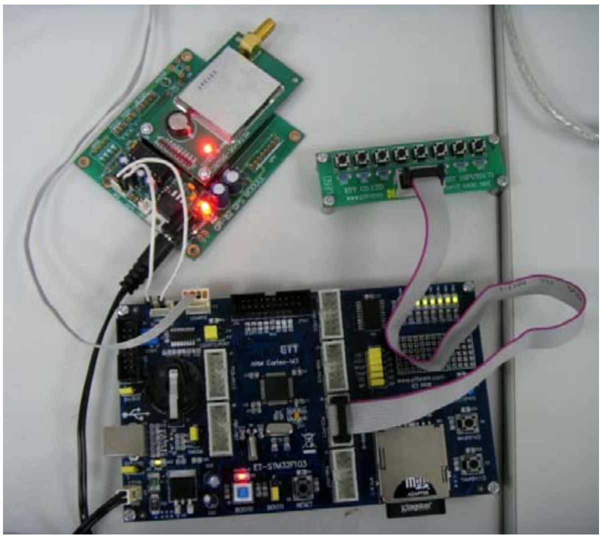

Fig. 1. Hardware components of the navigation device

Fig. 2. The user interface of the device

The device’s user interface, shown in Fig. 2, is quite simple. Its dimension is about 18 x 12 x 6 cm, which is slightly smaller but thicker than that of Longman Dictionary of Contemporary English. A cross body strap can be attached to the device later, because it may be too bulky to carry in hands at all time and the user needs not constantly interact with it.

There are six buttons (the labels in Fig. 2 were edited because they were difficult to read in black-and-white print) as follows. *Button 1* reads the latitute and longitude of the current position. *Button 2* reads the list of nearest reference points and their distance from the current position. *Button 3* and *Button 4* are for scrolling through the list of destinations. When the desired destination is read out, implying that it is selected, the user can press *Button 5* to find its distance from the current position, or *Button 6* to find a route to that destination.

B. Software

The navigation program stores a list of waypoints which can be buildings, traffic lights, tram stops, or junctions reachable by the campus's local roads. The buildings are also marked as destination points. For simplicity, we assume that the user only walks along pedestrian pavements. In Fig. 3, suppose that the user wants to walk from point *A* to destination *B*. The program determines an optimal route heuristically as follows:

– The next waypoint should be the nearest one and the one in the direction toward the destination. Therefore, waypoint *C* is chosen instead of *F*.

– The route toward the destination should be the shortest one that requires the fewest turns. Currently a compass has not been added to the device. Ideally, at waypoint *C* which is a junction, we prefer the user to walk ahead to waypoint *D* rather than making turn (in practice, when standing at *C*, the user may not always orient toward *D*).

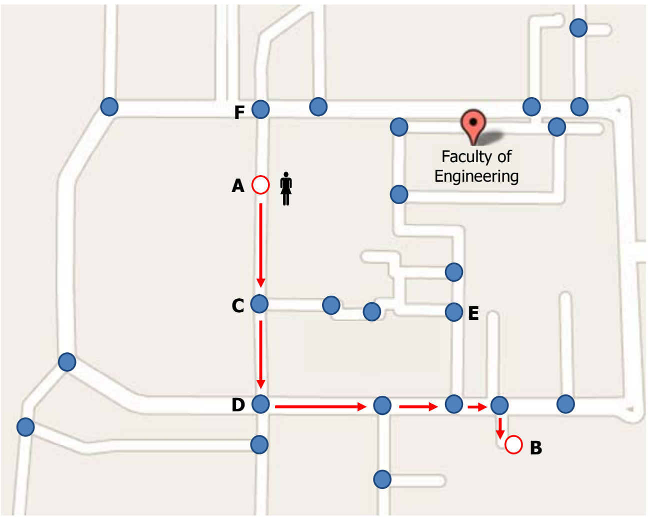

Fig. 3. Finding a route from A to B
(Campus map taken from Google Map)

Distance to the next waypoint is given in length expression. To avoid computation overhead, the program does not update the user's position continuously. However, at any time she may press *Button 1*, *Button 2*, *Button 5*, or *Button 6* on the device to check her position and orientation, or get a new route in case that she is completely lost. The latter is illustrated by Fig. 4. Suppose that the user is out of the suggested route when she presses *Button 6*. The program will search for a new route and suggest walking toward waypoint *E*, because it yields a shorter distance to the destination.

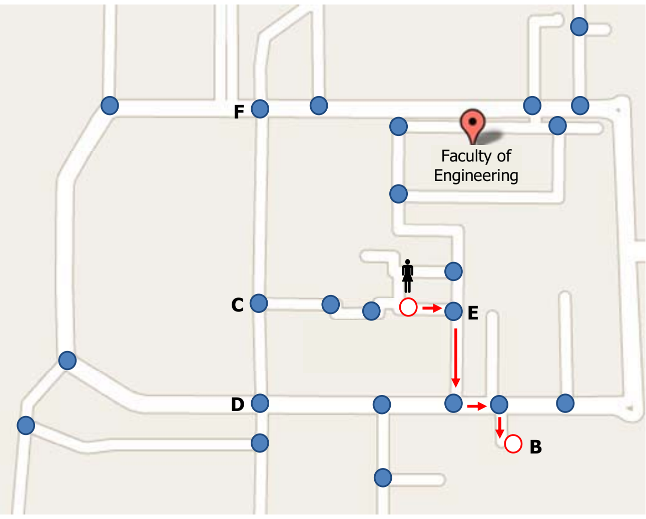

Fig. 4. Getting a new route to B
(Campus map taken from Google Map)

TABLE I
RESULT OF 5-M BLINDFOLD WALKING

Participant	Distance Walked (m)	Error (m)
1	5.70	0.70
2	3.10	–1.90
3	4.95	–0.05
4	6.18	1.18
5	3.56	–1.44
6	11.40	6.42
7	2.69	–2.31
8	7.98	2.98
9	5.46	0.46
10	9.34	4.34
Mean	6.04	1.04
S.D.	2.81	

C. System Tests and Limitations

We tested the device by walking blindfold from our faculty building to 10 random destinations. The participants were the second, third, and fourth authors of this paper. Although the device pinpointed the user's current location accurately, a few limitations were noted as follows.

Firstly, it could not detect the user's orientation and thus tell which direction she had to turn at a junction. It only told that she had to walk for *X* meters to the next waypoint *Y*. The user had to check her heading after she started walking. In 4 out of 10 trials, the user walked too far in the wrong directions. When checking her heading, she was in fact near other waypoints and the device suggested new routes instead. This may confuse the user if there were many junctions along a route; the user may receive different suggestions every time she checks the heading.

Secondly, we found the instruction to "walk for X meters" not easy to follow. We did a separate experiment by asking 10 students to walk blindfold for merely 5 m. The result is shown in Table I. Three of them severely overshot the distance while other three severely undershot the distance. A few students admitted that counting steps would have been easier to walk a specified distance.

IV. CONCLUSION

We have developed a GPS-based navigation device with audio guidance in Thai language. The device is composed of inexpensive hardware components. Its user interface is quite simple. However, there are still some limitations, as mentioned in Section III. One of our solutions is to add a compass board. We will also make the device monitor the user's position and orientation every certain time interval, so that the user keeps informed about how far she has been walking and is warned if she veers off the path. The user will also be able to set her preferences on distance and direction instructions. Moreover, the navigation program will be improved to ensure that safe routes are given. For example, ones that require crossing the campus's main roads or passing car park entrances should be avoided.

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