

User Interface of Assistant Navigation System in Smart Phone for the Blind

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Abstract

Under the development of mobile phones, the navigation can provide users with the location of and the path to the destination, such as the Google Map Navigation System. The users enter the correct destination into the mobile phone, and the system analyzes and indicates the paths. Users can also enter the designation by voice input; however, this method has low recognition rate and may be affected by the noise in the surrounding. Unlike the users with normal vision, the visually impaired users are unable to use mobile phones. To enable the visually impaired users to find paths, the study designed a “Smart Mobile Navigation System for the Blind”, which combines the Braille rules with the smart mobile phones. The Braille system can overcome the blind’s difficulty in message input and help them enter the correct destinations. As the voice output may not be completely received by the users, a vibration function is added to this system, in order to minimize the interference, reduce the errors in judgment, and avoid the impacts of the environmental factors on the blinds, thereby increasing their moving speed and improving their walking safety.

Keywords: *Blind, Smart Phone, Navigation System, User Interface*

1. Introduction

The number of mobile phone users has rapidly increased in recent years. The users are able to share large quantities of data for purposes from leisure and recreation to regular communication. However, evaluating whether mobile phones are equally feasible to develop self-sufficiency and convenience of use for visually impaired users are crucial issues. Concerning the price of mobile phones, phones designed specifically for visually impaired persons are relatively more expensive than regular mobile phones and are considerably more difficult to purchase. They are not available on the regular market, and buyers must make the purchase through special channels. In addition, the phone functions are insufficient to satisfy the requirements of visually impaired persons, who continue to experience a lack of mobile phone variety.

The Global Positioning System (GPS) function in smart phones is widely used. However, visually impaired persons cannot directly use the GPS function of touch-screen smart phones because current smart phones are designed for users with normal vision, and entering information and understanding the system is extremely difficult for visually impaired users. The navigation system used by the public requires users to enter their destination; the system then performs the necessary calculations and displays a map as well as the destination location. Users are required to view the screen to confirm their current position and follow the designated route as shown on the screen. The use of this type of navigation system, therefore,

creates considerable inconvenience for visually impaired persons. Although the voice input and output functions of smart phones have become increasingly advanced, the voice recognition rate is insufficient. Moreover, the voice input and output functions are often affected by noise in the surrounding environment, which results in limited usability for visually impaired users.

In general, visually impaired persons can navigate their way through an unknown area with the assistance of a guide dog. However, guide dogs do not know the traveller's desired destination; they are able to guide a visually impaired person only on a straight path and under safe road conditions. When arriving at an intersection, guide dogs pause and wait for the traveller's instructions before they proceed. Thus, navigation systems are highly useful tools for visually impaired persons. In this study, we designed a Braille module for touch-screen mobile phones. Visually impaired users used the Braille input method to enter their destination on the mobile device. The system then calculated the optimal route, enabling the users to provide instructions to the guide dog. In addition, the system was equipped with a vibration prompt function to notify users when to make turns. This function prevented loud noises at the intersection from hindering users from hearing the voice output, which may lead to potential danger.



Figure 1. (a) MPO Mobile Phone



Figure 1. (b) Samsung Conceptual Mobile Phone for Visually Impaired Users

Concerning visually impaired users, previous studies [1] have shown that standard mobile phones are inconvenient to use because of an excessive number of buttons for operation and overly complex systems. Although mobile phones have undergone significant improvements in recent years, interfaces specifically designed for visually impaired users are scarce. Among the few mobile phones available for visually impaired users, the MPO [2] uses the Braille input method. The MPO (shown in Figure 1(a)) interface shows 20 Braille characters on the upper portion of the device, and the device itself is equipped with eight Braille buttons. The system permits the sending and receiving of messages to and from a computer. In addition,

the input messages can be shown on the Braille display, and the output messages can be displayed as Braille characters or as voice output.

The Samsung mobile phone [2] (shown in Figure 1(b)) resembles a remote control, where the primary buttons are shown in Braille. The upper half of the device displays the numbers entered, and caller ID can be shown in Braille for the visually impaired users to read by touch. Because of these functions, the Samsung mobile phone won the 2009 Red Dot Award in Germany.

Other studies [3] have proposed converting text on the computer screen to voice output, or integrating the computer screen with a Braille display and transforming text into corresponding Braille characters. The Braille Window System (BWS) [4] shown in Figure 2(a) is an example of a Braille display.



Figure 2. (a) Braille Display

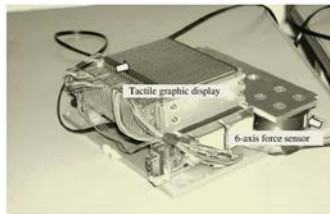


Figure 2. (b) Touch Machine Model



Figure 2. (c) Integrated Guidance System for Visually Impaired Users

Most Braille display devices are capable of displaying only text; therefore, to enable visually impaired users to understand images on web pages or in articles, researchers have developed graphic input/output devices.[5] By pressing on the interface, input signals can be produced. The concept is similar to the current touch-screen system used in smart phones,

users to perform data input and use voice feedback to provide the information that they require. The system overview is shown in Figure 4.

Regarding the Braille input method, we provided two types of input modes. The first mode was a single-touch input system: The touch screen was divided into six regions, where users performed the raised dot input by touching a specific region. The system then determined the Braille codes based on the input location. The second mode was a multi-touch input system: Users employed a multi-touch method to simultaneously enter raised dots; therefore, they were no longer required to use the traditional Braille writing method of inputting the dots sequentially.

Because navigation systems are normally used outdoors, they are prone to the influences of outside noises. This may result in difficulty for visually impaired users to hear the navigation instructions clearly. Therefore, we used the vibration function of smart phones to reinforce navigation instructions.

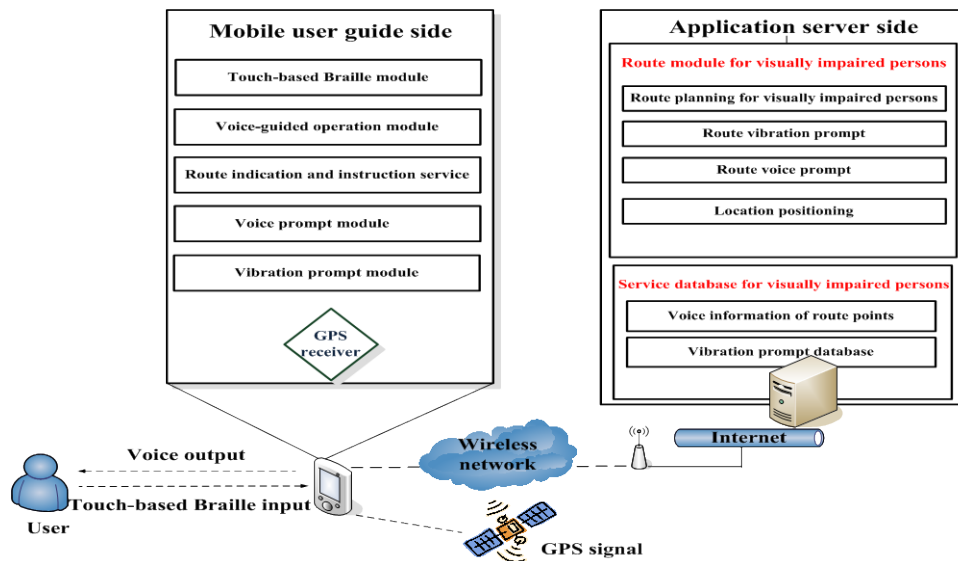


Figure 4. System Overview

2.3. Input Interface

Because the Braille rules require six regions, we divided the screen into eight regions: six had a Braille format, and the remaining two comprised buttons for *confirm* and *cancel* operations. To prevent the users from selecting the wrong regions when operating the touch screen, we added a customized screen protector film to the touch screen of a personal digital assistant (PDA), which was the mobile device adopted in this study. Lines consisting of raised dots were constructed on the protective film to outline the regions (such as the black dotted lines on the PDA touch screen shown in Figure 5). In addition, to help users identify the location of each Braille region, the edges of the device also featured lines consisting of raised dots. Using the raised dotted lines, visually impaired users could accurately locate the desired regions, thus reducing the probability of selecting the wrong region. Because the majority of current smart phones provide multi-touch functions, we examined the single-touch and multi-touch input methods and determined which of the two methods offered a shorter input time.

The Single-touch Braille Input Method

For the programming of the single-touch interface, Regions 1 to 6 on the mobile device respectively corresponded to Dots 1 to 6 in the actual Braille system, represented by the Braille blocks in red (Figure 5(a)). Below these regions were two additional blocks that represented confirm and cancel, respectively. The Bopomofo spelling method for the Braille system is described in the previous section, and the single-touch Braille method used the touch points in the designated regions to determine the desired characters. For example, to type the phonetic symbol *bo*, users need to press Regions 1, 3, and 5 sequentially on the touch screen. Based on the region and order of input, the system then converts the Braille codes into corresponding text characters, and then integrates all the characters to form the destination name for navigation.

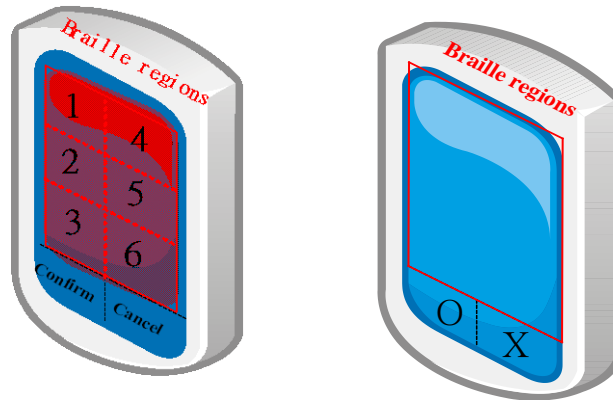


Figure 5. (a) Single-touch Interface (b) Multi-touch Interface

The multi-touch Braille Input Method

The multi-touch Braille input method enabled users to select multiple regions on the screen at once, instead of entering the six dots for the Braille codes separately. Compared to the single-touch method, which required users to input the dots sequentially at the correct location, the multi-touch method did not require users to place their fingers on the exact positions; the users merely had to enter the number of Braille characters. This function allowed the system operation to be relatively more rapid and accurate. Because Braille characters contain six dots, we divided the codes into the left and right side, with each side having a total of three dots for system interpretation. Thus, the multi-touch Braille system consisted of a maximum of three dots per input. To enter the symbol *bo*, users needed to press twice, that is, enter two separate inputs on the screen, the first using two fingers and the second using one. Despite the possibility of creating two words formed by an identical number of left and right input codes, two complete destination names comprising entirely identical Braille codes are highly unlikely. Therefore, the system began interpreting only after the users have entered all codes for the destination name. With its ease of use, the multi-touch method addressed the problem where two words comprise differing phonetic symbols but are formed by identical left and right input codes. The multi-touch method reduced the time required for input and eliminated the need to input information according to the Braille regions. Therefore, in contrast to the single-touch method, the multi-touch method decreased the level of input inconvenience for visually impaired users.

The Vibration Prompt Module

Under noisy conditions in an outdoor environment, it becomes extremely difficult for visually impaired users to listen to voice navigation. Therefore, we added vibration prompts to the navigation system for guiding users, informing them when to turn. The vibration prompts are encoded according to the following patterns: to signal the users turn left, it sent out continuous, short vibrations of approximately once per second; to signal the users to turn right, it sent out a continuous, long vibration of 3 s. The programming of the vibration frequency emphasized the duration instead of the number of vibrations to prevent the users from becoming overly anxious. The addition of the vibration prompts can facilitate visually impaired users in effectively instructing the guide dogs to move in the right direction when voice output could not be heard clearly.

3. Experiments

We combined a Braille module mechanism for visually impaired persons, a navigation module, and a vibration prompt module to create a navigation system for visually impaired users. To verify that this system could achieve the expected result for guiding visually impaired users in practice, we experimented and analyzed the proposed methods. First, the practicality and feasibility of the Braille system was verified. We then confirmed whether the vibration prompts could effectively guide the visually impaired users in making turns. Figure 6 shows the devices used during the experiment.



Figure 6. (a) Earphones. (b) Guide Dog and Saddle



Figure 6. (c) Single-touch Mobile Phone (d) Multi-touch Mobile Phone

The experiments were conducted at National Pingtung University of Science and Technology, which possesses its own guide dog training kennels and visually impaired volunteers; thus, testing the navigation system in practice was possible. The guide dogs used in this study were provided by Samsung Electronics. The walking procedure in which the navigation system was integrated with the guide dog is shown in Figure 7.



Figure 7. (a) Inputting the Destination into the System at the Beginning of the Trip. (b) The Vibration Prompt is provided when within 20 Meters of the Upcoming Intersection. (c) Instructing the Guide Dog at the Intersection

A total of 10 subjects were selected for this experiment, comprising nine males and one female. The subjects were between 22 and 35 years of age, all of whom were visually impaired. We divided the subjects into two groups: The first group performed the experiment without the vibration prompt and the second group performed the experiment with the vibration prompt. During the experiment, each visually impaired user was instructed to travel to three destinations. We recorded the amount of time spent by the users on inputting the destination. Once the users arrived at one destination, they were asked to input the next destination. The users were required to input three destinations in total for one trip. We compared the average input time for the three destinations spent by each subject for the two Braille input methods. The results are shown in Tables 1 and 2.

Table 1. Record of Time Spent by Subjects using the Single-touch Input Method

<i>Single-touch input</i>	<i>Destination 1</i>	<i>Destination 2</i>	<i>Destination 3</i>
Experimental subject 1	17.3s	19.6s	29.7s
Experimental subject 2	19.2s	20.1s	35.0s
Experimental subject 3	16.8s	19.2s	30.0s
Experimental subject 4	18.2s	20.5s	33.5s
Experimental subject 5	17.1s	21.3s	31.9s
Experimental subject 6	18.5s	20.0s	32.0s
Experimental subject 7	20.1s	25.3s	38.2s
Experimental subject 8	18.3s	23.1s	30.6s
Experimental subject 9	17.5s	20.9s	32.1s
Experimental subject 10	17.9s	19.0s	32.5s

Table 2. Record of Time Spent by Subjects using the Multi-touch Input Method

<i>Multi-touch input</i>	<i>Destination 1</i>	<i>Destination 2</i>	<i>Destination 3</i>
Experimental subject 1	9.3s	18.5s	21.0s
Experimental subject 2	10.2s	19.2s	22.5s
Experimental subject 3	8.9s	18.5s	21.5s
Experimental subject 4	11.5s	20.1s	22.0s
Experimental subject 5	9.9s	19.6s	20.8s
Experimental subject 6	10.5s	20.2s	23.6s
Experimental subject 7	13.2s	21.5s	25.7s
Experimental subject 8	11.8s	20.5s	22.7s
Experimental subject 9	9.6s	18.3s	21.3s
Experimental subject 10	12.3s	21.5s	21.9s

Table 3. Total Average Input Time

	<i>Total average time spent per person (Sec)</i>
Single-touch input	71.84s
Multi-touch input	52.81s

Table 3 shows the total average time spent by the 10 subjects to input the three destinations. The results clearly show that the input time was much shorter for the multi-touch input method.

Next, we summed the number of input errors made by each user for the two input methods, which are shown in Tables 4 and 5.

Table 4. The Number of Input Errors using the Single-touch Input Method

<i>Single-touch input</i>	<i>Destination 1</i>	<i>Destination 2</i>	<i>Destination 3</i>
Experimental subject 1	0	0	1
Experimental subject 2	1	0	3
Experimental subject 3	0	1	0
Experimental subject 4	0	1	2
Experimental subject 5	1	0	0
Experimental subject 6	1	0	0
Experimental subject 7	0	2	0
Experimental subject 8	0	0	0
Experimental subject 9	1	0	1
Experimental subject 10	0	2	0

Table 5. The Number of Input Errors using the Multi-touch Input Method

<i>Multi-touch input</i>	<i>Destination 1</i>	<i>Destination 2</i>	<i>Destination 3</i>
Experimental subject 1	0	0	1
Experimental subject 2	0	0	0
Experimental subject 3	1	0	0
Experimental subject 4	0	0	0
Experimental subject 5	0	1	0
Experimental subject 6	0	0	1
Experimental subject 7	0	0	0
Experimental subject 8	0	1	0
Experimental subject 9	0	0	1
Experimental subject 10	0	0	0

Table 6. Comparison of the Total Number of Errors

	<i>Total number of errors</i>
Single-touch input	15
Multi-touch input	6

Table 6 shows the total number of errors made by the users for the two input methods. The table shows that the multi-touch input method resulted in a shorter input time and a lower error rate. This is because it was easier for users to select the wrong regions when using the single-touch input method, whereas the multi-touch input method did not require the users to press specific regions, thereby avoiding input errors.

During the experiment, we tested whether the vibration prompt could more correctly indicate the direction for the subjects by creating loud background noises at the intersections

where the subjects were required to make a turn. If the subjects needed to use the voice or vibration prompt more than once to confirm direction, it was defined as a loss of direction. The results for the number of times that the subjects experienced loss of direction with and without the vibration prompt are shown in Tables 7 and 8, respectively.

Table 7. Loss of Direction when not Equipped with Vibration Prompt

<i>Single-touch input</i>	<i>Times loss of direction occurred</i>
Experimental subject 1	0
Experimental subject 2	1
Experimental subject 3	1
Experimental subject 4	1
Experimental subject 5	2
Total	5

Table 8. Loss of Direction when Equipped with Vibration Prompt

<i>Single-touch input</i>	<i>Times loss of direction occurred</i>
Experimental subject 6	0
Experimental subject 7	1
Experimental subject 8	0
Experimental subject 9	0
Experimental subject 10	0
Total	1

The statistical data show that the number of times that subjects experienced loss of direction without the vibration prompt was higher than that with the vibration prompt. This result proves that the vibration prompt could reduce errors related to direction.

Because the starting point of this study was to develop a Braille system and a vibration prompt system for visually impaired users, we conducted a questionnaire survey with the experiment subjects to understand their perceptions of the two systems. The questionnaires were scored using the following scale for satisfaction level: -2 = *extremely dissatisfied*, -1 = *dissatisfied*, 0 = *neutral*, 1 = *satisfied*, and 2 = *extremely satisfied*. The questionnaire scores are shown in Table 9.

Table 9. Satisfaction Rating

	<i>Multi-touch input</i>	<i>Single-touch input</i>	<i>Vibration prompt</i>
Experimental subject 1	1	2	0
Experimental subject 2	0	2	1
Experimental subject 3	0	1	0
Experimental subject 4	2	1	1
Experimental subject 5	-1	2	0
Experimental subject 6	-1	0	2
Experimental subject 7	1	0	1
Experimental subject 8	0	2	1
Experimental subject 9	-2	0	1
Experimental subject 10	1	2	2
Average	0.1	1.1	0.9

Table 9 indicates that the average score for the single-touch method was higher than that for the multi-touch method; therefore, the single-touch method was better accepted by the users. From the interviews with the subjects, we found that because the visually impaired

users were required to handle the guide dog, they were unable to use both hands to execute the multi-touch function, whereas the single-touch method only required the use of one hand for data input. Therefore, the multi-touch method was less appealing to the users despite providing a faster input speed and a more accurate input. Concerning the vibration prompt, the system received a high average score, indicating that it could significantly assist visually impaired users during the navigation process.

4. Conclusion

For visually impaired users, the current navigation systems installed in smart phones are almost unusable. The starting point of this study was to produce a navigation system that enables visually impaired users to travel through unfamiliar areas with the same ease as people with normal vision do. Because the biggest difficulty for visually impaired users when operating smart phones is the input and output of data, we developed an appropriate Braille input module, which enables the users to input data using familiar Braille codes. Furthermore, in addition to using voice output to indicate directions, we also used the vibration function of mobile phones to assist in guiding the users. Following practical operation and testing of the vibration prompt system by visually impaired users, we found that this system can clearly facilitate visually impaired users in using navigation systems. Although the technology we used in this study was not exceedingly advanced, it was able to provide significantly assistance to visually impaired users. Moreover, because the mobile phones we used were standard smart phones, they offered more advantages than devices specifically designed for visually impaired persons regarding pricing and functions. We plan to use this module for other types of application software to allow visually impaired users to better enjoy the convenience of smart phones.

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