The threshold of Route Guidance for Visually Impaired Based on Haptic Technology and Their Spatial Cognition

Guan-sheng Wang
The Air Force Xi'an Flight Academy Xi'an, 710300,Shanxi,China; College of Resource and Environment Sciences, Xinjiang University, Urumqi, 18700839887,830046,Xinjiang,China
wgs2010xjn@sina.com

Jiang-hua Zheng*
College of Resource and Environment Sciences, Xinjiang University,Urumqi,13579880590，830046,Xinjiang,China
zheng_jianghua@126.com

ABSTRACT
Haptic (vibration) information expression is an effective human-computer interaction mode and information transfer method. It makes up shortcomings of sound under certain conditions and be an important channel of information transfer for route guidance field. As a special kind of walkers, the visually impaired pedestrians have a specific type of cognition or perception of route guidance environment (including spatial orientation, distance and walking speed etc.). And they have more sensitive sense of touch than that the ordinary people have. This work integrated application of GPS, GIS and Haptic (vibration) technology to develop more reliable mode route guidance for the visually impaired. It provides different vibration to the user under two circumstances: key nodes of roads ahead and deviation planning path. It has several obvious advantages, such as higher anti-noise, sensitivity and effectiveness. Using HTC Legend phone, we developed the prototype and realized the designed functions, and verify the effectiveness of the system. We initially determined the thresholds of deviating from the path, those at road junctions and other nodes through experiments, interviews etc. And we used the thresholds for experiments testing and guiding. Then they were inspected, corrected and improved in the field practice. Finally, more reasonable thresholds were drawn out for future applications in reality.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—Haptic I/O; K.4.2 [Computers and Society]: Social Issues—Assistive technologies for persons with disabilities

General Terms
Human Factors

Keywords
visual impairment; route guidance; spatial cognition; haptic (vibration)

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1. INTRODUCTION
According to "the second disabled survey data of China in 2006", statistics showed that: China has the largest number of visually impaired people in the world. The up to 12.33 million visually impaired people is about 20% of the whole world, and the number is increasing at the rate of 450000 per year [1]. More than 80% of information in everyday life is obtained through vision [2]. Unfortunately, the visually impaired people, living in a dark world, have great difficulty in life, study, work and so on because of lack of vision. As a special group in the society, they should be given more care and attention. And one of the biggest troubles is to walk safely without other's companionship. With the development of economy and technology, their troubles in traveling environment were focused.

For ordinary people, the visual sense is the most effective way to obtain environmental information, including landmarks, location, direction, distance and speed and effective route guidance information. The visually impaired people inevitably are confronted with great challenge when walking in complex and mobile environment because of the loss of visual ability. For example: how to get certain distant and spatial information; how to acquire direction through the sign; how to keep the judgment and trace of the direction and location; and how to identify the specific sign when approaching it [3-4], etc. During their walking, if they could not only get support from general third-party assistant devices (such as a cane, guide dog, blind road, guide equipment etc.), but also obtain directions by their spatial cognition [5], they would more safe and convenient in individual walking.

The cane, as an assistant walking aid, has been widely adopted in reality. However, many restrictions in action of the blind make it has big challenge for effective applying [6]. Just because of its simple design, convenient usage, most visually impaired people still depend on a cane to scan in front of them. Simply from a functional point of view, a guide dog is a good choice of leading the visually impaired to walk, since they could understand master's various passwords and simple intentions, and take the blind to destination successfully. However, they can't plan a path or lead the blind man to the appointed place in an unfamiliar environment. And the training of the dogs is hard, time-consuming, and high cost. These restrict the popularization of guide dogs [7]. Nowadays, many countries equipped the visual impaired with basic blind roads and voice prompt equipments, and other guide facilities. However, their limited functions cannot meet walking requirements of the blind. Their functions are even more limited in china mainland because of low usage ratio and wide occupation of the blind road (there even has open manhole covers next to the blind road, etc.).

Aiming at relieve the walking troubles of the visually impaired, many research teams from various countries are working on better guide devices except traditional cane and guide dogs. Some obtained progress make the visually impaired more convenient and safe while walking, such as the successful development of Electronic Travel Aids [8-11], Guide Robots [12-15], Smart Cane [16-20] as well as Smart Guide System [21-25], and so on. Most of these products are voice-navigation based. But this kind of products has an obvious shortcoming that is they would lose most of the functions while it was noisy around. And. If the visual impaired wear head phone together, this may block the important guiding voice outside (such as the car's whistle). The visually impaired are depending on the non-visual way to groping forward. On this occasion, how to implement an effective and efficient guiding? We believe voice based on the haptic(vibration) guidance is a better solution [26].

This paper focused on haptic based mobile route guidance aided mode, which integrated GPS, GIS, haptic and the specific spatial cognition of the blind, for better walking of the visually impaired. Its prototype was developing on Google Legend phone. Field experiments showed its characteristics of better resistance of noise, real-time reflection and high effectiveness, etc. It makes up the shortcomings of sound under certain conditions. Integration of vibration and voice can be a better choice for visual impaired to travel safer and more convenient. The vibration thresholds of deviating from the path were discussed. We initially determined the threshold of deviating from the path, at road junctions by experiments, interview etc with the visually impaired students and staff of the Blind School of Urumqi. After inspecting, correcting and improving the thresholds by tests, we finally obtained more reasonable thresholds.

2.Design and Implementation

2.1 Design goals and ideas

The goal of this system is to provide the visually impaired people with different patterns of vibration so it can guide them when walking in an unfamiliar environment and make them efficient, timely, and accurate walking in right directions. The basic idea is to provide various appreciable vibration mechanism (frequency and vibrating size) while the visually impaired people deviating from the path (a slight deviation from the route, serious deviation from the route) or reaching intersections, Following figure 1[27]shows the mechanism.

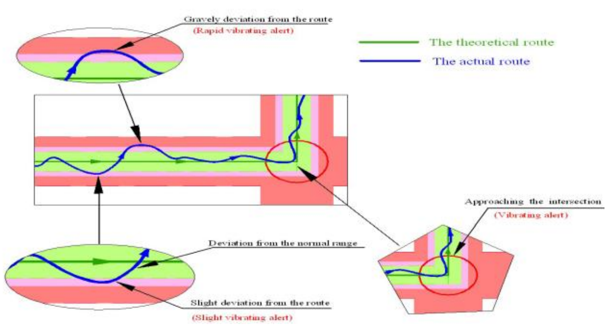


Fig. 1 Mechanism chart

2.2 Basic framework

The basic framework mainly includes GPS module, map module, routing module, multiple vibration prompting module and man-machine interface module etc. The system provided the visually impaired people, the vibration or integration of vibration and sound after processing the collected environmental information. The users understood the information combined with their spatial cognition and realized positioning and navigation based on them.

2.3 The working principle of the system

The work flow of the system is as following: 1) loads map after running main program; 2) the user inputs the starting point and the destination; 3) the optimal route computing and information display; 4) according to the route node information, the GPS module provides the latitude and longitude information real-time judge whether deviating from the route or to the next intersection nodes (the destination) when the visually impaired people are walking; 5) Haptic (vibration) module provides different patterns of vibration to route guidance.

According to the duration time of vibrating, three kinds of vibration modes were compared together, as shown in figure 2[28].

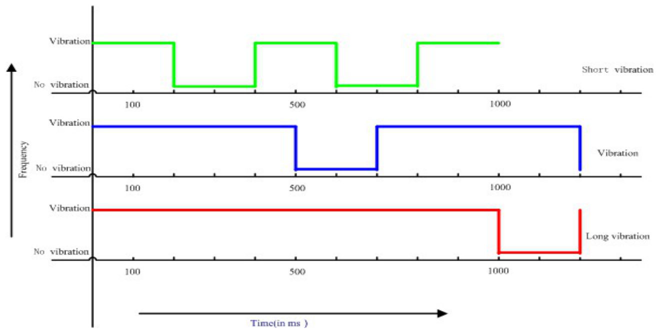


Fig.2 three groups of vibration mode

3.EXPERIMENTAL RESULTS

3.1 Experiment 1

The organization and implementation of experiments: The tests had 30 adult participants (including 20 ordinary people from Xinjiang University,10 visually impaired from short-term training classes of Urumqi Blind School). Experiments had been done respectively with vibration and voice for alert in a noisy environment (the school cafeteria and commercial street).The subjects were asked not to pay special attention to vibration or voice alert and do activities as usual. The mobile phones were placed in pocket or in hands. The vibration or voice volume was set to medium. In a certain period, the user accidentally made a phone call from the phone in their pocket. If he/she could feel or hear it, it will be recorded as right. Then we obtained the correct rates of vibration or voice. The results as shown in table 1.

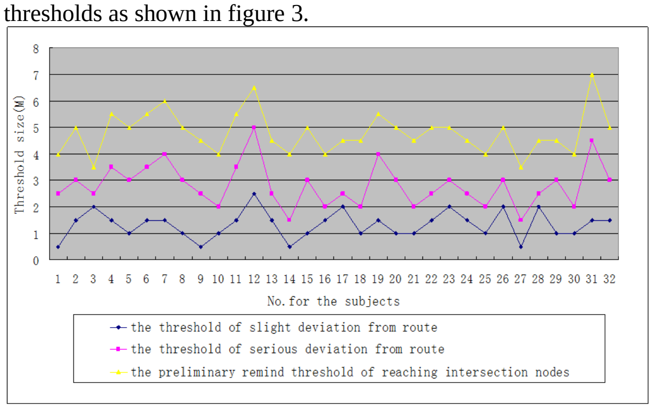
TABLE 1:The correct rate and error rate

The types of the subjects	Number of people	The school cafeteria(Vibration & Correct)	The school cafeteria(Voice & Correct)	Commercial Street(Vibration & Correct)	Commercial Street(Voice & Correct)	The total correct rate of the vibration	The total correct rate of the voice
The ordinary	20	75%	55%	65%	50%	70%	52.50%
The visually impaired	10	80%	60%	70%	60%	75%	60%

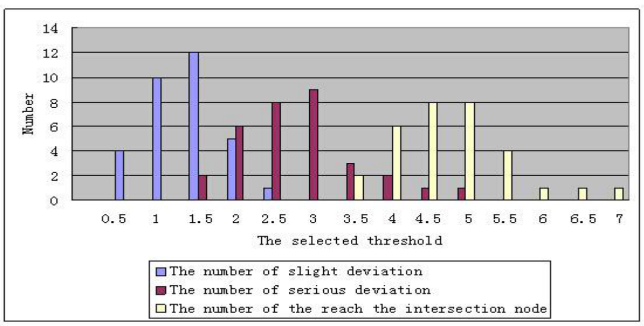
Note: The correct rate of the vibration is simplified as Vibration & Correct; The correct rate of the voice is simplified as Voice& Correct.

3.2 Experiment 2

Preliminary threshold settings: There were 32 visually impaired participants (including 11 blind,21 low vision) from short-term training classes of Urumqi Blind School, 20 males and 12 females, aged between 15 and 67 (average 30.31). There are three choice questionnaire about thresholds of deviating:1)the threshold of slight deviation from route; 2) the threshold of serious deviation from route; 3) the preliminary remind threshold of reaching intersection nodes. The answers are set form 0.5 meters to 5 meters, interval is 0.5 meters (For example: A 0.5 meters, B 1 meters, C 1.5 meters, D 2 meters, E 2.5 meters, F 3 meters, G 3.5 meters, H 4 meters, I 4.5 meters, K 5 meters, M above 5 meters, N Please write yourself - - - -, etc.). The psychological thresholds are selected by visually impaired and the classification of the thresholds as shown in figure 3.



a) Thepsychological thresholds are selected byvisually impaired



(b) The classification of the thresholds

Fig.3 the psychological thresholds of visually impaired

According to references, blind interviews, expert consultation (including orientation and mobility teachers), we preliminarily set predetermined thresholds based on spatial cognition and psychological factors for the visually impaired. We set predetermined thresholds of slight deviation as1 or 1.5 meters, serious deviation as 2.5 or 3 meters, and initial distance threshold to intersection node as4.5 or 5 meters. After experiments, the initial thresholds were inspected, corrected and improved for more reasonable ones.

We had illustrated and trained the corresponding relationship between the degree of deviation from route and vibration alert firstly before tests. And it let users to feel the differences of the vibrations until mastering it. Finally, we set up a vibration mode, so that the blind can quickly tell the corresponding deviation degree and bias, and make the corresponding action.

Ten volunteers (including 4blind, 6 having low vision) of 32 participants helped us and tried to experience it in our tests, and four of them were randomly selected (including 2 blind,2 having low vision) to have field tests of deviation from route and the rest to experience scene tests of intersection node. Test route was shown in Figure 4.

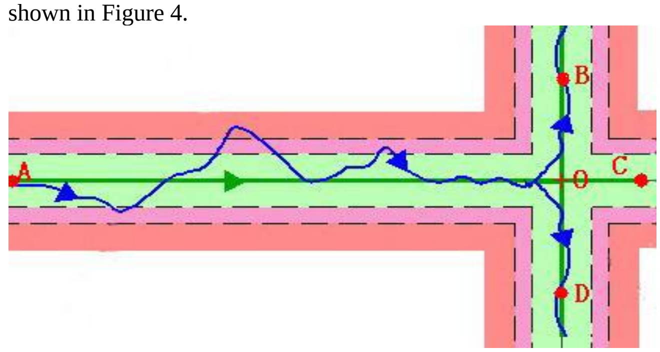


Fig. 4 Test route

3.2.1Scene tests of deviation from route

The tests were implemented according to the predetermined deviation as shown in table 2. It chose a straight line between two points A and O as the test route, as shown in Figure 8. The results showed that the testers could wander repeatedly and independently according to the differences of vibration alert and reach the designated destination eventually.

TABLE 2: The basis of deviation from the route tests

Bias/deviation degree	**Slight deviation to the left**	**Slight deviation to the right**	**Serious deviation to the left**	**Serious deviation to the right**
Vibration type	One long, one short	One long, two short	Two long, one short	Two long

3.2.2Scene tests of intersection node

The tests were implemented following the predetermined directions of passing through intersection node as shown in table 3, which contains lines between intersection nodes (A to B, A to C, A to D) as test routes. They were shown in Figure 7. Three volunteers respectively participated route AB, AC, AD tests. The results showed two testers could independently reach the designated destination and one of them (blind) also smoothly finished the experiment with the help of others.

TABLE 3: The basis of the intersection node tests

Degree/ turn to	**Approaching the intersecti-on node**	**Straight through the intersection**	**Turn to left**	**Turn to right**
Vibration type	Short	Long	One long, two short	Two long, one short

4. DISCUSSION

4.1 Discussion of the interviews with the blind

We drew some conclusions after having interviews with many visually impaired students and their teachers who teach orientation and mobility.

1) Most of the visually impaired students use cane as their walking assistant in strange environment. However, no tools are used in a familiar environment. The scope of their activities is relatively fixed, school or home community. They almost don't go out to unfamiliar environment. As to a new environment, they go there about 3-5 times with other's helps and after "mental maps" are formed in their minds, they go there individually.

2) The visually impaired people take obstacles (or other fixed objects, etc.) for route guidance, that is to say, they usually bring some obstacles to mind (where there is a what kind of obstacle) in familiar environment. When walking there again they can judge the position of the obstacles for position and navigation.

3) Not all blind people have a mobile phone. It mostly depends on the families' economic condition. With the price is also a very important factor.

4) There are some activity difference between Western and Oriental (China) blind. Chinese blind seldom go to unfamiliar environment, or is said not to let or not dare to. Generally, they go to unfamiliar environment with others help.

5) Young people with visual impairment, whose outdoor safety are considered too much by their supervisors, usually have poor sense of distance because they are rarely allowed to go out alone which may cause the lack of experience in space.

During the developing of navigation tools for the blind, convenient, intelligent, safety and the price are important factors. The most important factor is the fitness between navigation tools and the characteristics of the blind walking activities.

4.2 Discussion of experiment 1

The experiment 1 confirmed that vibration alert has superiority to voice navigation service in noisy environment. The total correct rate of vibration alert is 71.67 %(including the ordinary and the visually impaired), and the total correct rate of voice alert is only 55%. The experiment also demonstrated the visually impaired have more sensitive touch and hearing senses that ordinary people do. In comparison with the ordinary people, the visually impaired have a slight advantage over 5% in correct rate of vibration alert and voice alert.

4.3 Discussion of experiment 2

Experiments were conducted in relatively open areas. We took weather conditions and other factors into account. The GPS module got positioning information which met requirements of route guidance. The prototype can smoothly run and load the map. The routing module planned an optimal path according to the input of the starting position and the destination. While the user was walking, a cane was in one hand and the mobile in the other (as shown in Figure 5). It can alarm different vibration patterns while having different degree of deviating from the planned path or reaching to an intersection node according to a preset threshold of vibrating length and time cycle. The participants can obviously feel the different vibration patterns, and most of them can judge the deviation degree and make corresponding mobility combined with the blind spatial cognition. It had reached the initial testing purposes.

Fig.5 Training and testing of the outdoor for the blind

On the whole, the tests were practically successful and reached the initial testing purpose. The analysis of results showed that many aspects needed to be improved: 1)The corresponding relationships between the degree of deviation from route and vibration alert are more complicated, and they are not easy to remember; 2) Threshold setting should be optimized, the different people have various thresholds. It needs to do a lot of experiments and tests to obtain experience values suitable for various groups of the blind. 3) The GPS accuracy and sensitivity need to be further improved. 4) The dimension of the vibration is limited; we will consider the integration use of the multiple patterns of vibration and sound, and so on.

5. CONCLUSIONS AND FUTURE WORK

The lack of vision caused many inconvenience to the visual impaired people. Many scholars and experts around the world have committed themselves to invent various assistant equipments to improve the life quality of the visual impaired. The effect of voice guidance might be greatly reduced or even lost when in noisy and crowded environments. However, the development of route guidance with multiple patterns of vibration makes up the shortcomings and weaknesses of sound guidance under certain conditions including noisy one. The prototype realized basic functions of route guidance for the visual impairments. It can provide optimal planning path between two locations with multiple patterns of vibration alert during the walking, which could be a helpful auxiliary function for route guidance. And the field experiments demonstrated it make the blind walking efficiently and more accurate. We also obtain a set of reasonable thresholds of deviating from path.

We will continue to optimize the system and service, and try to obtain more reasonable thresholds by experiment combining with spatial cognition of the blind as our future work. The integration use of the multiple patterns of vibration and sound is considered as the next generation of our prototype. It will have stronger function in various environments and be closer to the market.

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