RFID-Based Road Guiding Cane System for the Visually Impaired

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Abstract. The RFID-based road guiding cane is a navigation system especially designed for the visually impaired. Geographic location, traffic light signals, and business information are saved in a series of RFID labels constructed beneath the sidewalk. With the road guiding cane reading the RFID labels, the visually impaired can locate themselves, be aware of traffic light signals, and find business information near them on the road. After users set the destination, the cane automatically directs the routes for users via voice by specifying the current location and keeping track of previous locations. Compared with the Global Positioning System, the RFID-based road guiding cane system is more reliable, more accurate, cost-saving, and versatile in providing precise location-based services for the visually impaired.

Keywords: RFID, visually impaired, road guiding cane, navigation system, Internet of things.

1 Introduction

Transportation safety can be a major issue for many people, especially those who are visually challenged. They could find themselves in very dangerous situations once they become lost and fail to receive help. Business information is also of great importance for them. Without knowing the surrounding environment, many people can have trouble finding shops or even a toilet when away from home on the road. Because few location-based services are often provided, the activity of the visually impaired becomes highly restricted.

To reduce these information barriers, an intelligent navigation system has been especially designed for the visually impaired to assist them in road navigation and information acquisition. The RFID application is considered to be very helpful in ensuring transportation safety of the visually impaired as well as helping to enrich their daily lives.

This study first introduces an analysis of interviews we conducted on the visually impaired to learn more about their difficulties in real life. Shortcomings of current sidewalks are summarized with an introduction to RFID technology. Then, the RFID-based road guiding system is presented for the overall system design, the hardware design, and the software design. Discussions and summary conclusions then follow.

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2 Interviews of the Visually Impaired

In December 2011, we conducted interviews with 10 visually-impaired people (8 males, 2 females; ages: 53 to 74) to learn about the transportation difficulties they encounter in real life. Seven were totally blind, and the other three had very low vision. The subjects were interviewed at a social welfare organization called “Hong Dandan” in Beijing China.

In the interview, we investigated the reasons why these individuals want to go outdoors, what they would like to carry with them, places they often went to, behaviors when they walked on the road, vehicles they frequently took, the influence of weather changes, and whether they were always accompanied by other family members. Additional difficulties they encountered in real life were also surveyed.

As identified from the interview, these individuals enjoyed to go to libraries to read Braille books or visit scenic spots to relax. Mobile phones, canes, and drinking cups were evaluated as necessary for them to carry. Besides, all of the subjects preferred to take the bus instead of the subway. They argued that subway transfers as well as the ticket system were too complex for them. Five subjects described their walking on a special sidewalk, while the other five would often walk against the curb of the sidewalk. Weather changes greatly influenced the choices of nine people when going out. Furthermore, only one person regularly ventured out with company. Others reported that they were always without company because they did not want to bother other family members.

Results from the interview shed light on the development of a new cane system. All subjects carried some kind of cane with them and stated it was useful to detect objects and for them to be recognized by other pedestrians. However, they also complained about the poor quality, the expensive price, and the heavy weight of these canes. They expected a cane of higher quality with more functions, and available at an affordable price. Nine subjects expressed their need for a navigation cane, and eight subjects preferred that the cane told them signal changes when they approached traffic lights.

3 Improvement of Sidewalks

Globally, the number of people of all ages who are visually impaired is estimated to be 285 million, of whom 39 million are blind [1]. Solving the transportation problems for these visually-impaired people will let them equally participate in social life. Currently, the main measure taken by the government is to build special sidewalks for the blind on the road. With the help of the sidewalk and the cane, the visually impaired can better sense objects in front of them and walk in a straight line or turn at crossroads.

3.1 Shortcomings of the Current Sidewalks

The tile of the current sidewalk for the visually impaired has been designed in two patterns - on one, there are four convex strips indicating a straightforward direction; the other tile pattern is 36 convex circles (6×6) to alert the visually impaired to the end of a road, a crossroad, or non-barrier facilities.

However, current sidewalk for the visually impaired has several inherent drawbacks:

- First, it only offers direction-leading and movement-restricting functions, so it cannot provide any location information to users. Thus, the visually impaired often miss their destination even they are on the sidewalk. In addition, visually-impaired people learn nothing about the facilities along the road, such as bus stops, shops, and public restrooms, which keeps them from taking advantage of these essential services;
- Second, the sidewalks can easily have other obstacles that may hurt visually-impaired users without any warnings;
- Finally, the convex part of the tile may trip females who wear high-heeled shoes.

3.2 Improvement Using RFID Technology

Radio-frequency identification (RFID) is the use of a wireless non-contact system to transfer data from a tag attached to an object for automatic identification and tracking purposes [2]. Its appearance sheds light on the improvement of the current sidewalk for the visually impaired because it offers several advantages:

- The RFID tag has a globally unique ID that can be used as a marker;
- To discern the RFID tag doesn't require a line of sight like the earlier bar-code technology [3];
- The passive RFID tag doesn't require batteries [4];
- The distance for identification of the tag can be adjusted by modifying the coefficient of the RFID receivers as well as the tag itself [5];
- The RFID tags can be protected by passwords set for content.

Thus, the RFID tag can store unique location information. In addition, as the tag requires little maintenance, it can be constructed beneath the sidewalk and be discerned distantly. As the password can protect it from malicious interpolations, the RFID tag can be both endurable and cost-saving.

In previous studies, the RFID was applied in a robot-assisted indoor navigation system [6, 7]. Kulyukin et al. utilized the RFID in robot-assisted navigation in grocery stores [8]. However, the robot was too big to carry. Apart from these studies, Shiizu et al. developed a white cane system that helped navigate people indoors using a colored navigation line and the RFID tags at turning points [9]. However, if this system was applied outdoors, the stability of the system would be challenged because the colored line could be damaged too easily.

4 System Design

4.1 System Overview

As shown in Fig. 1, the RFID-based road guiding system has two parts- the RFID tags and the road guiding cane. Location and business information is previously stored in the RFID tags which are later constructed beneath the sidewalk. When a visually-impaired person walks on the special sidewalk, the RFID receiver inside his road guiding cane will identify the RFID tags nearby. After the RFID tags are discerned, that information is transmitted to the embedded system in the cane. According to the type of information recorded, the embedded system will present business information or perform a real-time calculation to give precise direction to the destination. The feedback is given via voice.

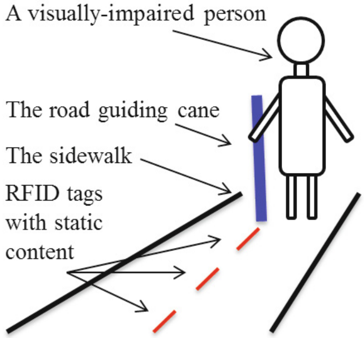

Fig. 1. System design under navigation mode

RFID tags with static content are put beneath the sidewalk. RFID tags with dynamic contents are used to indicate the traffic-light signals. As shown in Fig. 2, when the visually impaired person gets close to the traffic lights, the RFID receiver on the cane will identify the RFID tag with dynamic traffic content. The content of this tag is overwritten by an RFID transmitter on the traffic lights with the current signal. Thus, a person can obtain the current light information correctly via his cane.

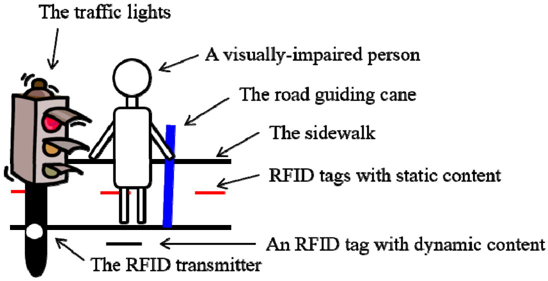

Fig. 2. System design under traffic-lights mode

It is often the case that roads are under maintenance and warning signs are placed around the obstacles. However, visually-impaired people cannot see these clearly; thus they are at serious risk. In order to ensure their safety, an RFID tag with obstacle content can be pasted on the warning signs. As shown in Fig.3, when the visually-impaired person approaches a warning sign, the road guiding cane will identify the RFID tag containing the obstacle information. Then, a warning is sent to the person via voice. Because the RFID tag is attached to the warning sign, as soon as the maintenance is over and the sign is removed, there will be no warning tags on the original sidewalk.

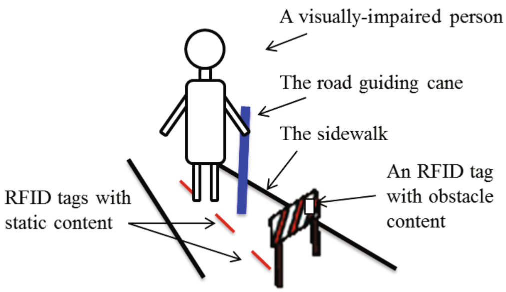

Fig. 3. System design under obstacle-detection and business information modes

RFID tags can store not only location, traffic-light signals, and warnings, but also business information. Shops along the route can place their product sales as advertisements into the tag in front of their shops; bus groups can store bus routes inside RFID tags near bus stops; public restrooms can also publish their locations. This extensibility may attract more sponsors to participate in the system construction, either by putting advertisements or other useful information in the RFID tags.

4.2 Hardware Design

RFID Tags

As shown in Fig. 4**,** each RFID tag contains two data parts. The first part specifies the type of tag- a normal static tag, a dynamic traffic tag, or a warning tag. The second part stores the text used to express the location, business message, or warning information. All content is protected by a password associated with the unique number of the RFID tag. Further, all passwords are kept in a safe database.

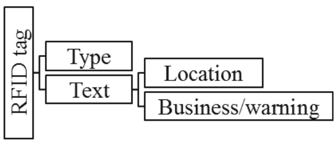

Fig. 4. Data storage in the RFID tag

According to users' suggestions in the interview, the distance between two consecutive RFID tags with static content is suggested to be 2 meters. The working frequency of the Ultra-High-Frequency RFID tags would be set at 915MHz to facilitate distant tag reading.

Road Guiding Cane

As shown in Fig. 5, the road guiding cane has three parts: Input, computation, and output. Keys were carved with Braille characters on the top of the cane for input. The RFID receiver with an antenna is utilized to identify the RFID tags within a region. All RFID tags form a network in which a single tag is treated as a node. If two nodes are connected to an edge, they become the closest nodes to each other. The map of the network is then stored in the memory. Then, the input is conveyed to the Micro Control Unit (MCU), which identifies the type of tag and calls different treatments. The message is finally outputted by an output trumpet with a power amplifier.

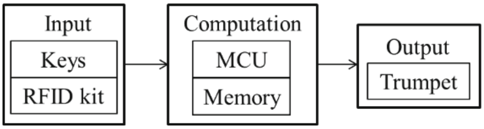

Fig. 5. Hardware framework for the road guiding cane

A prototype of the road guiding cane is shown in Fig. 6.

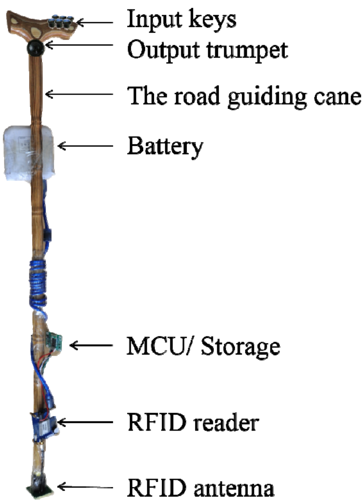

Fig. 6. Prototype of the road guiding cane

4.3 Software Design

The objective of the algorithm inside the MCU is to treat input information differently based on its type. If traffic-light signals are received, then the output message will be the signals. If warnings of obstacle are detected, then the trumpet outputs a warning message immediately.

As for normal static RFID tags, the aim of the algorithm is to give correct navigation to the destination. After the target is chosen by the user, the algorithm keeps a record of the location discerned. When a new RFID tag is scanned, the shortest path from this node to the final destination is computed using the Dijkstra algorithm [10]. As with previous locations, the current location, and the next optimal location are already determined, it is easy for the system to compute the direction of the next movement. In addition, navigation direction can be determined.

The program has been optimized as a robust design. It is known that when the RFID receiver detects a tag, it will often read it thousands of times in a second. This repetitive reading can be a major interference for the system. To solve this problem, the program reads 20 tags in each round of the algorithm. It then selects the tag with the highest occurrence frequency. We experimented in the process to show very good results in real contexts.

When visually-impaired people walk on the sidewalk, there are three potential circumstances where things can go wrong. The first circumstance is that they walk in the wrong direction and the tag being read is not on the optimal path to the desired destination. In this circumstance, the program will recalculate the optimal path, and navigate correctly with the help of previous locations. The second circumstance is the person misses some tags on the optimal path. In fact, this issue would not disturb the navigation. Hence, the program would not recalculate the optimal path. The third circumstance is when the person walks so slowly that the system reads the same tag multiple times. The system, however, is able to detect repetitive tag reading, so when this happens, repetitive routing will be neglected by the system.

5 Discussion and Conclusions

Compared with the Global Positioning System, the RFID-based road guiding cane system is better for the visually impaired in three respects.

First, the system is more accurate at providing location services. As for the GPS, the highest quality signal is reserved for military use, and the signal available for civilian use is intentionally degraded. The precision of civilian GPS is 10 meters (33 ft) [11]. However, the precision of the RFID-based road guiding system could be less than 1 meter (3.3 ft) if the parameters of the RFID receiver and RFID tags are properly set. Moreover, the GPS signal only covers outdoor locations, while the RFID-based system covers both outdoors and indoors if tags are laid at these places.

Second, the RFID-based system has more functions and contains business information that can greatly enhance the life quality of the visually impaired. By applying the RFID-based road guiding system, the visually impaired will not only get needed navigation services, but also acquire business information as well. For example, when a person walks past a shop, he or she will hear it from the cane. Thus, that person is able to "see" the shop just like a person with normal vision. On the other hand, the shop can put advertisements inside the tag and also support the construction of the sidewalk near its shop.

Third, the system costs less and is easy to update. The cost of the UHF RFID tag is less than $0.1 and the road guiding cane is about $100. The system is also easier to update than a GPS is. For the GPS, if new information is added, the whole system must be updated with firmware that might be as large as several gigabytes. However, if new tags are added to the RFID-based system, one only needs to modify the related RFID tags using an RFID writer. The sidewalk also needs no reconstruction since we could modify all tag content instantly via a password.

In this study, we carried out a "user-centered design" for the visually impaired so as to build an RFID-based road guiding system. Location, traffic light signals, and business information are kept in the UHF RFID tags constructed beneath a sidewalk. With a road guiding cane reading these RFID tags, a visually-impaired person can get navigation services, traffic light signals, business information, and warnings for obstacles when walking on that sidewalk. Compared to the use of a GPS, the proposed system has better accuracy and precision, more functions, and a major price advantage. This study should be followed by a field test of the visually impaired using this new system.

References

1. World Health Organization: New Estimates of Visual Impairment and Blindness (2010), http://www.who.int/blindness/en/
2. Wikipedia: Radio-Frequency Identification (2012), http://en.wikipedia.org/wiki/Rfid
3. Want, R.: An Introduction to RFID Technology. IEEE Pervasive Computing 5(1), 25–33 (2006)
4. Nikitin, P.V., Rao, K.V.S.: Performance Limitations of Passive UHF RFID Systems. In: Proceedings of the IEEE Antennas and Propagation Symposium, pp. 1011–1014 (2006)
5. Dobkin, D.M., Weigand, S.M.: Environmental Effects on RFID Tag Antennas. In: 2005 IEEE MTT-S International Microwave Symposium Digest, pp. 135–138 (2005)
6. Kulyukin, V., Gharpure, C., Nicholson, J., Osborne, G.: Robot-Assisted Wayfinding for the Visually Impaired in Structured Indoor Environments. Autonomous Robots 21(1), 29–41 (2006)
7. Kulyukin, V., Gharpure, C., Nicholson, J., Pavithran, S.: RFID in Robot-Assisted Indoor Navigation for the Visually Impaired. In: Proceedings of Intelligent Robots and Systems 2004, pp. 1979–1984 (2004)
8. Kulyukin, V., Gharpure, C., Nicholson, J.: Robocart: Toward Robot-Assisted Navigation of Grocery Stores by the Visually Impaired. In: Intelligent Robots and Systems 2005, pp. 2845–2850 (2005)
9. Shiizu, Y., Hirahara, Y., Yanashima, K., Magatani, K.: The Development of a White Cane which Navigates the Visually Impaired. In: Engineering in Medicine and Biology Society 2007, pp. 5005–5008 (2007)
10. Dijkstra, E.W.: A Note on Two Problems in Connexion with Graphs. Numerische Mathematik 1(1), 269–271 (1959)
11. Hightower, J., Gaetano, B.: Location Systems for Ubiquitous Computing. Computer 34(8), 57–66 (2001)