Wayfinding Systems Based on Geo-coded QR Codes and Social Computing for Individuals with Cognitive Impairments

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ABSTRACT

A novel wayfinding system is presented with an aim to increase workplace and life independence for cognitive-impaired patients such as people with traumatic brain injury, cerebral palsy, mental retardation, schizophrenia, and Alzheimer's disease. It is based on geo-coded QR codes which embed the coordinate (x, y, $floor$) and social computing that helps shorten the learning curve for the people who use it. According to psychological model of spatial navigation and the requirements of rehabilitation professionals, PDAs prompting with spatial photos at the right time and place can assist cognitively-impaired persons with navigating indoors or on the road. To do so, geo-coded QR codes which can be imagined as a new traffic sign system, are posted to selected positions on routes. The navigational photos are served on demand to the user who uses the built-in PDA camera to shoot the QR code when it is in eyesight range. A tracking function is integrated to timestamp the visited positions and issue alerts in case of anomalies. The tracking system increases the sense of security and also lowers the entry threshold to accepting the assistive technology. A prototype which consists of wayfinding devices, a training blog, and a tracking system, is designed and tested on a university campus. Compared to the sensor network approach, QR codes are easier and faster to deploy and the cost is lower. The experimental results show the computer-human interface is friendly and the capabilities of wayfinding are reliable.

Categories and Subject Descriptors

H.5.2 [Information Interfaces and Presentation]: User Interfaces–Evaluation/methodology, *User-centered design, Prototyping, Screen design*; K.4.2 [Computers and Society]: Social Issues–*Assistive technologies for persons with disabilities*

General Terms

Design, Human Factors.

Keywords

Cognitive disability, ubiquitous computing, user interface, QR codes, blog.

1. INTRODUCTION

Recent developments in information and communication technology and increasing problems in the health field, including population ageing and medical staff shortages, have opened the way to a whole set of new and promising research avenues, most notably, work on smart environments. A smart environment is an augmented environment with miniaturized processors, software communicating between each other, and multi-modal sensors that are embedded in any kind of common everyday objects[1]. In this context, a growing literature [2] [3] [4] [5] has begun to explore the process by which cognitive assistance, inside a smart home, is provided to occupants suffering from cognitive deficiencies such as Alzheimer's disease, traumatic brain injury, cerebral palsy, mental retardation, and schizophrenia, for the performance of their Activities of Daily Living (ADL). Putting on a larger scale, not only the home but also the community or even the city can be increased with intelligence to make people's lives easier, especially lives of those with less fortune. For example, the majority of otherwise-employable persons with mental impairments remain unemployed, rarely access appropriate community services, and are socially isolated. Wayfinding systems are an assistive technology targeting cognitive-impaired patients who are mobile and need to travel through both indoor and outdoor environments for work, shopping, socializing, therapy, and other purposes, thus increasing workplace and life independence.

One of the major factors affecting people's attitudes toward a new technology is the attributes of the technology itself [6,7]. Rogers [6] identified five main attributes of technology that affect its acceptance and subsequent adoption: relative advantage, compatibility, complexity, observability, and trialibility. Thus, a new technology will be increasingly diffused if potential adopters perceive that the innovation: (1) has an advantage over previous innovations; (2) is compatible with existing practices, (3) is not complex to understand and use, (4) shows observable results, and (5) can be experimented with on a limited basis before adoption.

Keeping the users attitudes in mind, we propose a novel personal guidance system based on geo-coded QR codes and social computing for individuals with cognitive impairments. Such a personal guidance system will help them safely and effectively with personal wayfinding and, thus improving the quality of life without the great cost and inconvenience of special assistive services. Based on psychological models of spatial navigation, an individual carrying a handheld is instructed by a photo showing directions when she reaches a position on a planned trip. Every such photo is triggered by a geo-coded QR code image displayed at important positions, such as street intersections, exits, elevator

doorways, and entrances to stairways. By practicing shooting the QR codes with his camera-ready handheld, the individual is able to receive guidance embedded within the photos just in time. Depending on the extent of mental retardation, proper training and repeated practices are required to use the wayfinding handhelds and familiarizing oneself with the user interface. Therefore, we develop an integrated coach system that helps the individuals learn how to use the guidance devices with social computing. Before hitting the road, a person can be trained in front of a blog with the help of coaches or family members. Furthermore, to increase the sense of security and help with precautionary measures, a tracking interface is included in the system for authorized personnel to observe an individual's trajectory while the handheld device is being used. The tracking functions by recording the person ID, timestamping the visited position, elapsed time after leaving the last position, and expected arrival time to the next position. In case anomalies occur, such as individuals failing to reach a position en route or prolonged elapsed time between two adjacent positions, actions can be taken by the support team or family members to make sure things are all right.

The paper is organized as follows. In the next section, we survey the state of the art in the wayfinding research for individuals with cognitive impairments. Then, prototype design which draws upon psychological models of spatial navigation is presented. Implementations and results are shown followed by some concluding remarks.

2. SURVEY

Difficulties in wayfinding hamper the quality of life of many individuals with cognitive impairments who are otherwise physically mobile. For example, an adult with mental disorder may want to lead a more independent life and be capable of getting trained and keeping employed, but may experienced difficulty in using public transportation to and from the workplace. Remaining oriented in indoor spaces may also pose a challenge, for example, in an office building, a shopping mall, or a hospital where GPS devices fail to work due to scarce coverage of satellite signals. In addition, the state of art displaying positions on the navigational interfaces has not taken into consideration the needs of people with mental disabilities.

Current methods in social services for aiding people with wayfinding are labor-intensive. For example, job coaches at several Taipei-based rehabilitation institutes, who work with individuals with mental impairments to support them in learning new jobs and maintaining paid employment, may work for weeks helping a person learn how to travel to and from work. Even then, the individual may at times still require assistance of one form or the other. While en route to the work, the person needs to be reminded by phones from the supporting group, or followed by the job coach invisible to the person, in order to keep things safe and in control. As a result the majority of otherwise-employable persons with cognitive impairments remain unemployed, rarely access appropriate community services, and are socially isolated [8] [9] [10].

The growing recognition that assistive technology can be developed for cognitive as well as physical impairments has led several research groups to prototype wayfinding systems. Researchers at the University of Colorado have designed an architecture for delivering just-in-time transit directions to a PDA carried by bus users, using GPS and wireless technology installed on the buses [11]. The Assisted Cognition Project at the University of Washington has developed artificial intelligence models that learn a user behavior to assist the user who needs help [12]. Later a feasibility study [13] of user interface was carried by the same team, who found photos are a preferred medium type for giving directions to cognitively impaired persons in comparison with speech and text. However, they used a manual approach to decide when to send photos based on location information uploaded by the shadow support team. In addition, route personalization was not considered; only fixed routes can be planned ahead of the trips. Our research is one step forward beyond their pioneering work in [13].

The prototype system presented in this paper is currently being developed in Taiwan to help persons with mentally impairments and social workers with their field tasks. It aims to enable the individuals to lead a more independent life by becoming capable of traveling outdoors and remaining oriented indoors as well. The system is smart and has unique strengths because it is designed to function in low-cost settings with geo-coded QR codes, instead of massive wireless sensors deployed in the network infrastructure. In addition, it can also be deployed in a shorter time frame than the sensor network approach to the smart environment. The QR codes trigger the downloading of photos with directional instructions, thus eliminating the need of a shadow support team behind the user. Route personalization is accomplished by the system identifying the user and the destination set ahead of time. Therefore, even shooting the same QR code on the same spot, different users may receive different directional instructions. It works indoors where GPS signals cannot reach. Even in the roadmap to building sensor-based smart environments on a larger scale, the QR-code approach can serve as a pilot study before massive deployment of sensors.

3. PROTOTYPE DESIGN

The wayfinding system consists of three parts: a handheld PDA, a training interface, and a tracking system. The design draws upon the psychological models of spatial navigation, usability studies of interfaces by people with cognitive impairments, and the requirements based on interviews with nurses and job coaches at rehabilitation hospitals and institutes.

3.1 Wayfinding Handhelds

To relieve the job coaches from labor-intensive aids with wayfinding, a PDA is carried by the individual who has difficulty in indoor wayfinding or taking public transit to and from work. The PDA shows the just-in-time directions and instructions by displaying photos, triggered by pictures of geo-coded QR codes taken by the built-in PDA camera. See Figure 1 for taking the pictures of QR codes and Figure 2 for the photo downloaded. However, the persons who carry the wayfinding PDAs may at times need assistance when they find themselves lost somewhere and cannot make themselves understood where they are. Note the system also works even for a stranger to this neighborhood.

Figure 1. A QR-code picture is placed to be taken by the PDA camera to guide the individual with mental disorder.

Figure 2. A just-in-time direction is shown on the wayfinding PDA.

3.2 Wayfinding Training

A multimedia training system helps job coaches to brief the individuals with cognitive impairments about the routes to and from the work. Photos and video clips of the checkpoints en route are listed in a sequential order and annotated by concise descriptions of the checkpoints. The photos will show the directions for the individual to take, whether they are straight ahead, left, right, waiting for a bus, or taking an elevator. Introducing the photos in the correct sequence helps the making of imprints for the people, thus reducing the chances of getting lost while they take the trip alone.

The rehabilitation institutes encourage the job coaches to keep track of the persons by saving their vitaes and historic records on the secured and private blogs. Because it is easy to create pages on blogs, they have become the novice's as well expert's web authoring tool. It is found that the blog is an effective and efficient tool of knowledge management [14]. Existing Knowledge Management (KM) tools are not as successful because many focus on collecting information and lack the contextualization of the information which is vital to the process of knowledge formation and sharing [15].

The reason of using blogs to hold users data is the free style of telling stories preferred by social workers, who usually considers web interfaces of table driven databases as not user friendly enough. In the evaluation of the prototype, social media such as blogs are found to be more capable of keeping scenarios and processes in the preferred forms of multimedia, whether they are text, mp3, photos, or video clips. Web 2.0 also comes into play in the prototype when we further improve the user interfaces. The labels that blogs use to make classifications are in particular helpful, because the job coaches can retrieve a comprehensive list of data for a person simply by the person name in labels.

Therefore, the training materials are stored in the job coach's private blog, labeled with the name of person who uses the route. All the route information can be maintained in one blog but retrieved with respect to whom the briefing will be made. The blog can be shared with the deputy coach in case the designated coach is not available, for example, calling in sick.

The hands-on training is as important as briefing, if not more important. In the blog, each photo that carries directions to take at a checkpoint, is associated with an image of QR code, which is geo-coded with the coordinates of the site. The QR codes are the same as those deployed where their embedded coordinates indicate in the physical world. Therefore, the person who carries a wayfinding PDA can practice shooting the QR-code image in the blog. The shooting sequence is monitored to make sure it is made in the same order as in the job coach's briefing. At each shooting, a photo will pop up which shows the direction to take at that spot. The practice is mean to help the individuals to take advantage of the wayfinding devices and social computing effectively. Job coaches may still need to accompany the individuals hitting the road for days, even though the wayfinding PDAs are in use. The training system is not to replace the road training but it reduces the time for the learning of wayfinding skills.

3.3 Tracking

The server at the heart of the prototype tracks the person who may deviate from the preset route to and from the work, and then in case of anomalies the support personnel can take standard procedures, such as making calls to the individuals who have cellular phones with them or issuing alerts that are sent to job coaches. This increases the sense of security and helps with precautionary measures. The tracking interface is for authorized personnel only to observe an individual's trajectory while the network-ready handheld device is being used. The tracking functions by the PDA recording the person ID, timestamping the visited position, elapsed time after leaving the last position, and sending all the information wirelessly to the server that performs tracking. By comparing expected arrival time to the next position, the system helps protect users from getting lost.

4. IMPLEMENTATIONS AND EXPERIMENTAL RESULTS

A prototype system is implemented for job coaches at several Taipei-based rehabilitation institutes funded by a government-sponsored social work program. The prototype consists of how PDA receives the photos, how QR codes trigger downloading, what photos should be downloaded accordingly, and how individuals are tracked. The PDA is equipped with a screen size 320*240, Wi-Fi 802.11g, Bluetooth, GPRS and a built-in camera with 2 million pixels. The server is a Intel-based PC server for authenticating the users, planning a trip, serving photos upon requests from PDAs, and receiving timestamps for each position visited. The connectivity is provided via Wi-Fi on a campus with 410 Access Points. In places where Wi-Fi is not available, GPRS can be used instead. The architecture is shown in Figure 3.
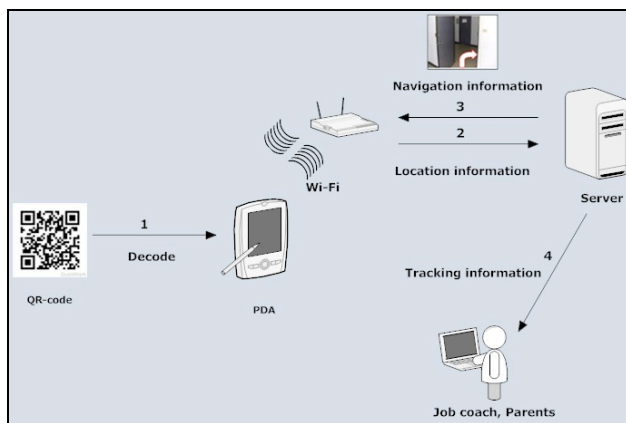

Figure 3. Architecture and system interaction of the wayfinding prototype. By shooting the QR code (1), the user PDA provides location information (2) sent over wi-fi, followed by the navigation server uses that location information to decide which photos to send (3). The user then follows the direction or prompt displayed on device. The navigation server records the positions, time, and user ID for the tracking purpose. An user interface is provided for job coaches or family members to retrieve the tracking information (4) which is then displayed on a map.

For the training system, a blog (Figure 4) is adopted to host the training materials including wayfinding photos and their associated QR codes. For the convenience of job coaches to brief the cognitively impaired persons, explanatory descriptions such as name of position, distance to the next position, and what directions to take, are also included.

An example is presented in Figure 4. The QR codes and the associated photos are listed sequentially as they appear en route. With assistance from coaches, the users are trained to familiarize themselves with shooting the QR codes one by one. The photo downloaded to the PDA is the same as seen on the blog.

Figure 4. QR codes and their associated photos listed sequentially.

Experiments are designed to test the implemented prototype. Four routes in different combinations of stairways, elevators, and turns have been planned in the study. Route 1 involves no floor changes, while Route 2 is outdoors, Route 3 involves taking the stairs down one flight, and Route 4 involves using an elevator and taking the stairs down one flight. As shown in Figure 5 (a) and 5 (b), Route 4 is from Laboratory 517, which is located on the 5-th floor, to an ATM machine, which is at the entrance at the ground floor. A position on Route 2 is shown in Figure 6.
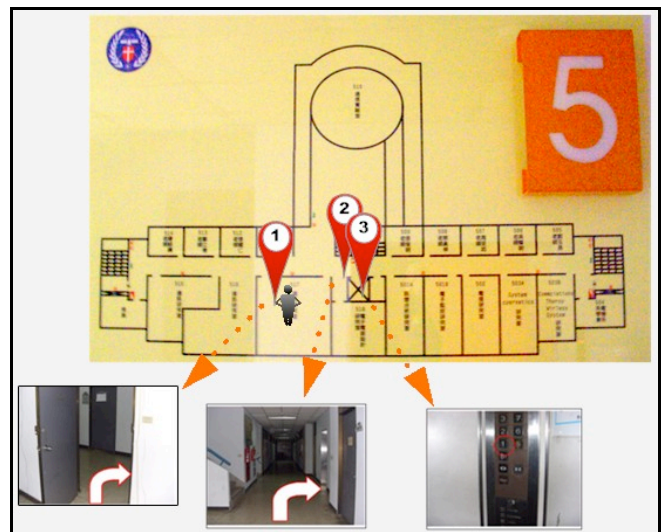

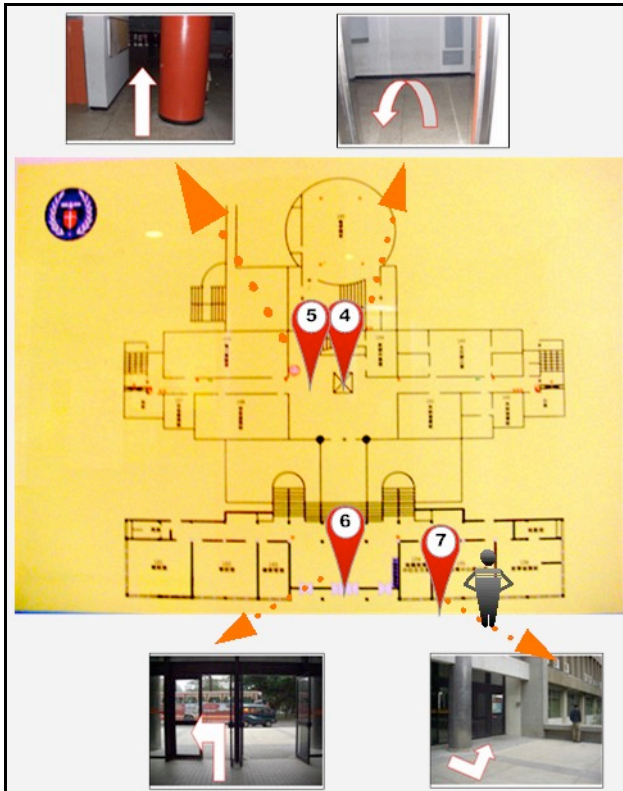Figure 5 (a). Floor plan of the 5-th floor in one of the experiments.

Figure 5 (b). Floor plan of the ground level with an ATM machine as the destination of a trip.

Figure 6. A campus sign with QR code posted for wayfinding.

In order to accomplish the trip, positions on the route have to be passed successfully. All the positions are posted with the QR codes, which are embedded with location information. Participants are shown the device and trained before the experiments. They are led to the starting location of each route and given the task of following the device's directions to a set destination. Participants are told their destination before starting their trips.

We summarize the experimental outcomes based on the observations of the prototype design team. In the forty trips made by ten cognitively-impaired participants taking the four routes respectively, the ratio of participants deviating from the set routes is 4%. Note the ratio can depend on the extent to which participants suffer from mental disabilities, the complexity of routes, the degree of received training and self-practices, and the distractions the participants may encounter.

In case people deviate, automatic alerts will be issued by the tracking server and show on the consoles or send to PDAs or cellular phones of authorized personnels, depending on the preferences set ahead of time. Figure 7 shows the web interface for the tracking purpose. Note that neither the human photos nor names are the participants (they are actually of the prototype design team), for reasons of privacy and ethics. The GUI is a mash-up of Google Maps and the tracking data received from the user handhelds via Wi-Fi. Blue bubbles stand for the positions users have passed and red ones stand for the destinations of planned trips. On the left of Figure 7, a user arrived at his destination, while another failed to arrive at the next position within the expected period of time (as shown in the right of Figure 7) and the question mark indicated the missed QR. Since the experiment is a pilot study, no job coaches, support staff, or family members are actually notified. In real cases, actions can be taken following the alert, such as calling the user by cellular phone, sending SMSs, or Skyping her on the PDA, whichever is available.

There are some limitations to the PDAs and user interfaces. PDAs are fragile and not weather proof. Therefore, protective measures need to be taken to keep them in good maintenance from frequent use. A challenge to us in the experiments is that strong sunshines can make the screen hardly viewable no matter what is downloaded and shown. Fortunately, the same problem seldom arises in indoor wayfinding. Form factors are also an issue. Although small and thin PDAs are easier to carry with, small screens are less useful for photo rendering. In the night time, the signs of QR code may not be clearly visible. However, most individuals with mental impairments are told to refrain from staying outdoors anyway. The web interface of tracking system works with Google Maps for outdoor routes. For indoor navigation monitoring, floor changes and moving elevators can complicate the GUI design. This remains a future work.

5. CONCLUSIONS

In this paper, we present a wayfinding prototype system based on QR codes and social computing for individuals with cognitive impairments. The design draws upon the cognitive models of spatial navigation and consists of wayfinding devices, a training blog, and a tracking system. Compared to the sensor network approach, it is easy to deploy because of low cost and short time frame. The prototype is implemented and tested with routes in the campus. The results show the prototype is user friendly and promising with high reliability. The success ratio can depend on the extent to which participants suffer from mental disabilities, the complexity of routes, the degree of received training and self-practices, and the distractions the participants may encounter. Limitations to PDAs and user interfaces are discussed and then

challenges are identified. A vision to the future is to realize a new system of traffic signs coexisting with the current one for the betterment of cognitive-impaired individuals with increased life independence.

6. ACKNOWLEDGMENTS

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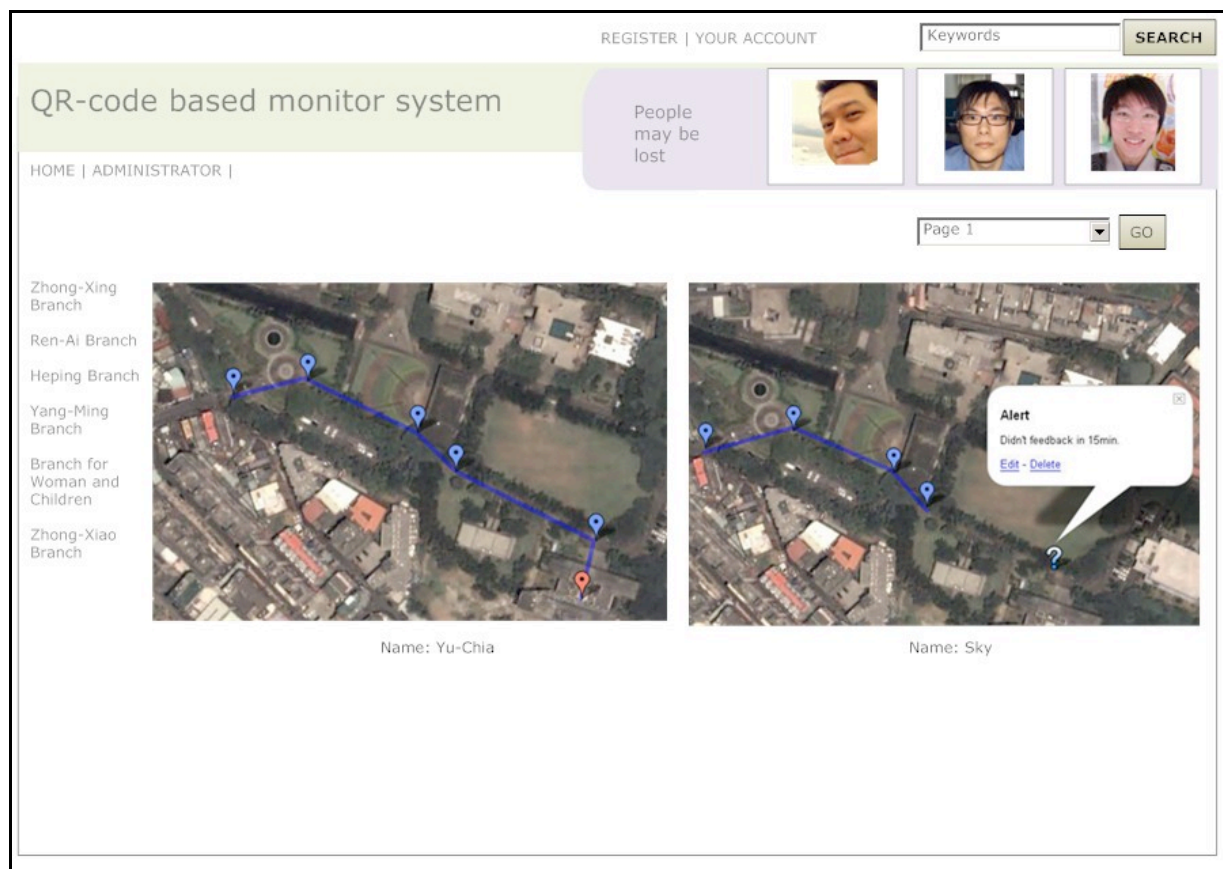
Figure 7. The tracking system shows a participant who passed all the positions en route (left) and another who missed the expected-to-arrive position and the prolonged elapsed time triggered an alert (right).