How do We Aid Visually Impaired People Safely Manage Unfamiliar Environments?

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Abstract

It is a challenge for researchers and engineers in the assistive technology (AT) community to provide suitable solutions for visually impaired people (VIPs) for orientation, navigation and mobility (ONM). Our literature review looked at the current state of the art in AT designed to aid VIPs in ONM. Given the spectrum of the AT solutions at the time of our survey, there are several papers in our review which raise the adoptability issue for AT solutions specifically designed for VIPs. We conducted a survey in order to gain insight into how this technology was actually being used by VIPs. We consider the underlying issues and challenges causing current AT solutions to fall short in addressing VIP's ONM needs. We felt that it is critical to re-examine and rethink the approaches that have been taken. It is our belief that we need to take a different and innovative approach to solve this problem while addressing the issues revealed in our survey and subsequent analysis. Motivated by these findings, we propose an integrated cyber-physical system (CPS) framework with "Agents" and "Smart Environments" to address VIP's ONM needs in urban settings.

Keywords

Assistive technology; cyber-physical systems; ONM

Introduction

It is a challenge for researchers and engineers in the assistive technology (AT) community to provide suitable solutions for visually impaired people (VIPs) for orientation, navigation and mobility (ONM). Whereas advancements have been made, affording VIPs improvements in work and study, the problem of being able to go from place to place safely and securely is still to be addressed. Crossing the street is problematic: knowing if it is safe, knowing when to cross, being sure to remain on path and not collide or interfere with objects and people, remain issues dissuading VIPs from a truly independent lifestyle.

Thus, we have arrived at a novel, innovative solution that we perceive will change this situation. We present our cyber-physical framework in which we define a smart environment and an agent, an individual outfitted with a personal internet of things (IoT) made up of sensors and actuators pertinent to the needs of the given subject, which then communicates via a controlling device - known as the personal information hub (PIH) - with the smart environment.

In our prior research (Goldberg 2015), we were interested in the question, if so many technologies are available – including solutions designed to help the visually impaired community with their ONM needs – how many, if any, are being utilized by VIPs?

Results in our survey show that there were not many made-for-the-blind AT solutions being adopted by VIPs for their ONM needs. We analyzed why this might be so and then defined an innovative approach to address the issue through cyber-physical systems (CPS).

Related Work

(Abascal and Civit 2000) suggested that mobile devices, in particular cell phones, helped to 'untether' VIPs from their homes by allowing them to carry their devices around with them. In (Kane, et al. 2009), they surveyed how VIPs and individuals confined to wheelchairs used various technologies to help them navigate their surroundings. They showed that VIPs were specifically concerned with not losing their bearings and would carry multiple devices just in case one failed.

Since then much research has gone into seeing what could be done with smartphones. As noted in our survey, smartphones are utilized readily by VIPs; however, it is noteworthy that VIPs use mainly what is generally available and develop their own strategies for what to do with these devices.

With more understanding of alternative technology as in (Abu Doush, et al. 2016), ideas for a more systematic approach to aiding VIPs has evolved. In (Brock, et al. 2014), this becomes more evident as the way to look at AT solutions. (Brock, et al. 2014) and (Abu Doush, et al. 2016) propose an interactive approach although the suggestion is only alluded to as the way forward.

(Ganz, et al. 2015) is noticeable as the population discussed is not the stock 290 million VIPs cited by WHO but rather recent VIPs due to combat (veterans) or complications due to diabetes. This emphasizes a very particular element of the VIP community – i.e. people who may have vocations in which they are now hindered by being a VIP. These VIPs cannot rely on long-learned habits.

We find that these perspectives are inspiring from a technical perspective, but their approaches fall short of providing a truly interactive solution for VIPs with their ONM needs. Our proposed CPS framework goes further to address the issues we have revealed in our survey.

Discussion

A determination was made to substantiate our understanding of the lack of adoption of made-for- the-blind AT for ONM by VIPs. We developed our survey which was sent to as many recipients as possible, through various blind agencies. We were able to get the New York chapter of the National Federation of the Blind, the New York State Commission for the Blind, the Association for Vision Rehabilitation and Employment (AVRE (US)), and the World Blind Union to distribute the link to our online survey. We received 32 responses (Available as an MS-Excel worksheet), mainly from the US, with one respondent who stated that she was in Auckland, New Zealand. This definitely suggests that VIPs do go out and about, and therefore ONM is of interest to them. We collected baseline data (Age, Gender, Degree of Difficulty) and found that we had a decent spread with about 62.5% identifying as female, 84.7% of the respondents were in the working age spectrum of 21 – 65 years old, and of the respondents we had 38.7% identify as totally blind, another 25.8% stating they had light and shapes with the rest having varying levels of low vision.

Current Use of Assistive Technology

We found that by and large, the subjects use white canes (78.6%), with 25% of the population using guide dogs. 96.5% of the respondent's use of smartphone; however, only 50% said they used a phone for ONM. 11 of the respondents told us of the applications they utilized. Of these 54.5% said they use either Apple or Google *Maps* with 18.2% saying they employed *BlindSquare*. When asked what GPS apps they employed, 57.1% stated they used *BlindSquare*, with 35.7% using *Trekker Breeze* or a version thereof. It should be noted that all but one respondent using the latter product are over 45, suggesting that they have been using it since before the apps everyone is using came to market and are still utilizing it.

One totally blind respondent said: *I use GPS apps to research nearby places and to get announcements of nearby streets and places when walking or riding, as well as to get turn-by- turn directions to places. I also use the app of my local public transportation system to find out about the scheduled time for routes, nearby stops, etc. I use [the] app of my local cab company to book taxi cab rides. If I am traveling by air, I use apps such as FlightView, Gate Guru, and Where To Go to find out my flight status, amenities at the airport, and locations of relief areas for my guide dog.*

Another, also totally blind, stated: *Mainly Google Maps. …. Basically, I use it to estimate distances from places (like whether we're approaching my bus stop), for walking directions (often with help from public to figure out new intersections) and for planning a route in the first place as my city (Auckland New Zealand) has a notoriously difficult-to-work-out bus network if you haven't been to any given suburb before. I use Blind Square a little bit to figure out what places are around. …., but most ideal for me would be some form of accessible mode in Google Maps that'd let you know when you need to cross a road when walking, and which side of the road a bus stop is on in the transit mode.*

One respondent with light and shapes said: *My phone serves as the platform on which I run my various ride-hailing and navigation apps. I use Apple Maps to provide GPS directions, and the Uber app to book a ride to my destination of choice.*

A low visual acuity respondent tells us: *I use [my phone] to help me see where I am on the map. I especially do this when I am in buses and can't easily view street signs through my telescope. I rarely took the bus before I got a smartphone.*

Another low visual acuity respondent told us: *GPS apps; help verify where I am, help track back to a specific location.*

Thus we find evidence that a good third of our respondents utilize their smartphone as a mobility aid. The question, though, is in what ways are they using specially made-for-the-blind applications? The application *BlindSquare* is most prominent. As a made-for-the-blind application, it is actually a veneer for a more generally utilized piece of software, *Foursquare*, and used pretty much for the same reasons. The interface is user-friendly for blind users. The *Seeing Eyes GPS* is a new version of *BlindSquare*.

In general, the replies tell the story of adaptation of readily available applications such as *Google* and *Apple Maps*, and *Uber* and *Lyft*.

Gauging Readiness to Use New Technology

We asked if respondents had taken part in clinical studies to which 77.2% of the respondents said “N/A”. We found one had used BrainPort; one, Argus-II; and one had been a subject with Sonic Glasses. Beyond that very few expressed any interest in pursuing this. We questioned them about use of crowd-sourced aids such as *VizWiz* and *TapTapSee.* Only 19.4% responded positively and when asked about electronic travel aids, 18.8% answered positively; one replied that he did use them, but did not like them!

Over all, we found a reluctance to adopt any made-for-the-blind technology other than *BlindSquare* which is a made-for-the-blind interface for a general purpose GPS based application, *Foursquare*. As observed by (Kane, et al. 2009), having GPS is of extreme importance to VIPs who sometimes carry more than one device to be assured of having a working app. Maintaining a sense of ONM is of extreme importance to VIPs.

Possible causes for the lack of adoption of current AT for ONM

We will discuss a few of the issues we see as problematic with current research and justify the need for a different approach. Firstly, we must realize that VIPs are people too. Placing a box on one’s head with a camera and wires all over the place is not something most people would wear, so why expect this of VIPs? But VIPs do need AT. Canes and dogs are limited in how they can help, and in today’s busy world, they are insufficient where safety and security are concerned. The research is often conducted in a controlled environment - as it should be - but when faced with reality, the results are less impressive. Ideas such as crowd-sourced (volunteer based) solutions such as *TapTapSee* are not very reliable if trying to service too many clients with multiple needs at odd hours of the night. Finally, there is the issue of cost. *Argus-II* has gone public and now costs $150,000; who is going to pay for it?

Our proposed CPS framework with an “agent” and a “smart environment” will shift much of the data storage, data processing and communication tasks to the “smart environment”. This would in turn reduce the computation power requirement for individual devices. It is possible for a VIP to just use his/her smartphone or a simple personal device, such as Raspberry Pi, to perform the functions of the agent.

Proposed Solution

In our research we propose an innovative approach to the often asked question, “How do we aid a visually impaired individual safely and effectively navigate an unfamiliar environment?” Thus far, assistive technology solutions have concentrated on passive approaches which by and large have not been adopted by the community for which they were created. By ‘passive’ we refer to the fact that solutions either: Read a situation and attempt to understand what is sensed with minimal information garnered from the environment. For example, a camera captures images and then attempts to ‘understand’ the given context through vision algorithms. Or, read data provided by the environment through a specially designed reading device and attempting to act upon it. In short, there is no ongoing interaction between the system analyzing the situation and the environment that is being navigated.

We present a cyber-physical solution that would aid an individual in his/her traversal of an environment, enabling the system to facilitate a secure and effective way through the area. The key CPS concepts, as defined in (Zhang 2015), bridge the physical world we live in with the cyber world, utilizing information that comes from the Internet of Things (IoT). People with vision loss or other special needs may have difficulties comprehending or perceiving signals directly from the physical world, but they can make connections in the cyber world. These cyber connections and real-time information exchanges will enable or enhance their interactions in the physical world.

It is natural to view the problem space from two perspectives: The person with special needs; the environment that the person needs to navigate through or around.

Therefore it is natural to design our AT solution with two subsystems:

1. The agent,
2. The smart environment.

The agent is a cyber-representation of an individual who is outfitted with a body-worn internet-of-things, controlled primarily through Bluetooth technology by a device we call a Personal Information Hub (PIH). The smart environment is a cyber-representation of a physical environmental infrastructure embedded with computer technology that can communicate with a set of agents at any given instance utilizing WiFi and Bluetooth technologies. The individual and the physical environment along with their cyber representations (agent and smart environment) form an integrated cyber-physical system framework.

Who better to know the environment than the environment itself? A major issue with current assistive technology solutions is that the agent has to work out the whereabouts of the individual and deal with the issues that might arise. In our framework, the smart environment would store data about the environment. We envisage a smart environment with a labeled 3D model – coupled with algorithms – built to take in data from an agent and able to give information back to the agent on all matters regarding the environment, such as traffic signals, information about the terrain, etc.

Through the PIH, continuous information could be exchanged with the smart environment via WiFi or Bluetooth. Prior to interaction, a handshake could be established in which the agent transmits a data file. This allows the smart environment to respond according to the needs of the individual represented by the agent. As with the smart environment, the agent is the optimal place to keep information about the individual. This includes which devices are part of the individual's personal IoT that can be utilized by the smart environment.

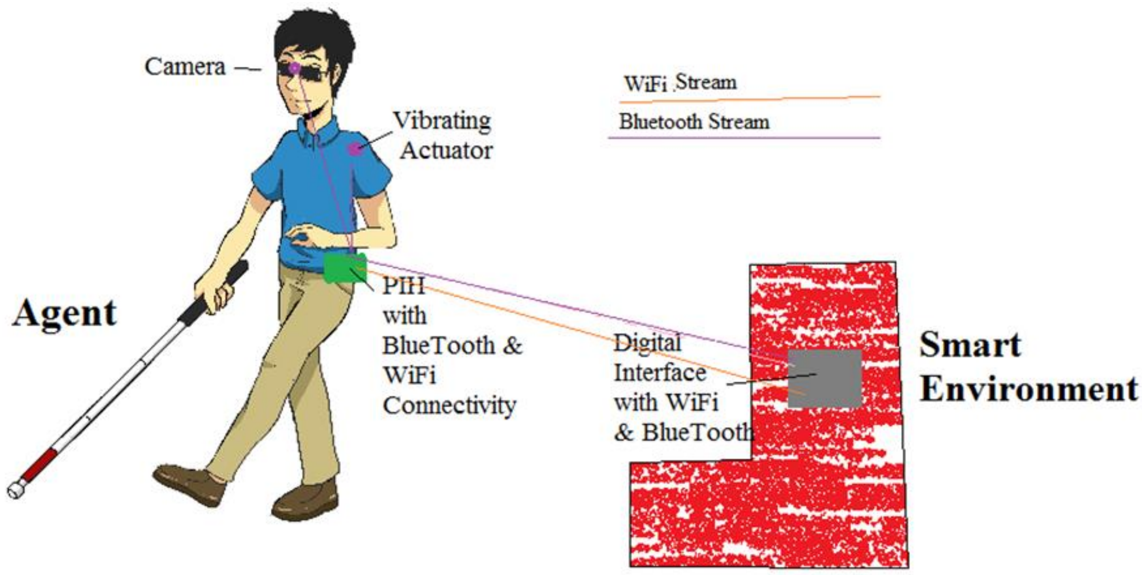

Fig. 1. The architecture of the cyber-physical system showing how the communications would work.

The architecture is described in Figure 1. A camera worn on the glasses could capture an image or video stream that can be processed according to the needs defined by the smart environment's algorithms.

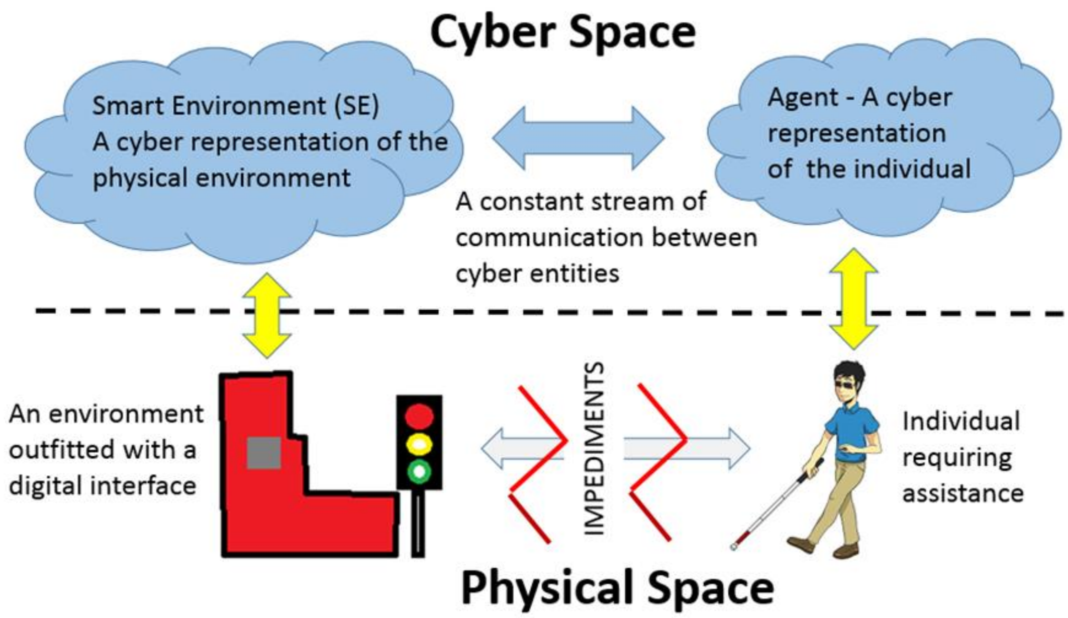

Fig. 2. Concept of the CPS Framework and how it operates

Figure 2 describes the cyber-physical framework concept. The entities in the physical world are represented by the elements in cyber-space. Problems arise in the physical world. The individual experiences certain difficulties in perceiving information from and reacting to his/her physical environment. In this instance, a VIP has a visual impairment that causes this difficulty. Thus, via connectivity in cyber-space, through elements representing the individual (the agent) and the environment (the smart environment), the VIP can mitigate the impediment in the physical world and be able to better interact with his/her surroundings.

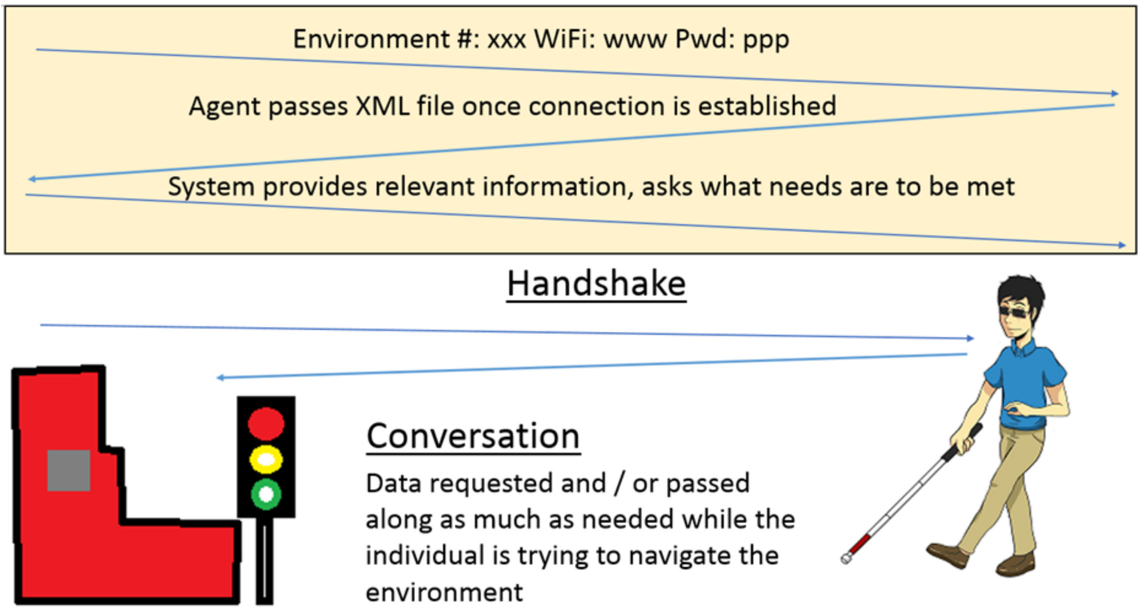

Fig. 3. A process diagram showing the handshake and the conversation.

Figure 3 describes the operation of this system. Through sensors such as cameras in the environment, the CPS would be able to monitor possible problem situations. Consider the following scenarios:

Let us take a cyclist riding irregularly through the environment or a vehicle which is disobeying the traffic rules. In each case, we have an anomaly which the individual is unable to capture but which could put the individual in danger. Here a CPS could be constructed to monitor such anomalies. Through the constant communication between the agents and the smart environment, the system would be able to warn individuals who may be in danger. In this case the message is transmitted to an agent's PIH, which in turn guides the individual in a personalized response that is designed to fit his/her specific needs, such as using customized audio or haptic messages for a VIP.

Even these simple real life examples require a sequence of timely information exchanges between the agent and the smart environment to enable the individual to safely navigate the physical environment. This is supported by integrated computing and communication systems, a CPS framework. Once such a CPS has been constructed and an agent is able to interact with it in the way intended, a chain of smart environments would be able to share data about expectations. An individual has an intended path and specific needs. The agent could relate this to the chain of smart environments. Should an issue arise, a communication down the chain could pass on relevant data that may help direct the individual more efficiently. Furthermore, should situations in a given environment be problematic, this could be shared between environments to better manage situations.

Our project is still in an early research stage. It could be implemented in steps, with currently available technologies, to integrate the CPS framework into the current urban infrastructure. This could be done the system would evolve seamlessly and with minimal interruption to a busy, ever evolving world.

Conclusion

Thus far we have reviewed the AT available for meeting the ONM needs of VIPs. While there is much in the way of research and ideas being proposed, we understand that little, if any AT is actually being adopted for use beyond the basic GPS applications that are readily available to the general public. While we have explained the concept and some key AT components here, it is in our ongoing research that we will design, develop and test the full framework and how it might be applied in urban settings.

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