Design and Implementation of SEE-Phone in SEES (Smart Environment Explorer Stick)

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Abstract – The mobility is a complex, yet not well understood, human cognitive process; it subsumes several different tasks such as walking and orientation. The visually impaired people (VIP) mobility heavily depends on the white stick (or white cane) which otherwise does not provide an efficient support for walking and orientation. Indeed, these two later functions implementation requires the usage of high technology which should be conveniently integrated to the white stick in order to obtain the smart stick. This paper proposes to fill this gap, and outlines the SEES (Smart Environment Explorer Stick). This paper focuses on SEE-phone as a part from whole SEES system. The first prototype of SEE-phone, a part of the SEES system, is presented.

Keywords: smart phone, GPS, Google map, web service, SEE-Phone, smart-stick, ubiquitous SEES, Visually Impaired People (VIP), assistive device

I. INTRODUCTION

Blindness and visual impairment are a major hindrance in daily life for accessing information, mobility, finding a way, interaction with the environment, communities and the others activities. Both of them became a very serious problem in health and social security. In addition, the other important issue for VIP is independent ability to move outdoor. Usually, they are able to move independently only along the routes which they have already learned together with a sighted guide [1]. On the other hand, they have a strong need to walk around by themselves, even when they are in new location or accidentally lost their way.

In general, navigation problems in the blind population have risen regarding mobility and orientation [2-3]. Mobility is the ability to travel safely, comfortably, gracefully, and independently [2]. Mobility of the visually impaired can also be interpreted as an activity that combines earlier defined capabilities (space perception, orientation, way-finding, navigation and obstacle avoidance). The human autonomous mobility is a capability to reach a place without assistance of any other person.

The below definition raises several problems which should be cognitively solved [4-5]: two of them are self orientation and space self awareness. The concept of self orientation means the knowledge of the relative spatial position between our current position and targeted spatial location. Two basic questions which subtend the orientation are: “where I am?” and “how to reach the destination from my current position?”. Consequently, the orientation allows to planning a specific route (path) to reach the targeted location from the current point.

Space awareness is the capability to know about urban and social data in our peri-personal space (“space around our body”), and our navigational space [6]. Some questions which subtend the space awareness might be: “what are the nearest streets located one with respect to the other and to me? what is the traffic light at the street I like to cross? where is the library I like to get in? “

This paper proposes a support for orientation and space awareness using the high level technologies, which should be integrated in the VIP mobility assistive device. More precisely, the SEES system (or ‘Smart Environment Explorer Stick’) is defined. The SEES system integrates: a global remote server (iSEE), an embedded local server (SEE-phone) and a smart stick (SEE-stick). In this paper, we focus on SEE-phone and its useful features such as GPS, camera, TTS (Text-to-Speech), voice command, etc.

Therefore, the paper is organized as follows: Section 2 provides a state-of-the-art on the existing commercial and academic solutions for VIP navigation and focus on their supports of orientation and space awareness concepts. Section 3 defines the SEES concept and outlines its implementation in the first prototype. Section 4 proposes the SEE-Phone concept and design. Section 5 addresses the results of the first SEE-Phone prototype experimental evaluation. The final section 6 indicates some future works toward the fully operational of SEES prototype.

II. STATE OF THE ART

Two complementary tracks are investigated for navigation assistance for VIPs design are GPS-based and vision-based solutions.

A. GPS-Based Navigation Technology for VIP

Since 1960 various assistive devices for the navigation system dedicated to VIP have been developed, ranging from the low to high technology devices. In 1991,
Golledge and team were persons who first proposed using of GIS, GPS, speech and the sound sensor (sonic sensors) to navigate the blind [7]. A sample of navigation system for VIP is Personal Guidance System (PGS) and an early model was developed in 1993 [8].

In general, it is possible to materialize the concept of a navigation system for VIP as a set of the following modules (figure 1): a) GPS for determination the traveller’s orientation and position, b) Geographic Information System (GIS), a software for route planning, c) The spatial database for relating the traveller’s orientation and GPS coordinates to the surrounding environment and d) the user interface.

![Fig. 1. Functional Components of PGS System](image)

The system usually provides a range of functions which generally contains simulation of a journey. It displays the route (path), searching in the database from a starting point to targeted (end) point. The provided in real-time audio instructions enable users to follow the path.

The PGS system above consists of three modules [9]. The first module is used for user location and orientation. A GPS receiver with differential GPS receiver (DGPS) is used to determine location and to trail the path of travel. The DGPS configuration also gives absolute positional accuracy on the order of 1m root-mean-squared error given good satellite availability. The second module is the GIS components that consist of a digitized base map and software design to trail the traveller’s path, select routes, recommend the traveller about local features and landmarks, correct for signal error or loss, and control dynamic access to the database. The module also contains the commands needed to navigation aid. The spatial attributes might concern some criterion of system centrality, feature or population density, connectivity, nearest neighbours, distances to other features and etc. The third module is the user interfaces that provides for two-way communication between the GIS and the user. In this part, there are two display options for GIS to user communication, namely a virtual acoustic display using binaural earphones and conventional speech display with an earphone or speaker.

There are some devices of GPS based navigation systems has been designed or modified, namely: Trekker of Human Ware, BrailleNote GPS, MoBIC, Loadstone GPS, Wayfinder Access and Mobile Geo [10]. The system provides a range of functions which generally contains simulation. It could display the route on the way, the search of database from a certain point and real-time instruction (audio) which enables users to follow the track to a specific destination.

**Trekker of Human Ware** is a personal digital assistant (PDA) or pocket PC adapted for the blind and visually impaired with talking menus, talking maps and GPS information. This device has a good functional possibilities and built-in TTS (Text to Speech). It can expand to accommodate new hardware platforms and more detailed geographic information. This device does not provide a route remote tracking for monitoring the user location and it cannot detect the obstacle.

**BrailleNote GPS** is a portable tool with speech and braille output. It is like a combination of a personal digital assistant, map-quest software and a mechanical voice. A BrailleNote has a GPS receiver, maps, and points of interest database that provide spoken and/or braille access to location information in any outdoor environment. This device does not have a route remote tracking for monitoring the user location and it cannot detect the obstacle.

**MoBIC** (Mobility for Blind and elderly people) is designed to allow a blind person access to information from many sources. The resulting system has two parts: the pre-journey system, and the outdoor system. The output system is in the form of spoken messages. The planning system helps blind people to study and plan their routes in advance, indoors. This device does not provide a route remote tracking for monitoring the user position and it does not have function to the obstacles detection.

**The Loadstone GPS** project develops open source software for satellite navigation for blind and visually impaired people. The device uses a smart phone, operated with screen reader, limited possibilities and unstable operation. Like with the previously device, the Loadstone GPS does not provide a route remote tracking for monitoring the user location and it cannot be used to detect the obstacle.

**Wayfinder Access** is a navigation system for mobile phones specially developed for visually impaired. This application is only for symbian phones, operated by screen reader and requiring a GPS maps. This device does not have a route remote tracking for monitoring the user location and it cannot detect the obstacle.

**Mobile Geo** is a product designed to convey most of the information displayed on commercial GPS receivers and location databases to people with visual disabilities. This device is used only for smart phones, PDA or Pocket PC with MS Window Mobile. It is operated with screen reader and requires GPS maps.

In general as conclusion, several systems above do not provide assistance for VIP space awareness for independent navigation. Those systems also do not have a route remote tracking for monitoring the user location and do not have the ability for detecting an obstacle (e.g. pole, traffic lights, building, etc.).

**B. Navigation System Based on Vision System for VIP**

It is important in independent mobility to provide an ability to detect a physical obstacle. The ability to know the presence of a physical object completely can be performed by vision system. Some of researchs on navigation systems for VIP have been developed the new devices by combining the orientation function (GPS and GIS) and vision system. The vision-based mobility systems an image is captured then conveyed to the VIP via different sensory channels such as sound or touch.
Concept of using video camera as vision sensors was introduced through portables systems by Peter Meijer, namely vOICE. The vOICE system [11] uses a head mounted single video camera and translates the image into sounds (headset). The scene in front of the user is scanned via head movements, from up to down, and all auditory data are cognitively integrated and interpreted by the end user. The system does not provide nor orientation neither space awareness assistance to the VIP.

The NAVIG system [12] attempts to combine the artificial vision and visual geo-located landmarks that will allow completion of the path using the GPS provided end-user current position. The NAVIG system has two main modules: the objects location is used to allocate the necessary objects for the user and the user positioning function is used to detect visual objects that are not displayed to the user, but it is used to improve GPS positioning. The system used Spike-Net NAVIG library that provides a fast algorithm based on visual research human.

Jie Xu, et.al [13] proposed a system - audio guide - which integrates GPS and vision on a PDA device. The system is made to provide contextual cues for VIP to navigate safely in dynamic situations. The PDA camera captures the dynamic information environment and information landmarks along the route of the map database using a Visual Studio eSuperMAP.

Do-Hoon Kim and Heung-Gyoon Ryu [14] proposed a navigation system for VIP which combines the GPS, camera and ultrasonic sensors. This system gets information about the environment using GPS and distance data using ultrasonic sensors, and then inform the user. The camera is used to assess the situation in front of users as a color. In the case of short-range obstacles, vibrators transmit sound and vibration to the user. This system used a bluetooth communication for transmitting data.

Conclusions from several systems above are these systems have combined the orientation function and vision function, the systems use camera and ultrasonic to detect an obstacles, but the systems do not provide a route remote monitoring for tracing the user location.

III. THE SEES SYSTEM

A. SEES Concept.

The SEES system aims to provide assistance for VIP mobility. This paper addresses the SEES support for VIP orientation and space awareness as defined in Section 1.

The main innovation of SEES is internet connection which enables the VIP to get help and be internet monitored [15], therefore it is possible to consider it as an ubiquitous smart stick.

The SEES system (figure 2) contains three main components: a global remote server (iSEE), an embedded local server (SEE-phone) and a smart stick (wheeled SEE-stick). iSEE is a global server providing the web services for the VIP such as remote real-time hint and help and remote monitoring (trace the VIP location).

The SEE-phone is based on a commercial smart phone. It is used as an embedded local server and provides the local services for the SEE stick such as route vector and internet access to iSEE. SEE-phone is always connected to SEE-stick through Wi-Fi.

Each sub-system provides independently assistance, to walking and to orientation of the VIP. SEE-stick collects data for walking, while SEE-phone is the key device for orientation.

The system provides two channel feedback to the VIP: tactile (point-wise) and audio. These feedbacks are elaborated by fusing several working in parallel sensors.

Notice that 6LoWPAN (IPv6 over Low Power Personal Area Network and) and RPL routing protocol are adopted to implement the SEE-stick thus according to the context the SEE-stick can connect P2P with the iSEE and future transportation system [16-17]. Therefore, the SEES system can be considered as the implementation of ITS ‘Intelligent Transportation System’ concept. It means that this system can be used in the near future by VIP to access urban transportation system such as car, bus and train.

The mobility cues collected by SEES sensors will be transformed into high level knowledge (passed to the VIP via voice or tactile feedbacks) in order to: 1) estimate or predict the status on an object (for example: status of the traffic light); 2) obtain the accurate location data (what allows to track the user and check if (s)he is on his/her correct way); 3) obtain a correct information about environment conditions such as obstacles, status of the traffic light and status of the walking surface; and 4) send quickly error/alerts messages to VIP when orientation mistake occurs.

B. Considered Mobility Cues and SEES Sensors.

SEES targets to assist some walking and orientation functions. The considered walking sub-functions are the following: obstacle detection, distance to obstacle estimation, obstacle shape recognition, walked distance estimation, surface roughness estimation and traffic light (position and status) detection.

The considered orientation sub-functions are: direction estimation to the targeted location and end-user current location/position estimation.

The assisted functions have a direct impact on selected sensors. The SEES available sensors are: ultrasonic sensor, camera, wheel encoder, accelerometer and compass.

![Fig. 2. Concept of SEES System](image-url)
The ultrasonic sensor is used to detect the obstacles in front of the VIP in very near distance (such as tree, wall, etc.) with provide the precision.

The camera in SEE-stick is used to identify and recognize the type of road junctions (e.g. crossroad, corner-road, side-road, etc.). In addition, the camera is also used to read the environmental conditions, such as illumination (day and night) of traffic light status.

Status of the traffic lights (figure 3) is detected also with the smart phone camera (in SEE-phone). The camera has a function dedicated to detect traffic lights status once the VIP gets the information from SEE-stick about traffic lights position.

![Fig. 3. The Traffic Lights Model](image)

The wheel encoder sensor is mounted on the SEE-stick wheels, and is used to estimate VIP travel distance from the starting place.

In association with camera information, accelerometer data is used to estimate walking surface roughness, such as the special road pad for VIP (figure 4).

![Fig. 4. The Special Road Pad for Blind People](image)

The compass sensor is used to detect a moving direction of the VIP. Data from the compass will be integrated with the GPS data and wheel encoder data to enhance the precision of VIP location and distance estimation.

The orientation function will use two main SEE-phone sensors: camera and GPS (includes a Google map).

The GPS is used to define the current location of the VIP, while the Google map allows to plans the user journey in order to reach his/her spatial target. Periodically the GPS data will be sent to the database server for remote monitoring the VIP, displaying and checking his/her itinerary in real-time.

Table 1 summarizes the different sensors and the mobility functions supported by the SEES system.

<table>
<thead>
<tr>
<th>Name of Sensor</th>
<th>SEES System</th>
<th>Output Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>UltraSonic</td>
<td>SEE-stick</td>
<td>Obstacle/object</td>
</tr>
<tr>
<td>Wheel Encoder</td>
<td>SEE-stick</td>
<td>Travel distance</td>
</tr>
<tr>
<td>Accelerometer</td>
<td>SEE-stick</td>
<td>Surface roughness</td>
</tr>
<tr>
<td>Compass</td>
<td>SEE-stick</td>
<td>Direction</td>
</tr>
<tr>
<td>Camera</td>
<td>SEE-stick</td>
<td>Color/obstacle</td>
</tr>
<tr>
<td>GPS</td>
<td>SEE-stick</td>
<td>Location/position</td>
</tr>
<tr>
<td>Phone</td>
<td>SEE-phone</td>
<td>Obstacle/object</td>
</tr>
<tr>
<td>See Stick</td>
<td>SEE-phone</td>
<td>Surface roughness</td>
</tr>
<tr>
<td>See Phone</td>
<td>SEE-phone</td>
<td>Direction</td>
</tr>
<tr>
<td>See Hand</td>
<td>SEE-phone</td>
<td>Color/obstacle</td>
</tr>
<tr>
<td>See Map</td>
<td>SEE-phone</td>
<td>Location/position</td>
</tr>
</tbody>
</table>

Data collected from different SEES sensors will be combined as follows in order to provide more reliable outputs (mobility cues): 1) Location data from GPS SEE-phone and SEE-stick will be combined into the end-user current accurate location. Location data communicates with data from encoder sensor (distance measurement); 2) Image data (color and obstacle) from camera SEE-phone and SEE-stick will be combined in accurate result color recognition and object detection. Ultrasonic and accelerometer data will also be fused with camera information; 3) Direction data from SEE-phone and SEE-stick (compass sensor) will be combined into an accurate direction. In case of disagreement a message may be sent to get help from the iSEE global server; and 4) Obstacle data from ultrasonic sensor, distance data from encoder sensor, and surface roughness from accelerometer sensor will be used as raw data for further processing.

The mobility cues will be the inputs to the SEES layer which will transform them into high level knowledge useful for mobility; this knowledge which can be directly conveyed to the VIP. Figure 5 shows the model of sensors interconnection in SEES system.

![Fig. 5. Sensors Interconnection Model in SEES System](image)

### C. SEES Running Models (Yusro 2013)

SEES is a modular system at the physical level. Data transmission between the SEE-phone and SEE-stick are performed via Wi-Fi protocol. Table 2 shows all detailed SEES modes. Each mode can be selected by the VIP when (s)he will go to a targeted location.

<table>
<thead>
<tr>
<th>Mode</th>
<th>SEES System</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SEE-stick</td>
<td>Basic mode</td>
</tr>
<tr>
<td>1</td>
<td>SEE-phone</td>
<td>Phone mode</td>
</tr>
<tr>
<td>2</td>
<td>SEE-stick</td>
<td>Local mode con</td>
</tr>
<tr>
<td>3</td>
<td>SEE-phone</td>
<td>Complete mode</td>
</tr>
</tbody>
</table>

![Table 2: The SEES Modes](image)
The SEES interface to VIP offers four assistance levels:
1) **Mode 0** (always active, SEES minimal configuration, only the SEE-stick is active). This mode will allow the VIP to walk without a smart phone.
2) **Mode 1** or phone mode (the SEES work by using the SEE-phone and iSEE). This mode will allow a user to stay moving without a smart stick. The navigation will be done using smart phone sensors (GPS, camera and compass) and iSEE server.
3) **Mode 2** or local mode connexion. In this mode, the VIP can get a remote help from persons who monitor the server as the SEES provide the selected travel specific hints and helps;
4) **Mode 3** or the complete mode. In this mode, the VIP can get a remote help as the SEES provides the selected travel specific hints and helps.

IV. SEE-PHONE

The SEE-Phone is a smart phone that be functioned to two main tasks are orientation and walking functions for a true independent mobility. SEE-phone is the key device for orientation; indeed, the SEE-phone communicates with the GPS, through the web server accessing to the map database and with the others mobile devices.

A. SEE-Phone as Orientation Function

As a function of orientation, the SEE-phone is used to give direction to destination location, create a new route or guide the way of the route that has been created previously (route remote tracking). To implement the navigation function, SEE-phone uses GPS on smart phone.

In general, the GPS on smart phone uses WGS84 (World Geodetic System 1984) as a reference system. WGS84 regards the earth as a spheroid object is determined based on the satellites observation satellites in earth orbit. The WGS84 major axis is 6,378,137.0 meters and a minor axis is 6,356,752.3 meters [18].

The tracking of a VIP during his/her travel can be decomposed in the two follow elementary operations:
1) Detection the VIP’s current position and
2) VIP’s current position real-time tracking with GPS and Google map.

The implementation of these tasks have goals as follows: 1) to develop an application on Android smart phone for detecting the VIP location; 2) to develop an application for tracking the VIP position in real time with GPS; 3) to connect the developed application to the server in the others place (campus), 4) to monitor VIP position from map display on monitor PC/notebook server; and 5) to display the VIP position by server.

Figure 6 shows the access model from GPS receiver (in smart phone) to database server. The VIP current location data is obtained from smart phone GPS and sent to the web server to be stored in database server. The last, the data can be shown on the monitor as line track/route.

B. SEE-Phone for Color Detection

The implementation of the traffic light status detection with SEE-phone requires the following elementary operations:
1) Traffic lights detection,
2) Traffic light (color) status recognition; and
3) Status data feedback to the VIP.

Figure 7 shows a possible SEES implementation, namely: the camera on smart phone will detect the traffic lights (through two ways detection models, namely: the traffic lights position is detected by the camera sensor in the stick (SEE-stick) and the traffic lights position is detected based on GIS data in database server), and take the image data from the traffic lights status; the Android smart phone will process the image; finally, the smart phone will produce the audio/voice output to VIP.

C. User Interfaces on SEE-Phone

Navigation guidance using verbal description and instruction is considered as efficient way to pass data to VIPs [19]. Two smart phone applications will be used: TTS and STT.

The mobile TTS (Text-to-Speech) is an application for smart phone screen message reading and audio translation for the VIP [20]. Figure 9 shows an overview of a typical TTS System.
A. Traffic Lights Status Detection (Yusro 2013)

In this experiment, a camera of smart phone Samsung SIII Model GT-i9300 has been used to capture the color image. This process uses simple application program to produce HSV level of color image. Table 3 shows data of HSV level from three colors image (red, yellow and green) in this experiment.

The average HSV is a reference data for the image captured by the camera (SEE-phone). When the value of the colors (traffic lights) is captured by the SEE-phone camera that was in the range of reference data, the program will call the voice application. In this experiment, the voice function used TTS (Text To Speech) concept. The TTS converted the result of images detection as voice, (“red stop here”, “yellow slowly run” and “green please run away”).

<table>
<thead>
<tr>
<th>TABLE 3: SAMPLE DATA OF HSV LEVEL</th>
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<tbody>
<tr>
<td>Color Images</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Red1</td>
</tr>
<tr>
<td>Red2</td>
</tr>
<tr>
<td>Red3</td>
</tr>
<tr>
<td>Red4</td>
</tr>
<tr>
<td>Average of Red</td>
</tr>
<tr>
<td>Yellow1</td>
</tr>
<tr>
<td>Yellow2</td>
</tr>
<tr>
<td>Yellow3</td>
</tr>
<tr>
<td>Yellow4</td>
</tr>
<tr>
<td>Average of Yellow</td>
</tr>
<tr>
<td>Green1</td>
</tr>
<tr>
<td>Green2</td>
</tr>
<tr>
<td>Green3</td>
</tr>
<tr>
<td>Green4</td>
</tr>
<tr>
<td>Average of Green</td>
</tr>
</tbody>
</table>

The results of this experiment are displayed in figure 12. The upper images (left to right) are signs of traffic lights status for pedestrian. The lower images (left to right) show results of color detection by SEE-phone. In this experiment, android application program can detect three colors: red, yellow and green.
In this experiment, Android Emulator Google APIs, Platform 4.1.2, Level 16 and Smart phone Samsung SIII Model GT-I9300, Android Version 4.1.1 were used.

Figure 14 shows a map of sample route in this experiment. The user walks carrying a smart phone (SEE-phone) from G point (start-point) to D point (end-point). When the user walks, the Android application will run and the GPS receiver is in “on” position. A GPS receiver of the smart phone will receive data from GPS satellite and SEE-phone will send the data to database server via Wi-Fi network.

C. TTS and Voice Command on SEE-Phone

In this experiment, we have tested the Google voice commands to run some functions. The experiments have run on smart phone Samsung SIII Model GT-I9300.

The system starts to work once the user said ‘on’, until to ‘off’ word recognition.

The ‘new’ command will create the new route when user moves and sends the track data to database server. The ‘stop’, finishes the application.

In the system SEES current version 2 menus (two classes of functions) are available:

1) ‘new route’ menu, for making the new route on database server, and
2) ‘follow route’ menu, for guiding the user displacements based on data that already existing in the database server.

Figure 16 below shows a display on database server when user walks on the wrong way (track in ‘green’ line). The database server will send the alert message to SEE-phone through voice (audio) that be heard by user.

VI. CONCLUSION

This paper has introduced the design and implementation of the SEE-Phone which is a part of SEE-system, an assistive device for the VIP to improve their orientation and walking skills.

The SEE-Phone has been technically evaluated in two preliminary conditions, namely: 1) detection of the color status of traffic lights; 2) conversion of traffic light data into speech for an audio feedback to VIP, and 3) development of the remote tracking with database server for remote monitoring the user during its walk.

The original concept of the SEES system integrates three main devices, iSEE, SEE-phone and SEE-stick which complements each other. The SEES system will be built as an Open Source platform and will integrates several sensors. Finally, the system will be validated with end users for its pertinence to targeted assistance and appropriation. Its technical performances will be evaluated and compared to these existing systems.

ACKNOWLEDGMENT

This work has been sponsored by the Indonesian and French governments, and French government research program “Investissements d'avenir” through the IMobS3 Laboratory of Excellence (ANR-10-LABX-16-01), by the
European Union through the program Regional Competitiveness and Employment 2007-2013 (ERDF–Auvergne region), and by the Auvergne region.

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