A Technological Innovation to Safely Aid in the Spatial Orientation of Blind People in a Complex Urban Environment

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Abstract—**In the broader context of smart cities, to ensure mobility of people regardless of their physical or sensory condition becomes a complex and difficult challenge to be treated. All papers referenced in this work are presented as a solution to equip the blind people with devices and sensors (controlled by a computational system) with the ability to capture environmental structure data and somehow describe it to the understanding of the blind people. Our work explores another side of this problem: how the environment can transmit data about itself to safely-help guide blind orientation in this environment? In other words, from our view, the environment must report data on its structure as opposed to make the blind person try to extract these data from this environment. So, here we propose to use an intelligent semaphore system (traffic lights) to communicate with a mobile system carried by the blind person and by the coherent processing of the signals sent and received between the mobile device and the intelligent semaphore, to conduct the blind in the streets crossing the crosswalk safely.**

Keywords-image and signals processing; smart cities; blind-pedestrian

I. INTRODUCTION

The ability to travel safely, comfortably, gracefully, and independently, referred to hereafter by the term "mobility." Mobility is a factor of primary importance in the life of a blind individual. The blind person who fails to acquire this ability usually displays a life style characterized by passive acquiescence to conditions proposed and arranged by others. The blind person who has acquired this ability often displays a life style characterized by the execution of plans of his/her own formulation. Yet, until recent years, it was not generally recognized that mobility could be resolved into a collection of related sub-skills, and that these skills could be taught [1].

The needs of the blind both from the social view point and from the scientific and technological end has been defined and explored. Advances have been made in the areas of social adjustment, rehabilitation, communication, and learning skills. With the advancement of computer vision, even driven by the quest to bring robotizing the condition of human vision, also considering the coexistence between robots and humans [2], there have been many advances in object segmentation and various other guidance methods in open or closed environments. This indicates that we can bring a more human view on the subject and allow the displacement or better urban mobility of an individual with visual impairment which is automatically more assisted and guided by intelligent systems that can even react because of their condition.

Based on the US FARS data (National Highway Traffic Safety Administration), from 2002 and 2006 the US averaged roughly 5 blind pedestrian deaths from motor vehicle crashes (27 blind pedestrians are dead) in the USA. – http://www-nrd.nhtsa.dot.gov. Given the small numbers involve, the count of blind pedestrian deaths was remarkably stable from year to year. Legally blind individuals accounted for roughly a tenth of a percent of all pedestrian deaths over this period. They presented a study [3] in which participants indicated when they would cross it suggested that blind pedestrians miss more crossing opportunities and make riskier judgments than sighted pedestrians. [4] They also did an exploratory analysis of crossing difficulties for blind and sighted pedestrians at Channelized Turn Lanes (CTL), the geometric nature of CTL facilities and the lack of signal control at the pedestrian crossing are factors that may negatively affect the delay and safety for blind pedestrians. Pedestrians waiting at the curb must judge the traffic moving in a circular motion, and they must deal with a significant amount of background traffic (i.e., noise) present at the main intersection. The findings show that crossings at all CTL crossing locations are significantly more difficult for blind pedestrians than for sighted pedestrians. Blind pedestrians tend to face a greater risk and a greater amount of delay.

How many of these individuals are guided by the noise emitted by vehicles moving or running, a new problem of difficult treatment applies with the advent of hybrid or electric vehicles, which emit low or no noise during their displacement. This problem has already been studied [US Department Transportation] which run-over pedestrians and cyclists tend to increase, since they are not detectable. This problem is aggravated when it comes to a visually impaired pedestrian.

In the broader context of smart cities, to ensure mobility of people regardless of their physical or sensory condition becomes a complex and difficult challenge to be treated.

Usually, the literature tries to provide the blind with devices that can capture environmental structures and somehow describe it to the understanding of the blind. Our work explores another side of this problem: which information the environment can transmit to the blind so that he can move safely. To carry out this promise, we have developed an intelligent semaphore, assembled with video cameras to provide image data to the computer vision system, WIFI *signal*, Bluetooth devices and GPS signal to guide the blind when crossing a road controlled by this semaphore on the crosswalk.

The problem treated here is to make the environment advise the blind through a mobile device when he/she may (or may not) cross a road, street, or avenue on the crosswalk in the road region controlled by intelligent semaphores.

The system should detect the arrival of the blind; detect the direction and the sense of its movement; warn that it is a region controlled by intelligent semaphores and must wait for the safe time to cross the road. While crossing the road, the system must track him/her to ensure safety when walking on the crosswalk. The mobile APP, presented in this work, when properly installed, is able to communicate automatically with those intelligent semaphore to send/receive data and process these received data that are transformed into instructions which are transmitted to the mobile APP that transform it into a voice in the speaker connected to the mobile device that instructs the blind when to proceed in order to accomplish crossing the road safely.

II. A Brief Overview of the Blind Mobility Issue

Improving the mobility of blind pedestrians will require the application of methods developed by human factors specialists. Mobility must be recognized as a complex skill, an analysis of which will provide the information that is needed for the design of mobility aids, the development of training methods, and the evaluation of both [5].

There are many different approaches to blind mobility aids. They all share something in common, which is the transformation of raw environmental data into a form suitable for non-visual perception by the blind user. However, when this transformation involves no direct “understanding” or complex interpretation of the data by the transforming device, the blind user is still faced with a formidable task of perceiving the data in some analog form, and must extract the complex structure of the external word from low level cues [6].

There exists a range of devices of widely varying technology, information gathering capacity, and market price shows that engineers and researchers have not been idle, but somehow have failed to reach their goal that of providing the blind traveler with a highly acceptable electronic aid to spatial perception [6]-[8]. That is, an aid which can be obtained readily by individuals generally with limited income, and an aid which they would freely choose to use in order to get about in their daily lives or relate more effectively to their immediate environment.

A real-time computer vision system designed for the limited environment of city sidewalks presented in this system is part of a prototype mobility aid for the blind [9]. The overall device endeavors to keep blind pedestrians on a safe path down the sidewalk, and also warn of upcoming obstacles extends to this idea by using more sophisticated computer vision techniques in conjunction with a depth sensor, which promotes the sensor fusion [10].

III. The Intelligent Semaphore and the Mobile System Improving

We have developed an intelligent semaphore (Fig. 1) (still on patent qualification phase) that is able to supervise the movement of vehicles in sections of roads where it is installed. This semaphore is composed of several devices interconnected by a computer system. The main of these devices are: video camera, WIFI antenna and Bluetooth antenna. The complete system is able to receive and send signals to both vehicles and pedestrian on this supervised point.

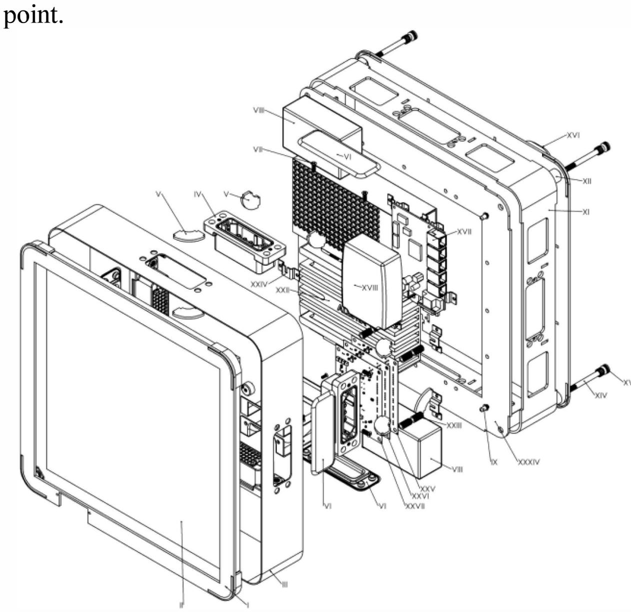

Figure 1. Intelligent semaphore design

A. Intelligent Semaphore

This smart device has been developed to perform a semaphore intelligently in order to aid vehicles and pedestrian in an urban environment. It comprises a series of hardware and software devices designed to capture, process, send and receive big data platform information with a purpose to optimize traffic and urban mobility in cities. The proposed article complements the design of intelligent traffic signals, bringing the functionality to target through image processing oriented trilateration WIFI signals and geo location (by Global Position System unit - GPS).

The proposal aims to deploy in every way connection, hotspot's that in addition to providing access to global computer network, performs authentication of its members who were on the platform. Applications for mobile devices for the visually impaired are also included in this list of applications. Using this feature, users or disabled do not only make use of transparent form of its geo location, spatial localization method based on WIFI trilateration technique and targeting images using the method shown below in this proposal [11].

B. Image Processing

In the context of this application, the computational cost is extremely important, since the computational power of each traffic signal device is considered small if all the effort required to rotate the device already has intrinsic purpose applications.

Therefore the consumption of computational resources with an additional process is relatively high. However, the use of low computational cost segmentation methods are best suited to perform the task of finding the pedestrian in the area now bounded by the spatial coordinates supplied by trilateration of the WIFI signals and/or GPS. A method already used and validated in uncontrolled environments and can operate in real time is "Motion History Image" [12]. Originally developed to detect and distinguish human motion sequences based on the composition of successive layers consist of points for the movement (silhouettes) detected for inter-frame images (visible spectrum). This method allows using such layers to form a vector that represents the overall time of movement, while constituting a marker (label) capable of promoting conditions to compute a schema matching (matching) among these points and thus discriminate the movement nature (such as distinguishing a person motion of a vehicle motion). Once the movement is segmented from an image sequence, the system extracts parts of the overall scene and treat them as a comparison model in the next frame to be analyzed. The constant search for the features extracted by edge analysis techniques, colors and geometric aspects, enables the system to track the individual movement within a specific region for a safe walking of a blind person. Since all these characteristics of movement in the scene are extracted, the system is capable to compute the space position of each object that is moving in the scene. So, if a blind person is located in an unsafe location, the system proceeds to create an alert to the blind user, as well as to the drivers that receive a luminous warning sign emitted by semaphore panel.

C. Mobile Device

Exist a range of devices of widely varying technology, information gathering capacity, and market price shows that engineers and researchers [13] have not been idle, but somehow have failed to reach their goal that of providing the blind traveler with a highly acceptable electronic aid to spatial perception. That is, an aid which can be obtained readily by individuals generally with limited income, an aid which they would freely choose to use in order to get about in their daily lives or relate more effectively to their immediate environment.

The idea of bringing a mobile application to help urban mobility for visually impaired person was chosen because of the popularity of these devices and its reasonable computing power coupled with the hardware and software already available (GPS, WIFI, Bluetooth, voice system, etc.). Many visually impaired have familiarities with such devices, so we decided to then present this technological proposal for a group of blind persons that gently assisted us in the development of this mobile application interface. The usability of this mobile application interface has been validated by three visually impaired people already using smart phones in their daily lives.

For now, the interface of this application does not include visual elements, but in future versions, this will be available featuring a visual interface capable of displaying a map (geo referenced) that shows the current position and the target position. This can be important because there may be the needs of the blind person to ask another non-blind person to confirm if the mapped route is correct.

The current version of the application for mobile devices includes: 1) voice recognition feature; 2) vibration and, 3) message transmitted by voice, in order to create a more appropriate communication channel between the device and the blind user.

The touchscreen device has different areas that, when touched it emits a sound message about its direction (Figure 2). If the blind user confirms the direction before approaching a crosswalk (monitored by the intelligent semaphore system), the system, installed in the mobile device, will transmit to the semaphore the direction of the movement desired by the blind user. The semaphore response (to mobile device) includes the information about the local environment conditions (if there are vehicles, if the vehicles are moving, if the semaphore is opened or closed). Even if the blind user has already started the crossing, the semaphore can guide it, and if the blind user goes out of the correct and safe route, a route error warning message is transmitted to the blind joint with instructions to perform the correction of this error. All those communication features with the blind user are made by voice, sounds and vibration of the mobile device.

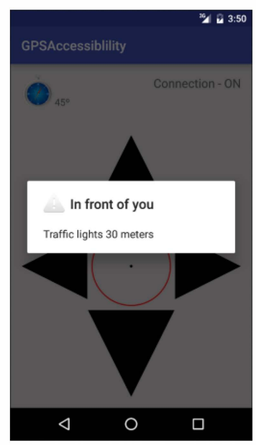

Figure 2. Mobile application interface for blind user.

D. The System Integration

Fig. 3 shows the system integration - as the intelligent semaphore, the mobile device and the blind user are integrated by the proposed APP. It also shows the data flow among different devices and the operations that are performed by the system. For the system to operate correctly, the first step is to detect if a blind user is close to the intelligent semaphore (region monitored). This is done by Bluetooth connection (or WIFI or both to operate in redundancy). The APP installed in the mobile device emits a signal warning for the semaphore that a blind person is in the monitored region.

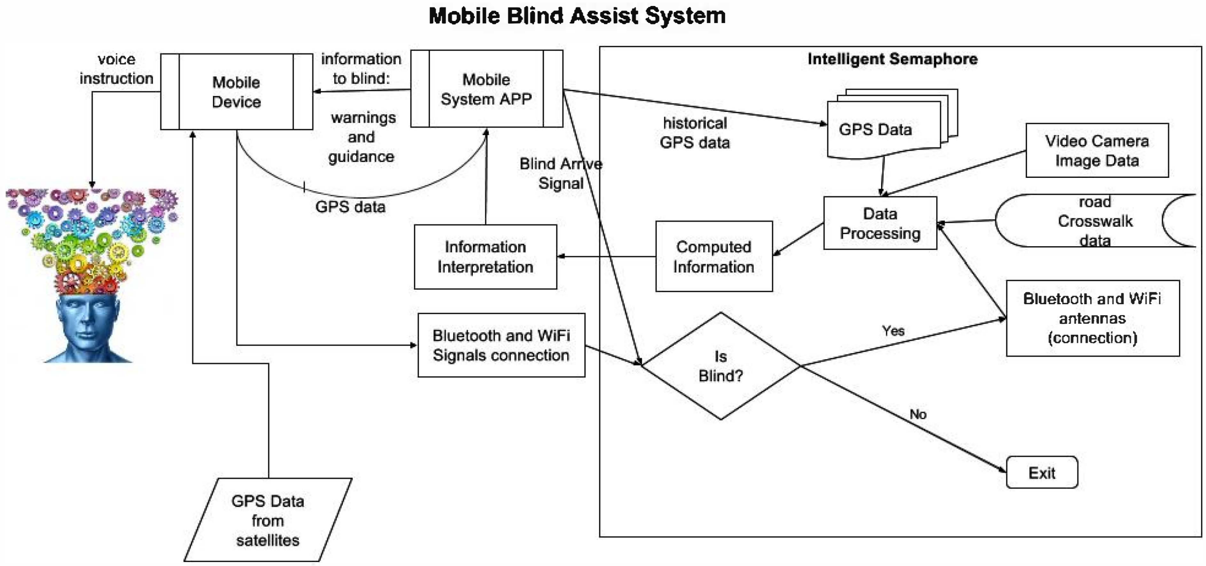

Figure 3. The system integration scheme.

Only when the APP validates a semaphore that a blind person is in the monitored region, a communication channel between the two devices involved (semaphore-mobile) is open and the necessary data can be transmitted and received by these two devices.

By establishing this communication channel, the semaphore emits a signal that requests that the mobile do transmission of a history of GPS coordinates data (previously acquired by the GPS antenna and stored in discrete periods of time while the blind user walks). This history of GPS coordinates serves to estimate the trajectory that the blind user is performing.

The semaphore panel changes its state when the light color changes (red, green, orange, etc.). These different colors are used to guiding and controlling the traffic of vehicles and pedestrians and it is capable to acquire and process image data relative to movement that occurs in the monitored region. The system embedded in the mobile device is capable accomplish processing those data received from semaphore, and coherently, transforms those data into information that are transmitted to the blind user by voice. The system transmits all the actions that the blind user should execute in order to cross the crosswalk safely.

The route used by pedestrians to cross the road on a crosswalk is constantly monitored by video cameras installed in the intelligent semaphore. The acquired image sequence data are processed to ensure that the pedestrian always uses the crosswalk while crossing the road. If a blind user of the system does any deviation from a permitted route on crosswalk, the semaphore emits a warning signal to the mobile user that is transformed in a voice alert - "You are out of the crosswalk. Stop!" So, the semaphore continues to emit signals that are transformed into voice message that explain actions that the blind user needs to return to the safe point (on crosswalk). While the blind user does not complete to cross the road, the semaphore does not change its state (remaining closed to vehicle flux). The drivers and other pedestrians are warned that a blind person is crossing the road (by semaphore panel).

When installed on the mobile device with GPS, WIFI and Bluetooth enabled, the system (APP) starts to receive data from the GPS satellite constellation to calculate the geographic position of the blind user. This data acquisition is done in constant and continuous time interval to compose a history of the blind user movement. Only when the mobile device connects to the semaphore, and the APP confirms this connection, the functionality to send this historical data of geographic positioning to the semaphore is executed. This transmission is done by sending an XML file. This historical data is composed of values of geographical positioning (geo location) that was acquired in the last two minutes when there was change in the geographical position of the blind user.

This amount of data is sufficient to determine the direction and sense of the blind user movement. The semaphore sends a set of signals that serve to warn the blind user that it is approaching a region controlled by an intelligent semaphore, and if the road is free to the traffic of vehicle flux or not. When the blind user is close enough to the semaphore, the system guides it to position yourself next to the crosswalk monitored by this semaphore. The crosswalk was duly registered, previously, by geo referencing when this semaphore was installed. In any miscommunication with the GPS when the system cannot perform the verification of latitude and longitude, it complements the spatial location data using a trilateration method of WIFI signals. One way to mitigate this problem is to install different WIFI access points in the monitored region by the semaphore so that the trilateration calculation is possible. When crossing the road, the mobile device of the blind user constantly sends its geographical coordinates (transmitted by APP) to the semaphore which confers if these data are in accordance with geo referenced data that have been acquired at the moment when that semaphore was installed. Furthermore, a video camera acquiring data images when processed, allows to accomplish the computation of the route made by each pedestrian on the crosswalk, resulting in a redundant system.

Continuously, the system of computational vision of the intelligent semaphore processes the scenes acquired and perform the segmentation of the road lanes limits pedestrians and stopped/moving vehicles near the crosswalk. How the system knows where the crosswalk is located, anyone who moves outside the boundaries of the crosswalk will be tracked by the vision system, and if at least one blind user is in the monitored region by the semaphore, the system will issue a warning to the blind user to stop its movement. Only the blind user receives this order. If the blind user stops its movement, the vision system is capable of detecting it, and in this way can guide it safely on the crosswalk.

IV. Conclusion

In the context of smart cities development, this study contributes to the development of an intelligent traffic service. This traffic light has several features such as: 1) to optimize the flow of vehicles on the roads, 2) to calculate the travel speed of vehicles, 3) to operate in wireless networks with other intelligent traffic lights, 4) to acquire and transmit images in real time from their places of scope for a traffic control central, 5) as well as being a traffic light, it can serve as a display panel capable of displaying images and text in high resolution, 6) to perform communication with pedestrians in possession of mobile devices (cell phones, tablets, antennas) or installed in vehicles (multimedia unities, antennas) via WIFI and/or Bluetooth signals, and 7) the ability to process WIFI signals, Bluetooth and real-time images. However, the scope of this work presents more functionality "to provide accessibility for blind people." The system of (physical and logical) accessibility presented operates with data redundancy. The WIFI signals and Bluetooth establish a communication channel between the mobile device blind user and intelligent traffic (redundancy). Through this channel together with the APP developed properly installed on the mobile device allows the lights to discover that a blind user is within the monitored region (messaging). By contrast, the user's mobile device stored data geo location (GPS coordinates) during the last two minutes that passed. This coordinate history serves to estimate the direction and the direction of its path (the light can predict where you are going). Imaging sensors acquire image sequences of all the movement that is taking place in the monitored area (both pedestrians and vehicles). When the lights stop the flow of vehicles, it will arrange for pedestrians to cross the road for pedestrian crossing in complete safety independent of physical and sensory condition of some of these areas. The light does not release the flow of vehicles while at least one pedestrian, who started crossing the road, is not safe. Between these pedestrians be at least one blind person, the lights will monitor with special care while crossing the road, because it already knows that person's path trend, and by computing GPS, triangulation WIFI signals and image processing (redundancy) the blind user will be safely conducted during their crossing. If there is loss of GPS signal, the WIFI*'s* signals are able to locate the user. If there is loss of WIFI*'s* signal, the system acquisition and image processing is able to locate the user. Recalling that all communication made between the light and the blind, organized by the APP installed on the user's mobile device is made by different sensory stimuli (vibration and sound) and the guidance messages and warnings are made by voice.

V. Future Works

A prototype for this intelligent semaphore was assembled. The first continuation is installing this system in a city with the objective to collect data about its functionality. After certifying that its function is correct and satisfactory, new possibilities can be implemented. Our idea is to install low cost systems throughout the city. Each of these systems will be able to report for the blind user what it is, how it is, what it has, where it is, ... about the elements existent in the environment involved in the vicinity of each point of installation. These systems can be installed in public buildings or for commercial use (pharmacies, banks, bookstores, bars, clubs, museums, etc.); we began offering accessibility and better standard of living for people with visual impairments.

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