VISUALLY IMPAIRED PEOPLE MONITORING IN A SMART HOME USING ELECTRONIC WHITE CANE

Mikaël A. Mousse

Institut Universitaire de Technologie,
Université de Parakou, Benin

ABSTRACT

The monitoring of visually impaired people is important in order to help them to travel safely. Then, many research works implement some travel aids. The proposed techniques are mostly based on the use of a white cane. This work introduces an electronic white cane based on sensors' technology. The proposed electronic cane helps its user to detect obstacles within two meters on the ground or in height. Once the obstacle is detected, the system sends vocal instructions via a Bluetooth headset to alert the person concerned. The ultrasonic and infrared sensors have been mounted on the white cane in order to provide it with the necessary intelligence. A raspberry pi performs the processing of the data. The proposed system also suggests using a mobile application to track the visually impaired in real-time. This application has a function that allows you to trace the visual patient's route. This is important to detect the possible cause of damage to patients during their travels. We use Python as programming language for electronic devices. The mobile application is Android. Though, the WEB application is a REST API developed using Python and NodeJs. The system is implemented and tested. The result shows the efficacity of the proposed system.

KEYWORDS

Electronic white cane, Sensors, human monitoring, smart home.

1. INTRODUCTION

Visually impaired people need some aid to interact with their domestic space which contains different types of obstacles. These obstacles are located in different types of places. Indeed, a visually impaired person can’t move freely or carry out any activity that requires vision. They need external assistance to facilitate their integration into society and allow them to make good decisions while moving. This assistance can take various forms such as caregivers, white canes, trained dogs, small electronic devices etc... Among these tools, one of the most used is the white cane [1]. Symbol of blindless, the white cane does not allow the visually impaired to freely carry out their daily activities because it not helps visually impaired people to avoid obstacles. Indeed, the obstacles above the belt are not recognized by the traditional white cane. The other major drawback of the white cane is that it does not alert its user to the imminence of an obstacle. These different situations expose visually impaired people to frequent severe body shocks.

To avoid these drawbacks, many researchers investigated electronic canes in order to help visually impaired people perform their tasks independently. They propose to endow traditional canes with intelligence by embedding different types of sensors. We can identify two main generations of electronic canes:

- Electronic cane based on ultrasound sensors and/or laser and/or IR sensors;

- Electronic cane based on cameras, electro-tactile system, Oh I see (the vOICe), stereovision systems.

The following paragraph briefly describes some state-of-the-art approaches.

Terlau and Penrod [2] suggest a system called K-Sonar. This system is based on ultrasonic sensor to detect obstacle points. The obstacle points are used to reconstruct the whole obstacle. This system does not provide assistance to orientation function [2]. Bouhamed et al. [3] proposed an electronic cane based on two ultrasonic sensors and one monocular camera to assist for visually impaired person. The approach suggested by them is used for obstacle detection as well as identification of floor states. Other research/industrial works [4, 5, 15] suggested the use of an ultrasound sensors for electronic cane realisation. The Portuguese project "SmartVision: active vision for the blind" proposed to use a set of ultrasound sensors to obtain an intelligent cane. The objective of this project is to obtain a competitive system for assisting the visually impaired person while navigating indoor outdoor [5]. Bhatlawande et al. [15] suggested the use of a network ultrasonic sensors to detect obstacles in front, left and right direction. Their proposed system uses AT89S52 microcontroller to process in a real time the data collected by the ultrasonic sensor network. The proposed system achieved a competitive performance for obstacles around subject up to 500 cm. Jain et al. proposed a system called Roshni [12]. Roshni is an indoor navigation system for blind person. This system consists helps the subject to:

- determine his position in a building;
- build a detailed interior map.

By using the associated mobile application, directions concerning position, orientation and navigation can be obtained from the portable system via acoustic messages. Dharani et al. [13] proposed a RFID based navigation system for blind person monitoring. The proposed system introduces a technological solution for travelling through public locations. Mehta et al. proposed a novel indoor navigation system for visually impaired people [14] and the paper illustrates a structure which uses the IR sensor and magnetic compass on the VI-Navi handheld device to determine the location and orientation of the user in a fast and a robust manner using a voice enabled GPS inside a closed environment. Meijer [6] proposed images to sound mapping-based system to develop a vision substitution device for blind people. The system provides to the blind people auditory image representations within some of limitations. Nie et al. [7] propose an auditory monitoring system for visually impaired people using environment information. Their system is a portable auditory guide system which is named SoundView. The proposed prototype consists of three elements:

- mini-CCD camera;
- digital signal processing unit;
- an earphone. working with built-in.

The prototype processed the images from the mini-CCD for objects detection. Lin et al. [8] also introduced a wearable stereovision. In addition to detecting obstacles, the proposed system stream real-time video feed via the 3G network. It consists of an eyeglass and a power embedded processing device. In view of all the above, we can note a real interest in the theme treated in this paper.

The system that we proposed in this work is a set of a smart stick and a real time tracking mobile application. The smart stick uses a network of ultrasound and IR sensors to detect obstacles (within a range of 2 meters in height or on the ground), a Raspberry Pi to process data and a GPS module to collect satellite data. The main challenges pursued in this project is the miniaturization of the electronic cane and reduction of energy consumption while maintaining competitive detection and tracking results.

In the rest of this paper, we present in the second section the proposed system. Section three presents the experimental results while section four discusses the performance of our system. Section 5 presents the conclusion.

2. Proposed System

2.1. System Overview

The system has three major components which communicate through an API. These components are: electronic cane, web application and mobile Application. Like the electronic cane offered in the state of the art, our proposed smart stick is a normal white cane which embeds sensors. These sensors are used to transform a physical value into a usable electrical value. Depending on the data you want to collect, they are a large number of sensors such as ultrasound, temperature, pressure, acceleration, infrared, laser, radar sensors. As far as the proposed system is concerned, sensors enable us to evaluate the distance between the visually impaired and obstacles. The Figure 1 resume the proposed system.

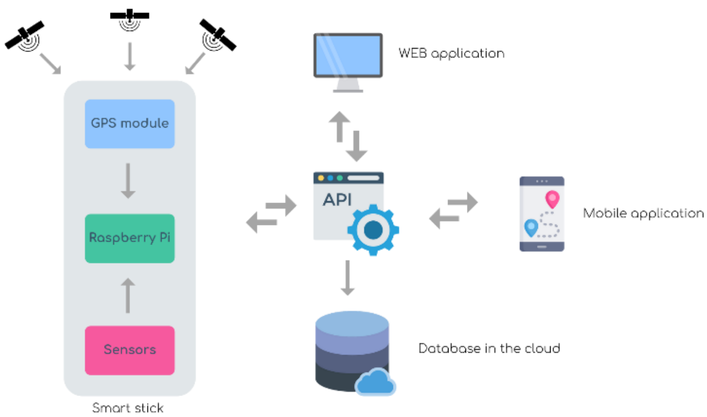

Figure 1. System architecture

2.2. Choice of sensors

GPS module NEO-6M

The GPS module is used to obtain location data from satellites. These data are longitude and latitude. In this work, the GPS information is collected with the GPS module EEPROM antenna. It sends a big stream of data in NMEA format. NMEA consists in several sentences. However, we just need one sentence. This sentence starts with $GPGGA. It contains useful information such as: coordinates, time. This information is comma separated. Thus, we can extract information from $GPGGA string by counting the commas. The latitude is found after two commas and the longitude after four commas. The GPS module sends data collected to the cane's process unit which is the Raspberry Pi.

Raspberry Pi

The information obtained from sensors are process using a Logical Processing Unit (LPU). This unit is used to communicate sensors' data to the stick's users. For this purpose, we can use microcontrollers such as Arduino, PIC18F46k80, etc. However, we are dealing with a two modules system. In fact, we have the stick and a software linked to it. A real computer is the best candidate to make them talk together. Then, we use the Raspberry Pi Zero W (Fig. 6) as the stick's LPU. It is a mono-card nano computer with a single core 1GHz processor, a micro-SD card, a mini-HDMI port, two micro-USB ports, (one for power, one for USB), and 512MB of RAM. It has a built-in WiFi and bluetooth. It needs 5V as operating voltage. The Raspberry Pi Zero W processes data collected by sensors and send them either to the REST API or the users. In fact, it computes the distance between the user and the obstacle and sends vocal instructions to users via a Bluetooth headset.

The Raspberry Pi Zero W only deals with digital signals. Ultrasound sensors and the GPS module send digital signals, directly processed by the Pi. However, IR sensors send analog signals. Our system uses an Analog to Digital Converter (ADC) to transform analog information into digital one. The IR sensor sends an analog signal in the form of voltage. If the voltage sent is not 0V, then, an obstacle is detected, and the ADC communicates this state to the Raspberry Pi as numeric value. The Raspberry Pi Zero W has two built-in Universal Asynchronous Receiver-Transmitter (UARTs), a PL011 and a mini UART. By default, on the Raspberry Pi Zero W, PL011 UART is connected to the Bluetooth module while the mini UART is used as the primary UART and will have a linux console on it. Because of the amount of the GPS module data stream, we reconfigure the Pi. We connect the bluetooth module with the mini UART and the primary UART to the Linux console. This new configuration helps us recover GPS data and process it on the Pi. The Raspberry PiWis also responsible of voice synthesis. In fact, it holds a text-to-speech engine which enables us to send vocal instructions to the stick's users. We use SVOX Pico, a small-footprint text-to-speech engine distributed with the Android operating system, but it can also be run on Linux and other POSIX systems. Since, Raspberry Pi runs on raspbian, a debian based OS, SVOX Pico is an optimal choice.

IR sensor Sharp GP2Y0A02YK0F

The IR sensor chosen is the Sharp GP2Y0A02YK0F. It is composed of an integrated combination of PSD (Position Sensitive Detector), IRED (Infrared Emitting Diode) and a signal processing circuit. The variety of the reflectivity of the object, the environmental temperature and the operating duration are not influenced easily to the distance detection because of adopting the triangulation method. Its distance measuring range is 20cm to 150cm. This device outputs an analog voltage corresponding to the detection distance. It needs 4.5 to 5.5 V supply voltage to work.

Ultrasound sensor HC-SR04

The ultrasound sensor chosen for the stick is the HC-SR04. Its detection range is 2cm to 400cm with 3mm of precision, 40kHz as frequency, 5V for the operating voltage, 5V as digital output and 30°as detection angle. Ultrasonic sensors use a transducer to send and receive ultrasonic pulses that relay back information about an object’s proximity. Indeed, the traducer receives distinct echo patterns. They can measure distances quite accurately [18, 4, 12]. The sensor determines the distance to a target by measuring time lapses between the sending and receiving of the ultrasonic pulse.

Rest API

The smart cane is the blind's decision-making tool. To help the blind's parent track him/her in real time, it is necessary to link the cane to a mobile application. To make the mobile app talk with the cane, we use an Application Programming Interface (API). The API is a Representational State Transfer (REST) one. In fact, it is a standard invented by Roy Fielding in his dissertation [11]. REST APIs are based on the Hypertext Transfer Protocol (HTTP) and mimic the way the WEB works in client-server communications. The client-server principle involves two entities that interact in a REST API: the cloud database and application modules which are clients. To interact with the cloud-based database, applications send HTTP requests: GET, POST, PUT or DELETE to the API. This last query the database. Requests' responses are still sent to clients through the API.

2.3. Electronic configuration

In order to detect obstacles accurately, sensors should be placed at optimal positions on the stick (Fig. 2). We propose a cane of length l, depending on its user height. The angle β, between the cane and the horizontal which is an input parameter. The proposed system uses three sensors. Two ultrasound sensors and an IR sensor. The IR sensor will detect obstacles on the ground and at a distance d1 less than or equal to 1m (d1<=1m). The lower ultrasound sensor, on the one hand, is placed at distance d4 and will detect obstacles on the ground at a distance d between d1=1 meter and d2 = 2 meters (d1 <= d <= d2). The upper ultrasound sensor, on the other hand, can detect obstacles above the belt up to 2m in height.

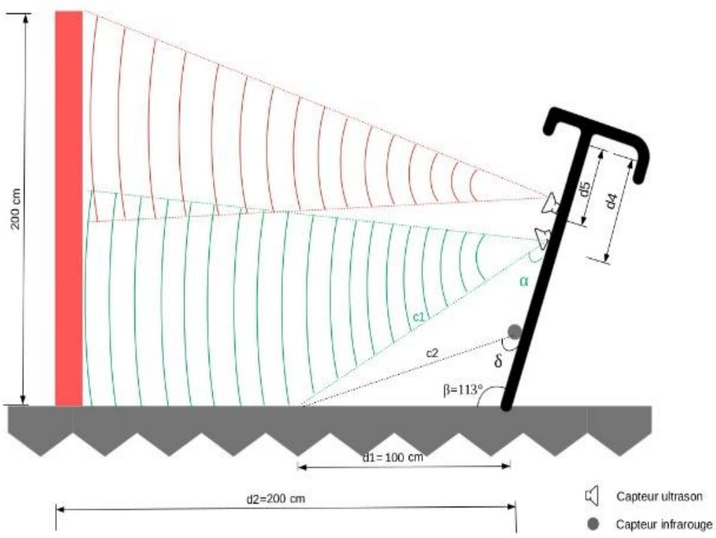

Figure 2. Electronic configuration

Several parameters are involved in the cane's electronic configuration. We will be interesting in finding γ, α, δ, c1 and c2 (Fig. 2).

- γ : the angle between the cane and the upper ultrasound sensor;
- α : the angle between the cane and the lower ultrasound sensor;
- δ : the angle between the IR sensor and the cane;
- c1: the distance between the end of the ultrasound sensor and the floor;

- c2: the distance from the end of the IR sensor to the floor.

To calculate them, we used geometric properties including the theorem of Al-Khashi or the law of cosines. The table 1 summarizes the sensors' inclination angles information.

Table 1. Sensor's inclinaison

Sensors	Measuring the angle of inclination
Upper ultrasound sensor	52°
Lower ultrasound sensor	46°
IR sensor	40°

The system driven circuit is presented by Fig. 3. This circuit shows us how the different electronic components are mounted to operate in the system. In addition, to the components mentioned in the previous section, we have, push buttons to activate the cane or alert in case of emergency, resistors, a buzzer for audible beeps and a Light Emitting Diode (LED). The components of the circuit are connected to the inputs of the Raspberry Pi (pins) including the ground, GND and VCC which provides an input voltage of 5V.

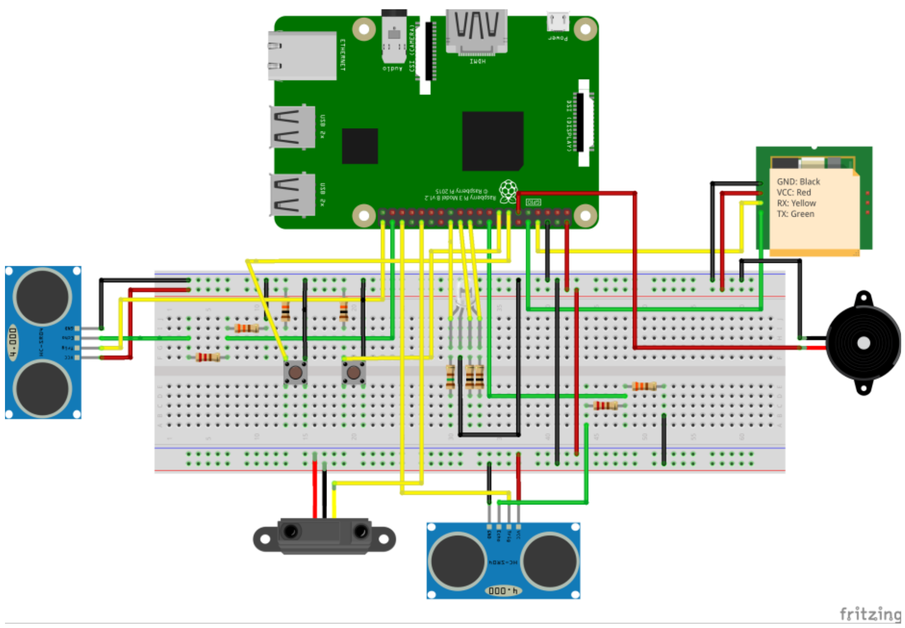

Figure 3. System driven circuit

3. Experimental Results

3.1. Experimental Environnment

To validate the algorithm, we performed tests in a smart home environment. It is indeed a piece of 10 m in length and 4.5 m in width. Inside the room, there are everyday objects such as: a dining table, a sofa, a wardrobe, etc...The Fig. 4 presents the 3D view of the environment setup.

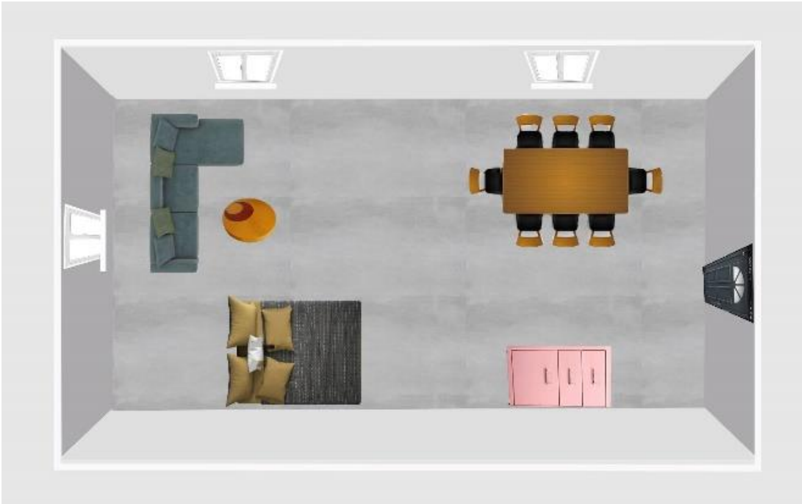

Figure 4. Experimental environment

This environment has been designed to allow the tests to be carried out under ambient living conditions. The tests were performed by an individual attempting to perform common operations such as: walking, sitting, getting up, and lying down. The GPS coordinates of each object have been recorded. This makes it possible to send voice commands suitable for carrying out the various actions.

3.2. Cane

Before assembling all the cane's components, we test each of them. Based on the time used by the ultrasound sensor to reach obstacles and analog outputs of the IR sensor we can evaluate our system performances. The table 2 summarizes results derived from computations and measurements. Even though the proposed solution has been influenced by [3]. The results show that combining infrared range and ultrasonic sensors may lead to a better decision-making system. The proposed system is also connected to mobile application to track the visually impaired people in real time.

Table 2. Comparative results (Ultrasonic sensor versus IR Sensor)

	Ultrasonic sensor			IR Sensor		
Distance (cm)	Time computed (s)	Time measured (s)	Error(s)	Analog output computed (V)	Analog output measured (V)	Error (V)
50	0.29	0.3	0.01	1.3	1.3	0
75	0.44	0.45	0.01	0.8	0.7	0.01
100	0.59	0.62	0.03	0.6	0.59	0.01
125	0.74	0.78	0.04	0.52	0.51	0.01
150	0.88	0.92	0.04	0.5	0.485	0.015
175	1.03	1.07	0.04	0.3	0.282	0.018
200	1.18	1.23	0.05	0.2	0.09	0.11

The cane is a set of the sensors, the raspberry pi, the buzzer, a battery and a USB input to charge the battery. Fig. 5 presents the prototype of the white cane.

Figure 5. Cane prototype

In addition, voice commands transmission via the headset is automatic. Because of this, we made a compromise related to the Universal Transmitter/Receiver (UART) of the raspberry pi. The raspberry pi has two UARTs: a PL011 or UART0 connected to the Bluetooth module and a mini-UART connected to the Linux console. For reasons of reliability and data flow sent by the GPS module, we reconfigured the UART of the raspberry pi. The UART0 has been connected to the Linux console and the mini-UART connected to the Bluetooth module. Thus, the performance of the Bluetooth module decreases since the mini-UART is less powerful than the UART0.

3.3. WEB/mobile application

The WEB application is a dashboard (see Fig. 6). To access it, you must first authenticate yourself. Once the authentication is successful, the home page is displayed. The site has five rubrics. They are:

- Home: There is information about each rubric;
- Add parent: This is a form to add a parent to the database;
- Parents list: This form is used to check the list of Parents which are store in the system;
- Visually impaired: This page contains the information about the visual impaired, a map on which he can be geolocated, a panel to contact a relative and a button to add a visual impaired;
- User guide: The system user guide.

The Android application allows you to track the visually impaired in real time. To have access to these features, you must first authenticate yourself. Once authentication is successfully completed, the user can track the visual impaired.

4. PERFORMANCE EVALUATION AND DISCUSSION

4.1. Performance Evaluation

After the implementation of the system and we compare the results to the state-of-the-art result. The results are mentioned in Table 3.

Table 3. Performance evaluation

Devices	Detection Range	Time Response	Power Consumption	Stair detection	Tracking module
Proposed system	**Hight**	**Fast**	**Low**	**Yes**	**Yes**
Bouhamed et al. [3]	Medium	Fast	Low	Yes	No
Hans et al [5]	High	Fast	Low	Yes	No
Bhatlawande et al.[15]	High	Fast	Low	No	No

4.2. Discussion

The experiments have shown that the proposed cane makes it possible to avoid obstacles at two meters. The comparison with the state-of-the-art algorithms presented in Table 3 demonstrates the competitiveness of the proposed system under smart home conditions. Thus, by using the designed prototype the detection is done quickly and the information is transmitted to the person using the cane. The low energy consumption is also one of the strengths of the system. Indeed, with the sensors used we manage to have an economical system in terms of electrical energy consumption. The guidance system associated with the cane allows easy movement of the person suffering who have visual difficulty. So, when the person wants to sit down, the voice command will inform him of his distance from the sofa. He knows what attitude to adopt to sit well. When in this process another obstacle stands in his way, the voice alert also allows him to avoid the latter. Thus, the proposed system has two major strengths:

- help the individual suffering from visual difficulty to avoid obstacles;
- accompany the individual suffering from visual difficulty to carry out certain tasks.

The reconstruction of the course using the android application makes it possible to identify the causes of a possible problem that has arisen. This allows for in-depth analysis and decision-making with the aim of improving the comfort of the person living in the smart home.

5. CONCLUSION

This work presents an electronic cane that enables visually impaired to move around without having to resort to caregivers or traditional solutions. The proposed system is based on a traditional white cane. On this cane, different types of sensors have been installed in order to collect the necessary information for our study. The processing of these information helps the user of the obtained cane to detect obstacles in height as well as on the ground within a radius of two metres (2m). Once the obstacle is detected, a voice command is sent so that it can be avoided. The GPS coordinates of the different places in the scene are also recorded in order to allow effective guidance of the subject. The proposed application (web/mobile) is important in order to reconstruct the person's journey in the event of possible collision problems. The cane is functional and achieves competitive results.

However, a camera module will allow us to have a visual information of the scene. It would therefore be useful to plan in the future to add it to the cane to have this information.

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AUTHORS

Mikael A. Mousse is an assistant professor in computer science at the Institut Universitaire de Technologie of Université de Parakou, Benin. His current research concerns about the automatic visual surveillance of wide area scenes using computational vision. His research interests focus on the design of multi-camera system for real-time multi-object tracking and human action recognition. He is recently focusing on the uncertainty management over the vision system using graphical models, and beliefs propagation. He is also interested in unsupervised learning approaches for human activity recognition.