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A new hybrid infrared-ultrasonic electronic travel aids for blind people

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ABSTRACT

The work presented here concerns the study of a new electronic travel aids for visual impaired and blind people for which the white cane represents, still today, the most widely used tool. The new system that we are going to present in this work is composed of two infrared sensors, an ultrasonic one, a microcontroller (to manage the input signals and take decisions) and four vibrating motors used to give signals to the user when an obstacles is intercepted. All these components are integrated in a belt that is easy to dress and is not very wearable. Here we also show all the characteristics of the sensors, their calibrating curves, the sensors spots and main noise in order to have a completely knowledge of these devices and to better understand their possible use. An energy consumption is studied in order to understand the autonomy of our device, being it portable. A geometric analysis is done to find the correct angular position of the sensor that influences the speed of response and the proper functioning of the entire system. Three different filters are implemented and compared in order to clean the input signals characterized by great noise due to the oscillation of the user during walk. Finally validation tests are made to check the ability of the device to intercept obstacles and to advice the user on time.

1. Introduction

Many studies are made to find a better way to assist the autonomous walking of blind people. The more diffuse and simple instrument used today is still the white cane although the great research made on the electronic travel aids (ETA). These devices have the task to assist blind people to intercept obstacles on their path. The common technologies used for this task are: Camera, GPS, Wireless sensor networks and ultrasonic and infrared sensors. The devices based on camera work by processing images and by translating them into sounds, vibrations or verbal messages [1–6]. The GPS technology [7–10] is commonly used to know the exact position and to conduct blind people to their destinations by verbal messages. A similar approach, but using a wireless sensor network, is presented in [11] in which the wireless network is used to find the exact position optimized by a triangulation of sensors. Other different approaches to the problem is the interception of immediately obstacles to the user by using detention sensors like ultrasonic [12–14] and infrared [15,16]. The main task of these devices is to intercept the obstacles by a variation of the distance between it and the user. The output signals are usually the same of the other devices based on the other technology.

In this work we present an hybrid device based on two infrared and one ultrasonic sensors. We think that this approach has the goal of simplicity and is very cheap in comparison with a lot of other technology especially with those based on the image processing. This reduction of components comports a little consumption of energy and then a great autonomy. On the other hand our hybrid approach, combined ultrasonic and infrared technology, allows us to take the best property of the two kind of sensors. The ultrasonic sensor has the possibility to intercept any kind of surfaces in contrast to the infrared one that cannot intercept glass or mirror. On the contrary the infrared sensor has the property to have a little spot, with respect to the ultrasonic sensor, then gives the possibility to intercept better the position of an obstacle.

In [15] it is shown an ETA composed of three infrared sensors with a different angular position. These three different signals allow to describe the kind of obstacle in front of the user. Following a similar approach, we implement a device with the two infrared sensors, disposed one on the left and one on the right side of the user, that aim, each one, in front of the foot where they are located. All the components of the device are integrated in a belt that is easy to dress and is not very wearable like clothes or shoes.

The recognition of the different kind of obstacles is given by the different output signals that can increase or decrease in intensity respectively at the increasing or decreasing of the obstacle

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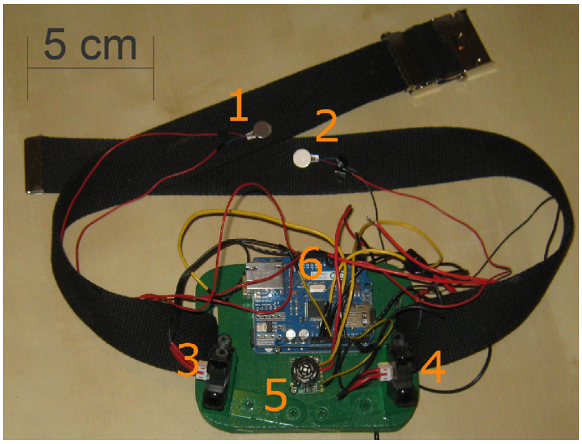

Fig. 1. First prototype: 1 and 2 – vibrating motors, 3 and 4 – infrared sensors, 5 – ultrasonic sensor, 6 – microcontroller.

dimension. We think that the simplicity of the output signals that the user have to learn to interpret is the goal of this device, for this reason we take the informations strictly necessary on the surroundings of the user and give to her/him only two kind of signals for each foot, depending on whether the obstacle is positive or negative. The introduction of the ultrasonic sensor, as after explained, is due only to functional reasons and to make more reliable the system.

2. Hybrid ETA based on infrared and ultrasonic sensors

The system is composed of two infrared sensor with the aim of intercept obstacles or one single descendant step in front of the user's feet, one ultrasonic sensor to cut the first part of the calibration curve of the infrared sensor and to intercept some particular surfaces, four vibrating motors to give the signals to the user and a microcontroller to manage the input and output signals and to develop the decisions. The infrared sensors are located, as is possible to see in Fig. 1, one on the left and the other one on the right of the system, this able us to intercept the obstacles near the feet. All components are placed on a belt, wearable on the user's body. This choice implies the presence of a great noise on the sensors signals so it will be necessary to implement a low-pass filter with the aim to clean it.

The VPM2 vibrating motors are produced by the Solarbotic just for this kind of applications. The four vibrating motors are located two on the front and other two on the backside of the user. This choice allow us to distinguish positive and negative obstacles in front of the left and right feet of the user and to make the interpretation of the signals as simple as possible. For example if there is an obstacle in front of the right foot will vibrate the motor located on the right front vice versa if there is a descendent step in front of the left foot will vibrate the motor located on the left backside. In Fig. 1 is shown the prototype of our device with all the components presented before.

With this configuration we test the absorption of energy by the device with all the sensors working in order to give a quantitative information for the autonomy of the device itself. In this system, the current is absorbed by different components. The microprocessor absorbs, without other loads, 48 mA, instead, each of the infrared sensors 33 mA, 3 mA for the ultrasonic sensor. The current absorbed by the whole system is equal to 117 mA, then, using a simple 9 V commercial battery with a capacity of 1200 mAh, our ETA has an energetic autonomy of more then 10 h.

In this section we will give all the characteristics of the ETA components.

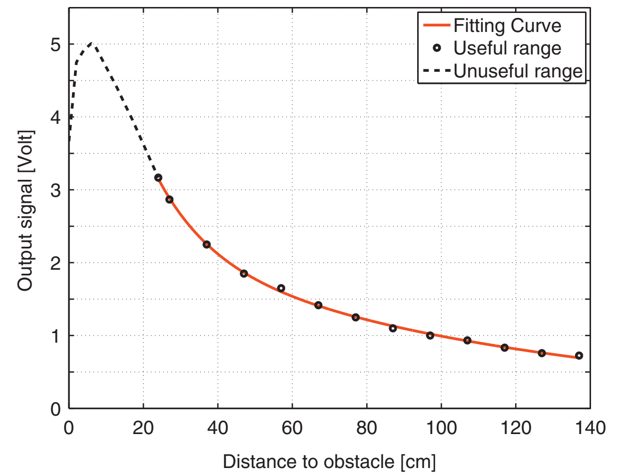

Fig. 2. Calibration curve of the Sharp-GP2Y0A02YK0F sensor. The black dot with the dashed line represents the sampled data, while the red line represents the fitting curve only for the useful range of the calibration curve. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

2.1. Infrared sensors characterization

The infrared sensor used is a Sharp-GP2Y0A02YK0F. Here we show all the main properties, the calibration curves experimentally obtained, the fitting curves used to transform the bit output in the true distance expressed in cm and the sensors noise. We had to conduce these experiments because in the datasheets of the sensors there are no exhaustive information to know what we can pretend from the sensors.

The infrared sensor chosen has a range distance that goes from 20 to 150 cm, a resolution of 0.5 cm, a frequency of 26.3 Hz and an analogical output that goes from 0 to 5 V. This sensor is characterized by a little spot and high precision. But the problems of these kind of sensors are the impossibility to intercept some kind of surfaces (like mirrors or glasses) and the interferences caused by light. The last problem is solved by the Sharp-GP2Y0A02YK0F thanks to its main circuit that triangulates three different signals.

To use the output signal of the sensor as a measure of distance one has calibrate the sensor. This is shown in Fig. 2 in which the output signal is plotted as a function of the distance. The equation chosen to convert the output of the sensor in distance is given by:

$$y = ae^{bx} + ce^{dx} \quad (1)$$

This equation converts the value of the voltage transformed in bit by the ADC of the microcontroller in distance expressed in centimeters. In Table 1 we show the value of the best fitted parameters for Eq. (2.1) with their 95% confidence interval.

From Fig. 2 it can be noticed that in the range 0–20 cm there are two different distances for the same output. Then, it is not possible to use the sensor for distances below 20 cm.

At the greatest distance of interest (see Fig. 3) the sensor spot is roughly 6 cm. This feature can able the user to intercept, precisely, any kind of obstacle in the front of his/her foot while he/she can

Table 1
Parameters with their 95% of confidence interval for Eq. (2.1).

Parameter	Value	Lower bound	Upper bound
a	692.4	480.2	904.5
b	−0.0683	−0.0878	−0.0488
c	306.1	259.9	352.3
d	−0.009511	−0.0109	−0.008117