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DEVELOPMENT OF AN ALGORITHM TO SUPPORT VISUALLY IMPAIRED PEOPLE USING ULTRASSONIC SENSORS

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Abstract. *In Brazil, according to IBGE (Instituto Brasileiro de Geografia e Estatística), 28,6% of the population has some deficiency. Among these, the visual impairment has the biggest representation, about 14,2% of Brazilians. Their locomotion through the streets of the Brazilian capitals has been an obstacle, mostly due to their lack in spatial location. To mitigate this problem, this project was developed with the goal to assist the visually impaired improving their circulation, based on computational methods and ultrasonic sensors. The developed algorithm is capable of performing distance measurements based on ultrasonic waves with a high level of reliability for distances until 1.6 meters. This signal is then transmitted to micro-motors that are equally spaced in a belt around the person. They then start to vibrate in the object direction with intensity proportional to the object distance, allowing a cheap excellent alternative to improve visually impaired people's life.*

Keywords: *Algorithm, Visual impairment, Ultrasonic Waves, Life quality.*

1. INTRODUCTION

Knowing the difficulties discovered by the visually impaired in large urban centers and their necessity of locomotion, the present project was developed. A spatial locator that aims to be innovative and economic is proposed. It is based on ultrasonic sensors and micro-motors, using the sensors signals to localize objects and the micro-motors to indicate their positions to the user.

The project uses an open source platform (Arduino) that is quite versatile and that can operate without the need of an external computer (Souza et al, 2011). The ultrasonic sensors would be positioned in a walking stick, where their data is transmitted through radio frequency to an Arduino that filters the signal and localize the closest object, sending its location to the user by means of vibrations in the micro-motors. A similar project was carried out at the Federal University of Pará. In it, the ultrasonic sensors were used to detect a presence or absence of vehicles in certain parking spaces (Bandeira et al, 2015), that project, however, took care only with static locations.

In our case, using that ability of spatial recognition of the sensors, we were able to use them to dynamically calculate the distance among the object and a person, regardless of the stick and person movement.

2. EXPERIMENTAL MATERIAL ANALYSIS

2.1 Ultrasonic Sensors

Ultrasonic sensors of the type HC SR04 were used with the objective of measuring distances between the sensor and the object, varying between 0.02 and 4 meters(m) with a precision of 0.003 m (Nakatani, et. al, 2014). During the process, after activating the trigger signal and before activating echo signal, the sensor sends waves with 40 KHz pulses. To perform such a measurement, the sensor emits ultrasonic signals that must reflect on possible objects and then return to the sensor, from the time taken to the sound to come back, it's possible to calculate the distance between both, knowing that the waves emitted propagate at the speed of sound (Cytron Technologies, 2013). A schematic of the sensor can be seen in figure 1.

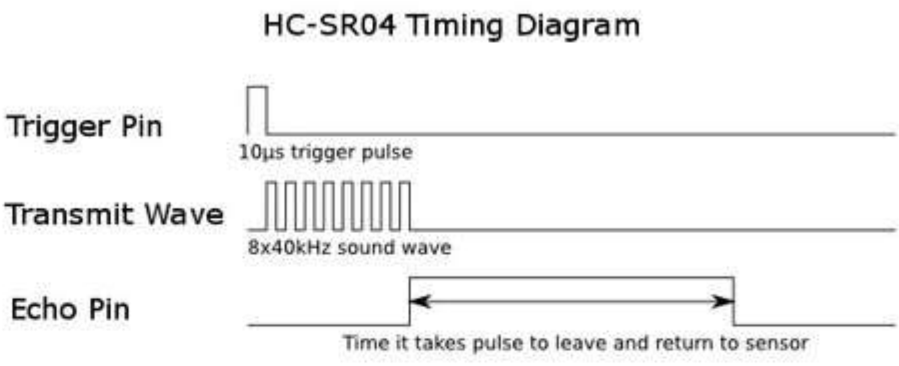

Figure 1 – Sensor Operating Diagram.
Source: <http://3.bp.blogspot.com/-gitI-m5q0AY/UiUQa86fOtI/AAAAAAAACIg/R9emtGkwSZU/s1600/HC-SR04-timing.jpg>

2.2 Radio Frequency Transmitter and Receiver

According to De Paula (2015), the transmitter and the receiver are modules that transmit and receive data by electromagnetic transmissions with AM modulation (Amplitude Modulation) and 433MHz frequency, from this, all transmitters and receivers based on radio frequency have bands within the spectrum of radio waves (3kHz to 300 GHz). According to Santos et al (2015), it was possible to establish secure serial data communication and transmission between the microcontroller boards at distances up to 200 meters, in addition, this reach could also improve by fixing the antenna on the transmitter and receiver.

2.3 Micro-motor DC

DC Motors are characterized by their versatility. It can be designed to display a wide variety of volt-ampere or speed torque characteristics for both dynamic and steady-state operation (Fitzgerald et. al, 2002). In this project we used micro motors with voltage within 3 and 6 volts(V), having its direct current controlled from microcontroller board.

3. THEORETICAL VALIDITY OF THE CHAUVENET METHODS

In experimental analysis with variable data and subject to environmental noise, it is necessary to use statistical methods to improve the results and to lower error probabilities during the development of the project. Therefore, the Chauvenet method rejects values that are likely to deviate from the mean by less than 1/2n, “n” is the number of sample values (Mc Cuen, 2003).

First, the mean value (x_m) and the mean deviation (d_i) of the sample are calculated from Eq. (1) and Eq. (2), respectively:

$$x_m = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{1}$$

$$d_i = x_i - x_m \tag{2}$$

Then, the sample variance (σ^2) and its standard deviation (σ) are calculated from Eq. (3) and Eq. (4), respectively:

$$\sigma^2 = \frac{1}{n}\sum_{i=1}^{n} (x_i - x_m)^2 \tag{3}$$

$$\sigma = \sqrt[2]{\sigma^2} \tag{4}$$

The Chauvenet method, being a Gaussian distribution, provides a data table among the number of samples and the maximum acceptable deviation from the standard deviation, which can be seen in Table 1. Therefore, any ratio discovered above the tabulated fixed value is rejected and a new average of the remaining samples will be calculated (Mc Cuen, 2003).

Table 1 – Chauvenet method for measure value reject.

Number of measurements	**Ratio of maximal deviation and standard error** d_{max}/σ
3	1,38
4	1,54
5	1,65
6	1,73
7	1,80
10	1,96
15	2,13
25	2,33
50	2,57
100	2,81
300	3,14
500	3,29
1000	3,48

Source: <http://www.fem.unicamp.br/~instmed/Criterio_Chauvenet.doc>

During the Project, the number of sample were 10, therefore $d_{m\acute{a}x}/\sigma$ will be 1,96.

Therefore, after discover the ratio among individual deviations and the standard deviation as in Eq. (5), will be make analysis in relation to each measure.

$$\beta_1 = (x_i - x_m)/\sigma \tag{5}$$

"β_1" the ratio.

If $\beta_1 > 1{,}96$, the value will be reject.

4. METHODOLOGY

The main idea of the algorithm is to use ultrasonic sensors in a walking stick to identify close objects and transmit this information to the user, which, in our case, will be through motor vibration around a belt in the user. For the project there are two microcontrollers (Arduino UNO and Intel Galileo) at disposal, one to deal with the ultrasonic sensor and transmit the data and the other to receive it and control the micro-motors vibrations. All possibilities were tested in order to see if an Arduino sensor is enough for this type of calculation or if a more robust sensor like the Galileo is actually needed. The two micro controllers can be seen in Figure 2 below.

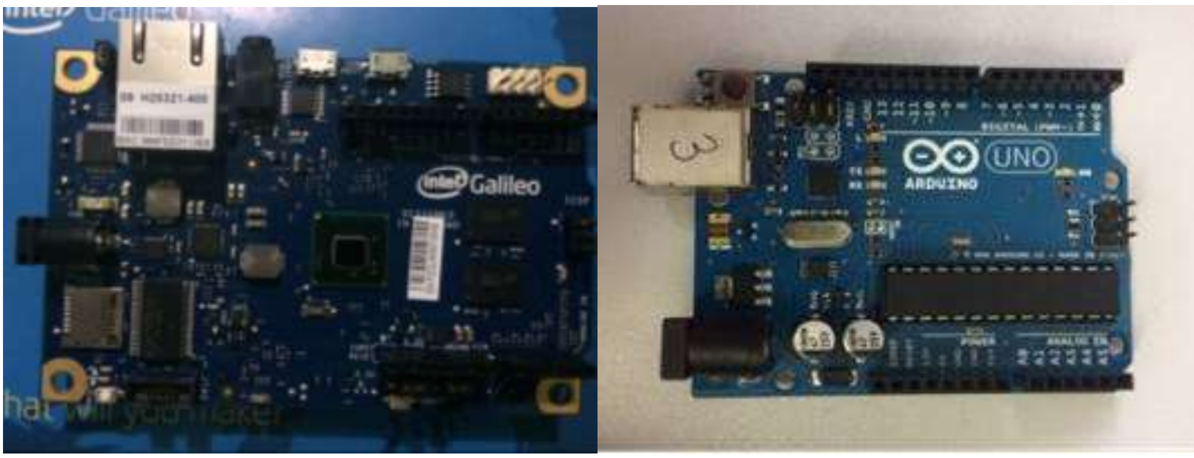

Figure 2 - Arduino and Galileo microcontrollers boards used during the project.

At first, a validation approach was done to ensure that the algorithm could work properly in the distance measurements.

The Chauvenet method was implemented in a way to remove outliers (Oliveira, 2008) and to allow sensor movement without big disparities, since the impaired people normally walk moving their walking stick. The validation was done putting obstacles in the direction of two moving sensors and measuring the distance with a measuring tape, the goal was to check if the measurements were accurate and if it was everything working fine with the algorithm that localizes the closest sensor. After the distance validation, a first prototype with three sensors and three motors was used, to qualitatively verify if the system and algorithms would work.

For all the process, we used:

- Ultrasonic sensor, Radio Transmission and Micro-motors.
- Arduino and Galileo micro controllers.
- Belt, Measuring tape and Drumstick.
- Matlab 2016b (MATLAB, 2016).

The main line of the developed algorithm works as follows:

- Measure the distance from the sensor to the object removing outliers.
- Identify in which direction the closest object is.
- Check if that distance is lower than a minimum threshold.
- If below threshold, transmit information to the micro-motor controller.
- Use the distance to regulate a logarithmic varying intensity vibration in the direction of the closest object.

The step 3 is necessary because normally it is necessary to the impaired person to be cautious only with objects that are approaching then, thus if the sensor vibrates to any distance (d), even in low intensity, it could make the user an insensitive, so it would not perceive them so strong after a while. In our work, that distance was set empirically to 1 meter.

The logarithmic scale was used in order to try to make a more realistic subjective analysis, where the person would need a more sense or danger as it gets closer to the object, which a linear intensity approach could not provide. This variation was done following the Eq. (6):

$$Intensity = A \,.\, e^{-d/\sigma} \tag{6}$$

The parameters A and α were founded based in a maximum and minimum vibration intensities. Since the current intensity is based in an unsigned int that goes from 0 to 255, we empirically choose 10 as minimum and 240 as the maximum. The intensities would vary from 0.1 meters (every measure closer would still have the 240 value) to 1 m.

So we found the constants to be: $A = 342.6$ and $\alpha = 28.32$. All the non-integer values were rounded.

The validation experiment can be seen in the Figure 3 together with some of the equipments used:

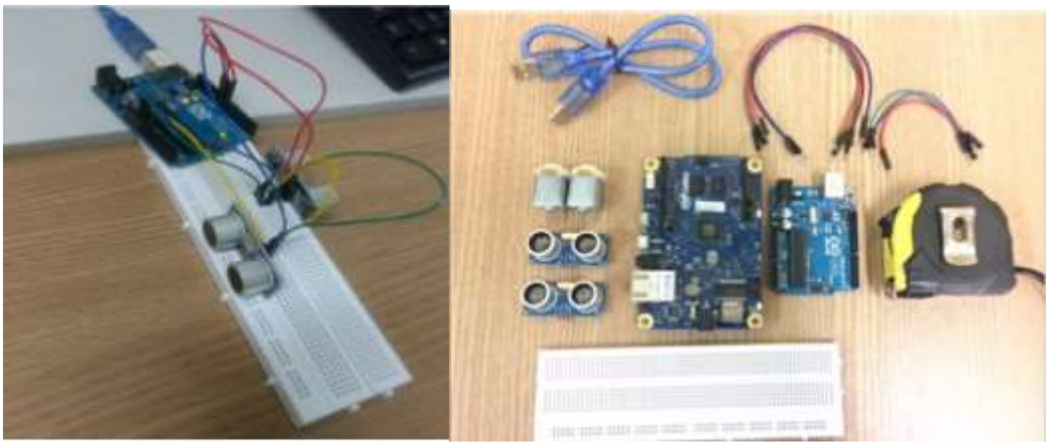

Figure 3 - Images representing the partial assembly of the system to carry out simulations and the components used.

The qualitatively test was a somewhat "maze run" with and without the ultrasonic stick. The authors would go blind folded from a start to end location with obstacles in between and count the number of times they hit an obstacle to verify if the algorithm and developed prototype could be useful to visually impaired people. An example of the "maze" can be seen in the figure 4 below.

Figure 4 - Example of "maze" with obstacles. The obstacles would change position at every different run.

5. RESULTS

The results of the validation were extremely good until the distance of 1.60 m, as can be seen in the figure 4 and 5. For distances above 1.60 m the standard error becomes relatively large. In our work, however, we would consider only the measurements below 1 m, which are far below the limit of accuracy founded.

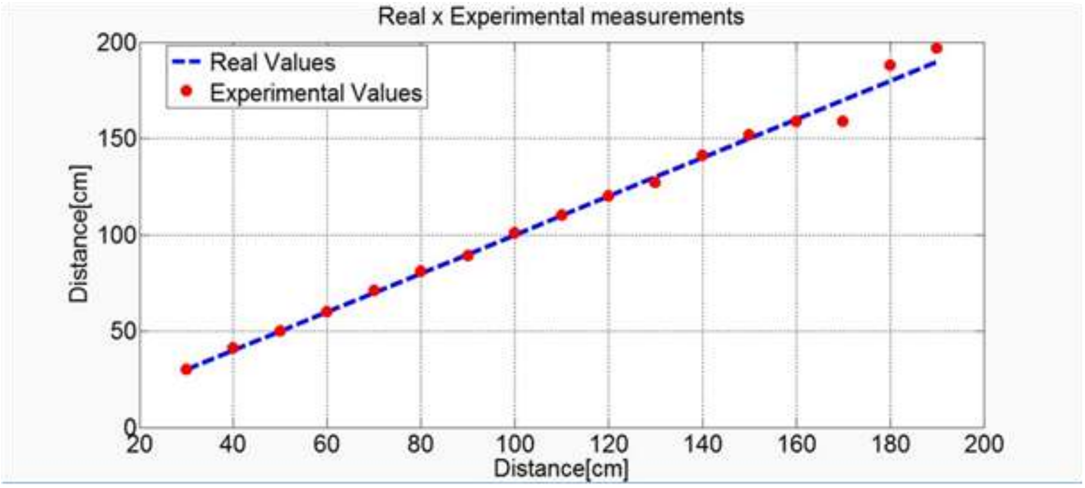

Figure 5 - Graph representing the relative error of the validation measurements (in red) in relation to the real ones (in blue).

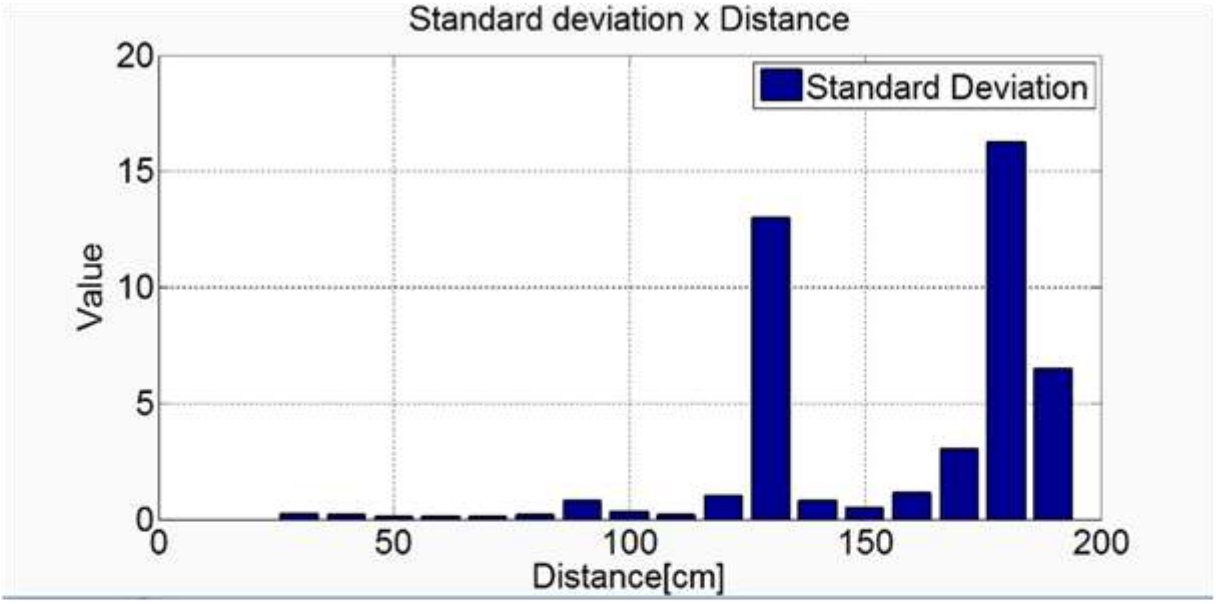

Figure 6 - Graph of Standard Deviation Ratio with distance.

In Figure 7, we see the distance of two objects from the 2 sensors in opposite directions and the distances in the radar plot. The algorithm could easily identify the close one, which is represented with the color red.

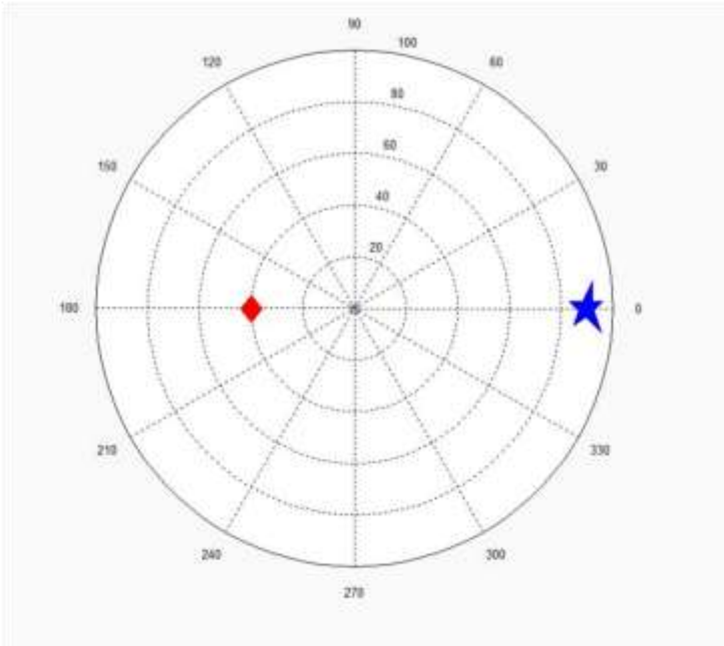

Figure 7 - Graph with the measurements of two sensors, identifying their obstacles and their distances.

The micro motors were glued with a tape in the used belt, where the controller was held behind. The total number of motors was three in the front, left and right positions. The glued motors can be seen in Figure 8.

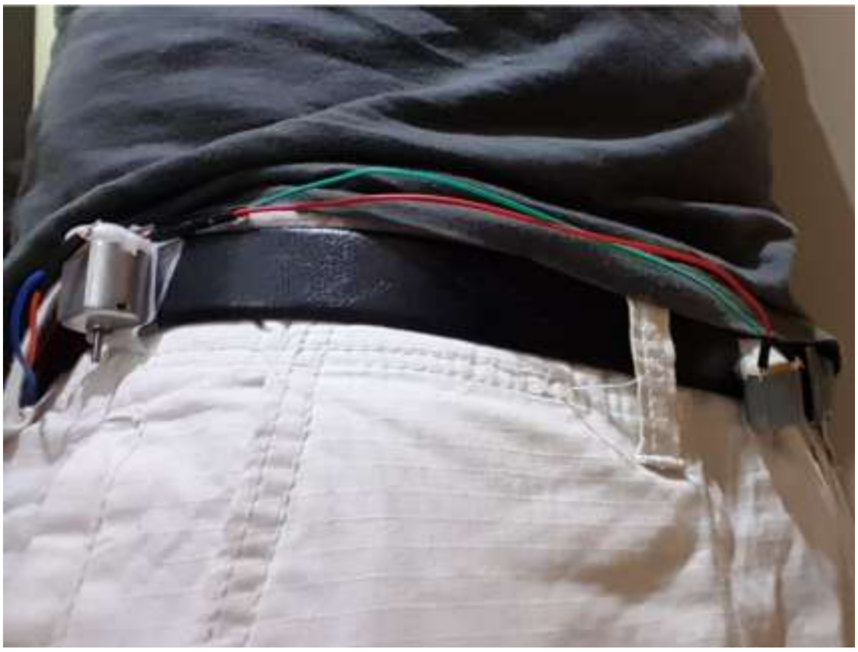

Figure 8 - Belt with micro motors.

Due to its facility a drumstick was used with three sensors that were fixed with a rubber band around them. The final arrangement can be seen in the figure 9.

Figure 9 - Drumstick with ultrasonic sensors.

The result of the qualitatively test can be seen in Figure 10. We had a mean of 4 hits without the ultrasonic help and only 0.5 hits with its help. The experiment, besides fun, proved with its results that the developed algorithm can be extremely helpful in helping people that are not able to see clearly.

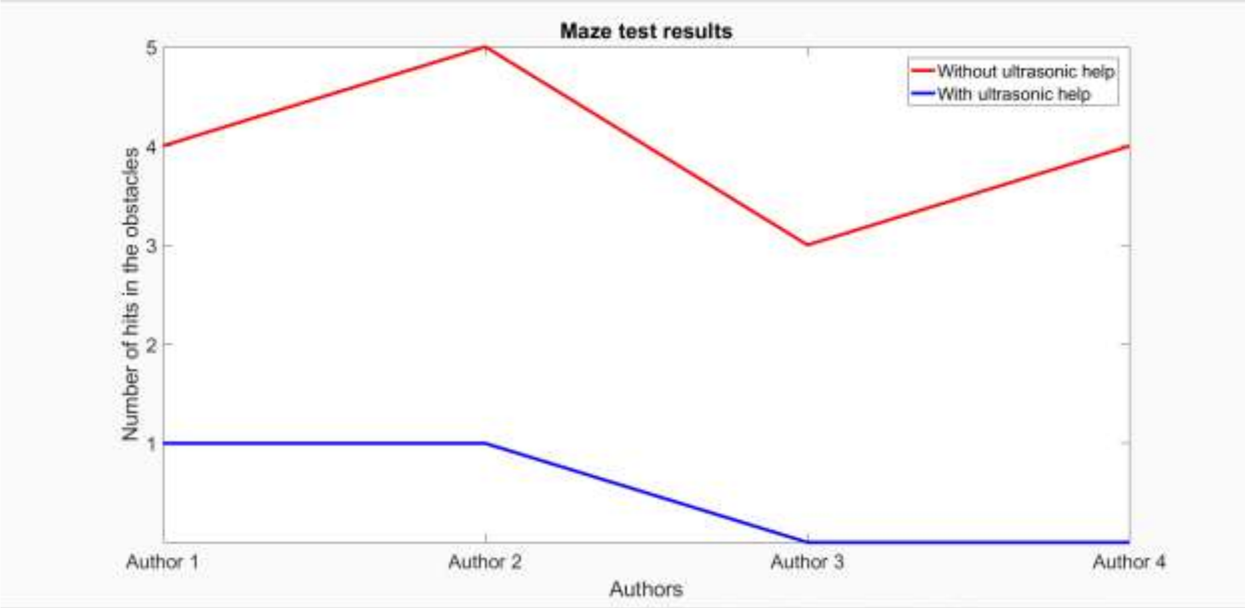

Figure 10 - "Maze" experiment results for all authors.

The Chauvenet algorithm implementation runs very smoothly both in the Arduino as well in the Galileo, which proves that one doesn't need a fast microprocessor to handle this algorithm, emphasizing that the proposed alternative could be useful and very cheap.

6. CONCLUSION

We were able to propose a cheap and doable algorithm to help visually impaired people. The results showed that it has a great accuracy for distances until 1.6m and that it can really help people who are with some visual difficulties to guide themselves through an unknown environment, reducing the mean number of hits in obstacles in almost 90%.

The prototype, however, still needs a lot of adjustment to become a good commercial alternative, as producing a big walking stick with more sensors that aren't expose, as well as a test with really visually impaired people to identify the better vibration intensities and thresholds.

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8. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.