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RESEARCH ARTICLE

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CANE WITH ELECTRONIC WET DIRT IDENTIFIER FOR THE VISUALLY IMPAIRED

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ABSTRACT

Vision impairment affects approximately 18% of the world population and impacts directly on people's quality and style of life. The cane is a self-help device used by visually impaired people to improve their functional abilities. When storing or handling a dirty cane with wet dirt on its tip the person may experience an embarrassing and hazardous situation, since the cane can be infected with harmful bacteria deriving from dirt exchanged on the street. This study developed an electronic wet dirt identifier containing an YL-69 moisture detector controlled by an Arduino Nano board installed on a cane with the objective of alerting the disabled through sound and vibration warnings at the presence of wet dirt attached to the cane. The equipment developed was tested and calibrated in a controlled environment and proved adequate to identify and distinguish types of wet dirt adapting to any type of cane. This research presents relevant social potential since it guarantees the physical integrity of the disabled and generates a versatile self-help device, which is cheap and easy to implement.

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INTRODUCTION

The challenges faced by people with disabilities go beyond pathology when faced with the need to adapt to the customs and rules imposed by society. Disability is a concept that presents the inequality imposed by environments that contain obstacles to a physically impaired body (Diniz *et al.*, 2019).
It is estimated that approximately 1.3 billion people (18% of the world population) live with some type of vision impairment, of which 826 millions with some impairment of close sight, 188.5 millions with light vision impairment, 217 millions with moderate to severe vision impairment and 36 millions blind. It is expected that, as population increases and ages this number will rise in the next years (Bourne *et al.*, 2017). For the visually impaired, sight loss hinders the performance of almost all routine activities, affecting the person's quality and style of life, personal relationships and career (Bhowmick and Hazarika, 2017). In 2006 the United Nations adopted the Convention on the Rights of Persons with Disabilities, which was legitimated by the Brazilian government in 2009, through resolution nº 6.949 (Brasil,

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2009). The rights of the visually impaired are respected once assistive technology (AT) are developed to assist integrating society and resulting in better life quality. The World Health Organization defines AT as a group of systems and services related to the supply of self-help products and services, which increase or improve functional abilities in a disabled person, allowing them to have a healthy, productive, independent, worthy life and to participate of the labor market and civil life (WHO, 2018b). Among the existing AT for vision impaired people, the cane stands out, since it is considered the best device for people with impairment, because, despite its limitations, it is simple, inexpensive, friendly and helps the person to walk allowing them to identify the obstacles around them (Fuentes *et al*., 2013). Along the years, several methods were tested on canes, in order to improve mobility and safety of people with vision impairment. Proposals search for solutions that automatically detect obstacles, holes and water puddles using especially ultrasonics sensors that interact with the user through sound (beeps or voice system) and/or tactile stimulation through vibration of the cane. Other solutions search for alternatives to the use of canes (Table 1). One of the approaches is automatic detection of obstacles and/or holes through sensors. The suggestions is a cane equipped with two ultrasonics sensors and two infrared sensors, which detect barriers from 20 until 305 cm of the cane and 2 until 10 cm of the tip of the cane respectfully. According to the distance of the obstacle, a warning is sent, through sound and/or vibration of the cane. The solution also contains a Global System for Mobile Communications (GSM) module, which allows communication of the cane with the mobile telephone network, and can be used to send an alert signal (to a previously recorded contact) in case the person requires help (Chaurasia and Kavitha, 2014).

The approach of other researches refer to the detection of obstacles with protrusions, holes and wet areas such as water puddles (Mahmud *et al*., 2013; Gayathri *et al*., 2014; Olanrewaju *et al*., 2017; Priyanka and Dharsana, 2017; Ikbal *et al*., 2018; Sahoo *et al*., 2019). An electronic circuit was proposed for the cane, made of a PIC microcontroller, ultrasonics sensors (to detect obstacles) and a pair of electrodes to detect moisture. The response signal vary according to the readings obtained by the sensors: the intensity of the motor vibration and the time gap between the beeps vary according to the readings. The research stands out due to the detection of wet (or muddy) and potentially slippery ground, though with no mention to the type of dirt (Mahmud *et al*., 2013). Another device researched is an smart cane which alerts people with vision impairment of obstacles such as protrusions, holes and water. It is equipped with sensors to supply information about the environment, used a Global Positioning System (GPS) module to determine possible routes to the desired destination and interacts with the user through voice messages (Gayathri *et al*., 2014). A solution was developed with the Arduino Uno board and ultrasonics sensor and water sensor, to detect obstacles and water near the cane. A beep is activated, in different ways, according to the type of barrier (liquid or solid) detected. The water sensor was tested with the presence of water and oil, and the results showed that the system was effective only with water. The sensitivity of the sensor was another problem, since the system continued to beep even after being removed from the water (until it was dry). The authors also registered the importance of the correct installation of the sensor on the tip of the cane, so that it can detect the presence of water while not suffering damages when touching a rough surface (Olanrewaju *et al*., 2017). Another proposal was a system to detect obstacles such as holes and water, with infrared sensor and a water sensor, controlled by Raspberry Pi board. The proposal also had a GPS receptor that identified location and can be used to inform if the user has reached their destination. Signals were generated through voice messages, which can be heard in a headphone. Although the headphone allows customizing messages, it can be a problem for the visually impaired since they will not be able to use audition to perceive the environment (Priyanka and Dharsana, 2017). In 2018, a cane was developed to detect obstacles, with two ultrasonics sensors and one infrared sensor. The sensors responses signals to an Arduino board and when detecting an obstacle the board activates a sound device and a vibration motor. The authors also included a water sensor and a temperature sensor with the objective of detecting the presence of water and/or temperature higher than 60 ºC. The system does not combine simultaneous activation of sound and vibrational warnings, which may be a problem in loud environments where the user would not hear the beep (Ikbal *et al*., 2018). In 2019, there was a proposal of a cane controlled by a Raspberry Pi board, connecting to ultrasonics sensor and water sensors, in order to detect obstacles and small water puddles or wet surfaces. The system also includes a GPS unit, which sends data of the user's location, through Wi-Fi connection, to a mobile application, which can be accessed by authorized people in order to identify the location of the person who uses the equipment. Although the system is controlled by Raspberry Pi board, another PIC microcontroller was necessary in order to monitor the water sensor and control motor vibration and the buzzer (Sahoo *et al*., 2019).

The researches of Sharma *et al.*, 2015, Mocanu *et al.,* 2016, Krishnan *et al*., 2016 and Ramadhan, 2018 there were proposals to alternative equipments other than the cane. There was a proposal for a wearable device controlled by an Arduino board and four ultrasonics sensors, installed in three places: cane, shoes and hat. When detecting an obstacle the system sends out a beep to a headphone. The limitation of the proposal is the need to use other especial objects besides the cane (Sharma *et al.*, 2015). Another device built is placed at the person's waste line (a kind of belt) and uses two data sources: ultrasonics sensors and a video camera (in a smartphone). The methodology used computer vision and machine learning techniques to identify the objects on the way of the user. The warnings were through beeps, which can be heard in a headphone. Even though it is an alternative to the use of a cane, the equipment exposes the user's smartphone allowing for theft (Mocanu *et al.,* 2016). The research the proposed an equipment for independent navigation with warnings of tracking and identification of objects. Data is collected by ultrasonics sensors and a video camera and transmitted via Bluetooth to a device installed in a smartphone that processed the data and activated the motor to start the movement. The solution resembles a car that guides the user through the path. Spaces with accessibility problems such as holes or lack of access ramp do not allow the use of the equipment (Krishnan *et al*., 2016). In 2018, a wearable smart system was proposed, to be worn on the arm. The system analysed the path taken by the user, responsed signal noise and activated vibration signal on the arm in case it detects any object on the way. Moreover, the system alerts family members or caretakers in case of emergency through Short Message Service sent by a GSM module, with the location of the user by GPS. Although the proposal is a wearable device similar to a watch, the equipment is big and disproportionate to the size of a person's arm (Ramadhan, 2018). Among the problems and conflicting situations faced by the users of cane, such as lack of accessibility on the streets, the contact of the cane with wet dirt such, leftover food and mud, is of great relevance. As for the foldable cane, that can be easily stored in the user's bag or placed on a table, not identifying the dirt may be extremely inconvenient, disturbing or embarrassing. Advances in Information and communication technology, allowed the emergence of new resources to be explored in the area of AT such as electronic travel aids, besides other handy and wholesome equipment that may arise. The research here proposed is justified since there were no researches found in Brazil, which involve low cost technologies for canes with artificial intelligence. Therefore, this research aimed at developing a low cost electronic device to be used in safety canes, for detecting wet dirt, leading to greater safety and independence as reducing the chances of embarrassment.

MATERIALS AND METHODS

This is an experimental and controlled research. The proposal consisted in the development of an equipment that receives data collected by a moisture sensor and informs the user through beeps and the activation of a vibrational motor the presence of dirt on the tip of the cane. The equipment was planned, developed and tested in the IF Maker laboratory of Federal Institute of Mato Grosso do Sul, campus of Campo Grande, during May and June 2019.

Materials: The electronic identifier was composed by Arduino Nano, a board for electronic prototyping containing a low cost ATmega328P microcontroller, hardware and open source code of low complexity for programming (Arduino, 2019), a moisture sensor type YL-69 with operating voltage between 3.3 until 5 V, with adjustable sensitivity, digital and analogic output and an integrated circuit type LM393, a buzzer, a piezoeletric signaling device, with operating voltage between 3.5 until 5 V, of continuous beep and a vibracall motor with operating voltage between 1.5 until 3 V, which receives an electric pulse that makes it spin and vibrate due to its scale shape. The moisture sensor was controlled by the Arduino Nano and the data collected was sent to the board: scores are between 0 (zero) and 1023, considering that score 0 (zero) represents absence of moisture and score 1023 the highest moisture detected. Originally, the YL-69 sensor is used to monitor the moisture level of the ground, but here it was tested to detect the presence of dirt at the tip of the cane. The buzzer and the vibracall motor were used to inform the user the presence of dirt on the extremity of the cane. A mini switch was added, so that the person can turn on the equipment. The switch is there so that the user turn off the equipment when needed, for instance, in case of using the cane in the rain, when the system would response signals noise, since the extremity of the cane would be wet. A box was built to cover up the circuit and attach it to the cane, printed in 3D (Figure 1). The box was modelled in a free 3D modelling software and printed with acrylonitrile butadiene styrene plastic (Tinkercad, 2019). The hardware of the wet dirt identifier depends on the implementation of a firmware. This firmware contains all the guidelines to set up the hardware and also enable the peripherals that are used on the electronic identifier. In order to implement the firmware the Arduino's integrated developing environment was used.

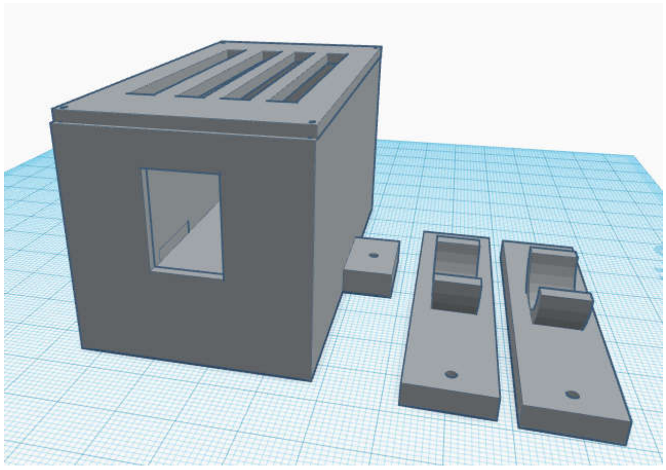

Figure 1. 3D model of the box built. Campo Grande MS- 2019

Prototype developed: The structure of the proposed electronic identifier is represented by Figure 2. At the center is the microcontroller Arduino, which is responsible for receiving the data collected by the moisture sensor type YL-69, processing them and activating the actuators (buzzer and vibration motor), according to the type of dirt identified.

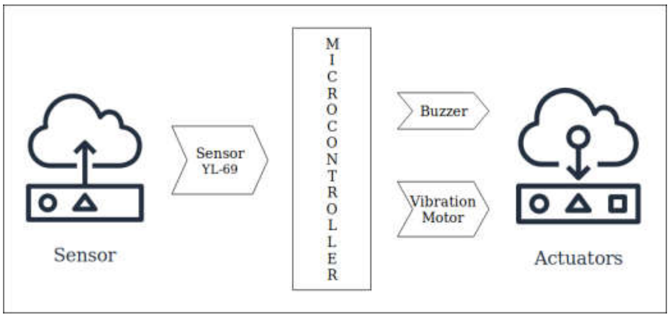

Figure 2. Structure of the proposed electronic identifier. Campo Grande MS- 2019

The moisture sensor type YL-69 was connected to an analogic port of the Arduino, while the buzzer and the vibration motor were connected to two digital ports. The mini switch controls the energy supply to the circuit by a 9 V battery. Figure 3 presents the connection of the components with the Arduino Nano board.

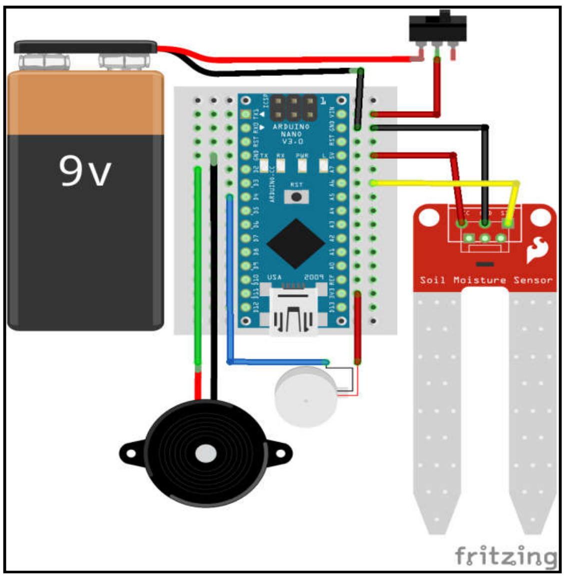

Figure 3. Connection of the components with the Arduino board. Campo Grande MS- 2019

The stimulation of the actuators depends on the type of dirt identified at the extremity of the cane. There are different rules to activate the actuators according to each type of dirt:

1. Wet extremity of the cane: response signal 1 beep, with the duration of 3 seconds, and activates the vibration motor, with the same time duration of the beep;
2. Extremity of the cane containing coffee grounds: response signals 2 sequential beeps, with the duration of 2 seconds each and 0.5 seconds break between them, and activates the vibration motor, during the break;
3. Extremity of the cane with mud or mate herb: response signals a sequence of 3 beeps, with the duration of 1 second and break of 1 second between each, and activates the vibration motor, during the break. Figure 4 shows the fluxogram of the system, demonstrating the conditions for identification of wet dirt.

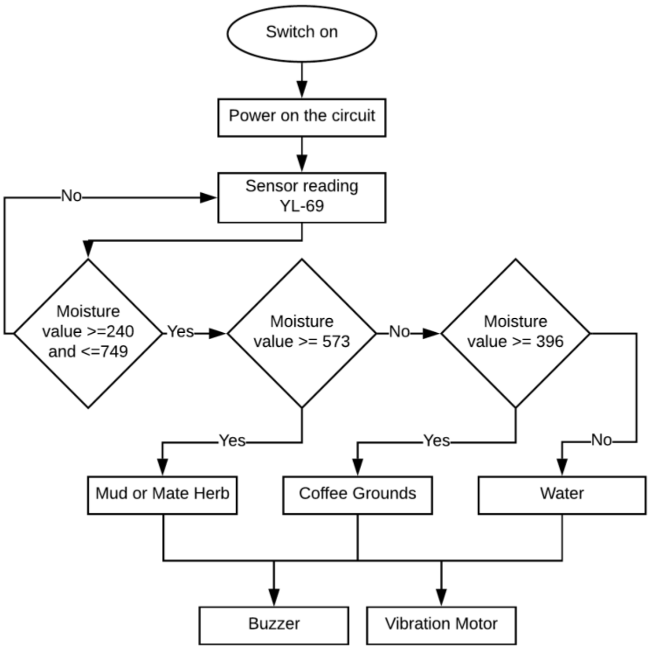

Figure 4. Fluxogram of the system. Campo Grande MS- 2019

The electronic identifier was attached to a foldable cane, as shown in Figure 5, and cost approximately US$ 25.00.

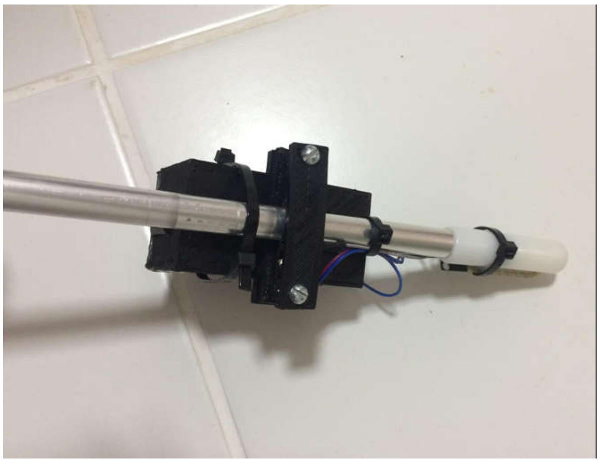

Figure 5. Electronic identifier for moisture detection attached to the extremity of a foldable cane. Campo Grande MS- 2019

Guidelines for dirt identification: In order for the objective of the research to be achieved, it was necessary to adjust the settings of the electronic identifier, so that it informs the user when any type of dirt is detected in the cane. Four types of dirts were used to capture the parameters of the settings of the system: water, mud, mate herb and wet coffee grounds. Data of the elements was collected in June 01, 2019, between 3:20 pm and 4:50 pm, for the settings. Each element was evaluated four times, every 30 minutes, with at least 10 samples collected each time. During that period, environment temperature varied between 26.6 ºC until 28.8 ºC and the relative moisture of the air was between 62.2% until 67.7%, according to the data obtained with the DHT22 sensor, connected to the circuit. The objective was to get the intensity returned by the moisture sensor in each one of the dirts. Therefore, the sensor was placed inside of the recipient with the corresponding dirt and a series of data was collected and evaluated. Between the end of the collection data of a specific dirt and the beginning of the collection data of another, the sensor was cleaned and dried, guaranteeing that there was no dirt on its surface.

Data Analyses: The analyses were simultaneous to the data collection, since the electronic identifier was connected to a computer through a USB cable, allowing the visualization of the data on the screen. The data presented was transferred to an electronic spreadsheet. In order to determine the value range that identifies each type of dirt only part of the values collected were used and for each supplied, a new value was produced from its arithmetic mean used the two following readings. The outliers identified on the coffee grounds category were also eliminated and the mud and mate herb categories were merged.

RESULTS

In this session, results obtained are presented, from the identification process of the electronic identifier setup parameters and its evaluation, based on the possibilities and limitations.

Dirt identification: The following values represent the scale identified by the YL-69 sensor, which varies between 0 (zero) until 1023, where 0 (zero) represents absence of moisture until 1023 the highest moisture detected.

Analyzing the data captured by the sensor, an overlap was identified between the data collected of the water and data collected of the coffee grounds, and also mud and mate herb.
Intensities obtained without statistical treatment was obtained in the water varied intensities between 151 until 401; in the coffee grounds it was between 208 until 600; in the mud between 496 until 699; and in the mate herb between 462 until 763. With the calculated of arithmetic mean of three registers, the new values obtained for each dirt were: water between 222 until 391; coffee grounds between 264 until 572; mud between 572 until 679; and mate herb between 500 until 740. The time series of the data obtained in the moisture sensor can be observed in **Figure 6**, separated by type of dirt evaluated. Comparing the values obtained between measurement 1 until 25 (the x-axis) and between measurement 26 until 45, greater overlap of data is identified on the second range of the data, especially on the identification of the presence of water and coffee grounds together. The values to determine each of the type dirts were obtained after data analyses. The minimum and maximum reference values to identify each of the type dirt

Table 1. Resources used on researches in order to improve mobility and safety of people with vision impairment. Campo Grande – MS, 2019

Resources	Related researches										
	Chaurasia and Kavitha, 2014	Mahmud *et al.*, 2013	Gayathri *et al.*, 2014	Olanrewaju *et al.*, 2017	Priyanka and Dharsana, 2017	Ikbal *et al.*, 2018	Sahoo *et al.*, 2019	Sharma *et al.*, 2015	Mocanu *et al.*, 016	Krishnan *et al.*, 2016	Ramadhan, 2018
Moisture sensor		x									
Infrared sensor	x				x	x					
Water sensor			x	x	x	x	x				
Ultrasonics sensor	x	x	x	x		x	x	x	x	x	x
Beep sound	x	x		x		x	x				x
Vibration motor	x	x	x		x	x	x				x
Voice synthesizer			x		x			x	x		
GPS			x		x		x			x	x
Camera									x	x	

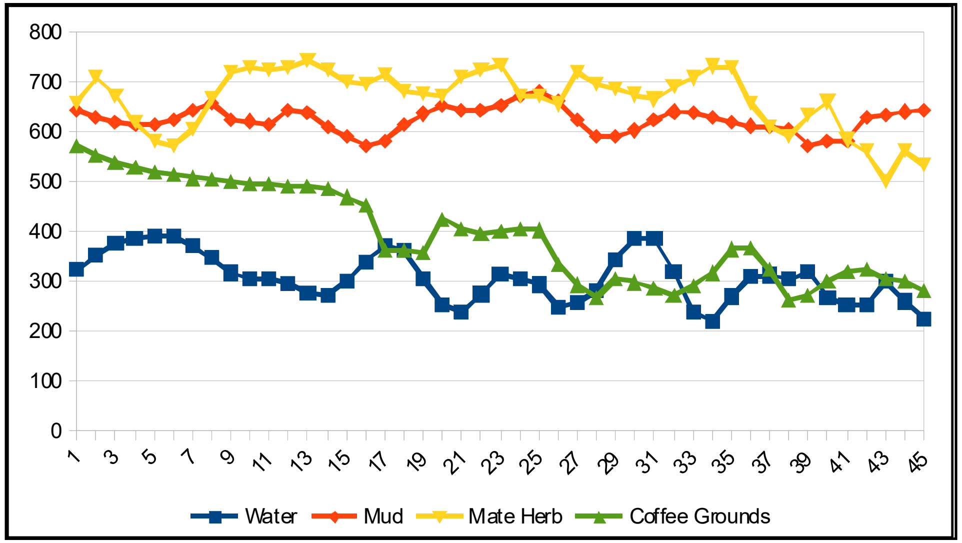

Figure 6. Time series of the mean values obtained from the collection in triplicate by the moisture sensor. Campo Grande MS- 2019

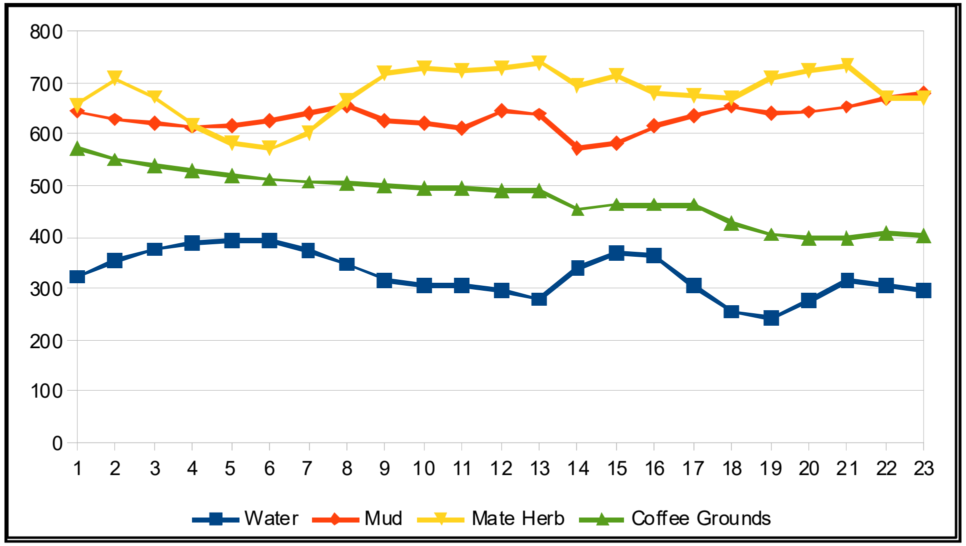

Figure 7. Time series of the break used to obtain the reference values for dirt classification. Campo Grande MS- 2019

evaluated are: water, 240 until 391; coffee grounds, 396 until 572; mud/mate herb, 573 until 740. Figure 7 presents the graph with the time series used to obtain the reference values. Intensity overlapping: With the intensities obtained on the moisture sensor, it was possible to identify the coffee grounds and water dirts. The exception was the classification of mud and mate herb, which presented similar intensities and were grouped in the same category. Additionally there were no false positive results in the obtained classifications.

DISCUSSION

The mean arithmetic calculation of the last 3 measurements in the moisture sensor reduced the overlapping of values between the dirts evaluated. However, shortly after removing the sensor from the recipient of the dirt it was observed that the intensity of the moisture obtained returned to 0 (zero) and the leftover dirt attached to the sensor was not enough to stimulate it again. That is, if the sensor does not obtain at least 3 measurement while it touches the dirt, there may be false-positive results.

Equipment evaluation

The main advantages of the electronic identifier are:

- Identification of different types of dirts;
- Different notifications to inform the user to the type of dirt identified;
- Compatible with all types of canes;
- Low cost development;
- Possibility to include new resources and firmware update.
- As limitation of the presented solution is regarding the types of dirts detected, once the sensor identifies only those preset and which present moisture values between the determined range (between 240 until 740).

In the evaluated scenario, the sensor was easily cleaned and disinfected after contact with the dirts. However, there can be elements such as animal feces, food waste, oil, etc, that are not easily removed and need bigger efforts. The SDs include several technologic resources that enable the accomplishment of daily activities by visually impaired people. The main contribution of the resource was to develop electronic identifier for dirt to attached in any cane, which informs the person of the presence of wet dirt at the extremity of the cane and identifies it. The device shows relevant social potential, since it guarantees the physical integrity of the disabled people and creates a cheap and easy to implement AT.

Conclusion

The device worked correctly in the evaluated environment and even with the overlapping of the values measured in some analyses there were no showed false-positive results, that is, whenever exposed to the wet dirts the detector was stimulated. The research highlighted the importance of developing TA that aims to include visually impaired people in society and improve their quality of life. The developed AT presented some important characteristics, among them the simplicity of the electronic device that allows its coupling in any cane, besides not substantially increasing the final cost of the AT. The actual research opens the opportunity for new researches, with further benefits to the disabled people who use the cane. A strategy must be developed to allow the user to clean the moisture sensor, after contact with other wet dirts that were not evaluated here. It is also necessary to run tests to evaluate especially: (1) the physical resistance of the sensor attached to the extremity of the cane against mechanical impact; (2) if the detector identifies correctly other wet dirts that were not evaluated; (3) the influence of temperature and moisture of the environment on the response of the moisture sensor; (4) if the instrumented cane adapts well to the need of the visually impaired in real conditions.

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Conflicts of Interest: None.

REFERENCES

Arduino. 2019. Arduino – Introduction. Available online at: https://www.arduino.cc/en/Guide/Introduction. Accessed in May 29th, 2019.

Bhowmick, A., Hazarika, S. 2017. An insight into assistive technology for the visually impaired and blind people: state-of-the-art and future trends. *Journal on Multimodal User Interfaces*., 11(2), p.149-72.

Bourne, R.R.A., Flaxman, S.R., Braithwaite, T., Cicinelli, M.V., Das, A., Jonas, J.B., *et al*. 2017. Vision Loss Expert Group. Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis. *Lancet Glob Health.*, 5(9):e888–97.

Brasil, 2009. Decreto n. 6.949, de 25 de agosto de 2009. Promulga a Convenção Internacional sobre os Direitos das Pessoas com Deficiência e seu Protocolo Facultativo, assinados em Nova York, em 30 de março de 2007. Brasília: Brasil. Available online at: http://www.planalto. gov.br/ccivil_03/_ato2007-2010/2009/decreto/d6949.htm. Accessed in July 07th, 2019.

Chaurasia, S., and Kavitha, K. 2014. An electronic walking stick for blinds. *International Conference on Information Communication and Embedded Systems* (ICICES2014). Available online at: https://ieeexplore.ieee.org/stamp/ stamp.jsp?tp=&arnumber=7033988. Accessed in July 07th, 2019.

Diniz, D., Barbosa, L., Santos, W. 2019. Disability, human rights and justice. *Sur, Rev. int. direitos human*., 6(11), p. 64-77.

Fuentes, J., Graffigna, J., Dipane, J., Segura, M. 2013. Prototype of a Communications System for Blind People in a City. *Journal of Physics: Conference Series*., 477, p.12-42.

Gayathri, G., Vishnupriya, M., Nandhini, N., Banupriya. 2014. M. Smart walking stick for visually impaired. *International Journal of Engineering and Computer Science.*, 3(3), p.4057-61.

Ikbal, M., Rahman, F., Kabir, M. 2018. Microcontroller based smart walking stick for visually impaired people. In *2018 4th International Conference on Electrical Engineering and Information Communication Technology* (iCEEiCT)., Dhaka, p. 255-259.

Krishnan, A., Deepakraj, G., Nishanth, N., Anandkumar, K.M. 2016. Autonomous walking stick for the blind using echolocation and image processing. In *2016 2nd International Conference on Contemporary Computing and Informatics* (ic3i)., p.13-6.

Mahmud, M., Saha, R., Islam, S. 2013. Smart walking stick - an electronic approach to assist visually disabled persons. *International Journal of Scientific & Engineering Research.*, 4(10), p.111-14.

Mocanu, B., Tapu, R., Zaharia, T. 2016. When ultrasonic sensors and computer vision join forces for efficient obstacle detection and recognition. *Sensors*., 16 (11), p.1807.

Olanrewaju, R.F., Radzi, M.L.A.M., Rehab, M. 2017. iWalk: intelligent walking stick for visually impaired subjects. In *Proc. of the 4th IEEE International Conference on Smart Instrumentation, Measurement and Applications* (ICSIMA) 28-30 November, Putrajaya, Malaysia.

Priyanka, M.M., Dharsana, M.M. 2017. Navigational aiding system for visually impaired. In *2017 Third International Conference On Science Technology Engineering And Management* (ICONSTEM)., p.1072-75.

Ramadhan, A. J. 2018. Wearable smart system for visually impaired people. *Sensors*., 18(3), p.843.

Sahoo, N., Lin H., Chang, Y. 2019. Design and implementation of a walking stick aid for visually challenged people. *Sensors*., 19(1), p. 130.

Sharma, P., Shimi, S.L., Chatterji S. 2015. Design of microcontroller based virtual eye for the blind. *International Journal of Scientific Research Engineering & Technology*, 3(8), p.1137-42.

Tinkercad. 2019. Tinkercad - From mind to design in minutes. Available online at: https://www.tinkercad.com/. Accessed in July 11th, 2019.

World Health Organization – WHO, 2018. Assistive technology. Available online at: https://www.who.int/news-room/fact-sheets/detail/assistive-technology. Accessed in July 07th, 2019.

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