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Abstract-- This article describes the design, implementation, and experimental validation of a smart cane for people with visual impairments, based on an integrated electronic system. The prototype incorporates an ultrasonic sensor (HC-SR04) to detect irregularities in the terrain and obstacles on public roads. The signal is processed by an Arduino Nano microcontroller and transformed into a vibrating signal that alerts the user to the presence of obstacles. The device also includes a strip of Neopixel LED lights controlled by a light sensor (LDR), which is automatically activated in low-light conditions so that the user can be seen by other pedestrians. In addition, it has an audible alert system that is activated when the cane falls out of the user's hand, making it easier to locate. The development process was organized using a methodology based on prototypes and key result planning (OKR), which allowed for structured and efficient execution. Tests carried out in simulated urban environments validated the system's performance, highlighting its usefulness as an accessible tool to support independent mobility in contexts with poor infrastructure.

Keywords: Visual impairment, smart cane, ultrasonic sensor, Arduino, accessibility.

Abstract-- This article describes the design, implementation, and experimental validation of a smart cane for people with visual impairments, based on an integrated electronic system. The prototype incorporates an ultrasonic sensor (HC-SR04) for the detection of terrain irregularities and obstacles on public roads. The signal is processed by an Arduino Nano microcontroller and transformed into a vibration signal that alerts the user to the presence of obstacles. The device also includes a Neopixel LED light strip controlled by a light sensor (LDR), which automatically activates in low light conditions to improve the visibility of the user by other pedestrians. It also has an audible alert system that activates when the cane falls from his hand, making it easier to locate. The development process was organized using a methodology based on prototypes and key results-based planning (OKR), which allowed for a structured and efficient execution. Tests conducted in simulated urban environments validated the system's operation, highlighting its usefulness as an accessible tool to support independent mobility in contexts with poor infrastructure.

Keywords: Visual impairment, smart cane, ultrasonic sensor, Arduino, accessibility.

INTRODUCTION

Visual impairment, defined as the total or partial loss of the ability to see, significantly affects the quality of life of those who suffer from it, limiting their autonomy and increasing their exposure to risks in non-adapted urban environments. In Mexico, according to data from the National Institute of Statistics and Geography (INEGI, 2020), a considerable part of the population with disabilities has visual difficulties, with Chihuahua being one of the states with the highest incidence. In particular, Ciudad Juárez faces a serious problem of poor urban infrastructure, characterized by uneven sidewalks, fixed obstacles, and poor road signage, conditions that aggravate the mobility of people with visual impairments (El Heraldo de Chihuahua, 2023; Borderzine, 2014).

Several previous studies have explored the development of smart canes using ultrasonic sensors, vibrators, GPS systems, and open or emerging technologies. Initiatives such as those by Tsormpatzoudis (2016) at the University of Manchester, Slade, Tambe, and Raitor (2021) at Stanford, and national projects such as that by Ontiveros, Rojas, and Martínez (2014) set important precedents in the design of devices aimed at improving the mobility of people with visual impairments. These experiences have served as the basis and inspiration for the present work, which focuses on a low-cost, accessible solution adapted to marginalized urban contexts.

Several projects have explored the implementation of artificial intelligence to optimize the functions of the cane (Ontiveros, Rojas & Martínez, 2014; Slade, Tambe & Raitor, 2021). However, many of these developments have limitations in terms of cost, technical complexity, or availability in marginalized contexts. In response to this problem, this study proposes the design and validation of a low-cost smart cane, based on an Arduino Nano microcontroller, capable of alerting the user by vibration to nearby obstacles, illuminating their position in low visibility conditions, and emitting an audible signal in case of loss of the cane to guide the user to its location.

This development seeks to respond to a specific need in the Juarez community through a functional, accessible, and easy-to-implement solution that contributes to the inclusion and safety of people with visual impairments.

General objective

Design and implement a functional prototype of a smart cane for people with visual impairments, integrating an ultrasonic sensor (HC-SR04), an Arduino Nano microcontroller, a vibrating actuator, a Neopixel LED strip controlled by a photoresistor (LDR), and an active buzzer, all powered by a rechargeable battery system and regulated by an L78S05 module. The device must be capable of alerting the user to the presence of obstacles, improving their visibility in low-light conditions, and facilitating their location, promoting safer and more autonomous mobility in urban environments.

Specific objectives

- Design the electronic system of the smart cane using an Arduino Nano microcontroller and sensors suitable for detecting obstacles and lighting conditions.
- Implement a vibrating feedback mechanism, activated by an ultrasonic sensor, that alerts the user to irregularities in the terrain at close range.
- Integrate an automatic lighting system using an LED strip (Neopixel) controlled by a photoresistor (LDR), which activates in low light conditions to improve the user's visibility to other pedestrians.
- Develop a sound localization system using a buzzer controlled by a presence button, which is activated when the user drops the cane, facilitating its recovery.
- Design and manufacture the prototype casing, taking into account factors such as ergonomics, impact resistance, and environmental conditions, using CAD modeling and additive manufacturing (3D printing).
- Simulate and validate the operation of the circuit on platforms such as Tinkercad before physical assembly to ensure the correct integration of the components.
- Perform the final assembly of the smart cane and implement functional tests to verify the operation of all integrated systems under simulated urban environment conditions.

Justification

Vision loss is one of the sensory disabilities with the greatest impact on the quality of life of those who suffer from it, as it significantly limits their interaction with their environment and their autonomy (World Health Organization [WHO], 2020). Despite technological advances, accessible and affordable solutions accessible and affordable solutions for the safe mobility of people with visual impairments are still insufficient, especially in urban contexts with poor infrastructure such as Ciudad Juárez, where a high rate of physical barriers for this population group has been identified (INEGI, 2020).

Given this situation, this project proposes the design and development of a smart cane that integrates ultrasonic sensors to detect uneven terrain and obstacles, notifying the user through vibrating signals. In addition, the device incorporates an LED strip controlled by a photoresistor, which makes the user visible in low light conditions, and an audible alarm system activated by a button, which facilitates its location in case of loss.

The innovation of the prototype lies in its affordability, without sacrificing functionality, as it is based on open platforms such as Arduino. The aim is to provide a tool that not only improves the user's mobility, but also promotes their independence and safety when traveling on public roads, a key aspect in exercising the right to a dignified and inclusive life.

Compared to similar developments such as WeWalk canes (2017) or experimental models developed at institutions such as the University of Manchester (Tsormpatzoudis, 2016) or Stanford (Slade, Tambe & Raitor, 2021), this project presents a more viable alternative in low-resource contexts, without relying on proprietary technologies or complex artificial intelligence systems.

In short, the proposed smart cane represents a tangible step toward the democratization of assistive technology by integrating functional, economical solutions adapted to the social and urban environment of the target user.

DEVELOPMENT

The white cane has historically been an essential tool for people with visual impairments, allowing them to interact with their immediate surroundings through touch. However, its traditional functionality has limitations in the face of current urban mobility challenges, especially in contexts such as Ciudad Juárez, where uneven sidewalks, exposed sewers, and a lack of adequate signage pose significant risks to this population (Borderzine, 2014; INEGI, 2020).

In response to this problem, a prototype smart cane was developed, with the aim of improving the autonomous mobility experience of blind people by integrating accessible and low-cost technologies

This device was designed with a lightweight and resistant physical structure, complemented by a 3D-printed casing, which guarantees its durability in urban environments.

The main system uses an HC-SR04 ultrasonic sensor to detect discontinuities or obstacles in the user's path. This information is translated into vibratory signals generated by a motor located in the handle of the cane, providing immediate haptic feedback (Cytron Technologies, 2013). The cane also incorporates a strip of Neopixel LED lights, which are activated by an LDR photoresistor when low light is detected, increasing the user's visibility to other pedestrians or vehicles (La Bobina de Tesla, 2021).

To enhance the functionality of the device, a piezoelectric buzzer controlled by a push button was included. This emits an audible alarm in case of loss, making it easier to locate (Victoria Gutiérrez, 2023). All components are integrated into an Arduino Nano board, allowing for modular control and programming of the system (Arduino.cc, 2023).

The electronic circuit was designed and simulated in Tinkercad, while the mechanical design was developed in SolidWorks, and the programming in Arduino IDE, using specialized libraries such as EasyBuzzer.h, Adafruit_Neopixel.h, and HCSR04.h. These tools enabled the creation of a functional, replicable, and economically viable prototype. Figure 1 shows the design in SolidWorks created for the project.

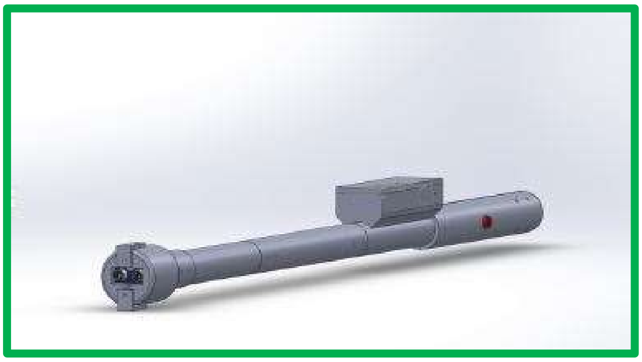

Figure 1. *Design of the smart cane created in SolidWorks*.

Source: *Own work* (2025).

DISCUSSION AND ANALYSIS OF RESULTS

During the prototype validation phase, functional tests were carried out in controlled environments that simulated urban conditions such as uneven surfaces, common obstacles, and low lighting. The

HC-SR04 ultrasonic sensor was able to detect objects at distances between 5 and 250 cm, successfully activating the vibration motor (Cytron Technologies, 2013). This haptic feedback was intuitive and effective, fulfilling its function without interfering with the user's other sensory abilities.

The LDR photoresistor, together with the Neopixel LED strip, worked correctly when turned on at light levels below 500 lux, increasing the user's visibility in nighttime or dim conditions, in accordance with urban mobility standards for people with disabilities (Government of Mexico, 2016).

The buzzer location system allowed the device to be recovered in less than 20 seconds in enclosed spaces, validating its usefulness as an emergency mechanism. The use of an active buzzer with an internal oscillator facilitated its efficient implementation with the microcontroller (Victoria Gutiérrez, 2023). In terms of production cost, the prototype does not exceed $50, well below commercial models such as those developed by WeWalk (2017) or Stanford (Slade, Tambe & Raitor, 2021), reinforcing its viability as an accessible tool.

These results suggest that the cane fulfills its functional purpose: to improve the autonomy, safety, and visibility of users, with low-cost technology, without sacrificing quality or efficiency. Figure 2 shows the cane being used during testing.

Figure 2. *Use of the smart cane during performance tests*.

Source: *Own elaboration* (2025).

CONCLUSIONS

The smart cane was designed to meet a real need for people with visual impairments, particularly in challenging urban environments such as Ciudad Juárez, where the infrastructure does not guarantee safe mobility (INEGI, 2020; Borderzine, 2014). Through the implementation of accessible electronic components, such as ultrasonic sensors, LEDs, vibrating motors, and open-source platforms, it was possible to develop a functional, economical, and replicable tool.

Beyond its technical capabilities, this project promotes social inclusion and user autonomy. Unlike other technological solutions, this prototype stands out for its simplicity, accessibility, and adaptability. It also sets a precedent for future improvements, such as the incorporation of GPS modules, Bluetooth connectivity, or integration with mobile applications, without compromising its economic and socially responsible nature.

This work demonstrates how technology can, from a humanistic and inclusive approach, improve the quality of life of vulnerable groups, provided that the design focuses on the real needs of the user and the context in which it will be implemented.

FUTURE WORK

The development of the smart cane represents a significant step forward in the inclusion of people with visual impairments in adverse urban environments. However, in order to expand its functionality and impact on society, a series of future improvements and adjustments are proposed, both at the technical and strategic levels.

First, we recommend incorporating a GPS module with Bluetooth or Wi-Fi connectivity, which would allow users to locate their position in real time and share it with family members or caregivers via a mobile app. This would facilitate not only navigation but also emergency response, increasing personal safety.

Another potential improvement is the use of LiDAR sensors or cameras with artificial intelligence, which would not only detect obstacles but also identify and classify them (steps, vehicles, people, poles, etc.), as proposed by prototypes developed by institutions such as Stanford (Slade, Tambe & Raitor, 2021). Although this technology increases the cost, an advanced version of the device could be considered for institutional contexts, such as civil associations or government programs.

In terms of ergonomics, a review of the structural design of the cane is suggested to make it lighter, foldable, and adjustable in length. This would facilitate its transport and storage, improving its portability in the user's daily context.

From a social perspective, it is recommended that this project be linked to urban inclusion and accessibility programs, promoting agreements with public institutions and non-governmental organizations to facilitate its production, distribution, and training in the use of the device. Coordination with policies on mobility, human rights, and public health could amplify its reach and social impact.

Finally, it is essential to consider the creation of an accessible instructional guide (Braille, audio, large print) for the use and maintenance of the cane, ensuring that anyone, regardless of their degree of visual impairment, can use its functions independently. These improvements would not only strengthen the functionality of the device, but also position it as a technological tool for social transformation, capable of closing gaps in terms of equity, safety, and full participation in public spaces.

REFERENCES

Adafruit Industries. (n.d.). *Adafruit NeoPixel Library Reference*. Retrieved from https://learn.adafruit.com/adafruit-neopixel-uberguide

Arduino.cc. (2023). *Arduino Nano Overview*. Retrieved from https://www.arduino.cc

Borderzine. (2014). *People with visual impairments face risks when walking in Ciudad Juárez*. Retrieved from https://borderzine.com

Cytron Technologies. (2013). *HC-SR04 Ultrasonic Sensor Technical Datasheet*. Retrieved from https://www.cytron.io

EasyBuzzer. (n.d.). *EasyBuzzer Arduino Library*. Retrieved from https://github.com/evert-arias/EasyBuzzer

El Heraldo de Chihuahua. (2023). *People with disabilities face delays and barriers in urban infrastructure*. Retrieved from https://www.heraldodechihuahua.com.mx

Government of Mexico. (2016). *Rules for the use of white canes for people with visual disabilities*. Retrieved from https://www.gob.mx

Gutiérrez Aguayo, V. L. (2023). *Design and construction of a smart cane for blind people [Bachelor's thesis, Ciudad Juárez Institute of Technology]*. ITCJ.

National Institute of Statistics and Geography (INEGI). (2020). *2020 Population and Housing Census*. Retrieved from https://www.inegi.org.mx

The Coil of . (2021). *Pull-down Pull-down with photoresistor*. Retrieved from https://labobinadetesla.com

Ontiveros, M., Rojas, C., & Martínez, A. (2014). *Design and construction of an electronic white cane for blind people*. Higher Technological Institute of Huauchinango.

World Health Organization (WHO). (2020). *World Report on Vision 2020*. Retrieved from https://www.who.int

Slade, P., Tambe, T., & Raitor, M. (2021*). Smart Cane Project*. Stanford University.

Tsormpatzoudis, C. (2016). *Smart Mobility Aid for the Visually Impaired Using 3D Printing and Sensors*. University of Manchester.

WeWalk. (2017). *Smart Cane Technology*. Retrieved from https://wewalk.io

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