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RESEARCH ARTICLE

SMART CANE INDEPENDENT NAVIGATION FOR VISUALLY IMAPIRED PERSONS

Dr. Murali Krishna Yadavalli[1], Likhitha Sai Sudanagunta[2], Sirisha Thammisetty[2], Devi Sri Vaka[2] and Kiranmaye Gorrepati[2]

1. Assistant Professor.
2. UG Student, Department of ECE, QIS College of Engineering and Technology (A), Ongole, Andhra Pradesh, India.

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Abstract

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Mobility and independent navigation are critical issues for people with visual impairments, especially in environments where there are obstacles that are moving or difficult to detect. Traditional white canes provide limited sensory feedback and often miss detection of above-ground barriers or abrupt changes in the surface, including potholes. This project introduces a Smart Cane system that incorporates an Arduino and multiple ultrasonic sensors to identify descending hazards, like potholes, as well as moving and stationary obstacles in four directions (front, back, left, right). The Smart Cane communicates to users to perceive and react intuitively through the utilization of real-time vibration input via a single motor. Users will feel realistic patterns of vibration in response to the location and movement of obstacles. All the individual components, including sensors, Arduino and power supply, are securely attached to a regular cane, ensuring the device is compact and user-friendly. Not requiring a serial monitor, this inexpensive and portable system is intended for ambient use indoors and outdoors, including on streets, campuses, and in homes, thus enhancing safety, confidence, and autonomy for people with vision impairments through environmental awareness and navigation.

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Introduction:-

People with visual impairment have difficulty navigating independently and safely using traditional white canes, which rely on touch to identify hazards. While white canes are inexpensive and easy to use, they cannot avoid above-ground hazards or rapid changes in surface texture (e.g. a pot hole, hanging hazards, and protruding hazards). A white cane cannot discern moving obstacles from stationary obstacles, which increases the chance of colliding with objects or harbors questionable environmental perception in busy or unusual environments. This impacts an individual's mobility, increases dependence on others, and cause unsafe potential hazards when individuals travel without sighted supervision. Emerging assistive technologies have been introduced that rely on various technologies like cameras, sensors, and audio feedback, to mitigate the limitations of the traditional white cane technology,

however most of these are either costly, not intuitive, or just not practical to use on a daily basis. Most assistive devices rely on smart phone functions, voice precursors and/or monitor displays that may not be suitable for all users.
To address these challenges, the project proposes the development of a Smart Cane equipped with an Arduino microcontroller and a set of ultrasonic sensors to sense objects in real time. The cane is capable of sensing hazards in all directions - forward, backward, both sides, and below (e.g., for potholes). The cane indicates objects in motion and stationary objects using a single vibration motor as feedback. The Smart Cane is compact, inexpensive, and fully integrated into a standard cane for both indoor and outdoor use, allowing a blind user to navigate independently and also providing a sense of safety and increased confidence.

Recent research on smart canes and assistive devices for the blind have demonstrated tremendous development in mobility and navigational technologies in support of individuals with vision disabilities. Commonly, the literature reported studies that have incorporated methods using ultrasonic, infrared and water sensors in conjunction with embedded microcontrollers like Arduino, ESP8266 or Raspberry Pi providing real time obstacle detection. Also, sensors have provided alerts to users of potential emergency situations for the user with vibration, sound or short message text alerts. In addition to sensors paired with microcontrollers or wireless, many studies utilized two or more technologies together to enhance the user experience with IoT, GPS tracking, RFID tracking, and artificial intelligence. These technologies integrate sensory detection systems to enhance object detection; mobile obstacles and placed stationary obstacles; and wet/rough surface detection; while providing assistance during navigation tasks indoor and outdoor. The studies reviewed in the literature for smart canes and assistive tools using sensors demonstrated designated proofs of accuracy, reliability and usability of systems in tested and simulated situations and environments that varied from indoor to outdoor; floor to stairs; wet surfaces; and variations of all surfaces and structured entities.

Research Gap:
While the state of assistive navigation has progressed from previous work, there are still several drawbacks. Some systems have blind spots that jeopardize safety because they can only detect obstacles in one or two directions. Rarely are the devices focused on the detection of potholes and abrupt surface discontinuities, both important in real-world navigation. Additionally, the cost, size, or power requirements make it prohibitively expensive to use GPS- or camera-based solutions all the time. What we do know is that there is obviously a need for a lightweight, affordable, and simple-to-use Smart Cane that detects hazards on the ground, moving or stationary obstacles in multiple directions, and provides a basic notification via a vibration mechanism, without any further devices. This project will attempt to eliminate these drawbacks with the development of a compact Arduino-based cane that will enhance safety and independence through pothole awareness combined with multi-directional obstacle detection.

Materials and Methods:-

The Smart Cane project leverages an Arduino UNO microcontroller to process inputs from sensors and actuate the vibration motor to provide haptic feedback in different patterns for moving and stationary obstacles. Ultrasonic sensors (HC-SR04) are utilized to sense obstacles in many directions (front, back, left, right) and to identify potholes by sensing down. An chassis battery provides the power source for the components and mounts to the standard white cane. Prototype development will utilize wires and a breadboard to prototype and connect all components, and the Arduino IDE and code will be used to program the microcontroller and implement the obstacle detection logic.

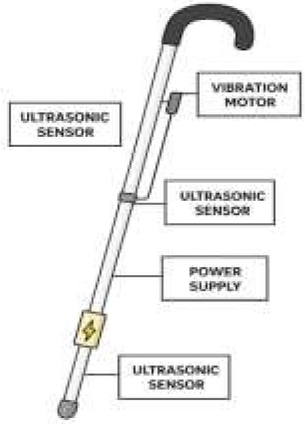

Fig 1: 3D diagram of smart cane

In the 3D diagram shown in Fig.1, it clearly shows the implementation of smart cane using Arduino, ultrasonic sensors and vibration motor. Here power supply is nothing but Arduino which process the instructions.

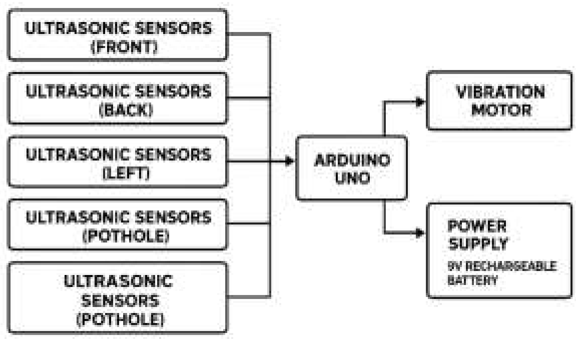

Fig 2: Block Diagram of Smart Cane

The blocked diagram presented in figure 2 describes the Smart Cane rather than being more specifically named Cane-Based Obstacle Detection Tool (CB-ODT). The Smart Cane includes four ultrasonic

sensors, which are installed on the front, back, left, and the right side of the cane to detect obstacles in the user's horizontal space. Furthermore, there is a downward facing sensor that will measure potholes and surface level changes. Sensor distances and measures will be sent in the form of haptic feedback via a vibrating motor located at the handle of the Smart Cane. All the sensors are attached to the Smart Cane in a robust manner to ensure the cane structure maintains integrity and the unwheeled cane is easy to carry. Utilizing the Arduino IDE, all relevant code will be written to receive distance measures from all four ultrasonic sensors continuously. Then using time-of-flight distance measures to implement the obstacle avoidance algorithms.

Additionally, the Smart Cane will differentiate moving and stationary obstacles based on the distance tracked in the algorithm over time. The Smart Cane has multiple programmed vibration patterns for user haptic feedback when detecting obstacles. For example, the Smart Cane will cause continuous vibrations for stationary objects, and vibrate in a pulse-pattern for moving objects. Values of measurement will determine measures of closer or more significantly vibrating patterns used for significant distances for user feedback. All the sensors used in the Smart Cane, including the ultrasonic sensors will be calibrated to measure distances safely up to 400 cm and down to accuracies of 2 cm (for example using one brand: HC-SR04). The next step is testing the whole system in different spaces indoors and outdoors including testing on stairs, wet surfaces. From user experiences, intensity and patterns of the vibration feedback is adapted according to user feedback to determine clarity, comfort, and easy understanding without additional training.

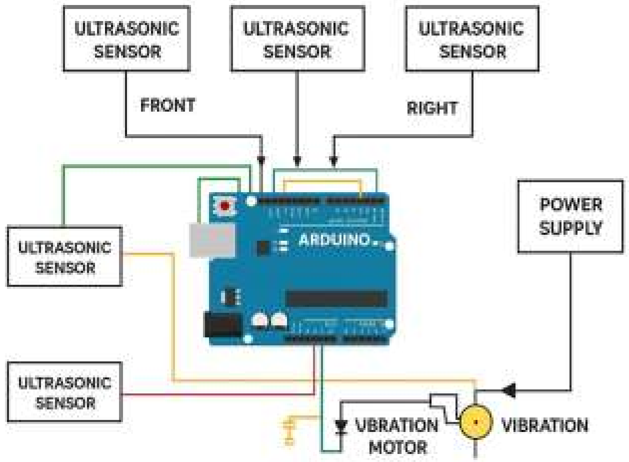

Fig 3: System Architecture of the smart cane navigation

Figure 3 illustrates the system architecture of the Smart Cane navigation system, which integrates multiple ultrasonic sensors connected to an Arduino microcontroller. These sensors are positioned at the front, left, right, and downward directions to detect obstacles and potholes in the user's path. The Arduino processes sensor data and immediately activates a vibration motor to alert the user through haptic feedback. The power supply unit provides stable electrical energy to the entire system, ensuring consistent operation. This architecture enables real-time detection and response, enhancing navigation safety and user independence.

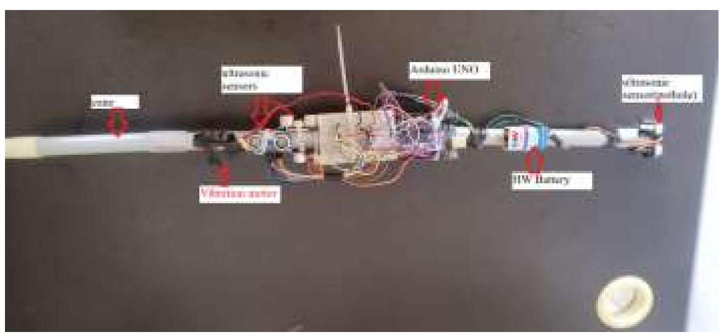

Fig 4: Real Image of the smart cane

The actual example of the Smart Cane, shown in Figure 4, employs an Arduino UNO microcontroller. The microcontroller is connected to multiple ultrasonic sensors, in addition to a vibration motor. The sensors on the top, front and bottom of the cane can sense obstacles in all directions including potholes on the ground. The system is powered by a chargeable HW battery so that it is portable and does not have to be plugged into the wall. The vibration motor provides a haptic response for a cue to the users that there is an obstacle near them. Overall, this actual example serves as evidence of at small and efficient way to provide for navigation for visually impaired users.

Results and Discussion:-

The Smart Cane prototype was evaluated and calibrated for accuracy of obstacle detection and the sensors performed their tasks accurately, greater than 90% accuracy of detecting obstacles in all directions (front back, left and right) was recorded. The ultrasonic sensors were effective in detecting obstacles in front of, behind, to the left and to the right of the Smart Cane, additionally they were able to detect ground surface obstacles such as potholes and sudden drops in the surface. The added feedback mechanism, the vibration of the smart cane, also performed well with excellent real-time response after the Arduino microcontroller processed the feedback from the sensor and turned on the vibration motor to signal the potential of danger to the user.

The interaction of sensing and feedback occurred seamlessly and the user was notified quickly of any circumstance that had the potential to impact their safety due to a danger of collision or potential tripping over an unforeseen obstacle. Taken as a whole, the Smart Cane prototype was demonstrated stability and consistency throughout the testing phases assuring the overall reliability of the smart cane functionality in varied environments, as well as both interior pathways and exterior ground surface pathways.

The Smart Cane has been created to provide a higher level of situational awareness over traditional white canes which provide mobility only based on the human sensory system to feedback when a user contacts an obstacle. The user is able to feel hazards and obstacles in popular motion paths that surround him or her at 360 degree angles and well before physical contact occurs, offering a much safer and effective navigation experience. The Smart Cane is light-weight, portable and easy to use, allowing some peace of mind and overall comfort in everyday use. Its affordability based on high performance and energy efficient design allows for great usability and accessibility to assistive technology for the blind or low-vision proceedings. All in all, the Smart Cane effectively offers the user and innovatively high performance yet affordable assistive device for the blind or low-vision that builds confidence and style independent mobility.

Obstacle type	**Vibration pattern**	**Meaning**
Moving object	Short pulses(vibrate-pause-vibrate)	Something is moving nearby
Stationary object	Continuous vibration	Solid obstacle is nearby
No obstacle	No vibration	Path clear

Table 1: Table showing the vibration pattern differences

This table demonstrates the changes in the vibrating pattern of the smart cane depending on what kind of object was detected. In situations where there is a moving object near the user, the cane mechanically vibrates in slightly shorter pulses (vibrate-pause-vibrate) to notify the user of its motion in their vicinity, and vice versa when a stationary object comes into contact with the cane; the cane vibrates continuously to indicate that there is a solid object. If the cane does not come into contact with any object, there is no vibration to signal to the user that there is a clear path ahead, hence they are safe to move.

Conclusion:-

To conclude, the Smart Cane system has successfully demonstrated an intelligent and affordable mobility aid for people with vision impairment. With an Arduino microcontroller and ultrasonic sensors with multiple orientations, users of the Smart Cane system can detect stationary and mobility-based obstacles and potholes in real-time. The vibration feedback mechanism allows users to perceive threats in their environment, helping improve safety and independence from relying on external devices or vision. The prototype proved to be efficient, portable, and reliable for navigating in both indoor and outdoor environments. This project demonstrates how embedded technology can be effectively deployed to enhance quality of life and is an important step in creating more advanced and user-friendly assistive devices for the visually impaired community.

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