

Extended Abstract

Arduino-Enhanced Smart Hat for Blind Navigation

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ABSTRACT

Arduino-Enhanced Smart Hat for Blind Navigation is an innovative wearable technology designed to improve mobility and safety for the visually impaired. Utilising an Arduino Uno, the system integrates ultrasonic sensors, a buzzer, and vibration motors, all embedded seamlessly into a comfortable hat. The ultrasonic sensors continuously scan the environment for obstacles, calculating distance with precision. When an obstacle is detected within a predefined range, the system triggers tactile feedback through a gentle vibration and an optional audible alert via a buzzer. This dual-sensory warning system allows users to navigate their surroundings with enhanced awareness, promoting greater independence and confidence in unfamiliar environments. The Guardian Hat is a practical, cost-effective solution that provides real-time, hands-free obstacle detection. By offering both vibration and sound alerts, it caters to diverse user needs, making it adaptable to varying levels of sensory perception. The simplicity, affordability, and user-centric design of the system make it a highly effective tool in improving the quality of life for the visually impaired, fostering autonomy and ensuring safety in daily navigation.

Keywords: Arduino, blind people, obstacle detection, ultrasonic sensor

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1.0 Introduction

As society becomes increasingly aware of the challenges faced by visually impaired individuals, the demand for more effective navigation aids has grown. Traditional aids often rely solely on physical contact with obstacles, restricting users' awareness of their surroundings and increasing the risk of accidents. This limitation necessitates the development of a more advanced solution that offers comprehensive environmental awareness, enabling users to navigate confidently in various settings. The Arduino-Enhanced Smart Hat for Blind Navigation aims to revolutionise mobility and safety for visually impaired individuals through innovative wearable technology. Its primary purpose is to provide real-time obstacle detection, enabling users to navigate their environments with enhanced awareness and confidence. By integrating ultrasonic sensors, vibration motors, and auditory alerts, this innovation addresses significant gaps in current mobility aids, such as traditional walking sticks, which often lack comprehensive environmental awareness and guidance. The Guardian Hat offers a proactive approach to navigation, significantly reducing the risk of accidents and allowing users to move independently in various settings. This is crucial for empowering visually impaired individuals to engage more fully with their communities and everyday environments. Unlike conventional mobility aids, the Guardian Hat is designed with user feedback and needs at its core. Its dual-sensory alert system via vibration and alarm sound caters to diverse sensory perceptions, making it adaptable for a wider range of users. By providing clearer directional feedback and 360-degree obstacle detection, the Guardian Hat fosters a sense of autonomy and self-assurance among users. The scope of the Arduino-Enhanced Smart Hat spans several key areas. The project incorporates customised and affordable

technology, including ultrasonic sensors and Arduino programming, to create a reliable yet user-friendly navigation aid. The ability to customise sensor settings enhances its adaptability for different environments. The Guardian Hat aligns with healthcare initiatives to improve assistive devices for individuals with disabilities. By reducing accidents and improving mobility, it can potentially lower healthcare costs associated with injuries among visually impaired individuals. As a consumer product, the Guardian Hat addresses a growing market for assistive technologies. Its affordability and practicality make it an appealing option for individuals, families, and organisations seeking effective mobility solutions. The Arduino-Enhanced Smart Hat for Blind Navigation is an innovative tool for enhancing the mobility and safety of visually impaired individuals and serves as a model for future developments in assistive technology. Its comprehensive approach has the potential to impact technology, healthcare, and consumer goods positively, making it a significant contribution to improving the quality of life for those with visual impairments.

2.0 Innovation

The design process for the Obstacle Detection Aid System began with identifying key components essential for effective obstacle detection. The Arduino UNO R3 microcontroller is central to this system, chosen for its versatility and ease of programming. Complementing the microcontroller are four ultrasonic sensors, four vibrator motors, and a buzzer. Each was selected for its ability to facilitate real-time feedback and alert users to potential hazards. The initial phase involved designing and assembling the device components, ensuring seamless integration of hardware. The ultrasonic sensor serves as the cornerstone of the system, tasked with detecting obstacles

within a range of 120 cm. The system's flow focused on programming the device using the Arduino UNO application, as shown in Figure 1. The code is structured to interpret data from the ultrasonic sensor accurately, enabling it to measure the time taken for sound waves to travel to an obstacle and back. The ultrasonic sensor operates by emitting high-frequency sound waves; when these waves hit an object, they bounce back to the sensor, allowing it to calculate the distance based on the elapsed time. For an effective obstacle detection range of 120 cm, the sensor measures the total distance covered by the sound waves 240 cm, which considers 120 cm to the object and 120 cm back to a receiver. When an obstacle is detected at this distance, the sensor outputs a high signal for 700 microseconds, triggering the corresponding vibration motors and buzzer to alert the user, as shown in Table 1. The integration of these components culminates in a user-friendly device that offers real-time feedback, significantly enhancing the user's navigation experience. To achieve this, the sensor must be carefully configured and calibrated to ensure accuracy in detecting objects within its field of vision.

The design incorporates the following pin allocation for the Arduino UNO:

Digital Pins 2-9: Dedicated to the ultrasonic sensors (trigger and echo pins).

Digital Pins 10-13: Connected to the vibration motors that provide tactile feedback.

Digital Pin A0: Used for the buzzer, which delivers audible alerts.

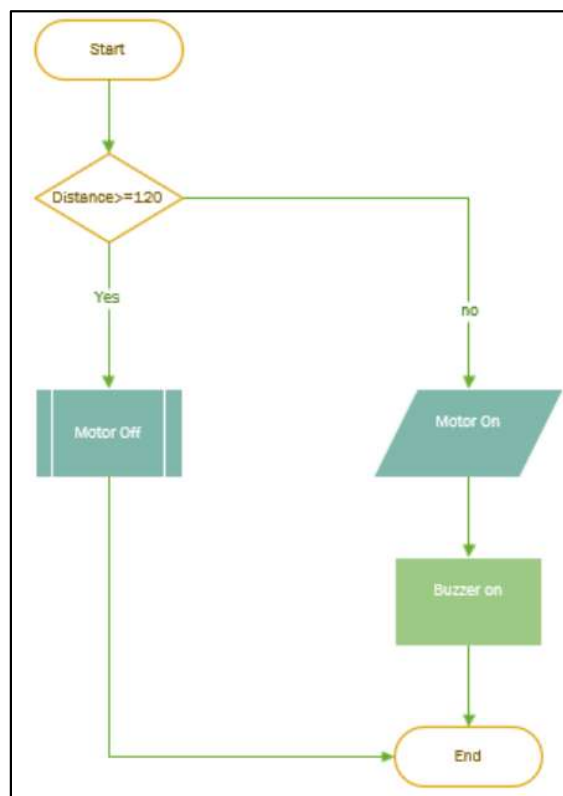


Figure 1: Flowchart of the Arduino-Enhanced Smart Hat for Blind Navigation system.

Table 1: The observations recorded during the temperature value testing.

Condition	Results
Obstacle in front of the left body	The ultrasonic sensor and vibrating motor on the front left side are activated. The buzzer is also triggered.
Obstacle in front of the right body	The ultrasonic sensor and vibrating motor on the front right side are activated. The buzzer is also triggered.
Obstacle behind the left body	The ultrasonic sensor and vibrating motor on the rear left side are activated. The buzzer is also triggered.
Obstacle behind the right body	The ultrasonic sensor and vibrating motor on the rear right side are activated. The buzzer is also triggered.

3.0 Uniqueness

The Arduino-Enhanced Smart Hat for Blind Navigation introduces a novel and highly effective solution for obstacle detection, offering unique advantages over existing products in the market. Visually impaired or blind individuals commonly rely on walking sticks as aids for navigation and mobility. Various new technologies, including smart sticks, have recently been developed and researched to enhance these traditional aids. However, these sticks come with notable limitations; for instance, they cannot provide a 360-degree view of the environment or detect obstacles at head level. Additionally, users must hold the stick, which restricts their ability to use both hands for other tasks. These papers highlight the need for innovative solutions that can address these challenges and improve mobility for visually impaired individuals, Nowshin *et al.* (2017) (1), Gbenga *et al.* (2017) (2), Kavitha and Akshatha (2023) (3), Shah *et al.* (2021) (4). Unlike traditional devices, this innovation covers a full 360-degree range, enabled by four strategically placed ultrasonic sensors that monitor the front, back, left, and right surroundings. One research paper explored the use of three ultrasonic sensors embedded in a hat for navigation; however, it only provided a buzzer as the output, Badoni *et al.* (2024) (5). This limitation resulted in a lack of clear directional guidance for visually impaired individuals, making it challenging to determine the safest path away from obstacles.

In contrast, this project enhances user guidance by incorporating vibration motors that activate based on the detected obstacles, indicating the safest direction for the user to navigate. Each sensor is paired with its corresponding vibration motor, providing direct feedback. This feature helps users intuitively identify obstacles and determine the safest path forward, offering a more comprehensive awareness of their

environment. In addition to its full-range detection, the system's flexibility is a key strength. Powered by Arduino, the distance sensitivity of the obstacle detection system can be reprogrammed to meet specific user needs. For instance, in crowded spaces, the trigger distance can be adjusted to 150 cm, offering extra protection and customisation for various scenarios. This reprogrammable feature provides users with an adaptable, hands-free solution that enhances both mobility and safety. Overall, the simplicity, affordability, and user-centric design of the Guardian Hat, combined with its unique 360-degree obstacle detection and customisable settings, make it an original and innovative tool for improving the quality of life for visually impaired individuals. It empowers users with greater independence and confidence, ensuring safety in diverse environments.

4.0 Commercialisation Potential

To successfully commercialise the Guardian Hat, several key factors must be addressed to ensure its effective and sustainable market entry. One crucial aspect is developing and testing prototypes in diverse environments to ensure the Guardian Hat performs reliably in various settings, such as crowded spaces, fast-paced areas, and on different terrains like stairs and ramps. Additionally, it is essential to ensure the product complies with all safety standards for wearables and electronics, particularly because it will be used by vulnerable individuals. Incorporating feedback from actual users, such as visually impaired individuals, is vital for refining the product to meet real-world needs. Market research should also assess the demand for assistive devices among visually impaired individuals and caregivers and identify target markets, such as visually impaired communities, healthcare institutions, and disability organisations. Pricing the product competitively is another key consideration,

particularly for users with limited financial resources. Offering different basic and advanced versions could cater to a wider range of budgets, increasing accessibility. Addressing these factors can establish a strong foundation for successfully commercialising the Guardian Hat, making it a viable and accessible product for visually impaired individuals.

5.0 Impact on Quintuple Helix

The Guardian Hat significantly enhances the quality of life for visually impaired individuals by improving their mobility, safety, and independence through hands-free, proactive obstacle detection. This reduces the risk of accidents, enabling users to navigate more confidently and fostering greater social inclusion while reducing dependence on caregivers. In academia, the Guardian Hat contributes to research in assistive technologies, wearable devices, and human-computer interaction, serving as a platform for innovations in mobility aids, sensor systems, and accessibility design. For governments, the Guardian Hat aligns with initiatives promoting accessibility and inclusivity for individuals with disabilities, supporting policies focused on universal design and public space access. It also holds the potential to reduce healthcare costs by preventing accidents and injuries. Environmentally, the Guardian Hat reduces reliance on traditional, less sustainable mobility aids, encouraging the development of eco-friendly assistive devices. Its compact and energy-efficient design aligns with efforts to minimise waste and energy consumption, promoting sustainability in wearable technology.

6.0 Conclusion

The Arduino-Enhanced Smart Hat for Blind Navigation represents a significant step

forward in assistive technology for the visually impaired, offering a practical, cost-effective, and user-friendly solution for real-time obstacle detection. The system provides dual-sensory feedback that enhances mobility and safety in unfamiliar environments by integrating ultrasonic sensors, vibration motors, and a buzzer. The simplicity of the design and adaptability to diverse sensory needs make the Guardian Hat an innovative and accessible tool that fosters greater independence, confidence, and autonomy for visually impaired users. Its affordability and hands-free functionality ensure widespread usability, improving the quality of life for those with visual impairments. This project underscores the potential of wearable technologies in addressing real-world challenges, providing a scalable model for future developments in assistive devices.

Authorship contribution statement

FAS: Data analysis, Methodology, Writing—original draft. **SACK:** Supervision, Funding acquisition, Formal analysis, Writing—review & editing. **SH, RA, NA, & SM:** Draft corrections – review & editing.

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Conflict of Interest

The authors declared that they have no conflicts of interest to disclose.

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