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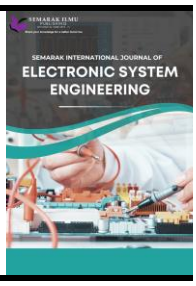

StepSafe Cane: Empowering Confident Steps for a Healthier Future

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ABSTRACT

Mobility is the capability of one to get to another place. Vision is defined as the faculty and power of seeing. As technology develops and grows, several devices and tools have aided those with mobility issues or impairment and those who are visually impaired. For those who are visually impaired, the traditional aid has been the white cane for a long time which only helps them navigate their way and detect obstacles without providing physical support. While those with mobility issues use a walking stick which does not help them in detecting surrounding obstacles. For those with both mobility issues and visual impairment, this becomes a problem as it is uncommon for a gadget or aid to tackle both these issues at once. The Smart Guide Cane is specially designed for this group of people with both issues. It can also help those with any of the two issues as it has many features that will allow them to be more confident in their movement, improving the quality of life for the disabled. Many steps have been taken in developing the Smart Guide Cane. A program was coded and simulated together with the circuit to ensure the functionality of the program. Then, the physical prototype was created, using Arduino UNO, HC-SR04 (ultrasonic sensor), MPU6050 (fall detector), TTP223 (touch sensor), vibration motor and buzzer as its main components. Tests have been done using this prototype circuit to demonstrate the feasibility and functionality of the Smart Guide Cane. From the prototyping and testing, it can be seen that all the components would function as intended in the Smart Guide Cane.

1. Introduction

Studying cane designs for the blind and the physically challenged is crucial today as it directly impacts these individuals' safety, mobility, and independence. Over the years, many innovative canes have been created to assist them, which can be seen in review papers by several authors [1-16]. However, traditional canes often have significant limitations. Some lack the sensitivity to detect critical hazards like pits, uneven surfaces, or low-hanging obstacles. Furthermore, the elderly and

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these disabled individuals often face considerable challenges with movement and safety. For them, even moving a few meters can be exhausting and challenging.

In order to overcome these limitations, this paper introduces the StepSafe Cane, an innovative mobility aid designed to enhance the independence and safety of the visually or physically impaired user. The originality of the StepSafe Cane is reflected in its distinct integration of advanced features for enhanced mobility and safety. While the MPU6050 continuously monitors balance and orientation to identify falls, the vibration motor vibrates when the cane detects obstructions or empty spaces, alerting users about potential hazards. When the MPU6050 detects a fall, the buzzer sounds. To make it more user-friendly, other features like an additional handle, an extension pole, a slip-resistant design, etc., are included. Together, these elements form a complete solution that enhances users' confidence in their mobility, allowing them to move freely and safely while going about their everyday business, improving their physical stability.

Therefore, the StepSafe Cane is a great option since it takes mind of possible issues, and prevents them, providing users with greater support. This cutting-edge tool lowers the risk of falls and encourages greater independence in the elderly, and physically or visually impaired people by helping them complete their daily tasks. The StepSafe Cane employs sensors and motors to identify possible hazards and impediments, providing the user with immediate feedback and direction. To guarantee dependable and innovative functioning, a great deal of study was done on the microcontroller (Arduino Uno) throughout the development of the StepSafe Cane. Frost *et al*., [17] provided an introduction to the Arduino Uno. The research that went into creating the StepSafe Cane was further driven by the studies done by Mexias *et al*., [18], Raza *et al*., [19], and Al-Dahan *et al*., [20] that used MPU6050 sensors to create fall detection systems. Combining ultrasonic sound sensors with traditional fall detection sensors can improve fall detection accuracy by adding more functions and giving precise distance measurement capabilities.

In this study, the emphasis of the StepSafe Cane is to ensure the safety for people who have vision or mobility issues, and particularly the people who face both these issues. This device aims to lessen the feelings of powerlessness and loneliness that are frequently connected to limited mobility, improving the user's mental health in addition to their physical safety. By assisting them with navigating their environment, the StepSafe Cane contributes to an overall sense of well-being for its users, helping them take back control of their life. Through encouraging their independence and confidence, it not only lessens physical barriers but also promotes mental and emotional wellness.

2. Methodology

2.1 Planning

The project was divided into three stages which are planning, implementing, and testing. The planning stage involved extensive information gathering, where we conducted research to understand the problem statement thoroughly. This involved analyzing existing solutions and outlining our project's objectives and requirements. During this phase, brainstorming sessions were held to generate innovative, creative and highly strategic ideas, ensuring that the ideas were aligned with our project's goals. We listed all the desired functions, such as obstacles detection, empty space detection, fall detection, slip-resistance, etc. We created the detailed sketches by highlighting every aspect of the design, making sure that all the desired functions were taken into account.

2.2 Implementing

Once the design was finalized, the project transitioned into the implementation stage. The primary focus during implementation was on developing the programming code or algorithms to be programmed into the microcontroller (Arduino Uno R3). This study integrated a range of sensors, actuators, and other hardware elements, utilizing the Arduino Uno R3 for smooth interaction between them. Repetitive testing and code optimization were part of the implementation stage, aiming to boost overall performance of the project. The successful completion of this stage meant that the project was ready for practical application. The flowchart of the StepSafe Cane is shown in Figure 1.

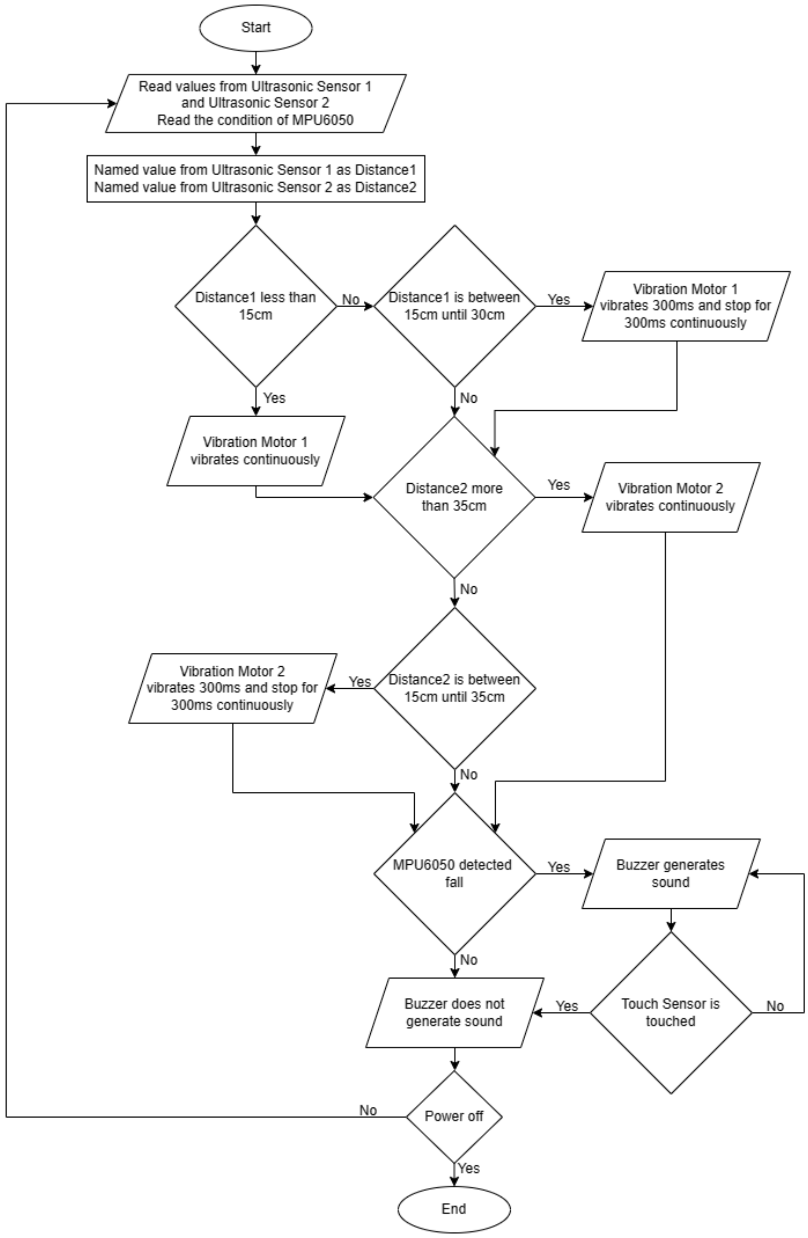

Fig. 1. Flowchart of the StepSafe Cane

2.3 Testing

Testing was the last step, necessary to confirm that the system met every design criterion and operated as expected. A number of thorough tests were set up to assess the system's reliability as well as its efficiency under various conditions. In order to identify any possible problems in the code or hardware integration, several test scenarios had to be executed. During the testing process, it was made sure the system complied with every design criterion and was reliable enough to handle practical applications. We were able to successfully complete the project by delivering a solution that was dependable and efficient after extensively testing the system.

3. Results and Discussion

3.1 Design

This design of the StepSafe Cane has highlighted its uniqueness and creative potential as assistive technology for people with visual problems, showing that it is indeed an innovative solution. The complete design of the StepSafe Cane is shown in Figure 2. In Figure 2, the StepSafe Cane include the touch sensor, vibration motor 1, vibration motor 2, buzzer, wrist rope, MPU6050, reflective strip, extension pole, ultrasonic sensor 1, ultrasonic sensor 2, extra handle and slip-resistant design.

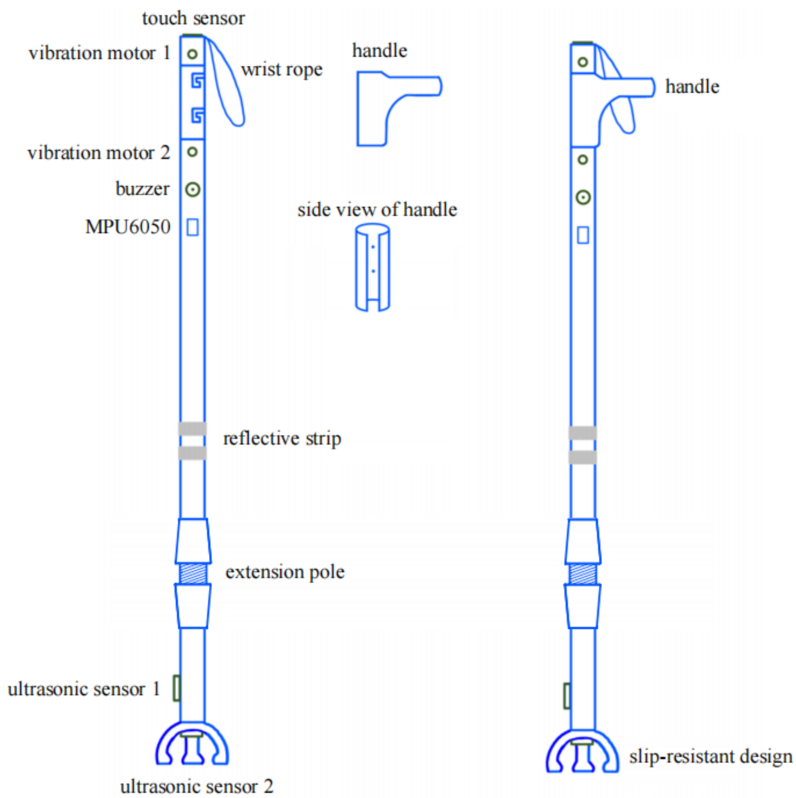

Fig. 2. Complete design of the StepSafe Cane

Figure 3 shows an illustration of obstacles detection. In Figure 3, the first ultrasonic sensor (ultrasonic sensor 1) is shown to detect the obstacles in front of the StepSafe Cane. Once the ultrasonic sensor detects the obstacles at less than 15cm away, the vibration motor above the handle (vibration motor 1) vibrates continuously. If the distance between the StepSafe Cane and the obstacle is in the range of 15cm until 30cm, vibration motor 1 vibrates 300milliseconds and stops for 300 milliseconds continuously to alert the user. This innovative integration makes it possible for the user to comprehend their surroundings on a deeper level, improving navigation and safety.

Figure 4 illustrates the StepSafe Cane's empty space detection. The second ultrasonic sensor (ultrasonic sensor 2) is shown in Figure 4 to detect the empty space below the StepSafe Cane. Once the ultrasonic sensor detects nothing below at a distance of more than 35cm, the vibration motor below the handle (vibration motor 2) vibrates continuously. If there is nothing below for a distance of 15cm until 30cm, vibration motor 2 vibrates for 300milliseconds and stops for 300 milliseconds continuously to alert the user. This function helps those who are visually impaired to determine the distance between the StepSafe Cane and the step below if they are going down a staircase or if there a hole in front. By using vibration motors, the user can be notified without disturbing surrounding people. Through its ability to distinguish between obstructions and empty areas, the ultrasonic sensor effectively lowers the probability of falls and accidents. To ensure that users can move securely in complicated areas with a variety of obstacles, this is especially crucial.

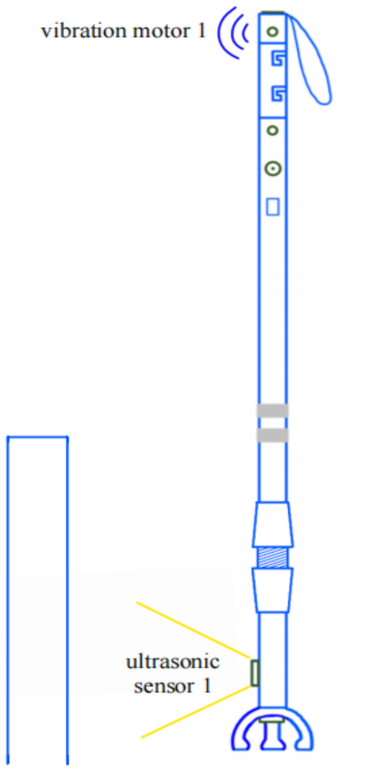

Fig. 3. Obstacles detection

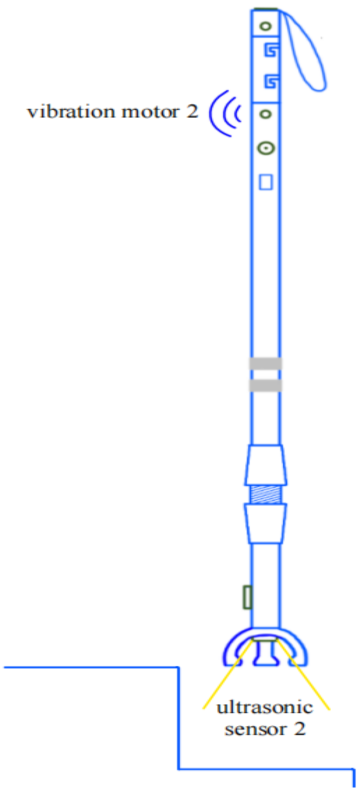

Fig. 4. Empty space detection

Figure 5 illustrates the fall detection system of the StepSafe Cane. When MPU6050 detects a fall, the buzzer will generate a sound as an alarm. The alarm can be snoozed by touching the touch sensor on top of the StepSafe Cane. When a visually impaired person drops the cane, the buzzer will generate the sound, allowing the user to locate the StepSafe Cane with the help of the alarm. Besides that, when the user falls and has a serious injury, the sound of the buzzer will draw attention, and the person can get help from others as soon as possible. To make the StepSafe Cane user-friendly, some extra features are added.

The illustration of the extra features is shown in Figure 6. The extra handle design is for the elderly and those who have mobility challenges, the cane with the handle can improve the user's balance and independence while reducing the risk of fall. The wrist rope is added to reduce the chance of the cane falling off from user's hand. The reflective strip on the StepSafe Cane increases the visibility while walking in high-traffic or low-light areas. The adjustable extension pole is designed, making the StepSafe Cane suitable for individuals of all heights. The slip-resistant design of tread pattern on the bottom of the cane helps create friction against slippery surfaces. This design once again reduces the risk of fall.

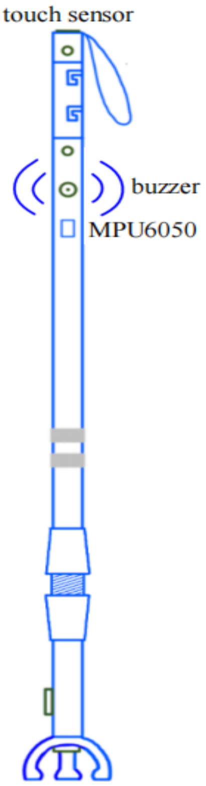

Fig. 5. Fall detection

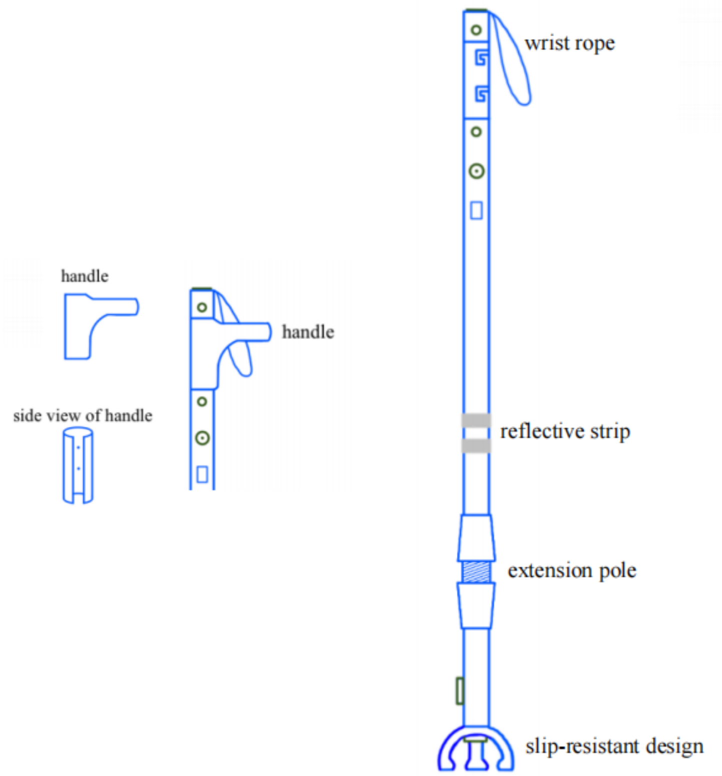

Fig. 6. Extra features

The development of the StepSafe Cane makes a significant impact on assistive technology and rehabilitation engineering. The cane improves the mobility and independence of visually impaired people, providing them with improved safety, independence, and mobility. Through the application of innovative technology and user-centered design, the cane enhances everyday mobility while also supporting more general social objectives of empowerment, participation, and accessibility.

The StepSafe Cane intends to be sustainable by utilizing energy-efficient components and durable materials, including the pole extension design that allows every user to adjust the length based on their preferences, reducing the need for frequent replacements and minimizing electronic waste. The long-lasting design ensures that the StepSafe cane remains as a reliable support device for extended periods, promoting a sustainable approach to safe mobility aids.

Economically, the StepSafe Cane has the potential to reduce healthcare costs associated with falls and related injuries for those who are visually impaired and have mobility challenges. By preventing falls and enhancing mobility, users may reduce medical treatments for related injuries, leading to cost savings for the users.

The StepSafe Cane significantly enhances the health and well-being of its users by empowering each step they take, instilling confidence in themselves. With the cane's advanced features, users can navigate their environments more confidently, encouraging them to be more physically active despite their disability. This can positively impact their mental health by reducing anxiety and depression due to their condition. Besides that, by reducing the risk of falls, the cane helps prevent injuries that can lead to long-term health complications.

3.2 Prototype

The prototype of the StepSafe Cane is shown in Figure 7. In this study, extensive field testing of the prototype was conducted to evaluate the effectiveness of the StepSafe Cane. In order to ensure the flexibility and reliability of the system in practical situations, every sensor's performance was meticulously recorded and analyzed across a range of environmental setting. For a more thorough explanation, view the recorded video by click on Figure 7.

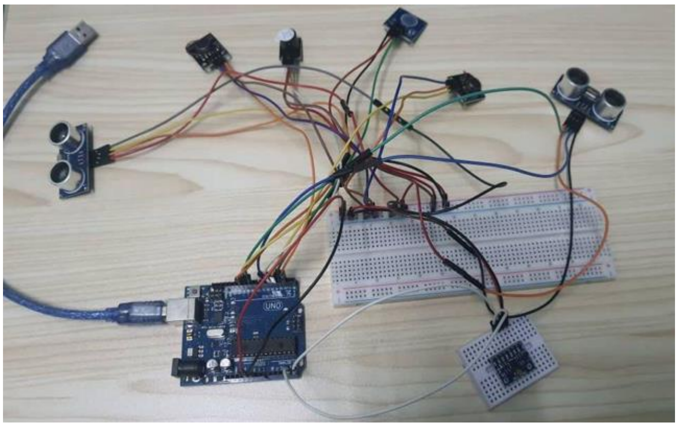

Fig. 7. Prototype of the StepSafe Cane

The demonstration of the functions of the StepSafe Cane are shown in Figure 8-10 through the prototype implemented.

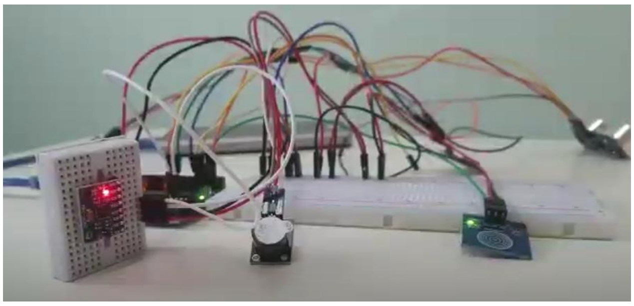

Fig. 8. Demonstration on fall detection

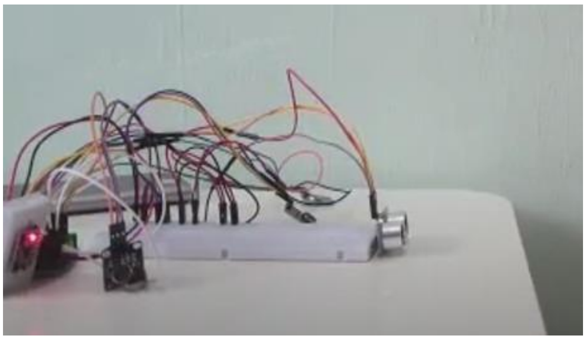

Fig. 9. Demonstration on obstacles detection

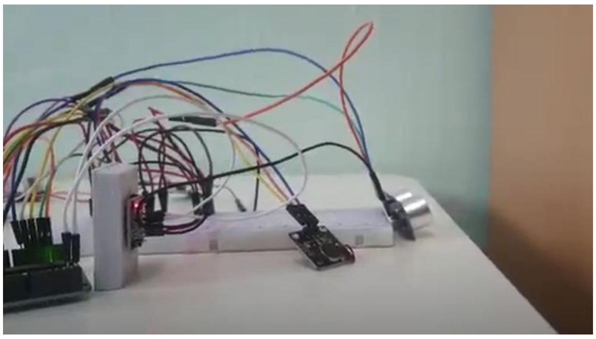

Fig. 10. Demonstration on empty space detection

4. Conclusions and Recommendations

The innovation of the StepSafe Cane has profound impact on the lives of visually impaired individuals. Enhanced mobility and independence are achieved through improved navigation features such as obstacles detection, empty space detection, fall detection, etc, which help the user navigate their environment safely. By reducing the difficulties associated with their limited mobility, the StepSafe Cane improves the quality of life of its users. Moreover, the social and psychological benefits are considerable, as increased safety and mobility boosts confidence and reduces anxiety for both users and their loved ones. The innovation of the StepSafe Cane enhances the wellbeing of visually impaired individuals with mobility issues.

Future research on the StepSafe Cane could explore the integration of an emergency call feature to further enhance user safety and independence. This additional feature would enable the StepSafe Cane to automatically contact emergency services in the event of a fall or other urgent situation. By incorporating GPS functionality, the cane could provide precise location information, ensuring timely assistance. Besides, the team is looking to expand towards integrating these functions with an application that is widely available for download on any smartphone platform. The integration of the smart guide cane with a mobile platform allows us to control the functions of the cane via a user-friendly interface.

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