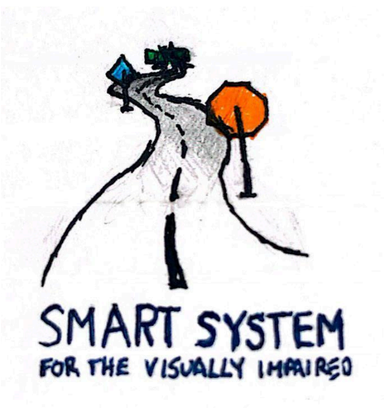
Boston University
Electrical & Computer Engineering
EC463 Capstone Senior Design Project

Problem Definition and Requirements Review

Smart System for Visually Impaired



Submitted to

Michael Hirsch
mhirsch@bu.edu
8 Saint Mary's Street, Boston, MA 02215

by

Team 29
Smart Bears

Team Members

Lukas Chin	lchin10@bu.edu
Jake T. Lee	jaketlee@bu.edu
Shamir L. Legaspi	slegaspi@bu.edu
David Li	dav@bu.edu
Jason Li	jli3469@bu.edu

Submitted: 10/18/2024

Client Sign-Off ______________________________

Smart System for Visually Impaired

Table of Contents

Project Summary

Due to the effects of visual impairments on people's ability to travel independently and access opportunities, people with visual impairments can face a reduction in quality of life. Current aids like white canes and guide dogs are often not accessible enough or do not provide enough improvement for them to be widely adopted. We propose the Smart System for the Visually Impaired as a solution to improve independent travel and navigation of environments. The system consists of two pieces, a wrist wearable and a head wearable. The wrist wearable will use distance sensors and haptic feedback to replace white canes as a hands-free solution. The head wearable will use a camera and computer vision to provide audio descriptions of the environment through a speaker to help users navigate the world.

1 Need for this Project

There are over 7 million people in the United States living with some sort of visual disability. Visual disabilities may make it hard for afflicted people to travel independently, reducing their engagement with society. This can also reduce their ability to participate in education, employment, and other activities. 27.7 percent of people with visual disabilities live below the poverty line, which is over double the rate of the total population. Over 70 percent of people with visual disabilities aged 21 to 64 are not employed full time compared to the estimated 16.5 percent of all people over 21 who are not employed full time. Current solutions like white canes, guide dogs, and other assistive technologies are not without their limitations. White canes leave users open to obstacles above the knee level. Guide dogs are not permitted in all scenarios. Other systems may be pricey. Overall, only 2 to 8 percent of visually impaired people use white canes and only about 2 percent use a guide dog. Existing solutions are not accessible enough or do not provide enough benefit to improve quality of life for people with visual impairments.

2 Problem Statement and Deliverables

Problem Statement:

Over 7 million people in the United States live with visual impairments that reduce their quality of life. This can affect their ability to engage socially and professionally, with poverty and unemployment rates among these people being much higher than the overall population. Less than 10 percent of people with visual impairments adopt alternative solutions like white canes and guide dogs. We strive to provide an accessibility solution that can improve the quality of life for those with visual impairments that will be easy to adopt.

Deliverables:

Our system aims to provide enhanced navigation and environmental awareness through a combination of wearable devices. The primary deliverable is a functional prototype consisting of two key components: a head-mounted device and a wrist-worn device, both equipped with sensors and feedback mechanisms to enhance the user's awareness of their environment.

The head-mounted device will feature a camera system to capture visual information about the surroundings. This will be complemented by speakers integrated into the headset design, allowing for audio feedback without impeding the user's natural hearing. The exact type and configuration of the camera and speakers will be determined during the development process to ensure optimal performance and user comfort.

The wrist-worn device will include at least one sensor to gather additional data about the user's movements and environment. This sensor will be chosen based on its ability to provide valuable information that complements the head-mounted device's capabilities. The wrist device will also incorporate a feedback mechanism to alert the user through tactile means.

As part of our intermediate deliverables, we will produce a finalized list of sensors for both the head and wrist devices. This list will be developed through careful research and testing to identify the most effective and appropriate sensors for our system's goals. Additionally, we will create basic circuit visualizations of the smart system, providing a clear overview of how the various components will interact and function together.

3 Visualization

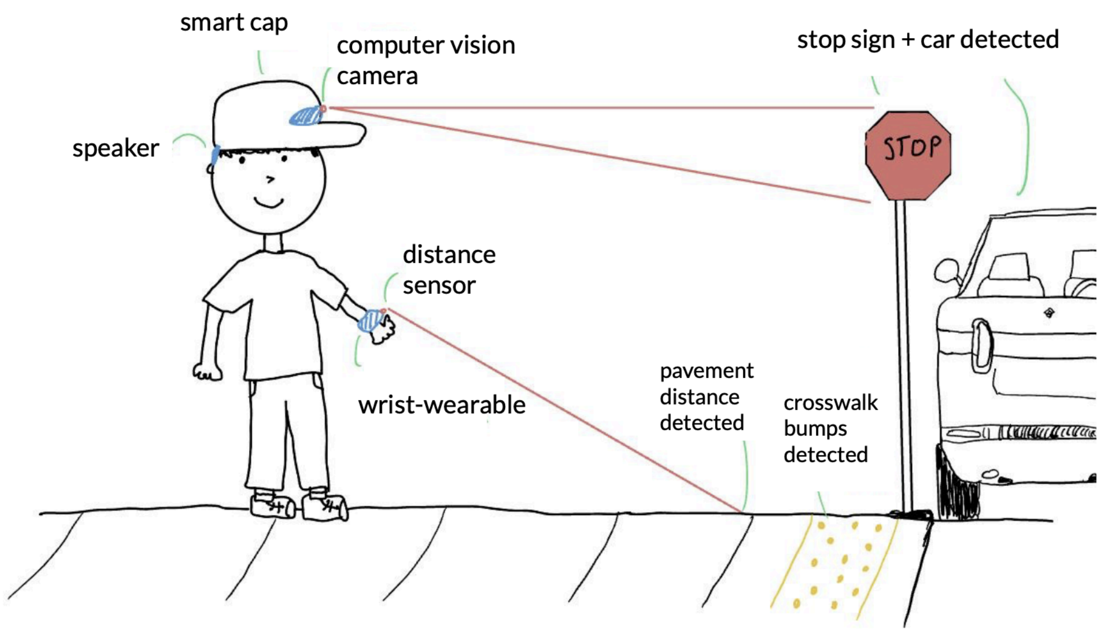


Figure 1. *Demonstration of Smart System for Visually Impaired. Consists of a computer vision-powered smart cap and a wrist-wearable device that provides auditory and haptic feedback to the user.*

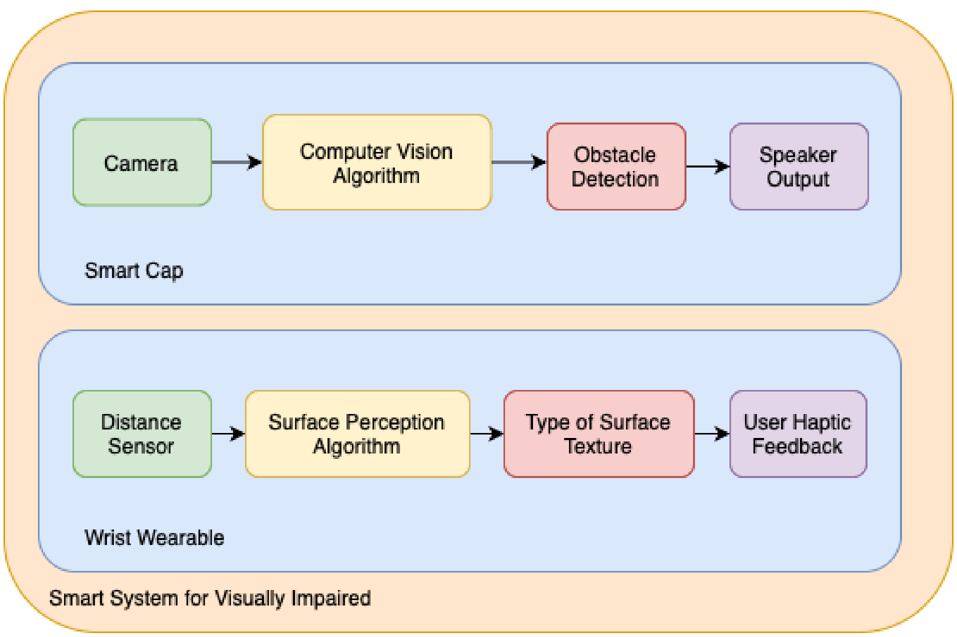


Figure 2. *Block diagram development of Smart System for Visually Impaired. The system consists of mainly two separate components: Smart Cap and Wrist Wearable. Through sensor and camera inputs, the two components will produce an algorithmic output that will aid the user with navigation through various modes of feedback.*

The Smart System for Visually Impaired is an innovative assistive technology designed to enhance the independence and safety of visually impaired individuals. At its core, the system consists of two main components: a smart cap and a wrist-wearable device, working in tandem to provide comprehensive environmental awareness and navigation assistance.

The smart cap is equipped with a computer vision camera that continuously scans the environment in front of the user. This camera feeds visual data into a sophisticated computer vision algorithm capable of detecting and identifying various objects, signs, and potential hazards. When obstacles or important visual cues are detected, such as stop signs or moving vehicles, the system alerts the user through a speaker integrated into the cap. This auditory feedback allows the user to navigate urban environments more safely, avoiding collisions and responding appropriately to traffic situations.

Complementing the smart cap is the wrist-wearable component, which adds another layer of sensory input and feedback. This device includes a distance sensor that analyzes the ground or surfaces in the immediate vicinity. The data from this sensor is processed by a surface perception algorithm, which can distinguish between different types of terrain or textures. Based on this analysis, the wrist device provides haptic feedback to the user, alerting them to changes in terrain, such as transitioning from pavement to grass, or warning of approaching curbs or steps.

The integration of these two components creates a powerful system that provides multi-modal feedback to visually impaired users. By combining visual information from the smart cap with tactile information from the wrist-wearable, users can build a more complete mental map of their surroundings. For example, the system can detect a crosswalk, alert the user through the speaker, and provide haptic feedback to guide them across safely. This comprehensive approach to environmental awareness significantly enhances the user's ability to navigate independently.

4 Competing Technologies

In the development of assistive devices for the visually impaired, we reviewed several competing products, patents, and technologies in order to gain a better understanding of the market to allow us to make more informed decisions on our project requirements. These technologies gave us the foundation for how we should shape the design of our project while also focusing on key elements such as real-time processing, portability, and sensor integrations.

The OrCam MyEye 3 Pro, for instance, is a wearable device designed to assist users by reading text aloud, recognizing faces, and identifying objects. This product's emphasis on a lightweight wearable design and real-time image processing highlights the need for portability and responsive feedback mechanisms, elements that we are looking to incorporate into our project.

In addition to products, we also reviewed patents such as US Patent 20220084433, which is described as an AI-powered smart backpack. This system combines multiple sensors to provide navigational assistance, pointing out the importance of sensor integration in wearable technology. By incorporating sensor inputs, the backpack allows for the accurate detection of obstacles while providing haptic feedback to the user. Through the insight of this patent, we were guided in our decision to implement light wearable devices in the form of a wrist-worn sensor to provide the user with obstacle detection and haptic feedback.

After researching many competing technologies, we were able to gain a better understanding of what we should implement as several key requirements for our project. First, real-time feedback is a critical key requirement for users to rely on fast and accurate feedback. This ensures that the user can navigate safely using our device. Our system will prioritize low-latency processing to meet this need. Next, the combination of sensors helps the user gather a comprehensive understanding of the surroundings of the environment. Finally, portability was also a key requirement to allow the user to easily use the devices. Ensuring that the device is non-intrusive and easy to use in their day to day life allows for a wide range of users.

5 Engineering Requirements

5.1 Tactile Feedback

1. The system must deliver haptic signals through vibration motors embedded in the glove's fingers and palm.
2. The haptic feedback must distinguish between at least three proximity ranges (e.g., near, mid-range, far), corresponding to the intensity of the vibration.
3. The haptic feedback must respond within 100 milliseconds of detecting an object within a 1-meter range.

5.2 Camera-Based Vision

1. The camera must be integrated into a wearable device (smart cap) and capture real-time video at a resolution of at least 720p.
2. The system must provide real-time speech output for text detection from objects such as signs, with a processing time of under 1 second.
3. The camera must support low-light environments and be functional in lighting as low as 10 lux.

5.3 Real-Time Feedback

1. The system must provide real-time feedback (via haptic or auditory signals) within 100 milliseconds of detecting an obstacle.
2. The system must distinguish between different types of objects, including static and moving, and provide distinct feedback for each type.
3. The system must operate continuously for at least 12 hours on a single charge, ensuring portability for all-day use.

5.4 Surface Scanning

1. The glove's infrared sensors must detect ground obstacles up to 1 meter ahead and provide either haptic or auditory feedback within 100 milliseconds.
2. The system must accurately identify obstacles with at least 90% detection accuracy in both indoor and outdoor environments.

5.5 Portability and Usability

1. The combined weight of the smart glove and smart cap must not exceed 300 grams.
2. The system must be comfortable for users to wear for up to 12 consecutive hours, with breathable materials for the glove and an adjustable fit for the cap.
3. The system must require no more than 30 minutes of user training for effective operation.

5.6 Power and Durability

1. The system must operate on a rechargeable battery that provides at least 12 hours of continuous use on a single charge.
2. The device must be water-resistant, withstanding exposure to light rain and water splashes, meeting the IPX4 standard.
3. The system must endure drops from a height of 1.5 meters without performance degradation.

5.7 Safety and Compliance

1. The feedback mechanism (vibrations or sounds) must be subtle enough to prevent discomfort or harm to the user while remaining noticeable.
2. The device must comply with ADA (Americans with Disabilities Act) regulations and FCC (Federal Communications Commission) standards to ensure safety and accessibility.

6 Appendix A References.

1. National Federation of the Blind. (n.d.). Blindness Statistics. https://nfb.org/resources/blindness-statistics
2. National University of Singapore. (2023). AiSee - Mobility Aid for the blind and visually impaired. Futurity. https://www.futurity.org/aisee-visual-impairment-ai-device-3175252/
3. OrCam Technologies. (n.d.). OrCam MyEye 3 Pro. https://www.orcam.com/en-us/orcam-myeye-3-pro
4. Ask Samie. (n.d.). Ara - Mobility Aid for the blind and visually impaired. https://www.asksamie.com/products/ara?variant=43683470442704&currency=USD
5. Shen, J., Chen, Y., & Sawada, H. (2022). A Wearable Assistive Device for Blind Pedestrians Using Real-Time Object Detection and Tactile Presentation. Sensors, 22(12), 4537. https://doi.org/10.3390/s22124537
6. Jiang, F., Yang, X., & Feng, L. (2021). A Wearable Navigation Device for Visually Impaired People Based on the Real-Time Semantic Visual SLAM System. Sensors, 21(4), 1536. https://doi.org/10.3390/s21041536
7. Wearable Technologies. (2018). These New Generation of Wearables are Empowering Blind and the Visually Impaired. https://wt-obk.wearable-technologies.com/2018/12/these-new-generation-of-wearables-are-empowering-blind-and-the-visually-impaired/
8. Srivastava, P., Tiwari, A., & Yadav, R. (2021). Design and Development of a Wearable Assistive Device Integrating a Fuzzy Decision Support System for Blind and Visually Impaired People. PMC, 8466919. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8466919/
9. Justia Patents. (2022). Wearable Device Enablement for Visually Impaired User. https://patents.justia.com/patent/20220084433