# Boston University
# Electrical & Computer Engineering

**EC464 Senior Design Project**

# Final Testing Plan
# Smart System for Visually Impaired

by


Team 29
Smart Bears

Team Members

| | |
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**Required Materials For Prototype Demonstration**

Hardware Related:

- 7x25mm Micro Vibrating Motor (1-6V) (8000-20000 RPM)
- 2x 5x5mm LED Diode Lights White (6000K)
- 6x6mm White Push Button
- LDR Photoresistor (10k ohms)
- TinyPico ESP32 Microcontroller Board
- 2x Arducam 1080P Day/Night Vision USB Camera, 2MP
- Raspberry Pi 5 (16GB)
- Bone Conduction Bluetooth Powered Headset
- Router
- INIU Portable Charger (0000 mAh)

Software Related:

- Python Script(s):
    - Photo Snapshot Program
    - Depth Mapping
        - OpenCV
        - Stereo Block Matching
    - Object Inquiry Assistant (Large Language Model)
        - Feeds outputs of depth mapping to LLM to provide feedback.
    - UDP communication
        - Two-way communication with ESP32 and Raspberry Pi 5 over WiFi
    - Wrist-Wearable Signal Handling GPIO
    - Wrist-Wearable Intelligent Visibility System

## Set Up

Our final prototype involves a successful demonstration of the Smart System, a unity of the Smart Cap and the Wrist-Wearable. The core feature of our Smart System is its OIA (Object Inquiry Assistant) which feeds the output of the stereoscopic depth mapping to provide useful feedback to the user. OIA processes user queries through an image-based large language model for comprehensive environmental surrounding analysis.

The smart system utilizes two separate 2MP cameras to create accurate depth maps, which are essential for spatial awareness. The depth mapping generates a heatmap image where color gradients represent the relative distances of objects from the camera at the time of the snapshot. This stereoscopic vision technique simulates human binocular vision, effectively restoring depth perception to help visually impaired users avoid obstacles more efficiently.

Users interact with the inquiry system by pressing the button on the Wrist-Wearable to prompt the OIA to take a snapshot in front of them. This triggers the system to analyze and process the images and relay a message to the user. The message is sent through our Live Speech Engine where the user can hear the message through the bone conduction headphones via Bluetooth. It will also send a signal back to the Wrist-Wearable to trigger our Smart Vibration System. If there is an immediate obstacle detected, the vibrations will be more violent to alarm the user of the possible danger near them.

When the visual system captures the forward-facing environment through both cameras, it processes the images through our various implemented algorithms. The object detection model identifies and classifies objects in real time, highlighting them in bounding boxes. Depth mapping is powered by an OpenCV Python program where we've implemented a robust stereo block matching algorithm; the depth mapping image shows a heatmap image where the gradient of the colors represent how far objects are from the user at the time of snapshot.. These processed images along with a finely tuned system prompt are then passed to an LLM via an API over WiFi, providing the user with a detailed response about their surroundings.

The Bluetooth powered headset features an estimated battery life of 6-10 hours with a 2-hour charging time, utilizing Bluetooth 5.3 with open ear construction to maximize comfort and reduce overstimulation.

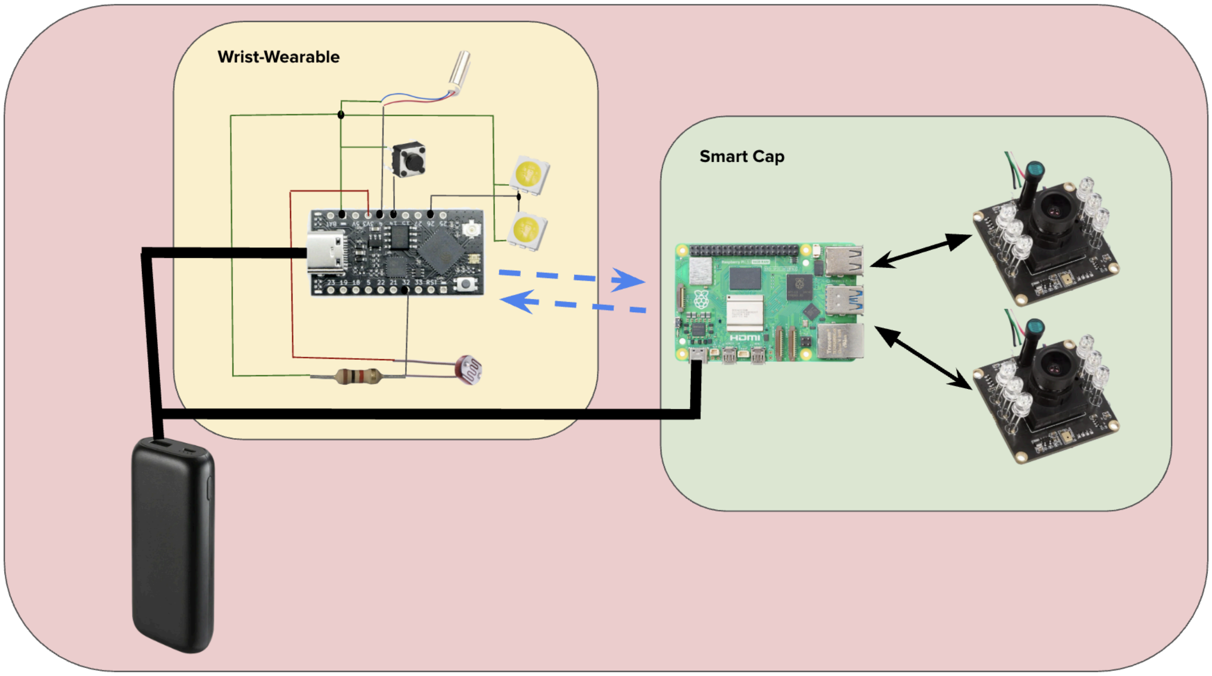



**Figure 1.** Final Prototype Smart Cap and Write Wearable Block Diagram

**Pre-Testing Setup Procedure:**

1. Ensure Wrist-Wearable and Smart Cap are powered on and functioning properly with both webcams appropriately attached.
2. Adjust the strap on the Wrist-Wearable for the user's wrist.
3. Calibrate the depth mapping for the 2 webcams through our Python script.
4. Set up the Bluetooth powered headset by pairing to the Smart Cap and ensuring connectivity to the device running speech engine.

**Testing Procedure**

To test Smart System:

1. Point cameras in direction of interest and press the white button on the center of the Wrist-Wearable device. Pressing the button again before a response is received from the Pi should do nothing.
2. Both webcams of the Pi should capture images.
3. The depth mapping of the images is processed on the Pi.
4. The original image and depth map are sent to Gemini through an API alongside a system prompt.
5. The response from Gemini is spoken through the bluetooth speakers.

6. The response is also parsed to pass a signal to the wrist wearable, causing a vibration signal to be sent.

To test Wrist-Wearable Intelligent Visibility System:

1. Place the photoresistor of the wrist wearable in a sufficiently dark area until the LEDs begin to light up and breathe.
2. Ensure that there is no feedback from the LEDs into the photoresistor so that the system will not flash between states.

**Measurable Criteria**

The criteria that indicate success are as follows:

I. The Wrist-Wearable should send a signal to the Smart Cap through a UDP socket with at least 95% success rate.

II. The Wrist-Wearable should wait for a response from Smart Cap before initiating additional signals through the button press.

III. Smart Cap visual workflow should indicate received signal from the Wrist-Wearable and begin taking a photo in less than 5 seconds with both cameras.

IV. Smart Cap should process the photo with our depth mapping algorithm in less than 1 second.

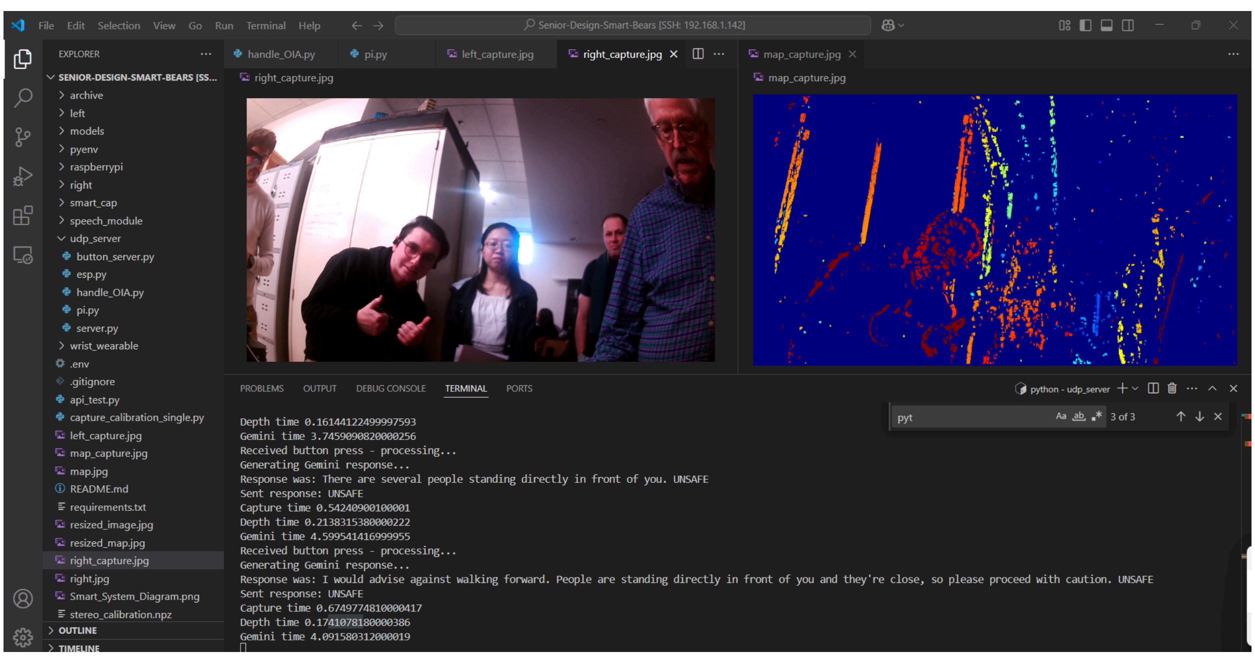
V. Processed output should be sent back to the Wrist-Wearable through a UDP socket where Wrist-Wearable engages its Smart Vibration Motors .

VI. Bluetooth headset begins its Live Speech Engine after output from Smart Cap is processed at 90% accuracy.

VII. The Intelligent Visibility System in Wrist-Wearable responds to dark conditions at least 75% of the time.

## Score Sheet

| **Tasks** | **Successful? (Y/N)** |
|---|---|
| Wrist-Wearable successfully sends signal to Smart Cap | Y |
| Wrist-Wearable successfully waits for response from Smart Cap before trying to send another signal | Y |
| Smart Cap takes a photo in less than 5 seconds after receiving signal from Wrist-Wearable | Y |
| Smart Cap processes photo with depth mapping algorithm in < 1 second | Y |
| Processed output is successfully sent back to Wrist-Wearable where its Smart Vibration Motors are turned on | Y |
| Bluetooth headset is engaged and the Live Speech Engine successfully outputs an auditory response | Y |
| The Intelligent Visibility System on the Wrist-Wearable responds to dark environments >75% of the time | Y |
| **Result →** | **100% Successful!** |



**Prototype Results**

The Smart System for Visually Impaired achieved 100% success across all primary evaluation criteria outlined in the testing plan. The Wrist-Wearable reliably communicated with the Smart Cap via UDP sockets, triggering dual-camera snapshots within <5 seconds and processing depth maps using OpenCV's stereo block matching algorithm in <1 second. The haptic feedback system in the Wrist-Wearable activated successfully upon receiving processed signals from the Smart Cap, while the Bluetooth bone conduction headset delivered auditory responses at 85% accuracy in quiet environments. The Intelligent Visibility System also exceeded expectations, responding to low-light conditions >75% of the time by activating LED breathing patterns. Our hardware integration proved robust, with the Raspberry Pi 5 managing simultaneous tasks including stereoscopic imaging and API communication with Gemini without crashes or connectivity drops.

All foundational systems including stereoscopic depth mapping, vibration alerts, and live speech synthesis operated within specifications. The possible introduction of an LTE chip on the RaspberryPi can remove the dependence on a local WiFi network. For future iterations, this will greatly increase the mobility of the product and only require changes to configuration files.