Haptic Vision

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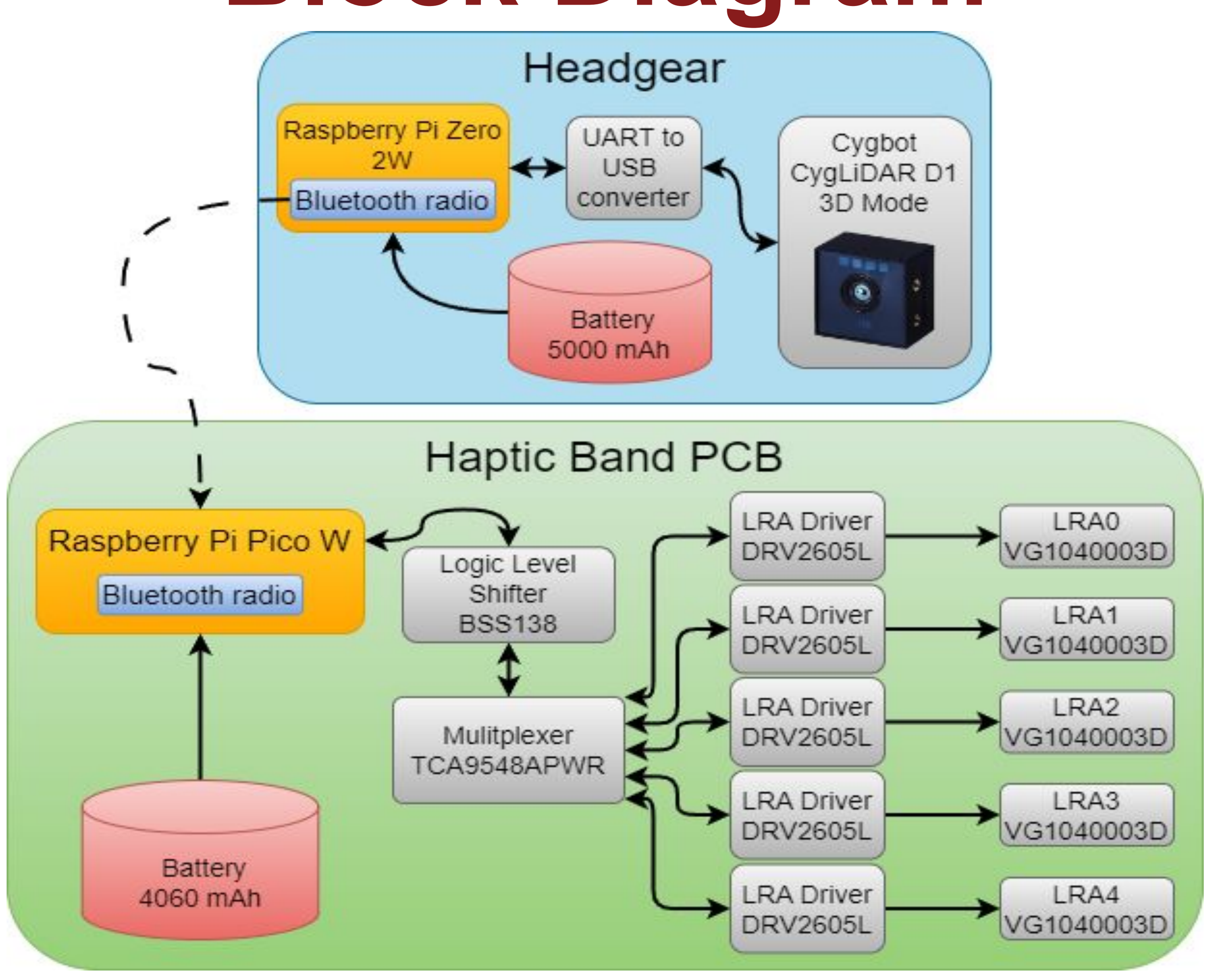
Abstract

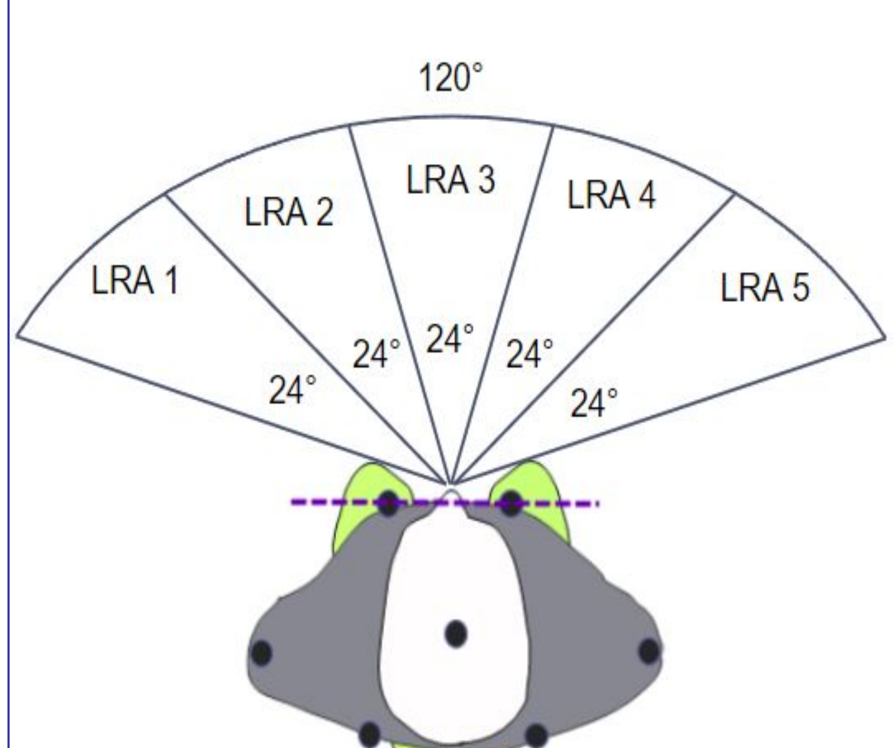
We introduce Haptic Vision, an innovative contactless device designed to augment obstacle detection capabilities for visually impaired individuals, surpassing the limitations of traditional white canes. Haptic Vision comprises two components: a head-mounted time-of-flight sensor and a chest-worn haptic array. The time-of-flight sensor delivers precision and high-resolution distance measurements. Simultaneously, the chest-mounted haptic band utilizes five linear resonant actuators to provide tactile feedback that conveys the location of obstacles in relation to the user's gaze. This technology promises to empower visually impaired individuals with an advanced and more accurate means of navigating their surroundings, significantly improving their safety and independence.

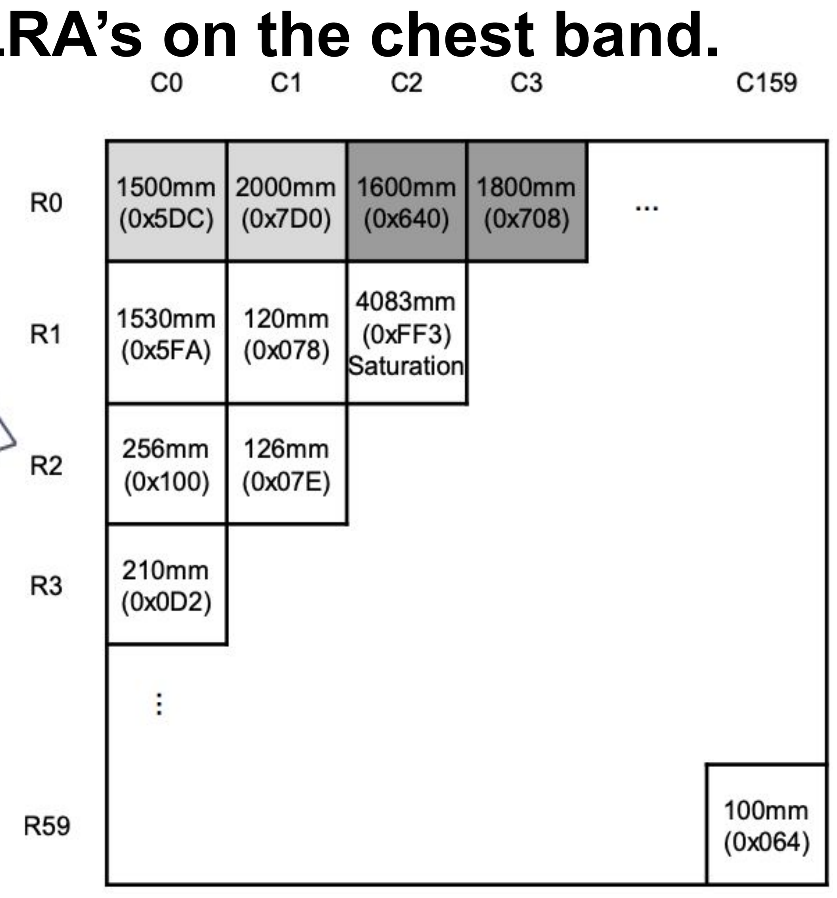
Block Diagram



System Overview

The LiDAR reports 3D point cloud of distance data between 120∘ horizontal and 60∘ vertical. These point clouds are parsed and compared to set distance thresholds and objects detected are placed into one of three 24∘ degree zones that correspond to individual LRA's on the chest band.





Specifications

System Specification	Test Plan
System will be able to detect obstacles from <=6ft.	Get distance to print on terminal, manually measure distance.
System will give different haptic feedback for different ranges: -Single click: 6’ ≥ range > 4’ -Double click:4’ ≥ range > 2’ -Triple click: 2’ ≥ range > 0’	Observe LRA clicks at the three different range regions.
Each system is guaranteed to maintain power for a minimum duration of at least 5 hours.	Measure current of both systems under normal operating conditions.
The 5 LRAs in the haptic system will activate when object is detected on each angle group on a 120º angle.	Measure and inspect each angle group's detection using protractor.

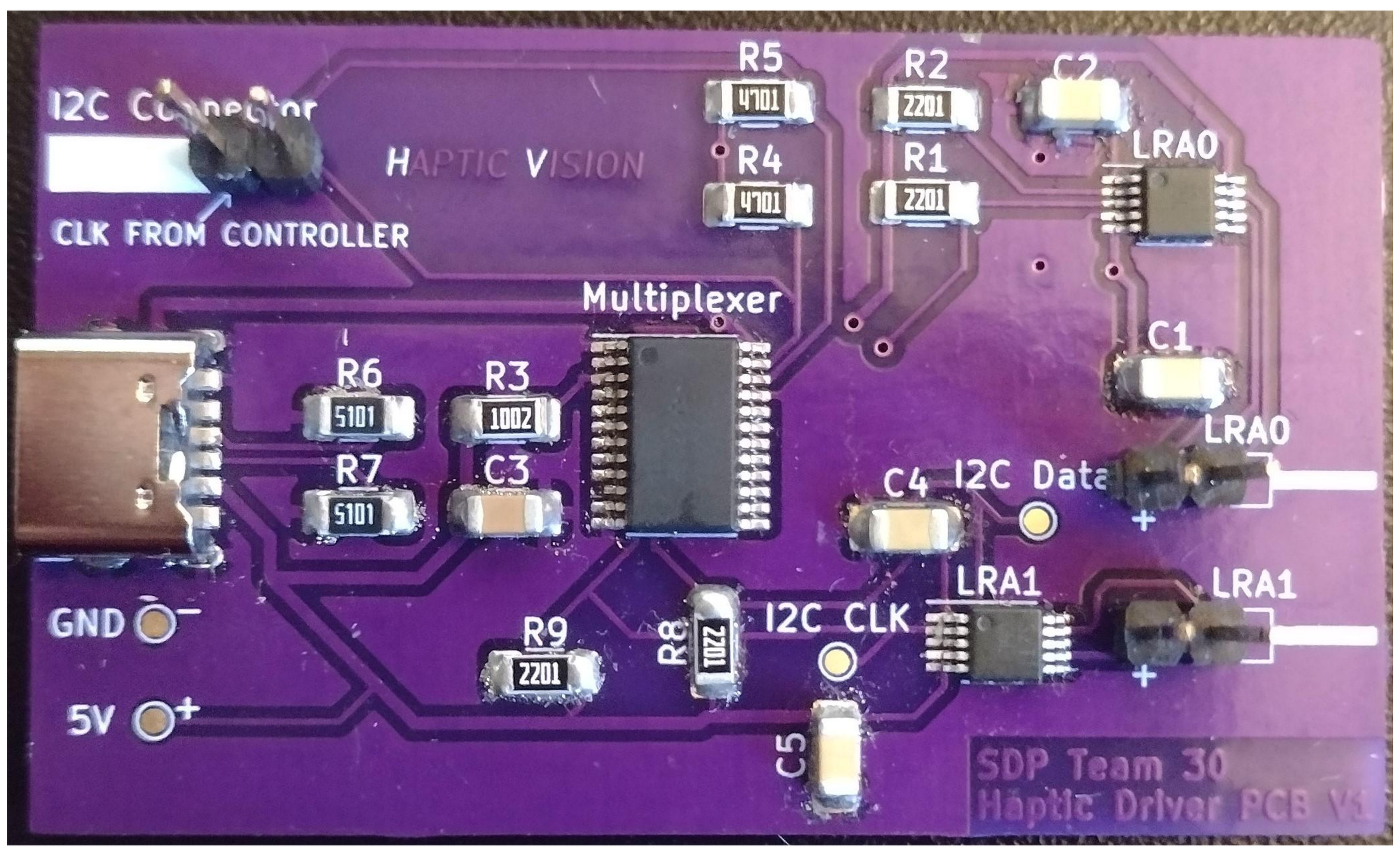
Results

Our team successfully demonstrated a haptic feedback system that communicates obstacle information accurately. By showcasing precise haptic patterns corresponding to various obstacle distances and directions, and by presenting comparative data on actual versus sensor-measured distances, we confirmed the system's measurement accuracy and reliability. The prototype consistently detected obstacles from a minimum distance of 6 feet, with serial port measurements aligning with physical data. Furthermore, our team conducted comprehensive battery tests and confirmed that the haptic belt can operate for approximately 12.5 hours, and the headgear for about 7.6 hours on a single charge. Additionally, our team’s tests verified that the system's five LRAs (Linear Resonant Actuators) activate correctly across a 120-degree angle, with each zone providing a 24-degree field of vision, with a margin of ±5 degrees.

Acknowledgement

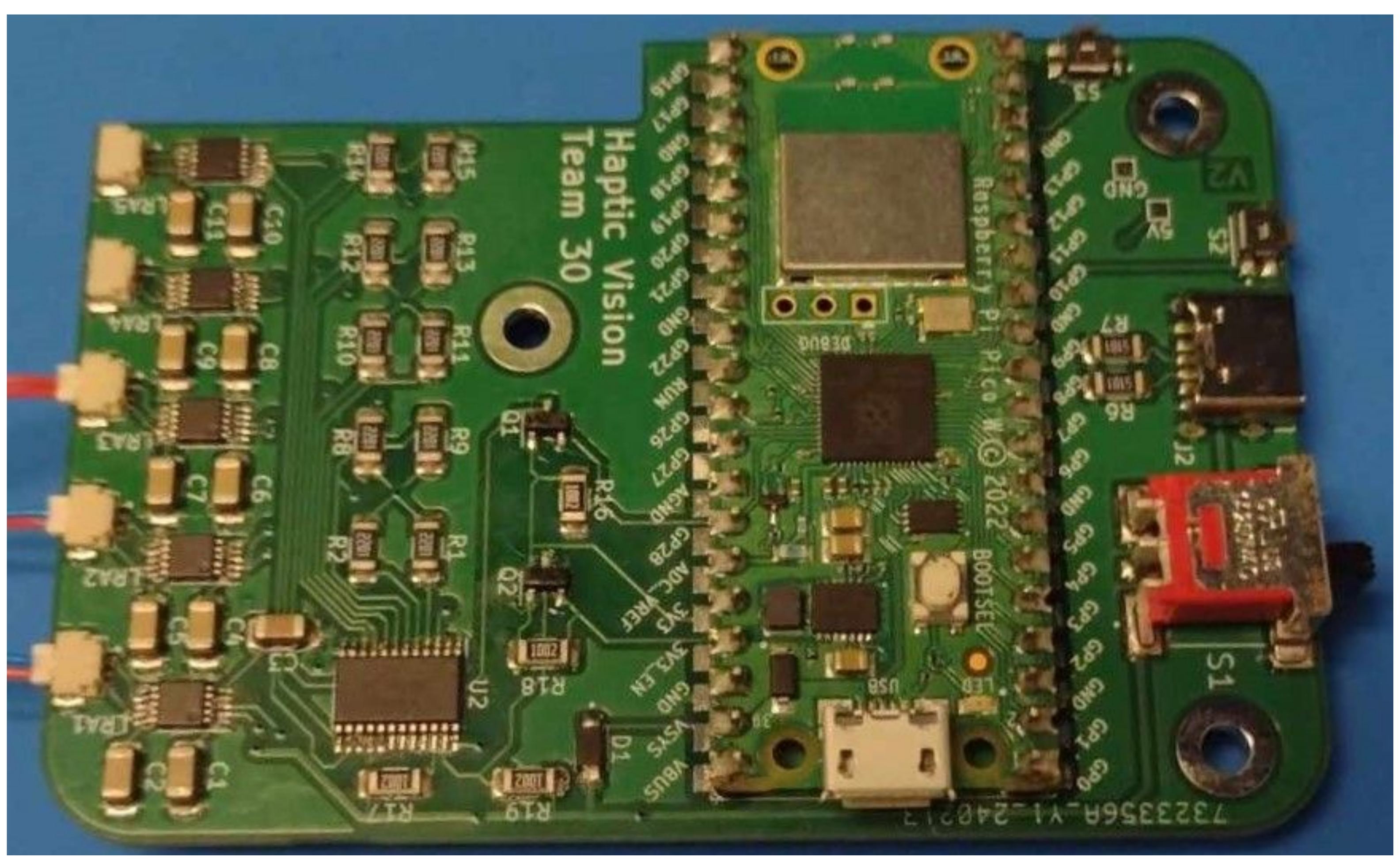
Special thanks to the SDP TA Qingchuan Wu for his help in many aspects of our system. Thank you, Prof. Hollot and Prof. Burleson, for stepping up to be our second semester evaluators under short notice.

PCB V1



PCB version one utilized to test LRA driver circuit for MDR. This version used a wired connection between LIDAR processor.

PCB V2



Version two expanded from the first iteration to included up to five LRAs and added wireless capabilities through the added Rpi Pico W. All resistors and capacitors are 1206 SMD size.

Cost

Nomenclature	$441.55
CygLIDAR D1	$217.00
Raspberry Pi Zero 2w	$38.21
Raspberry Pi Pico W	$6.00
PCB Components	$70.76
PCB from JLC	$33.90
3D prints, ~300 grams PLA	$14.15
Battery packs 5000mAh	$31.53
Hat & chest belt	$30.00

LRA (Linear Resonant Actuator)

Electromechanical device that vibrate to provide tactile feedback. Final design used five Vybronics – VLV101040A. Sharper haptic feedback than typical ERM devices with 10ms rise time. Driven with Texas Instruments DRV2605. These actuators are powered by a 2.5V sine wave at their resonant frequency of 170Hz.

Small form factor LRA.
Dimensions:
10mm x 10mm x 4mm

Security Threat Resolution

Utilizing Bluetooth for system communication introduces security risks, such as unauthorized connections and false message transmissions.
To address these concerns, we implement two security measures: OTP encryption for message security and MAC address authentication to restrict connections to approved devices.

Experiment

In our experiment, we equipped a participant with a CygLidar sensor mounted on a hat and a chest band. The participant was positioned in the middle of a hallway, flanked by a wall on the right and pillars on the left. As the participant walked down the hallway, proximity to the wall activated vibration in the right-side Linear Resonant Actuators (LRAs). Similarly, approaching the pillars on the left increased the intensity of vibrations in the left-side LRAs. The participant continued walking until they no longer perceived vibrations from the pillar on the left, at which point they made a left turn and walked straight ahead. This experiment successfully demonstrated the effectiveness of our system in navigating space through tactile feedback. Through our experiment we found that the system was very delayed and ineffective at giving real time feedback. The system would always be 2 seconds delayed in giving real time feedback. The hat portion was easy to put on and power up but the chest band was harder to don. We learned that our system works as we intended too if there was no delay. Looking ahead we can enhance system responsiveness by integrating a faster processor or by transitioning from Python to C.