Navigational Assistance for Visually Impaired Shoppers (NAVIS)

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***Abstract* — Visual impairments impact an increasingly large amount of the population and severely limit the independence of those afflicted. NAVIS aims to give these people back the independence they seek in one aspect of their lives – grocery shopping. This is an end-to-end grocery shopping experience management system for those who are visually impaired. We show how users can select the items they wish to gather and then navigate throughout a given store, while being notified how to get to the next item, all while avoiding any obstacles that may be in the way. We primarily utilize an active stereovision camera system and other sensors for localization within a ROS and SLAM software stack, with feedback provided to the user by audio speaker and haptic motors. We show the major components required to perform these tasks within.**

***Index Terms* — Active vision, assistive devices, object detection, feedback communication.**

I. Introduction

A. Project Motivation

Visual impairment presents a significant global health challenge, affecting an estimated 2.2 billion people worldwide [1]. While many cases are correctable with visual aids, a substantial portion involves "low vision," which is uncorrectable by conventional means and often linked to aging [2,3]. In the United States, the Centers for Disease Control and Prevention predict a doubling of low vision individuals over the age of 40 by 2050 [3,4]. This condition severely impacts an individual's autonomy in daily activities, including essential tasks like grocery shopping, necessitating constant assistance and diminishing their independence.

Current assistive technologies aim to address these challenges. The Visually Impaired Robot-Assisted Shopping (VIRAS) project, for instance, developed a motorized shopping cart with a navigation system, stereo cameras for 3D mapping, and AI-based object detection, providing audio guidance [5]. However, its reliance on store-provided specialized carts limits user portability and widespread adoption. Similarly, The Augmented Cane enhances traditional white canes by integrating LiDAR, cameras, GPS, and IMU for environment mapping and real-time audio/haptic feedback [6]. While portable, its design may impede the simultaneous maneuvering of a traditional shopping cart, limiting its practical application in a grocery store environment. These existing solutions highlight a critical gap: the need for a portable, user-mountable, and cost-effective navigation-assistive device specifically tailored for the grocery shopping experience.

B. Project Overview

The Navigational Assistance for Visually Impaired Shoppers (NAVIS) project aims to bridge this gap by developing a portable device that can be easily mounted onto a standard shopping cart. This device is designed to empower individuals with low vision to independently navigate grocery stores, fostering greater self-sufficiency and enhancing their quality of life.

The core functionality of NAVIS revolves around guiding users to within 0.5 meters of requested items and actively detecting and warning against potential collisions. To achieve this, the device integrates an active stereo vision system for a low computing precise depth mapping and object detection, an Inertial Measurement Unit (IMU) for accurate localization and movement tracking, and a robust feedback system comprising audio commands and haptic cues. Users will interact with the system via a mobile application to input their shopping lists, which the device will then use to generate an optimized route through the store. The system continuously processes sensor data to provide real-time directional guidance and obstacle alerts, ensuring safe and efficient navigation.

C. Organization and Subsystems

This paper is structured to provide a comprehensive overview of the NAVIS project. It will cover the engineering requirement specification, the selected components, the hardware and software design, and the testing and evaluation of the prototype. The primary subsystems for the product include electronics, optics, and software. The electronics covers sensors, peripheral

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TABLE I

PRIMARY ENGINEERING REQUIREMENT SPECIFICATIONS

Specification	Description	Target Value and Unit(s)
Distance User Guided from Product	Users must be brought to an object so that the object is in their conformable visual range, where they can identify and pick it. Audio and haptic cues will indicate to the user when they have successfully reached the target object.	Within 0.5 meters
Success Rate	The device must accurately bring users to the requested object within the specified range.	At least 90%
Collision Avoidance Latency	The object detection and avoidance system must accurately detect objects and obstacles within range and indicate them to the user in a time frame that allows them to react appropriately.	Less than 300 ms
Size	The dimensions of the portable device must be able to comfortably fit in a standard shopping cart.	Approx. 50x50x30 cm^3
Weight	The device must be reasonable to carry around and not interfere with the ability to maneuver the shopping cart.	3 – 5 lbs
Battery Life	Use of the device must last for the duration of the shopping trip, around an hour.	At least 1 hour
Connectivity	The delay between the sensors and the cues to the users must be short enough to provide effective navigational instructions and warn users in time to avoid collisions.	Within 100 ms
Setup/Teardown Time	The portable device must be fairly easy to mount and remove from the shopping cart.	Within 2 minutes

devices, power supply and management, and printed circuit board. The optics covers the laser, fiber, diffraction element, lens, and camera. The software employs depth processing, obstacle detection, and odometry to plan the user's route through the store and deliver timely cues for navigation and collision avoidance.

II. ENGINEERING SPECIFICATIONS

The NAVIS system's performance is defined by several key demonstrable specifications, ensuring its effectiveness and reliability in assisting visually impaired shoppers. The requirements are detailed in Table I, and the following is an overview of the three primary specifications for demonstration.

A. Distance User Guided from Product:

The system is designed to guide users to within 0.5 meters of the requested object. This target ensures that the item is comfortably within the user's visual range, allowing them to easily identify and pick it. Audio and haptic cues will clearly indicate when this target distance has been successfully reached.

B. Success Rate

A critical measure of the device's accuracy and efficiency, the system aims for a **minimum success rate of 90%** in accurately guiding users to their requested objects within the specified range. This high target emphasizes the importance of reliable navigation for user trust and independence.

C. Collision Avoidance Latency

To ensure user safety, the object detection and avoidance system must accurately identify obstacles and provide warnings within a **300 ms** timeframe. This latency allows users sufficient time to react appropriately and avoid potential collisions, which is crucial in a dynamic environment like a grocery store.

III. OPTICAL COMPONENTS

The selection of each component for the NAVIS system was driven by a balance of performance, cost-effectiveness, integration feasibility, and reliability, ensuring the device meets its core objectives while remaining portable and accessible.

A. Pigtailed Laser Diode

A fiber-coupled laser diode was chosen as a free space emitter since external collimating and coupling optics are not needed, something that can be both expensive to buy and implement due to its micrometer alignment requirements. Therefore, to produce a clean pattern of light, a custom made 650nm OM1 50mW pigtailed FP laser diode was chosen for its ease of integration.

B. Diffractive Optical Element

To generate a structured illumination, a diffractive optical element (DOE) was elected over other technologies due to its passive behavior, compact size, and cost. The pattern of the light is crucial to the ASV system since it needs to have enough features to give valid data but at the same time does not slow down the processing time with too many features.

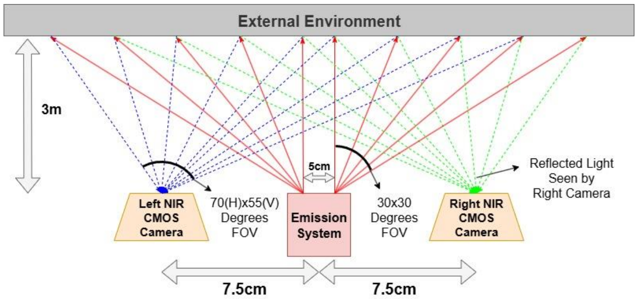

Figure 1 Optical Components for Active Stereovision

Therefore, the **LaserMate DOE-SG60** was chosen for its 60x60 grid pattern with a FOV of 30 degrees.

C. Collimating Lens

To collimate the light from our FC/PC fiber connector into a 2-4mm diameter beam, while keeping the optical system compact, a 6.0mm Dia. x 6.0mm FL, Uncoated, Plano-Convex Lens was chosen. This lens allows for high transmission at 650nm wavelengths because of its material N-SF11 allowing us to not have a coating.

D. Camera System

To accurately detect the emitted structured light, we opted for a global shutter camera to reduce motion blur and significant distortion when shopping cart is being moved around. A monochrome sensor was also a decision to maximize sensitivity at 650nm by eliminating the Bayer filters in the CMOS. Therefore the **Arducam 100fps Mono Global Shutter USB Camera, 720P OV9281** was chosen as our stereo vision cameras.

E. Bandpass Filter

To block other wavelengths of light from reaching the CMOS sensor and providing unwanted information to our algorithm to process, we use a **Coated 650nm Bandpass** filter that only allows 650nm light through.

IV. Electrical Components

A. Inertial Measurement Unit (IMU)

For general localization and movement tracking, an IMU was chosen over GPS or simple camera-based approximations. While IMUs can experience "drift" over time, this limitation is manageable given that item collection points provide known locations for correction, and slight drift is unlikely to significantly impact the navigation algorithm. The **BNO085 sensor** was selected for its optimal cost-per-performance ratio, robust hardware, and compatibility with ROS2, offering a simpler configuration compared to alternatives.

B. Audio Amplifier and Speaker

To deliver clear verbal commands to the user, a mini speaker was prioritized over piezoelectric buzzers, which are limited to producing tones. A **1.5 Inch 8 Ohm Voice Range Speaker** was chosen for its appropriate nominal impedance, low rated power (sufficient for close-range audible cues), and sufficient sensitivity (81dB SPL at 0.5m). To drive this speaker, the **PAM8302AASCR Class D amplifier** was selected due to its high efficiency (>90%), suitable 1-channel output, and ability to handle the 8 Ohm load.

C. Haptic Driver and Motor

Haptic motors provide supplementary directional cues and obstacle warnings. Eccentric Rotating Mass (ERM) motors were chosen over Linear Resonant Actuators (LRAs) and piezoelectric actuators for their ease of integration and lower cost, given that high precision in haptic output or response time was not a primary requirement. A **10mm by 3mm flat coin type vibrational motor** was selected for its small size and sufficient RPM (up to 12000) for user perception. The **DRV2605L haptic motor driver** was chosen to control these motors via I2C, simplifying control and enabling a range of distinct haptic effects for varied feedback.

D. Microcontroller

For low-level and low-power compute tasks, a microcontroller was preferred over custom logic solutions like ASICs or FPGAs. This decision was based on the microcontroller's ease of programming (using standard languages like C), extensive library availability, and the team's prior familiarity. The **ESP32-WROOM-32E** was selected for its wide software and hardware support, community backing, and sufficient capabilities (dual-core, 240 MHz, 16 MB flash) to handle peripheral control, IMU data processing, and web server hosting, while maintaining a low power draw.

E. Single Board Computer

For higher-performance computing, including complex navigation and route planning algorithms, a Single Board Computer was chosen over full desktop computers or mini PCs due to its optimized balance of power consumption, size, and cost. The **Raspberry Pi 5** was selected for this role. Its robust ARM64 Cortex processor, extensive software and hardware support within the embedded computing market (particularly for ROS2), and reliable availability made it the ideal choice for running the high-level software stack. The **16GB RAM** variant was selected due to our software stack being very demanding of this resource.

F. Power Supply

Rechargeable batteries were chosen over disposable or external power sources to ensure portability and long-term cost-efficiency. Among rechargeable options, **Lithium Iron Phosphate (LiFePO4) batteries (12V, 8Ah)** was selected. This chemistry offers enhanced safety, thermal stability, and a significantly longer cycle life (exceeding 4,000 cycles) compared to standard Li-ion or LiPo batteries. With a total energy capacity of 128 Wh and a continuous discharge rating (10A) well above the system's maximum current draw (7A), the LiFePO4 battery comfortably meets the requirement for at least one hour of operational runtime.

V. PCB Design

The hardware design of the NAVIS system is engineered to ensure robust performance, efficient power management, and seamless communication between all components. This section details the design of the primary logic board, the power management daughterboards, and the integration of the laser driver.

A. Primary Logic

The main board serves as the central hub for low-level processing, sensor integration, and user feedback control. Its primary component is the ESP32-WROOM-32E MCU, which manages interactions with various peripherals. It is programmed through a CP2102 USB-to-UART bridge, and handles incoming data from the web server over WiFi. For audio output, the MCU connects to the PAM8302A Class D amplifier to deliver audio signals through a dedicated digital-to-analog converter (DAC) pin. Another DAC pin is used to set and modulate the output of the optical subsystem. The audio and laser components and pinouts are separated on the board to isolate analog parts and signals. Haptic feedback is controlled via two DRV2505L haptic motor drivers, each connected to an ERM haptic motor. These drivers are I2C peripherals with the MCU as the controller, and both have a dedicated MCU GPIO pin to enable and disable the motors. The BNO085 IMU is also situated on the main board with a separate I2C bus pinout to the Raspberry Pi 5 which handles sensor fusion with the camera depth information. A separate UART channel is also established between the MCU and the SBC to communicate the sensor information to process cue outputs.

B. Laser Driver

Since the laser diode requires a constant current, a separate board was designed to utilize the ATLS1A104D laser diode driver IC. This board regulates the maximum current draw for the driver and connects to the DAC signal from the main board for precise output current control to the diode. Additionally, it offers a pinout to an analog-to-digital converter (ADC) pin on the MCU to monitor the output current.

C. Buck Converters

The buck converters are used to ensure proper supply voltage to all of the components from the 12.8V battery voltage. The Raspberry Pi 5 requires 5.1V and up to 5A, whereas the other components operate at 3.3V have a total maximum current draw around 2-3A. The LM2679 adjustable switching regulator is used for its relatively high efficiency and capacity to deliver up to 5A, and is adjusted on three separate boards. We have a dedicated 5.1V board for the Raspberry Pi, a 3.3V board for the main board MCU and haptic drivers, and a separate analog 3.3V output to the audio amplifier and laser diode driver.

VI. Waypoint Mapping and Route Planning

This section details the methodologies for environmental representation and navigation planning within an autonomous system, leveraging an active stereovision camera and an Inertial Measurement Unit (IMU) within a Robot Operating System (ROS2) and Simultaneous Localization and Mapping (SLAM) framework.

The system's architecture integrates various sensor inputs and processing modules for precise localization and environmental understanding. An overall flowchart of the entire software stack can be found in Figure 2.

A. Discrete Mapping

Discrete mapping approaches represent the environment by segmenting it into a finite set of distinct elements, often simplifying the complex real world into a structured grid or a network of interconnected locations. These maps prioritize capturing the connectivity and relationships between different places in an environment rather than their precise geometric accuracy. These maps are particularly useful for high-level navigation, where the robot needs to understand the sequence of areas to traverse. They are leveraged within SLAM for determining where, on a high level, to move to reach the next waypoint.

B. Continuous Mapping

Continuous mapping techniques provide a more granular and non-discretized representation of the environment,

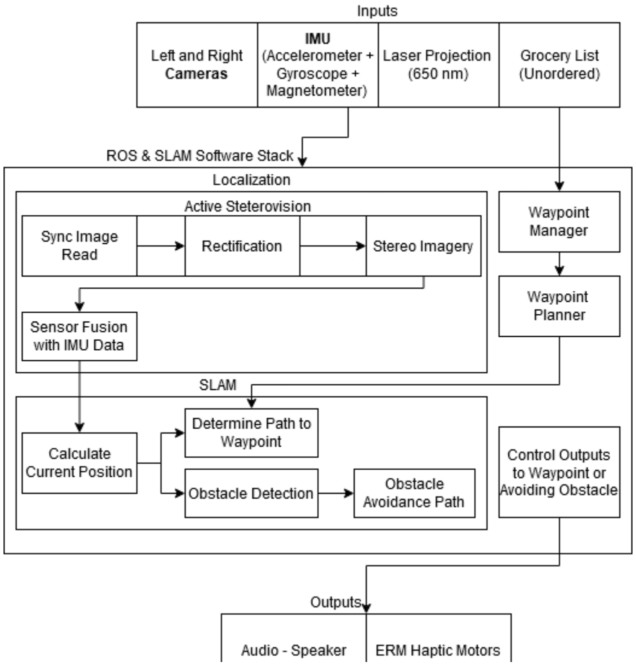

Figure 2 Software Control Flow Diagram

capable of preserving finer structural details and smoother surface representations. These are used to tell more precisely where the robot is and where it needs to move next to get to the waypoint. Among these, 3D point clouds are widely prevalent due to their inherent simplicity and the extensive availability of algorithms and tools for their processing. However, point cloud maps can be resource-intensive, particularly for the relatively low powered Raspberry Pi used here.

We utilize both discrete and continuous mapping in a hierarchical structure so that we can leverage the granularity that comes with continuous mapping along with some of the simplicities inherit with using discrete mapping techniques.

C. Route Planning

Route planning is a fundamental aspect of autonomous navigation, involving the determination of the most time-efficient and collision-free trajectory for the robot to collect all selected items. This task is often conceptualized as a variant of the "Traveling Salesman Problem" (TSP), where the goal is to find the optimal sequence of visiting multiple waypoints (grocery items) to minimize travel distance or time.

The system utilizes the A* algorithm for route planning. A* is an informed search algorithm that extends Dijkstra's algorithm by incorporating a heuristic function to guide its search towards the goal. This heuristic, often calculated as the Euclidean or Manhattan distance to the target, helps A* prioritize paths that appear to lead fastest to the solution. By combining the actual cost from the start node (g(n)) with an estimated cost to the goal node (h(n)), A* aims to find the path with the lowest cumulative cost. This approach makes A* more efficient than Dijkstra's algorithm for large environments, as it explores fewer nodes while still guaranteeing an optimal path, provided the heuristic is admissible and consistent. A* is well-suited for grid-based environments such as a grocery store, where the search area can be divided into small squares representing nodes.

VII. Active Stereovision

A. Optical Components

i. Laser-DOE

The system incorporates a laser-DOE projector that emits a light pattern at a wavelength of 650 nm. This projector serves to actively illuminate the scene by projecting a structured light pattern onto surfaces. This active illumination is crucial because it introduces texture into otherwise uniform or untextured surfaces, significantly simplifying the stereo matching process—the task of finding corresponding points between the left and right images. Additionally, by generating controlled features rather than relying on the textures of the natural scene, the system avoids excess feature density which reduces computational load.

ii. Cameras

The system employs a pair of left and right cameras, designed to mimic the principles of human-binocular vision. These cameras simultaneously capture slightly offset two-dimensional images of the same scene. This system leverages the subtle differences in the image location of an object as seen by each camera (referred to as stereo disparity) to compute its three-dimensional depth through triangulation. Accurate depth calculations require proper calibration, which includes knowing the baseline distance between the cameras, the focal length expressed in pixels and the coordinates of the optical center in the CMOS censor. These parameters give our algorithms a geometrical relationship between the cameras and the images, since they are critical for converting pixel location disparities into depth measurements.

B. Synchronized Image Reading

Synchronization in image reading from the two cameras in this system is not merely a technical detail but a fundamental prerequisite for accurate stereo vision. It

Figure 33 Sample SLAM Mapping

ensures that each captured image pair represents the scene at precisely the same moment in time. Any temporal misalignment between the images, even a slight delay, would introduce significant errors in the subsequent disparity calculation. Such errors would directly lead to inaccurate depth perception, thereby compromising the integrity of the environmental map and the overall localization performance. The fidelity of the system's 3D understanding of its environment is directly dependent on the precise temporal coherence of the stereo image pair.

C. Rectification

Image rectification is a pivotal transformation process in stereo vision, designed to project the captured stereo images onto a common image plane. The primary objective of this process is to ensure that corresponding points in the left and right images share identical row coordinates. This geometric alignment is crucial for simplifying the "correspondence problem," which involves identifying matching pixels that represent the same physical point in both images. By warping both images to appear as if they were captured with only a horizontal displacement between the cameras, rectification effectively ensures that all epipolar lines—the lines along which corresponding points must lie—become perfectly horizontal. This transformation dramatically reduces the complex two-dimensional stereo correspondence problem to a much more computationally efficient one-dimensional search, confined to horizontal scan lines. Accurate rectification is predicated on precise camera calibration, a process which is built into the stereo-cam library that is used in this project.

D. Stereo Imagery

Following the critical step of image rectification, the system proceeds to generate stereo imagery, which primarily involves two sequential processes: computing a disparity map and subsequently converting this map into a 3D point cloud. A disparity map is a pixel-wise representation that quantifies the horizontal difference in position between corresponding points found in the left and right rectified images. This disparity is inversely proportional to the object's distance from the cameras; closer objects exhibit larger disparities, while distant objects show smaller disparities. Algorithms such as block matching or more advanced semi-global block matching are employed to identify these correspondences and accurately generate the disparity map.

Once the disparities for each pixel are obtained, the system utilizes triangulation, a geometric principle, to calculate the precise depth for each pixel. This calculation leverages the known camera parameters, including the baseline distance between the cameras and their focal length. The result of this triangulation is the formation of a 3D point cloud, which provides a dense, three-dimensional representation of the sensed environment. This point cloud is an indispensable data structure for the SLAM system, serving as the foundational input for environmental mapping, accurate obstacle detection, and subsequent navigation planning.

The sequence of operations within the stereo vision pipeline—from synchronized image reading to rectification and then to stereo imagery generation—demonstrates a profound interdependence. Errors or inefficiencies at any preceding stage, such as inadequate temporal synchronization during image acquisition or inaccuracies during the rectification process, will inevitably propagate and degrade the quality of the final 3D point cloud. For instance, misaligned images from poor synchronization or incorrect rectification will lead to erroneous disparity calculations, resulting in a noisy or inaccurate 3D reconstruction of the environment. This directly impacts the SLAM system's fundamental ability to accurately map its surroundings and precisely localize the robot within that map. Consequently, the meticulous calibration of cameras and the implementation of robust algorithms at each stage of the stereo vision pipeline are paramount for achieving reliable and high-fidelity 3D environmental understanding.

VIII. LOCALIZATION AND ODOMETRY

Odometry, particularly through the Inertial Measurement Unit (IMU) and its sophisticated fusion with visual data, forms a fundamental cornerstone of the Localization block. This integration provides continuous, high-frequency estimates of the robot's motion and pose, crucial for maintaining an accurate understanding of its state within the environment.

A. Inertial Measurement Unit (IMU)

The IMU is an integrated sensor package that consists of a gyroscope, accelerometer, and magnetometer. Our IMU offers 9 Degrees of Freedom in tracking, although heigh measurements are not as critical as this value should stay relatively static throughout. While IMUs provide high-frequency data, enabling rapid motion tracking, they are inherently susceptible to drift over extended periods. This characteristic means that positioning errors can accumulate over time, leading to a degradation in long-term accuracy if not compensated for by fusion with other sensors.

B. Sensor Fusion

We utilize a Kalman filter for this process since they are extremely popular and computationally efficient, something which is especially important for this project where we are using a Raspberry Pi.

IMUs excel at providing high-frequency, accurate short-term motion estimates but suffer from cumulative drift over time. Conversely, cameras provide rich environmental features essential for long-term map consistency and localization, but they can struggle with rapid movements, motion blur, or environments lacking sufficient texture. Sensor fusion, particularly visual-inertial fusion, directly leverages these complementary strengths and weaknesses.

C. Localization

Localization is the fundamental process of precisely determining the robot's pose—its position and orientation—within the dynamically constructed map of the environment. The fused sensor data is provided to SLAM which continuously leverages this highly accurate and reliable localization to update the robot's current position within the evolving map, thereby forming the indispensable foundation for all subsequent path planning and obstacle avoidance maneuvers. Precise and continuous localization is paramount for the robot to successfully navigate to specific waypoints, such as individual grocery items, and to effectively avoid collisions with dynamic or static obstacles in its path.

IX. Peripherals and Control Outputs

A. Input - Item Selection

Before the user starts using the cart for navigation throughout the store, we use a website hosted on the Raspberry Pi to collect the items that they wish to collect. This is then provided to the Waypoint Manager ROS node for ordering and navigation within the store when the user arrives at a specified waypoint.

B. Output - Audio

We leverage audio outputs via a speaker device to effectively alert the user where to move next based on ROS commands. These are the main Control Outputs of the ROS system and are integrated directly on the primary logic control board. Sample commands that may be used include asking the user to move in a specific direction or telling them how far their next item is and on what shelf.

C. Output - Haptics

We implement haptic feedback via ERM motors, which are additional control outputs that provide feedback for which direction the user should move to achieve the movement instructions provided by the ROS and SLAM software stack introduced earlier.

X. Conclusion

This report has provided a comprehensive exposition of an autonomous routing system, meticulously detailing its architecture and functionality. The system is built upon a robust ROS and SLAM stack, integrating active stereovision and an Inertial Measurement Unit (IMU) to achieve intelligent navigation. The core capabilities of the system are underpinned by a sophisticated perception pipeline that includes synchronized image acquisition, precise image rectification, and the generation of high-fidelity 3D stereo imagery. This visual data is critically enhanced by active laser projection, which addresses the challenges of textureless environments. Furthermore, advanced sensor fusion techniques are employed to combine the visual information with IMU measurements, yielding highly accurate and drift-resilient localization. This robust localization forms the bedrock for the simultaneous mapping of the environment. The system's ability to process an unordered grocery list into a sequence of navigable waypoints, coupled with advanced route planning algorithms, ensures efficient and optimized navigation to specified targets. Dynamic adaptation to environmental changes, particularly through real-time obstacle detection and avoidance, is integral to its operational safety. Finally, the inclusion of audio and haptic feedback mechanisms provides intuitive and multi-modal human-robot interaction, significantly enhancing the system's usability and safety in practical applications such as grocery store navigation.

This system, with some future improvements, should help those with limited vision be able to restore some of the freedom that they do not have due to this disability while lessening the load of a potential caretaker. Although we understand that recently solutions such as Instacart seemingly make this solution obsolete, we also recognize that many people highly value their independence and even sometimes using a solution like this could greatly increase this for quite some time.

In the future, we wish to work directly with grocery stores to gain maps of their store along with inventory locations so the solution could be used in many more locations without as involved advance setup such as that we must undertake now.

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BIOGRAPHY

Matias Barzallo is pursuing a Bachelor of Science in Photonics Science and Engineering from the University of Central Florida's College of Optics and Photonics. Having worked in production, QA, and RnD at Everix, and worked with microstructured optical fibers at Professor Amezcua's research lab, he plans to pursue a career in optical design and implementation or farming.

Michael Castiglia is pursuing a Bachelor of Science in Computer Engineering, on the VLSI Digital Circuits Track, from the University of Central Florida's Department of Electrical and Computer Engineering. Having worked alongside engineers from Advanced Micro Devices, Inc (AMD) on research in the ECE department's DRACO Lab for the past two years, he will begin work at the AMD Orlando Design Center as a Silicon Design Engineer for Graphics Central Formal Verification. He will additionally be pursuing a Masters of Science in Computer Engineering from the University of Central Florida's Department of Electrical and Computer Engineering in a part time capacity.

Aden McKinney is pursuing a Bachelor of Science in Computer Engineering, from the University of Central Florida's Department of Electrical and Computer Engineering. After graduation, he will be attending Northeastern University to pursue a Master of Science in Robotics. Long term, Aden's goal is to pursue a Ph.D. and become an applied researcher at the intersection of modern machine learning and robotics.

Pavan Senthil is pursuing a Bachelor of Science in Electrical Engineering from the University of Central Florida's Department of Electrical and Computer Engineering and a Bachelor of Science in Biomedical Sciences from the College of Medicine. He has interned at Limbitless Solutions and plans on pursuing a career in developing assistive devices for clinical applications.

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