Development of a Guide-Robot to Assist the Blind with Mobility and Situational Awareness

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GOAL. The goal of the proposed (second FURI) research is to gain an understanding of how to use ROS, lidar, GPS, robot guide navigation, odometry and computer vision together with control algorithms to build a guide-robot to assist the blind with mobility and situational awareness. These devices and algorithms will be housed within an autonomous ground vehicle, which will be connected via an app to the user’s phone. The app will allow the user to input the destination they would like to reach (e.g. GPS coordinates). The robot will also “verbally” communicate path and surrounding information to the user.

MOTIVATION. Assistive technology has been gaining incredible attention over the past decade. Various devices, from ultrasonic canes to blind (braille-based) phones, have been created to improve the quality of life for those who suffer from severe visual impairment [1]-[6]. The causes of visual handicap are widely varied, but a low-cost flexible sense-and-alert platform is needed to facilitate comprehensive research in an otherwise less talked about field. While current technologies have provided life-enhancing improvement, a visually impaired person still relies very much on nearby people for help with day-to-day activities. One of the most common aids available for the visually impaired are guide dogs, but they are extremely expensive and last only (approximately) 10 years. Given the above, a key goal for the proposed project is to develop a flexible low-cost autonomous vehicle and its corresponding app too assist the blind with mobility and situational/environmental awareness. As such, this project is consistent with the research theme of health.

OVERVIEW OF WORK ACCOMPLISHED DURING FURI 1 (SPRING 2018). A strong understanding of how to use modern sensing, computing, and alerting devices together with algorithms to build a system of wearable sensing devices was laid during FURI 1. A foundation for the proposed guide-robot was also laid. The hardware studied included: HC-SR04 ultrasonic sensor to detect the distance between obstacles and the user; a Lidar (Light Detection and Ranging) for ranging, mapping and alerting a user of nearby obstacles; alerting devices such as an earpiece and pressure (haptic) devices to provide additional environmentally-driven processor-generated stimuli; high-speed transceivers to transmit data between sensors; and MPU-6050 IMU (inertial measurement unit) sensor to measure rotational motion and orientation of a body. A foundational understanding of Arduino board for simple functions and Raspberry Pi for more complex processing was obtained. Continuing work will lay a foundation for understanding RGB cameras for facial recognition and voice recognition software. A Jetson TX2 Nvidia board has also been studied for future development of high-speed high-fidelity image processing machine learning (neural network) algorithms for facial detection and recognition.

OBJECTIVE. With the aforementioned goal stated, the primary objective of the proposed project will be to build a low-cost autonomous vehicle that uses readily available components and that is sufficiently flexible to permit the development and demonstration of a wide range of empowering algorithms. Algorithms to be considered include obstacle detection and avoidance, environment mapping, thermal imaging, navigation, path planning, person and facial recognition, tracking, etc.

OVERVIEW OF SYSTEM HARDWARE. The guide-robot to be built will consist of an (1) Arduino processor for simple functions (e.g. computing range information), (2) Raspberry Pi and Nvidia TX2 for more complex processing (e.g. analyzing images and Lidar maps), (3) an inertial measurement unit (IMU) to measure translational and rotational accelerations/velocities/displacements, (4) an RGB camera with a pan-tilt mechanism for detection and recognition, (5) ultrasonic sensors for range information, (6) a GPS unit for positioning, (7) a Lidar (Light Detection and Ranging) for ranging and mapping, (8) Robotic Operating System (ROS) (9) high-speed transceivers to transmit data between sensors and the processors, (10) two-wheeled differential-drive Turtlebot, (11) motors with precision encoders and (10) a lithium-ion battery to supply required power. We plan to implement a recording (smart mapping) feature to permit remembering where the user has been before. Dr. Rodriguez will cover all expenses above the FURI $400 limit (see letter). While the proposed FURI is for Fall 2018, significant work will be completed over the summer.

OVERVIEW OF ALGORITHMS. The potential of the proposed guide-robot lies in its low-cost, flexibility and computational power that will permit the development and testing of many algorithms. The following algorithms will be examined:
- Kalman Filter for position estimation [7]-[9] – can be used to filter noisy (ultrasonic, Lidar and camera) measurements
- Obstacle detection [10]-[12] – can exploit sensors (e.g. ultrasonic, Lidar and camera) to detect obstacles
- Obstacle avoidance [11], [13] – can exploit sensors (e.g. ultrasonic, Lidar and camera) to avoid obstacles
- Simultaneous localization and mapping (SLAM) [14]-[17] – can exploit sensors (e.g. Lidar and camera) to map the environment and determine where the user is located within the map
• Path planning [18]-[19] – can exploit sensors (e.g. Lidar and camera) to plan, for example, a shortest distance path to a destination while avoiding obstacles
• Rapid mapping of an environment to a prescribed accuracy via Lidar [20]-[21]
• Tracking [22]-[23] – can be used to track a person or a “robotic dog” (i.e. small assisting ground robot) [21]
• Digital Image Processing [22] – to recognize the objects in a path.
• Guidance, navigation and control [22], [23] – to develop model-based algorithms to control the motion of the robot

CRITICAL QUESTIONS AND METHODOLOGY. During the proposed project, we plan to test each of the sensors (i.e. IMU, ultrasonic, camera, Lidar). Understanding their limitations will be critical. Other specific critical questions to be addressed are as follows:

1) **Obstacles:** Obstacle detection is critical for a visually impaired person. Given this, we will ask: How do we set obstacle detection and avoidance algorithm parameters to minimize false alarms and undue conservatism? How to we use the available sensors to differentiate between obstacles/obstructions/dangers (e.g. sign post, person, car, pot holes, glass, fire)? A few of the most common obstacles faced by a person in daily life will be examined [10]-[13].

2) **Range/Proximity Sensing:** Given that we will use ultrasonic sensors, a camera and Lidar, how well will we be able to determine and relay range/proximity information to the user? What range and “functional cone” will we be able to manage? What are the limitations of the sensors and our processors? What situations will our sensor-processor suite be able to comfortably handle? [25].

3) **Facial Detection:** How fast can our camera-processor-algorithm suite recognize a person? Will it be fast enough given the available computing power? Will we need another Raspberry Pi in order to process images faster? How about recognizing facial/emotional expressions? This will be done with machine learning (neural network) algorithms [24].

4) **Kalman Filter:** When is an extended Kalman Filter necessary for cleaning up noisy measurements? When will a regular Kalman filter suffice? When will a simple low pass filter suffice? How much can these improve IMU-based estimates? [7]-[9]

5) **SLAM Algorithm:** How do we adjust SLAM algorithm parameters to suitably tradeoffs mapping speed and mapping accuracy? [14]-[17]

SOCIETY RELEVANCE. The proposed guide-robot offers the potential for much greater environmental awareness and safe mobility at all times [5]. As such, it is likely to significantly reduce the risk of injuries that arise from accidents (e.g. a collision with an obstacle or person, falling because of an unanticipated obstacle). Given this, the proposed research will not only improve the lifestyle of many without sight, but it will also allow them to be active members of society. Over 70% of blind people in the United States are unemployed – often because they have problems getting to and from work. According to the World Health Organization, problems facing the blind in developing countries are far more formidable [23] – and the percent of visually impaired is far greater. The waste of valuable human power is therefore very significant – taking a high toll on the world’s workforce. Our proposed guide-robot can significantly help with this at a low cost – permitting a visually handicapped person to become self-sufficient and regain independence in the workforce. A larger workforce, in turn, would make for a more productive society.

FINAL DEMONSTRATION & DOCUMENTATION. The final demonstration will include a prototype guide robot which will demonstrate several algorithms (e.g. obstacle detection and avoidance, mapping and SLAM), implemented by the Robot Operating System (ROS) that would be controlled by the user via an app. All results will be documented in a final comprehensive report and on the final poster. This will include a cost-benefit analysis and summarizing the limitations of each of the sensing, computing and alerting devices being used. The work will be submitted for publication within the proceedings of the American Control Conference (ACC), the Frontiers in Education (FIE) and ASEE Conferences.

FURI ADVISOR. Dr. Rodriguez has worked in the area of Flexible Autonomous Machines operating in an uncertain Environment (FAME) for over 30 years. He has supervised over 50 graduate theses and over 300 projects. He is also the PI of a 5 Year, $5M NSF funded Scholarship program where each scholar is required to work on a career-shaping project. I am a scholar in his program. The proposed second FURI will permit me to work with Dr. Rodriguez alongside a team of highly motivated graduate and undergraduate students – many working on some aspect of embedded systems and using feedback algorithms to achieve intelligent behavior.

CONCLUSION. The main purpose of this project is twofold: (1) to gain a deeper understanding autonomous vehicles as well as algorithm implementation to assist the visually impaired with mobility and environmental awareness, (2) to prepare me for more advanced work and a direct PhD in this forward-looking area. Preliminary work can be found at: http://aar.faculty.asu.edu/research/assist-the-blind.html. I look forward to getting started on my Fall FURI during the summer of 2018.
REFERENCES:


TIMELINE FOR THE PROPOSED PROJECT

The following timeline will be followed to guide the proposed project.

Week 1-4  Conduct research on sensors (IMU, ultrasonic, GPS, camera, Lidar), processors (Arduino, Raspberry Pi), actuators (e.g. pressure), algorithms (guidance, navigation and control; digital image processing; obstacle avoidance)

Read research papers. Toward assist me with my embedded systems research, I have developed a very comprehensive website:

http://aar.faculty.asu.edu/research/assist-the-blind.html

Purchase all components/materials.

Week 5-7  Test sensors, ROS, LIDAR.

Determine limitations of all devices.

Week 6-10  Build prototype system and its corresponding app.

Week 7-12  Develop, implement and test algorithms.

Algorithms will include: obstacle detection, obstacle avoidance, mapping, planning and SLAM

I also plan to familiarize myself with algorithms for facial recognition

Week 11-14  Test system.

Collect and analyze data.

Week 14-15  Document all results in final report and poster to be presented during FURI symposium.
BUDGET FOR

Development of a Multi-Sensor Intelligent Embedded System to Assist the Blind with Mobility & Environmental Awareness

Bhavica Soni, ASU Undergraduate, Engineering Management
Advisor: Professor Armando A. Rodriguez, ASU, Electrical Engineering

Expenses over $400 will be covered by Dr. Rodriguez’ ASU-METS program.

<table>
<thead>
<tr>
<th>Budget Request Item</th>
<th>Expense</th>
<th>Qty</th>
<th>Total Cost</th>
<th>Budget Justification</th>
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<tbody>
<tr>
<td>Arduino Mega</td>
<td>$ 45.95</td>
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<td>$45.95</td>
<td>Necessary for inner loop motor control</td>
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<tr>
<td>Connector power chord</td>
<td>$ 8.99</td>
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<td>$8.99</td>
<td>chord for connection between Motor and battery</td>
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<tr>
<td>Battery 12 V</td>
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<td>$51.50</td>
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<tr>
<td>Jumper Wires</td>
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<td>$13.96</td>
<td>Required for connection between to pins</td>
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<tr>
<td>Header male to male</td>
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<td>$6.00</td>
<td>Required for connection between to pins</td>
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<tr>
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<tr>
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<td>$28.77</td>
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<tr>
<td>Sparkfun Haptic Feedback Driver</td>
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<td>$34.75</td>
<td>To drive Vibrational Driver</td>
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<tr>
<td>Viration motor</td>
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<td>5</td>
<td>$24.75</td>
<td>Vibration motor is used to get non audible and physical indications</td>
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<tr>
<td>MEMS Microphone Breakout INMP401</td>
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<td>$49.75</td>
<td>Need for Voice Recognition Capability</td>
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<tr>
<td>Sparkfun SAMD21 Mini Breakout</td>
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<td>Speaker</td>
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<tr>
<td>Bluetooth Module HC-06</td>
<td>$ 8.25</td>
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<td>$8.25</td>
<td>For smAll distance communication</td>
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**Total:** $399.07