Development of a Ground Robot with a Simultaneous Localization and Mapping (SLAM) Capability

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MOTIVATION. With increasingly powerful and inexpensive technologies, the world is seeing a resurgence in robotics research. This is particularly visible in the robotic vehicle arena. Such vehicles offer great promise across a broad range of applications. These include: search, rescue, reconnaissance, surveillance, distributed sensing and communications, mapping, area/infrastructure/agriculture inspection, law enforcement, first responder assistance, etc.

OBJECTIVE. Given the above, the main objective of this research is to build a ground robotic vehicle that is capable of (1) determining where it is – called localization and (2) mapping and unknown environment using LiDAR. When performed simultaneously, we get SLAM for simultaneous localization and mapping [1]-[5].

ROBOTIC PLATFORM TO BE BUILT. In order to address the above, we plan to build a differential-drive ground robotic vehicle based on prior work of Dr. Rodriguez’ students [6]-[10], [11]-[12]. The vehicle will contain: a styrene-based chassis, an Arduino microcontroller for inner-loop (cruise/position/directional) control, a Raspberry Pi for outer-loop (e.g. image processing) control, an inertial measurement unit (IMU) with accelerometers and gyroscopes, a Raspberry Pi 5MP (30 Hz) camera, ultrasonic sensors for range information, a 2D LiDAR (10 Hz) for ranging and mapping, a 2.4GHz spread spectrum wireless communications system, 1 Arduino motor shield, 2 motors with built-in high resolution encoders to provide accurate odometry data, front and rear caster wheels, a Lithium Polymer 12V battery, 2 supporting platforms (one is for battery and processing units; the other for the LiDAR and IMU). Taken collectively, the above components make the proposed vehicle a powerful research tool with a SLAM capability.

MODELING AND CONTROL. Vehicle modeling and control will be based on [6]-[13]. The control laws to be developed will be model based.

- Proportional-plus-integral-plus-derivative (PID) controllers will be implemented within the Arduino for inner-loop (speed/direction/position) control. This will utilize the encoders and IMU.
- A PID controller will also be implemented within the Raspberry Pi for outer-loop image-processing based control (e.g. following a path, obstacle avoidance).
MAPPING. The onboard LiDAR (light detection and ranging) will be used for mapping an unknown environment with an a priori specified accuracy in minimum time. The idea here is that by obtaining a map of an area, we can then return to the area and navigate within the area. As the map is being generated, one can use the data gathered (a “subarea” map) in order to navigate within the “subarea.” It must be emphasized that in this work we will be using a 2D LiDAR to construct 2D maps; i.e. “near ground-level area maps.”

SLAM ALGORITHMS. In order to simultaneously determine where the robot is and construct an environment map (e.g. map of a room), we will use the algorithms within [1]-[5]. As the LiDAR data is gathered a state estimator is used to clean it up; i.e. to better estimate where the vehicle is and the distance to environmental features. In this work, we will examine two classes of estimators: (1) a Kalman filter [1]-[3] and a (2) Rao-Blackwellised particle filter [4].

FINAL DEMONSTRATION. The final demonstration will show the robot

- following various paths and
- constructing a near ground level area map for an unknown area (e.g. classroom connected to a laboratory) to a pre-specified precision in minimum time.

DOCUMENTATION OF WORK. All project results will be documented within a final comprehensive report and on the required final poster. The work will also be submitted for publication within the proceedings of the American Control Conference (ACC) and the Frontiers in Education (FIE) Conference.

CAREER RELEVANCE. My technical passions lie entirely within the intelligent autonomous vehicle arena. For this reason, I have selected the proposed project. This project will provide an excellent step toward my next goal – to complete an MS here at ASU in the area of intelligent autonomous systems under the superposition of Dr. Rodriguez.

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. Relevant theses and papers are as follows: [6]-[13]. Recently, Dr. Rodriguez led a team of ASU students to become a finalist in the ASU ASURE 2017 Innovation Challenge. He is also the PI of a 5 Year, $5M NSF funded Scholarship program. Each scholar is required to work on a career-shaping project. The proposed FURI will permit me to work with Dr. Rodriguez alongside a team of highly motivated graduate and undergraduate students – all working in the area of intelligent autonomous systems. I especially look forward to developing a fleet of FAME and the planned robotic circus.
References


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