Control and Coordination of Multiple Intelligent Ground Robotic Vehicles

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MAIN GOAL. The proposed (second) FURI research project aims to develop algorithms and hardware to achieve autonomous control and coordination of multiple ground robotic vehicles.

WORK DURING FURI I (Spring 2018): FURI I established a solid foundation for the proposed FURI II work. One differential-drive robotic (Turtlebot) vehicle was built during FURI I. Two additional similar vehicles were built by other students belong to Dr. Rodriguez' group. The three (3) vehicles will be used as Intelligent Follower Vehicles (IFVs) during FURI II. The algorithms examined during FURI I are similar to those explored in [1-3], [6-12] – many developed by Dr. Rodriguez’ graduate students. The work performed during FURI I included the development of algorithms that make use of image processing to track (follow) a lead vehicle. Control system and obstacle avoidance algorithms were also used in order to achieve precise speed and spacing control, and to avoid potential obstacles. Each vehicle was outfitted with a suite of sensors to permit a variety of capabilities to facilitate high quality research. Each vehicle contains IMUs (inertial measurement units) to retrieve odometry data, solar panels for the solar-powered back up, cameras for image processing, an Arduino for low-level control and a Raspberry Pi computer for high-level control. The limitations of the Raspberry Pi for image processing were carefully examined. In order to achieve high speed image processing, an NVIDIA TX2 256 GPU core board was examined and shown to yield superior results (e.g. near 30 frames per second at high resolution). A more sophisticated RGB camera was also examined and shown to provide accurate depth and color information.

PROPOSED WORK DURING FURI II (Fall 2018): The proposed research project (FURI II) will build upon and improve upon the FURI I accomplishments – moving us towards the goal of controlling and coordinating multiple intelligent ground robotic vehicles. The main goal of the proposed FURI II is to demonstrate five (5) IFVs. Since 3 vehicles are already available (see FURI I work above), 2 additional (similar) Turtlebot vehicles will be built during the summer of 2018 so that they are ready for use during the proposed Fall 2018 FURI II effort. All vehicles will possess an Nvidia board and an RGB camera to permit high-speed high-resolution image processing. They will also possess Lidar to permit coordinated mapping capabilities. This work will involve significant modeling, analysis and control algorithm development – exploiting the ideas within [1-7], [10-15]. The algorithms developed in [1-7], [10-15] will be integrated into each of the 5 robots. This will permit precise speed and direction control [7], position control along a path [6], [10], [12] and obstacle avoidance [3-5].

MOTIVATION. The proposed FURI II research project is very important and has potential to be used in a multitude of applications. There are many areas where the deployment of platoons of autonomous vehicles in the place of human agents will lead to higher efficiency and lower costs. Some of these applications include search and rescue, mapping of large complex environments, law enforcement, national defense, planetary surface exploration, etc. The work being pursued is directly applicable to the rapidly growing area of intelligent driverless vehicles. The use of these vehicles could one day ensure smoother traffic flow (e.g. driverless fuel-saving platoons of vehicles), less accidents, less pollution, and less energy consumption. The proposed work will also provide a very powerful foundation for my future research in the area of autonomous vehicles and coordination of multiple intelligent vehicles.

TASKS TO BE PERFORMED AND CRITICAL ALGORITHMS. The following tasks and algorithmic work will be pursued to meet the objectives of the project:

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I) **Build Multiple IFVs.** While 3 of the 5 vehicles will be complete by the end of the spring semester, 2 additional vehicles will be built during the summer of 2018 [11-12].

II) **Vehicle Control Systems.** The development of the vehicle control systems will be one of the critical tasks to be undertaken. Model-based control system algorithms will be developed for directional and speed control – similar to that used during FURI I [1-3], [6-15]. Vehicle control will exploit the IMU as well as the camera – the latter permitting us to correct dead-reckoning errors.

**Separation Control and Obstacle Avoidance.** Another critical task to be conducted will be the development of algorithms for precision inter-vehicle spacing control and obstacle avoidance. Here, we will exploit the ideas within [1-5], [14-15]. Sensors such as the onboard IMU, ultrasonic sensors, Lidar and camera will be fully exploited in order to permit “tight precision coordinated control of the fleet.” Toward this end, each robot will be able to communicate with any other robot in the fleet; i.e. each robot will be equipped with a low-latency high-bandwidth communications system. It is well known and intuitively expected, for example, that when certain information is not available (e.g. platoon leader acceleration information), tight control spacing is not possible [6], [10-12].

III) **Testing.** The final task to be performed will be to test the vehicles extensively and ensure the robustness of the algorithms in coordinating the fleet. A recently purchased (sub-millimeter) indoor tracking system will be used in order to carefully examine control tightness.

**Final Demonstrations and Documentation.** The final demonstration will involve all 5 vehicles. We will specifically demonstrate cruise control along a line, along a curve, spacing control and obstacle avoidance. The 5 vehicles will follow a very tight figure 8 track. With a very small radius of curvature, collision at the intersection will be possible. As such, this demonstration will clearly show how well the developed algorithms address precision following and obstacle avoidance. When a vehicle is removed from the platoon, the remaining vehicles will adapt accordingly - increasing or decreasing the spacing, as needed. Obstacles will be introduced at any given point to further illustrate obstacle avoidance. All project results will be documented in 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), the Frontiers in Education (FIE) and ASEE Conferences.

**Career Relevance.** The proposed FURI will permit me to strengthen my systems-and-controls fundamentals and to lay down a foundation for pursuing my direct PhD, here at ASU, under the supervision of Dr. Rodriguez. To facilitate the latter, I intend to apply for a NSF Fellowship this Fall – allowing me to begin by PhD Fall 2019. The PhD will permit me to pursue an academic career – permitting me to perform cutting-edge research in the area of intelligent autonomous systems, advance the state-of-the-art, work closely with highly motivated students wanting to make a difference as well as national laboratories and industry. This is a future I look forward to.

**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 are as follows: [1-2], [6], [10-12]. Recently, Dr. Rodriguez led a team of ASU students to become a finalist team in the ASU ASURE 2017 Innovation Challenge. He is also the PI of a 5 Year, $5M NSF funded Scholarship program. I am a scholar in his 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. It should be noted that Dr. Rodriguez will provide additional funding to cover any costs in excess of the $400 FURI budget limit. This will ensure the development of research-grade vehicles that will benefit many future Fulton students. It should also be noted that Dr. Rodriguez will also be supporting my planned summer work – work that will prepare me for my Fall FURI and NSF Fellowship application.
References


