GRAVL Spring 2018 Research Summary

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1 Overview

Over the course of the past semester, the Ground Robotic Autonomous Vehicle Laboratory (GRAVL) research team has used the $945.00 awarded by the SAG Committee to develop our autonomous tractor as an advanced undergraduate robotics research platform, engage in paper-developing research, support the projects in ENGR3392 Robotic Systems Integration, and lay the groundwork for future platform improvements, projects, and research. The team's overall goals for the semester were as follows:

- Knowledge Transfer and Onboarding
- Autonomous Tractor Platform Development
- Support of ENGR3392 Robotic Systems Integration
- Groundwork for paper-developing research project in autonomous grading

In summary, the team's accomplishments over the course of the semester are as follows:

- Autonomous implement sensing and manipulation in 1 dimension
- Inertial Measurement Unit (IMU) sensor suite mounting, integration, and filtering
- RTK GPS-based point-to-point navigation and coordination between ground station and rover
- Full analysis and development of coordinate system transforms for tractor sensors and maps to support current and future advanced capabilities
- Research presentation to JPL involving autonomous surveying and grading of dirt roads
- Research presentation to JPL involving camera-based odometry and navigation
- Low level autonomy feedback loop built into tractor grading implement

2 Knowledge Transfer and On-Boarding

The fall and spring semester of GRAVL saw the team expand by three first years - Amy Phung, Kawin Nikomborirak, and Nathan Estill. These three students have each taken on individual projects under the guidance of more senior members of the team.

- Amy Phung: Teleoperated and autonomous actuation of tractor implement in 1 dimension; Low level autonomy feedback loop built into tractor grading implement
- Nathan Estill: Sensing of tractor implement position; Mounting of IMU suite; Low level autonomy feedback loop
- Kawin Nikomborirak: Configuration/Documentation of RTK GPS; Configuration of tractor onboard computer network; Configuration of package dependency files for gravl ROS package; Development of GPS-based point-to-point navigation.

With the help of these members, the team has created a list of future projects and developments for the tractor that are suitable for students with varying levels of experience.

Throughout the semester, the team also completed a full review of previous work done on the tractor and compiled a complete document detailing the electrical, mechanical, and software subsystems of the tractor. Additionally, the team formalized methods and locations for future documentation of GRAVL resources to address several inadequacies found when perusing earlier documentation of the platform.

3 Autonomous Tractor Platform Development

One of the main goals of GRAVL's spring semester was development of the tractor as a more sophisticated research platform. Aside from the major developments made to the actuation and sensing of the tractor's blade actuator (see Autonomous Grading Groundwork section for more details), other developments consisted of:

- **Tractor Coordinate System Transform Definitions:** This work allowed full localization of the tractor with respect to the world, and made path tracking and point cloud creation from lidar data possible
- **Point Cloud Creation Environment Development:** This work concatenated and set up libraries and packages necessary for the creation and visualization of pointclouds created from individual lidar scans
- **Tractor Onboard Computer Configuration:** This work set up the NUC on the tractor to be remotely accessed and implemented procedures for efficient transfer of code between student computers and the tractor. This development allows for distributed development of code by separate students to be tested on the tractor without having to use the tractor's computer to write the code.
- **RTK GPS Configuration:** This work setup and documented the Realtime Kinematic GPS w/ base station system, allowing the tractor's GPS location to be determined to a high degree of accuracy.

4 ENGR3392 Integration

One of the goals of the GRAVL team in the spring semester was to facilitate research done in ENGR3390 Robotic Systems Integration. To this end, the team has engaged in collecting various forms of data from differing sensors for analysis and use in two separate class projects.

The first of these projects is research and implementation of a form of visual odometry. The team provided multiple data bags of coordinated GPS and camera data while driving along both paved and dirt roads, as well as camera calibration video, on multiple occasions.

The second project is automated grading, a project that the GRAVL team is also developing further over the following semesters. the team provided multiple data bags of GPS, IMU, and Lidar data while driving along paved roads, dirt roads, and unstructured pasture. The team also supported multiple missions to test various components of the system and developments much of the subsystems to make the project possible.

5 Autonomous Grading Groundwork

The main research avenue explored by the team in the past semester was automated grading by the tractor. Over the course of the past semester, the team has implemented the necessary hardware and electrical interfaces for moving the tractor's grading blade in a controlled way. Additionally, the team has implemented the necessary sensors and filtering libraries to detect current road state. Further work in this area will involve creating higher-level algorithms that create an autonomous workflow that chains together several lower-level tractor movements. An example of this type of algorithm is a state controller that positions the blade based on information on the current state of the road and the desired state of the road.

6 Personal Reflection

As of the end of the 2018 spring semester, I have been involved with GRAVL for a full year, and have been the team's project manager (PM) for the majority of that period. As a consequence of my time as PM, I have developed both my technical and social skills. In particular, GRAVL has helped me in three large ways: systems-level design, team management, and project planning.

GRAVL's current primary purpose is to develop a robust autonomous ground vehicle to support undergraduate research. This goal has allowed me the opportunity to design a robotic platform from the ground up. I have been involved in all processes, from the mechanical mounting of motors and sensors to the electrical wiring of the power and data circuits. I've written low-level firmware to interface with actuators and I've written high-level software to create complex robotic behaviors. This varied experience has given me both a specific systems-level understanding of the tractor and a general concept for the design process of any autonomous system. Olin graduates (particularly in the robotics field) are desired for their ability to understand components of a system in the context of a whole, and I feel that GRAVL has given me a space to develop this ability.

GRAVL has also enabled me to refine techniques for building and running a team. After a year of organizing GRAVL meetings, running stand-ups, enabling communication, and developing documentation, I have a much better understanding of the ways in which a team leader's actions influence the health and effectiveness of a team. To provide an example: over the course of the past year, I've tried various forms of task management and communication. Over the summer, the team used Asana to track tasks. This platform worked well, as only two people were doing large amounts of work on the tractor. Since both students were committed to keeping Asana updated, the

software worked well.. However, when I tried to scale Asana to accommodate the large influx of new members in the ensuing fall semester, the platform failed to allow accurate task tracking, in part because of varying levels of commitment to the platform. When I switched the task management technique to physical sticky notes posted in our workspace during the following spring semester, students had a lower activation barrier to updating the tool and had a shared artifact about which to communicate, an aspect of task planning that was lost when using Asana. This example is one of several team-based interactions in which I have been able to refine how I manage teams based on experiences gained through GRAVL.

Finally, GRAVL has provided me a space to learn and refine techniques for project planning, timelines, and updates. Often at Olin, large class projects last (at most) for a semester, and only offer one chance for overall project planning. GRAVL has provided multiple opportunities for this kind of semester-long scaffolding of work. This feature has allowed me and the other team members to experiment with different ways of framing progress through the semester, deliverables, and checkpoints along the way. Through this analysis, we are directly refining our process to become more efficient and able to accomplish more throughout the semester. However, an equally important ability that we are gaining is the ability to analyze our current working situation, determine what facets work and which are detrimental, and create a plan to improve our workflow. This skill is arguably more important, as self-analysis and improvement is a skill that can be applied to many parts of life, and is not limited to a research group.

Overall, I feel like GRAVL has enabled me to develop my abilities in a range of areas ranging from hard to soft skills. My goal in the upcoming semesters is to run the research group in such a way so to allow others to have these same defining experiences, thereby enriching their Olin experiences.