

Developing an autonomous driving system for an existing lawn mower

Michael Pomales

Mentored by Dr. David Brown and Mr. Darren Brown

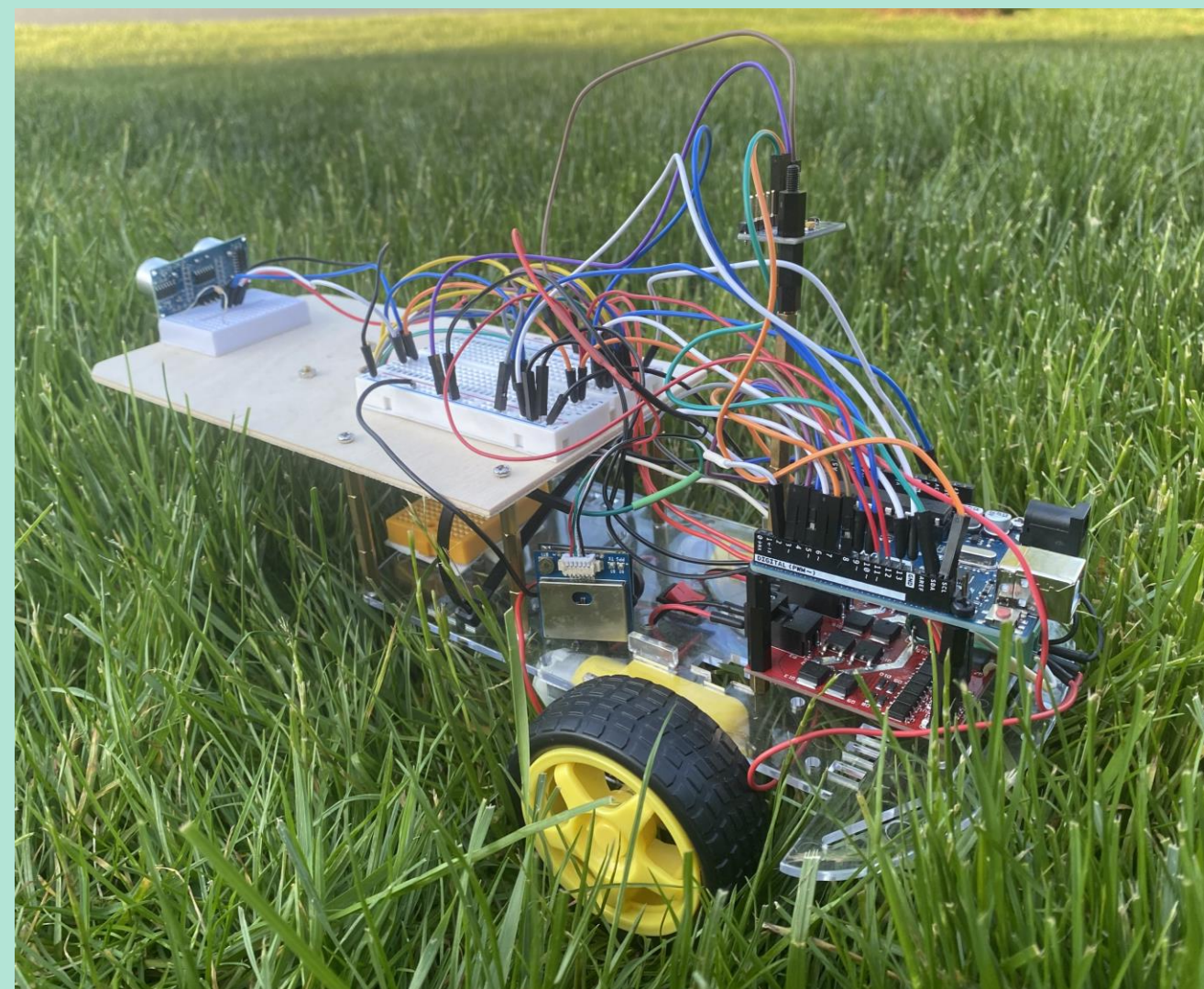
Introduction

A well-trimmed and kept lawn is a signature of any respectable space, with lawnmowers serving as the primary tool to maintain this staple of propriety. However, despite larger and more effective mowers emerging on the market, mowing a lawn remains a time consuming and potentially dangerous task. Lawnmowing accidents from 2006–2013 caused an average six thousand injuries a year, with average medical costs exceeding 36,000 dollars (Hottinger et al., 2018). This danger, as well as the potential to save time and manpower lends lawnmowing well to being an autonomized task. To that end, the autonomous lawnmower project's goal was to develop autonomous capability for an existing zero turn lawnmower, as autonomizing the mowing process would save significant manpower and improve the safety of mowing. Previous teams have built autonomous lawnmowers from the ground up which were successful in testing (Adeodu et al. 2018; Dexter et al. 2012). However, autonomizing an existing mower by developing an add-on would more easily enable widespread adoption in the existing market.

Materials and Methods

To create the subsystems of navigation, a scaled down model of the mower was created (shown in Image 1.). The Lawnmowing Autonomous Robotic System (LARS) emulated the major features of the Troy Bilt XP Mustang zero turn lawnmower (shown in Image 2.) to ensure a smooth transition from model to a mower through mimicking key features, including zero turn functionality and two independently controlled driving wheels. Programming took place via a GitHub repository created for the project. Due to development taking place remotely at times, this approach allowed for non-synchronous code development in which all developers had access and could suggest and implement improvements to programs in one single organized repository. Upon completion each sensor-based subsystem was tested with LARS to ensure functionality. From there the subsystems were adapted to the Mustang at the at the Chesapeake Systems garage before being tested in unison.

Image 1 (Right): Lawnmowing Autonomous Robotic System(LARS) used to develop/test autonomous subsystems. Ultrasonic sensor is mounted in front of wooden mounting piece, with optical flow sensor underneath. Arduino Uno, motor control board, and internal navigation units are contained on plastic chassis.



Materials and Methods (continued)

The final chosen method for navigation began with the optical flow sensor providing positional coordinates for the mower. This pathway was refined using an inertial navigation unit (INU) sensor to calibrate for exact positioning and moment-to-moment movement, although the INU's magnetometer faced calibration difficulties that impacted its ability to fulfill this task. Any obstacles in front of the mower were detected by the ultrasonic sensor, bringing the Mustang to a stop. Prior to any testing, a safety risk assessment was performed by the engineering team. This risk assessment identified potentially hazardous conditions that could have occurred during the construction, operation, and maintenance of the mower. Risk reduction and mitigation strategies were implemented in the final design, including a safety pull strap and remote-controlled activation and deactivation. The straight line navigational strategy was tested by measuring the Mustang's deviation from a fifty foot sample path. Deviations were calculated by laying a number line across the sample path and recording the mowers position relative to the line at various points via a camera mounted on the front of the mower facing the line. These deviations were then used to fit a linear regression of the mowers path with a coefficient of determination. These coefficients were then compared to a series of trials conducted by an experienced driver given the same path in a two samples t -test, with the goal that the mower would meet the straightness of the driver completing the path.

Image 2 (Right): Troy-Bilt XP Mustang zero turn lawnmower. The safety pulley were present alongside sensors and components mounted on the front. Linear actuators connected to drive levers enabled the Arduino microcontroller to direct the mower.



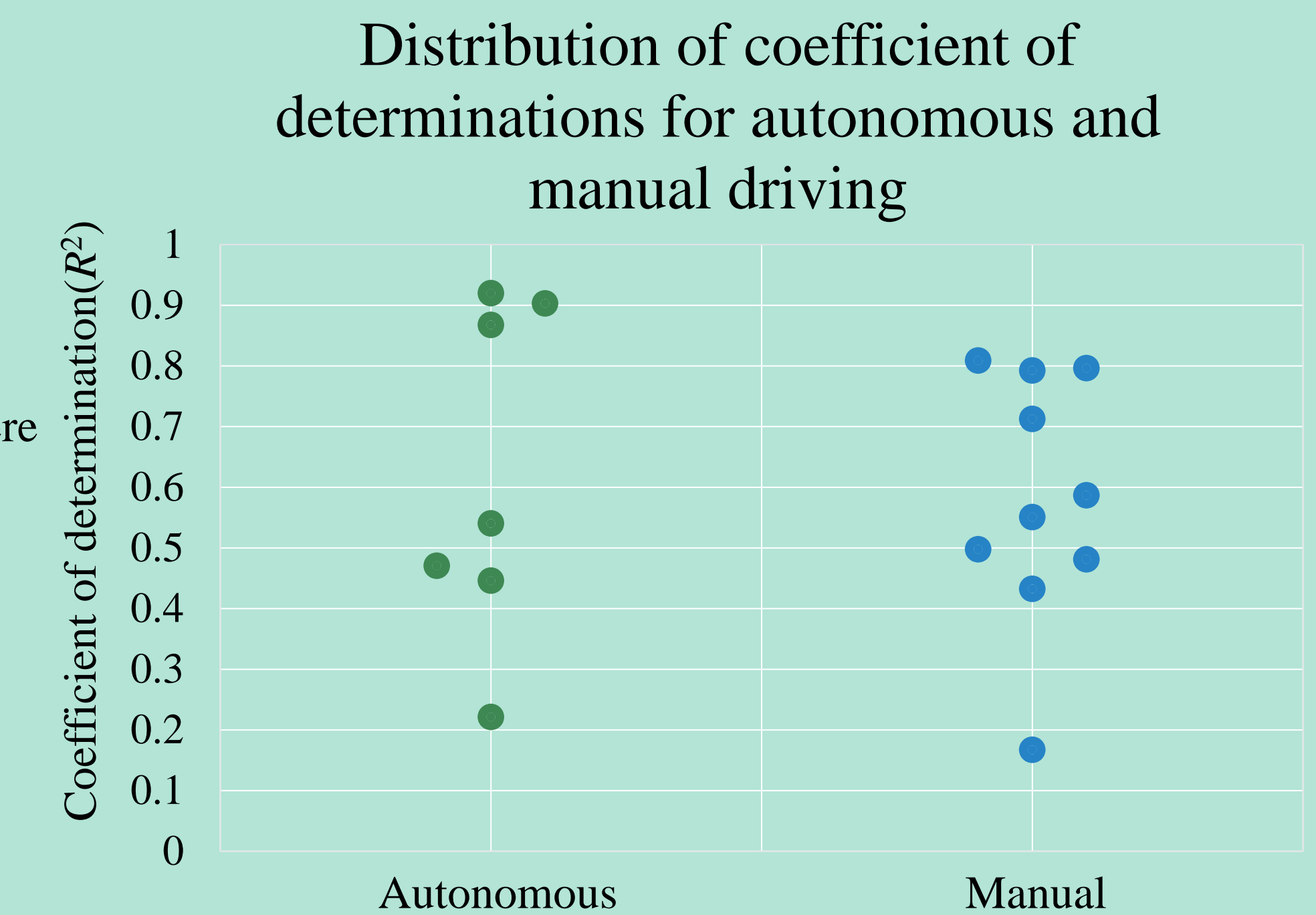
Results

The coefficient of determinations from the autonomous trial runs of fifty foot sample path were compared to a human driving through the same path across seven autonomous trials and 10 human trials (shown in Graph 1.). Using these measured coefficients, a two-sample t -test comparing the two modes showed the average autonomous coefficient ($M = 0.624$ $SD = 0.274$) did not significantly differ from the average human coefficient ($M = 0.583$, $SD = 0.103$), $t(10) = 0.34$, $p = .740$.

Results(continued)

The mean difference in the coefficient was 0.041 with a 95% confidence interval ranging from -0.230 to 0.313 . Using the alpha level of .05 the null hypothesis is supported, suggesting statistical similarity in navigation for human driving and autonomous driving.

Graph 1 (Right): Distributions of coefficient of determination in the autonomous driving trials compared to the human trial. There was not a statistically significant difference in human driving compared to autonomous driving.



Discussion

This project sought to develop an autonomous system capable of replicating human mowing. Overall, based on the results the attempts to replicate the human mowing ability in an autonomous mower were successful. This affirms the success of previous studies (Adeodu et al. 2018; Dexter et al. 2012) but presents them with a larger mower. These results support further research into more complex algorithms that could afford the mower more advanced means of navigation. Additionally, optical flow, while an effective means of navigation, would require more adaptation, including headlights and shadow containment, for effective lighting to infer position from. Thus, an INU or DGPS guided system may be less resource intensive while similarly effective.

References

- Adeodu, A. O., Daniyan, I. A., Ebimoghlan, T. S., & Akinola, S. O. (2018). Development of an embedded obstacle avoidance and path planning autonomous solar grass cutting robot for semi-structured outdoor environment. *Institute of Electrical and Electronic Engineers*, 1–11. <https://doi.org/10.1109/ICASTECH.2018.8506681>
- Dexter, R., Roadruck, B., Baine, N., Rattan, K. S, Thomas, S., & Gallagher, J. (2012). Navigation application to an autonomous lawnmower. *Institute of Navigation*, 376–3772.
- Hottinger, D. G., Nasr, I., Canner, J. K., Kattail, D., Koka, R., & Schwengel, D. (2018). Incidence, Distribution, and Cost of Lawn-Mower Injuries in the United States, 2006–2013. *Public Health Reports*, 133(5), 570–577. <https://doi.org/10.1177/0033354918785909>