Eagle Autonomous

Indy Autonomous Challenge

Round 1 Qualification Paper

Embry-Riddle Aeronautical University
Daytona Beach, Florida

Student Members:
Nick Hawthorne, Bryce Karlins, Maxwell Kline, Haley Lowe, Connor Mallow, Robyn Mehta, Rose Moskowitz, Matthew Oxamendi, Brady Slaughter

Faculty Advisors:
Dr. Marc Compere, Dr. Patrick Currier, Dr. Eduardo Divo, Dr. Charles Reinholtz

ABSTRACT

Embry-Riddle Aeronautical University's *Indy Autonomous Challenge* team, Eagle Autonomous**,** is a team of students based in Daytona Beach, Florida, seeking to compete in the *Indy Autonomous Challenge*. The team includes undergraduate and graduate students majoring in Aerospace Engineering, Mechanical Engineering, Unmanned Aircraft Systems and Engineering Physics. Eagle Autonomous is also supported by professors and staff with experience from several autonomy-focused research projects including the EcoCAR Mobility Challenge, the Maritime RobotX Challenge, the DARPA Grand and Urban Challenges, and numerous autonomy competitions including IGVC, SUAS, and the AUVSI competitions. In addition, Eagle Autonomous is sponsored by a Melbourne based company, iSENSYS, that develops and operates autonomous vehicle platforms. The team plans to test its methodology and system architecture in Purdue's Electric Vehicle Grand Prix (EVGP) for demonstrating Round 2 deliverables. The current plan is to use a reactive, probabilistic-type architecture with a combination of GPS, inertial, and LIDAR or RADAR as the primary guidance system sensors. Conceptually, the GPS and inertial sensors will provide rough waypoints along a path that the vehicle can follow, while the LIDAR or RADAR systems will sense nearby vehicles and the exact track position.

Table of Contents

1 INTRODUCTION

1.1 Problem Statement

The *Indy Autonomous Challenge* (IAC) is a collaborative effort among the next generation of science, technology, engineering, and mathematics students to develop the future of advanced algorithms and software for autonomous racing. The team's specific goal is to develop an autonomous vehicle controller in a virtual environment that translates into a winning performance on a physical vehicle. The car will effectively race against other autonomous vehicles at the Indianapolis Motor Speedway.

1.2 Team Composition

The advantages of attending a STEM university include the opportunity for undergraduate students to explore and specialize in their disciplines, especially in student projects. Of the team's current members, five are majoring in Mechanical Engineering; with four specializing in robotic and autonomous systems and one specializing in high performance vehicles. The remaining members include an Unmanned Aircraft Systems major, whose coursework incorporates autonomy, as well as an Aerospace Engineering major with an astronautics focus. Additionally, the team includes an Engineering Physics major, with a focus in spacecraft instrumentation and minors in computer engineering and mathematics. Eagle Autonomous is also fortunate to have experienced mentors giving insight on the project as it progresses, including a PhD student whose work focuses on vehicle dynamics and an extensive track record of leadership in International Collegiate Competitions such as Formula SAE. As a whole, Eagle Autonomous offers a collection of members with diverse skills directly relevant for the IAC.

Student Team

Degree of Study	*Team Member*	*Specialty*
B.S. Mechanical Engineering	Bryce Karlins	Team lead, software interfaces
B.S. Unmanned Aircraft Systems	Nick Hawthorne	UAS piloting, software development
Ph.D. Mechanical Engineering	Maxwell Kline	Racing vehicle dynamics
B.S. Engineering Physics	Haley Lowe	Sensing and instrumentation
B.S. Aerospace Engineering	Connor Mallow	Control, sensing, algorithms
B.S. Mechanical Engineering	Robyn Mehta	Mechatronics, software development
B.S. Mechanical Engineering	Rose Moskowitz	Project management, documentation
B.S. Mechanical Engineering	Matthew Oxamendi	Mechanical design, actuator interfaces
B.S. Mechanical Engineering	Brady Slaughter	Actuation, vehicle dynamics

Faculty and PhD Advisors

Title	*Faculty Advisor*	*Specialty*
Associate Professor, Dept. of Mech. Engineering	Dr. Marc Compere	Dynamics, simulation-based design
Associate Professor and Associate Chair, Dept. of Mech. Engineering	Dr. Patrick Currier	Autonomy, by-wire conversion
Professor, Dept of Mech Engineering	Dr. Charles Reinholtz	Autonomy, competition strategy
Professor and Chair, Dept. of Mech. Engineering	Dr. Eduardo Divo	Modeling and Simulation Strategic relationships

1.3 Team History with Automation

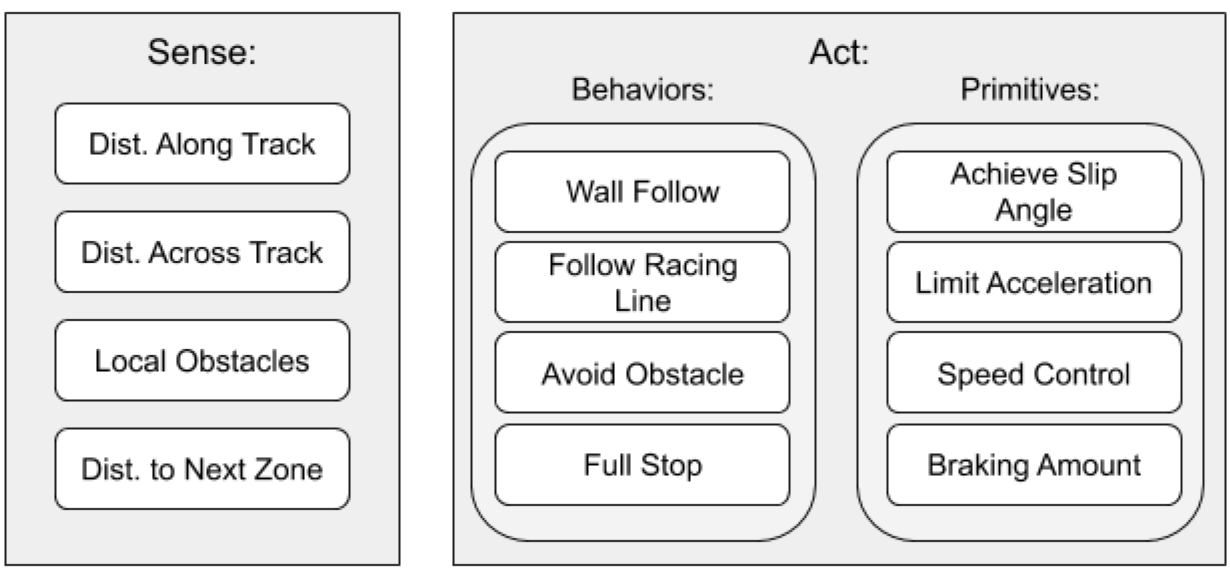
Eagle Autonomous represents a diverse team of students from the Colleges of Engineering, Aviation, and Arts and Sciences. Each team member has significant design experience in their discipline, and Embry-Riddle Aeronautical University (ERAU) boasts a variety of collegiate projects and faculty as resources for the team. The most relevant of these projects to IAC include the EcoCAR Mobility Challenge, Maritime RobotX, and Intelligent Ground Vehicle Competition (IGVC). Each of these projects challenges students to explore and improve upon existing autonomous vehicle operations. The challenge of autonomous racing was the primary factor that motivated the team to choose to participate in the Electric Vehicle Grand Prix (EVGP) over simply utilizing one of ERAU's existing projects for round 2 qualifications. Competing in EVGP offers a means of acquiring experience directly relevant to racing autonomous vehicles.

2 COMPETITION STRATEGY

2.1 Automated Vehicle Approach and Architecture

The approach to automated vehicle software architecture will be a probabilistic, behavior-based method as described in the literature [2]. Deliberative, planned approaches that take considerable time to compute motion commands based on highly detailed maps are not practical for a dynamic, multi-vehicle race scenario [1]. After considering a variety of literature concerning the structure of the vehicle behaviors, a subsumption architecture was eventually selected for the overall layout. A preference on a highly reactive, low-level system at the expense of intensive mapping is what led the team to this decision. In the application of autonomous racing, and fully embedded autonomy, a subsumption architecture will allow flexibility by separating the controller from the low level behavior and sensing code.

While both autonomous street vehicles and autonomous racing both require level 4 autonomy, autonomous racing differs in that the track environment is strictly controlled. There should be no unexpected obstacles or track blockages that the vehicle will have to deal with, except for other racing vehicles. Because of this, only a very basic localization system will be required, and there should be no need for global mapping. Without the need for accurate global localization, the team can safely utilize GPS for the vehicle's approximate position and heading. The track will be broken into large zones split up to encompass parts of the track that require a change in actions, i.e. starting a turn, track narrowing, apex, etc. Each zone boundary will have a set of associated goal values like speed, position across the track, and slip angle. The controller will then assess the sensor values such as distance to next zone and across the track. It will then pick behaviors and pass parameters in order to accomplish the goal of moving to the next set of values.



Organization of sample nodes in the subsumption architecture.

The controller will be designed in such a way that is parametric and platform agnostic. One of the main challenges of IAC will be the transition between the simulated model and the physical car. The controller will therefore utilize a lookup table with data relating empirically measured parameters, such as lateral acceleration, available steering moment, braking authority at varying speeds, etc. This table can be swapped out to seamlessly move the controller between the simulator, the production IL-15 car, or mule vehicles. A series of empirical tests with both mule vehicles and the simulated IL-15 vehicle will provide the data to generate these tables.

2.2 Simultaneous Localization and Mapping (SLAM)

The strategy for Simultaneous Localization and Mapping is related to the reactive and probabilistic architecture previously described. SLAM will become relevant once the vehicle can achieve basic track navigation with no vehicles or obstacles. Conventional SLAM with high accuracy maps, possibly with closed loops is not the priority or goal. A closed loop track may be of use but traditional high accuracy is neither necessary or advisable in a dynamic, fast-paced multi-vehicle race situation. Constructing and updating a track representation using left-to-right track width will help localize the vehicle to certain track segments. Likewise, observing characteristic changes in lateral track barrier distance will identify signature track barrier gaps that can help localize the vehicle to a track segment. This level of mapping detail is both possible and sufficient for preparing the controller for the next turn and next track segment.

2.3 Testing

Testing is the key to technology development. Defining certain subsystem and system-level tests that demonstrate functionality in both software and hardware will drive team progress. Tests will be planned for software subsystems including computing and communications, individual sensors, controller algorithms, and actuator commands. Hardware subsystems include platform mechanical, electrical, computing, sensing and actuating. A combination of simulation-based tests and hardware tests will drive the team workflow and schedule.

Once subsystems are matured and well-tested, vehicle-level tests will begin. These will advance to track driving tests. E-stop and low speed driving tests, including track barrier detection can be performed in a parking lot. Embry-Riddle has a good working relationship with the Daytona International Speedway (DIS) and has completed experimental automotive testing on the DIS track. Future collaboration is a goal with an additional possibility of testing at New Smyrna Speedway. Track test time is critical since it is the most realistic driving scenario for competing in both the EVGP and IAC.

3 PROJECT MANAGEMENT

3.1 Management Approach

Project management is critical to the team's awareness of the next immediate goal in relation to the overall schedule. Twice weekly meetings and group communications via email and GroupMe keep the team progress coordinated. Further, Microsoft Team will be used to assign and keep track of the tasks each member is working on. The designated project manager will hold team members accountable to completing their assigned tasks. Software and hardware tests will serve as milestones in the project schedule as the team approaches each round of the competition.

3.2 Fundraising Strategy

Both the Department of Mechanical Engineering and the College of Engineering have committed the resources to support this endeavor including faculty release, student stipends, travel funds, and operational funds to acquire the software and hardware necessary to achieve the team's goals. iSENSYS has also donated hardware as part of the partnership, providing the team with abundant resources to meet its goal.

3.3 Outreach and Publicity

Racing is a daily part of life at Embry-Riddle due to the campus's proximity to the Daytona International Speedway. The team understands the excitement that automotive racing brings to the public. IAC will help Autonomous Eagles share interest in autonomous vehicles with a larger segment of society. Both the Formula SAE and DOE EcoCAR teams at ERAU have relationships with the Daytona International Speedway. The team plans to leverage this relationship to showcase Eagle Autonomous research by tabling at racing events. One form of outreach the team is looking into is gaining partnerships or sponsorships with companies researching and developing autonomous vehicles. These companies, some of which are located in Daytona's own small-business incubator, will bring more recognition to IAC and ERAU, while further promoting research in autonomous racing. The team has already secured an industry partnership with iSENSYS, LLC, a company based in Melbourne, FL that develops autonomous ground, surface, and air vehicles. Eagle Autonomous is eager to work on the *Indy Autonomous Challenge* in order to get more people involved in autonomy and racing.

4.0 References

[1] Brooks, Rodney A. "Elephants don't play chess." Robotics and autonomous sys. 6.1-2 (1990): 3-15.
[2] S. Thrun, W. Burgard, and D. Fox, Probabilistic robotics. Cambridge, MA: MIT Press, 2010.