February 28, 2020

Indy Autonomous Challenge

Ariel Team

Ariel University, Israel

Introduction

We are pleased to submit our entry to the Indy Autonomous Challenge competition. Our team consists of students and faculty members of Ariel University, from several departments in engineering and computer science. In addition, our team includes enthusiastic volunteers from outside the university. We are bringing many years of experience in this field, mostly developing advanced algorithms to drive high performance autonomous vehicles. We are excited by the opportunity to put to practice our experience and algorithms in this pioneering challenge, which aims to push autonomous driving to new highs.

1. The Team

The team consists of faculty members, students and engineers from Ariel University, volunteers from other institutions, and representatives of sponsoring companies. The key members of the team include:

Prof. Zvi Shiller: Head, Department of Mechanical Engineering and Mechatronics, Ariel University, head of the Robotics and Autonomous Vehicles Laboratory (RAVLab). Areas of specialization: time optimal motion planning, vehicle dynamic stability, motion planning in dynamic environments.

Prof. Boaz Ben Moshe: Head, Department of Computer Science, Ariel University. Co-director of the Kinematics and Computational Geometry Laboratory (with Prof. Nir Shvalb). Specializations: navigation, localization and sensor-fusion.

Prof. Dror Rubinstein: Associate Professor, Department of Mechanical Engineering and Mechatronics. Specializing in multibody dynamics as applied to road and off-road vehicles.

Prof. Dov Oster: Associate Professor, Department of Mechanical Engineering and Mechatronics. Previously he served as Director of Systems Engineering at Israel Aerospace Industries, MLM division. He will contribute to the Indy autonomous challenge in Systems Engineering, Project Management, Testing and Evaluation.

Dr. Amos Azaria: Senior Lecturer, Department of Computer Science. Head of the data science and artificial intelligence center at Ariel University. Areas of specialization: machine learning, applied to motion planning of autonomous vehicles...

Dr. Shlomi Hacohen: Lecturer, Department of Mechanical Engineering and Mechatronics. His expertise is in the field of robotics and control as related to decision making under uncertainty for motion planning of autonomous vehicles and multi-agent systems, non-linear estimation methods applied to positioning problems.

Dr. Oren Musicant: Senior Lecturer, Department of Industrial Engineering and Management. Specializing in human machine interfaces as applied to autonomous vehicles.

Gabriel Hartmann: Doctoral student. Specializing in vehicle control using deep learning.

Tsury Messika: Master student. Department of Mechanical Engineering and Mechatronics. Working on sensor fusion and perception for autonomous vehicles.

Meir Shabtai: VP for Robotics and Autonomous Systems, Israel Aerospace Industry (IAI).

Zohar Golan: CTO, Robotics and Autonomous Systems Robotic Division, Israel Aerospace Industry (IAI).

Leon Altarac: Lieutenant Colonel (retired), an experienced system engineer who until recently was commanding the Robotics R&D unit in the Israeli Army.

Sanjeev Sharma, Founder and CEO of Swaayatt Robots; alumnus of the RAVLab. Developed a full-scale autonomous vehicle, including perception, motion planning, control. Will join the team as a software engineer. n the software development stage. Mainly for perception and how to integrate perception and planning. Swaayatt Robot is developing autonomous driving technology that works in highly stochastic traffic dynamics and in unstructured environmental conditions, using off-the-shelf cameras for perception.

2. Past experience with automation/autonomous vehicles/simulations

Our team brings vast experience in robotics and autonomous vehicles.

Prof. Zvi Shiller has over 30 years of experience in developing algorithms for autonomous driving in challenging environments. This includes motion planning of off-road vehicle, stability analysis of ground vehicles, and obstacle avoidance in dynamic environments. While at UCLA, he was supported by PATH to develop algorithms for emergency maneuvers of road vehicles, worked with FMC on the control of autonomous tracked vehicles, worked with NASA JPL on an efficient motion planner for Mars Rover, and after returning to Israel, worked with GM (Detroit) on collision warning algorithms.

Prof. Boaz Ben-Moshe is an expert in navigation algorithms with several granted patents related to GNSS accuracy improvement and many related papers. He designed and developed several autonomous platforms. During 2018 and 2019 his navigation team won first and second places in the navigation challenges of IPSN 2018, IPIN2018, IPIN2019.

Dr. Amos Azaria has published over 50 papers in artificial intelligence, machine learning and human-agent/vehicle interaction; some of the work was done in collaboration with several companies including general motors (GM). Some of his recent work focuses on autonomous driving at high speeds while avoiding unstable situations using reinforcement learning (model-free and model-based), which is highly related to the Indy autonomous challenge.

Prof. Dror Rubinstein is a world expert on vehicle dynamics. He developed dynamic simulations of road and off-road vehicles. His methods are now used in leading multibody simulations.

Sanjeev Sharma has 10 years research experience in the field of motion planning and decision making under uncertainty. Over the past 5 years his research spanned over all the key technology fronts in autonomous driving, i.e., planning, perception and localization. He received numerous awards, including Leading 40 Under 40 Data Scientist Award (2019) in India, and 51 Most Impactful Smart Cities Leaders Award (2019) Globally. He will put his unique experience to practice by helping us develop our perception module and integrate it with the other modules into a robust vehicle controller.

Prof. Dov Oster has vast experience in ground and flight testing of airborne systems while serving as director of engineering at IAI, MLM division. He was also a program manager and chief systems engineer of a project aimed at transforming a Hummer vehicle into an autonomous vehicle.

3. Existing facilities and infrastructure

We are currently in the process of converting a commercial passenger car (KIA Niro) into an autonomous vehicle. Called **Mobile-Lab**, it will serve as a testbed for our algorithms and vehicle-sensors integration. The **M-Lab** is instrumented with sensors that include four cameras, a Velodyne Lidar, and an Applanix GNSS device.

The Mobile-Lab vehicle

We are using Autoware with ROS as a middleware to read sensors (cameras, Lidar, GNSS), run algorithms for motion planning, localization and perception. It is running the vehicle controller and is integrated with a photo-realistic dynamic simulator (LGSVL).

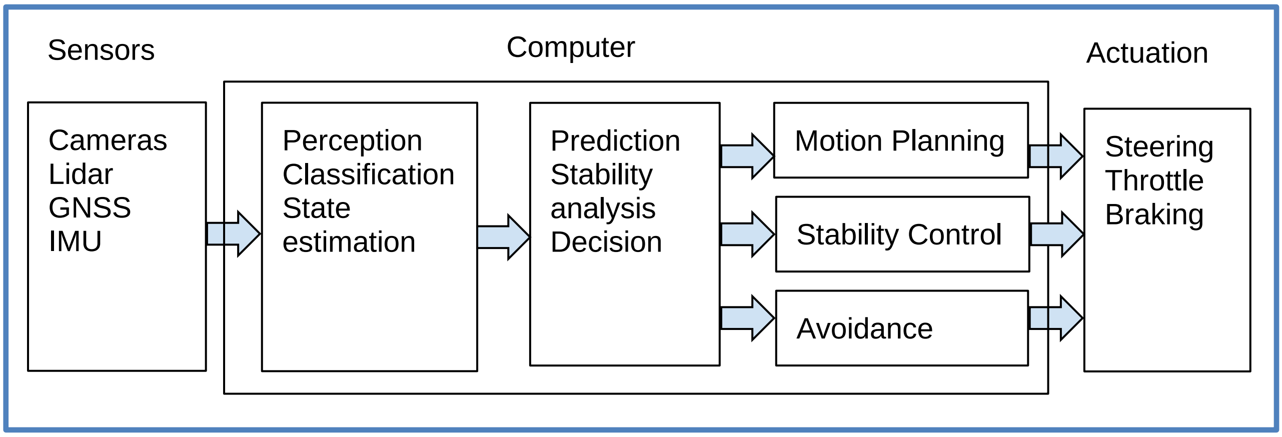
We have access to an advanced dynamic simulation, Altair MotionView, which is a user-friendly multibody modelling environment. Coupled with MotionSolve, it provides a high-fidelity vehicle dynamic simulation.

We have access to an HPC (High Performance Computing) cluster with 30 GPUs, worth over $1M, purchased by the university for deep learning and other uses. It will be used for this project.

4. Plans for competing in the Competition:

<u>Software architecture</u>

The software running the autonomous vehicle will consist of independent modules/functions, as outlined in the following block diagram:



The perception module identifies objects and estimates their velocities. The RTK-GNSS and IMU units are used to determine the vehicle state. The next module predicts the vehicle trajectory from its current state. It then analyses the vehicle dynamic stability.and predicts potential collisions with the neighboring vehicles. This module chooses the next maneuver, which either executes an obstacle avoidance maneuver, executes a stabilizing maneuver, or plans the next optimal trajectory segment from the current state. The selected action is then translated to steering and acceleration commands. This process is repeated at set time intervals. A variant of a particle filter will be used for implementing the sensor fusion and approximating the current state of the vehicle.

Motion planning

We will use our global time optimal motion planner that generates high speed trajectories from a given state to a goal state. It is based on a three-step approach: i) selecting promising path candidates in the configuration space, ii) computing the time optimal speeds along the selected paths, and iii) selecting the best trajectory (path and velocity profile). This process is repeated at given time intervals from the current state to a new goal. This planner takes into account vehicle dynamics, road geometry, and tire/ground interaction. It ensures that the vehicle maintains its dynamic stability, i.e. it does not slide or rollover. Sliding is expected to be dominant due to the low profile of the race car and the downward aerodynamic forces that applied on the vehicle at high speeds.

The head to head competition requires special attention to avoiding collisions between cars that maneuver at high speeds. To this end, we will implement our efficient algorithm for obstacle avoidance in dynamic environments. It is based on mapping the moving obstacles into the so called “velocity obstacles”, which greatly simplifies the selection of safe avoidance maneuvers. We will modify both algorithms (time optimal planner and obstacle avoidance) to account for the high speeds, yet low relative speeds, of the neighboring vehicles.

Model based machine learning

We have recently developed a module that allows driving at high speeds without losing dynamic stability. This module is based on model-based reinforcement learning. We plan on using this module in this project.

Perception and Localization

For perception, we will be using open source modules to identify road boundaries, moving vehicles and their velocities. Depending on the available sensors in the official vehicle, we will be using high precision GNSS for localization, tracking landmarks (that will be learned over repeated runs along the track) and matching Lidar scans to an HD map (e.g. ndt matching). The fusion between the various sensors will provide a more accurate and reliable localization.

Testing

Our software will be first tested in the LGSVL simulator. We then plan to test the software on the M-Lab by first driving through an obstacle course in an open test field. We will then drive the vehicle on a professional race track on one of the three commercial race tracks that are available in Israel.

Project management

The project will be managed by an experienced system engineer. The development team will be divided into small groups, each consisting of a few students, volunteers, and a faculty member. Each group will be responsible for developing one software module or another task as defined by the project manager. The project manager will coordinate the work of the groups and lead the integration of the individual modules into the vehicle control system. The software integration will be supervised by a professional computer engineer.

5. Budget

The total budget of $1,300,000 covers the cost for developing an inhouse test vehicle, related sensors and lab equipment, field tests of the vehicle on commercial race tracks, a one day race car training for key members of the team, salaries of three full time engineers, 5 graduate students, 20% of the salaries of 4 key faculty advisors, and travel to the US for hackathons, track practice days, and competition.

Item	Cost $
Test Vehicle	150,000
Sensors	60,000
Computers	50,000
Computer services	10,000
Scientific Software	10,000
Field tests	50,000
Race car training	20,000
Project manager	150,000
Computer engineer	150,000
Software engineer	150,000
5 Research students	250,000
4 faculty advisors	120,000
Travel/accommodation	100,000
Miscellaneous	30,000
Total	**$ 1,300,000**

6. Fundraising

We started this project with a generous fund from the Israeli national institute for transportation innovation for the acquisition and instrumentation of the Mobile-Lab (KIA Niro passenger car). We will be approaching the ministry of science and the ministry of transportation to support travel and hardware cost. Part of the equipment will be borrowed from existing research projects. The cost of students and faculty and partial cost of the engineers will be covered by Ariel University. Additional funds will be solicited from potential sponsors.

7. Sponsors/partners

So far, we managed to secure partnerships with Cogniteam, Vayavision and, Swaayatt Robots and sponsorship from Applanix. We are in serious negotiations with Israel Aerospace industry (IAI) for a substantial sponsorship. We are planning to solicit sponsorships from major car companies that have presence in Israel.

Contact

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