Texas A&M Autonomous Indy Race Team – White Paper

Texas A&M team is composed of faculty, graduate and undergraduate students, and local technology firms. The team is built around the faculty experience in developing algorithms for self-driving cars in rural roadways and complex driving conditions where HD maps are not available.

The Team

Ivan Damnjanovic, Ph.D.

Dr. Damnjanovic is an Associate Professor in Department of Civil Engineering at Texas A&M University. He graduated from University of Texas at Austin in 2006 with a PhD. degree in transportation infrastructure modeling. His core expertise is in risk analysis, project risk management, and other project-related studies that rely on stochastic modeling of complex systems. Two of his previous research efforts directly relate to this completion. First, Dr. Damnjanovic has studied free traffic flow speed in context of roadway geometric conditions. This research has defined procedures how to adjust highway geometric characteristics to reduce the propensity for traffic crashes; more specifically focusing on identifying "black spots." Recently, Dr. Damnjanovic was involved in a fundamental research to identify early signs of evolving risks and provide warnings. This research was conducted during his stay at the Centre for Risk Management and Societal Safety (SEROS) in Norway and involved a number of different industry segments including construction, oil and gas, transportation and others. Dr. Damnjanovic leads a College-wide research and education outreach in engineering project management. This multi-disciplinary program emphasizes project teaming, technology development, and collaboration with industry.

Roles and Responsibilities: Dr. Damnjanovic will lead the overall effort and coordinate different functions.

Stephanie Paal, Ph.D.

Dr. Stephanie Paal is Assistant Professor in Civil Engineering at Texas A&M University. Her research expertise is at the intersection of artificial intelligence and civil engineering. She has significant background in emerging technologies such as machine vision, machine learning, and unmanned aerial systems.

Roles and Responsibilities: Dr. Paal will be technical advisor for perception algorithms.

Reza Langari, Ph.D.

Dr. Reza Langari is Professor of Mechanical Engineering and J. R. Thompson Department Head Chair, Engineering Technology and Industrial Distribution at Texas A&M University. His expertise it is in computational intelligence and mechatronics with application to robotics and automotive control. He has worked on vehicle dynamics and control problems ranging from rollover stability of heavy vehicles to hybrid and electric vehicle energy management to autonomous vehicles.

Roles and Responsibilities: Dr. Langari will be technical advisor for control algorithms.

Byul Hur, Ph.D.

Dr. B. Hur received his B.S. degree in Electronics Engineering from Yonsei University, in Seoul, Korea, in 2000, and his M.S. and Ph.D. degrees in Electrical and Computer Engineering from the University of Florida, Gainesville, FL, USA, in 2007 and 2011, respectively. In 2017, he joined the faculty of Texas A&M University, where he is currently an Assistant Professor. He worked as a postdoctoral associate from 2011 to 2016 at the University Florida previously. His research interests include Mixed-signal/RF circuit design and testing, measurement automation, and educational robotics development.

Roles and Responsibilities; Dr. Hur will be advisor for system integration.

Dez Song, Ph.D.

Dr. Dezhen Song is currently a Professor of Computer Science and Engineering Department, Texas A&M University, Song has over eighteen years of experience in developing perception and vision systems for robots and autonomous vehicles. Song's team is very experienced with different sensors such as regular cameras, infrared cameras, night vision cameras, inertial sensors, LiDAR, and radar and has unique expertise in sensor fusion. Song has published 1 monograph and 86 journal and conference papers. Song's team is very experienced in robot navigation and scene understanding. Song co-lead the blue team to develop the world's first autonomous motorcycle to enter DARPA Grand Challenge (DGC) 2005 as a semi-finalist. It is worth noting that members of the blue team started a company in Berkeley after DGC and is responsible for building self-driving cars and streetview cars for Google. Song also has extensive work on understanding and recognition of buildings and natural objects. With many years of experience and lessons learned, Song's team is well positioned to take on new challenges in this project.

Roles and Responsibilities: Dr. Song will advisor for perception and testing.

Subsidized Graduate Research Assistant (GRA)

To address the multidisciplinary needs of this project, each department involved in this proposal will assign a GRA to this competition, while the total time spent on this competition by all GRAs will be equal to at least one full time GRA. Upon availability of funding from our team sponsors, this number will increase to enhance the quality of research and education. The selected graduate students should have the following qualifications:

- Background: The GRAs selected to participate in this competition will be chosen from doctoral students in the departments of Computer Science, Computer Engineering, and Civil Engineering.
- Expertise: The GRAs should have expertise in at least two (preferably more) of the following areas: computing (to work with sensors and computing platforms), machine learning (for sensing, object recognition and tracking, and mission planning), control (for control and diagnostics and functional safety), and transportation engineering basics (to ensure safe and reliable control of the vehicle in response to drivers, pedestrians, and bikes' behavior).
- Doctoral candidate: The GRAs should have passed the respective departments' qualification exams to ensure that they will stay with the team during the entire competition.

Roles and Responsibilities of GRAs

The selected GRAs are responsible for the following tasks:

- Providing support to undergraduate teams: The selected GRAs are responsible to work on one-on-one basis with the participating graduate students, guide them through hardware installation and calibration, assist them with software development and debugging, and participate in tests to assess the performance.
- Coordination (team level): The selected GRAs are responsible for coordinating the project tasks between undergraduate students. GRAs should monitor the performance and assign the tasks based on students' interests and capabilities. This requires close interaction with all team members.
- Coordination (project level): The selected GRAs are responsible to facilitate the communication among team members and the PIs. The GRAs will deliver daily updates and weekly reports on the progress of the team to the PIs. The PIs will meet with GRAs on a weekly basis to assess the progress and plan for the upcoming week. These weekly meetings are in addition to the PIs weekly meetings with undergraduate students and GRAs.
- Organizing Workshops: To keep track of the competition goals and to assess the progress towards them, GRAs will organize and chair a workshop every quarter. As part of these workshops, every participating undergraduate student at Texas A&M University will present their progress, exchange ideas, and get feedback from PIs, GRAs, and other undergraduate students. The workshop also serves as an outreach to attract interested individuals from all engineering disciplines.

Texas A&M University Facilities

Texas A&M Engineering is the largest public research, technology development and education organization in the US, a component of the Texas A&M University System, consisting of the Texas A&M Transportation Institute (TTI), the Texas A&M Engineering Experiment Station (TEES), the Texas A&M Engineering Extension Service (TEEX) and the College of Engineering of Texas A&M University, which enrolls more than 18,000 students and with more than 500 faculty members.

Texas A&M University has identified automation and autonomous systems as one of the key research areas. Accordingly, several new initiatives and infrastructure has been dedicated to this area of research. Recently, TTI and TEES led the Texas AV Proving Grounds Partnership that was selected by U.S. Department of Transportation (USDOT) as one of the 10 nationwide automated vehicles proving grounds. Texas AV Proving Grounds Partnership is focused on facilitating and motivating a safe transformation of new mobility and safety solutions, expanding capacity, and providing reliable means of transportation to disadvantaged people.

The Texas A&M University facilities that will be used throughout this competition are as follows:

The Texas A&M RELLIS Campus is a 2,000-acre campus being transformed into a high-tech, multi-institutional research, testing, education, and workforce development campus (See Figure 1). The RELLIS Campus is conveniently located adjacent to State Highways 47 and 21, a 15-minute drive from Texas A&M University's main campus. These proving grounds have long been a place where Texas A&M has conducted world-class research, technology development and workforce training in a variety of areas such as vehicle safety, traffic engineering, law enforcement training, robotics, connected and autonomous vehicles, and unmanned aerial systems.

Figure 1. Texas A&M RELLIS Proving Ground

The existing facilities at the RELLIS Campus include 6-miles of paved runway test tracks and proving grounds, 3 miles of urban grid roadways, a toll gantry test bed, a roadway safety device test bed and crash test proving ground, pavement marking proving ground, and automated pavement assessment equipment proving grounds. New improvements underway at the RELLIS Campus include seven new engineering research buildings and test beds that will provide state-of-the art research and testing capabilities, and encourage the development of additional public and private sector research facilities adjacent to the Texas A&M University System's (TAMUS) facilities at the RELLIS Campus. The primary research focus areas will include robotics, driverless and connected vehicles, advanced manufacturing, large-scale testing, as well as smart cities technologies in areas such as smart power grids, water systems, and parking.

Brazos HPC Cluster

Brazos, a major computing cluster at Texas A&M University, is designed to meet the high-throughput computing needs of A&M's computational scientists and engineers. Though capable of executing modest MPI applications, Brazos is optimized for handling large numbers of single-node computations. This form of computing is referred to as high-throughput or capacity computing.

- The computing power of Brazos comes from 309 computing nodes, with processors ranging from quad core Intel Xeon (Harpertown) and AMD Opteron (Shanghai), to 8-core AMD Opteron (Bulldozer) with 16GB to 128GB per node. Total peak performance is about 31.3 TFlops with a total of 10.1TB of RAM.
- Access to Brazos is via a login nodes load balanced using round-robin DNS. User home directories are supported by a 5TB NFS file system. Data storage is supported using the Fraunhofer Filesystem on a 241TB storage array running on 7 storage nodes. Operating software for Brazos includes the Linux operating system, GNU and Intel compilers, SLURM batch scheduler, several MPI and linear algebra packages, and numerous applications.

The compute nodes and servers of Brazos are connected internally via a modular switch, with Gigabit Ethernet connections to each compute node and 10GbE connections to the login node and the data

fileservers. The login nodes are connected to the Science DMZ network with 10GbE. The networking fabric for a large portion of the Brazos cluster is DDR Infiniband.

Machine Shop

Complete with mills, lathes, drills, presses, and full-time dedicated personnel to assist in the design and construction of custom-made equipment.

Texas A&M University Library

The Texas A&M System libraries including engineering, science and medical sciences libraries maintains an outstanding portfolio of prints and electronic resources, including 45,000 journals and over than 1400 databases. The Texas A&M System libraries offers more than 5 million volumes and 1.5 million e-books and is home to the University Writing Center, the Map & GIS Library and a Digital Library that provides support to the scholarly activities of our faculty. The Office of Scholarly Communication (OSC) serves the research and scholarly support needs of Texas A&M faculty, graduate students and other campus scholars through modern, web-based publishing and repository services.

Traffic Simulation Tools

PIs have developed traffic simulators over previous projects and plan to leverage this software for current projects. PIs have developed simulators that integrate transportation and communication of connected vehicles and driver behaviors. These simulators will be leveraged and enhanced to carry out the proposed work.

Competition Strategy: Research and Education

Graduate and undergraduate students are at the core of this competition and selecting interested, enthusiastic, knowledgeable, and responsible students is the key to constitute a competitive team. Moreover, the multidisciplinary nature of designing and operating autonomous vehicles requires a diverse and versatile team that can bring different expertise to the design process. To ensure that the competition team has all the above qualifications, the following three mechanisms will be used to select participants in this competition:

- College-wide graduate-level course: In coordination with all the participating departments in this competition as well as with other departments within the College of Engineering at Texas A&M University, a college-wide course will be developed. Interested graduate students from all disciplines can apply to participate in this design course taught by all the team members. Students will be selected based on the project needs, their abilities, and their interest in this research.
- Independent study courses: Independent study courses will be offered to attract interested students. Since graduate courses are designed for graduate students, independent study opportunities are critical to attract undergraduate students. Junior and senior students are the key to handling student rotation throughout the entire three-year competition.
- Elective stack courses: Stack courses (courses that both graduate and undergraduate students can register for) are another key element in assembling a team. These courses provide both GRAs and undergraduates to learn the basics of working on different aspects of designing and operating autonomous vehicles. Moreover, these courses, similar to the independent study

courses, provide the opportunity to attract junior and senior students to participate in this competition.