Round 1: Launch

1. **Team introduction:**

We are Team KAIST, consisting of 10 graduate students from the Unmanned Systems Research Group advised by Professor David Hyunchul Shim.

Our team is dedicated to the development and validation of cutting edge technologies for highly autonomous vehicles. We have developed various key technologies and algorithms related to unmanned systems. We're not just focusing on software algorithm design, but we're developing from hardware system that make up a system.

Our lab's autonomous vehicle research began in 2009 when we signed up for Hyundai Motor Company's Autonomous Vehicle Challenge. For this, we developed a complete set of in-house technologies such as low-level vehicle control, perception, localization, and decision making.

We have accumulated a plenty of first-hand experiences of developing numerous autonomous vehicles with the support of domestic companies such as Hyundai Motor Company, Samsung, LG, NAVER and so on. In 2017, with in-house solutions, our autonomous vehicle platform "EureCar" was authorized by the Korean government to lawfully conduct autonomous driving experiment on the public road.

We have published many papers in top journals and conferences such as IROS, ICRA, AIAA Scitech, and Journal of Field Robotics. Also, our team has participated in a number of domestic and international competitions such as Hyundai Motor Company's Autonomous Vehicle Challenge. In particular, our team won the inaugural 2016 IROS autonomous drone racing and ranked second in 2018 IROS racing. We also competed in 2017 MBZIRC, ranking fourth in Mission 2 and 3, and fifth in Grand Challenge. We are now participating in DARPA Subterranean Challenge as a joint team member with NASA JPL, MIT and Caltech. Most recently, we won the first round of Lockheed Martin's Alpha Pilot and won the third place in 2019 Hyundai autonomous driving competition.

You can find more about us in the website and Youtube channel:

Website : http://unmanned.kaist.ac.kr/bio.html
Youtube : https://www.youtube.com/channel/UCw34sS55VAr4yJr6Izd8BbA

2. Team members:

a. Advisor

David Hyunchul Shim received his B.S. and M.S. degrees in mechanical design and production engineering from Seoul National University, Seoul,Korea, in 1991 and 1993, respectively. He received his Ph.D. in mechanical engineering from the University of California Berkeley, Berkeley, CA, USA, in 2000. Between 1993 to 1994, he was associated with Hyundai Motor Company, Korea. From 2001 to 2005, he worked with Maxtor Corporation, Milpitas, CA, USA. From 2005 to 2007, he was with the University of California Berkeley as a Principal Engineer. He joined the Department of Aerospace Engineering, (KAIST), Daejeon, Korea in 2007 and is currently Full Professor at School of Electrical Engineering. He is also serving as Director of KAIST Robotics Institute and Director of Korea Civil RPAS Research Center. His research interests include dynamics and control, unmanned vehicle systems, and field robotics

b. Team Leader

Chanyoung Jung received his B.S. degree from Department of Electrical Engineering, Kyunghee Uni-versity, Yongin-si, Korea, in 2016. He received M.S. degree at the Division of Future Vehicle in the Unmanned System Research Group Laboratory, Department of Electrical Engineering, School of Mechanical Aerospace and Systems Engineering, College of Engineering, Korea AdvancedInstitute of Science and Technology (KAIST). He is currently pursuing his Ph.D. degree at the Department of Electrical Engineering, School of Mechanical Aerospace and Systems Engineering, College of Engineering, Korea AdvancedInstitute of Science and Technology (KAIST). His research interests include real-time autonomous vehicle control and software architecture for unmanned systems.

c. Members (to be added later)

Daegyu Lee received his B.S degree from Department of Automotive Engineering, Kookmin University, Seoul, Korea in 2018. He received M.S degree at the Division of Future Vehicle in the Unmanned System Research Group, Korea Advanced Institute of Science and Technology (KAIST) in 2020. He is currently a Ph.D student at the same research group that received a master degree under supervision of David Hyunchul Shim. His research interests are in the field of control, navigation, behavior planning and system integration of unmanned vehicle system.

Seungwook Lee received B.S degree from Department of Mechanical Engineering, Hanyang University, Seoul, Korea, in 2018. He is currently on his M.S at the Robotics Program, Department of Electrical Engineering in Korea Advance Institute of Science and Technology(KAIST). He has participated in the 14th Autonomous Vehicle Competition held by the Hyundai Motor Group as a member of the team Eurecar in 2019. He has also deeply involved in developing the KAIST USRG Tram. His research interests include autonomous driving software architecture, vehicle control and deep learning.

Hyunki Seong received his B.S degree from the Department of Mechanical Engineering, Inha University, Incheon, Korea, in 2019. He is currently working on an M.S degree in Robotics program, Department of Electrical Engineering in Korea Advanced Institute of Science and Technology(KAIST). He has participated in a project for implementing an End-to-End Learning-based Lane-Keeping System for real-world vehicles. His research interests are in the area of Autonomous driving and Reinforcement learning.

3. History of our team:

Our lab has developed various advanced autonomous vehicles since 2007. In 2009, we started developing autonomous vehicles using a commercial street-legal automobile initially for Hyundai Motor Company's Challenge. We then expanded our research for highly autonomous driving technologies aiming for "Level 5", i.e., fully autonomous driving without any human intervention. We have collaborated with a number of well-known companies such as Hyundai, Samsung, NAVER to name a few.

As we pioneer the autonomous vehicle research, we had to develop the entire set of technologies from low-level control to high-level perception and decision making. We have also actively adopted deep-learning based approach since 2015. We have successfully implemented road segmentation using SegNet using CNN. Only using our own technologies, we have developed a number of autonomous vehicles and were able to obtain multiple certificates for legal road testing, authorized by Korean government.

2009 → **Now**

Each platform was configured with a different set of sensors and computing equipment, depending on the vehicle and operating environment. The yellow car in the picture is our first self-driving car approved by the Korean government to drive autonomously on the public road. We are focusing on developing autonomous driving systems in complex urban environments using the various types of platforms.

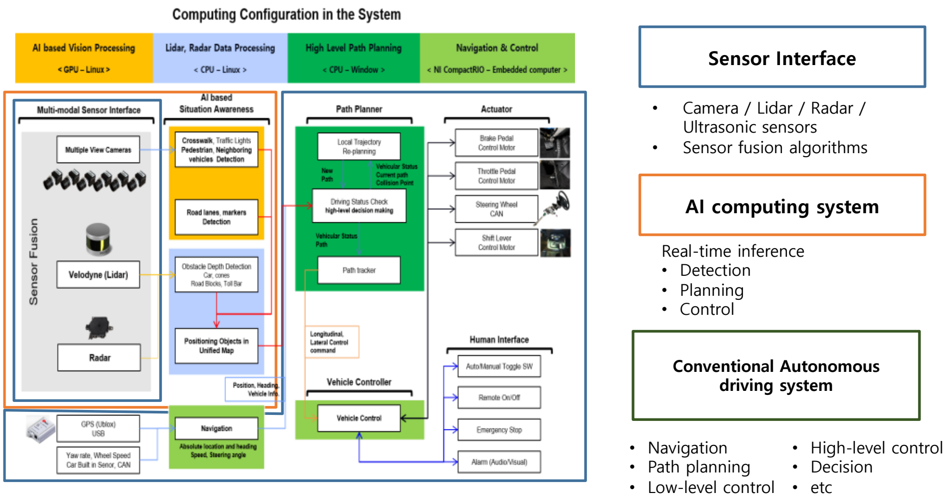
Based on our own self-driving technologies, we have participated in a number of domestic autonomous driving competitions. We participated in the Hyundai Motor Company's Autonomous Vehicle Challenge (AVC) in 2010, 2012, 2014. 2017 and 2019. In particular, in 2017, the competition was held in Inje speedway racing circuit, where the vehicle was required to drive around the track as fast as possible. Our team's car (Hyundai Avante) for this competition was able to drive as fast as 140 km/h and this result was covered by the program, *Daily Planet,* produced by Discovery Channel Canada in 2017 (as shown in the image above).

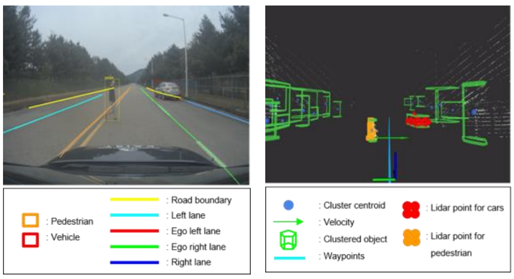
At the most recent competition, V2X communication technology was utilized and we developed technologies such as emergency stop for protecting pedestrians in the city center, compliant with various traffic laws, route generation, overtaking and yielding. In the final round, our autonomous vehicles succeeded in all missions and outperformed other competing teams with the fastest lap times.

Other than the street-legal vehicles, we are also developing other self-driving vehicles such as fully autonomous trams and delivery carts. These vehicles share quite a large subset of on-street self-driving cars, they also pose their own unique challenges. The common challenges of these are the full sustained autonomy. We are applying advanced algorithms for perception, localization, and decision making to address the challenges of these problems.

4. Our autonomous driving technology

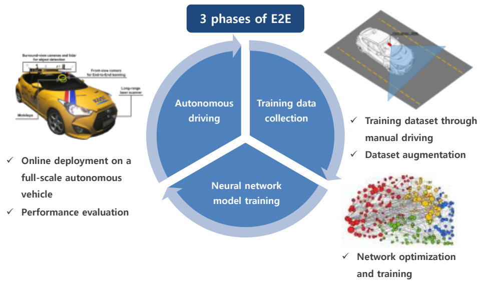
Our autonomous driving system can be categorized into three major compoents: perception, planning and control. Considering the characteristics of the algorithms that make up each module, it operates in a distributed computing system. The figure below shows a schematic of our autonomous vehicle system.





Since 2015, we are actively using deep learning algorithms, especially in perception subsystem. Contextual information extracted from multi-modal sensory data(gathered via camera, lidar, radar, GPS, IMU and so on) is further forward to planning subsystem. The planning module is responsible for decision making and planning required for autonomous driving such as lane change determination and trajectory planning, emergency stops, and velocity command generation and etc. Finally, the result from the planner is fed into the controller to follow the planned high-level command.

In addition to the conventional autonomous driving system consisting of a series of perception, planning, and control modules, we developed and verified the possibility of an end-to-end deep learning based autonomous driving approach that replaces a complex system with one single AI network.



Nowadays we are researching and developing various algorithms and approaches for real-world working solution. The stability and performance of in-house technologies are clearly validated through integration into full-scale autonomous vehicles, not just simulations.

5. Preliminary Plans for Indy Autonomous Car Competitions

- Technical side

So far, our autonomous driving technology has been mainly developed for the purpose of autonomous driving in public roads. However, we also have sufficient experiences for high speed autonomous driving on a race track as mentioned above. A new challenge in Indy Autonomous Competition is even faster speed and overtaking maneuver in the Indy Oval Circuit. We are confident that we will be able to develop our own approach to handle these challenges using advanced perception, localization, and decision making as outlined below.

a. **Control**
Obviously, one of the immediate challenge is how to exploit the full dynamic capability of the fabulous Indy car, which can drive as fast as 240km/h and sustain a very high g-force turn during the repeating 90degree left turns of the oval course. We are investigating a number of approaches to address this problem, including Model Prediction Control (MPC) and Deep Reinforcement Learning(DRL). We are currently testing these algorithms using scaled RC cars approach. First, we plan to estimate the dynamics model of the Indycar through the high-quality simulator provided in Round 3 and construct the MPC algorithm based on it. Then, we will use the simulator provided by the organizers to validate and then evaluate the candidate algorithms. Before testing on Indy cars, we will test it using our own vehicles desirably on a race track. Finally, after fully validated, we will test the algorithm on the actual Indy car when we receive it in May 2021.

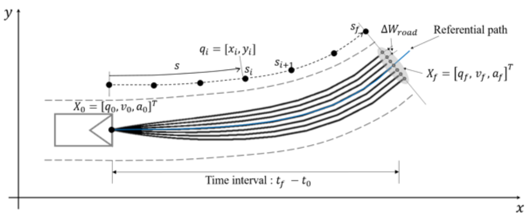
b. Perception

For perception, our team plans to actively utilize artificial intelligence technology. Specifically, image sensors will be used. The precise position and posture of the target vehicle in the image will be determined by applying sensor fusion algorithms between camera with lidar or radar which were developed before. To train the deep neural networks, training data will be acquired in various environments such video source and game simulator. More specific strategies will be planned in consideration of the vehicle setup and the sensor and the computing configuration.

Planned simulation tools
Left : CARLA
(open simulator)
Right : F1 2017 game

c. Planning

Overtaking is the most important function computed in the planning subsystem. To this end, we plan to expand the lane changing algorithm developed for urban autonomous driving. The existing lane changing algorithm is designed to create several paths which are collision-free, reliable and feasible in terms of vehicle kinematics and dynamics (Cost based decision making as shown below). By applying a similar process, it is planned to newly define the cost function for overtaking trajectory generation which is suitable for the racing vehicle. The performance and stability of the algorithm will be verified in advance through simulation, and the field experiment will be carried out by applying the algorithm to existing the full-scale autonomous vehicle.



$$C = k_j J_t + k_c g(t) + k_R \kappa_{candidate}$$

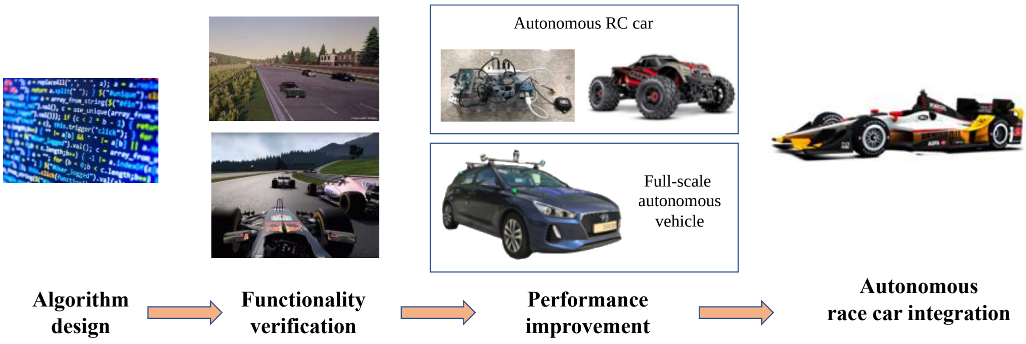
$$\text{where} \quad J(p_{candidate}(t)) = \int_{t_0}^{t_1} \dddot{p}^2_{candidate}(t) d\tau$$

$$g(t) = \begin{cases} infinite & \text{if } \min_i |p_{candidate}(t) - \mathcal{O}_f| < d_{collide} \\ \frac{1}{\min_i |p_{candidate}(t) - \mathcal{O}_f|} & \text{else} \end{cases}$$

$$\kappa_{candidate} = \left| \frac{\ddot{p}_{candidate}(t)}{(1 + \dot{p}_{candidate}(t)^2)^{\frac{3}{2}}} \right|$$

d. System integration and validation

While we have ample experiences on automating a regular vehicle from scratch, we are informed to receive fully customized Indy car that are already equipped with low level control systems and standard sensor packs. This will greatly reduce the time, cost, and risk of customization although our team has sufficient experiences in this field. We will focus on the development of more high-level tasks such as perception and decision making. The figure below illustrates our team's strategy for this challenge.



6. Logistics

It is not an easy undertaking to participate in challenges on advanced topics, especially when they are held abroad. As a matter of fact, we have successfully participated in a number of domestic and international competitions. Specifically, we have participated in 2017 and 2020 Mohammed Bin Zayed International Robotics Competition (MBZIRC). We have learned a great deal not only on the technical side, but on the logistic side as well. We have successfully managed the logistics to send robots, backup parts, tools, and materials, most importantly the actual team members to participate in the event. We have also participated in 2019 Lockheed Martin's Alpha Pilot, which demanded 6 separate travels (two workshops and four separate races) and one extended testing trips (we won 3rd place here). Finally, we are participating in DARPA Subterranean Challenge with JPL, MIT, and Caltech as a Team CoSTAR, which won 2nd place in phase 1. In summary, our lab has ample experiences in participating in international events and we are confident that we will be able to plan for the Indy Autonomous Car Challenge that will last for almost two years.

7. Funding

Our lab is vigorously working on a number of projects supported by government and private sectors. Annual research contract is usually more than 2 million USD in the last few years. Our lab is also affiliated with a number of research groups including KAIST Institute for Robotics, which is supported by our university for advanced research topics that are not currently supported by government or private companies. Thanks to these funding, we will be able to cover the operating cost as well as travel of a number of students to Indianapolis for extended days in multiple occasions.
Other than the existing funding, we will actively seek additional supports from our university as well as private companies such as LG, NAVER, or SK Telecomm, which may find this event highly relevant with their company.

Contact Information

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