AUTONOMOUS VEHICLE CONTROL IN CARLA CHALLENGE

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ABSTRACT

The introduction of Autonomous Vehicles (AVs) in a realistic urban environment is an ambitious objective. AV validation on real scenarios involving actual objects such as cars or pedestrians in a wide range of traffic cases would escalate the cost and could generate hazardous situations. Consequently, autonomous driving simulators are quickly evolving to cover the gap to achieve a fully autonomous driving architecture validation. Most used 3D simulators in self-driving cars field are V-REP (Rohmer, E., 2013) and Gazebo (KOENIG, N. and HOWARD, A., 2004), due to an easy integration with ROS (QUIGLEY, 2009) platform to increase the interoperability with other systems.

Those simulators provide accurate motion information (more appropriate for easier scenes like robotic arms) but not a realistic appearance and not allowing real-time systems, not being able to recreate complex traffic scenes. CARLA (DOSOVITSKIY, A., 2017) open-source AV simulator is designed to be able to train and validate control and perception algorithms in complex traffic scenarios with hyper-realistic environments.

CARLA simulator allows to easily modify on-board sensors such as cameras or LiDAR, weather conditions and also the traffic scene to perform specific traffic cases. In Summer 2019, CARLA launched its driving challenge to allow everyone to test their own control techniques under the same traffic scenarios, scoring its performance regarding traffic rules. In this paper, the Robesafe researching group approach will be explained, detailing vehicle motion control and object detection adapted from Smart Elderly Car (GÓMEZ-HUÉLAMO, C., 2019) that lead the group to reach the 4th place in Track 3 challenge, where HD Map, Waypoints and environmental sensors data (LiDAR, RGB cameras and GPS) were provided.

1. INTRODUCTION

The development of Autonomous Vehicles (AVs) is continuously evolving. At this moment, none organization has proved a robust testing methodology for L4/L5 AV, levels in which the driver is not involved, at least in most driving situations. As reported by the autonomous driving research community, it is due to, in spite of legal regulations defined in terms of L4/L5 levels, a fully-autonomous driving architecture is still years away, not only due to technical challenges but also due to legal and social ones (Maurer, 2016).

Commonly, most part of the systems that conform an AV are based on Artificial Intelligence (AI), which are trained by extracting patterns of real-world scenarios in order to be used in future actions to produce a specific output. This reasoning force to obtain tons of high-quality data, increasing the development time and cost exponentially when applying a physical approach due to the associated cost of the automated vehicles, the cost of the on-board sensors and the huge driving hours supervised by human beings.

Moreover, the progression of computed-rendered AV simulators enables an alternative way to obtain high-detailed information to validate fully autonomous driving architectures on any traffic situation, being able to recreate specific locations, weather conditions or hazardous traffic conditions without putting in danger any human or material resource.

CARLA is a novel hyper-realistic open-source simulator for autonomous driving research based on Unreal Engine 4 (UE4). The simulator provides an ecosystem of interoperable plugins, realistic physics and image quality, composing scenes by using 3D models of static objects, conforming the environment, and dynamic objects such as pedestrians, cyclists or vehicles, which can be controlled to perform any desired situation (Fig. 1).

Figure 1: CARLA traffic junction.

This simulator provides a wide range of on-board sensors, including cameras (RGB, semantic segmentated and depth) and LiDAR, performing the most common AV perception sensors. These sensors are completely adjustable to project needing, being able to modify their location regarding to the vehicle and also their main features, such as pixels width and height, FOV and distortion for cameras, and number of channels, points-per-second and rotation frequency for LiDAR sensors.

Furthermore, these sensors information and other data relative to the dynamic objects in scene are published using CARLA ROS-bridge, a ROS package that allows communications between the simulator and ROS, enabling interoperability with extern systems such as control and perception modules.

Additionally, traffic scenes can be recreated by using ScenarioRunner, a CARLA developed platform based on OpenScenario (JULLIEN, J., 2009) to define environments of a pre-fixed scenario to allow repeatability, defining the town, static and dynamic objects, weather conditions and also driving behaviors to cope with.

2. CARLA AD CHALLENGE

Until now, realistic AV validation systems where only available for large corporations, preventing smaller research groups from testing their autonomous driving architectures. Taking advantage of CARLA simulator features previously described, CARLA launched the CARLA Autonomous Driving Challenge on February 2019 to democratize autonomous driving development.

CARLA AD Challenge is formed by a collection of routes that AD agents, submitted as Docker images, must complete safely, reaching a destination point following a pre-defined route without traffic infractions. The final score of an agent will depend on the percentage of completed route and the infractions committed during the evaluation (Table 1).

Infractions	Discounted points
Invading lane in the opposite direction	2
Invading a sidewalk	2
Running a stop sign	2
Running a red light	3
Hitting the static scenery	6
Hitting another vehicle	6
Hitting a pedestrian	9

Table 1: Discounted points according to AV committed infraction.

During the challenge, the autonomous agents have to cope with traffic situations inspired by the NHTSA typology, including lane merging and changing, negotiation at intersections and roundabouts, following traffic lights and traffic signs as well as dynamic pedestrians, cyclists and other elements. Same routes may be repeated under different weather and obstacle conditions to test the flexibility of the vehicle, being correspondingly weighed on Eq. 1, where performance score is calculated.

Participants could subscribe up to four different tracks, depending on the information needed by their traffic agent, according to Fig. 2. On Track 1, LiDAR point cloud, GPS and cameras are allowed. On Track 2, autonomous vehicle could only use cameras and location to complete the testing. Tracked 3 grants access to HD Map of the environment, route waypoints to achieve destination and all sensors defined in CARLA (LiDAR, cameras and GPS). Track 4 instead only provides a scene layout of the town where the vehicle is driving along with GPS location.

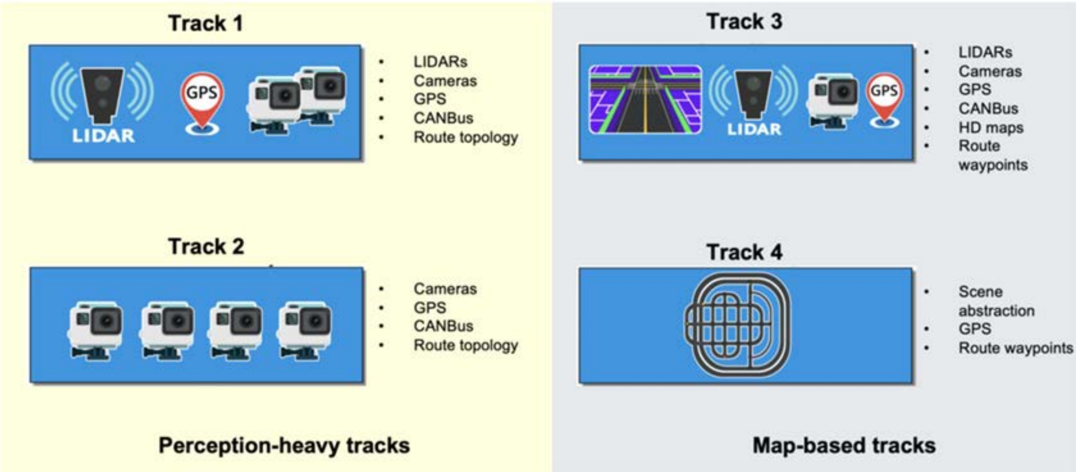

Fig. 2 – CARLA provided sensors information provided on each challenge track.

CARLA AD Challenge started on February 2019, publishing the rules that the candidates would have to follow in order to perform the challenge. The instructions explained how to run CARLA and ScenarioRunner, how to configure it, how to run the evaluation code in order to know the performance of the agent and some tools to analyze and develop car agents.

Later on, online validation stage began, submitting agents code to test their performance on a public server following the challenge rules, allowing for a finest agent tuning than offline stage. Agents must be contained in Docker images in order to be successfully evaluated.

Log files were provided in order to recover information about agent behavior, allowing to reproduce the behavior of the agent during the evaluation tracks in order to know the infractions committed by the vehicle, being able to solve them. Finally, the online testing stage arrived, starting the final evaluation of submitted agents.

In this phase only final score were provided without any log file, not being able to reproduce the behavior undertaken by the autonomous vehicle. The best score achieved by the subsequent agents submitted by the group will be the final score taken into account in CARLA AD Challenge results.

The performance score was calculated following the Equation 1,

$$Score(a) = 1/(R \cdot N) \sum_{i=1}^{R \cdot N} max(100 \cdot C(a, r_i) - I(a, r_i), 0) \quad (1)$$

where a represents the agent under evaluation, C is the amount of route completed for the i-th route, I is the total points discounted due to infractions according to Table 1, R represents the number of repetitions of a route, and N the total number of routes.

3. SUBMITTING CARLA AD CHALLENGE

As described before, CARLA AD Challenge is based on CARLA simulator, which is open-source and constantly evolving. For this reason, submitting to the challenge was a proposal which required much effort and dedication for all our research group.

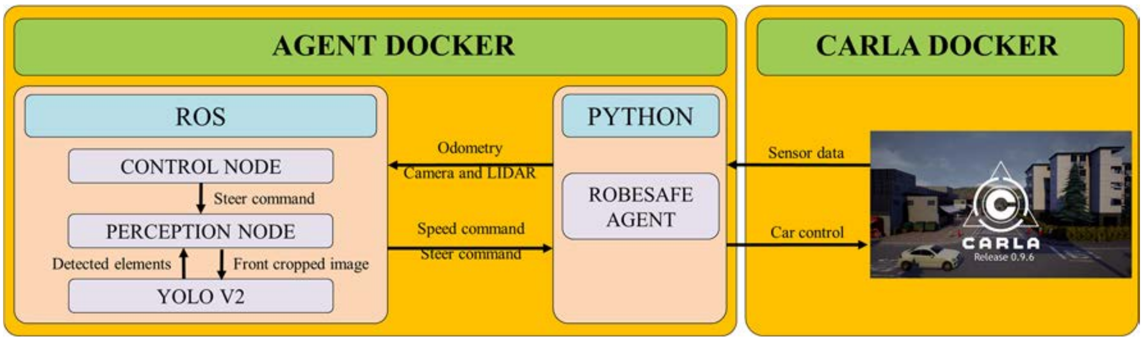

Figure 3: Autonomous agent approach on CARLA AD Challenge.

Since 2016 Robesafe has been developing the Smart Elderly Car, an open-source project to build an autonomous electric vehicle for elderly people to help them with the reduction of their abilities. The Smart Elderly Car was validated both on a real vehicle and V-REP simulator, reproducing use cases and testing its behavior.

When CARLA AD simulator was created, a huge leap in quality was made, freely releasing hyper-realistic simulated environments for autonomous vehicles training and validation. The switching between V-REP and CARLA was necessary to evolve in simulation realism, but it implied the adjustment of all developed systems to this new platform.

The Smart Elderly Car project was based on perception sensors to perceive the surrounding objects, avoiding dynamic obstacles, and GPS and odometry in order to navigate through a specified route.

The map was described using Lanelet 1, defining the context of the External Campus from Universidad de Alcalá.

As CARLA includes a wide range of on-board high-quality perception sensors, the perception module stayed invariable. RGB front camera, along with a YOLOv2 CNN, was used to detect traffic light and its state, vertical and horizontal traffic signs in order to respect traffic rules as well as crossing pedestrians to prevent personal injuries. A specific training was fulfilled in order to detect traffic light state directly as an output from the CNN, saving post-processing time. Also, a top LiDAR sensor was used to detect vehicles inside of the path in order to avoid car crashes.

CARLA simulator planification is based on waypoints, which are a series of points describing the path that the vehicle must follow instead of Lanelet approach, which defines lane edges. In furtherance of overcome this inconvenient, a new controller was implemented, following the waypoints provided by CARLA AD Challenge in Track 3 to successfully complete the route.

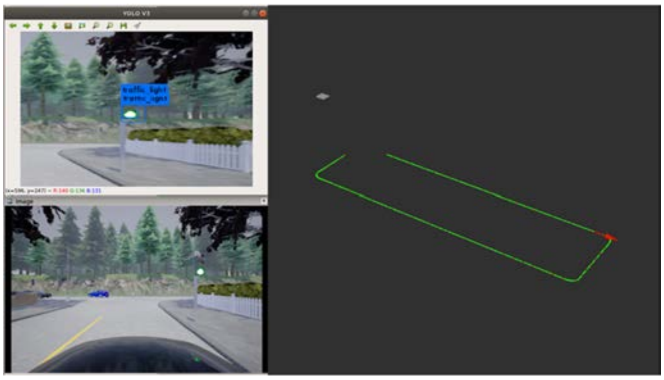

Figure 4: Autonomous agent YOLO image processing and waypoints trajectory.

The main described features can be observed in Fig. 4, showing YOLO image detection a traffic light on the upper left, front image from car dashboard on the lower left and waypoints trajectory (green line) along with car position and orientation (red arrow) on the right side.

4. RESULTS ON CARLA AD CHALLENGE

Moreover than 200 participants organized in 69 teams submitted to CARLA AD Challenge in some of its four available tracks, but only 10 of them could success. More than 5.700 hours of simulation were executed, travelling more than 6.500 km, which evidences the importance of simulation for autonomous vehicles validation.

In Track 3, Robesafe researching group achieved the 4th place over 200 participants worldwide. Furthermore, Robesafe proposal obtained the lowest penalty points among the 5 leaders of the final result, highlighting the correct behavior of the vehicle when moving in a complex urban environment.

The vehicle completed the 60% of the total route under different weather and obstacle conditions while respecting traffic rules and avoiding car crashes and pedestrian collisions.

Ranking	Route points	Infraction points	Total average
1st Team	79.97	13.7	66.83
2nd Team	77.48	11.87	66.05
3rd Team	81.05	20.9	60.47
4th Robesafe	**60.48**	**9.9**	**52.63**
5th Team	48.93	13.67	35.87

Table 2: Results in CARLA AD Challenge Track 3.

4. CONCLUSIONS AND FUTURE WORKS

This paper presented the Robesafe research group approach for an autonomous vehicle navigation in CARLA AD Challenge, describing the migrating process between Smart Elderly Car project, based on V-REP and a real electric vehicle, and CARLA driving simulator. As shown, CARLA AD Challenge stablishes a benchmark to validate fully autonomous vehicles in complex urban environments by recreating hyper-realistic scenes, democratizing the accessibility to cutting edge validation technologies reducing time and cost. Robesafe proposal, based on environment perception through RGB front camera and LiDAR sensor in order to follow traffic rules and respect other dynamic objects, and pursue the provided waypoints to achieve a destination resulted the 4th best of 200 submitted, obtaining the lowest penalty score of the top five.

As future works, 360 degrees object detection will be accomplished in order to acquire a higher safety degree, avoiding obstacles coming from all directions. Also, a tuned controller will be implemented to achieve better waypoint following to complete more route percentage without colliding with other obstacles, performing a safest behavior.

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