# Autonomous Driving Simulators: The advantages of CARLA

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## ABSTRACT
An autonomous vehicle is a vehicle which requires no human intervention. Nowadays self-driving car industry playing a vital role in the market. In order to describe about the way how a car can be driven on its own, a driving simulator software is required. This paper focuses on various type of simulators like CARLA, TORCS, AirSim, etc.

## Keywords
Automation, Autonomous Driving, CARLA, Sensors, Simulator, Unreal Engine

## 1. INTRODUCTION
Self-driving vehicles [18] can reduce human efforts, errors (that causes most of the accidents) in driving. The autonomous behavior [19] of the vehicles might range from basic driver assistance (Ex: Cruise control) to fully self-driving systems [14]. The real car's behavior on different tracks can be well explained by using a simulation software.

**Simulation software:** A Simulation software is a software which enables a user to create a virtual model of physical area. A driving simulator provides virtual tracks and platforms where the developer can test his ideas of autonomous driving instead of directly testing them on real world vehicles. Here he can also understand and analyze the way how the objects react to incoming events.

**Applicable areas:** Self-driving vehicles are useful in many industries like Logistics [15], Manufacturing, Health care, Aerospace, Mining etc. The usage of Autonomous vehicles can reduce traffic congestion, risk (while handling heavy loads) and transportation cost [21]. It can increase the Productivity and free up the parking lots.

## 2. FEATURES OF AUTONOMOUS DRIVING
Generally Driving automation ranges from level **0** to level **5**. In this level **0** indicates no automation. The automation of driving a vehicle increases from level 0 to level 5. The levels of Autonomous driving [1] are as follows:

Level 0: No automation

Level 1: Driver assistance

Level 2: Partial Driving Automation

Level 3: Conditional Driving Automation

Level 4: High Driving Automation

Level 5: Full Driving Automation

The number of features of autonomous driving increases with the increase in the level of automation.

Some important features of Self-driving are Emergency braking, Cruise control, Maps, Sensors, Actuators, Lane keeping, Blind spot detection [25] and Self steering etc.

## 3. AUTONOMOUS DRIVING SIMULATORS
Some widely used Autonomous vehicle simulation software are CARLA, TORCS, Airsim, AWS Deepracer, Baidu's Apollo, Nvidia Drive sim, Udacity, gazebo.

**3.1 CARLA:** Simulation software CARLA is an open-source platform [2] to support development, training and validation of Autonomous vehicles.

**3.2 TORCS:** It is highly portable simulator [10]. Works on Linux, Free BSD, open Solaris and Windows. It can simulate 3D car racing for Researchers, gamers, Engineers and Teachers.

**3.3 Airsim:** Simulator Airsim is developed by Microsoft Corporation [6] in 2017. It is specially used to simulate Drones and cars. It supports AI research and built on Unreal Engine. It is an Open-source and Cross platform.

**3.4 AWS Deep racer:** It is not fully open-source. This simulator works on Reinforcement learning. The developers or researchers of all skill levels can test their autonomous car on the models provided by AWS Deep racer [5].

**3.5 Baidu Apollo:** It is a platform which is designed to test the efficiency of autonomous vehicles. It is developed as a part of Baidu's Apollo open-source autonomous driving project. Apollo supports LIDAR, radar, cameras etc.

**3.6 Nvidia Drive Sim:** It's an end-to-end simulation platform [8]. It is developed from the ground to support large scale. This simulation platform is open, scalable and supports autonomous vehicle development where the developer can increase his productivity. It's not fully open source because the developer can only use the platform or he can select some required features.

**3.7 Udacity Self-Driving Car Simulator:** It provides two driving modes training mode and autonomous mode. By using these two modes the developer can first train the agent and after he can test the agent. It is an open-source simulation software. It has features like Tracks, data collection for deep learning. It is light weight and very easy to run.

**3.8 Gazebo:** Gazebo [7] is a powerful open-source robotics simulator commonly used for developing and testing robots, including Autonomous vehicles and drones. It provides a realistic physics engine, sensor simulation and robot environment which makes it as a popular choice for research.

## 4. CARLA (CAR LEARNING TO ACT)
Carla is an open-source simulator [9] for Autonomous driving

research. It has the following characteristics.

1) Scalability Architecture

2) Flexible API

3) Autonomous Driving Sensor Suite

4) Fast simulation for Planning and Control

5) Maps Generation

6) Traffic scenarios simulation

7) ROS integration

8) Autonomous Driving Baselines.

**Unreal Engine (UE):** Unreal Engine is a powerful real-time 3D creation tool developed by Epic Games. It is widely used for video editing, games simulation, Architectural visualization, Film production and even for AI research. Unreal Engine can be integrated with CARLA [3] to provide good Graphics while Simulation of AD vehicles.

Features of CARLA:

1) High Fidelity Simulation

2) Customizable Sensors

3) Multi-Agent Support

4) Python API

5) Weather Environment Control

6) Integration with ML Frameworks.


**Fig 1: Carla Environment [9]**

# 5. CARLA'S SYSTEM REQUIREMENTS

## 5.1 Hardware Requirements

**Processor:** Intel **I**5 **+ (or)** AMD Ryzen5 +
**GPU:** 6GB nvidia RTX 3050
**Storage:** 165 GB of Free disc space
**RAM:** 16GB

## 5.2 Software Requirements

**Operating System:** Windows 11/ ubuntu 18.04 +
**Programming language:** C++/ Python
**Dependencies:** UE 4.26 +, Nvidia Drivers, CUDA (API platform) & cuDNN (CUDA library).

## 6. COMPARISON OF CARLA WITH OTHER SIMULATORS

| | CARLA | TORCS | AirSim | DeepRacer | Apollo | nvidia | Udacity | Gazebo |
|---|---|---|---|---|---|---|---|---|
| **Open-Source** | Yes | yes | yes | No | Open-Source s/w stack | No | yes | yes |
| **Graphics** | High-end | Low | High-end | Low | High-end | Extremely high | Basic level | high |
| **Target Use case** | AD Research | Simple Driving Automation | Drones, Robots | AD Racing | Integrates With simulator | AD Research | Educational tool | Robot simulation |
| **Engine** | UE-4 | Simple Engine | UE-4 | Simple Engine | ROS | Advanced Engine | Very basic | Realistic physics |
| **Sensor Support** | Supports all sensors | Limited | Moderate | Only front camera | Limited | All | Only front camera | All |
| **Customization** | High | Moderate | High | limited | High | high | limited | High |
| **Learning Curve** | Python, UE | Python | C++, ROS | Python | C++, ROS | Python | Python | Python, C++, ROS |
| **GPU** | 6gb nvidia | Basic H/W is enough | 6gb nvidia | Runs in AWS cloud | 6gb nvidia | 6gb nvidia | Basic H/W is enough | 8GB nvidia |
| **Multi-agent support** | yes | yes | VR view requires | no | yes | yes | no | yes |

**Fig 2: Comparison of CARLA with other Simulators**

There is a need for an efficient and open-Source simulator for the Autonomous Driving Research. Some simulators are available as open-source [12]. But Software like Udacity is used as educational tool only. Udacity don't need any additional GPU. It provides very basic kind of user interface. AWS DeepRacer is a cloud-based simulator and is not an open-source simulator. AirSim is built on Unreal Engine and provides good user experience while simulating but it is suitable for drones and Robots. Apollo, TORCS cannot simulate all sensors. Gazebo, Nvidia and CARLA are the simulators which provide High end graphics among the all. But Gazebo mainly used to simulate Robots. Nvidia simulator is an efficient one but it is not an open-source software. Therefore, CARLA can be used for Autonomous car Driving Research.

In the below chart, Histogram bars represent the scores (out of five) of individual simulators for every specific functionality.

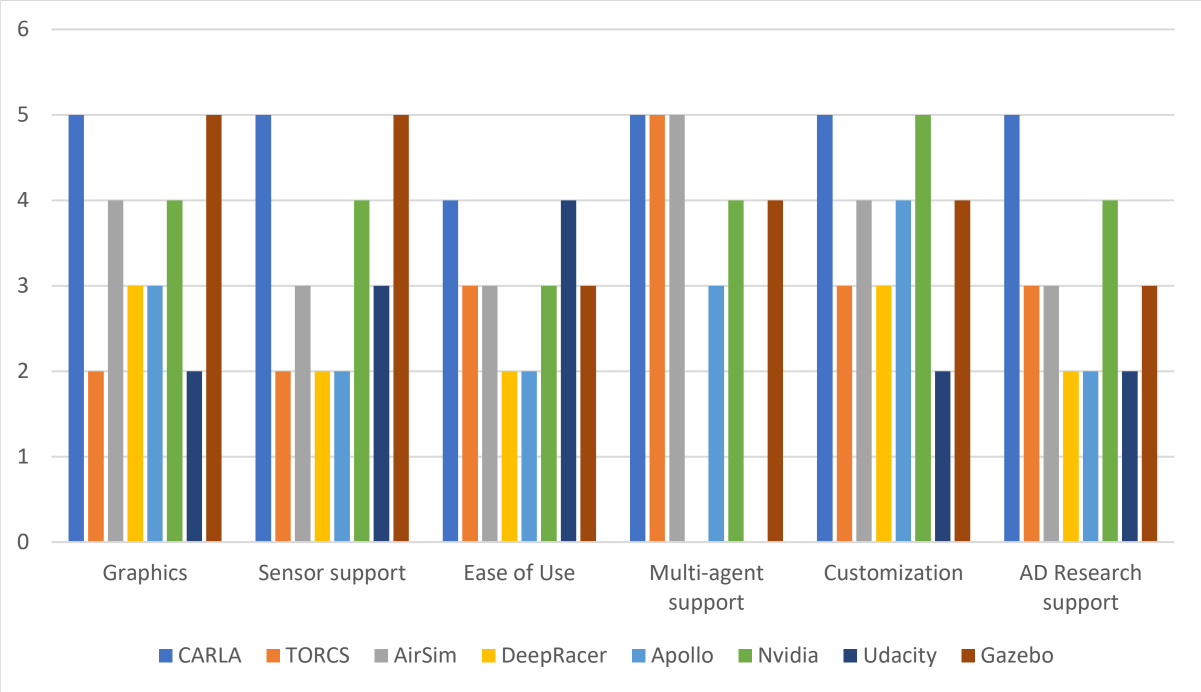


**Fig 3: Different functionality performances of various simulators**

## 7. CONCLUSION

In autonomous driving research, Simulator [4] plays a vital role. Instead of directly working on Real world Vehicles the developer can choose a Driving Simulation software to do Research and development. This can reduce cost, Efforts and human errors while dealing with Autonomous driving vehicles. Nowadays various types of simulators are available in the market to offer plenty of functionalities. Among all the simulators CARLA can simulate all most all the sensors. It can provide high-end graphics, multi-agent support with moderate hardware requirements. The researcher can consider CARLA [11] in different areas of development while doing Autonomous vehicle simulation to enhance autonomous capability of a vehicle.

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