A RounD-like Roundabout Scenario in CARLA Simulator

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SHORT SUMMARY

Evaluating the challenges and opportunities of cooperative autonomous vehicles (CAV) require an adapted simulation methodology reproducing realistic driving and sensory contexts. In this paper, we propose a RounD-like CARLA scenario reproducing in CARLA the driving context recorded in the RounD dataset. We focus in particular on roundabout scenarios, as they are considered particularly challenging for CAV. We present the methodology followed to generate the CARLA scenario and describe challenges to reproduce trajectories corresponding to RounD. Origin and destination of vehicles, waypoint and speed are extracted from RounD for CARLA vehicles to closely reproduce the driving patterns observed in RounD.The benefit of such scenario are manyfold, such as evaluating control algorithms of CAVs, deep AI reinforcement learning, or vehicular sensor data sampling under realistic driving contexts. It notably will reduce the gap of AI mechanisms for CAV between simulation scenarios and realistic conditions.

Keywords: Carla, Roundabout, RounD, synthetic scenario, Traffic simulation for C-ITS.

1 Introduction

Evaluating control algorithms under realistic driving and sensory contexts are critical to the success of future C-ITS applications. Over the last decades, various synthetic scenarios have been designed and calibrated for microscopic simulators (e.g. LuST (Codeca, Frank, & Engel, 2015), MoST (Codecà & Härri, 2017) for SUMO). Realistic traffic datasets such as RounD (Krajewski, Moers, Bock, Vater, & Eckstein, 2020) have been used to extract and learn precise driving statistics but cannot be modified to evaluate the impact of traffic control or control algorithms in the dataset environment. And if adapting the dataset in a microscopic simulator such as SUMO could be envisioned, the corresponding synthetic scenario would not be realistic enough for modeling the CAV control algorithm or its sensory context. The driving simulator CARLA[1] (Dosovitskiy, Ros, Codevilla, Lopez, & Koltun, 2017) has been designed to model robotic and sensory context in highly precise driving environment. Joining ROS control mechanisms with OpenDrive HD maps enables CARLA to reproduce driving and sensory context extremely precisely. However, most of the studies using CARLA focuses primarily on the control or the perception of an ego-vehicle either isolated or under unrealistic traffic handled by CARLA traffic manager (i.e. autopilote mode). Evaluating control or perception of an ego vehicle in an immersive realistic driving or environmental context is missing and remains challenging due to the lack of calibrated synthetic scenarios in CARLA. Deschaud (Deschaud, 2021) recently partially addressed that challenge and designed an ego-vehicle in CARLA with similar sensor configurations as the KITTI dataset [2]. This first attempts to create calibrated scenarios in CARLA was however limited to testing the KITTI sensors under configurable simulated heterogeneous sensory contexts. If benefiting from realistic sensory input is important to trajectory planning for cooperative autonomous ego-vehicles, realistic behavior and trajectories of other vehicles are equally critical to the ego-vehicle's trajectory planning and hazard avoidance.

In this paper, we address that challenge and describe our methodology to design a synthetic driving scenario in CARLA reproducing the RounD dataset[3]. Without loss of generalities, we focus on one single RounD roundabout in this work. Our proposed methodology is threefold:

[1]CARLA Simulator: https://carla.org/
[2]KITTI: http://www.cvlibs.net/datasets/kitti/
[3]RounD - https://www.round-dataset.com/

(i) reproduce the RounD roundabout in CARLA as precisely as possible; (ii) extract trajectories and speed data from RounD; (iii) design a CARLA agent following RounD short and long term planning. Our CARLA RounD-like scenario will be provided open-source to the community[4].

The rest of this extended abstract is organized as follows. Section 2 introduces CARLA and RounD and emphasizes the benefits of dataset-based CARLA scenarios. Section 3 describes the methodology followed to configure CARLA according to RounD. Section 4 discusses the results, while Section 5 concludes the extended abstract.

2 Background

2.1 RounD Dataset

The RounD (Roundabout Drone) dataset[5] (Krajewski et al., 2020) provides naturalistic trajectories of vehicles and vulnerable road users of selected German roundabouts. Each trajectory is recorded by drones with a error less than 10cm and includes vehicles (car, bus, trucks) as well as vulnerable road users (pedestrians, bicycles). The RounD dataset, as well as its related datasets (HighD,

Figure 1: The RounD Dataset

ExiD etc..) is a major source of naturalistic data for various applications, such as traffic data inference, AI/ML training, etc..However, as a dataset RounD cannot be dynamically altered and as such does not allow to evaluate the impact of a particular C-ITS application or CAV control algorithms on the rounD traffic.

2.2 CARLA

CARLA[6] is an open-source simulator for autonomous driving research. CARLA not only allows to simulate the precise trajectories (throttle, heading) followed by CAV, but also support models for various on-board sensors (lidars, cameras, etc..), which makes CARLA a powerful toolbox for developing and evaluating control or sensory algorithms for CAV. Compared to the well-known traffic simulator SUMO [7], CARLA is based on High Definition (HD) OpenDrive maps and enables a total control of the vehicles (throttle, heading, waypoints) rather than modeling them according to car-following algorithms (speed, inter-distance only). Moreover, the available digital assets available in CARLA enables more realistic sensor modeling compared to SUMO. CARLA finally supports co-simulations with SUMO, VISSIM, ROS, Matlab, or CarSIM through open APIs.

[4]RounD-CARLA - https://gitlab.eurecom.fr/cats/carla/round-carla
[5]RounD - https://www.round-dataset.com/
[6]CARLA Simulator: https://carla.org/
[7]SUMO - https://www.eclipse.org/sumo/

2.3 C-ITS & CAV Simulation Strategy Comparison

Traffic simulators such as SUMO have been widely favored for simulating C-ITS applications. But CAVs need a higher granularity in vehicular control or sensory environments requires to rely either on naturalistic datasets or on finer-grained simulators such as CARLA or Gazeebo. However, such approach is usually limited to one single ego-vehicle, and background traffic is either not available or modelled as a simplistic 'autopilot' mode (e.g. CARLA traffic manager).

In order to illustrate the need for a CARLA scenario representing naturalistic driving contexts, we compare in Table 1 four C-ITS simulation methodologies against four representative metrics for obtaining realistic CAV simulations. As it can be seen, if realistic CAV simulations require naturalistic, alterable, robotic-ego, robotic background traffic, a *dataset* strategy only fulfils two of them. *SUMO, CARLA or SUMO/CARLA* strategies fulfil two complementary metrics. In this work, we propose a CARLA scenario representing the naturalistic dataset RounD and accordingly fulfilling all requirements for realistic CAV simulations.

Table 1: Simulation Methodology Comparison

	naturalistic	**alterable**	**robotic control**	**background traffic**
Dataset	✓	x	x	✓
SUMO	x	✓	x	LuST/MoST
CARLA	x	✓	✓	auto-pilot
CARLA/SUMO	x	✓	✓	x
this work	✓	✓	✓	✓

3 Methodology

We describe now the three phases followed to extract data from the RounD dataset in CARLA.

3.1 Scenario Design

The first step is to design the roundabout in CARLA closely machining the one from RounD. We selected one of the 4 different roundabouts contained in RounD (Thiergarten, Alsdorf) and visualized it with the trajectories of all vehicles (see Fig. 2a). We then extracted the geometric parameters of the roundabout via basic trigonometry on the trajectories[8] and obtained the roundabout metrics depicted in Fig. 2b. Finally, we designed the roundabout using the Mathwork tool *Roadrunner*[9] (see Fig. 2c).

3.2 RounD Dataset Extraction

The second step is to extract the origin-destination (O/D) matrix and average speed from RounD. In this version, we only extracted data for private vehicles, although RounD contains trucks, pedestrians and bicycles as well.

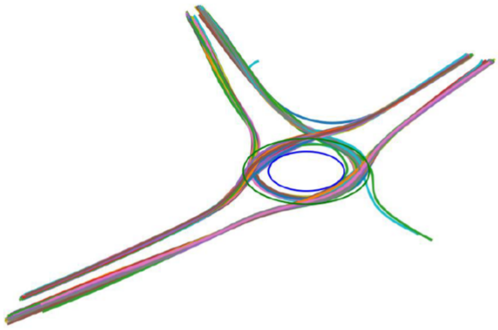
The extracted O/D matrix of the considered roundabout in RounD is depicted in Table 2.

	Inboud 1	**Inboud 2**	**Inboud 3**	**Inboud 4**	**Total**	**Probability**
Outboud 1	0	21	97	2	120	**46%**
Outboud 2	33	0	4	0	37	**14%**
Outboud 3	87	14	1	0	102	**39%**
Outboud 4	0	0	0	0	0	**0%**
Total	120	35	102	2	259	**100%**
Probability	**46%**	**14%**	**39%**	**1%**	**100%**	

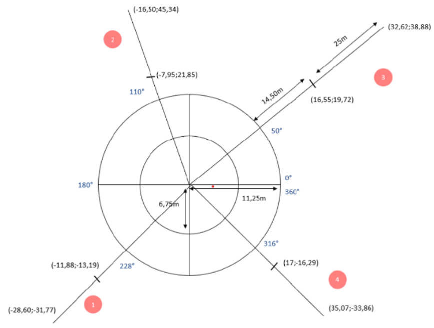
Table 2: O/D matrix of the Thiergarten roundabout in Alsdorf, Germany.

[8]Extracting such roundabout from OpenStreetMap did not lead to sufficient accuracy. We also did not have access to commercial HD maps.

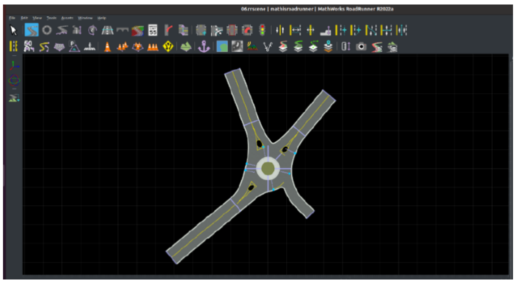
[9]https://fr.mathworks.com/products/roadrunner.html



(a) RounD roundabout under study

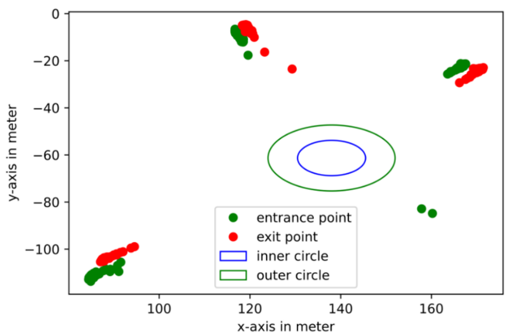


(b) RounD roundabout metrics



(c) RounD roundabout in Roadrunner

Figure 2: RounD scenario extraction for CARLA



(a) Origin and Destination (O/D) points in RounD

(b) RounD inbound roads for the O/D matrix

Figure 3: RounD O/D Data extraction for CARLA

3.3 Vehicle integration in CARLA

Once the roundabout schema and the O/D matrix are extracted from RounD, the final step is to integrate the RounD vehicles in CARLA. Two steps are possible: direct waypoint input or O/D-based input.

3.3.1 Direct Waypoint Input

The direct waypoint input consists of indicating to the CARLA traffic manager for each spawn vehicle to follow the waypoints at a target velocity described by the set of positions and speed extracted from RounD. Vehicles should therefore follow the same trajectories and speed in CARLA than in RounD. This however is challenging in CARLA. First, CARLA does not operate with *exact* rather *target* speed inputs, for which a PID (proportional–integral–derivative) controller needs to adjust the throttle. In other words, a target speed needs several steps to be reached. Such slow convergence with the significant number of waypoints (from RounD) lead to jigsaw effects on the speed profile and a non-negligible drifting between the CARLA and the RounD speed profiles. This drift desynchronizes the various trajectories and lead to traffic patterns and time-to-collision values not observed in RounD. Moreover, exact vehicle size are also required to avoid potential overlapping between vehicles in CARLA, which calls for vehicle blueprints in CARLA matching those from RounD.

3.3.2 OD-based Input

As having *similar* driving patterns from RounD might be more important than *exact* ones, another strategy is to only generate OD for each vehicle corresponding to the extracted RounD OD matrix. CARLA global planning generates waypoints between these OD to closely match the RounD trajectories. And CARLA local planning set a target speed corresponding to the mean speed observed in RounD. Collisions detection and avoidance are also handled by an internal CARLA agent function. However, even if O/D and speed data match RounD, collision avoidance will naturally make the scenario deviate from exact RounD driving patterns. It will however provide a RounD-like CARLA scenario.

4 Results and Discussion

The two described strategies have been evaluated, which generated a CARLA roundabout scenario containing 259 vehicles, reproducing the traffic density and average speed of RounD. Figure 4a depicts the integration in CARLA of one RounD trajectory. Challenges when applying the direct trajectory approach with respect to matching car size to RounD can be seen on Fig. 4b. If the OD and the waypoints correspond to RounD, cars overlap at the interactions of the flows in the roundabout, where the inter-distance between vehicles is the smallest. The provided RounD dataset does not provide sufficient details to extrapolate the right vehicle size and blueprint and as such, selected assumptions need to be taken on unavailable data.

(a) Origin and destination points in RounD (b) RounD inbound roads for the O/D matrix

Figure 4: CARLA roundabout scenario

The major weakness of the two approaches followed in this work lies in the unrealistic management of the driving patterns by the default CARLA PID controllers and obstacle detection & avoidance entity. A more precise strategy is to rely on advanced controllers for throttle and heading control (e.g. PID and Stanley Law), which more closely follow speed and trajectory profiles observed in real traffic, as well as an anticipatory collision detection to avoid conflict in a smoother way.

5 Conclusions

In this paper, we presented our methodology to reproduce a RounD-like roundabout scenario in the simulator CARLA. If a direct RounD trajectory integration in CARLA is challenging, a looser strategy to only match RounD speed and Origins/Destinations, showed to be an appealing alternative. Both strategies have been implemented and evaluated. The RounD-like CARLA scenarios will be released as open-source to the community and are expected to be beneficial to evaluate CAV sensing and control mechanisms to safety navigate through roundabouts. One weak point yet remains the realistic vehicular speed and heading control followed by CARLA traffic manager, which is critical for a realistic reproduction of any dataset into CARLA. This is our future work.

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