Realizing Natural Language Scenario Descriptions in CARLA Using Large Language Models

Description

Recent advances in Large Language Models (LLMs) have opened the door to using natural language as a flexible and powerful interface for defining autonomous driving scenarios. This thesis explores the realization of complex driving scenarios described in natural language within the CARLA simulator.

The main objective of this thesis is to design and implement a system that translates natural language driving scenario descriptions into executable setups within the CARLA simulator. This involves automatically determining the placement, orientation, and motion parameters (e.g., speed) of agents such as vehicles and pedestrians on the CARLA map to ensure that a specified post-condition occurs. For instance, given a description like “a pedestrian crosses at a junction while a vehicle approaches, resulting in a collision,” the system should compute and assign the initial positions and velocities of both agents so that a collision actually takes place during simulation.

While generating initial safety-critical scenario descriptions using an LLM is relatively straightforward—for example, by prompting the model with a simple request like "Provide some descriptions for safety-critical driving scenarios"—the real challenge lies in grounding these descriptions in executable simulation code**[1]**. Recent developments such as Scenic**[2]**, a domain-specific probabilistic programming language for defining scenes in CARLA using Python-like syntax, open up two compelling directions for this thesis: (1) guiding LLMs to autonomously generate Scenic scripts, and (2) fine-tuning language-to-code models like CodeGen**[3]** to produce valid Scenic code from natural language prompts. However, these approaches are not without challenges, including the risk of generating non-executable or invalid code, primarily due to the limited availability of training data and Scenic-specific API examples. Furthermore, solutions such as ChatScene also rely on having access to a well-curated library of Scenic code snippets to function effectively. This requirement further limits its generalizability and scalability, as such libraries are scarce and the scope of Scenic language usage on the internet remains relatively narrow.

Tasks

- Survey and review various Carla code generation systems and methods, including the references mentioned above.
- Extend or develop a system that translates natural language scenario descriptions into executable CARLA code using LLMs and LangChain.
- Calculate appropriate placements and velocities of agents so that desired outcomes (e.g., collision) actually happen in simulation.
- Experiment with multiple scenarios and evaluate the system’s correctness, generalizability, and automation level.

References

[1] J. Zhang, C. Xu, and B. Li, “ChatScene: Knowledge-Enabled Safety-Critical Scenario Generation for Autonomous Vehicles,” May 22, 2024, *arXiv*: arXiv:2405.14062. doi: 10.48550/arXiv.2405.14062.

[2] D. J. Fremont, T. Dreossi, S. Ghosh, X. Yue, A. L. Sangiovanni-Vincentelli, and S. A. Seshia, “Scenic: a language for scenario specification and scene generation,” in PLDI 2019. New York, NY, USA: Association for Computing Machinery, Jun. 2019, pp. 63–78. doi: 10.1145/3314221.3314633.

[3] E. Nijkamp *et al.*, “CodeGen: An Open Large Language Model for Code with Multi-Turn Program Synthesis,” Feb. 27, 2023, *arXiv*: arXiv:2203.13474. doi: 10.48550/arXiv.2203.13474.

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Research project: MANNHEIM-CeCaS

Type:
MA

Research area: Code Generation, automotive software testing

Programming language: Python

Required skills: Object-oriented programming with Python (must have); Experience with LLM related libraries like langchain (nice to have).

Language:
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