VILNIUS UNIVERSITY
FACULTY OF MATHEMATICS AND INFORMATICS
DEPARTMENT OF SOFTWARE ENGINEERING

Using Imitation Learning to Model Human-Like Behaving Non-Player Characters Acting in Simulated Traffic Environment

Master Thesis. Introduction

Author:	Kazimieras Senvaitis	(signature)
Supervisor:	Assist. Prof., Dr. Vytautas Valaitis	(signature)
Reviewer:	-	(signature)

Vilnius – 2018

CONTENTS

1. Research Problem Area

Research driving problem

Research in autonomous urban driving is constrained by infrastructure costs and the logistical difficulties of training and testing systems in the physical world. Instrumenting and operating even one robotic car requires significant funds and manpower. Furthermore, a single vehicle is far from sufficient for collecting the requisite data that cover the multitude of corner cases that must be processed for both training and validation. This is true for classic modular pipelines and even more so for data-hungry deep learning techniques. Training and validation of autonomous models for urban driving in the physical world is beyond the reach of most research groups. [DRC+17]

Available computer Solutions

Some computer games are used to provide an environment for training self driving cars or generating large data-sets. Modern open-world games such as Grand Theft Auto, Watch Dogs Theft Auto V (GTA-V) feature extensive and highly realistic worlds. Their realism is not only in the high fidelity of material appearance and light transport simulation. It is also in the content of the game worlds: the layout of objects and environments, the realistic textures, the motion of vehicles and autonomous characters, the presence of small objects that add detail, and the interaction between the player and the environment. [RVR+16]

However, since GTA-V was not developed as a research tool, it is difficult to collect data from the game. Community created game modification scripts are required to even begin to develop ways to collect data from the game, and even then a deep understanding of the game's APIs and structure is required to develop methods to collect the required affordance indicators. While it is possible to collect the data from video games, it is more beneficial to have a simulator solely dedicated to the purpose of training and testing autonomous vehicles. This leads to another drawback of GTA-V, its extensibility. While scripts can be written to access certain variables in the game, it does not natively support any add-ons and is difficult to add custom 3D models to the game. Though the environment of GTA-V is large and diverse, there is still only a limited amount of different scenes that can be produced. For example, most areas of the game are an urban setting, and thus, there is a lack of suburban or rural scenes, leading to a relatively limited amount of data being available for those environments. [MSF+17]

There are also approaches of linking microscopic 2D traffic simulators with 3D environments. One such traffic simulator is "Simulation of Urban MObility", or "SUMO" for short, which is an open source, microscopic, multi-modal traffic simulation. It allows to simulate how a given traffic demand which consists of single vehicles moves through a given road network. The simulation allows to address a large set of traffic management topics. It is purely microscopic: each vehicle is modelled explicitly, has an own route, and moves individually through the network. Simulations are deterministic by default but there are various options for introducing randomness. [BBE+11]

SUMO is made to communicate with Unity3D game engine, allowing 3D representation of high detail modeled and simulated 2D urban environments. 3D environment is additionally populated with static urban objects (trees, houses) and transformed road signs, line markings. As a result it provides configurable urban traffic environment. [BSO17]

Moreover, there are a few purpose built simulators for training self driving cars. One of them is CARLA, an open-source simulator for autonomous driv- ing research. CARLA has been developed from the ground up to support devel- opment, training, and validation of autonomous urban driving systems. In ad- dition to open-source code and protocols, CARLA provides open digital assets (urban layouts, buildings, vehicles) that were created for this purpose and can be used freely. The simulation platform supports flexible specification of sensor suites and environmental conditions. We use CARLA to study the performance of three approaches to autonomous driving: a classic modular pipeline, an end- to-end model trained via imitation learning, and an end-to-end model trained via reinforcement learning. The approaches are evaluated in controlled scenarios of increasing difficulty, and their performance is examined via metrics provided by CARLA, illustrating the platform's utility for autonomous driving research. [DRC+17]

One of the challenges in the development of CARLA was the configuration of the behavior of non-player characters, which is important for realism. We based the non-player vehicles on the standard UE4 vehicle model (PhysXVehicles). Kinematic parameters were adjusted for realism. We also implemented a basic controller that governs non-player vehicle behavior: lane following, respecting traffic lights, speed limits, and decision making at intersections. Vehicles and pedestrians can detect and avoid each other. More advanced non-player vehicle controllers can be integrated in the future [1]. [DRC+17]

Research performed in both linking of SUMO to Unity3D and CARLA points out the importance of non-player character behavior to realism. AI trained on such simulations potentially fails in real traffic. Simulation of a more human-like behavior traffic is also subject of interest in R&D department of AUDI group [Res18].

2. Research Subject

The subject of this research is agent-based driving algorithms in microscopic vehicle traffic simulations, including:

1. Driving properties of open source microscopic vehicle traffic simulators;
2. Aspects of human-like behavior in driving algorithms;
3. Measurement of human behavior likeliness in driving;
4. Application of deep learning in microscopic vehicle traffic simulations;

3. Research Goal and Tasks

This paper aims to improve current actor model-based decision-making algorithms used in microscopic vehicle traffic simulation, to produce traffic with human-like behavior.

In order to reach the goal the following tasks are raised:

1. Distinguish aspects human behavior likeliness in driving algorithms of vehicle traffic simulators;

2. Distinguish metrics describing human behavior likeliness in driving algorithms of vehicle traffic simulators;
3. Select a part of driving algorithm to potentially improve human-likeliness;
4. Teach neural network to act in particular driving activity;
5. Integrate the new neural network based driving related algorithm with other algorithms;
6. Measure properties of the new algorithm in selected vehicle traffic simulator;

4. Research Hypothesis

Applying reinforcement and imitation learning on parts of actor behavior properties induces human-like behavior properties.

5. Research Method

Writing this thesis, the following methodology will be applied:

1. Formation of research subject and preparation
    (a) Fine-graining of research subject
    (b) Selection of literature
    (c) Selection of research method
    (d) Developing research plan
2. Scientific literature analysis and summary
    (a) Analysis of technological solutions in traffic simulation algorithms
    (b) Analysis of criteria and metrics used in traffic simulation algorithms
    (c) Analysis of issues existing in traffic simulation algorithms
    (d) Analysis of human behavior likeliness criteria and metrics used in real world simulating computer algorithms
3. Preparation for experiment
    (a) Definition of algorithm implementation principles
    (b) Design of improved decision-making algorithm
    (c) Select criteria and metrics for decision-making algorithm
    (d) Selection of tools for the implementation of the algorithm
4. Conduction of experiment
    (a) Implementation of designed algorithm with selected tools;
    (b) Integrate implemented algorithm into existing traffic simulator;
    (c) Investigation of the implementation using selected criteria;
    (d) Measurement of the implementation using selected metrics.

6. Expected Results

1. Decomposed existing traffic simulators into algorithms;

2. Selected one of the decision-making algorithms and implemented a reinforcement and imitation learning based more human-like alternative;
3. Integrated the new algorithm into existing open-source traffic simulator;
4. Measured metrics of the new algorithm;

References

[BBE+11] Michael Behrisch, Laura Bieker, Jakob Erdmann, and Daniel Krajzewicz. *SUMO-Simulation of Urban MObility An Overview*. 2011. ISBN: 9781612081694. URL: http://sumo.dlr.de/pdf/simul%7B%5C_%7D2011%7B%5C_%7D3%7B%5C_%7D40%7B%5C_%7D50150.pdf.

[BSO17] Carlos Biurrun-Quel, Luis Serrano-Arriezu, and Cristina Olaverri-Monreal. Microscopic Driver-Centric Simulator: Linking Unity3D and SUMO. In pp. 851–860. 2017. DOI: 10.1007/978-3-319-56535-4_83. URL: http://link.springer.com/10.1007/978-3-319-56535-4%7B%5C_%7D83.

[DRC+17] Alexey Dosovitskiy, German Ros, Felipe Codevilla, Antonio López, and Vladlen Koltun. CARLA: An Open Urban Driving Simulator. Tech. rep., 2017. URL: http://proceedings.mlr.press/v78/dosovitskiy17a/dosovitskiy17a.pdf.

[MSF+17] Mark Martinez, Chawin Sitawarin, Kevin Finch, Lennart Meincke, Alex Yablonski, and Alain Kornhauser. Beyond Grand Theft Auto V for Training, Testing and Enhancing Deep Learning in Self Driving Cars, 2017-12. arXiv: 1712.01397. URL: http://arxiv.org/abs/1712.01397.

[Res18] Research/Development department at AUDI AG. Master's thesis - Artificial Intelligence for traffic simulation, 2018. URL: https://karriere.audi.de/sap/hcmx/download%7B%5C_%7Dna/job/8EE9983996021EE8B3BED22E13C8560E/Master%7B%5C%%7D27s%20thesis%20-%20Artificial%20Intelligence%20for%20traffic%20simulation.pdf?sap-client=200%7B%5C&%7Dsap-language=en.

[RVR+16] Stephan R Richter, Vibhav Vineet, Stefan Roth, Vladlen Koltun, and T U Darmstadt. Playing for Data: Ground Truth from Computer Games. Tech. rep., 2016. arXiv: 1608.02192v1. URL: https://arxiv.org/pdf/1608.02192.pdf.

Abbreviations