Robotics and Embedded Systems

Human Brain Project

Master/Bachelor Thesis - Semester Project

Spiking Neural Network for Autonomous Navigation based on LiDAR Sensor

Background

Autonomous navigation is one of the most challenging tasks for autonomous vehicles and robots, which usually involves many research fields including sensory perception, path planning, decision making, and motion control. For the commonly used sensors, Light Detection And Ranging (LiDAR) sensors have been widely used in autonomous robots due to the higher accuracy and robustness compared with cameras [1], which are able to obtain a precise point cloud for surrounding environment by actively project laser beams to objects.

With the development of deep representation learning and artificial neural network, reinforcement learning has become a powerful end-to-end framework to solve the autonomous navigation problem due to its extensive applications and the capability of learning complicated policies in high-dimensional environments [2][3]. However, due to the complexity of the deep artificial neural networks, the training and inference of deep ANN are still computationally expensive and power-consuming, which makes it barely suited to deploy on the power-constrained autonomous vehicles.

In recent years, spiking neural network has gained attention which is able to more closely mimic natural neural networks based on the temporal synaptic model and the Spike-timing dependent plasticity [4]. Furthermore, spiking neural networks have the potential to run on neuromorphic processors which enable the networks to perform computation in a highly efficient way [5]. In this thesis topic, we will focus on develop an end-to-end spiking neural network to solve the autonomous navigation problem with a LiDAR sensor.

Your Tasks

In this thesis project, you will learn about LiDAR sensors, reinforcement learning, and spiking neural networks for autonomous driving, and also the latest and the most widely-used programming framework of robots. You will be able to develop and deploy your algorithms in both the simulator environment and a real robot platform for different application scenarios. To be specific:

1. You will first learn about basic knowledge of LiDAR and do preliminary literature studies for spiking neural networks and reinforcement learning. You will be offered basic ideas, simulation environments, and source codes to get started.
2. You will widely read state-of-the-art publications and implement your own ideas and algorithms to solve the problem and possibly further improve the performances.
3. You will either run simulations or conduct prototype experiments to demonstrate your novel solutions.

Requirement

- High self-motivation and passion on research.
- Six-month working time.
- C++ and Python programming experiences.

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Figure 1 End to End Learning for Self-Driving Cars by Nvidia [6]

[1]. Li, Ying, et al. "Deep learning for LiDAR point clouds in autonomous driving: a review." IEEE Transactions on Neural Networks and Learning Systems (2020).
[2]. Sallab, Ahmad EL, et al. "Deep reinforcement learning framework for autonomous driving." Electronic Imaging 2017.19 (2017): 70-76.
[3]. Kiran, B. Ravi, et al. "Deep reinforcement learning for autonomous driving: A survey." IEEE Transactions on Intelligent Transportation Systems (2021).
[4]. Pfeiffer, Michael, and Thomas Pfeil. "Deep learning with spiking neurons: opportunities and challenges." Frontiers in neuroscience 12 (2018): 774.
[5]. Bouvier, Maxence, et al. "Spiking neural networks hardware implementations and challenges: A survey." ACM Journal on Emerging Technologies in Computing Systems (JETC) 15.2 (2019): 1-35.
[6]. Bojarski, Mariusz, et al. "End to end learning for self-driving cars." arXiv preprint arXiv:1604.07316 (2016).