TECHNISCHE UNIVERSITÄT
IN DER KULTURHAUPTSTADT EUROPAS
CHEMNITZ

Fakultät Informatik
Professur Neurorobotik

Master Thesis Description

Topic: Event-Based Spiking Reinforcement Learning for Autonomous Drone Navigation in Dynamic Environments

Description:

The aim of this work is to develop a neuromorphic navigation system for autonomous drones capable of avoiding dynamic obstacles in real-time using only onboard computation—all within a simulation environment. You will begin by setting up a simulation pipeline using AirSim integrated with the v2e event camera simulator to generate realistic event streams from a Dynamic Vision Sensor (DVS). The core of the thesis is the design and implementation of a Spiking Neural Network (SNN) policy trained with reinforcement learning to process these event streams and output control commands for navigating a drone through dynamic environments. You will study and implement appropriate training methods for Spiking Neural Networks adapted for reinforcement learning. The trained SNN policy will be benchmarked against existing baselines on metrics including navigation success rate, flight speed, and robustness etc. Additionally, you will investigate hardware-aware constraints by implementing post-training quantization of the SNN, analyzing the trade-off between performance and hardware feasibility through energy and latency estimations.

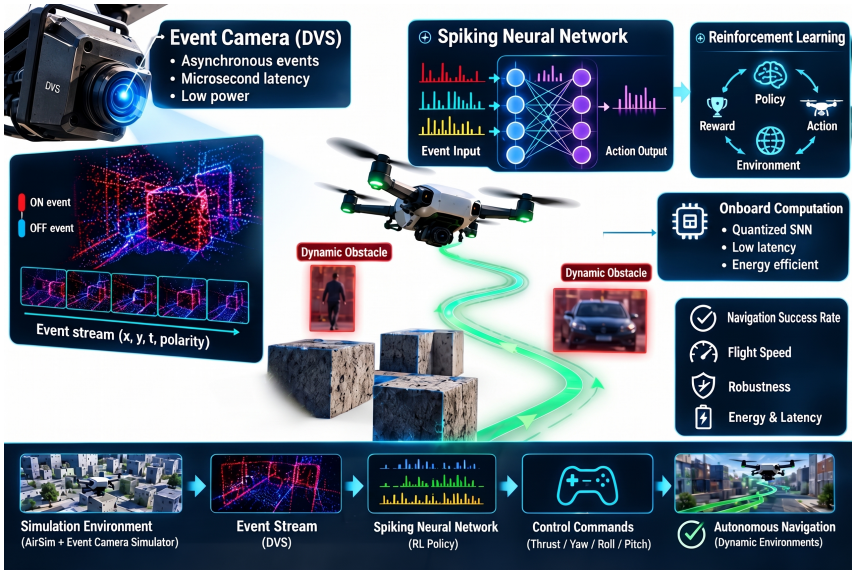

Figure 1: Overview of the proposed neuromorphic navigation pipeline. Event streams from a DVS are generated in AirSim, processed by an SNN policy trained with reinforcement learning, and mapped to drone control commands.

Motivation:

Enabling autonomous drones to navigate dynamic environments using only onboard computation remains a significant challenge due to strict latency and energy constraints. Traditional frame-based cameras and CNNs suffer from motion blur, high latency, and excessive power consumption. Event cameras offer a bio-inspired alternative by reporting only brightness changes with microsecond latency, and Spiking Neural Networks process this asynchronous data efficiently through discrete spikes. The paradigm shift from traditional frame-based vision to event-based sensing for high-speed autonomous systems is highlighted by Prof. Davide Scaramuzza in his IROS'25 keynote "Low-Latency Robotics with Event Cameras".



Reference papers

- Directly-trained Spiking Neural Networks for Deep Reinforcement Learning: Energy efficient implementation of event-based obstacle avoidance on a neuromorphic accelerator.
- Fully Autonomous Neuromorphic Navigation and Dynamic Obstacle Avoidance.

Requirements

- **Programming**: Strong proficiency in Python and experience with deep learning frameworks such as PyTorch.
- **Spiking Neural Networks**: Basic understanding of SNN architectures and neuron models.
- **Reinforcement Learning**: Solid understanding of reinforcement learning concepts and experience implementing RL algorithms.

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