Neuromorphic Event-Based Algorithms for High-Speed Applications

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Abstract: The ability to detect and track fast, small, and agile aerial objects in real time is becoming increasingly critical in modern sensing systems. Applications such as autonomous surveillance, airspace monitoring, defence, and collision avoidance demand visual processing pipelines that operate with ultra-low latency, high temporal precision, and low power consumption. In particular, high-speed scenarios such as drone detection and tracking, missile or projectile monitoring, high-speed robotics, and rapid industrial inspection require sensing systems that can respond within microseconds to milliseconds. Conventional frame-based cameras are often ill-suited for such tasks, especially when targets move rapidly, occupy only a few pixels, or appear in cluttered environments. Furthermore, processing high-frame-rate video introduces substantial computational and energy overheads, making real-time deployment on resource-constrained embedded platforms challenging.

Neuromorphic event cameras offer a fundamentally different sensing paradigm. Instead of capturing full image frames at fixed intervals, they asynchronously report changes in brightness at individual pixels. This results in sparse, low-latency, and high-dynamic-range data streams that are inherently well suited for fast motion analysis and real-time edge processing. These properties make event-based vision particularly attractive for applications such as drone detection and tracking, high-speed object interception, gesture recognition at high temporal resolution, and navigation in dynamic environments.

This PhD project focuses on the development of neuromorphic machine learning and signal processing algorithms tailored for event-based data. A key emphasis will be on designing computational pipelines grounded in neuromorphic principles, including asynchronous computation, sparse event-driven processing, temporal coding, memory-efficient dynamics, and bio-inspired perception. The research will explore methods for event-stream preprocessing, background suppression, moving-target enhancement, feature extraction, event-based detection, temporal data association, and robust tracking in complex and dynamic environments.

A central objective of the project is to develop a complete end-to-end system, encompassing algorithmic frameworks, learning models, signal processing modules, and embedded implementation strategies. Depending on the research direction, this may involve event-based neural networks, spiking and recurrent architectures, state-estimation techniques, and hardware-aware optimizations for real-time deployment on edge platforms. The resulting system will be designed to achieve low latency, energy efficiency, and robustness, while maintaining high accuracy under challenging real-world conditions.

Overall, this project aims to advance the state of the art in neuromorphic algorithms by integrating concepts from machine learning, signal processing, and neuromorphic engineering into a unified, scalable, and deployable sensing system for a wide range of high-speed applications, including drone detection and tracking, autonomous interception, and real-time situational awareness.

Preferred background:

We seek an applicant with strong foundations in linear algebra, probability, signals and systems, machine learning, and programming. Experience in computer vision, deep learning, state estimation, embedded systems, FPGA implementation, or neuromorphic hardware will be highly desirable, though not all are mandatory. Proficiency in Python, Pytorch and Tensorflow is expected. An interest in brain-inspired computation, event-based sensing, and real-time intelligent systems will be a strong advantage.