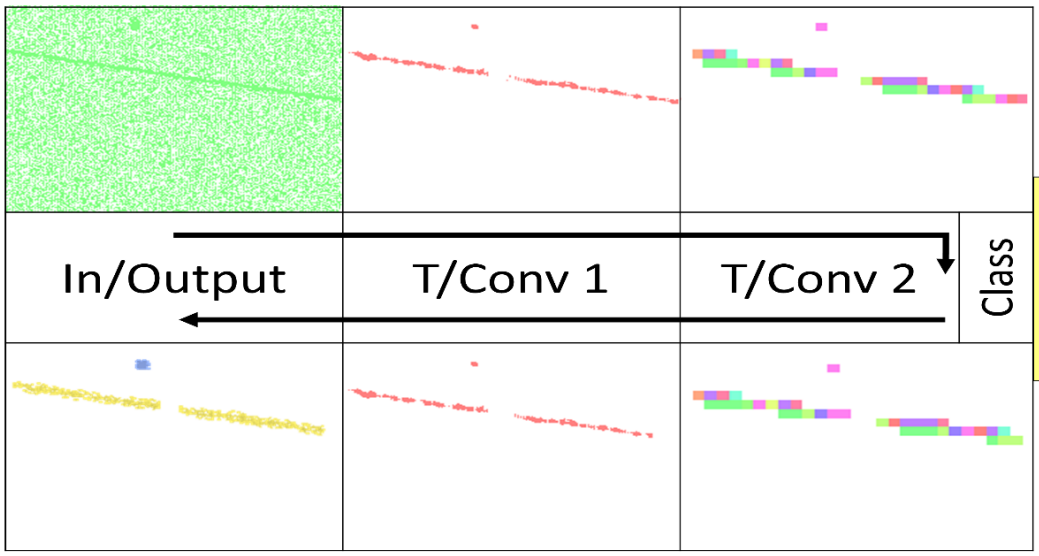
Space Situational Awareness Segmentation



NEU4SST - Neuromorphic Processing for Space Surveillance and Tracking

Executive Summary

Feasibility Study

Cognitive Cloud Computing in Space

Affiliation(s): University of Strathclyde

Activity summary:
In this project, we look at event-based sensing and processing for space situational awareness (SSA). Many advantages exist with the new paradigm of neuromorphic engineering, we investigate: If event-based optical data is suitable for the task and if processing with Spiking Neural Networks (SNN) provides advantages in terms of efficiency and efficacy. With the implementation of a novel heterogeneous LIF SNN, we surpass the state of the art in event-based SSA with a 15% increase in accuracy.

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1 Executive Summary

Space situational awareness (SSA) is a critical aspect of space exploration and operations [1]. It involves monitoring and tracking objects in space, predicting their behaviour, and detecting potential threats. Among the latest advances in the field of sensing and processing, the use of event-based visual sensing combined with Spiking Neural Networks (SNNs) represents an interesting approach to be investigated in this application domain.

Event-based visual sensors are a new generation of sensors that can capture high-speed visual information with low power consumption. Unlike traditional frame-based sensors, which capture images at a fixed rate, event-based sensors only generate data when there is a change in the visual scene. This allows them to capture more detailed and accurate information about moving objects [2, 3].

SNNs are a type of neural network that processes information in a way that is more similar to the human brain [4]. Unlike traditional artificial neural networks, which operate on discrete floating point values, SNNs use spikes, or continuous events, to encode and transmit information. This makes SNNs well-suited for processing the high-speed, event-based data generated by the event-based visual sensors.

Combining event-based visual sensors with SNNs has the potential to provide several benefits for SSA. The low-power consumption of event-based sensors allows for longer-lasting and more energy-efficient operation in space. The high-speed and accurate information capture of event-based sensors can improve the detection and tracking of objects in space. Moreover, event-based processing of SNNs can enable more efficient and effective analysis of the data [5, 6].

There are still challenges to be addressed in using event-based visual sensing and SNNs for SSA. One of the main challenges is the development of appropriate algorithms and models for SNNs to process the event-based data from visual sensors. This project looks at the development of such algorithms, advancing both the neuromorphic algorithmic research and the applicability of these systems to problem areas such as SSA. In particular, this work introduces the addition of heterogeneous neurons to the spiking convolutional neural networks. The aim of this is to allow a variety of temporal/spatio-temporal features to be extracted within one network, to represent the highly dynamic nature of the SSA task. Combining very long and very short integration times allows an efficient and effective manner to segment and track coarse spatial across a range of temporal resolutions.

The results from this project show that event-based sensing coupled with SNNs can indeed perform this complex task to a high level of effectiveness, compared with other state-of-the-art results within the field, with an informedness level of 89.1%, well above alternative methods. This has been delivered thanks to the novel introduction of heterogeneous neurons to spiking convolutional neural networks. This provided an effective method of representing different time scales for accumulation, a key factor in problems like SSA.

Overall, event-based visual sensing and SNNs show promise for improving space situational awareness. Further research and development in these areas can help to enhance the ability to monitor and protect space-based assets.

References

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