Towards Neurally Inspired Artificial Perception

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***Abstract*—Sensing and reacting to environmental stimuli is a crucial task required for meaningful behaviour by a mobile agent, whether robotic or biological. Such a process comes effortlessly to humans and many other animals, but is a computationally intensive task with which most artificial systems struggle. Observing that biology currently far outperforms artificial systems, the Neuromorphic group at the Singapore Institute for Neurotechnology (SINAPSE) is looking to bio-inspired techniques for sensing and perception. This short paper describes the motivation and methodology behind the work, as well as some of the ongoing projects.**

I. Motivation

Reacting in a sensible manner to environmental stimuli is a complex, but necessary task for meaningful behaviour. The task involves acquiring and processing sensory data to extract useful information which can later be used to guide physical interaction with the environment.

Biological systems are very good at this task, performing it almost effortlessly, but artificial systems struggle. We therefore look to biology for inspiration, which is not a new idea, but our ever improving modern understanding of biology reveals new principles and ideas, while modern technology provides us with the tools to implement these ideas for application to artificial systems.

Perhaps even more impressive than how effectively biological systems perform the task is how efficiently they perform, and efficiency is crucial for mobility (since energy sources must be carried). Thus, a mobile artificial system must perform both reliably and efficiently. Finding more reliable and efficient manners in which to sense and compute, would have consequences reaching far beyond robotics, into the massive handheld mobile device market, neural prostheses, and implantable devices where power consumption and dissipation are both limiting factors.

II. Methodology

We focus on visual sensing and processing as an exemplary task combining both sensing and computation. Early visual areas of the brain are some of the best understood thanks to the relative ease with which they can be stimulated using controlled visual stimuli, and the retinotopic organisation of early visual areas. Our test system comprises of a spiking front end visual sensor [1], often referred to as a “silicon retina”, combined with a spiking neural network for processing.

The project aims to develop spiking neural network algorithms and architectures for visual computation which will help realise the robustness and efficiency spiking neural systems promise to offer. In the process, we strive to figure out how such structures can be learnt or self-organise. Biological systems learn much through behaviour, and sensory input has a significant effect on the structure of brain areas responsible for sensory processing, as shown in many deprivation studies. While focusing on algorithms, we collaborate with world leaders in bio-inspired hardware, who provide us with state of the art sensors and hardware.

III. Vision Project

The two major tasks in the vision project involve motion estimation and feature extraction for recognition. In our poster we will briefly describe a network for each task. The poster will emphasise the benefits of using precise spike timing with respect to simplifying computation and reducing power consumption. We use a sensor which responds only to scene activity and a processing paradigm where computation is driven by incoming spikes. The computation rate of the system (and therefore the power consumption) automatically scales to the level required to process the current scene activity, allowing the same system to efficiently handle both slowly and rapidly changing scenes in real-time.

The main future challenges for this project, and for the field in general, are twofold. The first is to understand the computational principles which make biological spiking systems so robust and efficient. These principles are more easily investigated and tested when using a more biologically realistic system such as ours. The second challenge is to develop rapidly reconfigurable neural hardware for large scale implementation of artificial spiking networks. Looking even further ahead, and beyond the scope of this project, lies the challenge of developing reliable neural interfaces so that such artificial systems can be seamlessly integrated with the body.

IV. Conclusion

We are working towards an embedded artificial spiking visual system for sensing the immediate environment. In the process we investigate neurally inspired principles for learning and computation, and aim to demonstrate the robustness and efficiency that spiking approaches can offer.

References

[1] C. Posch, D. Matolin, and R. Wohlgenannt, “A QVGA 143dB dynamic range asynchronous address-event PWM dynamic image sensor with lossless pixel-level video compression,” *IEEE Int. Solid-State Circuits Conf. Digest of Technical Papers*, pp. 400–401, Feb 2010.