Biologically Inspired Neuromorphic Object Tracking Using FMCW Radar Data

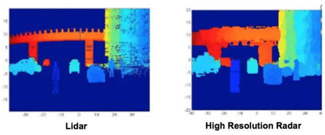

Fig. 1: Lidar vs. high resolution radar data. [1]

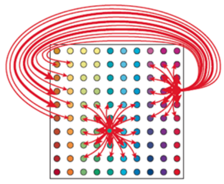

Fig. 2: Connections in an attractor network. [2]

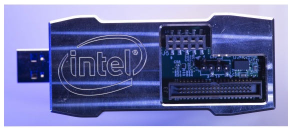

Fig. 3: Neuromorphic stick Kapoho Bay. [3]

Background

Although lidar sensors and vision systems are still the predominantly used sensors for automotive use cases, radar sensors receive more and more attention, mainly due to their robustness with regards to the weather. In contrast to lidars and cameras, radar sensors are able to detect objects even in problematic weather conditions like snowfall or fog and recent advances in FMCW radars increased the range/angle resolution significantly, as shown in Fig. 1, making it a viable alternative to lidar.

The detection and tracking of objects in automotive use cases is commonly done with either filter based algorithms [4] or artificial neural networks (ANNs) [5]. Both approaches, however, require extensive computational resources and with that electrical power, which is of course limited in autonomous vehicles.

Spiking neural networks (SNNs) are the third generation of neural networks [6]. Unlike artificial neural networks (ANNs), these networks process data asynchronously and sparsely, namely through so called spikes. This is inspired by the mammalian brain, where neurons are connected through numerous synapses and communicate through electrical impulses (spikes). This potentially leads to highly efficient networks with a reduced energy consumption compared to ANNs by a power of ten when implemented on specialized *neuromorphic hardware* [7].

Task Description

Based on an existing implementation of a spiking (continuous) attractor network [8], as shown in Fig. 2, for object detection and tracking you will be developing a neuromorphic solution on Intels Loihi [7], using their new Lava software framework [9]. Continuous attractor neural networks (CANNs) are a popular tool for computational neuroscientists to model neuronal processes such as associative memory or path integration [10], which is basically an egocentric tracking. While these networks are computationally powerful they have not been tested much for real (robotic) use-cases. After developing the network for Intels Loihi, you will therefore be conducting extensive evaluations on accuracy and performance of this network, first in the Intel cloud and then also on Kapoho Bay (see Fig. 3) - a portable neuromorphic computing stick.

During this project you will be

- doing an extensive literature research to find suitable approaches,
- familiarizing yourself with Intel Loihi and the software framework Lava,
- improving the existing implementation and porting it to Loihi,
- implementing the network in Python (using the Lava framework),
- testing the system on neuromorphic hardware and documenting your results.

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KI-ASIC

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References

[1] *Lidar vs. high resolution radar (image)*, https://www.microwavejournal.com/ext/resources/article-images-2020/Auto-Radar/Fig1.jpg.

[2] *Continuous attractor network connections (image)*, https://www.cognav.net/wp-content/uploads/2018/02/022118_0757_Howtorepres4.png.

[3] *Intel kapoho bay (image)*, https://newsroom.intel.com/wp-content/uploads/sites/11/2018/12/intel-kapoho-e1543949578455.jpg.

[4] S.-K. Weng, C.-M. Kuo, and S.-K. Tu, "Video object tracking using adaptive Kalman filter," en, *Journal of Visual Communication and Image Representation*, vol. 17, no. 6, pp. 1190–1208, 2006.

[5] G. Ciaparrone, F. Luque Sánchez, S. Tabik, L. Troiano, R. Tagliaferri, and F. Herrera, "Deep learning in video multi-object tracking: A survey," en, *Neurocomputing*, vol. 381, pp. 61–88, 2020.

[6] W. Maass, "Networks of spiking neurons: The third generation of neural network models," en, *Neural Networks*, vol. 10, no. 9, pp. 1659–1671, 1997.

[7] M. Davies, N. Srinivasa, T.-H. Lin, *et al.*, "Loihi: A Neuromorphic Manycore Processor with On-Chip Learning," *IEEE Micro*, vol. 38, no. 1, pp. 82–99, 2018.

[8] E. T. Rolls, "Attractor networks," en, *WIREs Cognitive Science*, vol. 1, no. 1, pp. 119–134, 2010.

[9] *Lava Software Framework — Lava documentation*, https://lava-nc.org/.

[10] S. M. Stringer, E. T. Rolls, T. P. Trappenberg, and I. E. T. de Araujo, "Self-organizing continuous attractor networks and path integration: Two-dimensional models of place cells," *Network: Computation in Neural Systems*, vol. 13, no. 4, pp. 429–446, 2002.

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