Implementation of shortest path finding in weighted graphs on the neuromorphic chip Loihi 2

The Group of Computational Synaptic Physiology led by Prof. Dr. Christian Tetzlaff at the University Medical Center Göttingen (https://tetzlab.com) offers a **Master’s thesis project** on single-source shortest path (SSSP) finding with neuromorphic hardware. The project will encompass the implementation of a novel algorithm to solve the SSSP problem in a local computation paradigm with Intel’s neuromorphic chip Loihi 2. The project shall start as soon as a suitable candidate is found.

Description

Finding the shortest path through a graph is an optimization problem relevant to a wide array of applications. These include routing of vehicles, planning layouts of facilities such as telecommunication networks and power grids, and robotics. Such problems can be mapped to a graph structure with nodes representing system states such as physical locations and edges representing the paths or actions to move between them. Importantly, in many applications there are large differences in the cost associated with particular paths or actions, for example, for a city street with traffic lights compared to a highway. Costs can be represented by introducing a specific weight for each edge in the graph, which can generally take into account factors like time, monetary cost, energy, or resources. One key problem in this setting is to find the optimal sequence of weighted edges between a source node and all other nodes in the graph, called single-source shortest path problem (SSSP). Up to now, no solution to this problem for weighted graphs has been implemented on neuromorphic hardware.

The goal of the proposed project is to implement a novel neuromorphic algorithm for shortest path finding in weighted graphs. The implementation shall be based on the Lava neuromorphic computing framework and run on Intel’s neuromorphic chip Loihi 2. To target weighted graphs, complementing previous efforts that have targeted unweighted graphs with a neuromorphic algorithm based on synaptic delays and a propagating wavefront (Aimone et al., 2021; Davies et al., 2021), an algorithm based on local summation and minimization of cost shall be used (cf. Michaelis, 2022, section 5.1). The project will be supported and co-supervised by Dr. Andrew Lehr and Dr. Jannik Luboeinski.

Specific objectives

- Implementing the algorithm in the Lava framework for test runs on CPU.
- Designing the algorithmic implementation for the Loihi 2 chip (together with the supervisors).
- Implementing the algorithm in the Lava framework to run on the Loihi 2 chip.
- Testing and benchmarking the implementation in different task paradigms.

Requirements

- Programming experience, preferably in Python.
- English skills sufficient for reading papers and scientific interaction.
- Experience with graph search algorithms (preferable but not mandatory).
- Experience with neuromorphic or fixed-point computation (preferable but not mandatory).

Key references

- Aimone, J.B., Ho, Y., Parekh, O., Phillips, C.A., Pinar, A., Severa, W., Wang, Y. (2021). Provable Advantages for Graph Algorithms in Spiking Neural Networks. In 2021 Proceedings of the 33rd ACM Symposium on Parallelism in Algorithms and

Architectures (SPAA). ACM, New York/NY, USA. https://doi.org/10.1145/3409964.3461813
- Davies, M., Wild, A., Orchard, G., Sandamirskaya, Y., Guerra, G. A. F., Joshi, P., ... & Risbud, S. R. (2021). Advancing neuromorphic computing with Loihi: A survey of results and outlook. Proceedings of the IEEE, 109(5), 911–934. https://doi.org/10.1109/JPROC.2021.3067593
- Michaelis, C. (2022). Think local, act global: robust and real-time movement encoding in spiking neural networks using neuromorphic hardware [Dissertation]. University of Göttingen. https://doi.org/10.53846/goediss-42

Contact

Dr. Jannik Luboeinski
Group of Computational Synaptic Physiology
Department for Neuro- and Sensory Physiology
University of Göttingen Medical Center
Humboldtallee 23, 37073 Göttingen, Germany
jannik.luboeinski[at]med.uni-goettingen.de