Event-based depth perception for neuromorphic robots

Project descritpion for a MSc Thesis of Jianlin Lu
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Motivation. Depth perception is an important capability for robots that are required to make sense of their surroundings and to plan goal-directed actions. In a table-top scenario, estimating depth facilitates segmentation of objects and allows to estimate their geometrical properties to plan grasping actions. For robotic vehicles, depth perception supports navigation and map formation.

Vision-based depth perception is computationally demanding, requires precise calibration of the cameras, and is error-prone. Neuromorphic, event-based approach has been proposed recently to facilitate real-time calculation of the disparity map for vision-based depth perception [2]. In this master thesis, we propose to continue this work, aiming at a fully neuromorphic solution that uses event-based computing, sensors, and hardware and efficiently computes a high-quality depth map that can be used in robotic tasks.

Background and methods. Neuromorphic computing is inspired by the neural networks of the mammalian brain and is realised in neuromorphic sensors (e.g., the dynamic vision sensor, DVS [1]) and processors (e.g., the Reconfigurable Online Learning System, ROLLS [3]), developed at INI, UZH/ETHZ. The neuromorphic hardware can accelerate computing of the depth map due to the parallel nature of computation and co-location of memory and computation. Neuromorphic sensor, in its turn, allows to use the temporal component of asynchronously sampled events from each pixel in two or more cameras to simplify the correspondence problem in calculating the disparity map.

Workplan. The task of the student will be to improve and extend a recently developed neuromorphic depth perception architecture [2] to obtain dense depth map and to apply this architecture in a robotic setting.

First, the sparse depth map will be obtained based on the events flow from a pair of neuromorphic DAVIS sensors, which have both an event-based and a sustained output component. **Second**, this depth map will be densified using the sustained component of the sensors and by filling-in the map in regions with low spatio-temporal contrast using constrained activation diffusion in a neural network representing the disparity. **Third**, active vision will be explored as a method to improve quality of the map, increasing number of stereo matches between the events from two DAVIS cameras. **Finally**, the architecture for depth perception will be ported to neuromorphic hardware and validated in a closed sensorimotor loop using a camera head mounted on a motorized pan-tilt unit. The depth perception will be augmented by a control architecture that moves the camera head in such a way that improves the depth map. Overall, the project will require development of a neuronal model, its implementation in neuromorphic hardware, and validation in robotic experiments.

Tentative time plan

- reading about neuromorphic hardware and neuronal algorithm for disparity calculation (2 weeks)
- getting acquainted with the code base and the neural disparity algorithm (2 week)
- improvement of the correspondence algorithm and densifying the map (5 weeks)
- hardware implementation and initial tests (6 weeks)
- experiments with a closed-loop, robotic system, refinement of the model (6 weeks)

- validation, benchmarking (3 weeks)
- writing up (3 weeks)

References

[1] P. Lichtsteiner, C. Posch, and T. Delbruck. A 128 X 128 120db 30mw asynchronous vision sensor that responds to relative intensity change. *2006 IEEE International Solid State Circuits Conference - Digest of Technical Papers*, pages 2004–2006, 2006.

[2] Marc Osswald, Sio-Hoi Ieng, Ryad Benosman, and Giacomo Indiveri. A spiking neural network model of 3D perception for event-based neuromorphic stereo vision systems. *Scientific Reports*, 7(December 2016):40703, 2017.

[3] Ning Qiao, Hesham Mostafa, Federico Corradi, Marc Osswald, Dora Sumislawska, Giacomo Indiveri, and Giacomo Indiveri. A Re-configurable On-line Learning Spiking Neuromorphic Processor comprising 256 neurons and 128K synapses. *Frontiers in neuroscience*, 9(February), 2015.