Building Brains for Robots: Neuromorphic SNN-based Controls for Robot Visuomotor Tasks

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ABSTRACT

The long term goal of this research within the framework of the European Human Brain Project (HBP) is to understand, to model and to translate biomorphic neural principles towards biocybernetic robot control systems. In comparison to conventional computing the brain is superior in terms of energy efficiency, robustness and adaptivity. Thus, we investigate into modeling biologic processes enabling the brain to perform sensomotoric computation and finally to implement it in silicon in form of biomorphic hardware. Todays neuromorphic hardware consists of spiking neural networks (SNNs)
which can perform fast and efficient computations with continuous input - output streams based on synaptic plasticity. We focus on brain like senso-motor control tasks and ground them with the help of real robots. Spiking neural networks have the potential on replicating real neurons reflecting parts of their biological characteristics. SNNs are capable
to perform synaptic spike-based communication with local brain functionalities supporting learning with the help of neural plasticity mechanisms. We assume, that the brain is forming sensor-motor primitives within building blocks composed for object detection, localization, event prediction, and finally the generation and execution of motion and interaction. The combination of neural motion primitives represent complex muscle motor synergies with the potential to learn complex large scale motions. Our SNN control architecture is capable to perform tasks like object recognition, object tracking, target reaching and grasping as well as collision- and obstacle avoidance. Closing the visuomotor loop by mapping the learned visual representation to motor commands show that SNNs learn without any planning algorithms nor inverse kinematics. SNNs are event driven and model free. We introduce deep continuous local learning mechanisms achieving state of the art robot accuracy on event stream benchmarks. Biologically plausible reward-learning rules based on synaptic sampling show that SNNs are capable of learning policies and various movement characteristics.

Links between reward-modulated synaptic plasticity and online reinforcement learning show proposing results. The hyper-parameters of this neuromodulation and their impact on performance are to be discussed with the help of some closed-loop sensorimotor experiments. The potential of deep reinforcement learning for target reaching affects object interaction, manipulation and grasping tasks and allows its realtime execution within timevariant situations. An event-driven binocular DVS system is used in stereo mode driven by micro saccades. The spiking feedback information from the DVS and from proprioception is mapped towards motion generating SNNs applying reward coupling and prediction error minimization techniques. Future work towards the effective use of neuromorphic vision with emphasis to eye movement, micro saccades, visual affordance learning and high performance event prediction will be discussed. In addition it can be shown, that the brain-inspired computational paradigm can be extended towards SNN based navigation and mapping (BSLAM) forming episodic spatial neural memories with multi-scale learning capabilities. A software framework for developing and programming the related SNN-clusters and a neural robot platform (NRP) is to be presented.

CV

Rüdiger Dillmann received his Ph. D. from University of Karlsruhe in 1980. Since 1987 he has been Professor of the Department of Computer Science and was Director of the Research Lab. Humanoids and Intelligence Systems at KIT. 2002 he became director of the innovation lab. IDS (interactive director at systems) at the Research Center for Information Science (FZI), Karlsruhe. 2009 he founded the Institute of Anthropomatics and Robotics at the Karlsruhe Institute of Technology. His research interest is in the areas of human-robot interaction, neurorobotics with special emphasis on intelligent, autonomous and interactive robot behaviour generated with the help of machine learning methods and programming by demonstration (PbD). Other research interests include machine vision for mobile systems, man-machine cooperation, computer supported intervention in surgery and related simulation techniques. He is author/co-author of more than 1000 scientific publications, conference papers, several books and book contributions. He was Coordinator of the German Collaborative Research Center "Humanoid Robots", SFB 588, and several large scale European IPs. He is Editor in Chief of the book series COSMOS, Springer.

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