Controlling a Redundant Articulated Robot in Task Space with Spiking Neurons

Samir Menon[1], Vinay Sriram[1], Luis Kumanduri[1], Oussama Khatib[1], and Kwabena Boahen[2]

Departments of Computer Science[1] and Bioengineering[2], Stanford University, Stanford, CA 94305, USA
smenon@cs.stanford.edu,vsriram@stanford.edu,luisk@stanford.edu, ok@cs.stanford.edu,boahen@stanford.edu

Abstract. Using spiking neural network (SNN) controllers [3] to implement multiple motor tasks for complex redundant robots requires efficient methods to compute complex kinematic and dynamic functions with spiking neurons. Three fundamental problems arise while using SNNs to compute high-dimensional robot kinematics using steady-state spike rate decoding (following the neural engineering framework [2]): first, differential maps from the generalized coordinates to task-space, task control Jacobians, cease to be humanly factorizable into sub-functions with low-dimensional domains; second, efficient Jacobian factorizations require multiple neuron layers, exacerbating neuron spike noise and latency; and third, function-agnostic sampling strategies require an exponential growth in the number of neural response samples as the number of input dimensions increases. Here, we present an SNN implementation that overcomes these problems to compute kinematic functions (Jacobians) for the *Kuka LBR iiwa*, and *Kinova JACO*, which have seven and six degrees-of-freedom respectively. Both robots are redundant for task space motion control. To control them, we developed a multi-task control system where task Jacobians, and a part of the Jacobian's dynamically consistent generalized inverse, were implemented with SNNs. Our SNN was an asynchronous spiking neural simulation with dynamical neurons modeled using the Neurogrid neuromorphic system's soma equations [1]; it thus serves as a model of what neuromorphic computers can achieve.

Keywords: Neurobotics, spiking neural networks, multi-task control

References

1. Benjamin, B.V., Gao, P., McQuinn, E., Choudhary, S., Chandrasekaran, A., Bussat, J.M., Alvarez-Icaza, R., Arthur, J., Merolla, P., Boahen, K.: Neurogrid: A mixed-analog-digital multichip system for large-scale neural simulations. Proceedings of the IEEE 102(5), 699–716 (May 2014)
2. Eliasmith, C., Anderson, C.: Neural Engineering: Computation, Representation, and Dynamics in Neurobiological Systems. MIT Press (2004)
3. Menon, S., Fok, S., Neckar, A., Khatib, O., Boahen, K.: Controlling articulated robots in task-space with spiking silicon neurons. In: Biomedical Robotics and Biomechatronics (2014 5th IEEE RAS EMBS International Conference on). pp. 181–186 (August 2014)