A spiking neural network control system for the investigation of sensori-motor protocols in neurorobotic simulations.

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We propose a functional bio-inspired multi-area model in NEST [1] for motor control where the information is frequency-coded and exchanged between spiking neurons.

Our model consists of a controller, representing the central nervous system, and an effector, modelled as an arm and implemented with PyBullet [2] (Fig 1).

Different functional areas build up the controller, each one modelled with spiking neuronal populations, which we implemented ad-hoc to perform mathematical operations (e.g., Bayesian integration [3]). Additionally, to study cerebellar role in motor adaptation, we included a detailed model of the cerebellum [4], consisting of EGLIF neurons [5] and ad hoc Spike-Timing Dependent Plasticity rules [6].

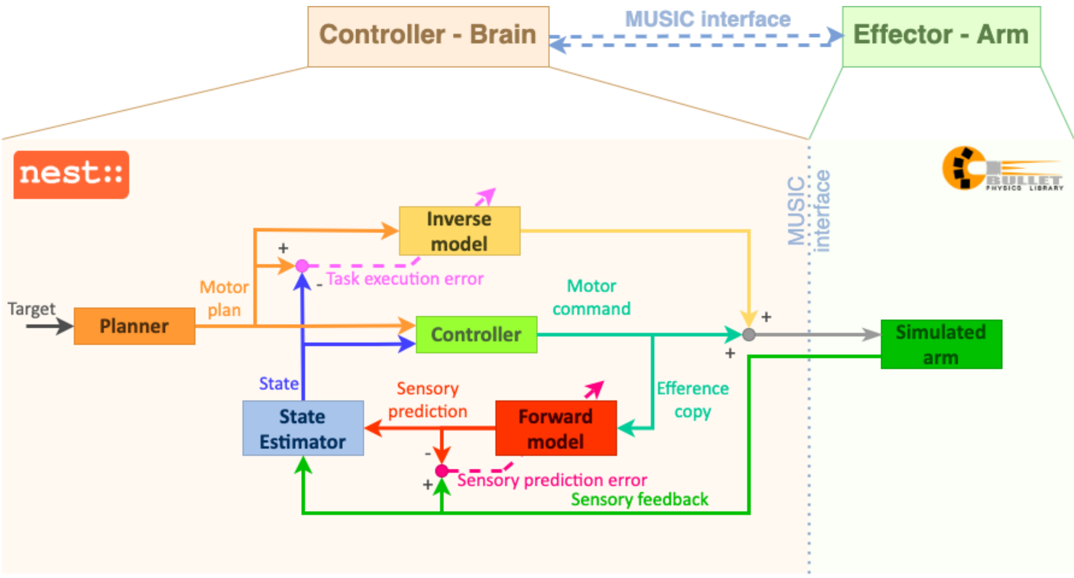

Figure 1: The model is divided into the controller and the effector, which exchange spike events through the MUSIC API. The controller consists of different functional blocks. The planner (orange) evaluates the kinematics to reach a certain target given a starting position. Both the controller (green) and the cerebellar inverse model (yellow) transform that kinematics into motor commands (i.e. torques) and are updated by the current state of the dynamical system. The cerebellar forward model (red) predicts the execution outcome from the efference copy and is updated by the prediction error. Finally, the state estimator (cyan) evaluates the current state based on both the prediction and the sensory feedback. The simulated arm is controlled in torques (directly the ones received from the controller) and provides the joint angles as frequency-coded sensory feedback.

Finally, to manage the communication between the brain and the arm, we make use of the MUSIC interface [7].

We used the model for the control of a single degree of freedom in the elbow joint. Preliminary simulations show proper signals transmission among areas in the model, bioinspired encoding/decoding of end-effector signals, and learning capability driven by the cerebellum. Finally, the MPI-based setup enables the use of distributed resources (i.e., we tested the system with 10 parallel MPI processes). This allows to address the computational requirements of simulations, facilitating also the control of multiple DoFs in future studies.

Acknowledgements

This research has received funding from the European Union's Horizon2020 Framework Programme for Research and Innovation under Specific Grant Agreement n. 945539 (Human Brain Project SGA3) and by the HBP Partnering Project CerebNEST.

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