Investigation of cerebro-cerebellar reward-based mechanisms on a virtual neurorobot

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***Abstract*—Combining computational neuroscience tools with robotic devices allows to reproduce and investigate the interactions between embodied functional brain models and sensory-rich environments, integrating neural activity and behavioral data. As these models seldom include faithful biological features, their development can be used to suggest and test hypotheses on neurophysiological or pathological mechanisms, eventually impacting on challenging clinical applications. This project implemented a virtual neurorobotic experiment aimed at investigating the functional role of cerebro-cerebellar interactions in motor learning tasks, specifically designed to clarify the contribution of different brain areas in motor preparation and execution during rewarded goal-oriented actions.**

***Index Terms*—Neurorobotics, reward-based learning, computational neuroscience**

I. Introduction

Adaptive behavior in biological organisms results from interactions among brains, bodies, and environments [1]. Neurorobotics allows to incorporate features of neuroanatomy and neurophysiology within robotic devices to generate biologically-comparable experimental data to study such mechanisms through supervised protocols. In particular, a neurorobotic device is a device that engages in a behavioral task, is situated in a structured environment and whose behavior is controlled by a simulated nervous system having a design that reflects, at some level, the brain's architecture and dynamics [1]. Thus, neurorobotic models allow to develop and test theories of brain-environment interactions with devices either implemented with hardware solutions or reconstructed via software. This project was developed using the Neurobotics Platform (NRP), an integrated software toolkit developed within the Human Brain Project (HBP) specifically aimed at allowing researchers to design and execute neurorobotic experiments with simulated robots using customized brain models [2].

II. Materials and Methods

A. The Neurorobotics Platform

To simulate behaviors, the NRP combines 3D physical environment reconstructions with realistic brain models based on spiking neural networks (SNN), whose information-processing mechanisms mimic the action potentials of biological neurons. Connections between these two components are implemented with transfer functions translating either the robot sensory information to brain model inputs (robot to neuron (R2N) functions) or neural network outputs to robotic motor commands (neuron to robot (N2R) functions). Therefore, this project required the implementation of both a virtual environment and a neural network model, with their respective transfer functions, to simulate the execution of a reward-based behavioural task by the robotic subject.

B. Behavioural task and virtual environment

The behavioural task that the robotic subject engages in is a reach-to-grasp associative task: in standing position, the robot places its hands on a resting bar and waits for a directional somatosensory stimulus, modelled as a rotating bar that touches the robot left/right shoulder. After this anticipatory signal, the robot waits without moving for a visual go-cue (given by a color-changing screen) after which it is required to reach one of the two cylindrical objects in front of it, mirroring the direction of the somatosensory stimulus: if no reaching contact is detected after a certain time delay, the task fails and the robot has to place its arms back on the resting bar to start a new trial, otherwise the task is completed and the subject receives a reward input signal. Among the available NRP robotic models, the iCub humanoid robot was chosen [3], being able to perform forelimb movements involved in the protocol. The virtual environment setup (Fig. 1) included all the objects required for the task execution, embedding