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The Neurorobotics Platform: virtual bodies for biologically realistic brain models and vice versa

Lorenzo Vannucci, Ugo Albanese, Murat Kirtay, Elisa Massi, Stefano Nardo,
Matteo Priorelli, Alessio Fasano, Cecilia Laschi, Egidio Falotico
The BioRobotics Institute, Scuola Superiore Sant'Anna, Pontendera (PI), Italy
{lorenzo.vannucci, ugo.albanese, murat.kirtay, elisa.massi, stefano.nardo,
matteo.priorelli, alessio.fasano, cecilia.laschi, egidio.falotico}@santannapisa.it

***Abstract*—The Neurorobotics Platform is a simulation software aimed at facilitating mutual interactions between robotics and neuroscientific studies. This tool allows roboticists and neuroscientists to fill the gap between the two disciplines by easing the job of connecting brain simulations with embodiments. This tool could enable a paradigm shift in neurorobotics. In this work, we focus on describing key features of the NRP and few examples on how the NRP can be used to perform neurorobotics research.**

***Index Terms*—neurorobotics, simulation, spiking neural networks**

I. Introduction

The human brain embodies skills that most advanced artificial systems, such as sensory-rich robots and computer-aided decision support systems, cannot demonstrate. That is why, over the last decades, a considerable amount of collective efforts –e.g., European Union's Human Brain Project and Japan's Brain/Mind project– have been made towards understanding the underlying principles of the brain mechanisms from different perspectives including engineering, medicine, robotics, and theoretical neuroscience [1].

This paper presents a simulation environment in development in the framework of the Human Brain Project (HBP). Here, our aim is to introduce the features of the Neurorobotics Platform (NRP) and present few use cases for the platform and its contributions to neuroscience and robotics fields. The vision of the NRP is twofold. On the one hand, the platform provides an opportunity to neuroscientists to test their theoretical and computational brain models on virtual agents with different embodiments in a physically realistic simulation environment. On the other hand, the platform enables roboticists to employ biologically realistic neural models (such as spiking neural networks). Furthermore, state-of-the-art machine learning and biologically motivated learning frameworks can also be integrated into the NRP. In principle, the same robotic task could be performed using different AI technologies.

The NRP is the only framework to provide this set of functionalities and aims at reaching a wide user base thanks to the fact that is released as open source software.

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II. The Neurorobotics Platform

The architecture of the NRP consists of two main parts: frontend and backend (Figure 1) [2]. The frontend contains design and visualization components and in particular the Experiment Simulation Viewer (ESV), a web-based graphical interface. The backend provides modules that enable the designed neurorobotic experiment to run. Both the frontend and backend have access to the storage infrastructure, containing software modules that save and load experiment data.

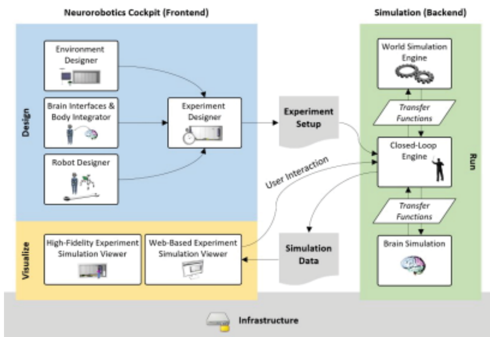

Fig. 1. Architecture overview diagram of the NRP.

The Backend comprises all the software components that are needed to simulate a neurorobotics experiment: the physical simulation of robots and their environment; the simulation of the neural network that controls the robot; the Closed Loop Engine (CLE), that implements the unique logic of each experiment and orchestrates the interaction between the two simulators.

Using the ESV, the user can control and visualize neurorobotics experiments. The ESV also provides a number of editors to design and configure the experimental protocol as well as the parts of the experiment such as environment, brain model, and connections between brain and robots. Besides the ESV, the interactive client, the user can control the platform via a scriptable interface, in the form of a python library, named Virtual Coach (VC). Giving the user a programmatic way of running simulations, the Virtual Coach is ideal for those experiments that require to be run multiple times in a loop, such as those involving reinforcement learning, for example.

III. USE CASES FOR THE NRP

In this section, we show three different experiments implemented with the NRP, starting with the most robotic one to the most neuroscientific one.

A. Evolutionary and Adaptive Robotic Locomotion

In this setup, a quadruped robot learns to locomote by using a combination of genetic algorithms and adaptive control [3]. In particular, the periodic gaits for the legs are implemented through oscillators whose parameters are found via a genetic algorithm, while the leg controllers employ cerebellar-inspired online learning techniques to overcome changes in the terrain or robot dynamics (Figure 2). Among the features of the NRP, this experiments makes use of the possibility to integrate artificial neural network in the control loop and of the VC to perform the genetic algorithm in a programmatic fashion. With this experiment we assessed the advantages of including the adaptive component during the evolutionary process.

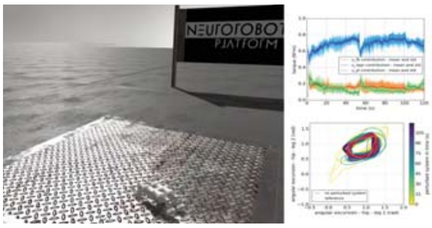

Fig. 2. The Fable robot in the NRP and plots showing the performances of the locomotion controller during a task in which a disturbance was applied.

B. Retinal visual tracking

In this experiment, a humanoid robot is controlled via a mixture of detailed brain models and classic control in order to perform a visual tracking task [4]. Target detection is done through a pipeline composed of a realistic retinal processing [5] and a spiking neural network, and this information is used by a classic robotic controller that moves the eyes of the robot towards the target (Figure 3). This experiment makes use of all the unique features of the CLE of the NRP such as the synchronization of different modules, and also shows how it is possible to integrate external frameworks in the simulation.

Fig. 3. Retinal visual target tracking experiment in simulation.

C. In-silico mouse rehabilitation experiment

The aim of this experimental setup is to reproduce, from both neural and physical sides, a neuroscientific experiment in which a mouse undergoes a post-stroke robotic rehabilitation procedure [6]. As a first step towards the complete simulation we developed an experiment with a musculoskeletal mouse forelimb, the robotic rehabilitation platform and a detailed model of the spinal cord circuit (Figure 4). The movement of the mouse forelimb was produced by injecting neurophysiological recordings of the mouse motor cortex as inputs to the spinal network, thus assessing the validity of the initial setup.

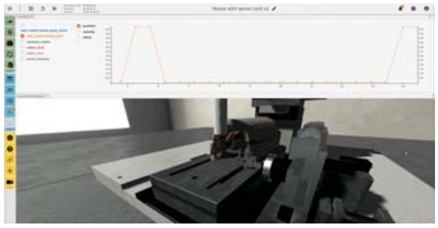

Fig. 4. Simulated mouse rehabilitation experiment in the NRP with the musculoskeletal embodiment and the robotic platform.

IV. CONCLUSIONS

In this work, we have presented the Neurorobotics Platform and use cases to illustrate some of its features. The presented uses cases show that the NRP can be used to implement both robotic and neuroscientific experiment, thus bridging the gap between the two communities.

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