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A Neuromorphic Motion Controller for a Biped Robot

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Humans beings, during their life, are exposed to dynamic environments that force them to quickly react to external stimulus, adapt to new situations and learn new sensory-motor control strategies. In an analogous way a humanoid robot which is supposed to operate in an unstructured environment is also required to learn and adapt while operating and performing different tasks.

Continuous Time Recurrent Neural Networks (CTRNN) represent a powerful paradigm to control mobile robotics systems [1]. They can be used to predict sensory inputs, for image processing, speech recognition and to generate motion trajectories [2]. Different learning methods can be applied to tune the CTRNN's synapses such as back-propagation through time [3], real-time recurrent learning [4], Kalman filters, etc. In particular, the reward-modulated Hebbian learning rule [5] represents a more biological plausible method where the adaptation depends on a binary signal encoding an instantaneous reward based on the average performance of the neural controller.

Here we propose a neuromorphic control system for a medium size humanoid robot under development in the Robotics and Mechatronics Department at Nazarbayev University (Fig.1) and in cooperation with Politecnico di Milano. The high level layer decides which motion primitives to generate according to the task. The middle level layer coordinates the low level modules setting the gait frequency, the step size and height. Finally the low level modules, that mimic the structure of microcircuits located in the primates cortex [6], generate the joints trajectories. More specifically, each module is represented by a CTRNN of 200 neurons randomly and sparsely connected with fixed synapses and capable to learn and reproduce tunable periodic trajectories. Each neuron in the circuit is modeled by a first order differential equation with a sigmoidal activation function. The adaptation takes place in the synapses of readout units that realize a linear combination of the neurons output in order to reproduce the target signals.

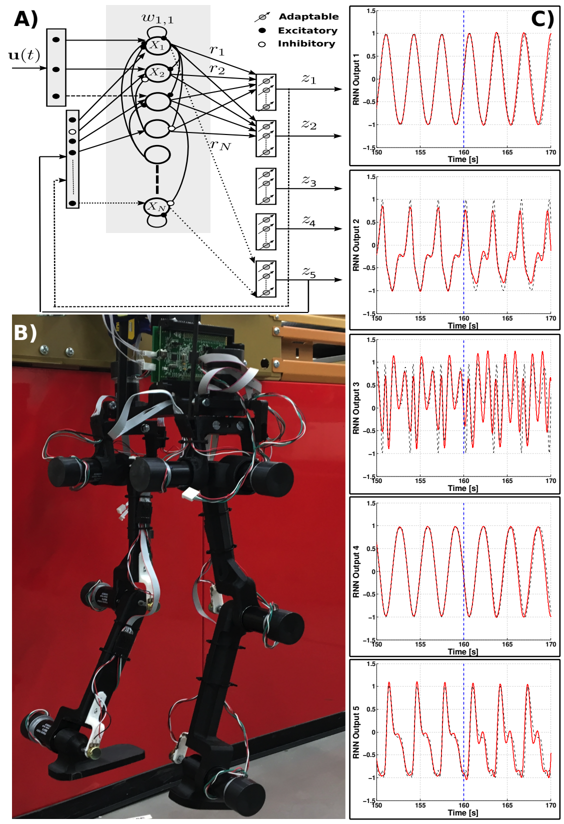

Fig. 1. **A)** A low level CTRNN module, **B)** Biped prototype under development at Nazarbayev University: 10DOFs, 4.5Kg, 0.6m height **C)** Learned trajectories for the five joints of the biped right leg obtained from a step simulation, the vertical blue dashed line indicates the learning time.

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