

A substantial gap remains between the effortless movements of animals in unknown environments and the ability of robots to reproduce these agile behaviors [1]. A key challenge stems from the animal nervous system, which is radically different from the computational architectures currently adopted in modern robotics. This motivates the growing interest in biologically inspired controllers, especially central pattern generators (CPGs). These nonlinear systems structurally encode rhythms and offer essential features for locomotion, including stable limit cycles [2], trajectory modulation [2], and entrainment [3].

In this study, we investigate CPGs with integrated sensory feedback and dynamic coupling with a physical robot. The goal is to adjust the generation of the rhythms to guarantee resilient robot locomotion in the presence of real-world perturbations. We work in the simplified setting of a hopper robot (Figure 1), controlling the force injected into a Hill-type muscle model [5].

As a first step, we revisit the classical design of a half-center oscillator (HCO) made of two bursting inhibitory neurons. This setup produces an endogenous rhythm but shows the limitations that traditional CPGs have when paired with systems that require precise actuation timing. As a second step, we show how these limitations can be addressed through the direct interconnection between a bursting neuron and the robot body. This defines a new CPG, whose rhythm is generated through the interplay of neural and robot dynamics. Specifically, an inhibitory synaptic connection from a robot sensor to a bursting neuron triggers a rebound burst, which, in turn, activates the contractile element of the muscle model driving the robot. This bidirectional coupling between neural dynamics and the physical body is a novel mechanism that ensures precise actuation of the hopper, which is robust to unexpected changes.

As a final step, by combining both architectures, we develop a robust controller capable of generating endogenous rhythm independently from the environment while enabling slow modulation and fast reactions from sensory feedback.

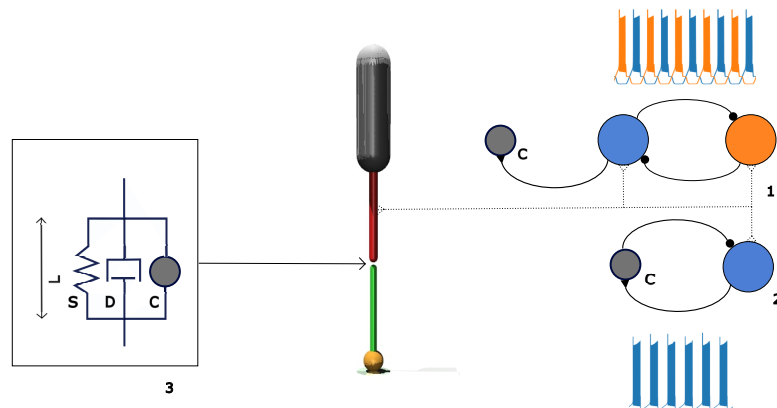


Figure 1: Either rhythmic (1) or reactive (2) actuation setups interact with the contractile element (C) of a Hill-like muscle model (3), with modulation provided by sensory feedback (dotted line).

References

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