Partially embodied motor control: towards a natural collaboration between body and brain.

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Abstract

Motor control systems in the brain humans and mammals are hierarchically organised, with each level controlling increasingly complex motor actions. Each level is controlled by the higher levels and also receives sensory and/or proprioceptive feedback. Through learning, this hierarchical structure adapts to its body, its sensors and the way these interact with the environment. An even more integrated view is taken in morphological or embodied computation. On the one hand, there is both biological and mechanical (robotics) evidence that a properly chosen body morphology can drastically facilitate control when the body dynamics naturally generate low level motion primitives. On the other hand, several papers have used physical bodies as reservoirs in a reservoir computing setup. In some cases, reservoir computing was used as an easy way to obtain robust linear feedback controllers for locomotion. In other cases, the body dynamics of soft robots were shown to perform general computations in response to some input stimulation. In general, very specific highly compliant bodies were used. We present recent results on two open questions regarding the way morphological computation could be exploited in biological motor control.

Generally, when reservoir computing has been used to exploit body dynamics for computation, the desired output signals were known. Clearly, in biological locomotion, the learning does not enforce specific muscle actuation signals. Instead, it rewards desirable forms of motion and penalizes undesirable ones. We show how a biologically plausible learning rule, reward modulated Hebbian learning, can enable the incorporation of compliant body dynamics into the control hierarchy, resulting in robust motor control.

Despite the many successes with using physical bodies as reservoirs, the relationship between compliance and computational power has hardly been investigated. Although biological bodies are partially compliant, they also have a very specific structure and many rigid parts. It therefore remains unclear to what extent this type of bodies can help in motor control. In our research, we use compliant four legged robots to address this issue. We present first results that indicate that for such robots, linear feedback of proprioceptive signals alone is often not sufficient to result in stable gait control. In addition, a first comparison of different levels of compliance indicate that a well chosen level of compliance can drastically simplify motor control, compared to both, too little and too much compliance, and that the body should therefore be considered as an integral part of the control.