Combined Control Strategies for Advanced Locomotion Control in a Six-Legged Robot

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Walking animals show a variety and self-organization of behaviors leading to effective locomotion over rough terrain as well as complex environments. These achievements of the animals are driven by reactive and self-organized learning mechanisms. Recognizing that, to date, most walking robots employ preprogrammed reactive control leading to a limitation of adaptivity and self-organization. As a consequence, they might have difficulty to locomote over unknown rough terrain. In contrast, we employ neural locomotion control based on a central pattern generator (CPG) [1] and a self-organizing neural learning mechanism (known as homeokinesis [2,3]) for self-organized locomotion generation over rough terrain. Accordingly, this combination allows a hexapod to successfully transverse over the terrain. This is because minimization of the objective function ($E=||v||*||v||$, called time loop error (Fig. 1)) of homeokinesis leads to sensitivity of the motor output with respect to changes in the proprioceptive sensory input and the predictability of future inputs by an internal model. This paradigm shows high exploration abilities enabling the hexapod to appropriately free its legs when getting stuck as well as find footholds based on the self-organization principle. We first evaluate the proposed controller via physical simulation where the simulated hexapod is situated in very rough terrain (Fig. 1). Experimental results show that the hexapod gets stuck and fails to walk through the terrain if only CPG based locomotion control is used. On the other hand, the hexapod successfully walks through the terrain if the combination of CPG and homeokinetic control is employed.
Besides these experiments, we also apply information theoretical measures to analyze and evaluate the performance of homeokinesis in a complex sensorimotor system (i.e., hexapod). In future work, we will implement the controller on the real hexapod platform AMOS II (Fig. 1) and test it in real complex terrains.

References:

[1] Manoonpong P., Woegoetter F., Pasemann F. (2010) Biological Inspiration for Mechanical Design and Control of Autonomous Walking Robots: Towards Life-like Robots. The International Journal of Applied Biomedical Engineering (IJABME), Vol. 3, No. 1, pp. 1-12.

[2] Der, R. (2001). Self-organized acquisition of situated behaviors. Theory Biosci., 120(3-4):179-187.

[3] Hesse, F., Martius, G., Der, R., and Herrmann, J. M. (2009). A Sensor-Based Learning Algorithm for the Self-Organization of Robot Behavior. Algorithms, 2(1):398-409.

[4] http://robot.informatik.uni-leipzig.de/software

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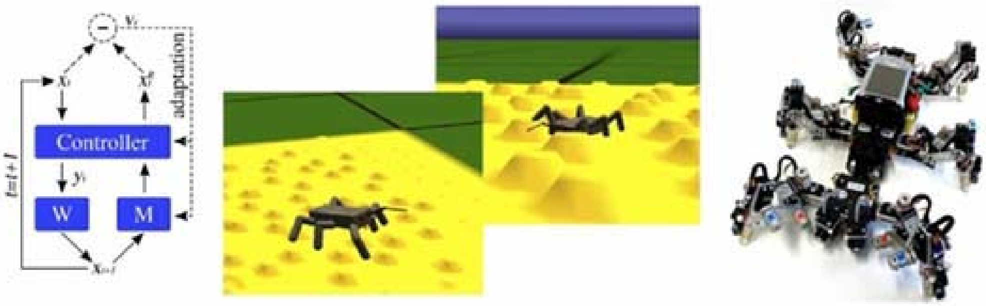

Figure 1: Left: Homeokinetic control structure and indicated learning scheme. The left part shows the sensorimotor loop where a sensor value x is processed by the controller to a motor command y. The execution of the latter in the world (W) leads to a new sensor value in the next time step. In the center part the closing of the time loop is depicted, where the new sensor value is propagated backward in time through an internal model (M) and through the controller, leading to a reconstructed sensor value at time t. The input shift v, measures the difference between the true sensor value and the reconstructed sensor value at time step t. The time loop error E=||v||*||v|| is used for the parameter adaptation of world model and controller. Middle: Simulations of hexapod in rough terrain using the lpzrobots software package [4]. Right: The real hexapod AMOSII.