Self-organized limit cycles and chaotic attractors in the sensorimotor loop of simulated and real-world robots

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Locomotion may arise either from top-down control or from self-organized attracting states in the sensorimotor loop. The dynamic phase space encompasses in the latter case both internal degrees of freedom of the robot and environmental variables. We present several types of self-organized robots for which the actuators are controlled by only one or two rate-encoding neurons. The state of the world is transmitted to the neurons exclusively via proprioception, which reduces for the case of wheeled robots to the measured angle of the wheel. The robots are either simulated within the LPZRobots simulation environment, or built using the LEGO Mindstorms hardware.

Highly complex behavior is observed, with regular and irregular locomotion corresponding respectively to limit cycle and to chaotic attractors in the sensorimotor loop. We show that the interaction with the environment may lead to changes of the attractor landscape in the sensorimotor loop and hence to behavioral state switching, which may be induced also through kick control.

Fig. 1. Simulated (left; click for movie) and real-world (right; click for movie) self-organized wheeled robots. All wheels are independent, being controlled by one (left) or two (right) neurons. Every neuron has access only to the current angle of its wheel. Note the coordinated self-organized motion for the chain of cars (left) and the emergence of an embodied chaotic attractor (right).

Fig. 2. The wheeled robot breaks time reversal symmetry spontaneously (click for movie), with forward/backward locomotion corresponding to distinct limit cycle attractors in the sensorimotor loop. The forward attractor is destroyed when the robot hits the wall. The basin of attraction of the backward attractor consequently expands, when the wall is hit, with the robot reversing its direction.
