Behavior transitions provided by dynamical features of recurrent neural network - a case study of complex phenomena in behavior based robotics

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Abstract. Complex phenomena like bistability, periodic and quasi-periodic oscillations, and chaos can be already observed in small artificial recurrent neural networks (RNN). We utilize this rich reservoir of dynamical properties for behavior control of autonomous mobile robots. Using a special evolutionary program, the ENS^3 (evolution of neural systems by stochastic synthesis), recurrent neural network structures of general type for robot control are developed. Structure and size of the evolving RNN are open to the evolutionary process, and parameters like synaptic strengths are optimized simultaneously.

The ENS^3 can also be utilized to extend or couple already existing RNNs to achieve additional functionality. In such a way different behavioral (sub)-functionality can be non-linearly integrated in one network solving a global robot task. On the one hand, this strategy allows an incremental evolution of complex control structures solving robot tasks including more and more subtasks and their effective coordination. On the other hand, such incrementally evolved RNNs give us a wide variety of empirical setups to investigate multifunctionality and robust behavior changes in complex systems provided by non-linear coupled neural systems.

As a first simple example of this method we present an incrementally evolved recurrent network generating a motivational driven robot behavior. Following an ALife approach the robot has to maintain the level of its internal energy reservoir. This energy reservoir decrease over time, but can be refilled from energy sources located in the environment. To maintain its energy level the robot has to switch between different behaviors. According to the dynamical features of the underlying network we observed that the transition from one behavior to another bases on the switching from periodic attractors to a domain of bistability and the otherway around. This attractor switching leads to increasing fluctuations on the macroscopic level, i.e. the observable robot-environment interaction. Therefore, we claim that behavior transitions are emergent phenomena generated by the attractor switching of the controller and the boundary conditions given by the robot-environment interaction.