Coordinated Action of a Large Scale Robotic System through Self-Organizing Processes

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Abstract. Within the context of *Artificial Life* and *Evolutionary Robotics* we are facing the problem of how to coordinate the behavior of large scale distributed robotic systems ($n > 100$). Following the ideas of decentralized control and self-organizing processes we present an example of how to implemented such principles in a homogeneous group of robots controlled by artificial recurrent neural networks (RNN). It is important to emphasize that we are aiming at situated and embodied real world robots acting in dynamically changing environments.

The behavior of the described overall system is determined by three kinds of *structural coupling*. Every agent within the group is controlled by a RNN. By following a modular neurodynamics approach three evolved basic behaviors are encoded within the RNN that (i) have to be coupled in a way to maintain stable behavioral patterns which (ii) have to be robust against dynamically changing environmental conditions. Furthermore, agents are able to interact with each other through acoustic signaling. Hence, due to this local interaction, each agent (iii) is coupled to others in its surrounding in a way that it can influence the behavior of others as well as itself can be influenced by others. Here, we want to focus on the latter aspect. On a macroscopic level we show how a group of robots coordinates individual foraging and homing behavior in order to transfer collected energy to a nest while avoiding obstacles. Within the control architecture of each single robot a neural pattern generator is implemented that is able to generate very low frequent internal rhythms (period lengths up to two million time steps are possible). This pattern generator determines whether the robot displays foraging or homing behavior. Each robot is able to communicate its behavior switching through acoustic signaling that in turn can reset the pattern generator of perceiving robots. To some extend this reset of internal neural oscillators through external stimuli is inspired by biological systems, for example the flashing of fireflies during mating.

We show that it is possible to almost perfectly synchronize the behavior of a population containing up to 150 autonomous robots through simple local interactions, whereby at the beginning their behavioral patterns are completely out of phase. Furthermore we can demonstrate that is also possible to get individual rhythms in-phase even if the period length of individual internal rhythms are different among the population.