Coevolving Communication and Cooperation for Lattice Formation Tasks

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Abstract. Reactive multi-agent systems are shown to coevolve with explicit communication and cooperative behavior to solve lattice formation tasks. Comparable agents that lack the ability to communicate and cooperate are shown to be unsuccessful in solving the same tasks. The control system for these agents consists of identical cellular automata lookup tables handling communication, cooperation and motion subsystems.

1 Introduction

In nature, social insects such as bees, ants and termites collectively manage to construct hives and mounds, without any centralized supervision [1]. The agents in our simulation are driven by a decentralized control system and can take advantage of communication and cooperation strategies to produce a desired 'swarm' behavior. A decentralized approach offers some inherent advantages, including fault tolerance, parallelism, reliability, scalability and simplicity in agent design [2].

Our initial test has been to evolve a homogenous multi-agent system able to construct simple lattice structures. The lattice formation task involves redistributing a preset number of randomly scattered objects (blocks) in a 2-D grid world into a desired lattice structure. The agents move around the grid world and manipulate blocks using reactive control systems with input from simulated vision sensors, contact sensors and inter-agent communication. A global consensus is achieved when the agents arrange the blocks into one indistinguishable lattice structure (analogous to the heap formation task [3]). The reactive control system triggers one of four basis behaviors, namely move, manipulate object, pair-up (link) and communicate based on the state of numerous sensors.

2 Results and Discussion

For the GA run, the 2-D world size was a 16×16 grid with 24 agents, 36 blocks and a training time of 3000 time steps. Shannon's entropy function was used as a fitness evaluator for the 3×3 tilling pattern task. After 300 generations, the GA run converged to a reasonably high average fitness value (about 99). The

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agents learn to explicitly cooperate within the first 5-10 generations. From our findings, it appears the evolved solution perform well for much larger problem sizes of up to 100×100 grids as expected, due to our decentralized approach.

Within a coevolutionary process it would be expected for competing populations (or subsystems) to spur an 'arms race' [4]. The steady convergence in physical behaviors appears to exhibit this process. The communication protocol that had evolved from the GA run consists of a set of non-coherent signals with a mutually agreed upon meaning. A comparable agent was developed which lacked the ability to communicate and cooperate for solving the 3×3 tiling pattern task. Each agent had 7 vision sensors, which meant 4374 lookup table entries compared to the 349 entries for the agent discussed earlier. After having modified various genetic parameters, it was found the GA run never converged. For this particular case, techniques employing communication and cooperation have reduced the lookup table size by a factor 12.5 and have made the GA run computational feasible.

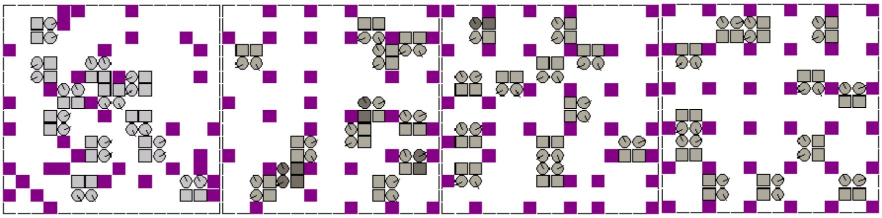

Fig. 1. Snapshot of the system taken at various time steps (0, 100, 400, 1600). The 2-D world size is a 16×16 grid with 28 agents and 36 blocks. At time step 0, neighboring agents are shown 'unlinked' (light gray) and by 100 time steps all 28 agents manage to 'link' (gray or dark gray). Agents shaded in dark gray carry a block. After 1600 time steps (far right), the agents come to a consensus and form one lattice structure.

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