Investigating Complexity with the New Ties Agent

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May 8, 2005

Abstract

It has been widely acknowledged that there are different levels of complexity and it increases if one starts from atoms and progresses towards societies [1, 6]. There are still many unresolved questions about how this increase takes place in different systems. One way to investigate this is by constructing systems that have this property of complexity increase. This is why agent based research seems to be a very good way of studying complexity. The New Ties project aims at setting up a large scale multi-agent simulation in which the population is to learn and evolve a social culture and individual capabilities that enables them to (co-) operate viable in their environment [9]. [1] The New Ties agent seems particularly suited to investigate complexity for the following reasons:

- the agents are complex,
- the agents are tools to analyse complexity,
- the agents have to form complex structures.

This abstract places emphasis on the first subject, since it gives an insight into how complexity is engineered. The subsequent two subjects are important from the point of view of the detection of complexity increase.

The New Ties agents are equipped with standard capabilities to perceive and act in their (virtual) world. They can recognize the objects of the world including messages sent by other agents. They can perform different actions like moving, picking up objects, and communicating with body language and auditory messages such as talking and shouting (for a complete description of the New Ties agent see the Technical Report [4]). Most of the complexity of the New Ties agent, however, resides in its capability to adapt.

In the New Ties agent we distinguish three types of adaptation or learning algorithms, namely individual, evolutionary and social learning. Each learning type is defined with respect to the direction of knowledge transfer from the perspective of an agent. In individual learning the knowledge transfer goes from the agent via the environment to itself. The learning agent is a sink. Individually learned knowledge remains with the agent that has acquired it, it is not passed to its offspring and in the absence of social learning it is not transferred to fellow agents either. In evolutionary learning the knowledge transfer is vertical, along the line of successive generations. Learning takes place at the population level. Good genomes are contained in well-performing individuals that obtain more offspring thus changing the allele distribution. In social learning the knowledge transfer is horizontal as the

[1] see also http://www.newties.org

knowledge that inhabitants learn individually is shared by explicitly "telling" it to each other, thereby collectively developing knowledge that covers different situations they encounter. To be able to tell 'something' there should be mutual understanding about the meaning of 'something'. We do not hardwire the meaning of words in agents: agents should develop language on their own. They have to find common words for objects in their world (for more details see [9]). Language evolution is thus an important aspect of social learning.

The agent controller, the decision making mechanism of the agent, will undergo all three types of learning. To integrate the different learning types in the controller we have developed the Decision Q -Tree, where a decision is made by tree traversal. A DQT consists of test, bias, and action nodes. In test nodes the decision determines whether the yes or no edge is taken. Every test node uses a model of the world, build by genetic and life time experience, that is used to make a decision. A bias node can have more edges. Each edge is labeled by a bias or a probability of choosing the given edge. An action node is almost similar to a bias node except that each edge leads to an action, while the edges of bias and test nodes can lead to any type of nodes. Individual learning, based on reinforcement learning [8], changes the preferences and decision making process in test nodes on the basis of rewards given to the action and propagates these rewards through the tree. Evolutionary learning uses the Genetic Programming paradigm [2] to recombine trees and evolves them further by means of specific mutation operators. Note that both operate on the initial tree templates of the parents to avoid Lamarkian evolution. Social learning changes the world model in the test nodes used for decision making.

With the statement "the agents are tools to analyse complexity" we mean that agents themselves can be used to analyse their environment, where the environment includes the other agents, as well. We can learn something from the environment and (other) agents by studying the agent. For example, information about (un-)successful behavior in a given environment can be extracted from the agent controller. Agents thus comprise knowledge bits of the world.

In the New Ties project one of the objectives is the formation of complex agent structures, or in other words the generation of complex patterns, which can be interpreted as social patterns. We expect the agents to start using tokens for trade, to learn to plan future actions, to remember their previous locations, and also to develop memory to span larger distances for going from one location to another. If the agents manage to learn and achieve some of the previously mentioned aims, it can result in a behaviour similar to the so-called Kula ring, which is an intricate social trading system practised by islanders to exchange necklaces in a non-competitive way to establish alliances with locals of the neighboring islands.(For a more detailed description see Gilbert et al. [3]). Another objective is the aforementioned language evolution, in particular the evolution of a grounded common language. These two objectives, considered as two major transitions in evolution [6], may contribute significantly to complexity research.

In the New Ties agents most of the complexity will be in the adaptive capability of decision making. This adaptive capability may allow for a second order emergence system as was described by Steels [7]; a system which is able to detect, amplify, and build upon emergent behavior. Learning mechanisms may cause a repeating loop of knowledge transfer with which new knowledge structures can be build that can be exchanged again. This may not only affect the knowledge structures, but also the way in which they are built. For example, evolution may find the controller structure best fitted for individual learning, which is known as the Baldwin effect [5]. This research may not only show that major transitions as societies and language development are possible, but it will also give us insight in how they *can* occur.

Our approach of studying complexity is thus by constructing large scale agent simulations. The project just started in autumn 2004. For now, we only have a vision, approach and design. We will gladly present them along with the first technical results by November 2005.

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