Polymorphic Self-* Agents using Game Theory for Large-Scale Complex Systems

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ABSTRACT

In the field of multi-agent systems, a lot of attention has been focused lately on investigating various architectures and methodologies that promote effective organization and coordination within large-scale, complex, distributed systems. Specifically, the interest is in developing approaches that can be implemented within multi-agent systems to produce desirable emergent behavior that coordinates individual actors in a system competing for resources such as bandwidth, computing power, and data. This extended abstract outlines polymorphic self-* agents that evolve a core set of roles and behavior based on environmental cues. The agents adapt these roles based on the changing demands of the environment. The design combines strategies from game theory, stigmergy, and other biologically inspired models.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence—*multiagent systems, coherence and coordination*

General Terms

design, experimentation

Keywords

multi-agent systems, self-* agents, polymorphism, stigmergy, game theory, SWARM

Multi-agent systems that exhibit self-∗ (self-organizing, self-managing, self-optimizing, self-protecting) behavior are increasingly being used to address difficult problems ranging from large-scale P2P resource sharing, routing, load balancing, and fault mitigation in real-time systems, to autonomous nanotechnology swarms (ANTS) that NASA is developing to explore Mars.

Many of these systems are based on game theory and various biologically inspired models. The paper included in these proceedings titled 'Polymorphic Self-* Agents for Stigmergic Fault Mitigation in Large-Scale Real-Time Embedded Systems', describes *polymorphic* agents that are capable of acting in multiple roles as directed by cues from the environment. Traditional fault mitigation techniques rely on specialized and redundant components that form a hierarchy of centralized control. Polymorphic agents on the other hand, evolve a core set of responsibilities, yet still possess the ability to take on alternate roles as they experience changes in the environment. The agents adapt to changing resource costs and availability using no centralized control, giving them a far wider range of roles than those found in traditional hierarchical systems. Other biologically inspired models such as *stigmergy* are also used. Game theory is used to prioritize local actions and analyze the overall behavior of the system.

The RTES/BTeV project is used to demonstrate the self-* properties of these agents. BTeV is a particle accelerator-based High Energy Physics (HEP) experiment currently under development at Fermi National Accelerator Laboratory. The data acquisition systems for the accelerator consists of approximately 2500 digital signal processors (DSPs) that are responsible for filtering incoming data at the extremely high rate of approximately 1.5 Terabytes per second.

The Distributed Multi-Agent Systems (DMA) Lab at Syracuse University, under the direction of Professor Jae C. Oh, is part of the Real-Time Embedded Systems (RTES) collaboration that is responsible for providing fault tolerance within BTeV. Given the number of components and countless fault scenarios involved, it is infeasible to design an 'expert system' that applies mitigative actions triggered from a central processing unit acting on rules capturing every possible system state. Instead, Derek Messie is investigating a distributed multi-agent systems approach that uses polymorphic, self-* agents to accomplish fault mitigation within the large-scale real-time RTES/BTeV environment.

This past fall, Mr. Messie assisted Professor Oh in organizing a workshop on games and emergent behavior in distributed computing environments. The workshop was designed to foster communication between researchers in the distributed AI and computer systems communities, one of the central themes of the DMA Lab. They hosted Prof. Rogerio De Lemos, a leader in the self-* community, from University of Kent at Canterbury, UK, as the invited speaker.

Derek Messie is a PhD Candidate and Research Assistant under Professor Jae C. Oh in the Department of Electrical Engineering and Computer Science at Syracuse University. His research focus is on self-organization and coordination within large-scale multi-agent systems. He holds an undergraduate degree in computer science from University at Buffalo, a Masters degree in computer science from Cornell University, and an M.B.A. from Syracuse University.

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