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Variations on Stigmergic Communication to Improve Artificial Intelligence and Biological Modeling

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Abstract
Stigmergy refers to indirect communication that was originally found in biological systems. It is used for self-organization by ants, bees, and flocks of birds, by allowing individuals to focus on local information. Through local communication among individuals, larger patterns are formed without centralized communication. This self-organization is just one type of system studied within complex systems. Systems of ants, bees, and flocks of birds are considered complex because they exhibit emergent behavior: the outcome is more than the sum of the individual parts. Emergent behavior can be found in many other systems as well. One example is the Internet, which is a series of computers organized in a self-organized fashion. Complexity can also be defined through properties other than emergent behavior, such as existing on multiple scales. Many biological systems are multi-scale. For instance, cancer exists on many scales, including the sub-cellular and cellular levels. Many computing systems are also multi-scale, as there may be both individual and system-wide controls interacting together to determine the output. Many multi-agent systems would fall into this category, as would many large software systems. In this dissertation I examine complex systems in artificial intelligence and biology: the growth of cancer, population dynamics,

emotions, multi-agent fault tolerance, and real-time strategic AI for games. My goal is twofold: a) to develop novel computational models of complex biological systems, and b) to tackle key AI research questions by proposing new algorithms and techniques that are inspired by those complex biological systems. In all of these cases I design variations on stigmergic communication to accomplish the task at hand. My contributions are a new agent-based cancer growth model, a proposed use of location communication for removing cancer, improved multi-agent fault tolerance through localized messaging, a new approach to modeling predator-prey dynamics using computational emotions, and improved strategic game AI through computational emotions.