Conspecific Emotional Cooperation Biases Population Dynamics:
A Cellular Automata Approach

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ABSTRACT

In this paper, the authors evaluate the benefit of emotions in population dynamics and evolution. The authors enhance cellular automata (CA) simulating the interactions of competing populations with emotionally inspired rules in communication, interpretation, and action. While CAs have been investigated in studies of population dynamics due to their ability to capture spatial interactions, emotion-like interactions have yet to be considered. Our cellular stochastic system describes interacting foxes that feed on rabbits that feed on carrots. Emotions enable foxes and rabbits to improve their decisions and share their experiences with neighboring conspecifics. To improve the system's biological relevance, it includes inter-species disease transmission, and emotions encode data pertaining to both survival and epidemic reduction. Results indicate that emotions increase adaptability, help control disease, and improve survival for the species that utilizes them. Simulations support the hypothesis that the acquisition of emotion may be an evolutionary result of competitive species interactions.

Keywords: *Artificial Life, Cellular Automata, Emotion, Population Dynamics, Predator-Prey*

INTRODUCTION

Population dynamics study the development of either a single or multiple interacting species. In ecology, computational models are used to study the evolution within populations of plants and animals, such as which trees will survive in a forest over many hundreds of years, or what ratio of species is sustainable. A major topic of population dynamics is the cycling of predator and prey populations. Predator-prey dynamics relate to a wide variety of ecological situations, from microbial phagocytosis to lions and gazelles. Most often predator-prey systems are built to describe animal species, with at least one species as prey and one as predator; however, they are not limited to describing only two species. The Lotka-Volterra (Lotka, 1925) equations are based on the classic logistic equation, and commonly used to model this type of

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mutual interaction. However, it has been argued that these equations are not sufficient for truly modeling natural phenomena, as the expected fluctuations in species numbers are not sustained properly (Lehman, 1997).

Cellular Automata (CA) offer a popular mechanism to analyze population dynamics as they directly represent spatial interactions between entities (Hogeweg, 1988). CA allow the creation of rules for determining how an entity will interact with its neighbors. The most popular version of a self-regenerating cellular automaton is the Game of Life, developed by Conway (Gardner, 1970). In the Game of Life cells are created or removed for the next time step based on the number of neighbors the cell has in the current time step. Although the rules can be completely defined in a single sentence, the dynamics are complex enough that they are still not completely understood. This ability of CA to give rise to complex dynamics via simple rules enhances its desirability for modeling complex phenomena, assuming that the appropriate simple rules can be designed. Thus, in population dynamics models, entities can explicitly exist on a grid and interact with specific neighbors. The system not only knows how many of each species is in the system, but to what extent they are mixed. The world can either be viewed as a torus with periodic boundary conditions or a bounded box that may or may not be square. A torus is beneficial for analysis and computation as all cells have the same number of neighbors. However, in many ways a bounded region is more realistic, as the ecosystem of a set of species will not extend completely around the world but instead exist in some localized area.

We increase the realism of evolutionary dynamics models in CA by introducing intra-species disease transmission and emotion-inspired rules for our predator and prey (foxes and rabbits). Real populations in nature are subject to epidemic diseases, a number of which can cross species. Such diseases have significant effects at the level of individual behavior and population dynamics. Evidence suggests that a primary contributor to the evolution of the emotion disgust is protection from the risk of disease (Curtis, 2004). We explore the relationship between disease transmission and emotional response. The development of emotions in higher animals has been conjectured to originate for purposes of survival in basic scenarios such as predator-prey (Blanchard, 2003; Löw, 2008), and thus emotionally-inspired rules are a natural extension to the traditional CA framework. Although they have been suggested previously for CA (Adamatzky, 2003), we are unaware of any work utilizing emotions in the context of predator-prey dynamics modeled within a CA framework.

Contradicting the older view that emotions typically interfere with decision making, in the last few years emotions were suggested to constitute an important part of adaptive decision making systems (Damasio, 1991; Sanfey, 2003). Case studies were reported describing people whose decision making was impaired when they suffered injury to or loss of areas of the brain related to emotion (Bechara, 2000). Instead of showing the benefit of decision making to an individual when emotions are involved as is done in these studies, we examine the benefit to the group when emotions are used.

Thus, we choose to include the six fundamental emotions as defined by Ekman (Ekman, 1999) to our rabbits and foxes, namely: happiness, sadness, fear, anger, disgust, and surprise. Emotions occur in response to specific world events, such as the happiness of food consumption and the fear of predator encroachment. Additionally, we enable conspecific communication of emotions to aid in coordination and cooperation. In other words, the emotional state of a member of a species will be communicated to a member of the same species within a restricted surrounding, and affect their emotional state. We consider this approach to emotional communication as an efficient way of transferring information that is crucial for the survival of the group. Our analysis shows that emotions enhance the realism of the simulation and offer increased utility to the modeled species. Additionally, we show that it is in the best interest of both rabbits and foxes to use

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