UNIVERSAL CONSTRAINTS TO LIFE DERIVED FROM ARTIFICIAL AGENTS AND GAMES.

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Introduction: This chapter explores evolutionary game theory in agent-based models within the context of astrobiology. Rooted in Evolutionary Prisoner's Dilemma, several variations on models are introduced, including Tit for Tat, Evolutionary Prisoner's Dilemma with birth and death, and deceptive communication. We found that access to global vs local information can influence whether artificial systems have an evolutionary stable strategy and parameters such as cooperation vs. competition have a significant impact on the sustainability of artificial systems. Only a small range of parameters and combinations of parameters lead to non-equilibrium in these systems, thus suggesting that systems that continue to evolve are constrained by very specific conditions. We explain which are these conditions and how these artificial systems are relevant for astrobiology.

Biological Applications of Agent-Based Models: Agent-based models are a common methodology to study complex systems, and compared with equation-based modeling, are less abstract, more complex and more straightforward. Agent-based models are computational models that simulate the behavior of autonomous agents in a specified environment, in order to assess their effects on the system as a whole. Agent-based models can be used to simulate or recreate emergent behaviors: through the simple behaviors enacted by agents locally, complex behaviors at the system level can be observed. Agent-based modelling has useful applications into astrobiology by creating scenarios and enabling us to observe universal constraints that delineate the boundaries of how and where life can exist.

Evolutionary Game Theory: Game theory fits well as a method to study astrobiology because it does not rely on assumptions about the environment and is based in logic and mathematics. Since we do not have enough understanding of the astrobiological environment or the biological structure of living-beings in space, we must rely on fundamental parameters to analyze such systems. The evolutionary game theory helps us understand the problem of strategy choice for an agent, biological or artificial. No behaviors are specified in the game; every pair of interactions can be interpreted as either cooperation or defection. The basic model we used in this respect is Iterated Prisoner's Dilemma (IPD). IPD consists of multiple rounds of PD, which simulates the behavior of "directed reciprocation".

Methodology and Simulations Experiments: We modeled cooperation and defection behavior of artificial agents in a series of agent-based models (ABM) with NetLogo.We have five models to simulate agents' interaction under different contexts. There are three main goals of these models: 1) To show the differences in behavior patterns under experimental tweaks. 2) The application of game theory strategies in simulating non-cognitive microorganisms. 3) To provide an idea for future research on similar topics. We used 5 different models, based on different variations of Prisoner's Dilemma and Tit-for-Tat. As exogenous parameters we used the rate of cooperation and defection award from game theory, adding movement and neighborhood radius for the spatial ones. Additionally, we implemented agent birth/death rate in one model and memory rates into another. Overall, we conducted more than 72000 simulations.

Results: We found that the defection award has large effects on how many simulations reach equilibrium (death) vs. how many simulations keep being out of equilibrium (evolving). The incorporation of random births and deaths in the systems leads the agents to choose a defection strategy at higher levels of defection award, no matter how short-lived the effects may be. Movement vs. non-movement of agents also has large effects on systems that reach equilibrium vs. which don't, both in how fast they move vs. how far they reach in their interactions. Our interpretation is that a larger reference radius will provide more global information for the agent to base its strategy on. Overall, our results are consistent with Axelrod's findings that the best strategy is to simply cooperate; when more agents start out playing "nice", the others follow suit very quickly (1981). In our simulation of deceptive communication, the simulations always show more trust receivers than honest signalers, regardless of the defection award.

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