Understanding Environmental Systems through the use of Agent Based Modeling and Genetic Algorithms

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Complex systems encompass a wide variety of situations, which describe phenomena studied in many different disciplines, such as social sciences, natural sciences and business. Understanding the behavior of complex systems and predicting the outcomes are of interest to scientists from all these disciplines. Starting from simple and well-defined initial rules, a complex system starts exhibiting complexity as an emergent behavior over time. This emergent behavior cannot be broken down into a set of starting rules, together with an evolution over time. The study of complex systems needs to be approached through innovative methods, since these systems have the limitation of not being able to be understood through traditional analytic approaches.

Agent Based Modeling (ABM) is recognized as an effective tool for the study of complex systems, and stands out from the traditionally used top-down methods due to its use of synthesis, rather than analysis to aid in understanding system behavior. Agent Based Modeling refers to the development of a model system where the participating and interacting entities are semi-autonomous. By building the model system with entities as the building blocks, the phenomenon of emergence inherent in these systems is naturally modeled.

Associated with a complex system and its rules are sets of parameters that define the behavior of the system. These parameter sets may be viewed as points in a parameter space. Generally, the number of points in a parameter space to be examined can be large, even for a complex system with a parameter space of three or four dimensions. Following the methods used by nature to find optimal solutions for complex problems, Genetic Algorithms (GA) are optimization algorithms which can be used to search the parameter space of a complex system for the best results. The Genetic Algorithms work in such a way as to improve the quality of solutions over successive iterations of the algorithm, thus maximizing resource utilization. Another advantage of applying a Genetic Algorithm is that they are very unlikely to misinterpret local optima for the global optimum, since they are good at balancing exploration and exploitation of the search space.

The system studied here is an ecosystem which is optimized for its ecological resilience. Ecological resilience is a measure of the amount of change a system can undergo without a change in its overall state. This factor is very significant in determining the stability of an ecosystem, its proximity to an unfavorable state, and also the key factors that might contribute its change into an unfavorable state. Here we investigate the resilience of a model ecosystem using the combined application of ABM and GA. This is the first approach to study environmental systems by a using these two powerful tools from computer science. It is a framework on which a real world ecosystem can be modeled to study various factors such as ecological risk assessment of toxic chemicals, extinction of species, the effect of human actions on the environment.