Optimal Control of the SugarScape Agent-based Model

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Abstract:

One of the challenges for the analysis of agent-based models is the determination of a strategy, policy or intervention that can produce a desired outcome from the model. For example, an intervention for a biomedical model to go from a disease state to health, a strategy for controlling an invasive species in an ecological model, or a tax policy that promotes growth in an economic model. Optimal control theory is a mathematical optimization technique that can be used to derive such interventions, however it is only applicable to continuous systems as described by differential equations and cannot be directly applied to an agent-based model. We posit that if a differential equation model is designed that approximates the agent-based model, then an optimal control derived for that different equation model may be applicable to control the agent-based model. In this research, we describe how we utilize this idea of model equivalency to apply optimal control theory to the well-known SugarScape agent-based model.

The SugarScape model was introduced in Epstein & Axtell’s book, Growing Artificial Societies: Social Science from the Bottom Up. It is a simple agent-based model that shows how wealth inequality can occur among a population of agents with heterogeneous attributes in a heterogeneous environment. Applying optimal control theory to SugarScape requires a series of steps: 1) define an objective function that captures the desired outcome as a set of constraints, 2) approximate SugarScape with a differential equation model, 3) derive the optimal control for the differential equation model and the objective function, 4) transform and apply the optimal control into SugarScape. Lastly, we can evaluate simulation results from applying the control to SugarScape and determine if we achieved the desired outcome. We will describe the challenges and results from each of these steps, and provide some insights into the possibility of using optimal control theory for more sophisticated agent-based models.