NIMBioS Working Group: Agent-Based Models of Biological Systems

Final report

After discussing the issues and approaches in optimal control of agent-based models, our group decided to focus on approximating ABM models by a variety of types of dynamical system models. We focused our efforts on two specific ABMs, rabbits-grass and Sugarscape (adapted from existing Netlogo models). The group adapted the Netlogo Sugarscape model to include individuals with different levels of ability to sense the landscape and move along a resource gradient and individuals are taxed according to their "sugar" wealth, ability, and location. The group successfully used a difference equation model to approximate the Sugarscape ABM. Pareto optimization was used to rank "tax" control strategies. For the Sugarscape ABM with a more complex landscape, approximation using nonlinear difference equations and on optimization using genetic algorithms was completed. For the Rabbits/Grass ABM model, a discrete time model counting the number of rabbits with the various energy levels was constructed to approximate the ABM, and control strategies were ranked with Pareto optimization. We have work in progress on partial differential equation approximation of those two ABMs and corresponding optimal control formulations.

The fourth meeting focused on working on current projects, writing a draft of a review paper on ABMs, and planning for the completion of several papers in progress. Progress made and lessons learned were discussed and some of those ideas will go into the review paper from this group.

We worked on the approximation of the Sugarscape ABM with a PDE system and on optimal control of that system corresponding to the sugar tax actions. Ben Fitzpatrick gave a report with some results on a new empirical systems identification approach to optimal control of our rabbits-grass ABM; progress was made on the PDE approximation and its control for that ABM. Jie Xiong presented new control results for the stochastic PDE system, which models a rabbits-grass interaction system, and we discussed the biological interpretation of the terms.

Members present for 4th meeting: Matt Oremland, David Gurarie, Scott Christley, Ben Fitzpatrick, Reinhard Laubenbacher, Suzanne Lenhart, Paula Federico, Rachael Neilan, Rene Salinas

Members calling in for 4th meeting: Gary An, Andrew Kanarek

Publications

- **Laubenbacher, R., Hinkelmann, F.,** and **Oremland, M**. (2013). Agent-based models and optimal control in biology: a discrete approach. In R. Robeva and T. Hodge (Ed.), *Mathematical Concepts and Methods in Modern Biology* (Edition 1, pp. 143 – 178). San Diego, CA: Elsevier.

- **Oremland, M**. and **Laubenbacher, R**. *Optimal control of agent-based models: scaling methods and heuristic algorithms*. Journal of Artificial Societies and Social Simulation, 2013, in press.

- **Oremland, M**. and **Laubenbacher, R**. *Optimal harvesting of a predator-prey agent-based model using difference equations.* Bulletin of Math Biology, 2013, under review.

- **Oremland, M**. and **Laubenbacher, R**. *Mathematical conversion of SugarScape to a system of analytical difference equations*. Journal of Economic Interaction and Coordination, 2013, under review.

- **P. Federico, S.Lenhart, D. Ryan and L. Gross**, Optimal Control in Individual Based Models: Implication from Aggregated Methods, American Naturalist 2013 (181), 64-71.

Manuscripts in Preparation

- **Oremland, M**., **DeAngelis, C., Susmann, H., Twohy, E., and Laubenbacher,** R. *A framework for solving optimization problems for agent-based models*. to be submitted January 2014.

- **Working group members,** A Systems of Agent-based Models in Biology, to be submitted to Bulletin of Mathematical Biology, 2014.

- **Fitzpatrick, B. and Federico, P.,** An empirical system identification approach to control of Agent-based Models, to be submitted in 2014.

- **Neilan, R. M., Christley, S., Oremland, M., R. Salinas, S. Lenhart,** Approximation and Optimal Control of the Sugarscape Model using PDEs, to be submitted in 2014

- **Lenhart, S., Xiong, J., and Yong, J.,** Optimal control of stochastic partial differential equations with an application in controlling rabbit population, to be submitted in 2014.

- **Federico, P., Oremland, M., Gurarie, D, Fitzpatrick, B., S. Lenhart, A. Kanarek,** Approximation and Optimal Control of a Rabbits-Grass ABM with a ODE/PDE system, to be submitted in 2014.