Fundamentals of Populations of Changing Composition in Agent Based Models

George Kampis[1]
gkampis@colbud.hu

László Gulyás[1, 2]
lgulyas@aitia.ai

[1]Collegium Budapest, Institute for Advanced Study, Szentháromság u. 2, H-1014 Budapest

[2]Aitia Inernational Inc., Czetz J. u. 48-50, H-1039 Budapest, Hungary

Abstract

We use agent based modeling (ABM) methodology to discuss simple yet crucial questions of modeling and social simulation. ABM is emerging as a new *de facto* standard for the modeling of social, biological and economic sciences and receives increasing recognition elsewhere. ABM offers itself as a critical methodology based on the „complete" definition of the individual, explicitly including its interactions, and for the possibility of fully embedded realizations in terms of encapsulated models. ABM models conceived in the above way offer the possibility of causally accounting for complex phenomena on the basis of fully specified agent properties (generic or idiosynchratic) and agent interactions in a transparent, bottom-up fashion.

In this respect, ABMs closely resemble Cellular Automata (CA), but there are important differences as well. In CA, there is typically a general definition and a connection rule obeyed by all local automata and global behavior is derived from these, together with specific configurations of initial conditions. CA-s therefore share a regular topology but also a lack of complexity and heterogeneity at the individual unit level. Also, CA's don't typically grow or shrink: the number of cells is kept constant. We can express all this by saying that CAs are space- and not object-centered. A particular category therefore of ABMs that are not well represented in CAs are systems of changing size and composition: biological populations, social systems (with migration and recruiting and with a characteristic lifetime), and various networks (mobile networks, economic transactions, etc.)

CAs have a widely known general methodology for handling occupancy/vacancy patterns where each local cell can be occupied by one or more individual token. Examples are M. Eigen and Winkler's seminal „Laws of the Game" or S. Wolfram's more recent „A New Kind of Science". In contrast, methodology is still lacking for general ABMs of changing composition. Looking for foundations of social and biological population modeling, we need to develop a comprehensive system similar in scope to the CA counterpart (and paralleling its results). This is attempted here.

Informed from studies in a varieties of fields (macroevolution, Markov processes, urn models, population modeling, economy, etc.) we provide a systematic study and a critical review of several mathematical formulations and their model counterparts for ABM systems of changing composition. We present experiments to illustrate the major categories of behavior, modeling principles, and common mistakes. We also study the realizability of mean-field systems in ABM models (for instance, Lotka Volterra competition models and other systems).

We start by developing a general mathematical formalism for dealing with CA and ABM models based on (Szemes and Gulyás 2006). We locate our population studies in this framework. Population approaches reviewed and tested include various inequivalent formulations such as birth-death processes, density-dependent and density independent population models, Polya urn models, various path dependent population rules and much else. We rely on the work of Mitzenmacher, S. Page, and others.

We found the dynamics of the above classes to be highly inequivalent, and the applied population simulation results (such as predator prey systems or social models or cooperation) to be highly dependent on the adopted formalism. For example, little known density-dependent drift models emerge under a variety of formal conditions leading to highly „selective" behaviors of populations without further constraints. Various widely available simulation platforms use several of these inequivalent forms without careful controls which according to our studies heavily influence the interpretability of results. We conclude with cases studies from our earlier work concerning evolving populations (de Back et al. 2007a,b) and cooperation behavior (Dugunji and Gulyas 2006, Gulyas 2007).

Acknowledgment
This work was supported by the EC grant QosCosGrid IST FP6 #033883. The authors wish to thank the hospitality of Collegium Budapest for the period of this study. L.G. acknowledges the partial support of the GVOP-3.2.2-2004.07-005/3.0 (ELTE Informatics Cooperative Research and Education Center) grant of the Hungarian Government. During a period of the work G.K. was Wayne G. Basler Chair at East Tennessee State University (ETSU), TN. The above supports are gratefully acknowledged.

References

de Back, W.; Gulyás, L. & Kampis, G. 2007a. Niche Differentiation in Various Multi-Resource Ecosystems, European Concerence on Complex Systems (ECCS), submitted.

de Back, W.; Gulyás, L. & Kampis, G. 2007b. Niche Differentiation and Coexistence in a Multi-Resource Ecosystem with Competition, European Conference on Artificial Life (ECAL07), submitted.

Dugundji, Elenna R. and László Gulyás (2006): "Socio-Dynamic Discrete Choice on Networks in Space: Impacts of Agent Heterogeneity on Emergent Outcomes", *Environment and Planning B* (*submitted*)

Gulyás, László. (2007): "Cooperation in Networked Populations of Selfish Adaptive Agents: Sensitivity to Network Structure", *Physica A,* Vol 378, Issue 1, 1 May 2007, pp. 110-117.

Kampis, George and László Gulyás (2006): "Emergence out of Interaction: Developing Evolutionary Technology for Design Innovation", Advanced Engineering Informatics, Volume 20, Issue 3, Design of Complex, Adaptive Systems, July 2006, pp. 313-320.

Szemes, Gábor and László Gulyás (2006): Complex Systems and Agent Based Simulations – A Framework and Communication Patterns, v11.4, manuscript, 20 October, 2006.