УДК 519.7

AGENT-BASED MODELING, COMPLEX NETWORKS AND SYSTEM DYNAMICS – PRACTICAL APROACHES

A. Buda, *Doctoral candidate,*
IFJ - Polish Academy of Science in Cracow
andrzejbudda@gmail.com
A. Jarynowski, *Doctoral candidate,*
Moldova State University in Kishinev
andrzej.jarynowski@uj.edu.pl

System dynamics (SD) or Agent-Based Modeling (ABM)? Mathematical methods and computer simulations have become more and more popular and successfully applied in explanations of phenomena observed in real word. social, economic and biological systems. We present two computational methodologies agent-based modeling (in NetLogo), system dynamics (in Vensim), and one analytical tool – network analysis (in Pajek), which allow to represent complicated and complex nonlinear system. Of course many various non mentions approaches were omitted like decision trees or game theory.

Differential equations (in use by system dynamics) were first applied to describe and predict those phenomena, but recently agent-based models appear even more often. Sometimes the same problem could be solved in both ways. Not always, because computer simulation has changed the world of mathematical modeling, agent-based models give better predictions and some hints for decision-makers even parallel development of numerical methods for differential equations. On the other hand, differential equations allow us to understand the core process, which could be missing in the agent-based approach. As a result, both perspectives are common among specialists and depend on theoretical or applied aspect percentage representations differ.

System Dynamics. There are several types of computer software used to SD like Dynamo, iThink, Stella etc., but we choose Vensim example. The graphical notation allows non-mathematician to build and solve sets of differential equations. The dynamical variables are

represented by stocks and rates of change as flows [Fig. 1].

This type of diagram shows relationships among variables, and output present change over time. With causal looks (representing more kind of nonlinear relations, like feedbacks). In this numerical approach of equilibrium conditions or systemic variables are traced in time.

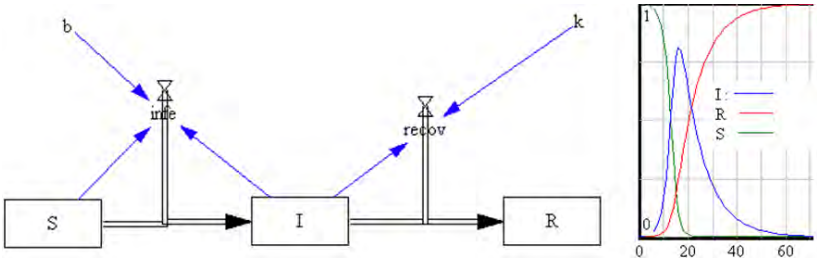

Fig. 1 Susceptible, Infective, Removed epidemic model in Vensim with parameters: b-infectivity, k-recovery rates [1]

Agent-based models. ABM is a computational technique to do experiments with artificial systems populated by agents that interact in non-trivial ways. We choose Netlogo, but other toolkits are also examples like Swarm, RePast, MASON. In NetLogo's turtle is representation of an agent (an autonomous, interacting entity). A patch is the elementary spatial unit in the NetLogo grid [*Fig. 2*]. The goral is to imitate real patterns by running a (often computerized) ABM under different treatments and conditions.

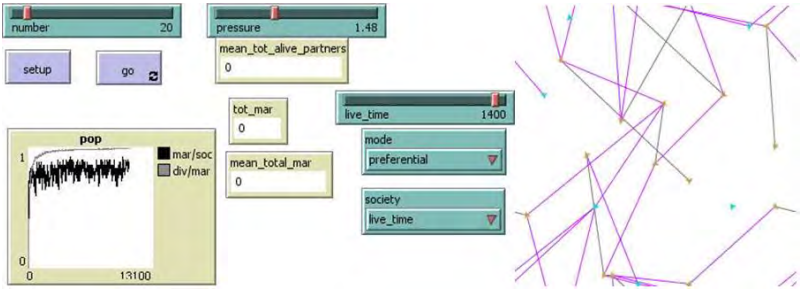

Fig. 2 Dialog window of marriage/divorce model in society, where links represents network of marriages [2]

Complex networks. We will focus on the most applied aspect of it: Social Network Analysis (SNA), which has origin in graph theory. Here topology is the most important: who is connected to whom [Fig. 3]. Each item is a node. Relations between them are connections (links). Degree is the links of given node. Shortest path length is he minimum number of connections to go through to get from one node to another. Clustering is a measure of whether the neighbours of a node are connected to each other (at the level of the network, it tells us how tightly clustered individuals are in general). Centrality tells us which nodes (or links) are the most important (e.g. act as 'brokers' between the most individuals or have the highest degree). The 'small-world' comes from the fact that most of us are linked by small chains of acquaintances. Community detection algorithms identify intermediate scale structure like different social groups. Preferential attachment property: a node is linked with higher probability to a node that already has a large number of links.

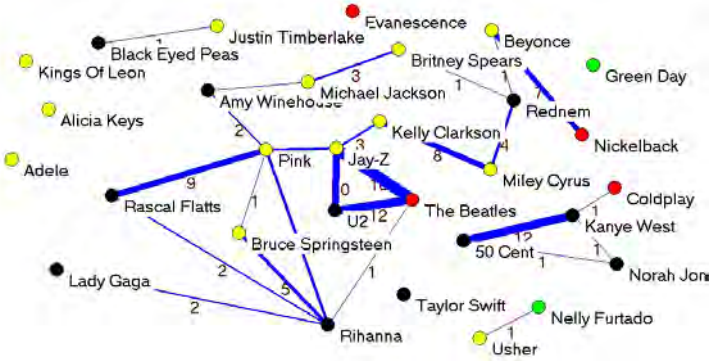

Fig. 3 Musical weighted network of Popstar artists [3]

Conclusions. Proposed methods analysis may develop new (more reliable) description of real systems.

Bibliography

[1] Anderson, RM., May, RM. *Infectious Diseases of Humans: Dynamics and Control*, Oxford, 1992.

[2] Jarynowski., A. Nyczka, P. Dynamic network approach to marriage/divorces problem. *ENIC- IEEE*, pp: 122-125, 2014.
[3] Buda, A., Jarynowski, A. Network structure of phonographic market with similarities between artists. *APP A*, 123(3), 2013.
Vensim: http://vensim.com/
NetLogo: http://ccl.northwestern.edu/netlogo/index.shtml
Pajek: http://vlado.fmf.uni-lj.si/pub/networks/pajek/