DEPARTMENT OF POLITICAL AND SOCIAL SCIENCES

Course Title

Doing Agent-based Modelling with NetLogo: An Introduction.

Instructor

Dr. Gianluca Manzo (gianluca.manzo@cnrs.fr) (http://www.gemass.org/manzo/)

Course Rationale

In the biological and social realm, high-level patterns arise from complex dynamics in which large populations of heterogeneous low-level entities influence each other over time. Well-developed descriptive techniques exist to map the statistical signature of these dynamic processes but these methods are not that flexible to model the complex interplay of micro- and network-level mechanisms triggering the high-level patterns. As T. Schelling (1971, p. 147) remarked, "the simple mathematics of ratios and mixtures tells us something about what outcomes are logically possible, but tells us little about the behaviour that leads to, or that leads away from, particular outcomes". Agent-based computational modelling is a powerful simulation technique that can be used to advance this problem. It is a powerful algorithmic approach that can be used to derive hypotheses on the system-level implications of complex interactions between structure and agency. However, agent-based computational modelling requires programming skills that are often still missing from standard *curricula* at the undergraduate and graduate levels. This course aims to provide attendees with these skills by using a specific programming language, i.e. NetLogo.

Course Style

The course is a systematic introduction to NetLogo, a flexible (free and open-source) programming suite to design, simulate, and study agent-based models. A hands-on approach is used throughout the course wherein the instructor explains each programming building block and comments the code implementing it. Sessions follow a Lego-approach: simple elements are progressively embedded in programming structures of increasing complexity.

Course Description

The course goes through six steps. *Session 1* provides an overview of the general epistemological and methodological features of agent-based computational modeling. *Session 2* moves on to the programming part introducing variable declaration, data structures, procedures, and control structures within NetLogo. *Session 3* introduces the general way NetLogo allows to manipulate "objects" through "agentsets" as well as specific types of objects like "patches" and "turtles", which are respectively needed to model space-based interaction structures and low-entities' behaviors. *Session 4* is devoted to the last class of Netlogo's objects, i.e. "link", which are needed to model network-based interaction structures. The *last two sessions* combine all these programming building blocks in order to implement two theoretical models step-by-step. In particular, *session 5* deals with Granovetter's (1978) threshold model of binary decisions whereas *sessions 6* focuses on Skvoretz's (2013) generative model of homophilious networks. The ABM implementation of these two models is then used to illustrate how an agent-based model should be analyzed. In particular, it is shown: a/ how to deal with the model's uncertainty; b/ how to

experiment with the model; c/ how to understand the model's behavior; and d/ how to analyze the simulated outcomes.

Course Goals

The course's structure is thought to serve two goals: 1/ to make attendees autonomous in programming and studying their first, theoretically meaningful agent-based model; 2/ to help them to explore the advanced features of NetLogo that are not covered by the course.

Requirements

Familiarity with programming languages like Java, C++, Python or R makes the class easier but it is not required.

Software (to be installed on attendees' laptop)

NetLogo 6.2.0 (http://ccl.northwestern.edu/netlogo)

Course Resources

At the end of the course, the instructor will provide attendees with: a/ all NetLogo codes commented line by line; b/ the slides covering all the topics discussed during the class.

Readings

GENERAL

Manzo G. (2014). The Potential and Limitations of Agent-based Simulation: An Introduction. *Revue française de sociologie*, 55, 4, 653-688 (https://www.cairn-int.info/abstract-E_RFS_554_0653--the-potential-and-limitations-of.htm)

De Marchi S., Page S. E (2014). Agent-based models. *Annual Review of Political Science*, 17, 1-20.

NETLOGO

The NetLogo 6.2.0 User Manual (in particular, pp. 56-82 & 107-144) (https://ccl.northwestern.edu/netlogo/docs/NetLogo%20User%20Manual.pdf)

Railsback S. F., Grimm V. (2011). *Agent-based and Individual-Based Modeling: A Practical Introduction*. Princeton, Princeton University Press (constant updates at http://www.railsback-grimm-abm-book.com/).

Wilenski U., Rand W. (2015). *An Introduction to Agent-based Modelling. Modelling Natural, Social, and Engineered Complex Systems with NetLogo*. MIT Press.

NETLOGO (Advanced topics)

Tisue, S. and Wilensky, U. (2004), NetLogo: Design and implementation of a multi-agent modeling environment (http://ccl.northwestern.edu/papers/).

Railsback S., Lytinen S. L., Jackson S. K.. (2006). Agent-based Simulation Platforms: Review and Development Recommendations. *Simulation, 82*, 9, 609-623.

Lytinen S. L., Railsback S. F. (2012). The Evolution of Agent-based Simulation Platforms: A

Review of NetLogo 5.0 and ReLogo (http://www.swarm.org/index.php/Software_Reviews)
Thiele J. C., Grimm V. (2010). NetLogo meets R: Linking agent-based models with a toolbox for their analysis, *Environmental Modelling & Software,* 25, 972-974.

Thiele J. C., Kurth W., Grimm V. (2012), Agent-Based Modelling: Tools for Linking NetLogo And R, *Journal of Artificial Societies and Social Simulation,* 15 (3) 8.

Thiele J. C., Kurth W., Grimm, V. (2014) Facilitating Parameter Estimation and Sensitivity Analysis of Agent-based models: A Cookbook Using NetLogo and R, *Journal of Artificial Societies and Social Simulation,* 17, 3, 11.

Railsback, S. F., D. Ayllón, U. Berger, V. Grimm, S. L. Lytinen, C. J. R. Sheppard, and J. C. Thiele. 2017. Improving execution speed of models implemented in NetLogo. *Journal of Artificial Societies and Social Simulation*, 20 (1)3.

Additional Readings (Link between mechanism-based thinking and ABMs)

Cederman L.-E. (2005). Computational Models of Social Forms: Advancing Generative Process Theory. *American Journal of Sociology*, *110*, 4, p. 864-893.

Manzo G. (2014). Data, Generative Models, and Mechanisms: More on the Principles of Analytical Sociology. In G. Manzo (ed.), *Analytical Sociology: Actions and Networks*, Chichester, Wiley, ch.1, 4-52.

Additional Readings (Advanced but still general introductions to ABMs)

Axtell R., (2000). Why Agents? On the Varied Motivations for Agent Computing in the Social Sciences. The Brookings Institution, Center on Social and Economic Dynamics, *Working Paper No. 17*.

Macal, C. M. & North, M.J. (2010). Tutorial on agent-based modelling and simulation, *Journal of Simulation*, 4, 151–162

Grimm V. et alii (2010). The ODD Protocol: A Review and First Update. *Ecological Modelling*, 221, p. 2760-2768.

Müller B. *et alii* (2014). Standardised and Transparent Model Descriptions for Agent-Based Models: Current Status and Prospects, *Environmental Modelling & Software*, 55, p. 156-163.

Additional Readings (Book-length treatments)

Epstein, J. M. and Axtell, R. (1996). Growing Artificial Societies. Social Science from the Bottom Up. Cambridge, MA: MIT press.

Axelrod, R. (1997). The Complexity of Cooperation: Agent-Based Models of Competition and Collaboration. Princeton University Press.

Epstein, J. (2006). Generative Social Science: Studies in Agent-Based Computational Modeling. Princeton University Press.

Miller J. H., Page S. E. (2007) *Complex Adaptive Systems: An Introduction to Computational Models of Social Life*, Princeton, Princeton University Press.

Additional Readings (Pleas for ABMs from a variety of disciplines)

Auchincloss A. H., Roux A. V. D. (2008). A New Tool for Epidemiology: The Usefulness of Dynamic-Agent Models in Understanding Place Effects on Health. *American Journal of Epidemiology*, 168, 1, 1-8.

Birks D., Townsley M., Stewart A. (2012). Generative Explanations of Crime: Using Simulation to Test Criminological Theory. *Criminology*, 50, 1, 221-254.

Billari F. C., Prskawetz A. (eds.) (2003) *Agent-Based Computational Demography: Using Simulation to Improve our Understanding of Demographic Behaviour*, New York (NY), *Heildelberg, Physica Verlag*

Farmer J. D., Foley D. (2009). The Economy Needs Agent-Based Modelling. *Nature*, 460, 685-686.

Fioretti G. (2013) Agent-Based Simulation Models in Organization Science.

Organizational Research Methods, 16, 2, 227-242.

Grimm V. *et al.* (2005). Pattern-Oriented Modeling of Agent-Based Complex Systems:

Lessons from Ecology. *Science* 310, 987

O'Sullivan D. (2008). Geographical Information Science: Agent-Based Models. *Progress in Human Geography*, *32*, 2, 541-550.

Smith E. R., Conrey F. R. (2007). Agent-Based Modeling: A New Approach for Theory Building in Social Psychology. *Personality and Social Psychology Review*, 11, 1, 87-104.

Wurzer G., Kowarik K., Reschreiter H. (2015). *Agent-based Modeling and Simulation in Archaeology*, Springer.

Additional Readings –Examples of ABM applications

THEORY-ORIENTED ABMS

–*Overviews*

Mcay M. W., Willer R. (2002). From Factors to Actors: Computational Sociology and Agent-

Based Modeling. *Annual Review of Sociology*, 28, 143-166.

–*Pioneering examples*

Schelling T. (1971). Dynamic Models of Segregation ». *Journal of Mathematical Sociology*, 1

–*More recent examples*

Miller, J. H. and Page, S. E. (2004). The Standing Ovation Problem. *Complexity*, 9(5):8–16.

Centola D., Willer R., Macy M. (2005) The Emperor's Dilemma: A Computational Model of Self Enforcing Norms, *American Journal of Sociology,* 110, 4, 1009–40.

Deffuant G., Huet S., Amblard F. (2005) An Individual-Based Model of Innovation Diffusion

Mixing Social Value and Individual Benefit, *American Journal of Sociology,* 110, 4, 1041–69

Manzo G. (2011). Relative Deprivation *in Silico*: Agent-based Models and Causality in Analytical Sociology. in P. Demeulenaere (ed.), *Analytical Sociology and Social Mechanisms*, Cambridge, Cambridge University Press, ch. 13, 266-308.

Manzo G., Baldassarri D. (2015). Heuristics, Interactions, and Status Hierarchies: An Agent-

Based Model of Deference Exchange. Sociological Methods & Research, 44, 2, pp. 329-387.

EMPIRICALLY-ORIENTED ABMS

–*General Pleas/Discussions*

Cointet Jean-Philippe, Roth Camille (2007) How Realistic Should Knowledge Diffusion Models Be? *Journal of Artificial Societies and Social Simulation*, 10, 3, 5.

Fagiolo, G., Moneta, A., and Windrum, P. (2007). A Critical Guide to Empirical Validation of Agent-Based Models in Economics: Methodologies, Procedures, and Open Problems. Computational Economics, 30:195–226.

Smith, J. A., & Burow, J. (2018). Using ego network data to inform agent-based models of diffusion. Sociological Methods & Research, 1–46. https://doi.org/10.1177/0049124118769100.

Pawel Sobkowicz (2009) Modelling Opinion Formation with Physics Tools: Call for Closer Link with Reality. *Journal of Artificial Societies and Social Simulation*, 12, 1, 11.

–*Pioneering examples*

Hägerstrand T. (1965). A Montecarlo Approach to Diffusion. *European Journal of Sociology*, 6, 1, p. 43-67.

–*Input-level Empirical/experimental Calibration*

Bruch E., Mare R. D. (2006). Neighborhood Choice and Neighborhood Change. *American Journal of Sociology*, 112, 3, 667-709.

DiMaggio P., Garip F. (2011) How network externalities can exacerbate intergroup inequality.

American Journal of Sociology, 116, 6, 1887–1933.

Wunder M., Suri S., Watts D. J. (2013) Empirical Agent Based Models of Cooperation in Public Goods Games, EC '13 Proceedings of the fourteenth ACM conference on Electronic commerce, ACM New York, NY, USA, 891-908

Manzo, Gianluca and van de Rijt, Arnout (2020) 'Halting SARS-CoV-2 by Targeting High-Contact Individuals' Journal of Artificial Societies and Social Simulation 23 (4) 10 <http://jasss.soc.surrey.ac.uk/23/4/10.html>. doi: 10.18564/jasss.4435

–*Output-level Empirical Validation*

Todd P. M., Billari F. C., Simao J. (2005). Aggregate Age-atmarriage Patterns From Individual Mate-search Heuristics. *Demography*, 42, 5559-74.

Gonzalez-Bailon S., Murphy T. E. (2013). Social Interactions and Long-Term Fertility Dynamics. A Simulation Experiment in the Context of the French Fertility Decline. *Population Studies*, 67, 2, 135-155.

Manzo G. (2013). Educational Choices and Social Interactions: A Formal Model and a Computational Test. *Comparative Social Research*, 30, 47-100.

–*Input-Output Experimental Validation*

Mäs M., Flache A. (2013). Differentiation without Distancing. Explaining Bi-Polarization of Opinions without Negative Influence. *Plos One*, 8, 11, e74516

–*Input-Output Observational Validation*

G. Manzo, S. Gabbriellini, V. Roux, F. Nkirote M'Mbogorihttp (2018) "Complex Contagions and the Diffusion of Innovations: Evidence from a Small-N Study", *Journal of Archaeological Method and Theory*, 25, 4, 1109-1154.

–*Examples from outside social sciences*

Thorne B. C., Bailey A. M., Peirce S. M. (2007). Combining Experiments with Multi-Cell Agent-Based Modeling to Study Biological Tissue Patterning. *Briefings in Bioinformatics*, 8, 4, 245-257.