GECO 6910 Computer Language Workshop

Coding Dynamical Systems and Agent-Based Models in *R*

Spring 2020 Syllabus

Time:	R 8-9.50pm
Location:	D1108
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Office Hours:	T 2.30-3.30pm, Room D1126

1 Course Outline

This course introduces the graduate students at the New School for Social Research to modeling computer simulations in *R*. The course combines simulation models as a theory of complex emergence (dynamical systems and agent-based models) and their implementation in *R*. In particular, the course will cover discrete and continuous dynamical systems in the first five lectures and agent-based modeling in the latter two. The course will examine generic dynamical models and their applications to economics. Ideally, the students should enter the course with a basic understanding of dynamical systems and *R* language, but it is not a prerequisite for the course[1]. Before the course begins, please install *R* on your laptop computer. Review sheets will be provided throughout the course.

R is a very flexible, powerful, open-source coding language that allows one to simulate data-generating dynamical processes, either using reproducible packages or at the base level. *R* can generate simulations and evaluate them statistically in faster and more sophisticated way than other specialized programs such as NetLogo.

In the first session, we will review the fundamentals of dynamical systems and how to computationally manage synthetic data in *R*. In the following four sessions, we will explore ways to code particular models in *R*: discrete logistic growth and an economic application (the Ricardian system), Lotka-Volterra oscillations and an economic application (the Goodwin model of capital accumulation), the forced van der Pol oscillator and an economic application (Harrod's endogenous business cycles), and the Flaschel-Semmler model of multi-sectorial growth. Parameters of low-dimensional dynamical models can be calibrated by econometric estimation using available empirical data. In the last two sessions, we will cover classic and current versions of agent-based models in a critical way, exploring strengths and weaknesses.

For students who are interested in going beyond the material covered in the seven sessions, some suggested avenues of further research include: (1) replicator dynamics following an evolutionary Schumpeterian approach for technological innovation (e.g. a small-scale model for green financial de-risking with two kinds of heterogeneous firms and their quite complex interactions), and (2) stock-flow consistent models simulating chapters of Godley and Lavoie's *Monetary Economics* and environmentally-extended SFC input-output models.

[1] If you need extra assistance, please let the instructor know.

2 Schedule

Session	Content
1/30	Fundamentals of Dynamical Systems and Data Management
2/13	A Discrete Dynamical System: Logistic Growth and Foley's Circuit of Capital
2/27	Lotka-Volterra Oscillations and the Goodwin Cycle
3/12	(Forced) van der Pol Oscillator and Harrod's Endogenous Business Cycles
3/26	Flaschel-Semmler Multi-Sectorial Growth under Technological Dynamics
4/9	Classic Agent-Based Models (from von Neumann to Wolfram)
4/23*	Current Agent-Based Models (from NetLogo to R)

3 Suggested Readings

3.1 Dynamical Systems

- **Session 1: Fundamentals of Dynamical Systems and Data Management**
  - Strogatz, S. H. (2018). *Nonlinear dynamics and chaos: with applications to physics, biology, chemistry, and engineering.* CRC Press
  - Foley, D. K. (xxxx). "Notes on Dynamical Systems," Columbia University of New York, mimeo
  - Barkley Rosser, J. (2000). Aspects of dialectics and non-linear dynamics. *Cambridge Journal of Economics*, 24(3), 311-324.
  - Foley, D. K. (2003). *Unholy trinity: labor, capital and land in the new economy.* Routledge.
  - Lines, M. (Ed.). (2007). *Nonlinear dynamical systems in economics* (Vol. 476). Springer Science & Business Media.
- **Session 2: A Discrete Dynamical System: Logistic Growth and the Simple Ricardian System**
  - Bhaduri, A., & Harris, D. J. (1987). The complex dynamics of the simple Ricardian system. *Quarterly Journal of Economics*, 102(4), 893-902.
  - Pasinetti, L. L. (1977). *Lectures on the Theory of Production.* Columbia University Press. [Chapter 1, especially pp.8-12]
  - Strogatz, S. H. (2018). *Nonlinear dynamics and chaos: with applications to physics, biology, chemistry, and engineering.* CRC Press [Chapter 10: One-Dimensional Maps]
  - *Foley, D. K. (1987). Liquidity-profit rate cycles in a capitalist economy. *Journal of Economic Behavior & Organization*, 8(3), 363-376.
  - *Basu, D. (2014). Comparative growth dynamics in a discrete-time Marxian circuit of capital model. *Review of Radical Political Economics*, 46(2), 162-183.
- **Session 3: Lotka-Volterra Oscillations and the Goodwin Cycle**
  - Goodwin, R. M. (1982). A growth cycle. In *Essays in economic dynamics* (pp. 165-170). Palgrave Macmillan, London.
  - Marx, K. (1990). *Capital.* Volume 1. Penguin Classics. [Chapter 25]
  - Tavani, D. (2014) "Notes on the Goodwin model," Colorado State University, mimeo
  - Desai, M., Henry, B., Mosley, A., and Pemberton, M. (2006). A clarification of the Goodwin model of the growth cycle. *Journal of Economic Dynamics and Control*, 30(12):2661-2670.

- **Session 4: (Forced) van der Pol Oscillator and Harrod's Endogenous Business Cycles**
  - Chian, A. C.-L. (2007). *Complex systems approach to economic dynamics*, volume 592. Springer Science & Business Media. [sections 2.3 and 2.4; on forced van der Pol]
  - Strogatz, S. H. (2018). *Nonlinear dynamics and chaos: with applications to physics, biology, chemistry, and engineering*. CRC Press. [pp. 254-256; on Belousov-Zhabotinsky reaction/Brusselator]
  - Izhikevich, E. M. and FitzHugh, R. (2006). Fitzhugh-Nagumo model. *Scholarpedia*, 1(9):1349.
- **Session 5: Flaschel-Semmler Multi-Sectorial Growth under Technological Dynamics**
  - Flaschel, P., & Semmler, W. (1987). Classical and neoclassical competitive adjustment processes. *The Manchester School of Economic & Social Studies*, 55(1), 13-37.
  - Flaschel, P. & Semmler, W. (1992). Classical competitive dynamics and technical change. In Halevi, J., editor, *Beyond the steady state: a revival of growth theory*, pages 198-221. Springer.

3.2 Agent-Based Models

- **Session 6: Classic**
  - Conway, J. (1970). The game of life. Scientific American, 223(4):4.
  - Epstein, J. M. and Axtell, R. (1996). *Growing artificial societies: social science from the bottom up*. Brookings Institution Press.
  - Schelling, T. C. (1971). Dynamic models of segregation. *Journal of Mathematical Sociology*, 1(2):143-186.
  - Schulman, L. and Seiden, P. (1978). Statistical mechanics of a dynamical system based on Conway's game of life. *Journal of Statistical Physics*, 19(3):293-314.
  - Stauffer, D. (2008). Social applications of two-dimensional Ising models. *American Journal of Physics*, 76(4):470-473.
  - von Neumann, J. (1966). *Theory of self-reproducing automata*. University of Illinois Press.
  - Wolfram, S. (1983). Statistical mechanics of cellular automata. *Reviews of Modern Physics*, 55(3):601.
  - Wolfram, S. (2002). A new kind of science. Wolfram Media Champaign.
  - Zhou, W.-X. and Sornette, D. (2007). Self-organizing Ising model of financial markets. *The European Physical Journal B*, 55(2):175-181.
- **Session 7: Current**
  - Albin, P. S., & Foley, D. K. (1998). *Barriers and bounds to rationality: Essays on economic complexity and dynamics in interactive systems*. Princeton, NJ: Princeton University Press.
  - Wright, I. P. (2011). Classical macrodynamics and the labor theory of value. *The Open University Economic Discussion Paper*, (76).
  - Jiang, X. (2015). Endogenous cycles and chaos in a capitalist economy: A circuit of capital model. *Metroeconomica*, 66(1), 123-157.
  - Suresh, S. G. and Setterfield, M. (2015). Firm performance, macroeconomic conditions, and "animal spirits" in a Post Keynesian model of aggregate fluctuations. *Journal of Post Keynesian Economics*, 38(1):38-63.
  - Caiani, A., Godin, A., Caverzasi, E., Gallegati, M., Kinsella, S., & Stiglitz, J. E. (2016). Agent based-stock flow consistent macroeconomics: Towards a benchmark model. *Journal of Economic Dynamics and Control*, 69, 375-408.
  - Vallès Codina, O. (xxxx). Economic Production as Life. *New School for Social Research Working Paper*

3.3 Evolutionary*

- Arthur, W. B. (2014). *Complexity and the Economy.* Oxford University Press.
- Heine, D., Semmler, W., Mazzucato, M., Braga, J. P., Flaherty, M., Gevorkyan, A., Hayde, E., and Radpour, S. (2019). Financing low-carbon transitions through carbon pricing and green bonds.
- Nelson, R. R. and Winter, S. G. (1974). Neoclassical vs. Evolutionary theories of economic growth: critique and prospectus. *The Economic Journal*, 84(336):886-905.
- Nelson, R. R. and Winter, S. G. (1978). Forces generating and limiting concentration under Schumpeterian competition. *The Bell Journal of Economics*, pages 524-548.
- Nelson, R. R. and Winter, S. G. (2009). *An evolutionary theory of economic change.* Harvard University Press.
- Nowak, M. A. (2006). *Evolutionary dynamics.* Harvard University Press.

3.4 Stock-Flow Consistent*

- Godley, W. and Lavoie, M. (2006). *Monetary economics: an integrated approach to credit, money, income, production and wealth.* Springer.
- Berg, M., Hartley, B., and Richters, O. (2015). A stock-flow consistent input-output model with applications to energy price shocks, interest rates, and heat emissions. *New Journal of Physics*, 17(1):015011.