Complex Social Systems:

A guided exploration of concepts and methods

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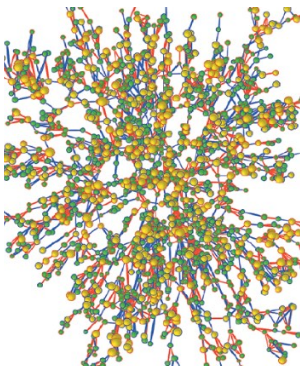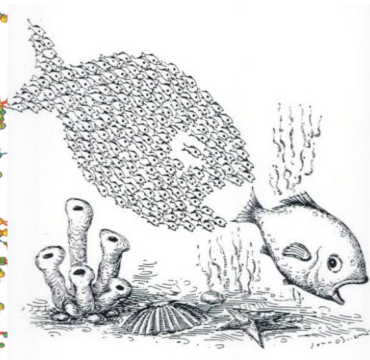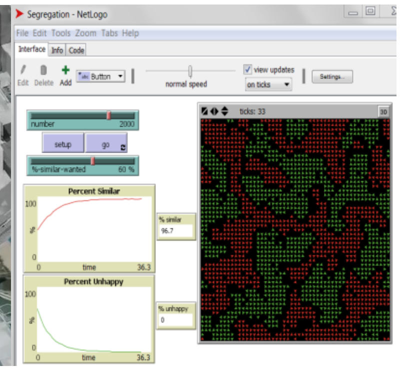

Complex systems are systems composed of interconnected entities that as a whole exhibit properties and behaviors not obvious from the sum of its individual parts. From the invisible hand of Adam Smith and the creation of Rousseau's general will, to revolutionary uprisings and state-of-the-art digital social networks, society is full of complexities. We discuss several of the new theories and practical tools that have been developed to study the ***emergence*** of ***non-linear macro patterns*** that arise out of a multiplicity of ***dynamical micro interactions***. We visit theoretical aspects, such as ***information theory***, ***computational complexity***, ***dynamical systems theory,*** and ***chaos theory*** (setting the limits of complex systems between order and randomness), as well as practical hands-on tools, such as ***dynamical social network analysis***, ***multi-level evolutionary analysis***, ***self-organizing complexity*** and ***agent-based modeling*** (computer simulations of social systems). We review a diverse set of analytical and numerical methods and also play around with diverse software tools to explore emergent phenomena in complex social systems in action. No prerequisites are necessary to participate in the course.

Course Outline (sessions of 2.5 - 3 hours each)

(1) Overview: What are complex systems?

Complex systems are composed of agents that are connected, interdependent, diverse, adaptive, and path dependent, and whose interactions result in emergent phenomena. In this session we discuss these features, introduce some analytical tools and ask about implications for the social sciences.

(2) Social Network Analysis (part 1): analyzing the structure of networks

We begin with a review of one of the most developed branches of social complex systems science. Per definition, a society is a network of individuals, which makes the analysis of social network structure decisive. We discuss concepts and metrics of social networks, such as different measures of centrality, network partitioning into groups and clusters, homophily, transitivity, structural and regular equivalences, and the implications of weighted ties, among others. We will also start using software to analyze social networks in practice.

(3) Agent-based Models (part 1): computer simulations

Traditional analytical methods reach a limit when trying to understand non-linear emergent phenomena with an intermediate degree of interdependence. Computer simulations allow us to obtain numerical results that provide a basic understanding of emergent dynamics in many kinds of social systems. These models create artificial societies of different levels of sophistication. We experience the logic unfold in hands-on software simulations of such artificial societies.

(4): Multilevel Evolution: what evolves?

In this session we revisit the theory of evolution and analyze the differences between biological- and social evolution. Social systems evolve at different levels, while interactions at a lower (micro) levels lead to emergent patterns on higher (macro) levels. We review some of the arising paradoxes (such as social altruism among selfishly evolving individuals) and review an analytical method that allows us to analyze the evolution at various levels (the Price equation).

(5): Between Chance and Order: between Shannon entropy and Kolmogorov complexity

Results from information theory and computer science have shown that information is a physical thing that is closely related to the ability to extract energy. Just as the nimble-fingered Maxwell's demon uses information to do work, so do social systems convert information into knowledge, and both into fitness. We review how social systems process information to grow.

(6) Diversity: aggregate models vs. agent-based diversity

Complex systems are made of diverse entities. Many of the mainstream aggregate models average or simplify this diversity, which works impressively well in some cases, but fails terribly in others. We discuss the main concepts to understand diversity. We review several examples of how diversity provides robustness and efficiency in social dynamics on the micro- and macro levels.

(7) Social Network Analysis (part 2): growing dynamic networks to make predictions

We review methods that allow us to test the validity of network models, such as Erdos-Renyi-, small world-, and preferential attachment networks. We also examine how we can grow dynamic social networks to make predictions in areas such as the spread of epidemics, innovations and ideas. Last but not least, we discuss the relation between network structure and function, and inspect how social networks can be optimized with regard to the tradeoff between efficiency and robustness.

(8) Agent-based Models (part 2): generative social science

The generativist motto of computer generated social science is: "If you didn't grow it, you didn't explain it!" We discuss the implications and limits of the new science of artificial societies. We also review new developments, such as the marriage of computer simulations with "Big (social) Data".

(9) Power-laws: omnipresent signature of complex systems?

Many social phenomena follow a long-tailed power-law, instead of a normal Bell curve. The unique properties of scale-free power-laws differ significantly from those of the traditional normal distribution. This has implications for understanding and intervening in manifold social dynamics. We discuss several of the fascinating generative mechanisms of power-laws, such as self-organized criticality, highly optimized tolerance, allometric scaling, and positive feedback. We also take a critical look at the authenticity of many supposed power-laws.

(10) Review and summary discussion

Basic texts

Castells, M. (2005). *The Network Society: from Knowledge to Policy*. Center for Transatlantic Relations.

Epstein, J. M., & Axtell, R. L. (1996). *Growing Artificial Societies: Social Science from the Bottom Up*. A Bradford Book.

Frank, S. A. (1998). *Foundations of Social Evolution*. Princeton University Press.

Gell-Mann, M. (1995). *The Quark and the Jaguar: Adventures in the Simple and the Complex*. NY: St. Martin's Griffin.

Gell-Mann, M., & Lloyd, S. (1996). Information measures, effective complexity, and total information. *Complexity*, 2(1), 44–52.

Hausmann, R., Hidalgo, C. A., et al., (2011). *The atlas of economic complexity*: mapping paths to prosperity. Harvard University Center for International Development, MIT Media Lab.

Mitchell, M. (2011). *Complexity: A Guided Tour*. Oxford University Press, USA.

Monge, P. R., & Contractor, N. (2003). *Theories of Communication Networks*. Oxford University Press.

Newman, M. (2010). *Networks: An Introduction*. New York: Oxford University Press, USA.

Page, S. (2009). *Understanding Complexity*. The Great Courses, Course No. 5181, Virginia.

Schelling, T. C. (2006). *Micromotives and Macrobehavior*. W. W. Norton & Company.

About the instructor

Martin Hilbert pursues a multidisciplinary approach to understanding the role of information, communication and knowledge in the development of complex social systems. He holds doctorates in Communication, and in Economics and Social Sciences, and a permanent appointment as Economic Affairs Officer of the United Nations. His work has been published in recognized academic journals such as *Science, Psychological Bulletin, World Development,* and *Technological Forecasting and Social Change,* and has been featured in popular magazines such as *Scientific American, The Economist, The Wall Street Journal, Wired, Washington Post, BBC, Die Welt, Correio Braziliense, La Repubblica,* among others. He has provided technical assistance to Heads of State, government experts, legislators, diplomats, companies and civil society organizations in over 20 countries. More in: http://www.martinhilbert.net