Agent-Based Modeling and Social Emergence I

Renjie Yang

COMPHI LAB for Data Science

May 2020

Outline

Complexity Systems Science

- A complex system, roughly speaking, is one with many parts, whose behaviors are both highly variable and strongly dependent on the behavior of the other parts.
- "Complex systems science" is the field whose ambition is to understand complex systems.

Complexity Systems Science

"Tools" refers to procedures for analyzing data, constructing and evaluating models, and measuring the complexity of data or models.

- Statistical learning and data mining
- Time series analysis
- Nonlinear dynamics
- Cellular automata
- Agent-based models
- Complexity measures

Social Emergence

- Societies are complex configurations of many people engaged in overlapping and interlocking patterns of relationship with one another.
- Emergence = "the action of the whole is more than the sum of the parts" (Holland, 2014)
- The effect of the emergent result on the decisions of the individuals.

Social Emergence

- How do complex social systems originate, when they are not consciously designed by anyone?
- What do social relations and configurations look like?
- Which societies are the most effective, and which are stable and long-lasting?
- How could a stable complex system ever change and evolve, as societies often do?
- What is the role of the individual in the system?

Social Complexity

- Complex Systems can be difficult to predict, control and manage, which in many ways is the goal of public policy
- Agent-Based Modeling and Complex Systems analysis is to provide a "flight simulator" rather than a perfect prediction (Holland, 1996; Sterman, 2000)

What is a Model?

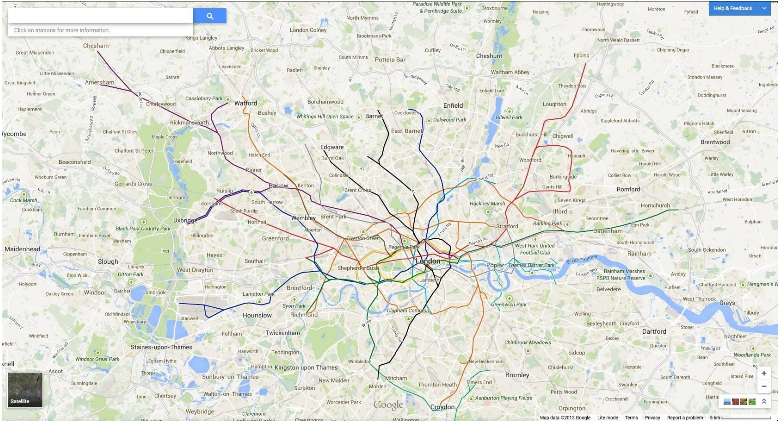
- An abstracted description of a process, object, or event
  Exaggerates certain aspects at the expense of others.

What is a Model?

"What do you consider the largest map that would be really useful?"
"About six inches to the mile."
"Only six inches!" exclaimed Mein Herr. "We very soon got to six yards to the mile. Then we tried a hundred yards to the mile. And then came the grandest idea of all! We actually made a map of the country, on the scale of a mile to the mile!"

— Lewis Carroll, *Alice's Adventures in Wonderland*

What is a Model?



https://ukmap.co/london-underground-map-real/

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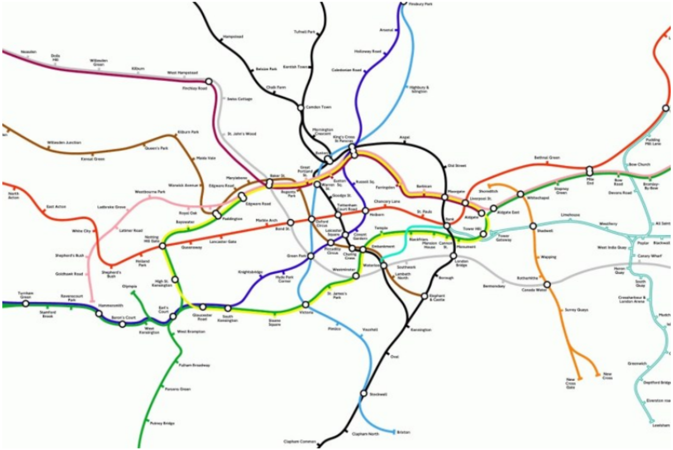

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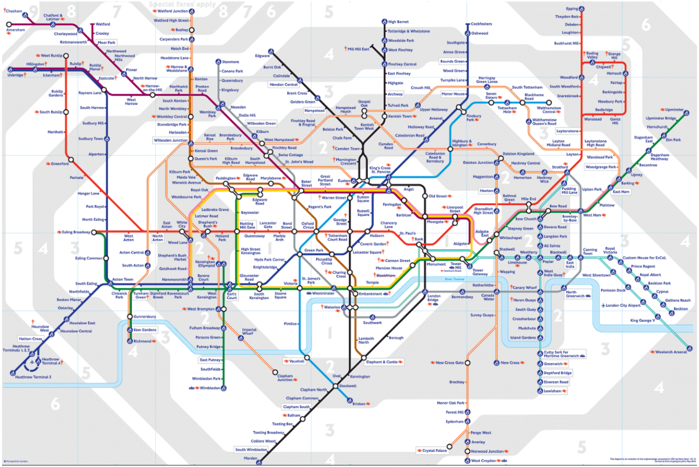


https://freetoursbyfoot.com/wp-content/uploads/2014/02/tube_map.gif

Representation

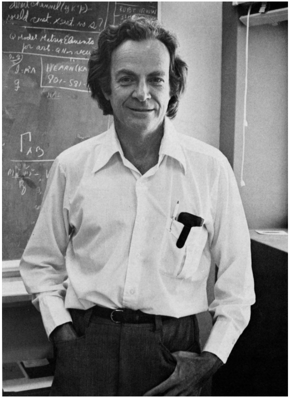
- Representation is the key to understanding any phenomenon
- As an example, the predator-pray model is a set of differential equations that describe the population of the two species and how they affect each other
- In many cases, agent-based representations are appropriate

Representation

"Nature/philosophy is written in this grand book - I mean the universe - which stands continually open to our gaze, but it cannot be understood unless one first learns to comprehend the language in which it is written. It is written in the language of mathematics, and its characters are triangles, circles and other geometric figures, without which it is impossible to humanly understand a word; without these one is wandering in a dark labyrinth..."

— Galileo Galilei

Representation



https://commons.wikimedia.org/wiki/Category:Richard_Feynman#/media/File:Richard_Feynman_1988.png

Representation of Complex Systems

- Complex systems are composed of many interacting parts
- Those parts are often connected in complex ways
- Agent-based modeling provides a powerful way to represent those connections

Artificial Society Models

- Segregation
- Sugarscape

A Third Way of Doing Science

- Euclid's *Elements*
- Newton's *Philosophiæ Naturalis Principia Mathematica*
- Generative - using first principles to generate a particular set of data that can create a general theory (Axelrod, 1997)

Outline

John von Neumann

- Helped develop one of the first computers, ENIAC
- Wanted to develop self-replicating machines
- Collaborating with Stanislaw Ulam create Cellular Automata
- Developed the Universal Constructor with 29 states

John Conway

Game of Life:

- If a cell has three neighbors it becomes alive (birth)
- If it has two or three neighbors it stays alive (persistence)
- Any other combination means the cell dies (overcrowding or loneliness)

Stephen Wolfram

Game of Life:

- Conducted a census of the 1-D CA rules with radius = 1
- Uniform, random, cyclical, and complex
- Made the claim that the whole world could be modeled using CA
- Created Mathematica

John Holland

- In 1975 published Adaptation in Natural and Artificial Systems, describing the Genetic Algorithm
- In 9/1987, he presented some of his ideas about adaptive agents at a meeting of the economy as a complex adaptive system

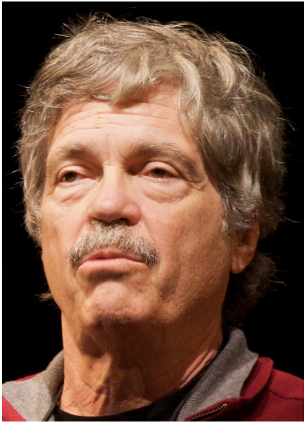
Santa Fe Institution

- Holland worked with Brian Arthur, Blake LeBaron, Richard Palmer, and Paul Tayler to create the Santa Fe Artificial Stock Market
- in 8/1986, John Reed, CEO of Citicorp met at SFI with Ken Arrow, Brian Arthur, and John Holland together to think about new ways to model economics, led to Swarm

Seymour Papert

- Studied with Piaget in Switzerland
- Papert, Feurzeig, Borrow and Solomon created Logo in 1969
- The turtle was developed post-Logo as a "body-syntonic" object to aid students in learning the language

Object-Oriented Programming

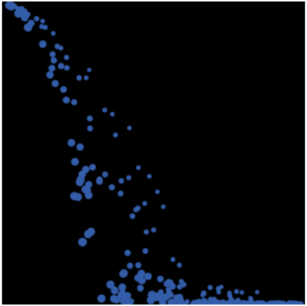


- Dahl and Nygaard developed simulations for maritime ships, and created the notion of a "class", which was an object that combined data and functions in the language Simula
- But the term "object-oriented programming" was not used until the development of Smalltalk by Alan Kay and colleagues (1972)

Parallelism

- In the 1980s Danny Hillis developed an architecture for a parallel computer he called a "connection machine"
- Unlike traditional von Neumann machines there wasn't a single CPU, but instead thousands of low-cost, low-capacity processors connected together
- By the end of the 80s special programming languages, such as StarLisp and C-Star were developed to program this machine

Computer Graphics



- Early on in computer graphics, visualizations were accomplished by using large flat surfaces and textures
- But surfaces don't work well for smoke, stars, light, or even birds
- Needed a point representation (Reeves, 1983), which came to be known as particle systems

Outline

References

- Uri Wilensky, William Rand (2015) *Introduction to Agent-Based Modeling*, MIT Press.
- William Rand's slides on Agent-based Modeling.
- Wikimedia Commons https://commons.wikimedia.org/