MCSS

Complex Systems Made Simple by Agent-Based Modeling

Erasmus Mundus Master's in Complex Systems Science
Ecole Polytechnique, Fall 2015

Course Information - Description - Topics
Organization - Grading Policy - *Schedule, Notes & Assignments*

Download Syllabus

Course Information

- **Credits:** 6 ECTS
- **Schedule:** *Tuesdays, **10:15–11:45** (through Nov 10)*
- **Classroom:** PC 16
- **Instructor:** Dr. René Doursat
- **Email:** rene.doursat@polytechnique.edu

Description

This course explores canonical examples of complex systems through agent-based modeling and numerical simulation. Complex systems are characterized by a large number of elements interacting locally and combining their individual behaviors to produce an emergent behavior at a macroscopic scale. It is often difficult or impossible to infer this emergence in analytical terms, whereas computational models are sometimes able to reproduce it and even make valid predictions.

Self-organized, decentralized and adaptive systems, whether physical, biological or human-made, are pervasive in the environment. Striking similarities in the observation of various complex phenomena also created a fruitful exchange of ideas and techniques among disciplines, such as the ecological perspective on economics, or the behavior of ant colonies exported to optimization problems.

Using the NetLogo simulation platform, we will review and become familiarized with some of the most popular case studies of complex systems across a variety of topics: cellular automata, pattern formation, swarm intelligence, complex networks, spatial communities, or morphogenesis. We also remark on the key concepts unifying these fields, such as: emergence, self-organization, decentralization, positive feedback, and so on.

Topics Covered (Tentative)

Complex systems constitute an immense interdisciplinary domain. Thus it cannot be the intention of this course to be exhaustive. Rather, it offers an exploration and discovery of complex systems through "sampling" of the literature and pragmatic experiments. Here is an illustrative list of cases, concepts, and fields that may be addressed in class:

(a) Cases of complex systems in nature & human structures

- spin glasses, convection cells
- excitable media & waves
- genes & cell differentiation
- animal patterns (coats, shells)
- insect societies (ants, termites)
- flocks, herds, schools
- ecosystems & evolution
- neurons, brain & cognition
- cities, economy, Internet
- etc.

(b) Unifying concepts of complex systems

- emergence
- self-organization
- nonlinear dynamics
- order, chaos, complexity
- competition/cooperation
- feedback & homeostasis
- phase transitions
- adaptation
- edge of chaos, criticality
- etc.

(c) Theoretical & computational fields of complex systems

- cellular automata
- artificial life, virtual ants
- swarm intelligence
- pattern formation
- oscillators, synchronization
- Boolean networks
- genetic algorithms
- neural networks
- small worlds
- etc.

Organization

- **Programming practice:** During class and at home, students will carry out experiments in the form of programming exercises, either derived from the models reviewed in class or from other models. All simulations whether labs, homeworks or the personal project must be coded in NetLogo. (Only the charts describing the results of the model in the final report and presentation may be produced with another tool such as MATLAB or Scilab.) *Bring your laptop with you, and install NetLogo 5.2 on it!*

- **Research project:** Students will also complete a personal modeling & simulation project on the topic of their choice. This involves three deliverables:

  - (A) a final project presentation in the style of a conference talk (PDF slideshow)
  - (B) a final project report in the style of a conference paper (PDF document)
  - (C) a final original source code and demo (NetLogo file, with comments in the code and a doc)

  While the model and simulations constitute the technical core of your paper and should demonstrate your creativity, entrepreneurship, and ability to carry out research and a functioning piece of program, their ultimate purpose is *support (or contradict) your intuition*, i.e. help you draw (provisional) conclusions about an interesting question that you had in mind. Most valued in this class are the research attitude/effort and the presentation work; less so the objective results of the model or actual scientific findings.

- ***Important deadlines:*** *(tentative)*
  - *1. project proposals (preliminary report and slides) → due and presented* ***Oct 13***
  - *2. first submission of report and code (B, C) → due* ***Dec 1***
  - *3. final revision of report and code (B, C) → due* ***Dec 11***
  - *4. project slides (A) → due and presented* ***Dec 15***

Grading (Tentative)

Both grading policy and scale are subject to change.

• Grading Policy

Homework 1	10%
Homework 2	20%
Project Report	30%
Project Slides & Talk	20%
Project Code & Demo	20%

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• Grading Scale

100 → 90	A, A-
89 → 80	B+, B, B-
79 → 65	C+, C, C-
64 → 55	D
54 → 0	F

Schedule, Notes & Assignments (Tentative)

This is a tentative schedule, subject to readjustment depending on the time we actually spend in class covering the topics. Please check again regularly. Course notes, assignments and exam solutions will be posted here.

Week	Date	Topics & Course Notes	Homework & Project Docs
1	Tue, Sep 8	Introduction to Complex Systems (1)	

2	Tue, Sep 15	NetLogo Tutorial	HW#1
3	Tue, Sep 22	Introduction to Complex Systems (2)	HW#2
4	Tue, Sep 29 *Sep 28-Oct 2*	Complex Systems Sampler (1) *One-on-one supervision (topic, interests)*	Project proposal assignment → *due:* ***Oct 13*** *(A, B)*
5	Tue, Oct 6 *Oct 5-9*	Complex Networks *One-on-one supervision (project, goals)*	
6	**Tue, Oct 13**	*Project proposal presentations*	Full project assignment: Submission → *due:* ***Dec 1*** *(B, C)*
7	Tue, Oct 20	OpenMole Platform by R. Reuillon and M. Leclaire *One-on-one supervision (model, interface)*	
8	~~Tue, Oct 27~~	***Fall break ("Vacances de la Toussaint") - no class***	
9	Tue, Nov 3 *Nov 2-6*	Complex Systems Sampler (2) *One-on-one supervision (model, code)*	
10	Tue, Nov 10 *Nov 9-13*	Commonalities of Complex Systems *One-on-one supervision (model, interface)*	
11	*Nov 16-20*	*One-on-one supervision (parameter space, paper)*	
12	*Nov 23-27*	*One-on-one supervision (paper)*	
13	**Tue, Dec 1** *Nov 30-Dec 4*	*Submission due (B, C)* *One-on-one supervision (detailed revision)*	Full project assignment: Revision → *due:* ***Dec 11*** *(B, C) and* ***Dec 15*** *(A)*
14	*Dec 7-11* **Fri, Dec 11**	*One-on-one supervision (revision)* *Revision due (B, C)*	

15	**Tue, Dec 15** 10:00-13:30 ISC-PIF	***Final project presentations*** *Slides due (A)*	

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Created and maintained by
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