Information Technology

Course

INF-51806 Modelling and Simulation of Complex Socio-Technical Systems

Course code	INF-51806
Period	6, afternoons
Contact Person	Gert Jan Hofstede
Lecturers	Gert Jan Hofstede, Behzad Behdani
Examiners	Gert Jan Hofstede
Language of instruction	English
Assumed prerequisite knowledge	• Fluency in English, written and oral • At ease with computers • Experience with modelling, any kind
Secretariat	Leeuwenborch building Room 6033 tel: 0317-485645 office.inf@wur.nl

WAGENINGEN UNIVERSITY
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Profile of the course

Aim: to be able to select and apply a method of modelling a socio-technical (possibly also –ecological, -economic) system fitting one's research question. The modelling approach should do justice to both the social side and the other aspects. The practical part of the course focuses on System Dynamics and Agent-Based Modelling.

Target group: This course targets PhD students and advanced MSc students who face the task of modelling complex systems that include feedback loops and human social behaviour. Following some tutorial exercises, they will bring their own cases. They need not be familiar with the modelling techniques taught.

Benefit for students: In any academic job, being conversant with various modelling approaches is key. One should be able to use modelling approaches as building blocks for approaching problem situations. This course gives you key concepts and practice. If you face a system with feedback loops, System Dynamics is important. If you face a social system, Agent-Based Modelling allows to capture social motives, heterogeneity and self-organisation.

Learning outcomes

After successful completion of the course the students:

1. Can view their own research topic as a complex socio-technical (-ecological, -economic) system.
2. Can select which sub-systems and actors to include.
3. Know the application scope of a range of analytical modelling approaches.
4. Can select an appropriate approach for their own case.
5. Can create (and have created) models for their own case, neither too complicated nor too simple.

Learning materials and resources

Power point presentations and Blackboard, plus a variety of resources.

Modelling and System Dynamics

- Bar-Yam, Y. (2003). Dynamics of complex systems, Westview Press.
- Behdani, B. (2012). 'Evaluation of Paradigms for Modeling Supply Chains as Complex Socio-Technical Systems', Proceedings of the 2012 Winter Simulation Conference, pp. 1-15, 2012.
- Robinson, S. (2004). Simulation: The Practice of Model Development and Use. Wiley.
- Robinson, S. (2008). Conceptual modelling for simulation - Part I: definition and requirements, Journal of the Operational Research Society 59(3): 278-290.
- Sterman, J. (2000). Business Dynamics: Systems Thinking and Modeling for a Complex World, McGraw-Hill.

Netlogo tutorials

- Netlogo tutorial at https://ccl.northwestern.edu/netlogo/; Netlogo principle MOOC tutorials; Netlogo crash course under development.

Modelling social subsystems

- Groeneveld, J., Müller, B., Buchmann, C. M., Dressler, G., Guo, C., Hase, N., . . . Schwarz, N. (2017). Theoretical foundations of human decision-making in agent-based land use models – A review.
- Hofstede, G. J. (2017). GRASP agents: social first, intelligent later. *Ai & Society*. https://doi.org/10.1007/s00146-017-0783-7
- GRASP World Netlogo model: to be added from OpenABM.

Supplementary reading

- Checkland, P., & Poulter, J. (2010). Soft Systems Methodology. In M. Reynolds & S. Holwell (Eds.), *Systems Approaches to Managing Change: A Practical Guide* (pp. 191-242). London: Springer.
- *Environmental Modelling & Software, 87*, 39-48. doi: http://dx.doi.org/10.1016/j.envsoft.2016.10.008
- Squazzoni, F., Jager, W., & Edmonds, B. (2013). Social Simulation in the Social Sciences: A Brief Overview. *Social Science Computer Review, 31*, 1-16.

Computer programmes

- VenSim for system Dynamics (free download at vensim.com)
- Netlogo, recent version, for Agent-Based modelling (free download at www.northwestern.edu/netlogo).

Educational activities

The course has two main elements.

- The first two weeks centre on introductory lectures and tutorial activity, with labs on System Dynamics (SD) and Agent-Based Modelling (ABM) that use audio-visual materials and exercises, and students working individually on tutorial assignments.
- At the end of this period, each students presents a recent article to class, selected together with one of the teachers. It can be from the 'learning materials' in this document, or from another source.
- The following weeks centre on team assignments. Each team of 2-3 students has a dedicated supervisor. The students pick a practical assignment to design and build a model, if possible for a real client. They concentrate either on SD or on ABM. They write a report and present it to the other teams, to receive and provide feedback.

Assessment strategy

The course has no formal exam, since learning objectives are so intricately linked to the students' own cases.

- 20% of the final mark will be based on class participation, in particular the article presentation in week 3.
- 80% of the final mark will be based on the final report.

The table below links learning outcomes to assessment.

	class	report
1. Can view their own research topic as a complex socio-technical system.	x	x
2. Can select which sub-systems and actors to include.	x	x
3. Know the application scope of a range of analytical modelling approaches.	x	
4. Can select an appropriate approach for their own case.		x
5. Can create (and have created) models for their own case, neither too complicated nor too simple.		x

Principal Themes

Systems approaches: which and why?

Socio-technical systems are always to some degree contestable, particularly as to their boundaries but also as to their objectives and as to the value system that makes them meaningful. This is why we start with a method that expressly addresses these definitional issues: SSM, Soft Systems Methodology. After that, we spend most of the course working with qualitative / quantitative, conceptually rich methods that allow to investigate the dynamics of systems, to see which policy measures, or which influences outside of our control, might cause which effects in the system. Our two main methods are System Dynamics (SD) and Agent-based modelling (ABM). Both methods allow defining

- Dependent variables that are policy-relevant system outcomes
- Independent variables, either under our control or not, that influence the dynamics of our system, and thus the value of the dependent variables over time.
- Policy measures on the independent variables, and their intended or unintended effects.

The methods differ in the mechanisms and level of detail that are possible. SD is strong on systemic feedback loops. ABM is strong on modelling social motives and differences between people, and on local conditions.

Iconic cases to compare SD and ABM

We'll cover three cases that are iconic in SD and concern some archetypical socio-technical systems:

- Diffusion (e.g. of a virus, of a purchasing behaviour, or of a hype)
- Urban dynamics (settlement, prosperity and decay of economic hubs)
- Commodity dynamics (mutual feedbacks between commodity use, resource exhaustion, and population size)

In addition, we'll discuss some iconic patterns that ABMs can generate: various feedback loops, fixes that fail, coexistence vs extinction, power laws, tragedy of the Commons, tipping points, synchronization, spatial clustering.

Outline and schedule

week	Theme	In class	Out of class	
			Self study	project
1	Introduction	2 lectures per day	Computer-aided tutorial Netlogo	Create team, brainstorm
2	ABM, SD, literature	2 lectures per day, also by students	Read chosen article for presenting	Pick topic, contact would-be clients
3	Case work			Scope analysis, design
4	Case work		flowcharting	Design, development
5	Case work		Vensim / Netlogo	Model development
6	Case work			Model development
7	Case work			Cross-check other team's work
8	End	Final presentations		Create final report