CIVIL 534: Computational systems thinking for sustainable engineering

Logistics

Lectures: Wednesday 9:15-11:00
Exercises: Wednesday 8:15-9:00 and 11:15-12:00 (time to work on graded assignments and project milestones)
Location: CO 121

Instructor: Andrew Sonta, Assistant Professor of Civil Engineering, ETHOS Lab
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Teaching assistant: Kanaha Shoji, PhD Candidate, ETHOS Lab
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Will be present during 11:15-12:00 exercise session

Project teaching assistant: Vasantha Ramani, Postdoctoral Scientist, ETHOS Lab
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Consultation by email

Course description

This course focuses on two key topics in the context of complex engineered urban systems: systems thinking and network analysis. The course focuses on both theory and computing. The objective of this course is to develop expertise in computationally analyzing and modeling complex systems in civil and urban systems engineering, with a particular emphasis on advancing sustainability.

Content

- Introduction to systems thinking: theory and applications
- Computational modeling of system dynamics
- Systems and sustainability (case studies on resource use and environmental impacts)
- Introduction to network analysis
- Computational modeling of networks with built environment applications
- Integrating computational and systems thinking
- Using computational tools for engineering decision-making for advancing sustainability

Learning objectives

- Explain what comprises a complex system in the built environment
- Model complex urban systems and system dynamics
- Explain the characteristics of graphs and networks
- Use network analysis to describe complex systems
- Develop and model strategies for intervening in systems to advance sustainability objectives

Transversal skills

- Communicate effectively with professionals from other disciplines.
- Take account of the social and human dimensions of the engineering profession.
- Demonstrate the capacity for critical thinking

Coursework and assessment

Coursework will consist of two graded assignments, two midterm exams, and one final project (which includes two graded milestones).

- Graded assignments (20% | 2 @ 10% each). These assignments will reinforce the concepts from lecture and will include a mix of theoretical questions and practical questions using Python and Jupyter Notebooks. We will use the EPFL noto interface for working in Jupyter Notebooks.
- Midterms (40% | 2 @ 20% each).
- Course project (40%). The course project description is available on Moodle. The project will involve three milestones and a presentation on the final day of the class. You will work in groups of 3-4.
    - Project milestones (20% | 2 @ 10% each)
    - Final presentation (20%)

Course schedule (subject to change)

Week	Date	Course Content	Readings	Due (Fridays at 17h)
1	19-Feb	Couse introduction What is systems thinking? What are networks? The role of systems + networks in sustainable cities		
	Part 1: Systems thinking			
2	26-Feb	Systems intro One-stock systems	"Top of the Food Chain" Meadows Chapter 1	
3	5-Mar	One and two stock systems Delays and oscillations Stock constraints	Meadows Chapter 2	
4	12-Mar	System behavior Resilience, self-organization, hierarchy Structure vs. behavior	Meadows Chapters 3 and 4	Assignment 1 (due Fri 14 March)
5	19-Mar	System traps and opportunities Intervening in a system	Meadows Chapters 5 and 6	
6	26-Mar	***Systems Midterm***		
	Part 2: Network analysis			
7	2-Apr	Networks intro Building blocks Types of networks	Newman Chapter 1; 6.1-6.4; 6.6; 6.10-6.11	Project milestone 1 (due Fri 4 April)
8	9-Apr	Edge properties Node properties	Newman 6.12; 6.14; 7.1	
9	16-Apr	Clustering Centrality	Newman 7.2-7.4, 7.6, 7.7	
10	23-Apr	No Class - Spring Break		
11	30-Apr	Networks in urban systems Random graph models Network structure Percolation	Newman 10.1-10.6, 11, 13.1-13.2, 15 Note: These chapters are much more detailed than what we cover in class	Assignment 2 (due Fri 2 May)
12	7-May	Naturally-defined, model-defined, and data-defined networks Systems thinking + networks	"Review and structural analysis of system dynamics models in sustainability science"	Project milestone 2 (due Fri 9 May)
13	14-May	***Networks Midterm***		
	Part 3: Wrap-up			
14	21-May	Engineering decision making and sustainability applications; Project consultations		
15	28-May	***Project presentations***		