Agent Based Modeling and Simulations L-T-P-C: 2-1-0-3

Course Description:

This course explores how to use agent-based modeling to understand and examine a widely diverse and disparate set of complex problems. During the course, we will learn to use agent-based modeling to understand complex systems and case studies on applying agent-based modeling in the past to study various domains such as economics, biology, business, and management. The course will train students to build a model from the ground up and how to analyze and understand the results of a model using NetLogo, a widely used ABM platform. Finally, we will introduce ways to ensure models to be sound and rigorous.

Course Objective:

At the end of this class, we expect the students to be able to do

1. Use an ABM tool like NetLogo to model, simulate and perform experiments in various domains, to find solutions to problems.
2. Familiarization with various other modeling tools and techniques.

Prerequisites:

1. Intro to C programming
2. Overview of Computers
3. Data Structures and Algorithms 1 & 2

Note: The course number and name might vary based on the semester/year.

Syllabus:

1. Introduction
    a. What is Agent Based Modeling
    b. Industrial and Scientific Applications of agent-based modeling
    c. When and Why to use ABM and its limitations
2. Systems, Complex Systems and Emergence
3. Creating Agent Based Models
    a. Introduction to ABMS through NetLogo
    b. Agents & Environment
    c. Domain analysis and designing ABMs
    d. Case studies/Examples of ABM in various domains
4. Analyzing Agent Based Models
    a. Designing Simulation Experiments
    b. Behavior Space and Analysis
    c. Graphs & Visual Analysis Interfaces
5. Verification, Validation & Replication
    a. ODD protocol for documenting ABMS
    b. Verification and Testing
    c. Validation and Calibration
    d. Replication and Sensitivity Analysis

6. Other Modeling Techniques
    a. System Dynamics
    b. Discrete Event Simulation
    c. Cellular Automaton
    d. Hybrid modeling techniques
    e. Advanced topics

Tentative Teaching Plan:

- Before Mid Sem: Module 1, 2 and 3. We may cover a little bit of Module 4.
- Before End Sem: Module 4, 5 and 6
- Very frequently we will present case studies of state-of-the-art ABM publications, success stories and analyze them in class.

Assessment:

1. Exams (60%)
    a. Mid Sem (25%)
    b. End Sem (35%) *[Semi-Comprehensive]*
2. Quizzes (20%)
    a. Scheduled Quizzes (10%)
    b. Class Participation Quizzes: (10%)
3. Project (20%)

Notes on Exams: ABMS is a practical course. So, both, the mid-sem and end-sem, alongside other theory questions, will have a practical component (You can think of this as a mini lab exam). The decision whether to conduct the practical (lab-exam) together with the theory exam (or) separately, is at the full discretion of the faculty and the institute. All exams are closed book exams. You may use the help menu of the tool during the practical component.

Notes on End-Sem: End-sem will have an additional comprehensive section. This section will be used to test the students on all topics in ABM course. But, most of the questions in the comprehensive section will be of objective type (MCQ or Fill-in-blank).

Notes on Project: The project may be an individual project or group project, depending on the strength of the class. The size of the groups will also be determined based on the total number of students in the class.

Notes on Quizzes: All quizzes will be N-best or M-conducted. The N and M will be decided later based on scheduling constraints. We will also take into consideration the inputs from the class committee.

Text Book:

- Wilensky, U., & Rand, W. (2015). An introduction to agent-based modeling: modeling natural, social, and engineered complex systems with NetLogo. Mit Press.

- Railsback, S. F., & Grimm, V. (2019). Agent-based and individual-based modeling: a practical introduction, Second Edition. Princeton university press.

References:

- NetLogo 6.1.1 User Manual (https://ccl.northwestern.edu/netlogo/docs/)

Industry Relevance:

ABM is applied for Operations Research in many industries. Following are a few Industrial success stories of ABM

- Southwest Airlines used an agent-based model to improve how it handled cargo (Seibel and Thomas, 2000).
- Eli Lilly used an agent-based model for drug development (Bonabeau, 2003a).
- Pacific Gas and Electric: Used an agent-based model to see how energy flows through the power grid (Bonabeau, 2003a).
- Procter and Gamble used an agent-based model to understand its consumer markets (North et al., 2010)
- Hewlett-Packard used an agent-based model to understand how hiring strategies effect corporate culture (Bonabeau, 2003b).
- Macy's have used agent-based models for store design (Bonabeau, 2003b).
- NASDAQ used and agent based model to explore changes to Stock Market's decimalization (Bonabeau, 2003b; Darley and Outkin, 2007).

References:

- Bonabeau, E. (2000), 'Business Applications of Social Agent-Based Simulation', Advances in Complex Systems, 3(1-4): 451-461.
- Bonabeau, E. (2003a), 'Don't Trust Your Gut', Harvard Business Review, 81(5): 116-123.
- Bonabeau, E. (2003b), 'Predicting the Unpredictable', Harvard Business Review, 80(3): 109-116.
- Darley, V. and Outkin, A.V. (2007), NASDAQ Market Simulation: Insights on a Major Market from the Science of Complex Adaptive Systems, World Scientific Publishing, River Edge, NJ.
- North, M.J., Macal, C.M., Aubin, J.S., Thimmapuram, P., Bragen, M., Hahn, J., J., K., Brigham, N., Lacy, M.E. and Hampton, D. (2010), 'Multiscale Agent-based Consumer Market Modeling', Complexity, 15(5): 37-47.
- Seibel, F. and Thomas, C. (2000), 'Manifest Destiny: Adaptive Cargo Routing at Southwest Airlines', Perspectives on Business Innovation, 4: 27-33.