Syllabus - MATH 8410: Boolean Networks

Undergraduate options: independent study MATH 4900 for undergraduate credit, or MATH 8410 for graduate credit (with permission of instructor)

Semester: Spring 2016
Time: 5:30-6:45 PM, MW
Where: DSC 109 + computer lab DSC 211B

Instructor: Dr. Dora Matache
Office: DSC 228
Phone: 554-3295
E-mail: dmatache@unomaha.edu,
Office Hours: 1:00-3:00PM TR or by appointment. If you send questions by email make sure you send them in a timely manner. Provide as many details as you can in your emails and pose clear, short, and precise questions. Include problem numbers.

Text: The instructor will provide course notes and will indicate specific references throughout the semester. New chapters and topics may be added to the course notes throughout the semester. The students will have the opportunity to consult suitable journal publications.

Prerequisites: Fair mathematical maturity: MATH 1960 (Calculus II), MATH 2230 (proof writing skills), MATH4740 or equivalent (basic probability theory), basic computer skills; or permission of the instructor.

Description: Network science is a new and emerging scientific discipline that uses network theory as an area of applied mathematics, to examine the interconnections among diverse physical or engineered networks, information networks, biological networks, social networks etc. It is the study of network representations leading to predictive models of real phenomena. Networks consist of a number of nodes whose (discrete) time evolution depends on connections with other nodes. The analysis of the time evolution of a network based on rules generated by interconnections allows for insight into the long term dynamical behavior of that network. In this course we will seek to answer questions like "Will a network settle down to a steady state in the long term, and if so, what are the possible steady states?", or "Does the long-term behavior of a system depend on its initial condition?", “Is the system robust to perturbations, or does it exhibit sensitivity? Is there a phase transition between ordered and chaotic behavior?”, “Can systems by synchronized?” etc.

There are various types of networks that one can consider. However, we will focus on certain models of complex networks, namely cellular automata and their generalization, Boolean networks, representing networks in which nodes can take on two values, ON and OFF and whose evolution from one time step to another is based on logical relationships with other nodes of the network. For example, a genetic or protein network has nodes that are expressed/regulated or not based on the expression levels of other nodes; in an epidemic network nodes are individuals that become infected or not based on their exposure to other infected nodes; in a prediction market network the nodes are traders that trade based on their positive or negative beliefs according to the interaction with other traders or market makers; in a social network the individuals may be influenced to adopt a certain opinion or not based on the interaction with the others; in a neural network the neurons fire or not based on signals from other neurons etc.

Some topics covered: Cellular automata, Boolean network basics (topology, dynamics, special types of networks), density of ones, mean field approximation, Hamming distance and Derrida plots; sensitivity to noise. Other topics will be considered based on students' interests and applications.

Grading:

What	Points	Weight	Notes
Hw/Written tasks	400	40%	Collected at the end of each chapter (tentative)
Class work	100	10%	Group work, interactions with the others and the instructor
Class presentations	100	10%	At least one per semester on a specified topic
Final Project/Research Report	300	30%	Research on a topic of your choice (starts around Spring break)
Final presentation	100	10%	Present the results of your research (last week of school – tentative)
Total	1000	100%	

Final grades will be assigned on the percentage of student's total score out of the total possible score. The normal ranges for grades based on these percentages will be:

Range	Grade	Range	Grade	Range	Grade
98-100%	A+	82-88%	B	70-72%	C-
92-98%	A	80-82%	B-	68-70%	D+
90-92%	A-	78-80%	C+	62-68%	D
88-90%	B+	72-78%	C	60-62%	D-

Grade F otherwise.

Learning management system: Blackboard https://blackboard.unomaha.edu/webapps/login/
It is the students' responsibility to check regularly for materials, announcements, updates etc.

Some expectations: In this course, *everyone* will be required to

- read and interact with course notes on your own and with the others;
- write up quality proofs and solutions to assigned problems;
- participate in discussions centered around the covered topics;
- give presentations on specified topics from the course notes;
- find a research topic of your choice and work towards a research goal (especially during the second half of the semester)
- call upon your own prodigious mental faculties to respond in flexible, thoughtful, and creative ways to problems that may seem unfamiliar on first glance.

Teaching style: None really! This is not a typical lecture class in which the students watch the teacher, read the material, solve homework exercises after the lecture and after the reading is done, and hope to learn the subject. This class is about taking responsibility for learning and interacting directly with the class material at all times. What you gain is a function of the effort, attention and interest you put in learning something new with minimal help from a teacher. You just need the desire to work hard as a ``practicing mathematician''.

The official terminology is ``Inquiry Based Learning'' (IBL) class, and the goal is to develop skills, approaches, and attitudes for ``doing mathematics'' as opposed to ``learning/studying mathematics''. So you will be an explorer this semester, thinking about concepts before asking questions, consulting other materials independently to clarify them, pushing your inquisitive minds to further topics. Your teacher will stand ready to help, however, you are expected to own the learning process. The course notes will guide you through the material without giving you too much information, and thus allowing you to explore.

In short, you will read the material on your own, trying to answer as many of your own questions as possible. In class, we meet for discussions, further exploration and readings together with other students, clarifications, and working on the assigned tasks. Team work is encouraged and more fun. Each of you will be an equal participant in the team effort though.

Computer: There will be a significant amount of time spent in the computer lab. You will learn how to deal with Matlab and will be asked to run simulations. The basic Matlab programs will be provided by your instructor. Given that there will be a significant amount of simulations to perform, students can save all graphs in appropriate files and collect them in folders that should be saved on the computer, a flash drive, your UNO web folder, or similar.

Tasks, homework: All the problems and exercises in the course notes are assigned. You are supposed to work on them mostly **outside** class. When we meet in class we discuss some of the questions you might have, we run simulations, we explore concepts together, and work on further tasks as listed in the course notes.

There will be one homework assignment per chapter (tentative), and you turn it in when you finish the chapter. Depending on the background of each student, the due dates may be different for different students (for example, a student who does not have a background in chaos theory, may need to spend time on that first). The assignments can be submitted as hard or soft copies with appropriate file names. Include the simulation results (well, not all, but the most significant ones).

Collaboration on tasks and homework assignments is encouraged. However, outright copying is not allowed. Your grade will reflect your own knowledge so make sure you really understand the material, but teamwork is the best tool for an efficient learning process. (it is more fun too!)

Research Project: You will (eventually) work on research projects that can help make conjectures and prove mathematical results. By the middle of the semester you should have a pretty good idea of some research projects as suggested in the course notes or based on your own interests.

You will be expected to complete a research project during the second half of the semester. You will focus on targeted readings to supplement your knowledge on that topic, become familiar with the literature, and identify steps to take for accomplishing a certain research goal. Thus every student or team could be doing something else.

Keep in mind that whatever you choose to work on, there may be the case that you will not be able to finalize all your goals by the end of the semester. In mathematics research it is very hard to set time limits. And the research evolves dynamically, based on what you find along the way. So the final product may look very different than your initial goal. It is OK and expected. Doing research is not the same as learning about research, since you are in charge with what you do, and you may have no clue on what should happen. But this ``mystery'' is the fun part!

You will be expected to give a brief but professionally structured presentation on the work and results of your project at the end of the semester.

Attendance: Regular attendance is expected, but you will not explicitly be graded on attendance. Yet, repeated absences may impact your evolution.

Class Etiquette: Students are expected to treat each other with respect. Students are also expected to promote a healthy learning environment, as well as minimize distracting behaviors. Moreover, every attempt should be made to arrive to class on time. If you must arrive late or leave early, please do not disrupt class.

Please turn off the ringer on your cell phone. I do not have a strict policy on the use of laptops, tablets, and cell phones. You are expected to be paying attention and engaging in class discussions. If your cell phone, etc. is interfering with your ability (or that of another student) to do this, then put it away, or I will ask you to put it away.

Final important word: Have fun! This is a class that combines math with various applications. It is very enjoyable, despite the hard work and challenges at times. Moreover, it prepares you for further research and gives you some skills in writing professional reports and papers. You can develop a thesis (Masters's or graduation) and, with further work, transform your project into a publishable paper.