SIE 505: Formal Foundations for Information Science, Spring 2020

School of Computing and Information Science, University of Maine

1 Contact Information

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1.1 How to Contact Me

If you are on campus, feel free to drop by my office if my door is open. I'm also planning to have regular office hours Mondays and Wednesdays, time TBA. Otherwise, email is the quickest way to get hold of me. For longer questions, please email to arrange for a time when to talk.

2 Objectives and Topics

2.1 Course Objectives

- Introduce students to the basic modes of thinking that underlie information processing: logical, relational, recursive, quantitative, and algorithmic thinking;
- Familiarize students with a variety of mathematical formalism (formal languages, mathematical structures and logical systems) to represent information;
- Equip students with the basic toolset to study more advanced formalism from mathematics and theoretical computer science on their own;
- Enable students to write up their ideas in a well-structured and formal manner.

2.2 Learning Outcomes

The goal of the course is to improve the mathematical and computational literacy of the student. Every student in the course is expected to learn to

- read, comprehend, and explain mathematical formalisms and simple proofs (formal or informal) presented in reference books or scholarly publications;
- present thoughts concisely using standard mathematical notation, structures and algorithms in writing and speaking;
- understand and apply the concept of recursion to define more complex structures and to prove properties about them inductively;
- use sets, functions, relations, sequences, and graphs to represent common problems in an information system;
- construct and use definitions, theorems, and simple proofs.

2.3 Covered Topics

We will cover the following topics with a focus on mathematical foundations and on their applications to information systems:

1. Logical thinking:
    - An overview of propositional and predicate logic
    - Uses of logic in mathematics, computer and information sciences
    - Basic strategies to construct logical arguments (proofs): direct proof, proof by contradiction, instantiation, proof by cases
2. Relational thinking through the study of basic discrete mathematical structures:
    - Finite and infinite sets, operations thereon, and ordered structures
    - Functions and relations and their properties
    - Equivalence relations and partially ordered relations
    - Graphs and trees, their traversal and computer representation
3. Recursive thinking:
    - Recursive functions and definitions
    - Proof by induction
4. Quantitative thinking:
    - Cardinality and countability of sets
    - Counting with functions
    - Problem size estimation
5. Algorithmic thinking:
    - Pseudocode
    - Introduction to Complexity

The intent is to appreciate the various ways information and data can be encoded in discrete forms rather than to provide a comprehensive overview over all kinds of discrete structures.

2.4 Tentative Term Schedule

Week	Topics	Reading Assignment from [Hun17] To Be Completed Beforehand
01/20	Introduction & Expectations, LaTeX	
01/27	Propositional Logic	1.1, 1.2
02/03	Predicate Logic & Logic in Math	1.3, 1.4
02/10	Proofs	1.5
02/07	Graphs and Sets	2.1, 2.2
02/24	Functions	2.3
03/02	Relations, Equivalences, Partial Orders	2.4, 2.5–2.5.3
03/09	Recursion & Induction	3.1, 3.2
03/16	*Spring Break (no class)*	
03/30	Recursive Definitions	3.3, 3.4, 3.5
03/23	*catch up*	
04/06	Counting: Permutations, Combinations, Functions	4.1, 4.2, 4.3
04/13	Algorithms & Counting	4.5, 5.1, 5.2
04/20	Algorithms: Estimation & Complexity	4.6, 5.3, 5.4

3 Expectations

I understand that everybody's background will be quite diverse, many of you having little previous experience with logic or discrete mathematics or having had your last mathematical course years ago. While a certain mathematical maturity and, at the very least, familiarity with college algebra (e.g. rational numbers, operations on fractions, etc.) are expected, no other technical background is required. However, I expect a willingness to work your way through complex and formal material. This being a graduate course, we will go over material fairly quickly. To keep up, you are expected to spent significant time (roughly 6-10h per week depending on your experience and abilities) outside the classroom on the readings, quizzes, and exercises. For example, you will need to reread the assigned sections multiple times or consult additional sources. Of course, I'm willing to help and guide you in this process.

This is essentially an inverted class, thus attendance and participation in a weekly class session (we will use the zoom videoconferencing software) are crucial to your learning success. If you are absent due to illness or another important reason, please email me prior to or immediately after your absence.

4 How this Class Works

This class uses an inverted classroom model with few lectures. Instead, class time is used to discuss the material, address questions, and review how to approach problems. We will cover new material and exercises every week. To give you some idea, this is what a typical week will look like:

1. You watch a short introductory video to the new material
2. You read the assigned sections from the textbook (typically around 2 sections)
3. You will take an initial attempt at the online quiz to see how you are doing and where there are gaps in your understanding (you're welcome to use the textbook to help you complete the quiz)
4. You start reviewing all the assigned preliminary exercises for the week
5. You comment on the discussion board about any questions you may have about the reading, the quiz or the exercises
6. You start compiling solutions for the assigned preliminary exercises and submit them *(Alternate weeks)*
7. We have a live discussion (around 60-75min long) on the more difficult exercises
8. You review and comment on somebody else's preliminary exercises *(Alternate weeks when you didn't submit exercises)*
9. You retake the online quiz (as often as you want)
10. You prepare a solution to the assigned final exercises (which are a subset of the preliminary exercises plus a few new ones)

This is the tentative outline of our week. Live sessions (with mandatory participation for at least one session a week) are currently scheduled for Tuesdays at 3-4pm and 7-8pm.

Day and Time	Who	Activity
1/27 Monday EOD	Instructor	Introductory video for readings posted
1/30 Thursday EOD	Students	Complete reading Complete at least one quiz attempt Post reflection and questions on discussion board
1/31 Friday	Instructor	Recorded Question & Answer session Help Session
2/3 Monday EOD	Students (alternate weeks)	Initial solutions for exercises
2/4 Tuesday	Everyone	Live session discussing exercises
2/5 Wednesday EOD	Students (alternate weeks)	Feedback on initial exercise solutions
2/9 Sunday EOD	Students	Final solutions to exercises Final quiz attempt

5 Course Materials

[Hun17] is one of the most accessible and well-organized introductions to the ways of thinking that information systems are build on. It is the only required textbook for the course.

You can additionally look at [Epp11] and [Hei09] to get a different perspective at much slower and more detailed pace. [Vel94] presents a more detailed introduction to logic and proofs. Wikipedia is also a good source for many of the concepts we cover. Try to figure out which sources you can learn best from – often it helps to read multiple versions of the same material to develop a deeper understanding.

[Hun17] David J. Hunter. *Essentials of Discrete Mathematics*. 3rd. Jones & Bartlett, 2017.

[Epp11] Susanna S. Epp. *Discrete Mathematics with Applications*. 4th. Brooks/Cole Cengage Learning, 2011.

[Hei09] James L. Hein. *Discrete Structures, Logic and Computability*. 3rd. Jones & Bartlett Learning, 2009.

[Vel94] Daniel J. Velleman. *How to Prove It: A Structured Approach*. Cambridge University Press, 1994.

6 Math Preparation

If your last math course is a few years back, I recommend a refresher at the beginning of the term. Below a list of the most relevant short lessons from Khan Academy (they are all free and come with some quizzes and practice questions). You can work through them at your own pace, for most of you, it shouldn't take too long.

Pre-Algebra (only if you're having difficulties with the algebra lessons):

https://www.khanacademy.org/math/pre-algebra/pre-algebra-factors-multiples
https://www.khanacademy.org/math/pre-algebra/pre-algebra-equations-expressions
https://www.khanacademy.org/math/algebra-basics/basic-alg-foundations
https://www.khanacademy.org/math/algebra-basics/alg-basics-algebraic-expressions

Algebra:

https://www.khanacademy.org/math/algebra/x2f8bb11595b61c86:foundation-algebra
https://www.khanacademy.org/math/algebra/x2f8bb11595b61c86:solve-equations-inequalities
https://www.khanacademy.org/math/algebra/x2f8bb11595b61c86:functions
https://www.khanacademy.org/math/algebra/x2f8bb11595b61c86:sequences
https://www.khanacademy.org/math/algebra/x2f8bb11595b61c86:absolute-value-piecewise-functions
https://www.khanacademy.org/math/algebra/x2f8bb11595b61c86:rational-exponents-radicals
https://www.khanacademy.org/math/algebra/x2f8bb11595b61c86:irrational-numbers
https://www.khanacademy.org/math/algebra/x2f8bb11595b61c86:quadratic-functions-equations
https://www.khanacademy.org/math/algebra/x2f8bb11595b61c86:quadratics-multiplying-factoring
https://www.khanacademy.org/math/algebra2/x2ec2f6f830c9fb89:rational
https://www.khanacademy.org/math/algebra2/x2ec2f6f830c9fb89:exp
https://www.khanacademy.org/math/algebra2/x2ec2f6f830c9fb89:eq
https://www.khanacademy.org/math/algebra2/x2ec2f6f830c9fb89:rational

A bit of pre-calculus:

https://www.khanacademy.org/math/precalculus/x9e81a4f98389efdf:series

A tiny bit of geometry:

https://www.khanacademy.org/math/geometry/hs-geo-congruence

7 Assessment

Your grade for the course will be calculated from the following components:

Weekly questions and discussions (Blackboard Discussion Board): 10%
You are expected to reflect at least once a week on the course material using Blackboard's discussion board and to respond to other's entries or questions. This may include posing some questions that arise from the reading that I can address in a (recorded) question and answer session, discussions of exercise or quiz questions reflecting on your thinking and potential confusion, applications or challenges you can think of (e.g. from your own experience, in the news, etc.). Your entries should demonstrate that you have carefully read the assigned chapter, are starting to gain familiarity with the new concepts and theorems, have thought about the exercises, and can link the abstract concepts to more concrete uses.

Weekly quizzes: 20%
The quizzes test your comprehension of the weekly reading. You can repeat them multiple times, but you are asked to complete at least one attempt by Sunday night and reflect on your blog on any misunderstandings that you may notice. As a guideline, aim for a score of at least 60% by Sunday night so that we can focus the Monday discussion on the remaining 40% (or less). While the exact score will not be reflected in your final quiz grade, consistent lower scores by Sunday night will negatively affect your question & discussion grade.
After the Monday discussion you can retake the quiz as often as you wish until the end of the week. Your final attempt will count towards this portion of the grade.

Weekly exercises: Initial solution attempts: 20%
Each week, you are given a set of exercises to work on. Every other week you will be asked to submit your initial solutions and present a question or two during the live session. The purpose of the live session is to iron out any conceptual errors and make sure you can complete the exercises.
In alternate weeks (that is, when you're not submitting and presenting initial solutions), you are asked to critique and improve someone else's initial solutions after we discuss them during the live session.

Weekly exercises: Final solutions: 30%
After the live session and with the feedback from one of your peers, you should revise as necessary complete the exercises on your own and submit a full solution. Everyone will be expected to complete selected additional exercises.

Final exam: 20%
This will be a take home exam during finals week, but is waived if your overall standing at this point is an A.

8 Other Required Syllabus Information

Please review the policies on academic honesty, students with disabilities, course schedule disruptions, observance of religious holidays, and sexual discrimination reporting:
`https://umaine.edu/citl/teaching-resources-2/required-syllabus-information/`