CS204: Discrete Mathematics

Course Introduction

2020

Sungwon Kang

Prof. Sungwon Kang

School of Computing, KAIST

Research Areas:

Software Engineering
Software Architecture
Software Product Line
Software Testing
Data-based Software Development

Books:

Sungwon Kang, *Invitation to Software Architecture* (In Korean), 3rd Ed., 2018.
Sungwon Kang, *Systematic Software Product Line Development* (In Korean), 2017.

Discrete Mathematics

- A Branch of Mathematics that deals with discrete objects.
- Discrete objects are
  - separated from or distinct from each other
  - countable.

Examples Integers, rational numbers, people, data structures of computer programs and etc.

Non-discrete objects (=> Need different mathematics):
- real numbers
- things that map to real number such as electrical signals

- In this course, we study

(1) discrete objects such as integers, propositions, sets, relations, functions and etc. for their concepts, their properties, and their relationships with each other and
(2) how to reason with discrete objects.

Discrete Mathematics helps . . .

- Ability to construct complex and powerful objects for computation:
  - **Data structures**: recursive and non-recursive
  - **Algorithms**: recursive and iterative, sequential and parallel
  - **Programming languages**: Procedural, Logic-based, Function-based

- Ability to state and prove facts about programs:
  - **Complexity of algorithms**: covered in Data structures & Algorithms courses
  - **Correctness of programs**: Partial correctness and total correctness
  - **Proof techniques**: Mathematical induction, Structural Induction,

- Essential to take advanced CS courses:
  - Data structures
  - Algorithms Design and Analysis
  - Compiler and Programming Languages
  - Software Engineering
  - AI, Robotics, Computer Graphics
  - Database, Inference
  - Etc.

Course Operation

- Each lecture predetermined class time of Tuesday or Thursday 13:00~14:30.

  Example The first class period is March 17 (Tuesday) 13:00~14:30. So the lecture slides for the first class will be posted before March 16(Monday)13:00.

- Each student has to finish each lecture by the end of predetermined class time and should submit answers to a quiz, which will be at the last part of the lecture slides.

  Example The first quiz should be submitted before March 17(Tuesday) 14:30.

- See the course syllabus for the detailed course schedule.

Questions and Answers

- Questions concerning the course contents:
  - These questions should be directed to the instructor.
  - To ask questions, use Course Q&A Board in KLMS.
  - The instructor will post answers to questions by 11:00 am each day. (If a question is not answered by this time, then it will be answer by the same time next day.)
  - There are no such thing as “bad questions”. So don’t hesitate to ask questions.

- Questions concerning grading of quizzes, homeworks and exams:
  - These question should be directed to TA first.
  - If there is an issues that cannot be resolved, then the instructor will take a look.

Instructor and TA

Instructor: Sungwon Kang

Instructor Office: E3-1, 1429

Instructor Office Hours: Please contact on-line.

Instructor Email: sungwon.kang@kaist.ac.kr

TA: See KLMS

TA Office: See KLMS

TA Office Hours: See KLMS

TA Email: See KLMS

Textbooks

[Rosen 19]
K. Rosen, *Discrete Mathematics and Its Applications,*
8th Edition, McGraw-Hill, 2019.

[Hunter 17]
David J. Hunter, *Essentials of Discrete Mathematics,*
3rd Edition, Jones & Bartlett Publishers, 2017.

[Johnsonbaugh 19]
Richard Johnsonbaugh, *Discrete Mathematics*,
8th Edition, 2019.

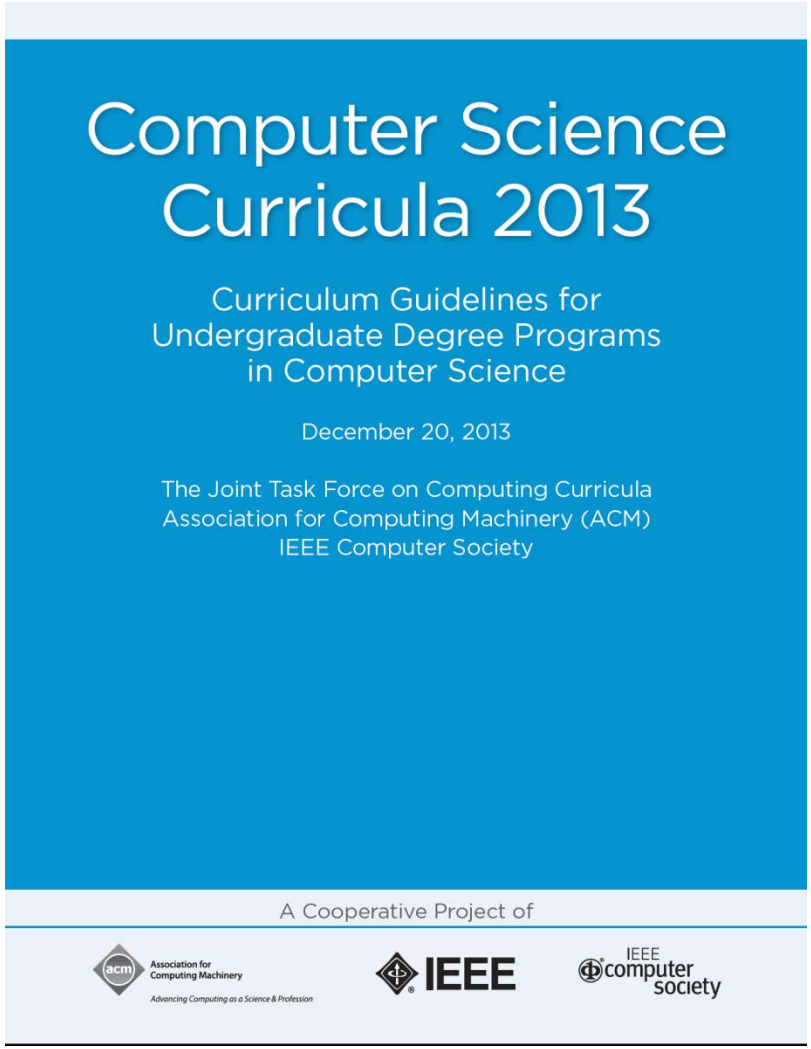
These books and their old editions are okay, too.

This course covers

Chapters of [Rosen 19]:

Ch1. The Foundations: Logic and Proofs
Ch2. Basic Structures: Sets, Functions, Sequences, Sums, and Matrices
Ch5. Induction and Recursion
Ch6. Counting
Ch7. Discrete Probability
Ch9. Relations
Ch10. Graphs
Ch11. Trees
Ch3. Algorithms (Time Permitting)

Goal: Cover the topics of ACM/IEEE guidelines



Discrete Mathematics

- Sets, Relations, and Functions
- Basic Logic
- Proof Techniques
- Basics of Counting
- Graphs and Trees
- Discrete Probability

Basic Logic

Topics:

[Core-Tier1 9 hours]

- Propositional logic (cross-reference: Propositional logic is also reviewed in IS/Knowledge Based Reasoning)
- Logical connectives
- Truth tables
- Normal forms (conjunctive and disjunctive)
- Validity of well-formed formula
- Propositional inference rules (concepts of modus ponens and modus tollens)
- Predicate logic
    - Universal and existential quantification
- Limitations of propositional and predicate logic (e.g., expressiveness issues)

Proof Techniques

Topics:

[Core-Tier1 10 hours]

- Notions of implication, equivalence, converse, inverse, contrapositive, negation, and contradiction
- The structure of mathematical proofs
- Direct proofs
- Disproving by counterexample
- Proof by contradiction
- Induction over natural numbers
- Structural induction
- Weak and strong induction (i.e., First and Second Principles of Induction)
- Recursive mathematical definitions

[Core-Tier2 1 hour]

- Well orderings

Sets, Relations, and Functions

Topics :

[Core-Tier1 4 hours]

- Sets
  - Venn diagrams
  - Union, intersection, complement
  - Cartesian product
  - Power sets
  - Cardinality of finite sets
- Relations
  - Reflexivity, symmetry, transitivity
  - Equivalence relations, partial orders
- Functions
  - Surjections, injections, bijections
  - Inverses
  - Composition

Graphs and Trees

Cross-reference: AL/Fundamental Data Structures and Algorithms, especially with relation to graph traversal strategies.

Topics:

[Core-Tier1 3 hours]

- Trees
  - Properties
  - Traversal strategies
- Undirected graphs
- Directed graphs
- Weighted graphs

[Core-Tier2 1 hour]

- Spanning trees/forests
- Graph isomorphism

Basics of Counting

Topics:

[Core-Tier1 5 hours]

- Counting arguments
  - Set cardinality and counting
  - Sum and product rule
  - Inclusion-exclusion principle
  - Arithmetic and geometric progressions
- The pigeonhole principle
- Permutations and combinations
  - Basic definitions
  - Pascal's identity
  - The binomial theorem
- Solving recurrence relations

  (cross-reference: AL/Basic Analysis)
  - An example of a simple recurrence relation, such as Fibonacci numbers
  - Other examples, showing a variety of solutions
- Basic modular arithmetic

Discrete Probability

Topics:

[Core-Tier1 6 hours]

- Finite probability space, events
- Axioms of probability and probability measures
- Conditional probability, Bayes' theorem
- Independence
- Integer random variables (Bernoulli, binomial)
- Expectation, including Linearity of Expectation

[Core-Tier2 2 hours]

- Variance
- Conditional Independence

Table of Contents

Grading

- **Homeworks (20%)**

  - Roughly once a week (about 2% each)

- **Exams (65%)**

  - Midterm (25%)

  - Final (40%)

- **Quizzes/Attendance (10%)**

  - Check attendance and understanding

- **Instructor discretion (5%)**

  - Participation in/out of class

  - Overall level of effort and progress

Homeworks

- **Roughly one homework each week**
  - Discussion with others encouraged
  - Final write-up must be your own work !
  - Due at midnight of the due date

Exams

- Midterm (25%)
- Final (40%) - Comprehensive

Quizzes

- To check your understanding as well as your class attendance
- Quizzes will be given at the end of slide sets.
- Submit your quiz answers to the QUIZ section in KLMS
- Not submitting quiz answers by the deadline will be considered to be “absent from class” and also the quiz score will be recorded as '0'.

Absence from class

- You may be absent from class once in the semester without penalty. (Sickness, trip to conference, etc. for any reason whatsoever)

- If you are absent more than once, your attendance score will be deducted. (Doctor's statement NOT accepted!)

How to read the lecture slide title

X-*Y* Lecture Subject – *Z*.pdf

X: Class number

Y: Slide set number

Z: Lecture Subject number

Example

2-1-Formal Logic-Classical Logic.pdf

-- This is the first lecture slides for the second class and its subject is "Formal Logic-Classical Logic.pdf"

3-1-Propositional Logic-2.pdf

-- This the first lecture slides for the third class and its subject is "Propositional Logic". In addition, this is the second lecture slides on the subject of "Propositional Logic".