JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

Computer Science 601.430/630
COMBINATORICS AND GRAPH THEORY IN COMPUTER SCIENCE
Spring, 2024 (3 credits, EQ)

Instructor

Professor Xin Li, lixints@cs.jhu.edu, http://www.cs.jhu.edu/~lixints
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Teaching Assistant

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Office: Malone Hall 216
Office hours: Fridays 3:00–4:00 pm, in person.

Meetings

Tuesday and Thursday, 1:30–2:45 pm, Hodson 216

Textbook

Required: Stasys Jukna, *Extremal Combinatorics: With Applications in Computer Science*. 2nd Edition.

Recommended: N. Alon and J. H. Spencer, The Probabilistic Method. 4th Edition.

Online Resources

Any related online material will be posted at the course website http://www.cs.jhu.edu/~lixints/class/spring24.html.

Course Information

- This is a combined graduate and undergraduate level course studying the applications of combinatorics and graph theory in computer science. We will start with some basic combinatorial techniques such as counting and pigeon hole principle, and then move to advanced techniques such as the probabilistic method, spectral graph theory and additive combinatorics. We shall see their applications in various areas in computer science, such as proving lower bounds in computational models, randomized algorithms, coding theory and pseudorandomness. Students may receive credit for only one of EN.601.430 and EN.601.630.
- **Prerequisites**
  Discrete Math or permission. Probability theory and linear algebra strongly recommended.
- **Selective Elective**

Course Goals

Specific Outcomes for this course are that:

- Students will learn to establish a formal foundation of the theory of computation.
- Students will learn to analyze and solve problems formally and mathematically.

This course will address the following Criterion 3 Student Outcomes:

- An ability to apply knowledge of computing and mathematics appropriate to the discipline (a)
- An ability to analyze a problem, and identify and define the computing requirements appropriate to its solution (b)

Tentative Course Topics

- Basic Techniques: Counting; Pigeon hole principle; Matching and Hall's theorem; Chains and Antichains, with applications to LIS.
- The Probabilistic Method: Basic method; Lovaz local lemma and its constructive proof; Linearity of Expectation; The deletion method; Concentration bounds; Random walks and randomized algorithm for finding satisfying assignment for 2-CNF.
- Spectral Graph theory: Basic properties of graph spectrum; Cheeger's inequality and approximation of graph expansion; Expander graphs and applications to superconcentrators and pseudorandomness; Error correcting codes and expander codes.
- Ramsey Type Theorems and Constructions of Ramsey Graphs.
- Additive Combinatorics: Sum product theorem, Szemeredi-Trotter theorem, Kakeya set problem and applications to randomness extractors.

Who should Take this Course

Students who have strong math background and math skills, and who are interested in theoretical computer science/combinatorics and graph theory are encouraged to take this course.

Who should not Take this Course

Students who don't have a strong math background, math skills, or strong interests in theoretical computer science/combinatorics and graph theory should not take this course. Specifically, just feeling your math background is not *weak* is not sufficient for taking this class. In addition, there will be a lot of formal definitions, math proofs, and abstraction in this course. If you have difficulties with these (e.g., you always need to look at specific graphs in order to think about a graph theoretical problem), then you should not take this class. Otherwise it's just going to be a hard time for everyone.

Course Expectations & Grading

There will be four or five homework problem sets, one mid-term exam and one final exam. Grading will be based on the following rule:

- Homework: 40%.
- Mid-term exam: 30%.
- Final exam: 30%.

Key Dates

The mid-term exam will be held on March 14. The final exam will be cumulative and be held on date TBD. The specific formats of the exams (either on-line or in person) will be decided later. No make-up exams will be given, unless you have legitimate reasons, so plan accordingly. If the exams are held in person, for the midterm, you may bring a single, 8.5x11 inch, handwritten sheet of paper (you may use both sides). For the final exam you may bring two sheets. No calculators are allowed (they won't be necessary).

Assignments & Readings

Assignments and further readings will be posted on the course website http://www.cs.jhu.edu/~lixints/class/spring24.html

Gradescope: https://gradescope.com/

CampusWire: https://campuswire.com/p/GA7466122 Code: 4255

Ethics Academic Integrity:

The strength of the university depends on academic and personal integrity. In this course, you must be honest and truthful. Ethical violations include cheating on exams, plagiarism, reuse of assignments, improper use of the internet and electronic devices, unauthorized collaboration, alteration of graded assignments, forgery and falsification, lying, facilitating academic dishonesty, and unfair competition.

Report any violations you witness to the instructor. You can also contact:

- For undergraduates: the associate dean of student conduct (or designee) by calling the Office of the Dean of Student Life at 410-516-8208 or via email at studentconduct@jhu.edu
- For KSAS Graduate Students: rseitz5@jh.edu
- For WSE Graduate Students: christinekavanagh@jhu.edu

[In addition, the specific ethics guidelines for this course are:

(1) *Collaboration policy:* While you should first think about homework problems on your own, I encourage you to discuss homework problems with your classmates. However, you must write up your own solutions. Students found sharing the same paragraph in their homework will receive 0 point for the homework, and risk further punishment such as automatic failure and report to the University. Furthermore, you must acknowledge any collaboration by writing the names of your collaborators on the front page of the assignment. You don't lose points by having collaborators.

(2) *Using other resources:* You can use other resources (e.g., online resources) to help you understand the topics generally. However, using resources other than those provided in class (textbook, notes, homework solutions) in your homework or exams is prohibited. Using unauthorized solutions from other resources in homework or exams is considered plagiarism and will result in 0 point for the assignments and potential further punishment as in (1). To clarify, unauthorized resources for homework or exams include artificial intelligence (AI) assistants such as ChatGPT and GitHub Copilot. Therefore, use of such AI assistants in homework and exams is not allowed in this course.

(3) *Late Policy:* You have a total of two late days without penalty for the homework. A day here means 24 hours. For example, if the deadline is 7pm, then one day means from 7pm to 7pm next day, and if you submit your homework any time after 7pm the first day until 7pm the next day, you are

considered to have used one whole late day. You can use your two late days freely, e.g., one late day for one homework and one for another, or two late days for one homework. Once you use up your late days, your late homework will not be graded, unless you have legitimate reasons.

You can find more information about university misconduct policies on the web at these sites:

- Undergraduates: https://studentaffairs.jhu.edu/policies-guidelines/undergrad-ethics/
- Graduate students: http://e-catalog.jhu.edu/grad-students/graduate-specific-policies/#misconduct

Classroom Climate

I am committed to creating a classroom environment that values the diversity of experiences and perspectives that all students bring. Everyone here has the right to be treated with dignity and respect. I believe fostering an inclusive climate is important because research and my experience show that students who interact with peers who are different from themselves learn new things and experience tangible educational outcomes. Please join me in creating a welcoming and vibrant classroom climate. Note that you should expect to be challenged intellectually by me, the TAs, and your peers, and at times this may feel uncomfortable. Indeed, it can be helpful to be pushed sometimes in order to learn and grow. But at no time in this learning process should someone be singled out or treated unequally on the basis of any seen or unseen part of their identity.

If you ever have concerns in this course about harassment, discrimination, or any unequal treatment, or if you seek accommodations or resources, I invite you to share directly with me or the TAs. I promise that we will take your communication seriously and to seek mutually acceptable resolutions and accommodations. Reporting will never impact your course grade. You may also share concerns with the Department Head (Randal Burns, randal@cs.jhu.edu), the Director of Undergraduate Studies (Joanne Selinski, joanne@cs.jhu.edu), the Assistant Dean for Diversity and Inclusion (Darlene Saporu, dsaporu@jhu.edu), or the Office of Institutional Equity (oie@jhu.edu). In handling reports, people will protect your privacy as much as possible, but faculty and staff are required to officially report information for some cases (e.g. sexual harassment).