CS592* Advanced Topics in Algorithms Syllabus, Policies, and Procedures

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Contents

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*CS690?

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1 Course description

This is a special topics course on advanced topics on algorithms. We will largely develop algorithms for fundamental problems in graph problems and combinatorial optimization with an infusion of modern techniques and perspectives, such as: randomization, approximation, continuous techniques, advanced data structures, spectral techniques, and more. The goal for most problems is to obtain *fast* and *scalable* algorithms for basic problems that (for the sake of efficiency) we allow to be randomized and/or approximate. There is particular emphasis on the *interplay* of these techniques. While the problems we consider are basic enough to be broadly applicable, we also hope to develop useful and versatile techniques that can transfer readily to diverse applications outside theoretical computer science that need very good algorithms. CS580 or equivalent background is expected. We expect the course to accessible to ambitious undergraduates who have taken the undergraduate algorithms course and have some mathematical maturity.

Topics. A tentative list of topics includes (1) advanced flow algorithms, (2) sparsest cut, (3) the cut-matching game for sparsest cut, (4) local cut algorithms, (5) algorithms for pagerank and personal pagerank, (6) nearly linear time algorithms for electrical flow, (7) network design and optimization, (8) spectral sparsification, (9) randomized rounding, (10) oblivious routing and applications, (11) Nash-Williams tree-packing theorem and other minimax theorems in combinatorial optimization, (12) Edmonds' polymatroid theorem and applications, (13) multiplicative weight updates, randomized multiplicative, weight updates, and fast approximate LP solvers, (14) submodular optimization, (15) isolating cuts, (16) expander decompositions, (17) primal-dual rounding, (18) randomized minimum cut, (19) matroid optimization, (20) matroid union and intersection, (21) hypergraphs, (22) interior point solvers and applications in combinatorial optimization, (23) first-order optimization and applications to flow problems, (24) nearly linear time algorithms for optimal transport, (25) maximum flow via continuous optimization, (26) dynamic graph data structures and algorithms, and (27) matchings and the matching polytope. These topics have many connections and unifying themes which the course will highlight.

2 Textbooks

There is no textbook for this course due to the emphasis on current techniques. Lecture notes and pointers to papers and other references on the web will be provided. Some helpful background references for classical topics are:

- A. Schrijver. *Combinatorial Optimization: Polyhedra and Efficiency.* Vol. 24. Algorithms and Combinatorics. Springer, 2003

- David P. Williamson and David B. Shmoys. *The Design of Approximation Algorithms.* Cambridge University Press, 2011

3 Grading

- 60% Homework (spread over 5 assignments, each with about 4 word problems)

- 30% Final project

- 10% Class participation

4 Learning outcomes

1. A wide acquaintance with the state-of-the-art for graph algorithms and combinatorial optimization.

2. Understand deep connections across problems and theorems in combinatorial optimization.

3. Fluency with randomized techniques and the ability to apply them in new contexts.

4. Comfort with and ability to perform approximation analyses of inexact algorithms.

5. Modeling and solving discrete problems via continuous techniques.

6. The broad ability the synthesize and mix different techniques and perspectives - discrete and continuous, deterministic (e.g., data structures) and randomized, exact and approximate - while staying disciplined in the design and completely rigorous in the analysis of the algorithms.

7. For some, a fruitful research direction in theoretical or applied algorithm design based on the topics and techniques in this course.

5 Academic integrity

Behavior consistent with cheating, copying, and academic dishonesty is not tolerated. Depending on the severity, this may result in a zero score on the assignment or exam, and could result in a failing grade for the class or even expulsion. Purdue prohibits "dishonesty in connection with any University activity. Cheating, plagiarism, or knowingly furnishing false information to the University are examples of dishonesty." (Part 5, Section III-B-2-a, University Regulations) Furthermore, the University Senate has stipulated that "the commitment of acts of cheating, lying, and deceit in any of their diverse forms (such as the use of substitutes for taking examinations, the use of illegal cribs, plagiarism, and copying during examinations) is dishonest and must not be tolerated. Moreover, knowingly to aid and abet, directly or indirectly, other parties in committing dishonest acts is in itself dishonest." (University Senate Document 7218, December 15, 1972). You are expected to read both Purdue's guide to academic integrity (http://www.purdue.edu/purdue/about/integrity_statement.html) and Prof. Gene's Spafford's guide (http://spaf.cerias.purdue.edu/integrity.html) as well. You are responsible for understanding their contents and how it applies to this class.

6   Posting Class Material

Posting material associated with this class (e.g., solutions to homework sets or exams) without the written permission of the instructor is forbidden and may be a violation of copyright.

7   Purdue's Honor Pledge

As a boilermaker pursuing academic excellence, I pledge to be honest and true in all that I do. Accountable together - we are Purdue. https://www.purdue.edu/provost/teachinglearning/honor-pledge.html

8   Grief Absence Policy

Purdue University recognizes that a time of bereavement is very difficult for a student. The University therefore provides the following rights to students facing the loss of a family member through the Grief Absence Policy for Students (GAPS). According to GAPS Policy, students will be excused for funeral leave and given the opportunity to earn equivalent credit and to demonstrate evidence of meeting the learning outcomes for missed assignments or assessments in the event of the death of a member of the student's family.

9   Conduct and Courtesy

Students are expected to maintain a professional and respectful classroom environment. This includes: silencing cellular phones, arriving on time for class, speaking respectfully to others and participating in class discussion. You may use non-disruptive personal electronics for the purpose class participation (e.g., taking notes).

10   Students with Disabilities

Purdue University is required to respond to the needs of the students with disabilities as outlined in both the Rehabilitation Act of 1973 and the Americans with Disabilities Act of 1990 through the provision of auxiliary aids and services that allow a student with a disability to fully access and participate in the programs, services, and activities at Purdue University. If you have a disability that requires special academic accommodation, please make an appointment to speak with the instructor within the first three (3) weeks of the semester in order to discuss any adjustments.

It is the student's responsibility to notify the Disability Resource Center (http://www.purdue.edu/drc) of an impairment/condition that may require accommodations and/or classroom modifications. We cannot arrange special accommodations without confirmation from the Disability Resource Center.

11   Emergencies

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website and/or announced via email. You are expected to read your purdue.edu email on a frequent basis. Emergency Preparedness: Emergency notification procedures are based on a simple concept: If you hear an alarm inside, proceed outside. If you hear a siren outside, proceed inside. Indoor Fire Alarms are mean to stop class or research and immediately evacuate the building. Proceed to your Emergency Assembly Area away from building doors. Remain outside until police, fire, or other emergency response personnel provide additional guidance or tell you it is safe to leave. All Hazards Outdoor Emergency Warning sirens mean to immediately seek shelter (Shelter in Place) in a safe location within the closest building. "Shelter in place" means seeking immediate shelter inside a building or University residence. This course of action may need to be taken during a tornado, a civil disturbance including a shooting or release of hazardous materials in the outside air. Once safely inside, find out more details about the emergency. Remain in place until police, fire, or other emergency response personnel provide additional guidance or tell you it is safe to leave. In both cases, you should seek additional clarifying information by all means possible: Purdue Home page, email alert, TV, radio, etc. Review the Purdue Emergency Warning Notification System multi-communication layers at `http://www.purdue.edu/ehps/emergencypreparedness/warning-system.html`. Please review the Emergency Response Procedures at *https://www.purdue.edu/emergencypreparedness/flipchart/index.html*. Please review the evacuation routes, exit points, emergency assembly area and shelter in place procedures and locations for the building. Video resources include a 20-minute active shooter awareness video that illustrates what to look for and how to prepare and react to this type of incident. See http://www.purdue.edu/securepurdue/police/video/

12   Violent Behavior Policy

Purdue University is committed to providing a safe and secure campus environment for members of the university community. Purdue strives to create an educational environment for students and a work environment for employees that promote educational and career goals. Violent Behavior impedes such goals. Therefore, Violent Behavior is prohibited in or on any University Facility or while participating in any university activity.

13   Mental Health and Wellness

If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try WellTrack (`https://purdue.welltrack.com`). Sign in and find information and tools at your fingertips, available to you at any time.

If you need support and information about options and resources, please contact or see the Office of the Dean of Students (`www.purdue.edu/odos`). Call 765-494-1747. Hours

of operation are M-F, 8 am- 5 pm.

If you find yourself struggling to find a healthy balance between academics, social life, stress, etc. sign up for free one-on-one virtual or in-person sessions with a Purdue Wellness Coach at RecWell (`https://www.purdue.edu/recwell/fitness-wellness/wellness/one-on-one-coaching/wellness-coaching.php`). Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is completely free and can be done on BoilerConnect. If you have any questions, please contact Purdue Wellness at `evans240@purdue.edu`.

If you're struggling and need mental health services: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) (`https://www.purdue.edu/caps/`) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office on the second floor of the Purdue University Student Health Center (PUSH) during business hours.

Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at (765) 494-6995 and http://www.purdue.edu/caps/ during and after hours, on weekends and holidays, or through its counselors physically located in the Purdue University Student Health Center (PUSH) during business hours.

14   Nondiscrimination

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. Purdue University prohibits discrimination against any member of the University community on the basis of race, religion, color, sex, age, national origin or ancestry, marital status, parental status, sexual orientation, disability, or status as a veteran. The University will conduct its programs, services and activities consistent with applicable federal, state and local laws, regulations and orders and in conformance with the procedures and limitations as set forth in Executive Memorandum No. D-1, which provides specific contractual rights and remedies.

15   Privacy

The Federal Educational Records Privacy Act (FERPA) protects information about students, such as grades. If you apply for a job and wish to use the instructor as a reference, you should

tell the instructor beforehand. Otherwise, the instructor cannot say anything about you to a prospective employer who might call. The instructor is happy to provide references and to write letters of recommendation for his students as needed.

16   Changes to the syllabus

This syllabus is subject to change and changes will be announced appropriately.