JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

Syllabus
Applied Mathematics and Statistics 553.766
Combinatorial Optimization
Spring, 2022

Description The main goal of this course is to introduce students to combinatorial optimization techniques. The first part of the course will focus on combinatorial algorithms for classical problems. The next part of the course will show how polyhedral theory can be used to deal with combinatorial optimization problems in a unifying manner. The final part of the course will introduce the use of semidefinite optimization and algorithmic geometry of numbers.

Prerequisites
No formal prerequisites. Familiarity with the basic notions of the following will be helpful.
Linear Algebra (EN.550.291 or AS.110.201 or AS.110.212)
Graph Theory (EN.550.472 or EN.550.672)
Probability (EN.550.420 or equivalent)

Instructor
Amitabh Basu, `basu.amitabh@jhu.edu`, `http://www.ams.jhu.edu/~abasu9/`
Office: See Blackboard for Zoom link to virtual office.
Office hours: Wednesday 5:00 pm – 6:00 pm, or email for appointment. Office Hours will be via Zoom.

Teaching Assistant
Phillip Kerger will be the TA for our class.
Phillip's email is `pkerger@jhu.edu`.
Office hours: Phillip's office hours will be on Mondays, 4:00 pm – 6:00 pm. See Blackboard for a Zoom link to Phillip's virtual office.

Meetings
Online Lectures: Tuesday, Thursday, 4:30 pm–5:45 pm. Check Blackboard for a passcode protected Zoom link.

Textbook
No required text, but the following resources are very helpful.

Useful textbooks (but not required):

- The "4-Bill Book": Combinatorial Optimization by Cook, Cunningham, Pulleyblank, Schrijver; 1st edition; ISBN 978-0-471-55894-1.
- Integer Programming by Conforti, Cornuejols, Zambelli; ISBN 978-3-319-11007-3. Online access from Springer from within campus.
- Theory of Linear and Integer Programming by Alexander Schrijver; 1st edition; ISBN 978-0-471-98232-6.
- Combinatorial Optimization (3 volumes) by Lex Schrijver; ISBN 3-540-44389-4.

- Geometric Algorithms and Combinatorial Optimization by Grotschel, Lovasz, Schrijver; ISBM 978-3-642-78242-8.

Online Resources
Course webpage: `http://www.ams.jhu.edu/~abasu9/AMS_553-766_Spring22.html`
Blackboard will be used for posting HWs, exams and grades.

Course Objectives
The main goal of this course is to introduce students to combinatorial optimization techniques.

Course Topics

PART I: Combinatorial algorithms for classic discrete optimization problems

(1) Quick Overview of flow problems : Maximum flow, Minimum Cut, Minimum cost flow.
(2) Matching theory:
    - Matchings and alternating paths
    - Tutte-Berge formula
    - Maximum cardinality matchings : Bipartite matching via flow, Edmond's blossom algorithm

PART II: Polyhedral Combinatorics : A unifying approach to combinatorial optimization

(1) Basic polyhedral theory
(2) Linear Programming :
    - Quick overview of duality, algorithms for LP
    - Equivalence of optimization and separation
(3) Integer Programming :
    - Totally unimodular matrices (TUM), Total Dual Integrality (TDI)
    - Cutting plane theory
    - Branch and bound, branch and cut algorithms
(4) Application of linear and integer programming theory to problems discussed in Part I

PART III: Other techniques for Combinatorial Optimization [Some subset of topics from the ones listed below]

(1) Lattice theory and algorithmic geometry of numbers
(2) Semidefinite Optimization
(3) Matroid Theory
(4) Submodular Optimization

A detailed lecture-by-lecture schedule or topics can be found here: `http://www.ams.jhu.edu/~abasu9/AMS_553-766/schedule-2022.html`.

Course Expectations & Grading
There will one take home Midterm and one take home Final Exam.

In addition, there will be regular (approx. weekly) homework assignments posted on the course webpage. You will be asked to hand in a subset of these HW problems which will be graded (approximately every two weeks). Seriously attempting ALL the homework problems is imperative for your success in the class, and they will give an indication of the kind of problems on the tests. The HW problems will be posted on Blackboard.

Key Dates
The Midterm will be posted on Blackboard by **Friday, March 11, 2022 by noon**. It will be due back the following **Thursday, March 17, 2022 at the beginning of class.**
The syllabus for the first midterm will be everything covered up to and including the lecture on Thursday, March 10, 2022.

The Final Exam will be posted on Blackboard by **Friday, May 6, 2022 by noon**. It will be due back the following **Friday, May 13, 2022 by noon**.
The syllabus for the Final Exam is all the material covered during the course of the semester.

Assignments & Readings
See the Blackboard course page for HW assignments.

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

(1) You may discuss HW problems with your fellow classmates. However, you have to write your own final solutions without looking at anyone else's solutions.
(2) MIDTERM AND FINAL EXAM RULES:
    - You are not allowed to discuss any problem with another human being (this includes your classmates, of course), except the instructor or the TAs.
    - You can use a computer only as a word processor; in particular, you cannot consult the internet in regards to the exams. You CAN use any other resource like the textbook, your notes, books from the library.
    - You CAN cite any result we have mentioned in class or from the HWs without proof. If you cite a result (e.g., from a book) that was NOT mentioned in class, you should include a complete proof of this fact.

Report any violations you witness to the instructor.
You can find more information about university misconduct policies on the web at these sites:

- Undergraduates: `e-catalog.jhu.edu/undergrad-students/student-life-policies/`
- Graduate students: `e-catalog.jhu.edu/grad-students/graduate-specific-policies/`

Students with Disabilities
Any student with a disability who may need accommodations in this class must obtain an accommodation letter from Student Disability Services, 385 Garland, (410) 516–4720, `studentdisabilityservices@jhu.edu`.

Personal Wellbeing

- Because of the ongoing COVID-19 pandemic special requirements will be in effect this term, and these may vary during the term. Please keep updated with these at the following sites:
  - University information: https://covidinfo.jhu.edu/
  - Whiting School of Engineering information: https://engineering.jhu.edu/covid-19/
- As of the start of the term all students, instructors and staff must complete health screening daily using the Prodensity app before coming to campus. Masks must be worn properly at all times while in the classroom and other indoor spaces. Vaccination is required unless an exception has been granted by the university for health or religious reasons. Periodic asymptomatic testing may be required. Please follow the university guidance faithfully.

- The Johns Hopkins COVID-19 Call Center (JHCCC), which can be reached at 443-287-8500 seven days a week from 7 a.m. to 7 p.m., supports all JHU students, faculty, and staff experiencing COVID-19 symptoms. Primarily intended for those currently within driving distance of Baltimore, the JHCCC will evaluate your symptoms, order testing if needed, and conduct contact investigation for those affiliates who test positive. More information on the JHCCC and testing is on the coronavirus information website.
- If you are sick please notify me by email so that we can make appropriate accommodations should this affect your ability to attend class, complete assignments, or participate in assessments. The Student Health and Wellness Center is open and operational for primary care needs. If you would like to speak with a medical provider, please call 410-516-8270, and staff will determine an appropriate course of action. See also https://studentaffairs.jhu.edu/student-life/student-outreach-support/absences-from-class/illness-note-policy/
- All students with disabilities who require accommodations for this course should contact me at their earliest convenience to discuss their specific needs. If you have a documented disability, you must be registered with the JHU Office for Student Disability Services (101 Shaffer Hall; 410-516-4720; http://web.jhu.edu/disabilities/) to receive accommodations.
- Students who are struggling with anxiety, stress, depression or other mental health related concerns, please consider connecting with resources through the JHU Counseling Center. The Counseling Center will be providing services remotely to protect the health of students, staff, and communities. Please reach out to get connected and learn about service options based on where you are living this fall at 410-516-8278 and online at http://studentaffairs.jhu.edu/counselingcenter/.
- Student Outreach & Support helps students manage physical and mental health concerns, personal and family emergencies, financial issues, and other obstacles that may arise during their college experience. Students can self-refer or refer a friend who may need extra support or help getting connected to resources. To connect with SOS, please visit this website: `https://studentaffairs.jhu.edu/student-life/student-outreach-support/` or email `deanofstudents@jhu.edu`, call 410-516-7857, or students can schedule to meet with a Case Manager by visiting the Student Outreach & Support website and filling out a referral form online.

Classroom Climate

As your instructor, 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/center chair/head/director (Fadil Santosa, `fsantos9@jhu.edu`), the Director of Undergraduate Studies (Donniell Fishkind, `dfishki1@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).

Family Accommodations Policy

You are welcome to bring a family member to class on occasional days when your responsibilities require it (for example, if emergency child care is unavailable, or for health needs of a relative). In fact, you may see my children in class on days when their school is closed. Please be sensitive to the classroom environment, and if your family member becomes uncomfortably disruptive, you may leave the classroom and return as needed.

University Policy on Incompletes
Students who are confronted with compelling circumstances beyond their control which interfere with the ability to complete their semester's work during the normal course of a term may request an incomplete grade from the instructor. This must be requested by the last day of class. Approval of such a request is neither automatic nor guaranteed, but it is expected that faculty will make every effort to accommodate students dealing with illness in the family and other pandemic-related hardships. The instructor and student must establish a timetable for submitting the unfinished work with a final deadline no later than the end of the third week of the subsequent semester. Exceptions to this deadline require a petition from the instructor to the student's academic advising office before this date. When entering an Incomplete grade in SIS, faculty must include a reversion grade which represents the grade the student will receive if they do not complete the missing work by the agreed-upon deadline.

Deadlines for Adding, Dropping and Withdrawing from Courses
Students may add a course up to **February 4, 2022**. They may drop courses up until **March 6, 2022** provided they remain registered for a minimum of 12 credits. **Between March 7, 2022 and April 15, 2022** a student may withdraw from a course with a W on their academic record. A record of the course will remain on the academic record with a W appearing in the grade column to indicate that the student registered and then withdrew from the course.
For more information on these and other academic policies, see
`https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/undergraduate-policies/academic-policies/grading-policies/`

ABET Outcomes

- Ability to apply mathematics, science and engineering principles.
- Ability to identify, formulate and solve engineering problems.
- Understanding of professional and ethical responsibility.
- Ability to communicate effectively.