CSCI: 2951-O
Foundations of Prescriptive Analytics

Department of Computer Science
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Welcome to Foundations of Prescriptive Analytics. We are excited to have you in this brand new course and join with you on this learning adventure!

Course Description

We are undoubtedly in the middle of an Analytics Revolution that enabled turning huge amounts of data into insights, and insights into predictions about the future. At the final frontier, Prescriptive Analytics aims to identify the best possible outcome given a certain objective function and a set of constraints. With that goal in mind, this course provides students with a comprehensive overview of the theory and practice of how to apply Prescriptive Analytics through optimization technology. A wide variety of state-of-the-art techniques are studied including Boolean Satisfiability, Constraint Programming, Linear Programming, Integer Programming, Local Search Meta-Heuristics, and Large-Scale Optimization.

The students are exposed to the industrially relevant software packages such as IBM Optimization Studio. The practical challenges encountered in implementing such systems is also explored. Additionally, the life-cycle of decision support systems is discussed and problems from real-life application domains such as planning, scheduling, resource allocation, supply-chain management, and logistics are addressed.

Course Objectives

The primary goal of this course is to introduce the fundamental ideas behind optimization technology to the extent that you can utilize this knowledge to build your own solvers based on various paradigms. Both complete and incomplete search methods, particularly tree-search and heuristic techniques will be covered in order to present different trade-offs.

By the end of this course you will be able to transform a given optimization problem into analytical models with complementary strengths, and then, tackle it using off-the-shelf general purpose solvers and/or writing your custom solutions.

This course shall also complement descriptive and predictive analytics as it connects data-centric approaches with their optimum decision-making counterpart.

Prerequisites

This course requires good programming skills and understanding of basic algorithms and data structures (e.g., stacks, queues etc.). Prior knowledge of linear algebra and matrix calculation can help but it is not required. For homeworks, some Java support code (e.g., data parsers, solver adapters) can be provided, but students are not enforced to uptake it.

– Required: CSCI-0320 or CSCI-0330, or consent of the instructor
– Recommended: CSCI-0530 (or MATH-0520, MATH-0540), CSCI-1570
– The capacity is limited to 20 students.

Optional Readings

The course material is designed to be self-contained, and as such, there are no mandatory textbooks. There might be suggested papers from the relevant literature.

The list below is provided for additional material and reference only.

- Boolean Satisfiability – Handbook of Satisfiability edited by Armin Biere, Marijn Heule, Hans van Maaren, Toby Walsh.
- Constraint Programming – Handbook of Constraint Programming edited by Francesca Rossi, Peter van Beek, Toby Walsh.
- Linear/Integer Programming – Integer and Combinatorial Optimization by Laurence A. Wolsey, George L. Nemhauser.
- Local Search – Stochastic Local Search: Foundations and Applications by Holger H. Hoos, Thomas Stützle.

Lectures

We introduce you to new solution techniques in the lectures. The tentative schedule below is designed such that a different technology is explored every week. This is complemented with practical projects.

The lectures ensure that you are becoming familiar with the concepts and algorithmic approaches, while the projects allow you to put this knowledge into action. It is therefore very important to join discussions during class time. If you are confused or need clarification, please take advantage of this in-class interaction. Doing so can save you a lot of hassle when working on the homeworks.

The slides and/or relevant notes will be available on the course website after each lecture. We strongly encourage you to read this material on your own. Since the lectures will be held in block sessions, the course material will build up rather quickly as time proceeds. Therefore, mastering each topic as it is introduced will be easier in the long run compared to falling behind and trying to catch up.

Assignments and Grading Policy

This is a hands-on course that provides you with the opportunity to implement your own optimization packages inspired by modern solvers. This will be an intellectually challenging and rewarding exercise. The assignments are designed to expose students to a number of well-known problems from the field.

Over the 14-weeks of the semester, there will be 5 projects in total. There are no other homeworks, midterm or a final exam. The due dates for the assignments are within 1 to 3 weeks depending on the particular project. The criteria to evaluate the solutions are as follows:

1. **Quality:** When applicable, the objective function and the optimality gap are quantitative measures of solution quality.

2. **Scalability:** The scale of problem instances that solutions can work with is an important aspect. There are challenge instances that your solution is expected to handle.

3. **Originality:** You have a lot of freedom in designing your algorithms. We strongly encourage you to experiment with unorthodox, outside-the-box ideas. Don't be afraid to take the unbeaten path and be creative! Even the final result does not turn out to be great, an interesting idea can still go a long way.

We believe class participation is an essential part of learning. It is important that you join the ongoing discussions, raise questions if anything is unclear, and provide your comments and suggestions. Following each project, you might also give a short presentation describing your solution strategy. All projects are weighted equally and the final grade is based on the criteria listed above, project presentations and class participation.

Time Requirement

In addition to class hours, you will be spending 10-18 hours per week building solutions for the assignments. Starting projects as early as possible is to your advantage as it gives you time to build an effective solution.

Collaboration Policy

We encourage you to talk to each other about concepts covered in the lectures and discuss your ideas at a high-level with other students. However, code-copying/code-lifting from other students or any other resource (e.g., internet) is strictly forbidden. Collaboration, by teams of 2 people, is allowed, however you cannot partner with the same person more than 2 times. When working in collaboration, only one hand in is required but each student is expected to contribute to the final approach. At any point, we may ask you to explain your program in great detail. If you have questions about the assignments or need any clarification, you can reach out to your TAs/Instructor for help.

It is your responsibility to take steps to prevent others from reading your electronic copies. Make sure your filesystem has proper permissions. If you do not know how to do this please consult with your TAs/Instructor.

If you are ever in doubt about whether your actions comply with the course policy or Brown academic code, make sure to double check with your TAs/Instructor, even after an incident occurs.

Due Dates and Late Policy

Assignments must be handed in by 10:00 PM on their due dates, unless specified otherwise. Everyone is allowed a total of 3 late days on projects which can be applied as needed over the course of the semester. Once these free late days are all used up, late submissions are not allowed. In extreme circumstances, extensions may be granted by the instructor. If you are ill, please do not ask for an extension without a note from health services.

Inclusive Course Goals

To ensure that students are able to plan around conflicts and obligations without adversely impacting their grades, we aim to set deadlines that plan around student obligations as best we can and provide extensions when appropriate. To ensure that students can voice their own concerns about the course, we aim to hold sufficient office hours and make it clear to whom students can go and how to voice their concerns.

Accommodations

If you feel you have physical, psychological, or learning disabilities that could affect your performance in the course, we urge you to contact SEAS. We will do whatever we can to support accommodations recommended by SEAS (`www.brown.edu/campus-life/support/accessibility-services/`).

Tentative Schedule

Topic	Topic	Release	Due
I	Intro. to Prescriptive Analytics		
II	Boolean Satisfiability	Project – I	
III	Constraint Programming		
IV	Linear Programming	Project – II	Project – I
V	Duality Theory	Project – III	Project – II
VI	Integer Programming	Project – IV	Project – III
VII	Local Search and Meta-heuristics		
VIII	Algorithm Configuration and Portfolios	Project – V	Project – IV
IX	Large-Scale Optimization		Project – V