6.S098: Course Project

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January 8, 2023

The goal of the project for this course is to use ideas from the class to tackle a problem you're interested in. The project is fairly open-ended and is meant to give you the chance to explore convex optimization applications outside of what we covered in the course. Of course, you're welcome to ask me for suggestions.

1 Project Description

You may propose any project you'd like that is related to course material. Some categories of possible projects are listed below. Modeling projects (the first category) are highly preferred given the time constraints of IAP.

Improved modeling approach. Most projects will be modeling projects: you will take a practical problem and formulate it as a convex optimization problem. Note that the project does not have to be completely novel. Implementation of an existing paper, with additional exploration and discussion, is a great project as well. The final report should include the following components:

- **Problem description.** Describe the problem you're tackling at a high level (no math!). Where does this problem come up? Why is this problem important? How do people currently solve this problem (and what are the strengths and weaknesses of the current approaches)?
- **Problem formulation.** Describe your formulation or the problem (or a simplified version of it) as a convex optimization problem or a nonconvex problem for which you can use a convex optimization-based heuristic. What are the variables? What are the constraints? What is the objective? How accurate is the formulation? (What can you handle and what can you not?) If the formulation is nonconvex, explain how you will solve (or approximately solve) it using convex optimization.
- **Verification.** Demonstrate that your approach works on real data. Compare it with existing approaches to the problem, if there are any. If your formulation is nonconvex, try it on some small instances where you can compute the global optimum. You must also submit well-documented code.

Some project ideas along these lines:

- Any problem in your field that can be phrased in terms of the language we developed in this course! Does the convex optimization viewpoint yield any new problem insight? How does it compare to existing approaches? Does it allow you to extend these approaches?

- Inverse design problems: optimization has become a powerful tool for tackling problems in engineering design, including mechanical design, circuit design, and photonic design. These problems have the following structure: we are allowed to choose some design parameters (e.g., the permittivity in a photonic device) at each point in the domain to minimize some function of the field or energy. The laws of physics are constraints that connect the design variables and the field variables. We want to find the design that minimizes our chosen objective.

- In class, we examined a number of classification and regression problems via a convex optimization lens. Choose a problem and solve it with these methods. Incorporate your prior knowledge (*e.g.,* are the weights nonnegative?) about the domain as additional constraints in the problem formulation. Compare your convex optimization approach to a naive one that does not use prior information.

- We briefly discussed robust and stochastic optimization but did not explore these topics in detail. Choose a particular problem (maybe something we've already seen in class or homework) and phrase the robust and stochastic versions of this problem. Compare the performance of these robust formulations to the deterministic counterpart. How fragile is the deterministic solution? How much does it matter for the problem domain?

Ideally, this type of project may form the basis of a future paper after this course.

X through the lens of convex optimization. These projects will summarize and explain how convex optimization is used within a particular field. You will produce a "lecture" and supporting material (*e.g.,* notes, code examples, etc.) that explores a particular field through the lens of convex optimization. You should do extensive literature review, then catalog or reformulate problems in the chosen field using the paradigm introduced in this course. Note that you cannot use a field that we've already explored extensively in class, including machine learning.

Some example projects:

- Convex optimization applications in communication systems

- Using convex optimization in financial markets

- Game theory via convex optimization

Software project. A software project involves building a new or improving an existing modeling tool for convex optimization problems, or developing an algorithm for some problem that uses convex optimization as a subroutine. While you can propose to develop a new or improve an existing convex optimization algorithm (*e.g.,* for large-scale problems), I discourage these projects because we did not cover algorithms in the course.

Some possible projects include:

- Implementing a new feature for `Convex.jl`
- Building a domain specific modeling language for a particular problem in your field, which transforms that problem into a convex program (*e.g.,* building a circuit design language).
- Building a software package that solves nonconvex problems by using convex optimization as a subroutine. This project will look a lot like a modeling project with additional emphasis on building a well-documented public software package that is usable by others and less emphasis on the novelty of the formulation or results.

Compared to a modeling project, these projects will have more emphasis on the software quality, documentation, and ease of use.

1.1 Deliverables

You must submit the following deliverables as part of the course project:

- **Project proposal (due at the end of week 2).** The proposal should include the team members (up to 2), project topic, some background (including references), the basic problem you're tackling, and preliminary ideas on the approach.
- **Final report & code (due before the last class).** If you worked in a group, please include a description of the contributions from each team member.

Latex is *strongly* encouraged for the final report. A great template is available at `https://web.stanford.edu/class/ee364b/latex_templates/`. All supporting code must be submitted as well and should be well documented.