Statistics meets Optimization

36-742: Approximate message passing algorithm

1 Basic course information

Instructor:	Yuting Wei; `ytwei AT cmu DOT edu`
Lecture:	MW 1:30-2:50pm; PH A19 Oct 21 to Dec 4, 6 units
Office hours:	Yuting Wei, by appointment, Location: BH 229J
Announcement:	will be posted on *Canvas*
Exceptions:	There will be no class Nov 25th and 27th due to Thanksgiving.

Synopsis: This is a Ph.D. mini class series in statistics. It contains two separate parts with course number 36-741 and 36-742 respectively. We will cover a selection of topics in modern statistics and optimization, with a focus on the analysis of iterative sketching algorithms and approximate message passing algorithm applied to statistics problems. One of the main goals is to provide students with some background to understand the ongoing statistics/optimization literature and provide motivated students with some mathematical tools for working on related research.

Prerequisites: This course is intended for Ph.D. students with strong mathematical background. There are no formal prerequisites for these minis, but students are expected to have completed at least one intermediate statistics course (like 10-705 at CMU), and preferably an advanced statistics course and one course on optimization. Students are suggested to be familiar with

1. basics for statistics estimation (loss function, least square estimator, efficiency)
2. basic concentration inequalities (such as Markov, Chebyshev, Hoeffding)
3. basics for optimization (convexity, convergence, line search, gradient methods)

2 Course descriptions

36-742: Approximate message passing algorithm

In this mini, we focus our attention on the recent development of the approximate message passing algorithm. We follow a rigorous approach that builds upon ideas from statistical physics, information theory and graphical models, and is based on the analysis of a highly efficient reconstruction algorithm. We start with some basics for probability graphical model, introduce the message passing algorithm and motivate the AMP algorithm along the way. Then we will discuss the exact asymptotic characterization in terms of the so-called state evolution, and talk about the applications in LASSO and more generally, high-dimensional robust M-estimation, also talk about how to do statistical inference based on AMP.

Tentative list of topics, some might be assigned as reading materials:

- Basics for probabilistic graphical model
- Elimination and message passing algorithm
- Approximate message passing algorithm
- Proximal operators, ISTA, FISTA, ADMM
- AMP for compressed sensing
- State evolution for AMP
- High dimensional robust M-estimation (with applications)
- Statistical inference using AMP

Textbook: Here are some references that are related to our topic and additional papers will be uploaded as the class proceeds.

References:

- *An Introduction to Probabilistic Graphical Models*, by M. I. Jordan.
- *Information, physics and computation*, Oxford University Press, 2009, by M. Mézard and A. Montanari.
- *Statistical estimation: from denoising to sparse regression and hidden cliques*, 2014, A. Montanari

3 Graded components

One component of the grades will be scribing one of the lecture notes. Each student will sign up for two slots on the sign-up list, one for being the main scriber, one for being a referee. The main scriber for each class will be in charge of scribing the full lecture notes and send the latex file to me, while the referee is the person to turn to for double-checking and question-answering. The due dates for lecture notes scribing for each week is the corresponding Sunday night 8pm. Of course please don't sign up for being both the main scriber and the referee for the same lecture :)

Another component of the grades will be a course project (10% for proposal, 50% for final report) for each of the minis. This project can either be a literature review or include original research:

- Literature review. We will provide a list of related papers that are not covered in the lectures, and the literature review should involve in-depth summaries and exposition of one of these papers.
- Original research. It can be either theoretical or experimental, with the approval from the instructor. If you choose this option, you can do it either individually or in groups of two.

Three timestamps for the course project:

- Proposal (Nov 13). Submit a short report stating the papers you plan to survey or the research problems that you plan to work on. Describe why they are important or interesting, and provide some appropriate references. If you elect to do original research, you are encouraged to connect this project with your current research (but is still related to our course content). Please do not propose an overly ambitious project. You will receive feedback from the instructor.
- In-class presentation (if applicable).
- A written report (Dec 13). You are expected to submit a final project report, up to 5 pages long (not including references), summarizing your findings/contributions.