16:332:533: Machine Learning for Inverse Problems

Course time and location: SEC-212, TTh 3:50 - 5:10 PM

Instructor: Shirin Jalali, shirin.jalali@rutgers.edu

Course Overview

Solving inverse problems is at the core of a wide range of Electrical and Computer Engineering applications. For instance, a necessary step for developing efficient solutions for computational imaging problems or two-way audio communication systems is to develop an algorithm that solves the corresponding inverse problem. Some of such inverse problems are well-studied and have a host of classic solutions. On the other hand, some others are novel problems that arise from emerging technologies. In recent years, machine learning has had a significant impact in this area leading to many novel solutions.

Designing efficient solutions for a given inverse problem involves developing a mathematical model of the system, developing a recovery algorithm using tools and techniques from signal processing, optimization, and machine learning, and finally using a great amount of artful engineering to develop a solution that works in practice. In this course, the students will learn about a host of different problems and various classic and modern solutions for solving them.

Key Topics

- **Fundamentals of Inverse Problems**: Introduction, diverse applications, and denoising techniques.
- **Optimization Techniques**: Iterative gradient-descent-based optimization methods such as projected gradient descent and proximal gradient descent, ISTA and FISTA.
- **Deep Learning Approaches**: Utilization of deep learning, end-to-end neural networks, and generative models in solving linear inverse problems. Supervised and unsupervised learning methods for unknown or partially known linear inverse problems.
- **Non-Linear Inverse Problems**: Introduction, phase retrieval, and machine learning applications in complex problem-solving.
- **Algorithm Integration**: Combining neural networks with ADMM methods to tackle linear and non-linear inverse problems.
- **Specialized Applications**: Addressing highly underdetermined problems, snapshot compressive imaging, and challenges posed by non-additive noise.
- **Online Learning and Modern Algorithms**: System identification, echo cancellation, and the role of machine learning in nonlinearities, with a focus on both classical and modern online learning algorithms.

Course audience

Students with an interest in algorithm design for practical optimization challenges in imaging and online learning will benefit from this course. It's also ideal for ECE, CS, Applied math, and Stat students seeking a deeper understanding of theoretical underpinnings of current methods.

Prerequisites

- Introductory Linear Algebra (01:640:250)
- Convex Optimization (16:332:509), or introduction to the fundamental concepts in convex optimization (e.g., convex sets, convex functions, gradient descent method)

Grading and assessment

The course will involve homework assignments, an in-class mid-term exam and a course project.