BME 6550 Transport methods in signal processing and machine learning
Fall 2020
Tu/Th 11:00am-12:15 pm, online through zoom

Instructor:
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Office hours: TBD

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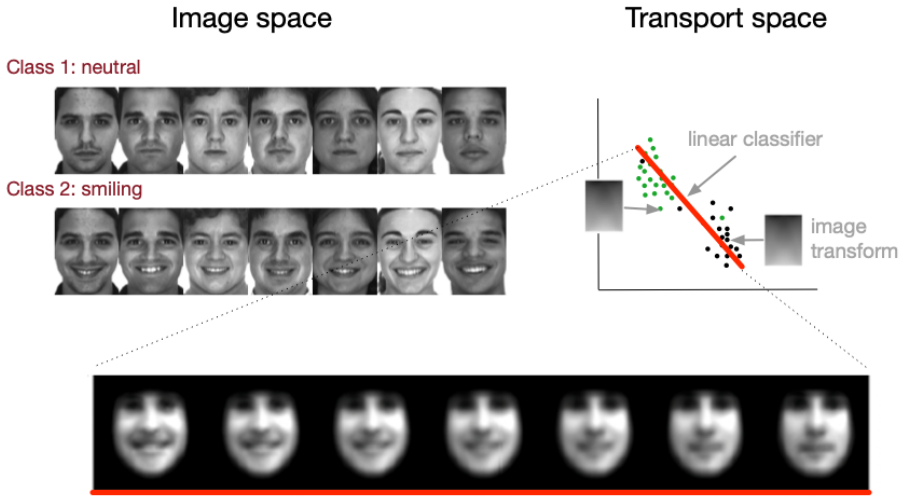
Office hours: TBD

Course communications will be handled through Collab/Piazza. We will do our best to respond within 24 hrs.

Prerequisites: linear algebra, python programming, and signal or image processing (or permission of instructor)

Overview:
Mathematical formulas are required representing and modeling information in signals and images. They are used for designing algorithms for speech recognition, computer vision, medical imaging, and many other applications. The goal of this course is to introduce the mathematics of transport (including optimal transport) to problems related to signal and image processing as well as data science and machine learning. Course will cover both basic theory and applications including modeling signals and images, signal and image classification problems, as well as estimation, reconstruction and inverse problems. The goal of the course will be to provide graduate students with foundational mathematical tools as well as practical algorithms (including software) with which to solve practical problems in these areas.



Topics outline:

Introduction

- Linear representation methods: PCA, Fourier and Wavelet transforms
- Radon-CDT
- Physical -Motivation

Theory

- History
- Optimal Transport background
- Methods for numerical optimization
- 1D Transport and the Cumulative Distribution Transform
- N-D transport and The Linear Optimal Transport transform
- Sliced Wasserstein Distances and the Radon CDT
- Properties and data geometry
- Statistical properties

Applications

- 1D signal estimation
- Image registration/alignment
- 1D signal classification with the CDT
- 2D Image classification with the R-CDT
- 2D Image classification with the LOT
- 1D sparse signal approximation with the CDT
- Model-based signal/image reconstruction
- Transport-based morphometry
- Machine learning

[demonstration iPython notebooks will be distributed for each lecture/topic]

Learning Objectives. By the end of the course, you will:

1. Know basic theory of optimal transport, history, numerical methods and applications.
2. Understand the basic terminology relating to transport, optimal transport, and related signal and image representation techniques
3. Be able to implement and analyze numerical methods related to transport, optimal transport, and related signal and image representation
4. be able to develop computer programs to analyze real data or model systems. Specific tasks include signal/image registration, alignment, tracking, classification, morphometry, supervised & unsupervised learning

Assessment:

Problem sets will constitute 60% of the grade, class participation 10%, while a final project will constitute 30%. Students will work in groups for homework assignments and project. Class participation will be measured by attendance at scheduled times, as well as interactive questions/discussions.

Extra credit, 5%, submit your project report to a peer reviewed journal.

Required Materials:

computer capable of running python/matlab

Reference material

- *Optimal mass transport: signal processing and machine-learning applications*
  https://ieeexplore.ieee.org/document/7974883
- *Computational optimal transport*
  https://arxiv.org/abs/1803.00567
- *Lecture notes to be distributed in class*

Students with disabilities or learning needs

It is my goal to create a learning experience that is as accessible as possible. If you anticipate any issues related to the format, materials, or requirements of this course, please meet with me outside of class so we can explore potential options. Students with disabilities may also wish to work with the Student Disability Access Center to discuss a range of options to removing barriers in this course, including official accommodations. Please visit their website for information on this process and to apply for services online: sdac.studenthealth.virginia.edu. If you have already been approved for accommodations through SDAC, please send me your accommodation letter and meet with me so we can develop an implementation plan together.