EE599: Vector Space Methods for Signal Processing
Spring 2013

Instructor: Justin P. Haldar
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Office Hours: 3:30pm-5:00pm MW

Objectives: To provide a rigorous understanding of vector space and functional analysis concepts and tools that are commonly encountered in a variety of modern signal processing applications (e.g., signal compression, approximation, and restoration; linear inverse problems such as deconvolution, tomography, and Fourier imaging; spectrum estimation, beamforming, etc.). The course covers a range of advanced topics including linear inverse problems in finite and infinite dimensional vector spaces, the singular value decomposition and the Moore-Penrose pseudoinverse, conditioning and regularization, Banach and Hilbert spaces, optimal design of experiments, iterative methods for solving linear systems, subspace methods, constrained convex optimization, sparse and low-rank approximation, and compressed sensing.

Coursework will include proving theorems, deriving methods and algorithms for solving signal processing problems in vector spaces, and using Matlab to apply these methods to real-world signal processing problems.

Credit: 3.0 Units

Lectures: 2:00pm-3:20pm MW, Taper Hall (THH) B10

Grading: 30% Homework, Reading, and Matlab Assignments
30% Midterm (March 13th)
40% Final project presentation (April 29th or May 1st) and report (May 10th)

Prerequisites/ Corequisites: EE 441 – Applied Linear Algebra for Engineering
EE 483 – Introduction to Digital Signal Processing
EE 464 – Probability Theory for Engineers

Recommended Texts: T. Moon and W. Sterling, *Mathematical Methods and Algorithms for Signal Processing*, Prentice Hall, 2000

D. Luenberger, *Optimization by Vector Space Methods*, Wiley, 1969

Course Outline (subject to change):

Week 1	Linear inverse problems in $\mathbb{C}^N$ Left and right inverses
Week 2	Projections Minimum norm least squares solutions Moore-Penrose pseudoinverse
Week 3	Singular value decomposition Low-rank matrix approximation
Week 4	Conditioning and regularization Total least squares Subspace fitting
Week 5	Iterative methods for linear least squares problems Design of experiments
Week 6	Applications in Harmonic Retrieval and Sensor Array Processing Variable projection, MUSIC
Week 7	Normed vector spaces and inner product spaces Linear operators
Week 8	Finite and infinite dimensional vector spaces
Week 9	Hilbert spaces and infinite dimensional linear inverse problems
Week 10	Bases and frames
Week 11	Hilbert spaces of random variables Linear Minimum Variance and Best Linear Unbiased Estimation
Week 12	Topics in Constrained Convex Optimization: Projection onto Convex Sets, Lagrange Multipliers
Week 13	Topics in Constrained Convex Optimization: Nesterov's Method, Alternating Direction Method of Multipliers
Week 14	Compressed sensing with sparsity and low-rank matrix constraints
Week 15	Project presentations

Statment for Students with Disabilities:

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

Statment on Academic Integrity:

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. *Scampus*, the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A:

http://www.usc.edu/dept/publications/SCAMPUS/gov/

Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at:

http://www.usc.edu/studentaffairs/SJACS/