# MATH 623, Summer 2018
# Sparse Representations and Randomized Sampling
# Time: Tuesdays and Thursdays, 6:00pm-8:30pm
# Classroom: TBA

Prof. Nathaniel Strawn
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Office Location: St. Mary's Hall, Office 302
Office Hours: Tuesdays and Thursdays 4:30pm - 5:30pm

This syllabus is subject to change at any time.

**Course Synopsis:** This course covers concepts and algorithms from compressed sensing and applications to signal processing. Everyday media (MP3s, million-pixel images, and high-definition videos) are high-dimensional signals (i.e. vectors with many entries) which are well-approximated using sparse representations (i.e. linear combinations where many of the coefficients are zero) in an appropriate basis (e.g. columns from a Discrete Fourier Transform matrix). Compressed sensing deals with the recovery of such sparse representations using a reduced number of random samples, but slightly more computational resources. In typical cases, the number of samples required to reconstruct high-fidelity approximations to the original signal can be less than 20% of what the classical theory suggests. Moreover, the reconstruction algorithms can be implemented using standard linear programming or simple iterative thresholding techniques.

Throughout the course, examples from image processing will be used to motivate compressed sensing concepts and techniques, but the techniques are applicable to a wide class of media. A typical example involves examining a fraction of the pixel values from a high-resolution digital image, and then producing a high-fidelity reconstruction of the image from only those pixel values, or producing a compressed representation of that image using only those pixel values. Topics covered include basis pursuit, recovery guarantees, linear programming for recovery, the least absolute shrinkage and selection operator (LASSO), phase transitions in compressed sensing, and iterative thresholding algorithms. If time allows, optional topics include total variation minimization and image inpainting.

**Credit Hours:** 3.0

**Principal Textbook:** *Sampling Theory: Beyond Bandlimited Systems* by Y. Eldar

**Supplementary Textbooks:** *A First Course in Wavelets with Fourier Analysis* (2nd Ed) by A. Boggess and F. Narcowich, and *Lectures on Linear Algebra* by I. Gelfand

**Technology Inventory:** Programming for coursework will be carried out in the R programming language and the students are highly encouraged to use the RStudio IDE. R and the RStudio IDE are both freely available for Window, OS X, and Linux. Online office hours and meetings will be carried out using Google Hangouts. Students are advised to visit the course Blackboard page at least once a day to view announcements and assignments.

**Prerequisites:** Linear Algebra (MATH 150 or equivalent), Probability, familiarity with Matlab or R.

**Grade Weights:**

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| Weekly Assignments | 40% |
| Midterm | 20% |
| Final Exam | 20% |
| Written Project | 20% |

**Tentative Letter Grade Brackets:**

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|---|---|---|---|---|---|
| A | $\geq 95\%$ | B- | $\geq 75\%$ | D+ | $\geq 55\%$ (undergraduate) |
| A- | $\geq 90\%$ | C+ | $\geq 70\%$ (undergraduate) | D | $\geq 55\%$ |
| B+ | $\geq 85\%$ | C | $\geq 65\%$ | D | $\geq 50\%$ (undergraduate) |
| B | $\geq 80\%$ | C- | $\geq 60\%$ (undergraduate) | | |

**Written Project:** Students will form groups of no more than four individuals, and produce a paper detailing an application of techniques from the course. In this project, students are expected to find an application, determine techniques from the course that can be used in the application, construct an implementation of those techniques, and then report the results. The student is expected to submit a paper consisting of no less than 4 pages and no more than 8 pages, as well as any supplementary code.

**Honor Code:** Please be aware of the academic integrity rules. You are encouraged to collaborate with other students when you study and when you do your homework. Some in-class work will also be in small groups. When working on a homework assignment or a practice exercise, start by yourself, then talk to other students, ask questions, share your ideas, then complete the work on your own. Do not copy homework from others and do not permit others to copy your work. You are not allowed to cooperate with other students or seek any outside help on any exams. All in-class exams are strictly closed-notes and closed-book. Computers, notes, and books are allowed for take-home portions of exams, but no help from other people is allowed.