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# Math 596 – Mathematical Data Science

## Fall 2024

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### Instructor

Dr. Christopher W. Curtis

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Lectures: GMCS 325, MWF, 12:00-12:50

Office hours: TBD

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### Course - Practical information

Website: See Canvas Site

Textbook: Data-Driven Science and Engineering, Machine Learning, Dynamical Systems, and Control by Steven L. Brunton, J. Nathan Kutz

Prerequisite: Math 340 or equivalent, and Math 254 or equivalent

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### Grading

Homework: Eleven homework assignments will be given throughout the semester. Each assignment will have at least two extra problems at the graduate student level that are mandatory for graduate students and optional for all other students.

Final Project: Students will develop a final project based on how their particular interests intersect with mathematical data science. The project will consist of a twelve page paper as well as a 25 minute presentation of results. For the twelve page paper, ten pages should address technical matters while two pages, using the linked reading material in Canvas, should be dedicated to exploring how data driven technologies can exacerbate or create societal inequities.

Final grade: Final percentages will be computed according to the following rules -  
60% Homework + 40% Final Project

The final grades will be chosen according to the following scale:

- A: 90% and above
  - B: 80% and above
  - C: 70% and above
  - D: 60% and above
  - F: otherwise
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## Student Learning Objectives

In this class, you will:

- Develop the linear algebraic theory of singular-value decompositions.
- Practice using singular-value decompositions for data analysis and compression.
- Develop the analytic theory of Fourier and Wavelet transforms.
- Practice using Fourier and Wavelet transforms for data analysis and compression.
- Develop techniques and theory for sparse regression.
- Practice using sparse regression for efficient data analysis.
- Develop the theory of nonlinear optimization and practice using it for various data fitting problems.
- Develop the theory of clustering and practice using it for problems in data classification.
- Develop the theory of neural networks and practice using them for classification and prediction in dynamical systems.
- List and analyze inequities created by modern data driven technology through the use of readings from “Weapons of Math Destruction”, “Automating Inequality”, or the writings of Timnit Gebru or similar scholars and researchers.

## Course outline

This course is a senior level/beginning graduate student introduction to the common theoretical and practical tools used in the emerging area of mathematical data science. Beginning with an introduction to the singular value decomposition, the course will proceed to cover standard tools from signal processing and image analysis, after which it will explore regression and affiliated optimization techniques. Finally, it will culminate with an introduction to machine learning by way of using neural networks. Applications will come from signal processing, image analysis, classification problems, and dynamical systems.

## Tentative schedule

Week 1: Linear Algebra Review (HMWK Zero Due: 8/30)

Week 2: SVD: Theory, Coding and Applications (HMWK One Due: 9/6)

Week 3: SVD, k-means clustering, unsupervised learning

Week 4: Fourier Series, Transforms: Theory, Coding, and Applications

Week 5: Short Time Fourier Transforms: Theory, Coding, and Applications

Week 6: Wavelet Transforms: Theory, Coding, and Applications

Week 7: Probability Review, Histograms, Bias/Variance Tradeoff Analysis

Week 8: Linear Polynomial and Harmonic Regression, Cross Validation

Week 9: Optimization: Lagrange Multipliers, Constraints, Gradient and Alternating Descent

Week 10: Optimization: Convex Sets, the Geometry of Norms

Week 11: LASSO/L1-penalized Linear Regression

Week 12: Dictionary Learning

Week 13: Dictionary Learning

Week 14: Support Vector Machines, Theory, Coding, and Applications

Week 15: Support Vector Machines, Theory, Coding, and Applications

Week 16: Final Presentations

## University Policies:

**Accommodations:** If you are a student with a disability and are in need of accommodations for this class, please contact Student Ability Success Center at (619) 594-6473 as soon as possible. Please know accommodations are not retroactive, and I cannot provide

accommodations based upon disability until I have received an accommodation letter from Student Ability Success Center.

**Student Privacy and Intellectual Property:** The [Family Educational Rights and Privacy Act](#) (FERPA) mandates the protection of student information, including contact information, grades, and graded assignments. I will not post grades or leave graded assignments in public places. Students will be notified at the time of an assignment if copies of student work will be retained beyond the end of the semester or used as examples for future students or the wider public. Students maintain intellectual property rights to work products they create as part of this course unless they are formally notified otherwise.

**Religious observances:** According to the University Policy File, students should notify the instructors of affected courses of planned absences for religious observances by the end of the second week of classes.

**Medical-related absences:** Students are instructed to contact their professor/instructor/coach in the event they need to miss class, etc. due to an illness, injury or emergency. All decisions about the impact of an absence, as well as any arrangements for making up work, rest with the instructors. [Student Health Services](#) (SHS) does not provide medical excuses for short-term absences due to illness or injury. When a medical-related absence persists beyond five days, SHS will work with students to provide appropriate documentation. When a student is hospitalized or has a serious, ongoing illness or injury, SHS will, at the student's request and with the student's consent, communicate with the student's instructors via the Vice President for Student Affairs and may communicate with the student's Assistant Dean and/or the [Student Ability Success Center](#).

**SDSU Economic Crisis Response Team:** If you or a friend are experiencing food or housing insecurity, or any unforeseen financial crisis, visit [sdsu.edu/ecrt](https://sdsu.edu/ecrt), email [ecrt@sdsu.edu](mailto:ecrt@sdsu.edu), or walk-in to Well-being & Health Promotion on the 3rd floor of Calpulli Center.

**Resources for students:** A complete list of all academic support services--including the [Writing Center](#) and [Math Learning Center](#)--is available on the Student Affairs' [Academic Success](#) website. [Counseling and Psychological Services](#) (619-594-5220) offers confidential counseling services by licensed therapists; you can Live Chat with a counselor at [http://go.sdsu.edu/student\\_affairs/cps/therapist-consultation.aspx](http://go.sdsu.edu/student_affairs/cps/therapist-consultation.aspx) between 4:00pm and 10:00pm, or call San Diego Access and Crisis 24-hour Hotline at (888) 724-7240.

**Academic Honesty:** The University adheres to a strict [policy prohibiting cheating and plagiarism](#). Examples of academic dishonesty include but are not limited to:

- copying, in part or in whole, from another's test or other examination;
- obtaining copies of a test, an examination, or other course material without the permission of the instructor;
- collaborating with another or others in work to be presented without the permission of the instructor;
- falsifying records, laboratory work, or other course data;
- submitting work previously presented in another course, if contrary to the rules of the course;
- altering or interfering with grading procedures;
- assisting another student in any of the above;
- using sources verbatim or paraphrasing without giving proper attribution (this can include phrases, sentences, paragraphs and/or pages of work);

- copying and pasting work from an online or offline source directly and calling it your own;
- using information you find from an online or offline source without giving the author credit;
- replacing words or phrases from another source and inserting your own words or phrases.

The California State University system requires instructors to report all instances of academic misconduct to the Center for Student Rights and Responsibilities. Academic dishonesty will result in disciplinary review by the University and may lead to probation, suspension, or expulsion. Instructors may also, at their discretion, penalize student grades on any assignment or assessment discovered to have been produced in an academically dishonest manner.

**Classroom Conduct Standards:** SDSU students are expected to abide by the terms of the Student Conduct Code in classrooms and other instructional settings. Prohibited conduct includes:

- Willful, material and substantial disruption or obstruction of a University-related activity, or any on-campus activity.
- Participating in an activity that substantially and materially disrupts the normal operations of the University, or infringes on the rights of members of the University community.
- Unauthorized recording, dissemination, or publication (including on websites or social media) of lectures or other course materials.
- Conduct that threatens or endangers the health or safety of any person within or related to the University community, including
  1. physical abuse, threats, intimidation, or harassment.
  2. sexual misconduct.

Violation of these standards will result in referral to appropriate campus authorities.