Project Instructions
Math 324: Linear Algebra

Guidelines.

- *Dates* Below is a list of the important dates.

  - Topics List (3 Topics of Interest per Group) **November 8**
  - Abstract Due **November 15**
  - Paper Draft Due **November 26** 5 pm, on Canvas
  - Presentations **December 9-12**
  - Paper Due **December 13**

- *Groups* You will work in self-selected groups of 2-4 based off of desired topic area.

- *Abstract* Your abstract will have the following information:

  - topic choice;
  - group member names, alphabetical by last name;
  - presentation date;
  - a paragraph briefly describing the topic and why it is important.

  A sample abstract is included below. An Overleaf template will also be provided.

- *Paper* Every group will submit a 3-5 page paper on their topic. This paper must describe the topic, where the linear algebra is, and the motivation for studying it. Include at least 1 proof and at least 1 computational example. You must also include at least 2 references other than our textbook. It should be readable by everyone else in the class. Use full sentences everywhere.

- *Presentation* Every group will give a 15 minute presentation on their topic to the class. This presentation can either be done via projector or on the chalkboard.
  The presentation will be graded on Delivery, Content, Organization, Visual Aides, and Evidence of Learning.
  I highly recommend you practice the presentation more than once before giving it.

- *Reflections* You are required to attend every day of group presentations and provide a reflection on it. Details will be given when we start presenting.

- *Document Preparation* You must use LaTeX/Overleaf to write your abstract and paper. A template will be provided.

- *Participation* All group members are expected to contribute. It is the responsibility of individuals and groups to make sure this happens and determine an equitable distribution of labor.

  You will be asked to reflect on your participation at the end of the project.

- *Computational Software* It is your choice whether or not you will be using any Mathematical Software for your project. Make sure to reference it when you do and if you have any pertinent code it appears somewhere in the paper.

Possible Topics.

You are welcome to pursue any topic you wish as long as it pertains to linear algebra. Below is a list of topics, in no particular order, that is meant to inspire your search.

Come to me if you have questions, are having a hard time of choosing a topic, or are having a hard time finding a group to work with.

Our book has many Applications sprinkled throughout. Additionally there are many topics we do not have time to cover in a ten week course.

- Biology and Life Sciences
  - Age Distribution of Animals

    Eigenvalues have a variety of applications to biological sciences, including the study of age distribution in a population. For example, in the case of rabbits you may want to know what proportion are babies, adults, or seniors.
  - Throughout the text there are paragraphs with information about "linear algebra applied". Use these as inspiration for further research.
- Business and Economics
  - Further study of input-output models

    Beyond the simple examples we have studies, large scale economic systems can be studied. Moreover, the mathematics proving the usefulness of these models is fascinating.
- Engineering and Technology
  - Cryptography

    We only touched the surface of what one can do using linear algebra to encrypt messages.
  - Coding Theory

    Linear algebra is used to communicate with satellites and other objects sent into space. Learn about how linear algebra is used to reduce and correct errors in communication.
  - GPS, Triangulation, and Trilateration

    The GPS in your phone uses data sent by several satellites to approximate your location. This done using linear algebra!
  - 3D graphics

    Our computers can only show us 2D objects so how are we able to make 3D images?
  - Robotics

    Robotic arms move based on rotations about a point in space. But rotations are just matrices!
- Physical Sciences
  - Eigenvalues and Stress Points of Bridges

One can determine whether a suspended bridge will hold through a wind storm or earthquake using matrix translations and eigenvalues.

- Force and Hooke's Law

  Model physical occurrences through matrices.

- Statistics and Probability
  - Markov Chains

    Use of matrices to predict future state values.

  - Regression analysis

    Extending the study of least squares regression to additional approximations.

- Mathematics
  - History of Gaussian Elimination

    Gauss was not the first one to use the method of Gaussian Elimination. For this project, dive into the history behind this method of solving a linear system.

  - Graph Theory

    A *graph* is a finite collection of points and edges connecting them. We can encode a graph as a matrix and use the matrix to study the graph.

  - Recurrences

    We can use linear algebra to get a formula for things like the Fibonacci numbers!

  - Quadratic Forms

    Conics–parabolas, hyperbolas, ellipses, circles– can be described using linear algebra! Specifically we can look at $\mathbf{x}^T A\mathbf{x}$.

  - Finite Fields

    There are systems of numbers other than those we have studied so far. In particular interest for us there are finite fields: $\mathbb{Z}_p = \{0, 1, 2, \ldots, p-1\}$ where p is prime. Addition and multiplication in this set of numbers is given *modulo* p, which you can think about this like a clock–0 is on the top and the numbers increase around.

  - Lattices

    All term we have been working over a field, specifically $\mathbb{R}$. What happens when we decide to look at scalars only in $\mathbb{Z}$ what falls apart, what sticks around?

  - Number Theory

    We can look at the complex numbers, $\mathbb{C}$, as a two-dimensional vector space over $\mathbb{R}$. Similarly, consider the rational numbers, $\mathbb{Q}$. Vector spaces exist over $\mathbb{Q}$, for example $\mathbb{Q}[\sqrt{2}] = \{a + b\sqrt{2} \text{ s.t. } a, b \in \mathbb{Q}\} = \mathbb{Q} + \sqrt{2}\mathbb{Q}$.

Linear Algebra

Author 1, Author 2, ... and Author n

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Abstract. Linear Algebra is a field of mathematics with an exceptional number of applications both to other areas of mathematics and to sciences in general. In math 324, we examine vectors, matrices, linear transformations, vector spaces, bases, and eigenvalues. A large amount of what we study boils down to the equation:

$$A\vec{x} = \vec{b},$$

where A is a matrix and $\vec{x}$ and $\vec{b}$ are vectors. This simple equation encodes a variety of applications and mathematical topics.