CSPB 2820 - Truong - Linear Algebra with Computer Science Applications

Syllabus

CSPB 2820: Linear Algebra with Computer Science Applications

Instructor Information

- Name: Hoang Truong
- Email: hoang.truong@colorado.edu
- Office hours: Mon 8:00 PM - 9:00 PM MT and Wed 3:30 PM - 4:30 PM MT
- IMPORTANT DATES - Mark your calendars

Midterm One	**Friday**	Sep 22th	**7:30 am - 9:30 pm (any 2 hour window)**
Midterm Two	**Friday**	Nov 17th	**7:30 am - 9:30 pm (any 2 hour window)**
Final Project	**Monday**	Dec 19th	**FINAL PROJECT DUE**

Learning Goals

This course should teach students how to:

- Use and reason about vectors, theoretically and in computer science applications
- Use and reason about matrices, theoretically and in computer science applications
- Understand and use linear functions, and the relation between linear functions and matrices
- Solve systems of linear equations, and reason about the computation complexity of them

List of topics:

- Vectors
- Linear functions
- Norm and distance
- Writing linear algebra code
- Clustering
- Linear independence
- Matrices
- Matrix examples
- Linear equations
- Linear dynamical systems
- Matrix multiplication
- Matrix inverses
- Least squares
- eigenvalues, eigenvectors, and singular values
- Least squares data fitting
- Least squares classification

Textbook

Available for free online:

Introduction to Applied Linear Algebra – Vectors, Matrices, and Least Squares

More information and book resources

Assessments and Gradebook

Grade weights are as follows:

- 2 Midterms: 40%
- Graded Exercises in Study Guides: 30%
- Quizzes: 10%
- Analysis, Reflection and Participation in Piazza: 10%
- Final Project : 10%

Bonus:
The lowest 2 Study Guide scores will be dropped to give you 2 extra chances to understand the grading method.
One each of the lowest Piazza Posts and Quizzes will be dropped.

Use these bonuses to only turn in your best work.

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Study Guide instructions: <<<IMPORTANT!!!
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- **Submit your work in Gradescope as a PDF - you will identify where your "questions are."**
- **Identify the question number as you submit. Since we grade "blind" if the questions are NOT identified, the work WILL NOT BE GRADED and a 0 will be recorded. Always leave enough time to identify the questions whe submitting.**
- **One section per page (if a page or less) - I prefer to grade the main solution in a single page, extra work can be included on the following page.**
- **Do not start a new question in the middle of a page**
- **Solutions to book questions are provided for reference.**
- **You may NOT submit given solutions - this includes minor modifications - as your own.**
- **Solutions that do not show individual engagement with the solutions will be marked as no credit and can be considered a violation of honor code.**
- **If you use the given solutions you must reference or explain how you used them, in particular...**

For EACH book exercise in the Study Guides one of the following methods must be identified FOR EACH QUESTION.

Identify one or more of the following methods so that it is clear how the solution will be understood and communicated:

Method 1 - Provide original examples which demonstrate the ideas of the exercise in addition to your solution.

Method 2 - Include and discuss the specific topics needed from the chapter and how they relate to the question.

Method 3 - Include original Python code, of reasonable length (as screenshot r text) to show how the topic or concept was explored.

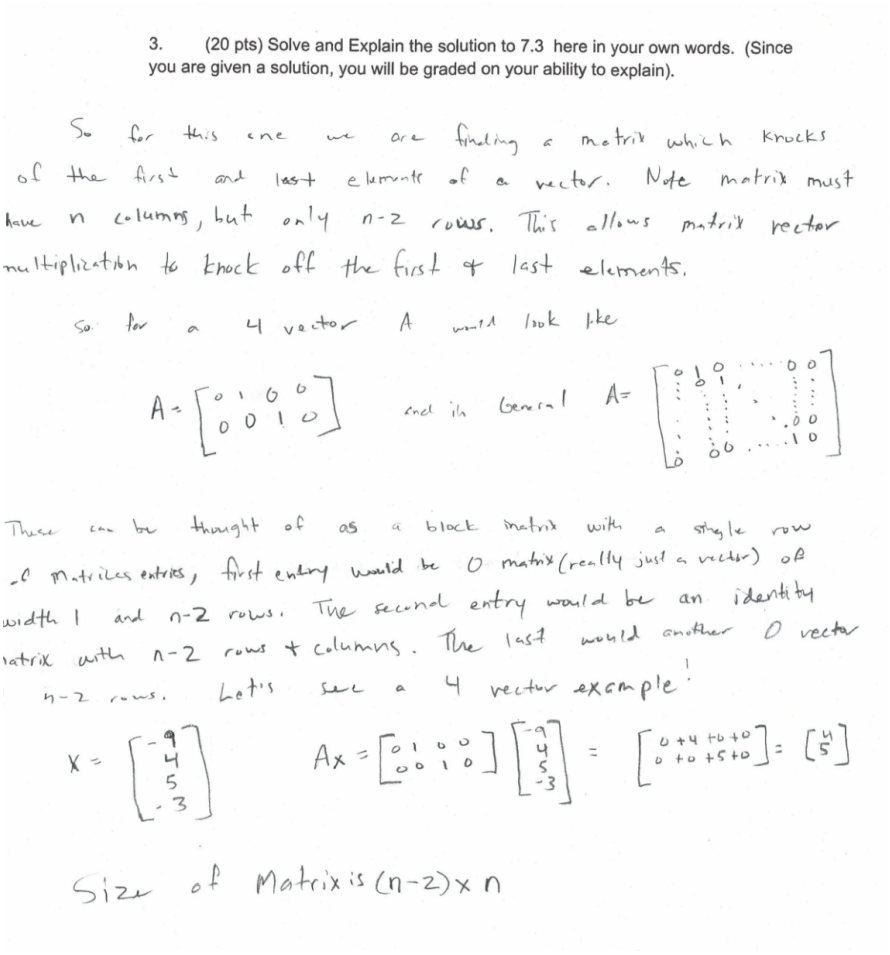
Method 4 - Expand the given solution in a significant way, with additional steps and comments. All steps are justified. This is a good method for a proof for which you are only given a basic outline.

Method 5 - Attempt the exercise without looking at the solution and then the solution is used to check work. Words are used to describe the results.

Method 6 - Provide an analysis of the strategies used to understand the exercise, describing in detail what was challenging, who helped you or what resources were used. The process of understanding is described.

Here are 2 examples of Method 4 and 6:

Method 4



3. (20 pts) Solve and Explain the solution to 7.3 here in your own words. (Since you are given a solution, you will be graded on your ability to explain).

So for this one we are finding a matrix which knocks of the first and last elements of a vector. Note matrix must have n columns, but only n-2 rows. This allows matrix vector multiplication to knock off the first & last elements.

So for a 4 vector A would look like

$A = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$ and in General $A = \begin{bmatrix} 0 & 1 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 1 & & \vdots & \vdots \\ \vdots & \vdots & & \ddots & 0 & 0 \\ 0 & 0 & \cdots & & 1 & 0 \end{bmatrix}$

These can be thought of as a block matrix with a single row of matrices entries, first entry would be 0 matrix (really just a vector) of width 1 and n-2 rows. The second entry would be an identity matrix with n-2 rows & columns. The last would another 0 vector n-2 rows. Let's see a 4 vector example!

$X = \begin{bmatrix} -9 \\ 4 \\ 5 \\ -3 \end{bmatrix}$ $Ax = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} -9 \\ 4 \\ 5 \\ -3 \end{bmatrix} = \begin{bmatrix} 0+4+0+0 \\ 0+0+5+0 \end{bmatrix} = \begin{bmatrix} 4 \\ 5 \end{bmatrix}$

Size of Matrix is $(n-2) \times n$

Method 6:

5. (10pts) Explain the solution to 3.4 here in your own words. (Since you are given a solution, you will be graded on your ability to explain).

   Norm identities. Verify that the following identities hold for any two vectors a and b of the same size.

   a. $(a + b)^T (a - b) = \|a\|^2 - \|b\|^2$

   These are my first thoughts on the problem. I decided to start with the right hand side instead of the left. My answer did not come out correct, so then I peaked at the solution to see where I was going wrong. Below are my corrections in red on the problem.

   $(a + b)^T (a - b) = [(a_1 + b_1) * (a_1 - b_1)] + \ldots + [(a_n + b_n) * (a_n - b_n)]$

   Step 1:

   $\|a\|^2 - \|b\|^2 = a^Ta - b^Tb$

   → properties of norms, inner product of a n-vector with itself
   → This made sense and was logical to me

   Step 2:

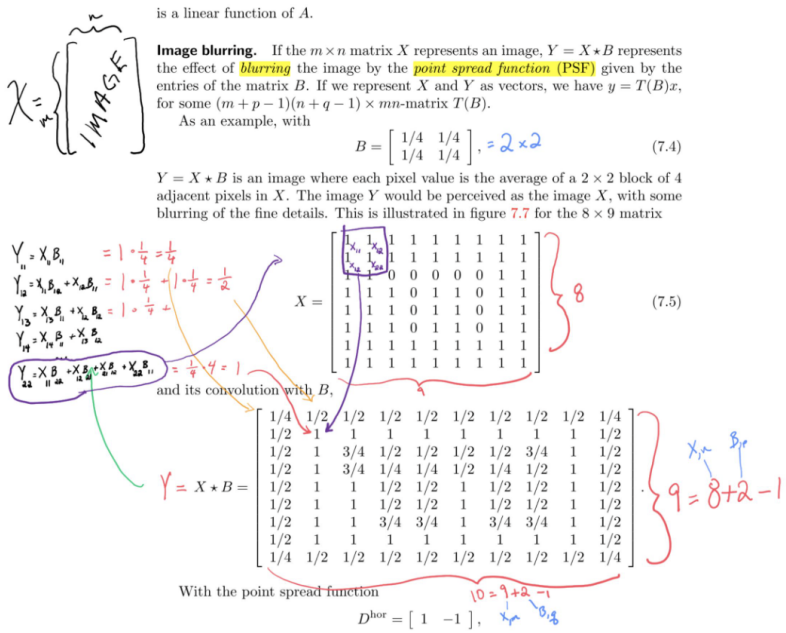
   ~~$= (a_1^2 + \ldots + a_n^2) - (b_1^2 + \ldots + b_n^2)$~~
   ~~→ expand out the inner product of the vectors~~
   → Here is where my errors with this problem started. I tried to expand out the inner product of the vectors and was stuck on where to go next. Since I did this problem backwards I wasn't able to see the connection by adding back in $-a^Tb + a^Tb$ to the problem. Let's add that back in here and I should be able to understand the rest myself.
   $= a^Ta - a^Tb + a^Tb - b^Tb$

   Step 3:

   ~~$= (a_1^2 + \ldots + a_n^2 - b_1^2 - \ldots - b_n^2)$~~
   ~~→ distribute negative sign in~~
   → Now instead, we can clearly see that this was an instance of where we foil some terms together to get these terms. This was clear to me because we have seen this when we talk about the norm of a sum in equation 3.1.
   → We see a^T in ¾ of the terms and b^T in ¾ of the terms, where there are minuses on half of them. So we know it will look something like: $a^T(a - b) + b^T(a + b)$
   → If we expand this out we see $a^Ta - a^Tb + a^Tb + b^Tb$
   → We're pretty close but off in the last term that needs to be a minus
   → So we have:
   $= a^T(a - b) + b^T(a - b)$

ave View

Annotation Example:



is a linear function of A.

Image blurring. If the $m \times n$ matrix X represents an image, $Y = X \star B$ represents the effect of *blurring* the image by the *point spread function* (PSF) given by the entries of the matrix B. If we represent X and Y as vectors, we have $y = T(B)x$, for some $(m + p - 1)(n + q - 1) \times mn$-matrix $T(B)$.

As an example, with

$$B = \begin{bmatrix} 1/4 & 1/4 \\ 1/4 & 1/4 \end{bmatrix}, \quad (7.4)$$

$Y = X \star B$ is an image where each pixel value is the average of a 2×2 block of 4 adjacent pixels in X. The image Y would be perceived as the image X, with some blurring of the fine details. This is illustrated in figure 7.7 for the 8×9 matrix

$$X = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix} \quad (7.5)$$

and its convolution with B,

$$Y = X \star B = \begin{bmatrix} 1/4 & 1/2 & 1/2 & 1/2 & 1/2 & 1/2 & 1/2 & 1/2 & 1/4 \\ 1/2 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1/2 \\ 1/2 & 1 & 3/4 & 1/2 & 1/2 & 1/2 & 1/2 & 3/4 & 1 & 1/2 \\ 1/2 & 1 & 3/4 & 1/4 & 1/4 & 1/2 & 1/4 & 1/2 & 1 & 1/2 \\ 1/2 & 1 & 1 & 1/2 & 1/2 & 1 & 1/2 & 1/2 & 1 & 1/2 \\ 1/2 & 1 & 1 & 1/2 & 1/2 & 1 & 1/2 & 1/2 & 1 & 1/2 \\ 1/2 & 1 & 1 & 3/4 & 3/4 & 1 & 3/4 & 3/4 & 1 & 1/2 \\ 1/2 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1/2 \\ 1/4 & 1/2 & 1/2 & 1/2 & 1/2 & 1/2 & 1/2 & 1/2 & 1/2 & 1/4 \end{bmatrix}$$

With the point spread function

$$D^{hor} = \begin{bmatrix} 1 & -1 \end{bmatrix},$$

Standard Course Policies

Collaboration Policy

We welcome collaboration! Sharing insights, asking questions, learning by doing, and learning by helping others are essential skills in learning computer science.

Collaboration is discussing ideas of the course with others, sharing insights and extra resources, working through similar questions to an assignment, sharing resources, and helping others. The Piazza forum in your class is an ideal place to share ideas, lead a discussion or or be the hero that asks the "dumb question" everyone else is afraid to ask. And Piazza is often a source for content for instructors to include in letters of recommendations. Your leadership, courage, and determination will not go unnoticed.

Collaboration is not:

- "Having a partner." In particular, Group Projects, or projects that specify "working with a partner" will have individual guidelines.
- One student solving problems 1-4, and another solving 6-10.
- An identical group solution submitted by multiple students.

Unless specified in the assignment, all submitted coursework is individual.

In general:

- You must document resources and collaboration on any assignment. This should be in the form of comments at the start of code and/or within solution notes.
- Cite Your Sources: If you collaborated with someone on an assignment, or if your submission includes quotes from a book, a paper, or a web site, you must clearly acknowledge the source.
- Plagiarism is forbidden. Copying answers directly or indirectly from solution manuals, web pages, or your peers is **a violation of honor code**. The assignments and code that you turn in should be written entirely on your own.
- Copying/soliciting a solution to a problem from the internet or another classmate constitutes a violation of the course's collaboration policy and the honor code and may have serious consequences.
- You may not actively search for a solution to the problem from the internet. This includes posting to sources like StackOverflow, Reddit, Chegg, CourseHero, etc.
- StackExchange Clarification: Searching for basic techniques in Python/C++ is totally fine.
- If you have taken this course prior to this semester and have done some/all of homeworks previous code or previous homework solutions may not be reused. You must start each homework from scratch.
- When in doubt, ask. If something doesn't seem right - you are not sure if you can use a resource or if you are feeling pressure to share a specific solution - please reach out to your instructor.
- Note: Other information on the Honor Code can be found at www.colorado.edu/policies/honor.html and https://www.colorado.edu/sccr/honor-code.

Individual Check-In

If you have a unique situation that may be affecting your work or class experience -or-you need clarification of an email, Piazza, or ZOOM exchange, please email your instructor with the subject line "Individual Check-In". Your instructor will email you back to set up a Zoom call to discuss the specific situation and work with you to develop a solution and/or strategy to move forward.

Service Interruptions and Support

Due to the online nature of the program, there is always the possibility of service interruptions. If you are unable to access the course materials (Moodle, Piazza, etc), we encourage you to visit https://www.isitdownrightnow.com/applied.cs.colorado.edu.html.

For non-urgent issues relating to platform support, please contact helpcs@colorado.edu.

For urgent issues, for example, attempting to upload a homework near a deadline, email your instructor directly.

In cases of documented exceptional illness or circumstances affecting assignments, instructors may or may not offer an alternative assessment (which may differ in form or content) at the instructor's discretion. Please consult the campus policy for medical leave if needed.

Classroom Behavior

Students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote, or online. Failure to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation, or political philosophy.

For more information, see the classroom behavior policy, the Student Code of Conduct, and the Office of Institutional Equity and Compliance.

Requirements for Infectious Diseases

Members of the CU Boulder community and visitors to campus must follow university, department, and building health and safety requirements and all public health orders to reduce the risk of spreading infectious diseases.

The CU Boulder campus is currently mask optional. However, if masks are again required in classrooms, students who fail to adhere to masking requirements will be asked to leave class. Students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct & Conflict Resolution. Students who require accommodation because a disability prevents them from fulfilling safety measures related to infectious disease will be asked to follow the steps in the "Accommodation for Disabilities" statement on this syllabus.

For those who feel ill and think you might have COVID-19 or if you have tested positive for COVID-19, please stay home and follow the further guidance of the Public Health Office. For those who have been in close contact with someone who has COVID-19 but do not have any symptoms and have not tested positive for COVID-19, you do not need to stay home.

Accommodation for Disabilities, Temporary Medical Conditions, and Medical Isolation

Disability Services determines accommodations based on documented disabilities in the academic environment. If you qualify for accommodations because of a disability, submit your accommodation letter from Disability Services to your faculty member in a timely manner so your needs can be addressed. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance.

If you have a temporary medical condition or required medical isolation for which you require accommodation, which is affecting your class performance, please let me know by email asap. Also see Temporary Medical Conditions on the Disability Services website.

Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the Honor Code may include but are not limited to: plagiarism (including use of paper writing services or technology [such as essay bots]), cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty.

All incidents of academic misconduct will be reported to Student Conduct & Conflict Resolution: honor@colorado.edu, 303-492-5550. Students found responsible for violating the Honor Code will be assigned resolution outcomes from the Student Conduct & Conflict Resolution as well as be subject to academic sanctions from the faculty member. Visit Honor Code for more information on the academic integrity policy.

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. University policy prohibits sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, protected-class discrimination and harassment, and related retaliation by or against members of our community on- and off-campus. These behaviors harm individuals and our

community. The Office of Institutional Equity and Compliance (OIEC) addresses these policies, and individuals who believe they have been subjected to misconduct can contact OIEC at 303-492-2127 or email cureport@colorado.edu. Information about university policies, reporting options, and support resources can be found on the OIEC website.

Please know that faculty and graduate instructors have a responsibility to inform OIEC when they are made aware of any issues related to these policies regardless of when or where they occurred to ensure that individuals impacted receive information about their rights, support resources, and resolution options. To learn more about reporting and support options for a variety of concerns, visit Don't Ignore It.

Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, please let me know via email at least 1 week beforehand to resolve the schedule confliction.

See the campus policy regarding religious observances for full details.

Mental Health and Wellness

Free and unlimited telehealth is available through Academic Live Care. Please note that at this time this service is not available to students outside of the United States.

Last modified: Tuesday, 22 August 2023, 12:57 PM