MAT 422: Mathematical Methods in Data Science Fall 2024

Instructor: Professor Haiyan Wang
Phone: 602-543-5635
Email: Haiyan.Wang@asu.edu
http:// http://www.public.asu.edu/~hwang49/
Office: CLCC 278

Time and Location: Time and Location: None – Online Video Lectures. Your ASU courses can be accessed at my.asu.edu

Text: Mathematical Methods in Data Science, Jingli Ren and Haiyan Wang, Elsevier, 2023 (Students are not required to purchase the textbook and the instructor will provide necessary lecture materials)
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Course Description: Introduction to the theoretical and practical mathematical methods for data analysis and prediction. The primary methods to be covered are based on linear algebra, calculus, probability, networks and graph theory, and optimization. While the emphasis will be on the mathematical concepts, students are expected to use Python (or MATLAB, R) to produce predictions and visualize outcomes using machine learning methods. No previous programming experience is assumed. In addition to mathematical students, computer, statistical and engineering students are also encouraged to attend the course. This course provides an opportunity for students with various backgrounds to learn theoretical and practical aspects of data science.

Office Hours: Thursday 12:00 PM – 2:00PM, in person at CLCC 278 with Zoom https://asu.zoom.us/j/8162794176 and by appointment.

Prerequisite: MAT 343 (Applied Linear Algebra) and 210 (Brief Calculus) or equivalents are preferred**.** We will review necessary background knowledge for this course.

Assessment: You grade will be based on weekly homework assignments and a term project. Homework assignments will have programming components with Python, MATLB or R. Projects will be based on the knowledge in this course for data analysis and predictions. Later assignments will not be accepted.

Arizona Standard Time: Assignment and exam due dates follow Arizona Standard time. Note that Arizona does not observe daylight savings time.

Grading: Your final grade for this course will be based on the percentage of points obtained out of the total possible points.

Homework	**45%**
Attendance of Seminar	**5%**
Term projects and presentation	**50%**

A+	***A***	***A-***	***B+***	***B***	***B-***	***C+***	***C***	***D***	***E***
97-100	93- 96.9	*90-92.9*	*87-89.9*	*83-86.9*	*80-82.9*	*77-79.9*	*70-76.9*	*60-69.9*	*< 60*

Attendance of Seminar: I am organizing AI seminars on Tuesdays: Sept. 3, Oct. 1, Nov. 5, Nov. 19 from 3-4PM at ASU West Valley Campus. You are expected to attend the seminars (in person or online). I encourage you attend the seminars in person and I look forward to meeting you. Pizza / appetizers will be served at the seminars. If you have conflicts, you need to email me with supporting documents.

Course Outcomes:

Upon completing this project, students will achieve a comprehensive understanding of both the theoretical and practical aspects of data analysis and prediction. They will gain proficiency in applying mathematical concepts such as linear algebra, calculus, probability, network analysis, and optimization to real-world data sets. Additionally, students will develop skills in using Python (or MATLAB, R) for machine learning, data visualization, and predictive modeling. By collaborating in teams to produce a detailed research paper, students will enhance their abilities in literature review, methodology formulation, experimental design, result interpretation, and comparative analysis. This project will prepare them to tackle complex data science problems and contribute effectively to interdisciplinary research and development.

Specifically, students will develop a comprehensive understanding of the following mathematical foundations necessary for advanced studies and applications in data science and machine learning, and will be proficient in implementing these concepts using Python.

Linear Algebra

1. Understand the Fundamentals: Describe and apply the basic concepts of linear algebra, including linear spaces, orthogonality, and the Gram-Schmidt process.
2. Analyze Eigenvalues and Eigenvectors: Compute and interpret eigenvalues and eigenvectors, and understand their significance in various applications.
3. Implement Linear Regression: Perform linear regression analysis using QR decomposition and least-squares methods.
4. Perform Principal Component Analysis (PCA): Use singular value decomposition to conduct PCA and understand low-rank matrix approximations.

Probability

5. Grasp Probability Concepts: Explain and apply the axioms of probability, conditional probability, and the behavior of discrete and continuous random variables.
6. Evaluate Independent Variables: Analyze joint probability distributions, correlation, and dependence between random variables.
7. Apply Maximum Likelihood Estimation (MLE): Use MLE techniques for estimating parameters from random samples and apply these concepts to linear regression.

Calculus and Optimization

8. Understand Continuity and Differentiation: Explain limits, continuity, and the process of differentiation, including Taylor's theorem.
9. Optimize Functions: Identify and solve unconstrained optimization problems using necessary and sufficient conditions for local minimizers, convexity principles, and gradient descent.
10. Implement Regression and Clustering Techniques: Apply logistic regression, k-means clustering, and support vector machine (SVM) algorithms.
11. Develop and Train Neural Networks: Formulate neural networks mathematically, understand activation functions and cost functions, and implement backpropagation algorithms.

Network Analysis

12. Model Networks: Understand graph modeling techniques and their applications in network analysis.
13. Perform Spectral Graph Bipartitioning: Use spectral methods to analyze and partition graphs.
14. Understand Network Embedding: Explain and implement network embedding techniques.
15. Predict with Networks: Analyze spatial network data and apply network-based methods for predicting phenomena such as influenza outbreaks.

Computer Requirements: This is a fully online course; therefore, it requires a computer with internet access and the following technologies:

- Web browsers (ChromeLinks to an external site., Mozilla FirefoxLinks to an external site., or SafariLinks to an external site.)
- Adobe Acrobat ReaderLinks to an external site. (free)
- Webcam, microphone, headset/earbuds, and speaker
- Microsoft Office (Microsoft 365 is free for all currently-enrolled ASU students)
- Reliable broadband internet connection (DSL or cable) to stream videos.

Note: A smartphone, iPad, Chromebook, etc. will not be sufficient for completing your work in ASU Online courses. While you will be able to access course content with mobile devices, you must use a computer for all assignments, quizzes, and virtual labs. Students are responsible for any technical issues on their own computers.

Help: For technical support, use the Help icon in the black global navigation menu in your Canvas course or call the ASU Help Desk at 1+(855) 278-5080. Representatives are available to assist you 24 hours a day, 7 days a week.

Student Success: To be successful:

- check the course daily
- read announcements
- read and respond to course email messages as needed
- complete assignments by the due dates specified
- communicate regularly with your instructor and peers
- create a study and/or assignment schedule to stay on track
- access ASU Online Student Resources

Digital Literacy: Below are some of the skills you'll need to utilize to be successful in this ASU Online courses:

- Using Canvas LMS - For additional help on this, visit the Canvas Resources for Students or the Student Canvas GuideLinks to an external site.. Be sure to bookmark these resources for future reference!
- Using email with attachments
- Creating and submitting word files
- Copying and pasting
- Downloading and installing software
- Using presentation and graphics programs

The ASU Library has a number of tutorials available to support students in expanding their digital literacy skills: ASU Library tutorials

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Communicating With the Instructor

Community Forum

This course uses a discussion topic called "Community Forum" for general questions and comments about the course. Prior to posting a question or comment, check the syllabus, announcements, and existing posts to ensure it's not redundant. You are encouraged to respond to the questions of your classmates.

Email questions of a personal nature to your instructor. You can expect a response within 72 hours.

Chat

The Chat tool in Canvas allows students and teachers to interact in real time. Use Chat only for informal course-related conversations unless your instructor informs you otherwise. Chat is not ideal for questions about assignments; instructors are not required to monitor it and conversations may be buried or lost.

Email

ASU email is an official means of communication among students, faculty, and staff. Students are expected to read and act upon email in a timely fashion. Students bear the responsibility of missed messages and should check their ASU-assigned email regularly.

All instructor correspondence will be sent to your ASU email account.

Communication Expectations (Netiquette)

Learning takes place best when a safe environment is established. Students enrolled in this course have a responsibility to support an environment that nurtures individual and group differences and encourages engaged, honest discussions. Doing so will effectively contribute to our own and others intellectual and personal growth and development. We welcome disagreements in the tolerant spirit of academic discourse, but please remember to be respectful of others' viewpoints, whether you agree with them or not. The following are some guidelines to consider when engaging in online discussion and discourse:

- **Be kind and polite.** Be mindful of your tone and do not make fun of another person for any reason.
- **Be respectful.** Being part of an academic community means being exposed to diverse perspectives and viewpoints. Be respectful in all situations and in your critiques. If you wouldn't say it face to face, don't say it online
- **Be wary of sarcasm**. In person, sarcastic comments can be funny and break up a tense situation. Online, it's hard to tell the difference between when someone is being sarcastic and when someone is genuinely being rude.
- **Avoid stereotyping**. Just because someone holds view X, and some people you know of who hold view X also hold view Y, doesn't mean that holding view X means holding view Y.
- **Use proper grammar and spelling**. Typos and basic spelling mistakes will happen, but if it's detracting from you message, it can be difficult to figure out what you mean. Also, you should avoid using all caps as this can imply shouting in the online environment.

ASU Online Course Policies

View the ASU Online Course Policies

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Inclusive Environment

Throughout this course, you may be presented with ideas or perspectives that you are unfamiliar or uncomfortable with. We encourage you to critically examine these ideas and take risks by offering your own experiences and perspectives through civil discourse. In return, I will work to foster and create an environment where you feel supported in taking these risks.

When possible, human biases were addressed in the design of this course. If there are aspects of the design, instruction, and/or experiences within this course that result in barriers to your inclusion, please reach out to me with suggestions on how I can further improve this course for you or for others.

Syllabus Disclaimer

The syllabus is a statement of intent and serves as an implicit agreement between the instructor and the student. Every effort will be made to avoid changing the course schedule but the possibility exists that unforeseen events will make syllabus changes necessary. Remember to check your ASU email and the course site often.

ASU Academic Integrity

Academic honesty is expected of all students in all examinations, papers, laboratory work, academic transactions, and records. Students in this class must adhere to ASU's academic integrity policy. Students are responsible for reviewing this policy and understanding each of the areas in which academic dishonesty can occur. All academic integrity violations will be reported to the New College Academic Integrity Office (AIO). The possible sanctions include but are not limited to appropriate grade penalties, course failure (indicated on the transcript as a grade of E), course failure due to academic dishonesty (indicated on the transcript as a grade of XE), loss of registration privileges, disqualification, and dismissal The AIO maintains records of all violations and has access to academic integrity violations committed in all other ASU college/schools.

Generative AI is Permitted, with Parameters

The use of AI tools and techniques on *specified* assignments (according to individual assignment descriptions) is permitted, provided that the following guidelines are followed:

- AI tools may augment the student's work, but should not be the sole basis for the assignment.
- The use of AI tools should be appropriately acknowledged and documented, with proper citations and references. For reference, see this website: How to Cite ChatGPT in APA Format.
- The ethical and social implications of using AI should be considered when deciding to use AI tools in assignments.
- Students should not use AI tools to engage in academic dishonesty or plagiarism. Students should be familiar with ASU's Academic Integrity Policy and should reach out to the instructor with any questions regarding use of generative AI on individual assignments. Additional information can be found on the Office of the University Provost's Generative AI FAQ website.

ASU Student Code of Conduct

Students are expected to follow the ASU Student Code of Conduct, especially when communicating with peers, staff, and instructors. Violations of the student code of conduct may result in withdrawal from the class.

Academic Status Reports

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This course incorporates an early alert reporting system called Academic Status Reports (ASRs) to give you helpful updates throughout the semester. An ASR will let you know if you are progressing well or if there are concerns related to your class performance. Concerns may be related to missing classes, missing assignments, or the quality of your work. ASR notifications will be sent to your ASU email address and are visible on My ASU in the My Classes box. The ASR may provide recommended actions, such as meeting with your instructor, TA, or academic advisor. If you receive an ASR, don't ignore it and keep calm (it might be good news).

Read the message, follow the suggested instructions, and don't delay. Information for making an appointment with your academic advisor can be found on My ASU in the Academic Support Team box. Students should view ASRs as confirmation of good work or use them as a catalyst to make changes, seek assistance, and improve in the course.

You can learn more about ASRs on the Academic Status Report Resources page.

https://students.asu.edu/academic-status-report

Assessments

Please be aware that student scores on exams or other graded work may be used to assess program goals of degrees offered by the School of Mathematical and Natural Sciences. This course uses HonorLock technology for all exams. This technology is offered free to students and helps to ensure the academic integrity of this course. Students will need to have a camera, microphone and identification as well as a private space when taking exams-see computer requirements above. Students are expected to take all exams following the ASU academic integrity guidelines.

Attendance/Absence Policies

In addition to the instructor's general policy on absences and missed work, excused absences and conditions for making up work include Accommodation of Religious Practices and Missed Classes Due to University-Sanctioned Activities (ACD 304-02. Students must notify their instructors of these absences as early as possible in the semester.

Community of Care Guidelines

ASU's response to COVID-19 for preserving and protecting every community member's health will continue to be dynamically adjusted to keep our community healthy and well. Please consult the ASU Coronavirus website and Coronavirus FAQ for up-to-date information on status, current risk, and appropriate response.

Copyright Infringement

All course content and materials are copyrighted materials. Students may not share outside the class, upload to online websites not approved by the instructor, sell, or distribute course content or notes taken during the conduct of the course [see Academic Affairs Manual policy 304–06: Commercial Note Taking Services and Student Code of Conduct policy 5-308 F.14 Prohibited Conduct (page 10) for more information]. This includes lectures, recorded lectures, and lectures administered and recorded using Zoom. Students must refrain from uploading to any course shell, discussion board, or website used by the course instructor or other course forum material that is not the student's original work unless the students first comply with all applicable copyright laws. Faculty members reserve the right to delete materials on the grounds of suspected copyright infringement.

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Course/Instructor Evaluation

The course/instructor evaluation for this course will typically be conducted online 7-10 days before the last official day of classes of each semester or summer session. Your response(s) to the course/instructor is anonymous and will not be returned to your instructor until after grades have been submitted. The use of a course/instructor evaluation is an important process that allows our college to (1) help faculty improve their instruction, (2) help administrators evaluate instructional quality, (3) ensure high standards of teaching, and (4) ultimately improve instruction and student learning over time. Completing the evaluation is not required for you to pass this class and will not affect your grade, but your cooperation and participation in this process are critical. About two weeks before the class finishes, watch for an e-mail with "NCIAS Course/Instructor Evaluation" in the subject heading. The e-mail will be sent to your official ASU e-mail address.

Emergencies/Campus Power Outage

In the event of a campus power outage or other event affecting the ability of the University to deliver classes, any decision to cancel classes will be announced using the ASU emergency notification system. For this reason, it is imperative that students register with ASU's emergency notification system LiveSafe. In cases where a limited number of buildings are affected, students should check the University website and/or call the School office at (602) 543-6050.

Final Exam Make-up Policy

ASU's Final Exam Schedule will be strictly followed. Exceptions to the schedule and requests for make-up examinations can be granted only by the Associate Director of the School of Mathematical and Natural Sciences for one of the following reasons: 1) religious conflict; 2) the student has more than three exams scheduled on the same day; 3) two finals are scheduled to occur at the same time. Make-up exams will NOT be given for any of the following reasons: non-refundable airline tickets, vacation plans, work schedules, weddings, family reunions, or other such activities. Students should consult the final exam schedule before making end-of-semester travel plans.

If there is a last-minute personal or medical emergency, the student may receive a grade of Incomplete and make up the final within one calendar month. The student must provide written documentation and be passing the class at the time to receive an incomplete. A signed Request for Grade of Incomplete must be submitted by the student and approved by the student's instructor and the Associate Director of the School of Mathematical and Natural Sciences.

Incomplete

A grade of incomplete will be awarded only if a documented emergency or illness prevents a student doing acceptable work from completing a small percentage of the course requirements at the end of the semester. The guidelines in the current general ASU catalog regarding a grade of incomplete will be strictly followed. A signed Request for Grade of Incomplete must be submitted by the student and approved by the student's instructor and the Associate Director of the School of Mathematical and Natural Sciences. **A grade of incomplete will NOT be awarded unless there is documented evidence of extreme personal or immediate family hardship.** Changes in work hours or other similar personal problems will not be approved as reasons for awarding incompletes. The Associate Director of the School of Mathematical and Natural Sciences must approve any incomplete grade requests.

Grade Grievances

Any student seeking to appeal a grade must follow the following steps. This process does not address academic integrity allegations or faculty misconduct. Student grade appeals must be processed in the regular semester immediately following the issuance of the grade in dispute (by commencement for Fall or Spring semesters), regardless of whether the student is enrolled at the University. There are two stages to the grievance process: the informal process and the formal process. Each process

contains a series of steps that must be followed in order. The informal process, outlined below and facilitated by the School of Mathematical and Natural Sciences, must be followed prior to escalation to the formal process:

1. A one-on-one meeting must be scheduled with the instructor. During this meeting, a student must state the reason for questioning that the grade was not given properly/in good faith. The instructor must review the matter, explain the grading procedure, and explain how the grade was determined. The student and the instructor must work toward resolution, and grade grievances should ideally be resolved at this level.
2. If the issue is unresolved, the student can appeal to the School of Math and Natural Sciences Grievances committee (MNSgrievances@asu.edu). The student must provide a written rationale and evidence that the grade was not given appropriately as well as a summary of the instructor's response/the meeting with the instructor.
3. If MNS Grievances policy do not resolve the issue, the student can appeal to the Associate Director and Director of the School of Math and Natural Sciences.
4. If the issue is not resolved at the level of the School of Math and Natural Sciences, the student can confer with the Dean's Representative in the New College of Interdisciplinary Arts and Sciences (Executive Director of Academic Services and Strategic Initiatives) who will review the case and explain the formal process to the student.

Policy against Threatening Behavior

In the classroom and out, students are required to conduct themselves in a manner that promotes an environment that is safe and conducive to learning and conducting other university-related business. All incidents and allegations of violent or threatening conduct by an ASU student will be reported to the ASU Police Department (ASU PD) and the Office of the Dean of Students. Such incidents will be dealt with in accordance with the policies and procedures described in Section 104-02 of the Student Services Manual.

Potentially Offensive Content

If you find any of the content in your class offensive, please bring your concerns to the instructor immediately. If raising the issue with the instructor is problematic, these concerns should be brought to the attention of the Director and Associate Director of the School of Mathematical and Natural Sciences.

Reasonable Accommodations for Students with Disabilities

Student Accessibility and Inclusive Learning Services (SAILS) provide information and services to students with any documented disability who are attending ASU. Individualized program strategies and recommendations are available for each student as well as current information regarding community resources. Students also may have access to specialized equipment and supportive services and should contact the instructor for accommodations necessary for course completion.

Respectful Communications

As a beacon for critical thought and the advancement of knowledge, ASU values dissenting opinions. Acknowledging that someone else's opinion matters as much as our own is the first step to creating a respectful dialogue. However, we must also distinguish between opinion, fact, and policy. Valuing and respecting those opinions that are different from our own does not mandate acquiescence or violation of policy. We expect all written, e-mail, verbal, and otherwise communications to be conducted with a respectful tone and tenor, and in compliance with established protocols and the ASU Code of Conduct.

Title IX

It is a federal law that no person be excluded on the basis of sex from participation in, be denied benefits of, or be subjected to discrimination under any education program or activity. Both Title IX and university policy make clear that sexual violence and harassment based on sex is prohibited. An individual who believes they have been subjected to sexual violence or harassed

on the basis of sex can seek support, including counseling and academic support, from the University. If you or someone you know has been harassed on the basis of sex or sexually assaulted, you can find information and resources at ASU's website for Sexual Violence Awareness, Prevention, and Response. As mandated reporters, faculty are obligated to report any information of which they become aware regarding alleged acts of sexual discrimination, including sexual violence and dating violence. ASU Counseling Services are available if you wish to discuss any concerns confidentially and privately.

Withdrawals

Specifically, students should be aware that non-attendance will NOT automatically result in being dropped from the course. Therefore, if a student does not attend class during the first week or for any extended period of time during the semester, they should not presume that they are no longer registered. It is the student's responsibility to be aware of their registration status. Any withdrawal transaction must be completed by the deadline date in accordance to the appropriate session at the registrar's office. If not, you will still be officially enrolled and receive a grade based on your completed work. For additional information about ASU's withdrawal policy and the possible consequences of withdrawing from a class, contact Registration Services or your academic counselor.

Table 1: Some Calendar Reminders – Session C

Event	Date
Classes Begin	**August 22, 2024**
Last Date to Register or add a Class	**August 28th, 2024**
Labor Day Observed- ***Classes excused/University closed***	**September 2, 2024**
Last Date to Drop a Class	**November 6, 2024**
Veterans Day Observed- ***Classes excused/University closed***	**November 11, 2024**
Thanksgiving Holiday Observed- ***Classes excused/University closed***	**November 28-29, 2024**
Course Withdrawal Deadline	**December 6, 2024**
Complete Session Withdrawal Deadline/Last Day of Classes*	**December 6, 2024**
Final Grades Due	**December 9 - 16, 2024**

ASU's Full Academic Calendar

*****As part of a complete session withdrawal, a student must withdraw from all classes in that session. Beginning the first day of classes, undergraduate students are required to work with a Student Retention Coordinator to facilitate the withdrawal process. Please refer to the ASU Registrar's webpage How to Drop, Add, and Withdrawal.