THE OHIO STATE UNIVERSITY

COLLEGE OF ARTS AND SCIENCES

SYLLABUS: STAT 6560
APPLIED MULTIVARIATE ANALYSIS
AUTUMN 2024

Course overview

Instructor

Instructor: Sebastian Kurtek
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Phone number: 614-292-0463 (communication via e-mail is highly preferred)
Office hours: Mondays, 2–3PM or by appointment

Graduate teaching associate: Jiahao Ping
Email address: ping.24@osu.edu
Office hour: TBD

Course description

STAT 6560 is an introductory multivariate statistical analysis course designed for graduate students in the Department of Statistics. The aim of the course is to introduce a variety of standard statistical methods used to analyze multivariate data, emphasizing the implementation and interpretation of these methods. Topics covered include matrix computation of summary statistics, graphical techniques, geometry of sample data, multivariate normal distribution, inferences on a mean vector, principal component analysis, factor analysis, classification/discrimination, as well as cluster analysis and canonical correlation analysis if time permits.

Prerequisites: STAT 6450 (Applied Regression Analysis) or equivalent and MATH 2568 (Linear Algebra) or equivalent. Some experience with statistical computing packages is required to successfully complete this course.

Course materials

Required

Applied Multivariate Statistical Analysis, 6th Edition by Richard A. Johnson and Dean W. Wichern

I will highlight other useful references as the course progresses.

Course technology

For help with your password, university e-mail, Carmen, or any other technology issues, questions, or requests, contact the OSU IT Service Desk. Standard support hours are available at https://ocio.osu.edu/help/hours, and support for urgent issues is available 24x7.

- **Self-Service and Chat support:** http://ocio.osu.edu/selfservice
- **Phone:** 614-688-HELP (4357)
- **Email:** 8help@osu.edu
- **TDD:** 614-688-8743

Baseline technical skills necessary

- Basic computer and web-browsing skills
- Navigating Carmen

Technology skills necessary for this specific course

- CarmenZoom (for some lectures)

Necessary equipment

- Computer: current Mac (OS X) or PC (Windows 10+) with high-speed internet connection
- Webcam: built-in or external webcam, fully installed
- Microphone: built-in laptop or tablet mic or external microphone

Necessary software

This class requires you to use the statistical software package called R (The R Project for Statistical Computing; http://www.r-project.org/). This software package is available as Free Software.

- You can download R for Windows, Mac, and Linux, from the CRAN archive at https://cran.r-project.org.
- An in-depth introduction to R is available at http://cran.r-project.org/doc/manuals/R-intro.pdf.
- Hands-on tutorials are available in the Swirl system, which you can learn about at http://swirlstats.com/. In particular, “R Programming: The basics of programming in R” is an appropriate first tutorial for students who have never used R.

An easier to use interface to R is available in the software package RStudio. This package is available for Windows, Mac, and Linux and can be downloaded for free from http://rstudio.org. **Note that RStudio requires R to be installed.**

Instructions for data analysis using the software will be given in class. Most homework assignments will require some computing.

Course delivery

- This class will take place in person three times per week on Mondays, Wednesdays and Fridays, 11:30AM-12:25PM in Hitchcock Hall 306.
- All assignments will be posted on the Carmen class website. You will be given ample time to complete the assignments. Assignment due dates will be announced in class and on the Carmen course webpage.
- I will hold weekly in person office hours in my office in Cockins Hall 440B.

Grading and faculty response

Homework and exams

Assignment or category	Percentage
Homework	30
Midterm	35
Final Project	35
Total	100

Grades will be recorded on the class website.

Homework

I will assign homework regularly (about every other week) throughout the semester. You may discuss the homework with other students, but DO NOT copy any part of someone else's work or solutions from any other sources. Violations of this policy will be treated as academic misconduct. I encourage you to talk to me or the GTA (during office hours) if you have questions after serious attempts have been made to work on an assignment.

Homework preparation rules: Put your name on your homework assignment. Submit the problems in order, clearly numbered, making sure that computer output and discussion are placed together (do not put computer output at the end of homework). Raw computer output is not acceptable. Make it clear what parts of the output are relevant and show how they answer the questions posed in the homework. All homework assignments will be submitted via the Carmen course webpage. For homework assignments requiring computing, computer code must be submitted on Carmen as an appendix to the assignment. Your code should include comment statements that indicate what sections of the

code correspond to the specific homework questions so that, if needed, the grader can read and check your code for its accuracy.

Exams

There will be one midterm exam with the tentative date listed on the schedule at the end of the syllabus and below. Any potential date changes will be communicated well in advance in class and on the Carmen webpage. The midterm exam will be closed book/closed notes. During the exam, you will need to work independently without any form of assistance or communication with anyone. A basic calculator is permitted; however, using a cell phone, tablet, laptop or any other device for this purpose is not permitted.

Midterm	Friday, November 1	in class

The midterm will cover the material up to and including Monday, October 28.

Final Project

The final project assignment will be described in class later in the semester. It will involve application of multivariate statistical methods to data analysis. The instructor will provide the dataset(s) for the final project.

Late assignments

Generally, late assignments will not be accepted, and no make-up exams will be provided. However, if there are extenuating circumstances beyond your control, please contact the course instructor immediately.

Grading scale

93–100: A
90–92.9: A-
87–89.9: B+
83–86.9: B
80–82.9: B-
77–79.9: C+
73–76.9: C
70 –72.9: C-
67 –69.9: D+
60 –66.9: D
Below 60: E

Faculty feedback and response time

I am providing the following list to give you an idea of my intended availability throughout the course. (Remember that you can call **614-688-HELP** at any time if you have a technical problem.)

Grading and feedback

For homeworks and exams, you can generally expect feedback within **7-14 days**.

E-mail

I will reply to e-mails within **24 hours on school days**.

Attendance and participation

Student participation requirements

The following is a summary of everyone's expected participation:

- **In person class meetings: REQUIRED**
  While formal attendance will not be taken during class, all students are required to attend all in person lectures and are responsible for all material presented during these lectures. Students will be expected to participate, discuss, and answer questions in lectures.
- **Logging in**: **AT LEAST THREE TIMES PER WEEK**
  Be sure you are logging in to the course in Carmen each week, including weeks with holidays. If you have a situation that might cause you to miss an entire week of class, discuss it with me *as soon as possible.*
- **Office hours**: **OPTIONAL**
  All office hours will be held in person in my office in Cockins Hall 440B. Office hours are optional. If you are required to discuss an assignment with me, please contact me at the beginning of the week if you need a time outside of my scheduled office hours.

Religious accommodations

It is Ohio State's policy to reasonably accommodate the sincerely held religious beliefs and practices of all students. The policy permits a student to be absent for up to three days each academic semester for reasons of faith or religious or spiritual belief.

Students planning to use religious beliefs or practices accommodations for course requirements must inform the instructor in writing no later than 14 days after the course begins. The instructor is then responsible for scheduling an alternative time and date for the course requirement, which may be before or after the original time and date of the course requirement. These alternative accommodations will remain confidential. It is the student's responsibility to ensure that all course assignments are completed.

Discussion and communication guidelines

The following are my expectations for how we should communicate as a class. Above all, please remember to be respectful and thoughtful.

- **Writing style**: While there is no need to participate in class discussions as if you were writing a research paper, you should remember to write using correct grammar, spelling, and punctuation.

- **Tone and civility**: Let us maintain a supportive learning community where everyone feels safe and where people can disagree amicably.
- **Citing your sources**: When we have academic discussions, please cite your sources to back up what you say. (For the textbook or other course materials, list at least the title and page numbers. For online sources, include a link.)
- **Backing up your work**: Consider composing your academic posts in a text editor or word processor, where you can save your work, and then copying into the Carmen discussion.

Other course policies

Health and safety

The Ohio State University Wexner Medical Center's Coronavirus Outbreak site (https://wexnermedical.osu.edu/features/coronavirus) includes the latest information about COVID-19 as well as guidance for students, faculty and staff. Guidelines and requirements for campus safety from the University's COVID-19 Transition Task Force were published on the Safe and Healthy website (https://safeandhealthy.osu.edu).

Potential disruptions to instruction

- As much as is possible, students will have access to material online if they are unable to attend class because of positive diagnosis, symptoms, or quarantine required following contact tracing. However, please note that lectures will not be recorded.
- If the instructor is unable to be present in person because of positive diagnosis, symptoms, or quarantine following contact tracing, the course will temporarily shift to online instruction. Details will be given on the course website if this arises.

Student support services

Student support services offered on the OSU main campus http://ssc.osu.edu.

Academic integrity policy

Policies for this course

- **Midterm**: You must complete the midterm without any external help or communication.
- **Homework assignments**: You are expected to produce original and independent work for homework assignments. Although students are often encouraged to work together on homework assignments, all students must submit their own written work in their own words. Note that allowing others to copy your work is considered academic misconduct. Academic misconduct will not be tolerated and will be dealt with procedurally in accordance with University Rule 3335-31-02. (This policy can be found at http://oaa.osu.edu/coam.html.)

- **Reusing past work**: In general, you are prohibited in university courses from turning in work from a past class to your current class, even if you modify it. If you want to build on past research or revisit a topic you have explored in previous courses, please discuss the situation with me.
- **Falsifying research or results**: All research you will conduct in this course is intended to be a learning experience; you should never feel tempted to make your results or your library research look more successful than it was.
- **Collaboration and informal peer-review**: The course will include opportunities for formal collaboration with your classmates. While study groups are encouraged, remember that comparing answers on an assignment is not permitted. If you're unsure about a particular situation, please feel free just to ask ahead of time.

Ohio State's academic integrity policy

It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term "academic misconduct" includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-487). For additional information, see the Code of Student Conduct http://studentlife.osu.edu/csc/.

Copyright disclaimer

The materials used in connection with this course may be subject to copyright protection and are only for the use of students officially enrolled in the course for the educational purposes associated with the course. Copyright law must be considered before copying, retaining, or disseminating materials outside of the course.

Statement on title IX

Title IX makes it clear that violence and harassment based on sex and gender are Civil Rights offenses subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories (e.g., race). If you or someone you know has been sexually harassed or assaulted, you may find the appropriate resources at http://titleix.osu.edu or by contacting the Ohio State Title IX Coordinator at titleix@osu.edu

Accessibility accommodations for students with disabilities

The university strives to make all learning experiences as accessible as possible. In light of the current pandemic, students seeking to request COVID-related accommodations may do so through the university's request process, managed by Student Life Disability Services. If you anticipate or experience academic barriers based on your disability (including mental health, chronic, or temporary medical conditions), please let me know immediately so that we can privately discuss options. To establish reasonable accommodations, I may request that you register with Student Life Disability Services. After registration, make arrangements with me as soon as possible to discuss your accommodations so that they may be implemented in a timely fashion. SLDS contact information: slds@osu.edu; 614-292-3307; http://slds.osu.edu; 098 Baker Hall, 113 W. 12th Avenue.

Accessibility of course technology

This course requires use of Carmen (Ohio State's learning management system) and other online communication and multimedia tools. If you need additional services to use these technologies, please request accommodations with your instructor.

Your mental health

As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a student's ability to participate in daily activities. The Ohio State University offers services to assist you with addressing these and other concerns you may be experiencing. If you or someone you know are suffering from any of the aforementioned conditions, you can learn more about the broad range of confidential mental health services available on campus via the Office of Student Life's Counseling and Consultation Service (CCS) by visiting ccs.osu.edu or calling 614- 292-5766. CCS is located on the 4th Floor of the Younkin Success Center and 10th Floor of Lincoln Tower. You can reach an on-call counselor when CCS is closed at 614-292-5766 and 24 hour emergency help is also available through the 24/7 National Suicide Prevention Hotline at 1-800-273- TALK or at suicidepreventionlifeline.org

Disclaimer

This syllabus should be taken as a reliable guide for the course content. However, you cannot claim any rights from it and I reserve the right to change due dates or the methods of grading and/or assessment if necessary. Any changes will be communicated to you through official course announcements.

Course schedule (tentative)

Week	Dates	Topics
1	Aug 21 Aug 23	Introduction, Data Organization, Summary Statistics, Graphics and Distance (Chapter 1)
2	Aug 26 Aug 28 Aug 30	Matrix Algebra and Geometry: Inner product, Projection, Spectral Decomposition, Quadratic Forms, Positive Definite Matrices (Chapter 2.1-2.3)
3	Sep 2 Sep 4 Sep 6	**Labor Day, No Class (September 2)** Powers of Matrices, Random Vectors and Matrices, Mean Vectors and Covariance Matrices (Chapter 2.4-2.6)
4	Sep 9 Sep 11 Sep 13	Matrix Inequalities (Chapter 2.7), Sample Geometry, Random Sampling, Expectation of Sample Mean and Covariance Matrix (Chapter 3.2-3.3), Matrix Operations for Descriptive Statistics (Chapter 3.5), Generalized Variance (Chapter 3.4)
5	Sep 16 Sep 18 Sep 20	Multivariate Normal Distribution and Its Properties, MLE (Chapter 4.1-4.3), Sampling Distribution of Sample Mean and Covariance (Chapter 4.4)
6	Sep 23 Sep 25 Sep 27	Large-Sample Behavior of Sample Mean and Covariance (Chapter 4.5), Assessing Normality Assumption, Detecting Outliers, and Transformations to Near Normality (Chapter 4.6-4.8)
7	Sep 30 Oct 2 Oct 4	Principal Component Analysis, Population Principal Components (Chapter 8.1-8.2), Summarizing the Sample Variation by Principal Components (Chapter 8.3)
8	Oct 7 Oct 9 Oct 11	Selection of the Number of Components, Interpretation of the Sample Principal Components (Chapter 8.3), Graphing Principal Components (Chapter 8.4), Numerical Examples of PCA **Autumn Break, No Class (October 11)**
9	Oct 14 Oct 16 Oct 18	Factor Analysis, Orthogonal Factor Model (Chapter 9.1-9.2) Methods of Estimation - Principal Component Method (Chapter 9.3)
10	Oct 21 Oct 23 Oct 25	Maximum Likelihood Method, Likelihood Ratio Test (Chapter 9.3), Factor Rotation (Chapter 9.4)
11	Oct 28 Oct 30 Nov 1	Factor Scores (Chapter 9.5), Data Examples **Midterm (November 1)**

Week	Dates	Topics
12	Nov 4 Nov 6 Nov 8	Introduction to Classification, Classification for Two Populations (Chapter 11.1-11.2), Optimal Classification Rule, Bayes Error Rate (Chapter 11.2), Expected Cost of Misclassification (Chapter 11.2), Classification with Two Normal Populations (Chapter 11.3)
13	Nov 11 Nov 13 Nov 15	**Veterans Day, No Class (November 11)** Fisher's Linear Discriminant Analysis, Quadratic Discriminant Analysis (Chapter 11.3), Classification with Several Populations (Chapter 11.5)
14	Nov 18 Nov 20 Nov 22	Fisher's Linear Discriminants (Chapter 11.6), Evaluation of Classification Rules (Chapter 11.4), Numerical Examples of Classification, Inferences about a Mean Vector (Chapter 5.1-5.2)
15	Nov 25 Nov 27 Nov 29	Hotelling's T-square (Chapter 5.3), Confidence Regions for a Mean Vector (Chapter 5.4) **Thanksgiving Break, No Class (November 27 and November 29)**
16	Dec 2 Dec 4	Likelihood Ratio Test for a Mean Vector (Chapter 5.4), Additional Topics (Time Permitting)
	Dec 10, 5PM	Final Projects Due on Carmen