Course Syllabus

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MA481 Mathematical Statistics

Course Description:

This course discusses the theory behind many of the statistical methods you encounter in other courses. How do we know the Central Limit Theorem works? When is the sample mean the best estimator for the population mean? What do we mean by "best" estimator? After a review of probability theory, we examine the properties of estimators from a random sample. We then consider likelihood-based estimation and inference. Throughout the course we emphasize the *application* of theory. We make use of statistical computing throughout as a bridge between the classical theory and the modern approaches to examining statistical methodology.

Learning Objectives:

As in any statistics course, we emphasize statistical literacy (interpretation and clear communication of statistical methods, results, and concepts) and statistical reasoning (modeling variability in a process, defining the need for data to address questions, choosing appropriate methodology, and critiquing an analysis). This class also emphasizes the underlying theory of statistical methodology. Specifically, after taking this course, students will be able to accomplish the following tasks:

(A) **Describe** the role of probability theory when making inference on a population.

(B) **Compare** and **contrast** modes of convergence and **describe** their role in sampling distributions.

(C) **Construct** a proof to establish a property of an estimator or sequence of random variables.

(D) Given an analysis situation, **formulate** research questions as measurable statements about parameters in the population.

(E) **Associate** a given statistical method with various statistical properties such as consistency, unbiasedness, and asymptotic normality.

(F) Clearly **communicate** statistical theory and its applications through both written and oral presentations.

(G) **Appreciate** the use of mathematics in statistical theory and **compare** and **contrast** mathematical and statistical thinking.

(H) Using fundamental ideas of convergence, likelihood, and probability, **research** a topic in statistical theory not discussed in the course and **educate** your peers on the topic.

Course Prerequisites

MA382 or the combination of MA381 and MA223. In particular, students should have a firm grasp on basic statistical methods and exposure to essential probability theory. In addition, mastery of integrals and derivatives will be expected. Other courses which may be useful (but not required) include linear algebra, real analysis (ability to construct well-written proofs), and statistical computing.

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Office Hours:
I do not have regular office hours dedicated to this class. When you have questions, feel free to email or drop by. A copy of my schedule is available on my office door. Or, you may email me to schedule an appointment.

Instructor Biography

After graduating from Rose-Hulman Institute of Technology in 2006 with a degree in Mathematics and Economics, I attended graduate school at North Carolina State University where I earned my Ph.D. in Statistics under the direction of Dr. Dennis Boos and Dr. Len Stefanski. My primary interest is biostatistics - the application of statistical methodology to medical research. As a former participant in the NHLBI Integrated Biostatistical Trainee Program for CVD Research, I spent five years as an intern at the Duke Clinical Research Institute serving as a statistical consultant under the direction of Karen Pieper.

My research interests include methods for variable selection (the process of discerning which variables are useful for predicting a response) and statistics education (how to teach my discipline in a way that gives the best student learning experience).

I was hired into the math department to teach primarily statistics. Since joining the faculty at Rose-Hulman, I have completely redesigned this course to develop a complete introduction to statistical theory through the lens of likelihood-based inference. In addition to teaching statistics, I am the faculty adviser for the InterVarsity Christian Fellowship chapter on campus.

Textbook (Required)

- **Title:** **Mathematical Statistics: An Introduction to Likelihood Based Inference**
- **Author:** Rossi
- **ISBN:** 978-1-118-77104-4

The textbook is **highly recommended for an additional source**. I have yet to find a textbook which covers the topics I want to include in the course at a level appropriate for your background with equal weight given to theoretical development and application of that theory. This text is the closest I have come, as it has the same framework we will present in the course. While reading assignments will not be made out of the text, it should be clear which sections serve as useful reference.

Course Notes

Each module in the course includes a packet of guided course notes. The guided notes promote participation in class discussions and examples. The guided notes provide a framework for your course notes. Additional comments made during the term, especially in response to student questions, should be added to your course notes.

Software

- **RStudio:** R is a freely available statistical computing language. RStudio provides a nice interface to the computing language. While you can obtain a copy from the website for your machine, Rose-Hulman faculty, staff, and students have access via a web interface; the link to this interface is provided under the Key Resources block on the right-hand side of the course page. It is extremely useful for writing simulations and statistical programs. No familiarity with the program is expected. While you may use any computing environment you wish, R will be demonstrated in class.

Colleagues

Instructors and fellow students will be invaluable during this course. Like many other theory-heavy courses, relying on others will be important. Do not hesitate to ask questions or work in teams. Often, the best solutions to theoretical problems come after bouncing ideas off someone else. The instructor is a potential resource, as well as your fellow students.

This course tries to balance two competing ideas: exposure to several areas of theory and mastery of a few areas. I think there is a sweet spot in the middle, but that increases the temptation to learn just enough to get by...the result is that you leave the course feeling ill-prepared to read statistical literature or succeed in graduate school. I want this course to create a strong foundation for you, even if only a small foundation. In order to help you achieve this, along with the objectives of the course, I will be implementing a version of "specifications-based grading." That is, instead of taking a weighted average of points earned on a series of assignments throughout the term, you will earn grades based on the requirements you choose to complete (described below). Each assignment is graded pass/fail (meaning no partial credit is awarded). In order to help you achieve a passing score, very clear expectations will be provided on every assignment. You have complete control over your grade in the course; I will provide you with the necessary tools and feedback to help you achieve your desired grade.

Homework:

Homework Assignments are the meat of the course. You should expect to spend several hours each week working on homework. **It is ill-advised to attempt to complete an assignment in a single sitting.** One homework assignment will be given for each module (for a total of 9 assignments). The due date for each assignment is listed on the calendar for the course; typically, homework will be due each Tuesday. **Each homework is due by 5:10 pm on its due date**. Late homework will not be accepted unless previous arrangements have been made with the instructor at least 24 hours prior to the due date.

Each homework assignment will consist of 8 potential problems, 2 from each of 4 categories:

- Derivations: deriving quantities in specific applications based on definitions presented in the course which had been abstracted to general settings.
- Establishing Properties: showing that a particular property is exhibited in a particular setting. Similar to a proof, but not as broad of an application.
- Additional Theorems: proving general results beyond those discussed in class.
- Applications: applying the theoretical concepts being discussed in the course to problems which are directly related to data analysis.

You must submit **1 problem from each of the 4 categories** (for a total of 4 problems). Homework is an *individual* assessment (each student must complete their own assignment); however, you are encouraged to work with one another (see the **guidelines for appropriately working together**).

Homework is to be type-written (using software which typesets mathematical equations; LaTeX or Word, as an example) or neatly hand-written. If code is required, the code (along with any appropriate output generated) should be attached with the assignment. Homework is a chance to demonstrate what you know; it should be well communicated (anyone familiar with statistical theory should be able to pick up your assignment and understand what you mean by your solution).

Each problem will be graded using the **course rubric**. In order to successfully complete an assignment, you must earn 14 out of the potential 16 points.

Midterm Exams:

Midterm exams are to ensure that you can make connections between the course material and identify the appropriate approach to take in various situations. There will be two comprehensive take-home midterm exams given during the course (approximately weeks 4 and 8). These exams permit the use of course materials and static materials found online and in other texts. However, you may *not* ask for help from anyone other than the instructor during the exam (including the use of message boards). Be sure to follow all instructions given with the exam. Each exam will consist of 10 questions of varying difficulty.

Each problem will be graded using the **course rubric**. The number of points earned on the exams will contribute towards your course grade.

Capstone Project:

Over the course of the term, we will cover quite a bit of material regarding the theory underlying many statistical methods. However, there are countless fascinating topics we will leave untouched. The **capstone project** is an opportunity to explore some of these topics. This assignment is only required for those wanting to earn an A or B in the course. The project asks you to read a peer-reviewed journal article, textbook section, or a post on a well-established website (provided by the instructor) regarding a topic of your choosing (from a list approved by the instructor). **All topics must be approved by the end of the 6-th week of the course as no more than 2 students may present on the same topic.**

Each topic will extend the material covered in the course. You will have a few minutes to present the major ideas to the remaining students in the course (similar to a "journal club"). All presentations will take place during 10th week. You will want to ensure you give yourself adequate time to dig into the material and learn it to a sufficient depth to be the "expert in the room" on the topic. This is more than reading a section of a textbook.

On the last day of the course, students completing the **capstone project** will take an in-class assessment on the topics presented. As a result, it is highly encouraged that you deeply engage with the presentations. Successful completion of the **capstone project** requires the following:

- The presentation should clearly motivate the topic.
- The presentation must include a brief introduction to the relevant statistical theory through the inclusion of a well-chosen example. The theory developed should be "connected story" (not a list of fragmented components) and presented without major errors. The example chosen should be meaningful (not trivial).
- While you need not be an expert on all areas of the topic presented, you should know more than what was presented. You are expected to have an idea of how the material connects to other topics and major ideas. You should be able to answer reasonable questions posed by other students and the instructor.
- Achieve an 80% on the in-class assessment.

While this assignment may sound daunting, it is meant to be an enjoyable way to celebrate your learning in the course. You get to be in the driver's seat. You get to decide what is important to be learned. Your presentation could be a slide presentation, rely solely on board work, use computer programs to illustrate a concept, include an active-learning activity, include a hand-out, etc. There are many styles to a lecture (even short ones). You will not be graded on your presentation style...only the content.

Rewrites:

I recognize that life happens. We each have our individual priorities, and these may not align with the course schedule and requirements at all times. In those moments, the nature of the course grading scheme may be overwhelming. The best way to prevent this is to start assignments early in order to provide an opportunity to ask intelligent questions of the instructor and others when you need help. Waiting until the last minute to begin an assignment will often result in work that does not meet the criteria for a successful completion.

An alternative is to make use of assignment rewrites. This policy is solely here to promote learning the course content, not for bailing you out when you make poor choices. You should not abuse the policy. Each student will be given 2 "tokens" in the course. Tokens create a type of barter economy in the course. You can use your tokens toward a rewrite on a course assignment according to the following policy.

- A homework assignment earning 12 out of 16 possible points may rewrite the assignment at *no cost* to the student.
- A homework assignment earning less than 12 points may be rewritten at the cost of 1 token.
- A midterm exam may be rewritten in order to earn up to an additional 4 points (1 letter grade) at the cost of 1 token.
- No more than two homework assignments may be submitted each week (the assignment due and 1 rewrite, or 2 rewrites, for example).
- All rewrites must be submitted by the last day of the term.

When submitting a rewrite, include *both* the original submission as well as corrected versions of the problems you are reworking. It is *not* sufficient to just write in the margins of the original submissions. You must actually submit a clean corrected solution. Be sure to note at the top of the submission that you are handing in a rewrite.

Grade Computation:

Course grades are earned according to the following rules:

Letter Grade	Requirements
A	Successfully complete 8 homework assignments. Obtain at least an 85% on both midterm exams. Successfully complete the **capstone project**.
B	Successfully complete 7 homework assignments. Obtain at least a 75% on both midterm exams. Successfully complete the **capstone project**.
C	Successfully complete 6 homework assignments. Obtain at least a 70% on both midterm exams.
D	Successfully complete 5 homework assignments. Obtain at least a 60% on both midterm exams.
F	Failure to meet requirements for a D

A "plus" grade in the course can be earned by meeting all requirements for the corresponding base grade and making significant progress (determined at the discretion of the instructor) toward the next letter grade.

Academic Misconduct Penalty

Expectations for upholding academic integrity, and the importance of academic integrity within the institution, as well as the departmental policy on academic integrity, can be located in the last chapter of the course syllabus (Institute Policies). In this section, we simply outline the penalty for academic misconduct. If a student commits academic misconduct on an assignment, the following action will be taken by the instructor:

- A letter will be sent to the student, the student's academic advisor, the Head of the Department of Mathematics, and the Dean of Students outlining the incident.
- The student will receive a 0 for the assignment on which the misconduct took place; no rewrite will be possible.

This policy is consistent with the **Mathematics Department's Academic Integrity Policy**.

To ensure you are not found in violation of the standards of academic integrity, you are encouraged to read the **Student Handbook**. Finally, note that all assignments in the course are "individual" assessments, meaning you are fully responsible for all content you put on the page. The instructor reserves the right to ask you to justify your work in person at any time; failure to be able to adequately describe your thought process will suggest academic misconduct on the assignment and will be subject to the above policy.

Students with Disabilities

Rose-Hulman is committed to working with students who have special needs or disabilities. Such students may be eligible to receive accommodations that provide equal access to learning, the living and learning environment, and college activities. After being admitted to Rose-Hulman, students must establish their eligibility for accommodations by notifying the Disability Services Coordinator of the disability and providing sufficient documentation. Students must provide as much documentation as possible about the disability and resulting substantial limitations. Documentation less than three years old by a psychiatrist, psychologist, medical doctor, school counselor, licensed clinical social worker, or other licensed health provider is acceptable.

Students with documented disabilities should contact **Student Accessibility Services**, 30 days prior to the course start date, for current regulations and more information and assistance. **Students requiring extended time on an exam should contact the instructor at least 3 days prior to an in-class quiz or exam to arrange a time to take the assessment.**

Emergency Information

To receive email or text messages regarding emergency situations that may impact campus and, possibly, the delivery of classes, register for RAVE alerts and/or follow @Rose-HulmanAlert on Twitter. Any announcements about the Institute's ability to offer classes will be shared on Rose-Hulman's website.

Student Handbook

This course adheres to all policies described in the **Student Handbook**. A few key sections are briefly outlined below. *Rose-Hulman expects its students to be responsible adults and to behave at all times with honor and integrity. All students are expected to abide by this code and to aid in its enforcement by reporting violations of it.*

Dropping the Course

You are responsible for understanding the university's policies and procedures regarding withdrawing from courses found in the current catalog. You should be aware of the current deadlines according to the **Rose-Hulman Academic Calendar.** More information for Drops and Adds can be found on the **Registrar's site here**.

Academic Integrity

Academic integrity is an integral part of the Rose-Hulman community. It is important that all members of our community learn to properly acknowledge the important contributions of others in our respective fields, both within Rose-Hulman and external to Rose-Hulman. Understanding how to work in collaboration with others and how to incorporate their work into your own, and then appropriately acknowledging them, demonstrates your intellectual maturity and a high degree of professionalism. Academic integrity refers to maintaining a high standard of honesty in academic conduct. All students and faculty are encouraged and required to show academic integrity at all times. On the other hand, academic misconduct is a failure of academic integrity. Specifically, academic misconduct is cheating, plagiarism, or interfering with the academic progress of other students.

The **Academic Rules and Procedures document** provides extensive rules and procedures for academic and other misconduct. The Mathematics Department follows these rules seriously. The minimum penalty for such misconduct is for the instructor to award zero credit for whatever test, exam, project or quiz on which the misconduct occurs, even if it results in a lowered or failing grade. A report of the misconduct will be sent to the Dean of Students, Mathematics Department Head and the student's adviser. Faculty members may exact a higher penalty, up to and including failure in the course if they feel the misconduct warrants such action. Students may appeal the sanctions to the rules and discipline committee, per the cited web page.

Plagiarism is a serious offense, and students are expected to adhere to the Rose-Hulman policy on plagiarism and cheating. Some individuals might say that they did not understand what plagiarism was when they took credit for someone else's ideas, but ignorance is not an excuse for lack of academic integrity. It is each student's responsibility to know the Rose-Hulman policy on academic honesty, including plagiarism, cheating, dishonest conduct, and collusion. This not only includes misrepresenting others' work as your own, but also summarizing, paraphrasing, use of any other material in your work, and incorrect or incomplete citations and references. Using the same work for multiple courses is also dishonest. If you have any questions concerning rules, procedures, or about academic honesty, plagiarism, cheating, dishonest conduct or collusion, please speak with your instructor or with the Associate Dean of the Faculty.

Course Information Copyrights

For further information please refer to **Rose-Hulman Library information on Copyright**.

Statement of Non-Discrimination

It is the policy of Rose-Hulman Institute of Technology to admit students on the basis of their academic ability. Rose-Hulman Institute of Technology does not discriminate based on race, religion, color, national origin, sex, age, citizenship status, disability, veteran status or sexual orientation.

The Higher Learning Commission

Rose-Hulman is accredited by the **Higher Learning Commission**, Chicago, IL 60602-2504, 312-263-0456.