Physics 629: Statistical Tools for Physics Research

Dr. Anuradha Gupta

Fall 2023

Class Hours: TTh 9:30 - 10:45 am
Office Hour: By appointment
E-mail: agupta1@olemiss.edu
Zoom: https://olemiss.zoom.us/j/95414974946

Class Room: Lewis 104
Office: Lewis 208

Course Description

This course aims to provide a general introduction to statistics and how to make sense of datasets and how to extract physics from the data. We will cover the basic ideas from classical (frequentist) and Bayesian statistics, hypothesis testing, model selection, parameter estimation, population inference, and time series analysis.

Course Objectives

The course will be useful for students working in the area of Physics that requires handling and analyzing large amount of data. The topics will not be expounded in great depth, but some of the key ideas will be described to provide familiarity with the concepts. The goal of the course is to establish sufficient grounding in statistics that students will be able to understand research seminars and papers, and know where to begin if carrying out research in their own dissertation.

Prerequisite

Some basic knowledge of Python programming is desirable. Taking Phys 540: Introduction to Scientific Computing before this course would be ideal.

Textbook

I will mainly be following: “Statistics, Data Mining and Machine Learning in Astronomy: A Practical Python Guide for the Analysis of Survey Data” — Ž. Ivezić, A. J. Connolly, J. T. VanderPlas, and A. Gray, but will be taking inspiration from other books on statistics, online courses on statistics, and my own research.
The astroML project accompanying the text is freely available.

**Topics Covered**

- Role of probability in inference
- Frequentist inference
- Bayesian inference
- Bayesian parameter estimation and model selection
- Exploratory data analysis and visualization
- Regression analysis
- Time-series analysis
- Machine learning and neural networks (if time permits)

**Grading**

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Homework</td>
<td>40%</td>
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<tr>
<td>Class Participation</td>
<td>15%</td>
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<tr>
<td>Midterm Exam</td>
<td>15%</td>
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<tr>
<td>Final Project</td>
<td>30%</td>
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<tr>
<td><strong>Grand Total</strong></td>
<td><strong>100%</strong></td>
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**Grading Scale**

- 90% ≤ A ≤ 100%
- 80% ≤ B < 90%
- 70% ≤ C < 80%
- 50% ≤ D < 70%
- F < 50%

**Evaluation**

**Homework**

Homework will be due weekly on Fridays at 11:59 pm CT. We will use GitHub to submit homework. Further details will be discussed on the first day of class. All solutions must include narration to explain how the problem was solved. Solutions without adequate method commentary will have points deducted. Code will be graded on (i) how well it is commented, (ii) how well it is structured, (iii) how well it is made compact and optimized, (iv) its speed, and (v) its efficacy in delivering the correct answer.
Class Participation

A class will be a combination of me explaining the material (lecture format) and we solving problems collaboratively using Jupyter notebooks running on personal laptops. Participation credit will be assigned by submitting your completed copy of the lecture Jupyter notebook, with required tasks indicated therein. All completed lecture notebooks for the class must be submitted by 11:59 pm CT on the day of the class. Credit is given for making a reasonable attempt at all tasks in the notebooks.

Mid Term Exam

A midterm exam will be conducted during one of the classes where the exam will have some theory-based questions and some code-based questions. Date of the midterm is not decided yet.

Final Project

Student will complete a capstone project on a topic of their choosing (but will require my approval). This should employ data-analysis principles learned in the course, and can involve data from their field of study. Student will write a journal-style article (4 to 5 pages without references) that includes an abstract, introduction, methods, figures, references, and appendix material. The primary goal of this project is to take something complicated and find a simpler way to explain it (in your own words). Don’t just repeat information from the textbook or other resources. The appendix material should be in the form of a Jupyter notebook that can reproduce the main calculations and figures of the article. The grading rubric for this project is as follows:

- By October 20th, please e-mail me with your topic. (10%)
- By November 3rd, please e-mail a 1-page abstract of your project. (10%)
- During class-time on November 14th and 16th, make a conference-style 15 minute presentation to the class on your project. (20%)
- By 11:59 pm CT on December 5th, submit your article PDF and appendix Jupyter notebook to me by email. (60%).

Course Policies

Attendance Policy

Attendance is required. If a student is absent for more than 3 class meetings during the semester, the final calculated grade will be reduced by a letter grade when final grades are assigned. If you are unable to attend in-person for any reason, I will make every effort to accommodate you. Note that allowances will be made in case of illness due to covid-19 or other illness. University of Mississippi policy requires that attendance be verified for every student during the first two weeks of classes.

Academic Integrity and Honesty

Every student of the University of Mississippi, by virtue of choosing to be part of the university community agrees to abide by the University of Mississippi Creed and the UM Academic Integrity Policy which covers academic integrity. Cheating on any assignment is forbidden and, in this course, will result in a zero grade on the given assignment. If
a second case of cheating occurs, this will result in an F for the entire course. Students should familiarize themselves
with the UM Academic Integrity Policy which is available in the Course Documents folder on Blackboard.
UM Creed The University of Mississippi is a community of learning dedicated to nurturing excellence in intellectual
inquiry and personal character in an open and diverse environment. As a voluntary member of this community:

• I believe in respect for the dignity of each person
• I believe in fairness and civility
• I believe in personal and professional integrity
• I believe in academic honesty
• I believe in academic freedom
• I believe in good stewardship of our resources
• I pledge to uphold these values and encourage others to follow my example

All materials distributed electronically and in hard copy in this class are protected under intellectual copyright. Any attempt to upload these documents onto the Internet (or to distribute them by some other means) or to profit from the distribution (by Internet or other means) of these documents constitutes theft and will be in violation of intellectual property law and the UM Academic Conduct Code unless expressly permitted for by the instructor. Accessing such materials for your own use is also in violation of the UM Academic Conduct Code. Additionally, the distribution of your own class notes via the Internet or other means, or access of such materials, is strongly discouraged except for occasional loaning of notes to students concurrently enrolled in the class.

University of Mississippi Access and Inclusion

The University of Mississippi is committed to the creation of inclusive learning environments for all students. University policy calls for reasonable accommodations to be made for students with disabilities on an individualized and flexible basis. It is the responsibility of students with disabilities, however, to seek available assistance at the University and to make their needs known. The University offices that help to ensure equitable access for students with disabilities are the Office of Student Disability Services, the Office of Equal Opportunity and Regulatory Compliance (The Executive Director of Equal Opportunity and Regulatory Compliance is also the ADA Coordinator), and the Office of the University Attorney. Students can contact Student Disability Services at 662-915-7128 so that office can facilitate the removal of barriers and ensure you have equal access to the same opportunities for success that are available to all students.