

CDS DS 120: Foundations of Data Science

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Office Hours: Monday : 11:30am-1:00pm, Wednesday : 11:30am-1:00pm, Friday 11:30am-1:00pm in CCDS 1402 (TC)

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Peer tutors: Info coming soon!!!!

Course Description

CDS DS 120 is the first in a three-course sequence (including CDS DS 121 and CDS DS 122) that introduces students to theoretical foundations of Data Science. The three courses take an iterative (spiral) approach to a set of foundational material in Calculus, Linear Algebra, and Probability.

DS 120 covers an introduction to key concepts from Proofs, Logic, Linear Algebra (vector spaces, matrices, and linear systems), Calculus (Differentiation and Integration), and Probability (discrete and continuous random variables). The four areas find culminating applications in Algorithms, hypothesis testing, gradient descent for neural networks, and regression. A detailed topic list is provided at the end of this syllabus.

The course is aimed at building the foundations of mathematical thinking, specifically through the use of problem sets that require students to answer mathematically-posed questions.

Hub Learning Outcomes

Quantitative Reasoning I (QR1) Learning Outcomes:

Students will develop understanding of a large set of fundamental theoretical tools used in quantitative reasoning: derivatives, random variables, probability distributions, summary statistics, vector spaces, matrices, and linear systems.

Through problem solving during discussion sections, students will develop skills in using computation to answer questions posed in mathematical terms.

Students will learn to interpret data in terms of probability distributions and also in terms of vectors. Students will develop skills presenting data visually in terms of plots, histograms, etc; symbolically in terms of matrix-vector equations and linear systems; and numerically in terms of summary statistics and fitted model parameters.

Students will develop an understanding of how regression relates to causality, the risks of misinterpreting correlations in data as indicating causal relationships, and techniques for establishing causal relationships.

Other Learning Outcomes (e.g., School, Department, and/or Program Outcomes)

On completion of DS 120, students will achieve proficiency in:

- Using probability to describe data and construct models, including models involving univariate distributions and discrete and continuous random variables.

- Using basic linear algebra (vectors and matrices) to describe and solve systems of linear equations, to represent data as points in vector spaces, to represent linear transformations in terms of matrices and matrix inverses, and to represent distances and lengths in terms of norms and inner products.
- Deriving derivatives of functions with multiple variables, and using differentiation to solve problems.
- Expressing solutions to mathematical and data analysis problems in computational terms and writing code to solve those problems.

This course contributes to the learning outcomes of the BS in Data Science with respect to:

- Foundations:
 - Mastery of the principal tools of data driven decision-making, including defining models, learning model parameters, and making predictions.
 - Understanding of how to use probabilistic models to make decisions.
- Integration and Application:
 - Ability to interpret and explain results .

Instructional Format, Course Pedagogy, and Approach to Learning

This course will be primarily a lecture heavy course where students will learn the mathematical foundations required for interpreting data during the lectures. The lectures don't require students to carry laptops. It will be pen and paper lectures with in class participation.

The discussion sessions will concentrate on applying the concepts learnt during the lectures to solve mathematical questions along with a review of the topics learnt during the lecture and on practicing further problems to bolster students' understanding of the concepts. The HomeWorks will serve as a method of applying the concepts learnt during the lectures and discussions to applied problems with almost every lecture followed by a homework. HomeWorks are also meant to check the students understanding of the concepts taught in class.

Books and Other Course Materials

The students may find the following free references useful for the course material:

Hefferon, Linear Algebra. Available free online:

<http://joshua.smcvt.edu/linearalgebra/>

Lane, Online Statistics Education: A Multimedia Course of Study. Available free online: <http://onlinestatbook.com/>

Strang, Calculus. Available free online:

<https://ocw.mit.edu/ans7870/resources/Strang/Edited/Calculus/Calculus.pdf>

Courseware

We'll be using Blackboard and gradescope for distributing assignments, collecting assignments, grading, and the distribution of course notes. <https://learn.bu.edu>
We'll be using Piazza for Q&A.

Gradescope entry code : RKZ5R2

Piazza Sign up link: https://piazza.com/bu/fall2023/23fallcdsds120_a1

Assignments and Grading

Students would be evaluated on their HomeWorks which would be given to them after every lecture. The HomeWork assignments are meant be short with occasional challenge questions to ensure the students' understanding of the concepts taught in class. HomeWorks will be due by the end of the week. HomeWork grading will involve grading one Random question from each homework so students are encouraged to solve and submit all the questions in the homeworks. **No HomeWorks sent via emails will be entertained. THERE WILL BE NO EXCEPTIONS TO THIS RULE.**

There will be occasional bonus questions which the students can use to make up for missed homeworks or lower homework grades.

Student participation is class (**especially discussions**) along with their involvement in Piazza will hold value as well.

If a student fails to attend at least 60% of the Discussions, they would not be graded for their Bonus Homeworks

In addition, students will be tested via two midterms and a final exam. All of these are written, in-class exams.

Grading:

40% Homework Assignments

25% Final Exam

15% Midterm1

15% Midterm2

5% Class Participation (Lecture, Piazza and **Discussion**)

Resources/Support/How to Succeed in This Course:

1. To succeed in this course students should attend all lectures, come to discussion prepared with questions, complete all assignments on time, and discuss problems and material with fellow classmates.
2. Students are welcomed and encouraged to visit office hours.
3. The [Education Resource Center](#) offers free individual and group tutoring.
4. Accommodations for Students with Documented Disabilities: If you are a student with a disability or believe you might have a disability that requires accommodations, please contact the Office for Disability Services (ODS) at (617) 353-3658 or access@bu.edu to coordinate any reasonable accommodation requests. ODS is located at 25 Buick Street on the 3rd floor.

Community of Learning: Class and University Policies

1. Courtesy expectations. Students are responsible for supporting a courteous learning environment. Please show respect for other students' questions, and maintain an attentive attitude in class. If you have an advanced question to ask, try to make it accessible to the rest of the class. Explain things to other students with a polite tone.

2. Attendance & Absences. Attending class is optional but highly encouraged; behavior in class does carry some small participation weight. Regular absence

without notice will, however, be penalized. Attending recitation carries some participation credit. However, either can be waived with a reasonable request for accommodation. We will in particular waive for religious holidays; see the University [Policy on Religious Observance](#).

3. Assignment Completion & Late Work. Assignments will be submitted as PDF on Gradescope. After the deadline, **NO** late submissions will be allowed. ***NO HomeWorks submitted via email will be graded.***

4. Academic Conduct Statement

Students are expected to abide by the guidelines and rules of the Academic Code of Conduct. <https://www.bu.edu/academics/policies/academic-conduct-code/>

General Course Plan with Topics to be Covered: (Not written in stone!)

HomeWorks will be due by Saturday of every week.

Introduction

Module 1: Truths and Proofs

Introduction to Proof techniques and understanding a good proof

Introduction to proofs by Mathematical Induction

Introduction to Logic: Understanding mathematical statements and truth values, Existential vs. Universal Quantifiers, Specifying Quantification sets

Negation of Mathematical statements

Conditional statements, truth tables, Set Operations and Logical Connectives, Converse and Contrapositives, Biconditional Statements

Necessary and Sufficient Conditions, Proving logical equivalences

Module 2: Probability and Statistics

Overview of Sets

Introduction to Probability, choosing with and without order, Random Variables, Binomial Distribution

Introduction to Conditional Probability, Joint Distribution, Introduction to Bayes Rule

Expectation

Distribution and variance

Gaussian Distribution and Central Limit Theorem

Sampling Errors and Confidence Intervals

Bias and Bessel's Corrections

t-Distributions

Hypothesis Testing : t-tests, z-tests

Chi Square tests (if time permits)

Module 3: Linear Algebra

Introduction to Linear Algebra, Gaussian elimination, RREF

Introduction to vectors and Matrices, Operations on Vectors and Matrices

Introduction to Vector spaces and Bases, Matrix Inverse, Linear combinations, Linear independence

Ranks, Isomorphisms and Kernels

Projections

Linear Regression: Line of best fit

More linear fits, Introduction to Multiple Regression

Module 4 : Calculus and Gradient Descent

Introduction to Multivariable Calculus: review of Single Variable Calculus concepts, Derivatives w.r.t particular variables, second order derivatives, Maxima, Minima, Saddle Points

Introduction to Gradient: Second order Partial Derivative test, Directional Derivatives

Introduction to Gradient Descent and its limitations

Lagrange Multipliers

Introduction to Integral Calculus

Important Dates (Tentative)

Midterm1: October 16th , 2023

Midterm2: November 15th , 2023

Final: December 18th , 2023 (TBD by Registrar's Office)