

Bayesian Machine Learning

Overview

Instructor Name and Contact Information:



Dr. William Basener

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Subject Area and Catalog Number: Data Science DS 6014

Year and Term: Spring 2021

Class Title: Bayesian Machine Learning

Level: Graduate

Credit Type: Graded

Class Description

Bayesian approaches explicitly account for the uncertainty present in most machine learning problems. This uncertainty derives from both randomness in observational processes and incompleteness in problem understanding. This course focuses on building models from data that provide predictions and quantify the uncertainty in these predictions. Students will learn how to think probabilistically and apply this understanding to problems in a variety of areas.

Prerequisites

This course will be mathematical. You should have a good grasp of multivariate calculus and linear algebra. A previous course in statistics covering multiple linear regression and programming with familiarity in either Python or R are also required.

Required Text

- Barber, D., *Bayesian Reasoning and Machine Learning* (Cambridge: Cambridge University Press, 2012).
- Theodoridis, S., *Machine Learning: A Bayesian and Optimization Perspective* (Netherlands: Elsevier Science, 2015).
- Robert, C.,. *The Bayesian Choice: From Decision-Theoretic Foundations to Computational Implementation* (New York: Springer, 2007).
- Bishop, C.M., Bishop, P.o.N.C.C.M., *Pattern Recognition and Machine Learning* (Singapore: Springer, 2006).

Optional Reading

- DeGroot, Morris, *Optimal Statistical Decisions* (New York: McGraw-Hill, 1970).
- Gelman, Andrew, John B. Carlin, Hal S. Stern, and Donald B. Rubin *Bayesian Data Analysis*, 3rd Ed. (Boca Raton, FL: Chapman & Hall/CRC, 2011).
- Kruske, John K., *Doing Bayesian Data Analysis: A Tutorial with R, JAGS, and Stan* (London: Academic Press, 2015).
- Martin, Osvaldo, *Bayesian Analysis with Python*, 2nd Ed. (Birmingham, UK: Packt, 2018).
- Ross, Sheldon, *Introduction to Probability Models*, 9th Ed. (Burlington, MA: Academic Press, 2007).

Learning Outcomes

Upon successful completion of this course, you will be able to:

1. Apply the appropriate probabilistic technique to use based on the characteristics of the problem.
2. Demonstrate the ability to convert actual data science problems from different domains into formal, mathematical representations.
3. Demonstrate the ability to apply appropriate analytical or computational solutions to obtain solutions to real problems.
4. Use results from current applied technical papers and video presentations to understand the latest methods and newest discoveries in Bayesian machine learning.

Delivery Mode Expectations

Web-based with weekly live meetings

Required Technical Resources and Technical Components

- [VPN app: Cisco AnyConnect](#)

Class-Specific Information

Class Instruction and Activities

The topics covered in this course include the following:

- Bayesian supervised learning
- The expectation maximization algorithm
- Variational approximation
- Markov chain Monte Carlo
- Bayesian graphical models

Evaluation Standards and Assessments

Homework	There are five homework exercises spread across the modules to provide problem-solving experiences that illustrate the concepts of Bayesian machine learning.
Participation	Participation includes module discussions, responses to peer posts, and participation and answering questions in live sessions, as well as helping others answer questions.
Quiz	This course has one quiz containing short answer questions. Example questions will be provided during the live sessions.

Project	Students will work in groups on a problem of their choosing and present their findings in a recorded presentation.
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Your final letter grade will be determined by the following scale:

A+	100	98.0
A	97.999	93.0
A-	92.999	90.0
B+	89.999	87.0
B	86.999	83.0
B-	82.999	80.0
C+	79.999	77.0
C	76.999	73.0
C-	72.999	70.0
D+	69.999	67.0
D	66.999	63.0
D-	62.999	60.0
F	59.999	0

Class Schedule

Live sessions will be held on Tuesday evenings from 7:00–8:00pm EDT.
Specific dates are in the "Live Sessions" tab in Collab.

Communication & Student Response Time

Discussion boards are set up in each module and are designed to be a place where students can reach out to peers and instructors to ask questions related to content and technology. Students are encouraged to check the discussion boards daily for updates and correspondence. Specific queries regarding your progress should be addressed to me via email, and you will receive a response within 24 hours. Throughout our time together, the sooner you inform me of any problem (personal or academic) that may affect your attendance or performance, the better the chance we have of solving it together.

Assignments

Homework (45% of grade)

All the homework exercises provide problem-solving experiences that illustrate the concepts of Bayesian machine learning. Hence, they provide the opportunity to demonstrate understanding of class material. These assignments will include both analytical problem solving and data analysis. For both parts, student answers should be written out, showing results with tables and graphs and explanations in the text.

Participation (10% of grade)

Student participation makes the course more interactive and enriching and includes module discussions, responses to peer posts, and attendance, participation, and answering questions in live sessions, as well as helping others answer questions.

Quiz (15% of grade)

The course will have one quiz containing short answer questions and is closed book. Example questions will be provided during the live sessions.

Project Presentation (15% of grade) and Project Report (15% of grade)

The goal of the project is for students to apply Bayesian machine learning to a real dataset in an advanced way to ensure students can apply probabilistic reasoning to a nontrivial problem of their choosing. The project will be graded based on the approach used and the demonstration of the students' understanding of probabilistic modeling and not on the comparative performance of different techniques. Students will work in groups of two or three people of their choosing, but may also choose to work alone with permission from the instructor. Students will first submit a one-page project proposal describing the problem, data, and approach, and the instructor will provide feedback. Students will present their projects as a group followed by a final four-page project report containing the problem, approach, results, and their conclusions and recommendations.

Grading

Assignment	Percent of Grade	Due
Attendance & Participation	10	All modules
Homework	45	Modules 2–12
Quiz	15	Module 12
Project	30	Module 12

Electronic Submission of Assignments

All assignments must be submitted electronically through Collab by the specified due dates and times. It is crucial to complete all assigned work—failure to do so may result in failing the class.

Technical Support

Technical Specification : Computer Hardware

- Operating system: Microsoft Windows 8.1 (64-bit) or Mac OS X 10.10
- Minimum hard drive free space: 100 GB, SSD recommended
- Minimum processor speed: Intel 4th Gen Core i5 or faster
- Minimum RAM: 4 GB
- Python 3.0 or later

Technical Support Contacts

UVA Collab: collab-support@virginia.edu

UVA Policies

SDS Grading Policies

The standing of a graduate student in each course is indicated by one of the following grades: A+, A, A-; B+, B, B-; C+, C, C-; D+, D, D-; F. B- is the lowest satisfactory grade for graduate credit.

Attendance

Students are expected to attend all class sessions. Instructors establish attendance and participation requirements for each of their courses. Class requirements, regardless of delivery mode, are not waived due to a student's absence from class. Instructors will require students to make up any missed coursework and may deny credit to any student whose absences are excessive. Instructors must keep an attendance record for each student enrolled in the course to document attendance and participation in the class.

University Email Policies

Students are expected to check their official UVA email addresses on a frequent and consistent basis to remain informed of University communications, as certain communications may be time sensitive. Students who fail to check their email on a regular basis are responsible for any resulting consequences.

Mid-Term and End-of-Class Evaluations

Students may be expected to participate in an online mid-term evaluation. Students are expected to complete the online end-of-class evaluation. As the semester comes to a close, students will receive an email with instructions for completing this. Student feedback will be very valuable to the school, the instructor, and future students. We ask that all students please complete these evaluations in a timely manner. Please be assured that the information you submit online will be anonymous and kept confidential.

University of Virginia Honor System

All work should be pledged in the spirit of the honor system at the University of Virginia. The instructor will indicate which assignments and activities are to be done individually and which permit collaboration. The following pledge should be written out at the end of all quizzes, examinations, individual assignments, and papers: "I pledge that I have neither given nor received help on this examination (quiz, assignment, etc.)." The pledge must be signed by the student. For more information, visit www.virginia.edu/honor.

Special Needs

It is my goal to create a learning experience that is as accessible as possible. If you anticipate any issues related to the format, materials, or requirements of this course, please meet with me outside of class so we can explore potential options. Students with disabilities may also wish to work with the Student Disability Access Center to discuss a range of options to removing barriers in this course, including official accommodations. Please visit their website for information on this process and to apply for services online: sdac.studenthealth.virginia.edu. If you have already been approved for accommodations through SDAC, please send me your accommodation letter and meet with me so we can develop an implementation plan together.