CS282R: Topics in Machine Learning / Stat 317
The Ultimate Inference Bake-off... with Bayesian Nonparametrics!

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Class Time and Location: MW 9:30-11 in MD G125
Office Hours: Finale: Wednesdays 3:30-4:30, MD 219, Pierre: Wednesday 4:30-5:30, SC 712

Overview

This course is fundamentally about gaining a deep understanding of state-of-the-art inference techniques for probabilistic models, with the goal of also thinking of ways to address their shortcomings. Since probabilistic models are obviously a very large area, we'll focus on Bayesian Nonparametric (BNP) models, which have the nice property that they can expand their capacity depending on the complexity of the patterns in the data.

After a brief overview of Bayesian Nonparametric models, we'll dive into one particular model, the Beta-Bernoulli process... and will begin our ultimate inference bake-off! We'll start by implementing the tried-and-true techniques (uncollapsed and collapsed Gibbs samplers, slice samplers, the most basic of variational inference schemes) and compare those to the current state-of-the-art. Along the way, we'll also discuss and debate different measures of inference quality. Importantly, while the course will focus on one model and its relatives, the core ideas will be broadly applicable.

Prerequisites

Students will be expected to be comfortable with distributions and inference at the level of something like CS281 or Stat 211. What that means: Can you derive the equations for Bayesian linear regression and implement it so it will run on a modestly-sized data set? Derive and implement a Gibbs sampler for a mixture model, perhaps with a custom MH proposal? Write the objective for variational inference? These should all be easy for you; we will be jumping quickly into more sophisticated inference techniques that go beyond these basics. Students may code in any language that they choose, but support will only be provided in Python and R.

Format

During the first four weeks of class, we will have lecture on Mondays and lab on Wednesdays. *Please bring laptops on lab days to participate in the labs.* The labs will also give students a head-start on the homework assignments. The goal of this first phase is to get everyone up to speed with—and have implementations of—basic inference for the Beta-Bernoulli process. For the remainder of the course, we will be reading and discussing papers. For papers that are particularly interesting to implement, we will augment that paper with a lab session. We hope that you'll be inspired by some of these additional lab sessions to explore the algorithms farther outside of class, but there will not be any additional required homeworks after the first four weeks.

Assignments and Assessment

There will be four programming assignments in the first four weeks of class which will require implementing different inference techniques (28% total). Students will also be expected to participate and lead discussions on papers (32% total) and complete a substantial project (40%).

Homework

The goal of the homework assignments is to get you familiar with Indian Buffet Processes (IBPs) and their inference; you will likely be using your code for future baselines so keep appropriate architectures in mind! Each assignment will "officially" start in lab on the Wednesday before it is due, but we will try to give you the assignments in advance so that you can also budget your time as needed. You will have two late days to use whenever you wish in the term, except for final project write-ups.

What you should submit: You should submit a write-up answering the questions posed in each assignment. Your write-up should be no more than 2 pages, though you may reference plots on additional pages (please do not make your plots tiny just to make them fit). Your code should be appended to the end of the write-up. *You will be graded on the write-up only. We will not run your code.*

Collaboration: You must include the names of any people you worked with at the top of your write-up, and in what way you worked them (discussed ideas vs. team coding). If you code with others—which can be very productive!—you must have been an active participant. We may occasionally check in with groups to ascertain that everyone in the group was participating in a team-coding exercise. Your write-up must be your own.

Paper Discussions

Starting with the fifth week of class, we will rotate through students presenting and discussing papers (the number of times each student presents will depend on the number of students in the class).

Presenters are responsible for reading the paper in advance and preparing a presentation (a) explaining the key ideas of the paper and (b) points for discussion. Expect to spend about half the class presenting and half the class in discussion.

Participants are responsible for reading the paper in advance and posting to Canvas with either some part of the paper you found interesting/insightful that you think is worth sharing with the class, or a question that you would like to have clarified.

Final Projects

The ideal final project would be something that you could submit to a workshop on Bayesian nonparametrics, or perhaps even something that could be grown into a conference paper. That said, the projects will be evaluated on the quality of your research process. It is entirely okay to try out a creative idea and find it doesn't quite pan out—as long as you can explain *why.*

We suggest one of three broad directions:

- *Application: Try out a Bayesian nonparametric model on a data set that you care about.* If you have an application that could use a Bayesian nonparametric model, this is the perfect opportunity to dive deep into figuring out what you need to do to make it work and compare performance to standard baselines!

- *Inference: Improve upon existing inference techniques for the Beta-Bernoulli process, its relatives, or another Bayesian nonparametric model.* As you will see in the class, inference in these models is far from solved. In this project direction, you would develop novel methods and compare them to existing methods for your chosen model.

- *Modeling: Explore alternate constructions for existing Bayesian nonparametric models, or develop new models that fill a modeling need.* New constructions for existing models can be interesting because they help us relate models and often are associated with novel inference approaches/bounds.

The final project need not involve Beta-Bernoulli processes, although that is a natural starting point. It must pertain either to Bayesian nonparametric models or modern inference. Assessment will include two checkpoints (5% each): In checkpoint one, you will submit a 2-3 paragraph summary of your intended project direction, along with relevant references. In checkpoint two, you will submit a 2 page update which includes (a) a clear statement of the question you are trying to solve, (b) how you intend to solve it, (c) assessment/how you will know when you have solved it, and (d) any preliminary results. The final report (30%) will be an expansion of this basic format. It is absolutely critical that your writing is clear, and that you explain *why* your ideas succeeded or failed. A series of indecipherable equations followed by dazzling plots alone will not result in high score, no matter how dazzling the plots!

Calendar

The following is a calendar of readings and assignments. Assignments will be due on Canvas.

Date	Theme	Assignments
Monday, January 23	Intro Lecture on BNP	
Wednesday, January 25	LAB: Simulating from the IBP	HW1 out
Monday, January 30	Posterior Inference: Gibbs Sampling with the IBP	
Wednesday, February 1	LAB: Gibbs Sampling with the IBP	HW1 due and HW2 out
Monday, February 6	Posterior Inference: Slice Sampling with the IBP	
Wednesday, February 8	LAB: Slice Sampling with the IBP	HW2 due and HW3 out
Monday, February 13	Posterior Inference: Variational Methods for the IBP	
Wednesday, February 15	LAB: Variational Methods for the IBP	HW3 due and HW4 out
Monday, February 20	Reed and Ghahramani; Shah, Knowles, and Ghahramani	
Wednesday, February 22	Evaluation	HW4 due
Monday, February 27	Evaluation	
Wednesday, March 1		Project Checkpoint 1 due
Monday, March 6	Inference	
Wednesday March 8	Models	
Monday, March 13	Spring Break	
Wednesday March 15	Spring Break	
Monday, March 20	Inference	
Wednesday, March 22	Inference	
Monday, March 27	Models	
Wednesday, March 29	Models	Project Checkpoint 2 due
Monday, April 3	Inference	
Wednesday, April 5	Inference	
Monday, April 10	Inference	
Wednesday, April 12	Inference	
Monday, April 17	Models	
Wednesday, April 19	Models	
Monday, April 24	Final Project Presentations	
Wednesday, April 26	Final Project Presentations	Final Project Write-ups due