Introduction to Bayesian Inference

(PSYCH 3KK3)

Term 2, 2009

Instructor
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Description
This course explores the far-reaching applications in science of a simple but remarkably insightful equation. First introduced in 1764, Bayes' equation (also known as Bayes' theorem) elegantly embodies the scientific method, in which predictions made from hypotheses are put to the test, and inferences regarding the relative merits of the hypotheses are drawn from the resulting data. Bayes' equation is increasingly used as a powerful research tool by scientists in all disciplines. Students will apply Bayes' equation to gain insight into core concepts of scientific reasoning, such as induction and deduction, and heuristics such as Occam's Razor. They will then learn modern statistical analysis techniques, derived from Bayes' equation, that provide a coherent and attractive alternative to the conventional p-value methods. This conceptually sophisticated course is presented in a fun, interactive, and mathematically accessible fashion.

The course meets twice per week in room BSB/B154: Mondays, 9:30 - 10:20 AM, and Thursdays, 9:30 - 11:20. A tutorial is held on Tuesdays, 10:30 - 11:20 AM, in ABB/270. Students are strongly encouraged to attend tutorial.

Lectures will be interspersed with critical thinking activities called Bayesian Brain Bogglers, which collectively account for 10% of the course grade. In addition, students will be graded on weekly homework exercises, two midterm tests, and one comprehensive final exam (see below for grading details).

The course web site plays an integral role in this course. The web site contains this syllabus, links to the online course textbook, homework assignments, and Bayesian inference information on the web, a form for anonymous feedback to the instructor, and a password-protected system for students to check

their marks. The web site also contains "Heads-Together," an online discussion forum for the students.

Objectives

Upon completion of this course, the student will understand:

- the concept of conditional probabilities
- how to work with the sum and product rules of probability theory
- the meaning of each element of Bayes' equation: prior, likelihood, and posterior
- key features of the scientific method which naturally emerge from the application of Bayes' equation, such as the interplay between deduction and induction in scientific reasoning, Occam's razor, the importance of open-mindedness, and the importance of skepticism.
- how Bayesian inference differs from the traditional (frequentist) statistical method
- how to apply Bayesian inference to simple two-and three- hypothesis situations drawn from clinical diagnostic testing scenarios (sensitivity and specificity problems), genetics testing (inferring genotype from phenotype), and other such scenarios.
- how to use Bayesian inference to estimate the values of binomial, Poisson, and Gaussian parameters
- how to apply Bayesian inference to linear and non-linear curve-fitting
- how to perform Bayesian model comparison and Bayesian model averaging

Materials

Required Textbook: Goldreich, D. (2008) Introduction to Bayesian Inference (online)

Students are responsible for reading each book chapter in its entirety. Some homework and exam questions may be based on material in the book that was not covered during lectures.

Note: The online book is a work in progress and may be modified slightly throughout the semester. If you are planning on printing the book, please wait until we reach the corresponding course section before printing each chapter, to ensure that you print the most recent version.

Required Calculator: The McMaster Standard Calculator (Casio FX-991) is permitted in exams and for in-class Brain Boggler exercises unless otherwise specified. This calculator is available at the McMaster Bookstore. No other calculator is permitted.

Schedule

The table below shows weekly topics, assigned readings, and homework assignments. Students are encouraged to read the assigned material prior to each lecture. At least 12-hours prior to each lecture, the instructor will link each topic description to a PDF file containing the majority of the slides that will be shown in lecture.

Week	Topic	Homework Assignment

	Basic Bayesian Inference & Parameter Estimation (Chs. 1 & 2)	
Jan 5 / 8		--
Jan 12 / 15		HW 1 (Due Jan 15)
Jan 19 / 22		HW 2 (Due Jan 23)
Jan 26 / 29		HW 3 (Due Jan 29)
Feb 2 / 5	Review (Feb. 2); Midterm Test 1 (Feb 5)	HW 4 (Due Feb 5)
	Curve Fitting, Robust Estimation & Etc. (Chs. 3 - 5)	
Feb 9 / 12		
Feb 23 / 26		HW 5 (Due Feb 26)
Mar 2 / 5		HW 6 (Due Mar 5)
Mar 9 / 12	Review (March 9); Midterm Test 2 (March 12)	HW 7 (Due Mar 12)
	Model Comparison & Averaging, Bayesian Brain (Chs. 6 - 8)	
Mar 16 / 19		
Mar 23 / 26		HW 8 (Due Mar 26)
Mar 30 / Apr 2		HW 9 (Due Apr 2)
Apr 6		--
TBA	Final Exam (comprehensive, 3 hours)	

Note: The course schedule may be modified during the semester, at the discretion of the instructor. Modifications will be made directly to the table above and announced in class.

Evaluation

The student is responsible for understanding all material covered in class (lectures and Brain Boggler exercises) and in the homework assignments. Any material covered in class or in homework assignments may appear on exams, including material that does not appear in the assigned readings.

The student's course percentage score is a weighted average of the following five items:

Item	Weight
Bayesian Brain Bogglers	10%
Homework Assignments	10%
Midterm Test 1	20%
Midterm Test 2	20%
Comprehensive Final Exam	40%

The student's course grade will be determined from the student's course percentage score, as follows:

Course Letter Grade	Course Percentage Score
A+	90-100
A	85-89
A-	80-84
B+	77-79
B	73-76
B-	70-72
C+	67-69
C	63-66
C-	60-62
D+	57-59
D	53-56
D-	50-52
F	0-49

Homework

Homework assignments will be linked from the schedule table (above).

Each homework assignment is due at the beginning of the corresponding class period. Late homework returns will not be accepted.

Students are encouraged to type their answers whenever possible.

Students may collaborate on homework assignments, if they wish, and collaborating students may choose to submit a single, group answer (maximum group size: 3 students). If this is done, then the name and signature of each contributing student must appear on the homework submission. Each student in the group will receive the same mark on that homework assignment. Students may change groups throughout the semester, or choose to submit their assignments individually.

The point value of each question will be indicated on the homework assignment.

The score for the entire homework assignment will always be reported on a 0-to-100% scale. For example, suppose an assignment has three questions, worth 2, 4, and 4 points each. If a student earns half credit on the first question, full credit on the second, and half credit on the third, then the student's score will be 1 + 4 + 2 = 7, and the score will be reported as 70%.

The student's homework assignment scores are reported online in the check marks system.

At the end of the term, the student's lowest homework assignment score will be dropped. The average of the student's remaining homework assignment scores will then be calculated. This is the student's course homework score.

Bayesian Brain Bogglers

The brain bogglers are in-class exercises designed to encourage critical thinking about Bayesian inference.

Some of the brain boggler exercises will require a calculator; the student should bring the McMaster Standard calculator (Casio FX-991) to class.

On average, about one brain boggler will be given in each hour of class time.

Unless otherwise announced, each brain boggler exercise is worth 2 points. Each answer will receive either zero, half, or full-credit (0, 1, or 2 points).

The student's running brain boggler total is reported online in the check marks system.

The student's brain boggler percentage score, used in the student's course percentage score calculation, is the number of brain boggler points earned divided by the total number of points possible.

Exams

The student should bring the McMaster standard calculator (Casio FX-991) to all exams. Only the McMaster standard calculator will be allowed.

Midterm exam 1 covers material from the first four course topics (weeks 1-4)

Midterm exam 2 covers material from the next four course topics (weeks 6-9)

The final exam is comprehensive; it covers material from all course topics.

Each exam is given a mark on a scale from 0 - 100%.

The student's exam marks are reported online in the check marks system.

Create-a-Question: As an optional exercise, students are encouraged to try to generate an excellent exam question of their own. Please email the instructor with your proposed exam question and answer. Questions that are carefully and articulately worded, and that probe student understanding of important concepts, will be considered for inclusion. The instructor will not inform you in advance of the exam whether your question will be used, and will not provide feedback as to whether your answer is correct. If it is used on an exam, your name will not be attached to your question, but a note will be attached to indicate that the question was student-generated. Furthermore, if it is used, your question may be edited and/or otherwise modified by the instructor.

Extra Credit

There are three ways for students to earn extra credit points in this course:

I. Students who provide an excellent, original answer on the Heads-Together forum, in response to another student's question regarding the course material, can earn an extra credit point.

An excellent answer is one that correctly and articulately explains a conceptually challenging topic. The answer is original if no similar answer has yet been posted by another student.

Each student can earn a maximum of one Heads-Together extra credit percentage point per week. The teaching assistants will read the forum each week in search of excellent original answers, and bring these to the attention of the instructor for final evaluation.

The student's extra credit points, if any, are reported online in the check marks system.

The extra credit points will be applied to the student's next exam score. For example, a student with 3 extra credit points, who scores 80% on an exam, will receive an exam mark of 83%. Extra credit points are added to the exam score up to a maximum of 100% on the exam. Any remaining points are then held over to the next exam. For example, if a student with 3 extra credit points scores 98% on an exam, then the exam score will be recorded as 100%, and the student's remaining extra credit point will be held over for the next exam.

II. If, in class, a student raises an excellent question that the professor cannot answer, the professor

may nominate the question for a Stump-The-Prof exercise.

If the student who asked the question is able to find a documented answer to the question, and email the answer to the professor, the student will earn the point.

Each student can earn a maximum of one Stump-The-Prof extra credit percentage point per week.

Like Heads-Together extra credit points, Stump-The-Prof extra credit points wil be applied to the student's next exam score.

III. Students who find a substantive mistake (e.g., a calculation or procedural error, not just a typographic error) in either the online textbook or in a homework assignment question, will earn an extra credit point for bringing that mistake to the instructor's attention.

Course Percentage Score Calculation Formula

The following formula is used to calculate the student's course percentage:

Course percentage score = (course homework score)(0.1) + (course brain boggler percentage score)(0.1) + (midterm exam 1score) (0.2) + (midterm exam 2 score) (0.2) + (final exam score) (0.4)

Missed Work

If a student misses a class period or an exam due to illness, personal circumstances, or late registration, it is the student's responsibility to notify the instructor and to submit appropriate documentation (e.g. note from physician) to the appropriate Faculty/Program office. A mark of zero will be entered for all missed Brain Boggler exercises, homework assignments, and exams unless the Faculty/Program office gives its approval. (If a student is unable to attend a class, then the student may submit the homework assignment by email, prior to the class period, to the instructor. Late email submissions will not be accepted.) It is the student's responsibility to learn all material that the student missed for any reason; this can be done by consulting with classmates, the teaching assistants, and/or the instructor.

Missed class periods: If Faculty/Program office approval is obtained for missed class periods, the total number of Brain Boggler points in the course used to calculate the student's Brain Boggler percentage score will be reduced by the number of excused Brain Bogglers that the student missed. Similarly, if Faculty/Program office approval is obtained for missed homework, the total number of homework points in the course used to calculate the student's homework percentage score will be reduced by the number of excused homework assignments that the student missed.

Missed Tests: If Faculty/Program office approval is obtained, tests missed due to illness or personal circumstances may be made up, or the course grade may be redistributed such that more weight is

applied to the other test / exams, at the discretion of the instructor. Make-up tests, if given, may differ in format and specific content from the original test. For example, a test consisting of written questions (1-hour) and oral questions (-hour) may be given in place of a 2-hour written original test.

Academic Integrity

As a student, you are expected to behave honestly and ethically at all times.

According to McMaster University's Academic Integrity Policy, you are engaging in academic dishonesty if you "knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage" (Academic Integrity Policy, p. 6).

This behaviour can result in serious consequences, such as a grade of zero on an assignment, loss of credit with a notation on the transcript that reads “Grade of F assigned for academic dishonesty," and/or suspension or expulsion from the university.

It is your responsibility to understand what constitutes academic dishonesty. The following are just three forms of academic dishonesty:

1. Plagiarism.
2. Improper collaboration.
3. Copying or using unauthorized aids in tests and examinations.

For more information on academic dishonesty and academic integrity, please read the Academic Integrity Policy: http://www.mcmaster.ca/academicintegrity

Online Privacy

This course makes use of an online discussion forum. You should be aware that your chosen forum username will be apparent to all other students in the course. The technology used in the course web pages is designed to keep private all additional information you provide (your name, email address, student number, and passwords). However, you should be aware that submission of such information on this or any other web site always carries some risk that the information will become public (for example, if the web site is "hacked" unlawfully). Your continuation in this course will be interpreted to indicate that you consent to the disclosure of your chosen username in the online forum, and that you accept the risk of submitting the additional requested information. If you have any questions or concerns about the privacy of your information, please discuss these with the instructor.