Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science
6.438 Algorithms for Inference
Fall 2021

Information Sheet

Lecturers

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Lectures:	Tuesday and Thursday, 9:30am–11am, Room 32-123
Recitations:	Friday, 10–11am or 11am–noon, Room 1-190
Office Hours:	Days, times and locations posted on stellar site.

Welcome to 6.438 !

This is a graduate-level introduction to algorithms for statistical inference, with an emphasis on those arising out of graphical representations. As such, it is a core graduate subject for students in the relevant subfields both within and beyond Course 6 (EECS). The material in this course constitutes a common foundation for work in, for example, machine learning and data science, artificial intelligence, signal processing, computer vision and computational imaging, communication, bioinformatics and neuroscience, finance and data analytics, and networks, robotics, and control. Moreover, it is the companion subject to 6.437 (Inference and Information) which is offered each Spring; 6.437 and 6.438 may be taken in either order.

It is worth stressing that 6.438 is an *introductory* graduate subject: it is not an advanced graduate subject for students who already have a mastery of statistical inference algorithms, and now want to understand such material at an even more sophisticated level. That said, the structure of this subject will be somewhat different than other such introductions to the topic.

Ultimately, the subject is about teaching you contemporary approaches to—and perspectives on—problems of statistical inference and learning. The development of the material that forms the basis for this subject has historically been very much driven by applications, and continues to be. However, our focus in the course will not be on these applications—which form the basis for entire courses of their own—but rather on the common problem-solving frameworks that they share. Nevertheless, we will cite various relevant applications as we develop the material and sometimes extract simplified examples from these contexts.

As with other core subjects, 6.438 has lectures and recitations, which are designed to complement each other. Recitations begin the first week of classes. There are two possible recitation times to choose from, as indicated above. Select to attend whichever suits your schedule best. In addition, the course staff will hold several scheduled office hours throughout the week, the details of which are provided on the class web site. You are welcome and encouraged to come to any and all of them you think might be helpful to you in clarifying your understanding of the material.

Prerequisites

The official prerequisites are 6.008, 6.041, 6.436, or 18.600, and 18.06, or their equivalents. Ultimately, what we require is *fluency* with both basic quantitative probabilistic analysis and linear algebra, together with some subsequent solid exposure to the engineering application of both. When in doubt, students whose undergraduate degrees are not from MIT should consult the staff to determine if they have had subjects that are effectively equivalent to the official prerequisites.

Reading

There is an evolving set of course notes for the class, which you will access by clicking on the Materials tab in the navigation bar of the class website and going to the "Course Notes" Section. The notes will be posted one section at a time over the course of the semester, with each installment posted in advance of its corresponding lecture(s). These notes are under perpetually active development, and as such are necessarily rough in places and contain bugs, which we will count on you to help us catch. Also, occasionally a section of the notes will be marked with a "$*$" after its number. Such sections constitute bonus material and thus optional reading; read them as your interests dictate and your time permits.

You may also find sections of some of the following supplementary texts to be useful and more in-depth auxiliary references for parts of the term:

C. M. Bishop, *Pattern Recognition and Machine Learning*, Springer, 2006. Available here.

M. I. Jordan, *Introduction to Probabilistic Graphical Models*, Lecture notes. Available here.

D. Koller and N. Friedman, *Probabilistic Graphical Models: Principles and Techniques,* MIT Press, 2009. Available here.

D. J. C. MacKay, *Information Theory, Inference, and Learning Algorithms,* Cambridge University Press, UK, 2003. Available here.

M. Mezard and A. Montanari, *Information, Physics, and Computation*, Oxford University Press, 2009. Available here.

These references are also listed in the the "On-Line Reference Texts" section under the Materials tab in the navigation bar of the class website. We suggest you initially hold off purchasing any books while you are gauging their usefulness to you.

More generally, if you are interested in further reading, either to strengthen your background, reinforce some of the concepts from lecture, or to probe some topics in more detail, you might want to take a look at the additional references on the course website, which have been selected with some care. To find them, click the Materials tab in the navigation bar of the class website and go to the "Further Reading" section. In particular, you'll find several papers containing a variety of useful insights, which are worth the effort to work through.

Note that the class material, including supplementary reading, is for your personal use only, as we have specifically been asked to not share or otherwise distribute any portions of them to others outside the subject.

Finally, we emphasize that the course notes do *not* replace the lectures and recitations. The notes will be necessarily incomplete, and many of the perspectives, interpretations, and insights will be developed in class. Conversely, lectures and recitations are not a substitute for the notes. Indeed, we will defer many details of our development to the reading materials. Thus, you should view class and the written materials as strongly complementary.

Problem Sets, Computational Problems, and Exercises

There will be 10 problem sets. Problem sets are due by 5pm on the Tuesday they are due (except the final problem set, which is never due). You will submit your problem set by scanning it and uploading to GRADESCOPE via the class web site. Problem set solutions will be available on the class website shortly after the due dates and times, and submissions received after the solutions are posted will be recorded as completed, but not graded.

While you should do all the assigned problems, only a randomly chosen subset will actually be graded. You will find some problems in the problem sets marked as "practice". These are not required, but you might find it helpful to work through them if you are looking for more practice working with the concepts introduced in class.

Don't be misled by the relatively few points assigned to homework grades in the final grade calculation! While the grade you get on your homework is only a minor component of your final grade, working through (and, yes, often struggling with at length!) the homework is a crucial part of the learning process and will invariably have a major impact on your understanding of the material.

Some of the problem sets will involve a computational component, to help you explore additional aspects of the material. These computational problems will be PYTHON-based, and will be graded separately from the rest of the problem set that they appear on.

Many students find collaborating with one or two classmates on the problem sets helpful, and we very much support and encourage this. Just remember that your writeup (and all code) needs to be your own, and you need to identify your collaborators in your writeup. While you'll no doubt meet classmates to collaborate with in lecture, recitation, and office hours, you may also find others through Pset Partners, which is an online system developed at MIT that matches students to small groups for working on problem sets, based on the preferences specified by each student. The first matching round will take place on Friday September 10.

To help you get started with the problem sets, sometimes there will be an accompanying exercises handout posted on the website at the same time. These exercises are simple worked examples that illustrate some of the basic calculations that the problem sets will, in turn, build on. You're free to use these exercises any way you find helpful to you in preparing for the homework. Note that the exercises are a new resource we are currently developing for the class, so we do not yet have a complete set of them and thus their coverage will be uneven until we do.

Exams

There will be two quizzes in the subject. The first quiz will be held Wednesday evening, October 20, 7-10pm in 32-141. The second quiz will be held during finals week, on Thursday, December 16, 9am-noon, in Walker Memorial (50-340). The quizzes will be designed to require 1.5 hours of effort, but we'll use the three hour format to minimize the effects of time pressure. The quizzes will both be *closed book*. You will be allowed to bring *two* 8.5×11-inch sheet of notes (both sides) to the Midterm Quiz, and *four* 8.5×11-inch sheets of notes to the Final Quiz. You will take the quizzes in-person, and immediately thereafter scan and upload your completed quiz (e.g., using a phone camera) to the class Gradescope site discussed later in this document.

Class Grade

The final grade in the class is based upon our best assessment of your understanding of the material during the semester. Roughly, the weights used in grade assignment will be:

Midterm Quiz	35%
Final Quiz	40%
Problem Sets	15%
Computational Problems	10%

with an additional property that if you do better on the Final Quiz than the Midterm Quiz, and you have done all the homework, then the Midterm Quiz will not count, i.e., the Midterm quiz can only help you if you are doing all the homework.

As always, other factors such as contributions to the lecture discussion and other interactions can make a significant difference in the final grade.

Online Platforms and Resources

We will make use of multiple online platforms and resources in 6.438.

Stellar, Athena, Certificates

We will make announcements via email, and we will post information and handouts on the 6.438 class website, which resides on the Stellar platform:

`http://stellar.mit.edu/S/course/6/fa21/6.438`

You should first make sure that you have an active Athena account (by visiting `http://ist.mit.edu/support/accounts/` if necessary) as well as a personal certificate (by visiting `https://ca.mit.edu/ca/` if necessary). If you have problems or if you are not a regular MIT student, please contact one of the TAs for assistance.

You will need to have a valid certificate *and* be on the official course list to access the website. If you have pre-registered for 6.438, this should have already been set up; just double-check that you can access the website (try to download a handout, for example). Otherwise, contact one of the TAs. If you can access content on the website, you should also be receiving all of the course announcements.

Gradescope

You will submit homework and quizzes on Gradescope, which you can access via the Gradescope tab in the navigation bar of the class website, logging in with MIT as your school credential and providing the entry code `GE82GX` as necessary.

Piazza

We will use Piazza as an online discussion forum, which you can access (and enroll yourself in) via the Piazza Forum tab in the navigation bar of the class website. Through Piazza you can post questions or comments (anonymously to your peers or otherwise) about any aspects of the material, which your peers and the staff can respond to. It is a popular resource in the course for clarifying potential points of confusion in class notes, problem sets, computational problems, recitation handouts, etc.

Email

Finally, if you have administrative questions during the term, you can send email to

6.438-admin@mit.edu

We will be glad to help you, but please be sure that your question isn't already answered in this handout before you email us!

Tentative Syllabus and Schedule

Homework				Lectures	
Out	**Due**	**Day**	**Date**	**#**	**Lecture Material**
1		R	9/09	1	Introduction and overview
		T	9/14	2	Directed graphical models
		R	9/16	3	Undirected graphical models and factor graphs
2	1	T	9/21	4	Marginalization and the elimination algorithm
		R	9/23	5	Computing beliefs on trees: sum-product algorithm
3	2	T	9/28	6	MAP elimination and max-product algorithm
		R	9/30	7	HMMs; forward-backward, Viterbi algorithms
4	3	T	10/05	8	Inference on factor trees
		R	10/07	9	Junction tree algorithm
		F	10/08		*Add date*
5	4	T	10/12	10	Loopy belief propagation
		R	10/14	11	Loopy belief propagation: the Bethe interpretation
6	5	T	10/19	12	Variational methods
		W	10/20	Q	**Midterm Quiz**, 7-10pm (through L11 and PS5)
		R	10/21		*No class*
		T	10/26	13	Sampling methods I
		R	10/28	14	Sampling methods II
7	6	T	11/02	15	Equivalence of inference tasks
		R	11/04	16	Gaussian graphical models
8	7	T	11/09	17	Gaussian belief propagation
		R	11/11		*Veterans Day – No class*
		T	11/16	18	Gaussian HMMs and Kalman Filtering
		R	11/18	19	Sampling methods III: particle filtering
					Drop date
9	8	T	11/23	20	Parameterization, learning DAG parameters
		R	11/25		*Thanksgiving Vacation – No class*
		T	11/30	21	Learning MRF parameters
		R	12/02	22	Learning with latent variables; Baum-Welch algorithm
10	9	F	12/03		
		T	12/07	23	Exponential families; structure learning
		R	12/09	24	TBD
		12/13–12/17		Q	**Final Quiz** (through L24 and PS10)