CS5691: Pattern Recognition & Machine Learning

Jan-May Semester 2026
Slot: G
Class Timings: Monday: 12:00-12:50 pm, Wednesday: 5:00-5:50 pm, Thursday: 10:00-10:50 am, Friday: 9:00-9:50 am

Prof. Sukhendu Das, SSB 302; Phone: 4367
Email: *sdas@cse.iitm.ac.in*

Course TAs: CS21D015, CS23D002, CS25M030, CS25M035, CS25M041, CS25M037

Note: The course webpage is link. Please check your e-mail and Moodle regularly.

1 Course Objectives

In the recent past, algorithms of solving many ill-posed problems in the field of multi-dimensional signal processing and big data analytics have gained importance. New methods of signal representation, modeling, optimization and learning have been formulated, which spans over various areas of Machine Learning, Pattern Recognition, Vision and Natural Language Processing, Bioinformatics, HCI, Speech and Acoustics etc. This course will provide an overview of the theories and current practices, required by students and industrial practitioners who intend to specialize in this field, to understand and solve complex problems in Machine Learning for various fields of relevant applications

2 Learning Outcomes

- To learn existing algorithms of Machine Learning (ML) and Pattern Recognition (PR).
- To have hands-on experience in implementing various ML techniques on different datasets.
- To learn to compare the performance of two learning systems.
- To study few optimization methods used to estimate the parameters of a model during training.
- At the end of the course, the students should be able to design and implement machine learning techniques for solving pattern recognition tasks such as classification, regression, and clustering, and be able to evaluate and interpret the results of the techniques.

3 Course prerequisite(s)

Basics of Linear Algebra, Probability theory and statistics.

4 Classroom Mode

Traditional lectures (4 × [50 mins. slots] per week) with slides. 3-4 tutorials are tentatively planned to be conducted within these slots.

5 Textbooks

- Christopher M. Bishop, "Pattern recognition and machine learning", Springer, 2006.
- T. Hastie, R.Tibshirani, J. Friedman, "The Elements of Statistical Learning: Data Mining, Inference and Prediction", Springer Series in Statistics, 2009.

6 Reference Books

- V. N. Vapnik; "Statistical Learning Theory", Wiley, 1998.
- Kevin P. Murphy, "Machine Learning, a Probabilistic Perspective", MIT Press, 2012
- S. Theodoridis and K.Koutroumbas, "Pattern Recognition", Academic Press, 2009.
- Journal of Machine Learning Research; JMLR, Inc. and Microtome Publishing (United States).
- Conference Proceedings of ICML, NIPS, ICLR.

7 Course Requirements

You are required to attend all the lectures. If you miss any of them it is your responsibility to find out what went on during the classes and to collect any materials that may be handed out. Class participation is strongly encouraged to demonstrate an appropriate level of understanding of the material being discussed in the class. Regular feedback from the class regarding the lectures will be very much appreciated.

8 Planned Syllabus

Basics of Linear Algebra, Probability Theory and Optimization: Vectors, Inner product, Outer product, Inverse of a matrix, Eigenanalysis, Singular value decomposition, Probability distributions – Discrete distributions and Continuous distributions; Independence of events, Conditional probability distribution and Joint probability distribution, Bayes theorem, Unconstrained optimization, Constrained optimization – Lagrangian multiplier method.

Methods for Function Approximation: Linear models for regression, Parameter estimation methods - Maximum likelihood method and Maximum a posteriori method; Regularization, Ridge regression, Lasso, Bias-Variance decomposition, Bayesian linear regression.

Probabilistic Models for Classification: Bayesian decision theory, Bayes classifier, Minimum error-rate classification, Normal (Gaussian) density – Discriminant functions, Decision surfaces, Maximum-Likelihood estimation, Maximum a posteriori estimation; Gaussian mixture models – Expectation Maximization method for parameter estimation; Naive Bayes classifier, Non-parametric techniques for density estimation -- Parzen-window method, K-nearest neighbors method, Hidden Markov models (HMMs) for sequential pattern classification -- Discrete HMMs and Continuous density HMMs;

Discriminative Learning based Models for Classification: Logistic regression, Perceptron, Multilayer feedforward neural network – Gradient descent method, Error backpropagation method; Support vector machine.

Dimensionality Reduction Techniques: Principal component analysis, Fisher discriminant analysis, Multiple discriminant analysis.

Non-Metric Methods for Classification: Decision trees, CART.

Ensemble Methods for Classification: Bagging, Boosting, Gradient boosting.

Pattern Clustering: Criterion functions for clustering, Techniques for clustering -- Kmeans clustering, Hierarchical clustering, Density based clustering and Spectral clustering; Cluster validation.

9 Tentative Grading Policy

The following allocation of marks is tentative. The flexibility will be used to the benefit of average grades for the entire class.

MID-SEM (50 mins)	15-20
End Sem Exam (120-150 mins)	35-40
Assignments*	25-30
Tuts	05-10
Attendence	05-10
Total	100

* Students are expected to make their own arrangements- personal laptops, servers or desktops in their respective departments, or even use Google Collab.

Tentative Schedule (Dates)

Tentative dates of activities throughout the semester:

Tutorial 1	25/02/2026
Tutorial 2	22/04/2026
Mid Semester exam	05/03/2026
Extra Classes	TBA
Assignment submission deadlines	
Assignment 1	04/02/2026
Submission Deadline	27/02/2026
Assignment 2	04/03/2026
Submission Deadline	31/03/2026
Assignment 3	01/04/2026
Submission Deadline	02/05/2026
End Semester Exam	**14/05/2026**

10 Academic Honesty

Academic honesty is expected from each student participating in the course. NO sharing (willing, unwilling, knowing, unknowing) of assignment code between students, submission of downloaded code (from the Internet, or anywhere else) without stating credit of source is allowed.

Academic violations will be handled by IITM Sen- ate Discipline and Welfare (DISCO) Committee. Typically, the first violation instance will result in ZERO marks for the corresponding component of the Course Grade and a drop of one-penalty level in final course grade. The second instance of code copying will result in same as above for marks but drop of two levels of final course grades at end of semester. The DISCO Committee of IIT Madras will also be intimated of the matter.

Please protect your Moodle account password. Do not share it with ANYONE. Do not share your aca- demic disk drive space on the Campus LAN.

*Each **proxy** in the attendance will be penalized by **5%** of (absolute) marks. It becomes 2% each for the donor & beneficiary, if both accept the fault. Surprise attendance checks will be carried out randomly 2-3 times within the semester.*

*In case of defaulters of attendance, you are requested to apply formally using appropriate mechanisms (over workflow or email to Dean-AR office, say) only. Better check the protocols and regulations yourselves. Kindly do not disturb the faculty or TAs on this matter. If any such requests are found, a **penalty of 1%***

of marks will be deducted from the total score, before grading, for each such email/request.

11 Miscellaneous Restrictions

TAs may only be accessed over the following:

- *Status of attendance, as per records;*
- *Clarification of Tutorial or exam paper verification (with timelines as specified from time to time)*
- *Enquiry over Exam timings, or alterations of class timings, extra class hours (if any)*
- *Technical Clarifications over Assignments, deadlines etc.*
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Verification of exam papers often cause hazards/dissatisfaction. To ensure smoothness, the following protocol will be followed:

- *No scribbles/over-writing on paper will be allowed.*
- *Each such scribbles/strikeout will attract **50% penalt**y over the marks for that question; hence be over-careful while writing (ala bank cheque norms in RBI-GOI).*
- *Do not come with pen for paper verification; this will be done with groups of 2-3 students iteratively over timeslots*
- *No arguments with TAs or faculty over disagreement on the Q&A. As per ACAD circular guidelines, pl. maintain proper discipline, decorum and mannerism. Else, it will be treated as follow-up of exam and reported. We may record this session (on camera).*
- *You may be requested to write your argument against any answer which you feel to be not properly evaluated; - like a formal complaint. The entire answer paper may be reevaluated in such cases, along with correctness over English+Technical matter specified in query writeup. So, write the complaint and submit with caution*
- *After reevaluation, if you are still not satisfied, you may check with Fac Adv or HOD on this.*
- *Re-evaluation of End sem paper, after summer vacation is quite a hazard, for several reasons (faculty know). Simple verification may only be entertained.*
- *Finally, do not attempt to shift/move the dates of Endsem exams, as specified by ACAD section. This may be due to any reasons – Medical, personal, **Internship**, **placement**, competitions etc. Will try our best to adhere to the schedule given by ACAD section. If this is inconvenient, it may be better to avoid this elective course and choose alternate ones. Each such request (inspite of this notification) will be awarded with a small penalty.*
- *For Makeup and Supplementary – pl, follow official protocol (check academic ordinances and email/instructions from Dean AC office). Do not disturb the teacher or TAs on this.*

Tutorials are not exams. Occasional exchange of technical ideas are permitted, but not copying. No complaints of copying will be entertained after the tutorial. If you find anybody copying, immediately inform the TA's present in classroom. If found guilty, their copies will be taken away and they will obtain 0 marks for that tutorial. In case if classes are conducted in online mode, recording of any discussions on your digital device without taking permission of the teacher is disallowed. If any found to do that, will be reported to Dept/IITM level ethical committee.

*We will get a **signature** on a form, declaring that you have read and understood all these conditions specified in handout. Few items may later be added or modified. All these are done for smooth conduct of a large class (we are learning; also think of norms in nation-wide large exams in HSE, JEE, Gate, JAM, GRE etc.). If you do not sign this document, you may not be kept on roll - then recommended to be dropped from the course.*