Modules

This page shows the list of all the modules, which will be updated as the class progresses. There are three types of modules:

- [date]: It was covered in class, and you are responsible for the material.
- offline: It was not covered in class, but you are responsible for the material.
- optional: It was not covered in class, and you are not responsible for the material.

Date	Module	Links	Description
General			
Sep 23	Course content	html:slides,1pp,6pp pdf:1pp,6pp	What are we covering in this course?
Sep 23	AI History	html:slides,1pp,6pp pdf:1pp,6pp	Three histories of AI (logical, neural, statistical).
Sep 23	Ethics and responsibility	html:slides,1pp,6pp pdf:1pp,6pp	How should we think about the societal impacts of AI?
Prerequisites			
offline	Linear algebra	video pdf	Vectors, dot products, geometric interpretations.
offline	Vector calculus	video pdf	Taking gradients.
offline	Probability 1	video	Discrete random variables and probability distributions, mean, variance (from Khan Academy).
offline	Probability 2	video	Marginal and conditional distributions (from Khan Academy).
offline	Complexity	video pdf	Basic big-Oh notation, complexity.
offline	Optimization	video pdf	Continuous optimization, objective functions, gradient descent.
offline	Python	video code	Tutorial on using Python for this course.
Machine learning			
Sep 25	Overview	video (6:49) html:slides,1pp,6pp pdf:1pp,6pp	Overview of machine learning.
Sep 25	Linear regression	video (22:43) html:slides,1pp,6pp pdf:1pp,6pp code	Linear regression (with loss minimization and gradient descent).
Sep 25	Linear classification	video (28:01) html:slides,1pp,6pp pdf:1pp,6pp code	Linear classification (with loss minimization using hinge loss and gradient descent).
offline	Stochastic gradient descent	video (15:04) html:slides,1pp,6pp pdf:1pp,6pp code	Stochastic gradient descent.

optional	Learning demo	html:slides,1pp,6pp pdf:1pp,6pp	Interactive learning demo for supervised learning and k-means.
Sep 30	Group DRO	video (17:39) html:slides,1pp,6pp pdf:1pp,6pp	How to ensure more equitable performance.
offline	Non-linear features	video (14:04) html:slides,1pp,6pp pdf:1pp,6pp	How to get non-linear functions from linear machinery.
offline	Feature templates	video (11:51) html:slides,1pp,6pp pdf:1pp,6pp	How to design and organize features.
Sep 30	Neural networks	video (18:35) html:slides,1pp,6pp pdf:1pp,6pp	Introduction to neural networks.
Sep 30	Backpropagation	video (30:46) html:slides,1pp,6pp pdf:1pp,6pp	Computation graphs and backpropagation algorithm for computing gradients.
offline	Algorithms and distribution	video pdf	Ethical frameworks related to how algorithms distribute burdens and benefits.
optional	Differentiable programming	video (37:41) html:slides,1pp,6pp pdf:1pp,6pp	How to build larger deep learning models by composition.
Oct 2	Generalization	video (14:53) html:slides,1pp,6pp pdf:1pp,6pp	Basic introduction into generalization.
Oct 2	Best practices	video (23:49) html:slides,1pp,6pp pdf:1pp,6pp code	Best practices, cross-validation, etc.
Oct 2	K-means	video (19:23) html:slides,1pp,6pp pdf:1pp,6pp	K-means algorithm.
Search			
Oct 7	Overview	video html:slides,1pp,6pp pdf:1pp,6pp	Going from single action to sequences.
Oct 7	Modeling	video html:slides,1pp,6pp pdf:1pp,6pp	Defining search problems.
Oct 7	Tree search	video html:slides,1pp,6pp pdf:1pp,6pp code	(Prerequisite) Basic exhaustive search, BFS, DFS.
Oct 7	Dynamic programming	video html:slides,1pp,6pp pdf:1pp,6pp code	Recurrences, practice forming states.
Oct 9	Uniform cost search	video html:slides,1pp,6pp pdf:1pp,6pp	Uniform cost search (UCS).

Oct 9	Uniform cost search correctness	video html:slides,1pp,6pp pdf:1pp,6pp	Programming UCS and proving correctness.
offline	Externalities and dual use technologies	video pdf	Explaining externalities and dual use technologies.
optional	Structured perceptron	video html:slides,1pp,6pp pdf:1pp,6pp	Learning the costs of a search problem.
offline	A-star	video html:slides,1pp,6pp pdf:1pp,6pp	Speeding up UCS with heuristics. Correctness, efficiency, and admissibility.
offline	A-star relaxations	video html:slides,1pp,6pp pdf:1pp,6pp	Generating heuristics using relaxed search problems.
offline	Recap	video html:slides,1pp,6pp pdf:1pp,6pp	Recap of search.
Markov Decision Processes (MDPs)			
Oct 14	Overview	video html:slides,1pp,6pp pdf:1pp,6pp	Motivating MDPs.
Oct 14	Modeling	video html:slides,1pp,6pp pdf:1pp,6pp code	Defining MDPs, Dice game, transportation problem.
Oct 14	Policy evaluation	video html:slides,1pp,6pp pdf:1pp,6pp	Policy evaluation, discounting factor.
Oct 16	Value iteration	video html:slides,1pp,6pp pdf:1pp,6pp	Value iteration.
Oct 16	Reinforcement learning	video html:slides,1pp,6pp pdf:1pp,6pp	Introducing to reinforcement learning.
Oct 16	Model-based Monte Carlo	video html:slides,1pp,6pp pdf:1pp,6pp	Model-based Monte Carlo.
Oct 16	Model-free Monte Carlo	video html:slides,1pp,6pp pdf:1pp,6pp	Model-free Monte Carlo.
optional	SARSA	video html:slides,1pp,6pp pdf:1pp,6pp	SARSA, Model-free Monte Carlo vs SARSA.
offline	Q-learning	video html:slides,1pp,6pp pdf:1pp,6pp	Q-learning, on-policy vs off-policy.
offline	Epsilon-greedy	video html:slides,1pp,6pp pdf:1pp,6pp	Epsilon-greedy exploration.

offline	Function approximation	video html:slides,1pp,6pp pdf:1pp,6pp	Generalization, Function approximation.
offline	Recap	video html:slides,1pp,6pp pdf:1pp,6pp	Recap of MDPs and reinforcement learning, Deep RL, and applications.
Games			
Oct 21	Overview	video html:slides,1pp,6pp pdf:1pp,6pp	Overview of games.
Oct 21	Modeling	video html:slides,1pp,6pp pdf:1pp,6pp code	Definition of games, Halving game.
Oct 21	Game evaluation	video html:slides,1pp,6pp pdf:1pp,6pp	Given two policies, what is the value of the game?
Oct 21	Expectimax	video html:slides,1pp,6pp pdf:1pp,6pp	Find the optimal agent policy against a fixed (random) opponent policy.
Oct 21	Minimax	video html:slides,1pp,6pp pdf:1pp,6pp code	Find the optimal agent (max) policy against the worst-case (min) opponent policy.
Oct 23	Expectiminimax	video html:slides,1pp,6pp pdf:1pp,6pp	Minimax with randomness in the game.
Oct 23	Evaluation functions	video html:slides,1pp,6pp pdf:1pp,6pp	Limited depth DFS and bottom out with a cheap evaluation function.
Oct 23	Alpha beta pruning	video html:slides,1pp,6pp pdf:1pp,6pp	Alpha-beta pruning to speed up minimax.
optional	AI Misalignment	video pdf	The AI Alignment problem, specifically reward hacking and negative side effects.
optional	TD learning	video html:slides,1pp,6pp pdf:1pp,6pp	Temporal Difference (TD) learning for learning the value function.
optional	Simultaneous games	video html:slides,1pp,6pp pdf:1pp,6pp	Two players go at the same time, pure and mixed strategies, minimax theorem.
optional	Non-zero-sum games	video html:slides,1pp,6pp pdf:1pp,6pp	Prisoner's Dilemma, Nash equilibria.
Oct 23	Recap	video html:slides,1pp,6pp pdf:1pp,6pp	Recap of games, and applications.
Constraint satisfaction problems			

Oct 28	Overview	video (13:49) html:slides,1pp,6pp pdf:1pp,6pp	Overview of variable-based models.
Oct 28	Definitions	video (19:11) html:slides,1pp,6pp pdf:1pp,6pp	Factor graphs (variables, factors, assignments, weights).
Oct 28	Examples	video (24:54) html:slides,1pp,6pp pdf:1pp,6pp	Examples of factor graphs.
Oct 30	Dynamic ordering	video (19:16) html:slides,1pp,6pp pdf:1pp,6pp	Backtracking search, re-order the variables and values.
Oct 30	Arc consistency	video (14:09) html:slides,1pp,6pp pdf:1pp,6pp	Prune the domains locally based on factors. AC-3 algorithm to use in the context of exhaustive search.
Oct 30	Beam search	video (14:29) html:slides,1pp,6pp pdf:1pp,6pp	Approximate search (pruned BFS).
Oct 30	Local search	video (12:42) html:slides,1pp,6pp pdf:1pp,6pp	Start with an assignment and improve each variable greedily.
optional	Inference demo	html:slides,1pp,6pp pdf:1pp,6pp	Interactive inference demo for factor graphs.
Markov networks			
Nov 4	Overview	video (14:11) html:slides,1pp,6pp pdf:1pp,6pp	Connect factor graphs with probability.
Nov 4	Gibbs sampling	video (17:54) html:slides,1pp,6pp pdf:1pp,6pp	Gibbs sampling for computing marginal probabilities.
offline	Encoding human values	video pdf	Encoding human values in AI systems.
optional	Conditional independence	html:slides,1pp,6pp pdf:1pp,6pp	Exploit conditional independence in Markov networks (slides only).
Bayesian networks			
Nov 4	Overview	video (10:42) html:slides,1pp,6pp pdf:1pp,6pp	Overview of Bayesian networks.
Nov 4	Definitions	video (28:39) html:slides,1pp,6pp pdf:1pp,6pp	Bayesian networks, properties, explaining away, etc.
offline	Probabilistic programming	video (15:32) html:slides,1pp,6pp pdf:1pp,6pp	View Bayesian networks as a program, whirlwind tour of lots of models.
Nov 6	Probabilistic inference	video (15:16) html:slides,1pp,6pp pdf:1pp,6pp	Inference in general Bayesian networks via reduction to Markov networks.

Nov 6	Forward-backward algorithm	video (16:32) html:slides,1pp,6pp pdf:1pp,6pp	Efficient exact inference algorithm for HMMs.
Nov 6	Particle filtering	video (24:01) html:slides,1pp,6pp pdf:1pp,6pp	Approximate inference alogrithm for HMMs with large domains.
Nov 11	Supervised learning	video (31:43) html:slides,1pp,6pp pdf:1pp,6pp	Learning parameters of a Bayesian network when all variables are observed. Maximum likelihood = counting + normalize.
Nov 11	Smoothing	video (7:01) html:slides,1pp,6pp pdf:1pp,6pp	Laplace smoothing to avoid overfitting.
Nov 11	EM algorithm	video (37:28) html:slides,1pp,6pp pdf:1pp,6pp code	Learning parameters of a Bayesian network when only a subset of variables are observed. Maximum marginal likelihood using EM. Application to decipherment.
Logic			
Nov 13	Overview	video html:slides,1pp,6pp pdf:1pp,6pp	Motivation for logic (represent and reason).
Nov 13	Propositional logic syntax	video html:slides,1pp,6pp pdf:1pp,6pp	Syntax of propositional logic.
Nov 13	Propositional logic semantics	video html:slides,1pp,6pp pdf:1pp,6pp	Semantics of propositional logic. General concepts such as entailment, contradiction, contingency, Ask/Tell, satisfiability, model checking.
Nov 13	Inference rules	video html:slides,1pp,6pp pdf:1pp,6pp	Soundness, completeness.
Nov 18	Propositional modus ponens	video html:slides,1pp,6pp pdf:1pp,6pp	Modus ponens is sound and complete for propositional logic with Horn clauses.
Nov 18	Propositional resolution	video html:slides,1pp,6pp pdf:1pp,6pp	Resolution is sound and complete for propositional logic. Conversion to Conjunctive Normal Form (CNF).
Nov 18	First order logic	video html:slides,1pp,6pp pdf:1pp,6pp	Syntax and semantics of first-order logic.
offline	First order modus ponens	video html:slides,1pp,6pp pdf:1pp,6pp	Modus ponens generalized to first-order logic requires notions of substitution and unification.
offline	Explainability and interpretability	video pdf	Explainability and Interpretability in AI Systems
optional	First order resolution	video html:slides,1pp,6pp pdf:1pp,6pp	Generalizes resolution to first-order logic. Conversion to CNF, Skolem functions.
offline	Recap	video html:slides,1pp,6pp pdf:1pp,6pp	Recap of logic.

Conclusion

Dec 2	Conclusion	html:slides,1pp,6pp pdf:1pp,6pp	Summary of topics in CS221, future courses, and conclusion.