1. <https://stanford-cs221.github.io/spring2024/modules/>
2. Stanford AI youtube: <https://www.youtube.com/playlist?list=PLoROMvodv4rOca_Ovz1DvdtWuz8BfSWL2>
3. Nptel AI: <https://www.youtube.com/watch?v=NCq26BvEYIg&list=PLyqSpQzTE6M91QQRszLbb7QYKrD1EYJx8>

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.

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| --- | --- | --- | --- |
| **Date** | **Module** | **Links** | **Description** |
| **General** | | | |
| Sep 23 | [Course content](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=general/course-content.js) | html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=general/course-content.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=general/course-content.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=general/course-content.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/general/course-content.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/general/course-content-6pp.pdf) | What are we covering in this course? |
| Sep 23 | [AI History](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=general/history.js) | html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=general/history.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=general/history.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=general/history.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/general/history.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/general/history-6pp.pdf) | Three histories of AI (logical, neural, statistical). |
| Sep 23 | [Ethics and responsibility](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=general/responsibility.js) | html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=general/responsibility.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=general/responsibility.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=general/responsibility.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/general/responsibility.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/general/responsibility-6pp.pdf) | How should we think about the societal impacts of AI? |
| **Prerequisites** | | | |
| offline | [Linear algebra](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=6820e7fa-975c-4d35-92cb-b1f0000b6ce2) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=6820e7fa-975c-4d35-92cb-b1f0000b6ce2)  [pdf](https://stanford-cs221.github.io/autumn2024-extra/modules/prerequisites/linear-algebra.pdf) | Vectors, dot products, geometric interpretations. |
| offline | [Vector calculus](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=db6f50d9-a274-49fc-8bbd-b1f0000b8be8) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=db6f50d9-a274-49fc-8bbd-b1f0000b8be8)  [pdf](https://stanford-cs221.github.io/autumn2024-extra/modules/prerequisites/vector-calculus.pdf) | Taking gradients. |
| offline | [Probability 1](https://www.khanacademy.org/math/ap-statistics/random-variables-ap/discrete-random-variables/v/discrete-probability-distribution) | [video](https://www.khanacademy.org/math/ap-statistics/random-variables-ap/discrete-random-variables/v/discrete-probability-distribution) | Discrete random variables and probability distributions, mean, variance (from Khan Academy). |
| offline | [Probability 2](https://www.khanacademy.org/math/ap-statistics/analyzing-categorical-ap/distributions-two-way-tables/v/marginal-distribution-and-conditional-distribution) | [video](https://www.khanacademy.org/math/ap-statistics/analyzing-categorical-ap/distributions-two-way-tables/v/marginal-distribution-and-conditional-distribution) | Marginal and conditional distributions (from Khan Academy). |
| offline | [Complexity](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=f63dfb44-0338-48cb-bd44-b1f0000b9c6b) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=f63dfb44-0338-48cb-bd44-b1f0000b9c6b)  [pdf](https://stanford-cs221.github.io/autumn2024-extra/modules/prerequisites/complexity.pdf) | Basic big-Oh notation, complexity. |
| offline | [Optimization](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=725d80d5-2382-415f-98b3-b1f000398fbf) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=725d80d5-2382-415f-98b3-b1f000398fbf)  [pdf](https://stanford-cs221.github.io/autumn2024-extra/modules/prerequisites/optimization.pdf) | Continuous optimization, objective functions, gradient descent. |
| offline | [Python](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=90289fa2-5aa8-48da-a5ce-b1f000390bb9) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=90289fa2-5aa8-48da-a5ce-b1f000390bb9)  [code](https://colab.research.google.com/drive/1-9Z_dLRJBWZdKaMNLqBMF9TrXc1553IK?usp=sharing) | Tutorial on using Python for this course. |
| **Machine learning** | | | |
| Sep 25 | [Overview](https://www.youtube.com/watch?v=mtrYwgIrRNk) | [video (6:49)](https://www.youtube.com/watch?v=mtrYwgIrRNk)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/overview.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/overview.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/overview.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/overview.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/overview-6pp.pdf) | Overview of machine learning. |
| Sep 25 | [Linear regression](https://www.youtube.com/watch?v=nEWNNt2KmfQ) | [video (22:43)](https://www.youtube.com/watch?v=nEWNNt2KmfQ)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/linear-regression.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/linear-regression.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/linear-regression.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/linear-regression.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/linear-regression-6pp.pdf)  [code](https://stanford-cs221.github.io/autumn2024/modules/machine-learning/live-coding/gradientDescent.py) | Linear regression (with loss minimization and gradient descent). |
| Sep 25 | [Linear classification](https://www.youtube.com/watch?v=WcaMiqJR09s) | [video (28:01)](https://www.youtube.com/watch?v=WcaMiqJR09s)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/linear-classification.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/linear-classification.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/linear-classification.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/linear-classification.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/linear-classification-6pp.pdf)  [code](https://stanford-cs221.github.io/autumn2024/modules/machine-learning/live-coding/gradientDescentHinge.py) | Linear classification (with loss minimization using hinge loss and gradient descent). |
| offline | [Stochastic gradient descent](https://www.youtube.com/watch?v=bl2WgBLH0tI) | [video (15:04)](https://www.youtube.com/watch?v=bl2WgBLH0tI)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/stochastic-gradient-descent.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/stochastic-gradient-descent.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/stochastic-gradient-descent.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/stochastic-gradient-descent.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/stochastic-gradient-descent-6pp.pdf)  [code](https://stanford-cs221.github.io/autumn2024/modules/machine-learning/live-coding/stochasticGradientDescent.py) | Stochastic gradient descent. |
| optional | [Learning demo](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/learning-demo.js) | html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/learning-demo.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/learning-demo.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/learning-demo.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/learning-demo.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/learning-demo-6pp.pdf) | Interactive learning demo for supervised learning and k-means. |
| Sep 30 | [Group DRO](https://www.youtube.com/watch?v=ZFK2XtWqUbw) | [video (17:39)](https://www.youtube.com/watch?v=ZFK2XtWqUbw)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/group-dro.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/group-dro.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/group-dro.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/group-dro.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/group-dro-6pp.pdf) | How to ensure more equitable performance. |
| offline | [Non-linear features](https://www.youtube.com/watch?v=eIxbNkB4byY) | [video (14:04)](https://www.youtube.com/watch?v=eIxbNkB4byY)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/non-linear-features.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/non-linear-features.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/non-linear-features.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/non-linear-features.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/non-linear-features-6pp.pdf) | How to get non-linear functions from linear machinery. |
| offline | [Feature templates](https://www.youtube.com/watch?v=2QfSBLtvioE) | [video (11:51)](https://www.youtube.com/watch?v=2QfSBLtvioE)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/feature-templates.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/feature-templates.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/feature-templates.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/feature-templates.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/feature-templates-6pp.pdf) | How to design and organize features. |
| Sep 30 | [Neural networks](https://www.youtube.com/watch?v=pnKXgBHuN58) | [video (18:35)](https://www.youtube.com/watch?v=pnKXgBHuN58)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/neural-networks.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/neural-networks.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/neural-networks.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/neural-networks.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/neural-networks-6pp.pdf) | Introduction to neural networks. |
| Sep 30 | [Backpropagation](https://www.youtube.com/watch?v=OcAF-l2xB9Y) | [video (30:46)](https://www.youtube.com/watch?v=OcAF-l2xB9Y)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/backpropagation.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/backpropagation.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/backpropagation.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/backpropagation.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/backpropagation-6pp.pdf) | Computation graphs and backpropagation algorithm for computing gradients. |
| offline | [Algorithms and distribution](https://drive.google.com/file/d/1uwT0rDj47qmB61TvueUlgMdEjmROg6SZ/view?usp=sharing) | [video](https://drive.google.com/file/d/1uwT0rDj47qmB61TvueUlgMdEjmROg6SZ/view?usp=sharing)  [pdf](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/algorithms-and-distribution.pdf) | Ethical frameworks related to how algorithms distribute burdens and benefits. |
| optional | [Differentiable programming](https://www.youtube.com/watch?v=c5btEEisp_g) | [video (37:41)](https://www.youtube.com/watch?v=c5btEEisp_g)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/differentiable-programming.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/differentiable-programming.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/differentiable-programming.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/differentiable-programming.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/differentiable-programming-6pp.pdf) | How to build larger deep learning models by composition. |
| Oct 2 | [Generalization](https://www.youtube.com/watch?v=Gq-Ah-QrOQM) | [video (14:53)](https://www.youtube.com/watch?v=Gq-Ah-QrOQM)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/generalization.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/generalization.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/generalization.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/generalization.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/generalization-6pp.pdf) | Basic introduction into generalization. |
| Oct 2 | [Best practices](https://www.youtube.com/watch?v=ouvGV2YZEEM) | [video (23:49)](https://www.youtube.com/watch?v=ouvGV2YZEEM)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/best-practices.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/best-practices.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/best-practices.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/best-practices.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/best-practices-6pp.pdf)  [code](https://stanford-cs221.github.io/autumn2024/modules/machine-learning/live-coding/ner.py) | Best practices, cross-validation, etc. |
| Oct 2 | [K-means](https://www.youtube.com/watch?v=5-Fn8R9fH7A) | [video (19:23)](https://www.youtube.com/watch?v=5-Fn8R9fH7A)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/k-means.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/k-means.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=machine-learning/k-means.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/k-means.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/machine-learning/k-means-6pp.pdf) | K-means algorithm. |
| **Search** | | | |
| Oct 7 | [Overview](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=865b581a-02c0-48c2-910a-b202005bc316) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=865b581a-02c0-48c2-910a-b202005bc316)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/overview.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/overview.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/overview.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/overview.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/overview-6pp.pdf) | Going from single action to sequences. |
| Oct 7 | [Modeling](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=5bbd7b51-b998-48e5-b1fc-b202005c231f) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=5bbd7b51-b998-48e5-b1fc-b202005c231f)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/modeling.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/modeling.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/modeling.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/modeling.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/modeling-6pp.pdf) | Defining search problems. |
| Oct 7 | [Tree search](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=67e514da-c539-4090-b8e9-b202005bcc93) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=67e514da-c539-4090-b8e9-b202005bcc93)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/tree-search.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/tree-search.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/tree-search.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/tree-search.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/tree-search-6pp.pdf)  [code](https://stanford-cs221.github.io/autumn2024/modules/search/live-coding/tram-backtracking.py) | (Prerequisite) Basic exhaustive search, BFS, DFS. |
| Oct 7 | [Dynamic programming](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=929364eb-5bb0-4580-a966-b202005bfb03) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=929364eb-5bb0-4580-a966-b202005bfb03)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/dynamic-programming.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/dynamic-programming.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/dynamic-programming.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/dynamic-programming.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/dynamic-programming-6pp.pdf)  [code](https://stanford-cs221.github.io/autumn2024/modules/search/live-coding/tram.py) | Recurrences, practice forming states. |
| Oct 9 | [Uniform cost search](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=d531e201-631b-470b-8b69-b202005bd367) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=d531e201-631b-470b-8b69-b202005bd367)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/uniform-cost-search.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/uniform-cost-search.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/uniform-cost-search.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/uniform-cost-search.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/uniform-cost-search-6pp.pdf) | Uniform cost search (UCS). |
| Oct 9 | [Uniform cost search correctness](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=5b24f0ba-b456-49d6-b6ef-b202005be36b) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=5b24f0ba-b456-49d6-b6ef-b202005be36b)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/uniform-cost-search-correctness.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/uniform-cost-search-correctness.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/uniform-cost-search-correctness.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/uniform-cost-search-correctness.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/uniform-cost-search-correctness-6pp.pdf) | Programming UCS and proving correctness. |
| offline | [Externalities and dual use technologies](https://drive.google.com/file/d/1gbzdQ8nmGHsKLLL838uuBPoiEdb6ICnt/view?usp=sharing) | [video](https://drive.google.com/file/d/1gbzdQ8nmGHsKLLL838uuBPoiEdb6ICnt/view?usp=sharing)  [pdf](https://stanford-cs221.github.io/autumn2024-extra/modules/search/externalities-and-dual-use-technologies.pdf) | Explaining externalities and dual use technologies. |
| optional | [Structured perceptron](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=84b43471-52de-45c4-9576-b202005bce48) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=84b43471-52de-45c4-9576-b202005bce48)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/structured-perceptron.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/structured-perceptron.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/structured-perceptron.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/structured-perceptron.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/structured-perceptron-6pp.pdf) | Learning the costs of a search problem. |
| offline | [A-star](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=c198049c-35e7-4a39-b420-b202005bc843) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=c198049c-35e7-4a39-b420-b202005bc843)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/a-star.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/a-star.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/a-star.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/a-star.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/a-star-6pp.pdf) | Speeding up UCS with heuristics. Correctness, efficiency, and admissibility. |
| offline | [A-star relaxations](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=1a44a5bb-9429-4c3a-b1ca-b202005bc809) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=1a44a5bb-9429-4c3a-b1ca-b202005bc809)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/a-star-relaxations.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/a-star-relaxations.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/a-star-relaxations.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/a-star-relaxations.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/a-star-relaxations-6pp.pdf) | Generating heuristics using relaxed search problems. |
| offline | [Recap](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=dd9fbf3c-3af0-48c8-a7d8-b202005c2da6) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=dd9fbf3c-3af0-48c8-a7d8-b202005c2da6)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/recap.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/recap.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=search/recap.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/recap.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/search/recap-6pp.pdf) | Recap of search. |
| **Markov Decision Processes (MDPs)** | | | |
| Oct 14 | [Overview](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=72857fe6-6716-4c67-b7da-b2050044465f) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=72857fe6-6716-4c67-b7da-b2050044465f)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/overview.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/overview.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/overview.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/overview.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/overview-6pp.pdf) | Motivating MDPs. |
| Oct 14 | [Modeling](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=4b8e18d9-79d3-45ff-995b-b2050044424b) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=4b8e18d9-79d3-45ff-995b-b2050044424b)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/modeling.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/modeling.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/modeling.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/modeling.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/modeling-6pp.pdf)  [code](https://stanford-cs221.github.io/autumn2024/modules/mdps/live-coding/tram.py) | Defining MDPs, Dice game, transportation problem. |
| Oct 14 | [Policy evaluation](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=731b5747-3491-42d8-95ab-b20500442759) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=731b5747-3491-42d8-95ab-b20500442759)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/policy-evaluation.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/policy-evaluation.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/policy-evaluation.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/policy-evaluation.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/policy-evaluation-6pp.pdf) | Policy evaluation, discounting factor. |
| Oct 16 | [Value iteration](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=14dcf63d-92d0-4b3d-a984-b205004427ea) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=14dcf63d-92d0-4b3d-a984-b205004427ea)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/value-iteration.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/value-iteration.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/value-iteration.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/value-iteration.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/value-iteration-6pp.pdf) | Value iteration. |
| Oct 16 | [Reinforcement learning](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=75b84100-a93d-4642-aaf9-b2050044683f) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=75b84100-a93d-4642-aaf9-b2050044683f)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/reinforcement-learning.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/reinforcement-learning.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/reinforcement-learning.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/reinforcement-learning.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/reinforcement-learning-6pp.pdf) | Introducing to reinforcement learning. |
| Oct 16 | [Model-based Monte Carlo](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=72086131-e0d8-4453-a155-b20500445f1e) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=72086131-e0d8-4453-a155-b20500445f1e)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/model-based-monte-carlo.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/model-based-monte-carlo.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/model-based-monte-carlo.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/model-based-monte-carlo.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/model-based-monte-carlo-6pp.pdf) | Model-based Monte Carlo. |
| Oct 16 | [Model-free Monte Carlo](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=3032e033-554a-4585-9edd-b20500444cd4) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=3032e033-554a-4585-9edd-b20500444cd4)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/model-free-monte-carlo.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/model-free-monte-carlo.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/model-free-monte-carlo.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/model-free-monte-carlo.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/model-free-monte-carlo-6pp.pdf) | Model-free Monte Carlo. |
| optional | [SARSA](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=68932ae1-ab52-4f60-a5a1-b20500442789) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=68932ae1-ab52-4f60-a5a1-b20500442789)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/sarsa.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/sarsa.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/sarsa.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/sarsa.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/sarsa-6pp.pdf) | SARSA, Model-free Monte Carlo vs SARSA. |
| offline | [Q-learning](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=47e16c22-51e0-4cbb-851a-b2050044436e) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=47e16c22-51e0-4cbb-851a-b2050044436e)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/q-learning.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/q-learning.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/q-learning.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/q-learning.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/q-learning-6pp.pdf) | Q-learning, on-policy vs off-policy. |
| offline | [Epsilon-greedy](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=8edbabd2-c38e-4a51-8d76-b20500446502) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=8edbabd2-c38e-4a51-8d76-b20500446502)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/epsilon-greedy.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/epsilon-greedy.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/epsilon-greedy.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/epsilon-greedy.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/epsilon-greedy-6pp.pdf) | Epsilon-greedy exploration. |
| offline | [Function approximation](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=003f190d-5ef2-4e8f-bd1f-b2050044569a) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=003f190d-5ef2-4e8f-bd1f-b2050044569a)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/function-approximation.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/function-approximation.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/function-approximation.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/function-approximation.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/function-approximation-6pp.pdf) | Generalization, Function approximation. |
| offline | [Recap](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=22213d40-3106-420f-a14f-b205004427b4) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=22213d40-3106-420f-a14f-b205004427b4)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/recap.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/recap.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=mdps/recap.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/recap.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/mdps/recap-6pp.pdf) | Recap of MDPs and reinforcement learning, Deep RL, and applications. |
| **Games** | | | |
| Oct 21 | [Overview](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=8b80dc17-d4b0-45ba-8e84-b20d00608551) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=8b80dc17-d4b0-45ba-8e84-b20d00608551)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/overview.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/overview.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/overview.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/overview.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/overview-6pp.pdf) | Overview of games. |
| Oct 21 | [Modeling](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=20a5436d-1baa-4526-9922-b20d0060b34d) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=20a5436d-1baa-4526-9922-b20d0060b34d)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/modeling.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/modeling.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/modeling.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/modeling.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/modeling-6pp.pdf)  [code](https://stanford-cs221.github.io/autumn2024/modules/games/live-coding/live-game.py) | Definition of games, Halving game. |
| Oct 21 | [Game evaluation](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=b49cf0ab-7f6b-4e23-b4e0-b20d0060b922) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=b49cf0ab-7f6b-4e23-b4e0-b20d0060b922)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/game-evaluation.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/game-evaluation.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/game-evaluation.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/game-evaluation.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/game-evaluation-6pp.pdf) | Given two policies, what is the value of the game? |
| Oct 21 | [Expectimax](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=d242760c-8ace-4c11-abbf-b20d0060d419) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=d242760c-8ace-4c11-abbf-b20d0060d419)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/expectimax.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/expectimax.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/expectimax.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/expectimax.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/expectimax-6pp.pdf) | Find the optimal agent policy against a fixed (random) opponent policy. |
| Oct 21 | [Minimax](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=0ab3fc9c-17c5-42ff-aacd-b20d0060b6cb) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=0ab3fc9c-17c5-42ff-aacd-b20d0060b6cb)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/minimax.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/minimax.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/minimax.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/minimax.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/minimax-6pp.pdf)  [code](https://stanford-cs221.github.io/autumn2024/modules/games/live-coding/game.py) | Find the optimal agent (max) policy against the worst-case (min) opponent policy. |
| Oct 23 | [Expectiminimax](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=66895011-3483-43e3-b215-b20d0060e5b7) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=66895011-3483-43e3-b215-b20d0060e5b7)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/expectiminimax.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/expectiminimax.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/expectiminimax.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/expectiminimax.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/expectiminimax-6pp.pdf) | Minimax with randomness in the game. |
| Oct 23 | [Evaluation functions](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=9b62c343-3b5e-49c3-a8a1-b20d0060e932) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=9b62c343-3b5e-49c3-a8a1-b20d0060e932)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/evaluation-functions.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/evaluation-functions.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/evaluation-functions.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/evaluation-functions.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/evaluation-functions-6pp.pdf) | Limited depth DFS and bottom out with a cheap evaluation function. |
| Oct 23 | [Alpha beta pruning](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=6badbde8-a0b9-480d-a8d5-b20d0060bf17) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=6badbde8-a0b9-480d-a8d5-b20d0060bf17)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/alpha-beta-pruning.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/alpha-beta-pruning.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/alpha-beta-pruning.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/alpha-beta-pruning.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/alpha-beta-pruning-6pp.pdf) | Alpha-beta pruning to speed up minimax. |
| optional | [AI Misalignment](https://drive.google.com/file/d/1DwUrpkIQTY7U_3O1kBOq5I7-KW9Wz5Cq/view?usp=sharing) | [video](https://drive.google.com/file/d/1DwUrpkIQTY7U_3O1kBOq5I7-KW9Wz5Cq/view?usp=sharing)  [pdf](https://stanford-cs221.github.io/autumn2024-extra/modules/games/ai-alignment-problem.pdf) | The AI Alignment problem, specifically reward hacking and negative side effects. |
| optional | [TD learning](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=74d755ed-6180-43b6-aea8-b20d006084b9) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=74d755ed-6180-43b6-aea8-b20d006084b9)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/td-learning.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/td-learning.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/td-learning.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/td-learning.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/td-learning-6pp.pdf) | Temporal Difference (TD) learning for learning the value function. |
| optional | [Simultaneous games](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=1e3ed5fb-3eb9-41b9-a2bf-b20d00608500) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=1e3ed5fb-3eb9-41b9-a2bf-b20d00608500)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/simultaneous-games.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/simultaneous-games.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/simultaneous-games.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/simultaneous-games.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/simultaneous-games-6pp.pdf) | Two players go at the same time, pure and mixed strategies, minimax theorem. |
| optional | [Non-zero-sum games](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=9cd1de4d-f8e9-4056-9789-b20d0060a2e5) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=9cd1de4d-f8e9-4056-9789-b20d0060a2e5)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/non-zero-sum-games.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/non-zero-sum-games.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/non-zero-sum-games.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/non-zero-sum-games.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/non-zero-sum-games-6pp.pdf) | Prisoner's Dilemma, Nash equilibria. |
| Oct 23 | [Recap](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=db01a8a3-eabf-425c-9358-b20d00608523) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=db01a8a3-eabf-425c-9358-b20d00608523)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/recap.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/recap.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=games/recap.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/recap.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/games/recap-6pp.pdf) | Recap of games, and applications. |
| **Constraint satisfaction problems** | | | |
| Oct 28 | [Overview](https://www.youtube.com/watch?v=-IO4fPO0rxk) | [video (13:49)](https://www.youtube.com/watch?v=-IO4fPO0rxk)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/overview.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/overview.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/overview.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/csps/overview.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/csps/overview-6pp.pdf) | Overview of variable-based models. |
| Oct 28 | [Definitions](https://www.youtube.com/watch?v=uj5wCcHsSlA) | [video (19:11)](https://www.youtube.com/watch?v=uj5wCcHsSlA)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/definitions.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/definitions.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/definitions.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/csps/definitions.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/csps/definitions-6pp.pdf) | Factor graphs (variables, factors, assignments, weights). |
| Oct 28 | [Examples](https://www.youtube.com/watch?v=Tu6BiZhMDCc) | [video (24:54)](https://www.youtube.com/watch?v=Tu6BiZhMDCc)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/examples.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/examples.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/examples.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/csps/examples.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/csps/examples-6pp.pdf) | Examples of factor graphs. |
| Oct 30 | [Dynamic ordering](https://www.youtube.com/watch?v=Lyu8VzbIe_A) | [video (19:16)](https://www.youtube.com/watch?v=Lyu8VzbIe_A)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/dynamic-ordering.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/dynamic-ordering.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/dynamic-ordering.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/csps/dynamic-ordering.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/csps/dynamic-ordering-6pp.pdf) | Backtracking search, re-order the variables and values. |
| Oct 30 | [Arc consistency](https://www.youtube.com/watch?v=5rlIYGJdPy4) | [video (14:09)](https://www.youtube.com/watch?v=5rlIYGJdPy4)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/arc-consistency.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/arc-consistency.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/arc-consistency.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/csps/arc-consistency.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/csps/arc-consistency-6pp.pdf) | Prune the domains locally based on factors. AC-3 algorithm to use in the context of exhaustive search. |
| Oct 30 | [Beam search](https://www.youtube.com/watch?v=XuWMeIHGkus) | [video (14:29)](https://www.youtube.com/watch?v=XuWMeIHGkus)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/beam-search.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/beam-search.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/beam-search.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/csps/beam-search.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/csps/beam-search-6pp.pdf) | Approximate search (pruned BFS). |
| Oct 30 | [Local search](https://www.youtube.com/watch?v=VwZKPlK6jUg) | [video (12:42)](https://www.youtube.com/watch?v=VwZKPlK6jUg)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/local-search.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/local-search.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/local-search.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/csps/local-search.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/csps/local-search-6pp.pdf) | Start with an assignment and improve each variable greedily. |
| optional | [Inference demo](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/inference-demo.js) | html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/inference-demo.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/inference-demo.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=csps/inference-demo.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/csps/inference-demo.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/csps/inference-demo-6pp.pdf) | Interactive inference demo for factor graphs. |
| **Markov networks** | | | |
| Nov 4 | [Overview](https://www.youtube.com/watch?v=neeaJb3wCYw) | [video (14:11)](https://www.youtube.com/watch?v=neeaJb3wCYw)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=markov-networks/overview.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=markov-networks/overview.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=markov-networks/overview.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/markov-networks/overview.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/markov-networks/overview-6pp.pdf) | Connect factor graphs with probability. |
| Nov 4 | [Gibbs sampling](https://www.youtube.com/watch?v=k6aZZF2pk7k) | [video (17:54)](https://www.youtube.com/watch?v=k6aZZF2pk7k)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=markov-networks/gibbs-sampling.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=markov-networks/gibbs-sampling.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=markov-networks/gibbs-sampling.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/markov-networks/gibbs-sampling.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/markov-networks/gibbs-sampling-6pp.pdf) | Gibbs sampling for computing marginal probabilities. |
| offline | [Encoding human values](https://drive.google.com/file/d/1MYf_sSda-uSpLQnWy9KLlKuv3AHTpmET/view?usp=sharing) | [video](https://drive.google.com/file/d/1MYf_sSda-uSpLQnWy9KLlKuv3AHTpmET/view?usp=sharing)  [pdf](https://stanford-cs221.github.io/autumn2024-extra/modules/markov-networks/encoding-human-values.pdf) | Encoding human values in AI systems. |
| optional | [Conditional independence](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=markov-networks/conditional-independence.js) | html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=markov-networks/conditional-independence.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=markov-networks/conditional-independence.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=markov-networks/conditional-independence.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/markov-networks/conditional-independence.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/markov-networks/conditional-independence-6pp.pdf) | Exploit conditional independence in Markov networks (slides only). |
| **Bayesian networks** | | | |
| Nov 4 | [Overview](https://www.youtube.com/watch?v=fA7zP6EcVdw) | [video (10:42)](https://www.youtube.com/watch?v=fA7zP6EcVdw)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/overview.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/overview.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/overview.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/bayesian-networks/overview.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/bayesian-networks/overview-6pp.pdf) | Overview of Bayesian networks. |
| Nov 4 | [Definitions](https://www.youtube.com/watch?v=xvC6XmZmR_U) | [video (28:39)](https://www.youtube.com/watch?v=xvC6XmZmR_U)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/definitions.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/definitions.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/definitions.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/bayesian-networks/definitions.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/bayesian-networks/definitions-6pp.pdf) | Bayesian networks, properties, explaining away, etc. |
| offline | [Probabilistic programming](https://www.youtube.com/watch?v=ZVk8y1zVoD4) | [video (15:32)](https://www.youtube.com/watch?v=ZVk8y1zVoD4)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/probabilistic-programming.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/probabilistic-programming.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/probabilistic-programming.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/bayesian-networks/probabilistic-programming.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/bayesian-networks/probabilistic-programming-6pp.pdf) | View Bayesian networks as a program, whirlwind tour of lots of models. |
| Nov 6 | [Probabilistic inference](https://www.youtube.com/watch?v=-dGOWB9Zh8s) | [video (15:16)](https://www.youtube.com/watch?v=-dGOWB9Zh8s)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/probabilistic-inference.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/probabilistic-inference.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/probabilistic-inference.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/bayesian-networks/probabilistic-inference.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/bayesian-networks/probabilistic-inference-6pp.pdf) | Inference in general Bayesian networks via reduction to Markov networks. |
| Nov 6 | [Forward-backward algorithm](https://www.youtube.com/watch?v=N-ZPbpJOQs0) | [video (16:32)](https://www.youtube.com/watch?v=N-ZPbpJOQs0)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/forward-backward.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/forward-backward.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/forward-backward.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/bayesian-networks/forward-backward.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/bayesian-networks/forward-backward-6pp.pdf) | Efficient exact inference algorithm for HMMs. |
| Nov 6 | [Particle filtering](https://www.youtube.com/watch?v=8sOtXbQIOuE) | [video (24:01)](https://www.youtube.com/watch?v=8sOtXbQIOuE)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/particle-filtering.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/particle-filtering.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/particle-filtering.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/bayesian-networks/particle-filtering.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/bayesian-networks/particle-filtering-6pp.pdf) | Approximate inference alogrithm for HMMs with large domains. |
| Nov 11 | [Supervised learning](https://www.youtube.com/watch?v=_rbDjsJTgm8) | [video (31:43)](https://www.youtube.com/watch?v=_rbDjsJTgm8)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/supervised-learning.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/supervised-learning.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/supervised-learning.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/bayesian-networks/supervised-learning.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/bayesian-networks/supervised-learning-6pp.pdf) | Learning parameters of a Bayesian network when all variables are observed. Maximum likelihood = counting + normalize. |
| Nov 11 | [Smoothing](https://www.youtube.com/watch?v=M7rWvN_0xbw) | [video (7:01)](https://www.youtube.com/watch?v=M7rWvN_0xbw)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/smoothing.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/smoothing.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/smoothing.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/bayesian-networks/smoothing.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/bayesian-networks/smoothing-6pp.pdf) | Laplace smoothing to avoid overfitting. |
| Nov 11 | [EM algorithm](https://www.youtube.com/watch?v=CPVFJBd-Qcg) | [video (37:28)](https://www.youtube.com/watch?v=CPVFJBd-Qcg)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/em-algorithm.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/em-algorithm.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=bayesian-networks/em-algorithm.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/bayesian-networks/em-algorithm.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/bayesian-networks/em-algorithm-6pp.pdf)  [code](https://stanford-cs221.github.io/autumn2024/modules/bayesian-networks/live-coding/decipher.py) | 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](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=bdf12d96-25f5-4e56-9f84-b227018a96a9) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=bdf12d96-25f5-4e56-9f84-b227018a96a9)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/overview.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/overview.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/overview.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/overview.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/overview-6pp.pdf) | Motivation for logic (represent and reason). |
| Nov 13 | [Propositional logic syntax](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=a387fed0-c5f8-4230-965b-b227018a9c4a) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=a387fed0-c5f8-4230-965b-b227018a9c4a)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/propositional-logic-syntax.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/propositional-logic-syntax.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/propositional-logic-syntax.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/propositional-logic-syntax.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/propositional-logic-syntax-6pp.pdf) | Syntax of propositional logic. |
| Nov 13 | [Propositional logic semantics](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=198ad0fa-7ac4-4f05-b67a-b227018a98b4) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=198ad0fa-7ac4-4f05-b67a-b227018a98b4)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/propositional-logic-semantics.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/propositional-logic-semantics.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/propositional-logic-semantics.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/propositional-logic-semantics.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/propositional-logic-semantics-6pp.pdf) | Semantics of propositional logic. General concepts such as entailment, contradiction, contingency, Ask/Tell, satisfiability, model checking. |
| Nov 13 | [Inference rules](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=f54d2e19-8a2a-427e-8810-b227018a858f) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=f54d2e19-8a2a-427e-8810-b227018a858f)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/inference-rules.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/inference-rules.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/inference-rules.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/inference-rules.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/inference-rules-6pp.pdf) | Soundness, completeness. |
| Nov 18 | [Propositional modus ponens](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=2b24f4de-dc48-45e6-b6c0-b227018a9e1f) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=2b24f4de-dc48-45e6-b6c0-b227018a9e1f)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/propositional-modus-ponens.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/propositional-modus-ponens.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/propositional-modus-ponens.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/propositional-modus-ponens.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/propositional-modus-ponens-6pp.pdf) | Modus ponens is sound and complete for propositional logic with Horn clauses. |
| Nov 18 | [Propositional resolution](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=3f4b8fdb-ecee-4012-9d8d-b227018aa0ee) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=3f4b8fdb-ecee-4012-9d8d-b227018aa0ee)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/propositional-resolution.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/propositional-resolution.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/propositional-resolution.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/propositional-resolution.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/propositional-resolution-6pp.pdf) | Resolution is sound and complete for propositional logic. Conversion to Conjunctive Normal Form (CNF). |
| Nov 18 | [First order logic](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=9a321a50-2d7a-4190-aa0e-b227018a85e3) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=9a321a50-2d7a-4190-aa0e-b227018a85e3)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/first-order-logic.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/first-order-logic.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/first-order-logic.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/first-order-logic.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/first-order-logic-6pp.pdf) | Syntax and semantics of first-order logic. |
| offline | [First order modus ponens](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=262d5b79-27fd-4ae1-bb5f-b227018a860d) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=262d5b79-27fd-4ae1-bb5f-b227018a860d)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/first-order-modus-ponens.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/first-order-modus-ponens.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/first-order-modus-ponens.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/first-order-modus-ponens.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/first-order-modus-ponens-6pp.pdf) | Modus ponens generalized to first-order logic requires notions of substitution and unification. |
| offline | [Explainability and interpretability](https://drive.google.com/file/d/10_VksMdeu8TywR6x3CAqXYO2V3DeFf0W/view?usp=sharing) | [video](https://drive.google.com/file/d/10_VksMdeu8TywR6x3CAqXYO2V3DeFf0W/view?usp=sharing)  [pdf](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/ai-explainability-and-interpretability.pdf) | Explainability and Interpretability in AI Systems |
| optional | [First order resolution](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=21ff0f44-8c88-433d-9218-b227018a85b9) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=21ff0f44-8c88-433d-9218-b227018a85b9)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/first-order-resolution.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/first-order-resolution.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/first-order-resolution.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/first-order-resolution.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/first-order-resolution-6pp.pdf) | Generalizes resolution to first-order logic. Conversion to CNF, Skolem functions. |
| offline | [Recap](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=62e68fa3-e8ed-4d9b-822b-b227018aa5a8) | [video](https://stanford-pilot.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=62e68fa3-e8ed-4d9b-822b-b227018aa5a8)  html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/recap.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/recap.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=logic/recap.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/recap.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/logic/recap-6pp.pdf) | Recap of logic. |
| **Conclusion** | | | |
| Dec 2 | [Conclusion](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=conclusion/conclusion.js) | html:[slides](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=conclusion/conclusion.js),[1pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=conclusion/conclusion.js&mode=print1pp),[6pp](https://stanford-cs221.github.io/autumn2024/modules/module.html#include=conclusion/conclusion.js&mode=print6pp)  pdf:[1pp](https://stanford-cs221.github.io/autumn2024-extra/modules/conclusion/conclusion.pdf),[6pp](https://stanford-cs221.github.io/autumn2024-extra/modules/conclusion/conclusion-6pp.pdf) | Summary of topics in CS221, future courses, and conclusion. |