Today: Midterm Reviews, Team Formation

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Bookkeeping

- HW3 moved back: due 10/26 @ 11:59 PM
  - Gives a full week to work on decision tree problems
- Today's class
  - What's on the midterm?
  - A quick review of topics covered
  - An overview of the class project
  - Team formation and project brainstorming

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What Will the Exam Be Like?

- Closed book
- Broadly:
  - Turn a problem description into a solution
  - Work through a problem to reach a solution
  - Demonstrate a conceptual grasp of the material
- Be able to go from concepts to/from algorithms and implementations
- Basic idea: you need to **understand the ideas** behind the material we have covered, and be **able to apply** them to solving problems.
- **Generally** easier than the homeworks (but please don't get complacent)

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What Kind of Questions?

- T/F, multiple choice, fill in the blank
- Write **definitions of terms** ← really!
- Work through an {algorithm|solution type|problem}
- Draw something – search trees, states, Bayes nets, paths through a map, …
- Write a **short** answer to English questions
  - E.g.: "What approach would you use to solve this problem?"
  - E.g.: "We know these are independent. Why?"
- Write a **medium length** essay (half a page or less)
- Write a short Python function that performs a task

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What Do I Need To Do?

- Homeworks and lectures should be good practice
- Minor coding questions (not minor syntax mistakes, etc.)
  - We're looking for "I understand this well enough to implement it," not "I know Python really well"
  - Please don't study Python
- Look at **homeworks**, **sample problems** in lectures, and **class exercises**
- Look at lectures' "Why?" questions.

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Scoring

- Follow directions.
- Start with a perfect score, mark down for mistakes
  - If I ask for 2 examples, and you give 3, one of which is wrong, it's -1/2
- Read carefully.
  - You have time.
    - "I didn't see the part that said…"
- Ask for clarification on, e.g., unfamiliar words

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Topics: AI

- What is intelligence?
- What is AI?
- What is it used for? Good for?
- Historical events and figures

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Topics: Agents

- Agents
  - What kinds are there?
  - What do they do?
  - How do we characterize them (what traits do they have)?
    - Autonomy, rationality, ..?
  - How do they interact with an environment?
- Environments
  - What's an environment?
  - How is it characterized?

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Topics: Search

- What is it for?
- Elements of a search problem
  - State spaces, actions, costs, ...
  - How do state spaces pertain to search?
  - To problem-solving?
- Exploring search space (selecting, expanding, generating, evaluating)
- Specific algorithms: How do they work? What are they good for? What are their weaknesses?

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Topics: Formalizing Search

- What are the elements of a search problem?
  - "Express [X] as a search problem." What does that mean?
- **States**: every state a puzzle can be in
- **Actions/Operations**: how you get between states
- **Solutions**: you need a goal test (and sometimes a heuristic, or estimate of distance from goal)
  - Sometimes we care about path (planning), sometimes just goal (identification). Can you say which, for a given problem?
- **Costs**: not all solutions or actions are equal

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Topics: Uninformed Search

- Why do uninformed search?
- Come up with some examples of uninformed search problems
- Important algorithms: BFS, DFS, iterative deepening, uniform cost
- A likely question: "What would be the best choice of search method for [*problem*], **and why**?"
- Characteristics of algorithms
  - Completeness, optimality, time and space complexity, …

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Topics: Informed Search

- Some external or pre-existing information says what part of state space is **more likely** to have a solution
- **Heuristics** encode this information: *h(n)*
  - What does *h(n)* = 0 mean?
- Admissibility & Optimality
  - Some algorithms can be optimal when using an admissible heuristic
- Algorithms: best-first, greedy search, A*, IDA*, SMA*
- What's a good heuristic for a problem? Why?

A heuristic applies to a **node/state**, and can give optimal solution with the right **algorithm**

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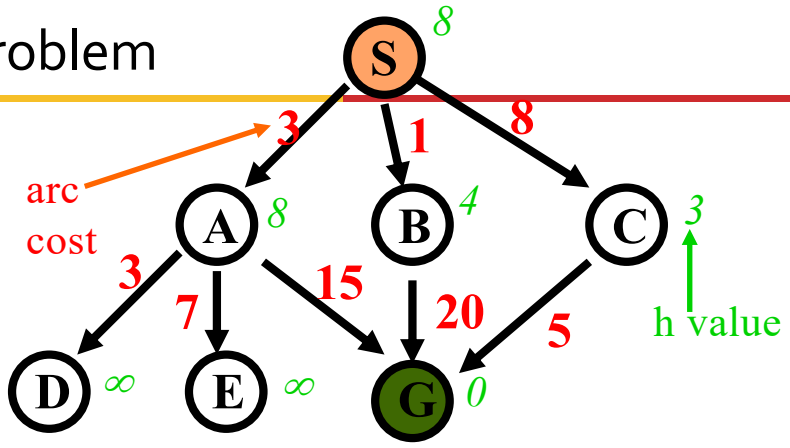
Sample Problem



Apply the following to search this space. At each search step, show: current node being expanded, $g(n)$ (path cost so far), $h(n)$ (heuristic estimate), $f(n)$ (evaluation function), and $h^*(n)$ (true goal distance).

Depth-first search
Uniform-cost search
Breadth-first search
Greedy search
A* search

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Topics: Local Search

- Idea: Keep a single "current" state, try to improve it
  - Don't keep path to goal
  - Don't keep entire search in memory
  - Go to "successor states"
- Concepts: hill climbing, local maxima/minima, random restarts
- Important algorithms: hill climbing, local beam search, simulated annealing

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Topics: Search

- How many states are there?
- What operations fully encode this search problem?
  - That is: how can you reach every state?
- Are there loops?
- How many states does pure DFS visit?
  - If there are loops?
- What's a good algorithm? A bad one? (For a specific problem?)

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Topics: CSPs

- Constraint Satisfaction: subset of search problems
  1. **State** is defined by **random variables** X_i
  2. With values from a **domain** D
  3. Knowledge about problem can be expressed as **constraints** on what values X_i can take
- Special algorithms, esp. on constraint networks
- **How would you express [*something*] as a CSP?** As a search? How would you represent the constraints?
  - E.g.: "Must be alphabetical"

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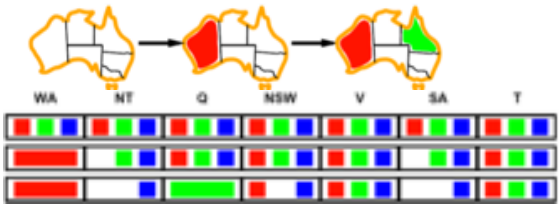
Topics: Constraint Networks

- **Constraint propagation**: constraints can be propagated through a constraint network
  - Goal: maintain **consistency** (constraints aren't violated)
- Concepts: Variable ordering, value ordering, fail-first
- Important algorithms:

1. **Backtracking:** DFS, but at each point:
   - Only consider a single variable
   - Only allow legal assignments
2. **Forward checking**



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Topics: Games

- Why play games? What games, and how?
- Characteristics: zero-sum, deterministic, perfect information (or not)
- What's the search tree for a game? How big is it?
- How would you express game [*X*] as a search? What are the states, actions, etc.? How would you solve it?
- Algorithms: **(expecti)minimax, alpha-beta pruning**
  - Many examples on slides

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Topics: Basic Probability

- What is uncertainty?
- What are sources of uncertainty in a problem?
  - Non-deterministic, partially observable, noisy observations, noisy reasoning, uncertain cause/effect world model, continuous problem spaces…
- World of all possible states: a complete assignment of values to random variables
- Joint probability, conditional probability

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Topics: Basic Probability

- Independence: A and B are independent
  - $P(A) \perp\!\!\!\perp P(B)$ iff $P(A \wedge B) = P(A)\,P(B)$
  - A and B do not affect each other's probability
- Conditional independence: A and B are independent given C
  - $P(A \wedge B \mid C) = P(A \mid C)\,P(B \mid C)$
  - A and B don't affect each other if C is known

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Topics: Basic Probability

- $\mathrm{P}(a \mid b) = \dfrac{\mathrm{P}(a \wedge b)}{\mathrm{P}(b)}$
- $\mathrm{P}(a \wedge b) = \mathrm{P}(a \mid b)\ \mathrm{P}(b)$

P(*smart* ∧ *study* ∧ *prep*)	*smart*		¬*smart*	
	study	¬*study*	*study*	¬*study*
prepared	.432	.16	.084	.008
¬*prepared*	.048	.16	.036	.072

- What is the prior probability of smart?
- What is the conditional probability of prepared, given study and smart?
- Is prepared independent of study?

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Topics: Probabilistic Reasoning

- Concepts:
  - Posteriors and Priors; Bayesian Reasoning; Induction and Deduction; Probabilities of Events
  - [In]dependence, conditionality, marginalization
- What is Bayes' Rule and what is it useful for?

$$P(H_i \mid E_j) = \frac{P(E_j \mid H_i)P(H_i)}{P(E_j)}$$

$$P(cause \mid effect) = \frac{P(effect \mid cause)P(cause)}{P(effect)}$$

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Topics: Joint Probability

- What is the **joint probability** of A and B?
- *P*(A,B)
- The probability of any set of legal assignments.
- Booleans: expressed as a matrix/table

	alarm	¬ alarm
burglary	0.09	0.01
¬ burglary	0.1	0.8

≡

A	B	
T	T	0.09
T	F	0.1
F	T	0.01
F	F	0.8

- Continuous domains → probability functions

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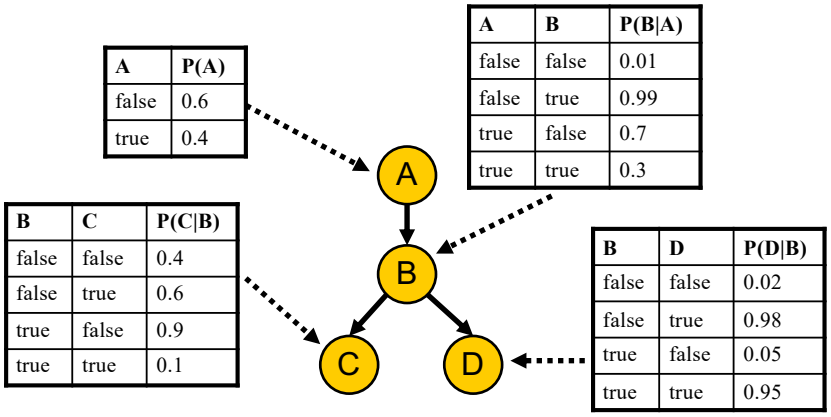
Conditional Probability Tables

- For X_i, CPD $P(X_i \mid Parents(X_i))$ quantifies effect of parents on X_i
- **Parameters** are probabilities in conditional probability tables (CPTs):



Example from web.engr.oregonstate.edu/~wong/slides/BayesianNetworksTutorial.ppt

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Bates belief net Definition

- AKA Bayesian Network, Bayes Net, belief net
- A graphical model (as a DAG) of probabilistic relationships among a set of random variables
- Links represent direct influence of one variable on another

Slides from Dr. Oates, UMBC

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Simple Bayesian Network

P(S=no)	0.80
P(S=light)	0.15
P(S=heavy)	0.05

$C \in \{none, benign, malignant\}$

Smoking=	no	light	heavy
P(C=none)	0.96	0.88	0.60
P(C=benign)	0.03	0.08	0.25
P(C=malig)	0.01	0.04	0.15

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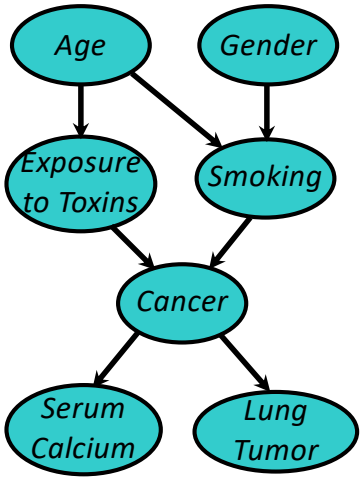
More Complex Bayesian Network



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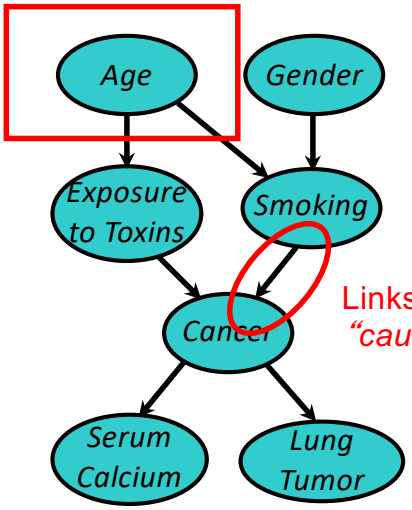
More Complex Bayesian Network

Nodes represent variables



Links represent *"causal"* relations

- Does gender cause smoking?
- Influence might be a more appropriate term

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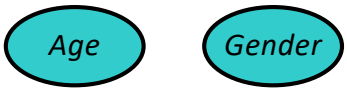
Independence



Age and *Gender* are independent.

$P(A,G) = P(G) * P(A)$

$P(A \mid G) = P(A)$
$P(G \mid A) = P(G)$

$P(A,G) = P(G|A)\ P(A) = P(G)P(A)$
$P(A,G) = P(A|G)\ P(G) = P(A)P(G)$

Slides from Dr. Oates, UMBC

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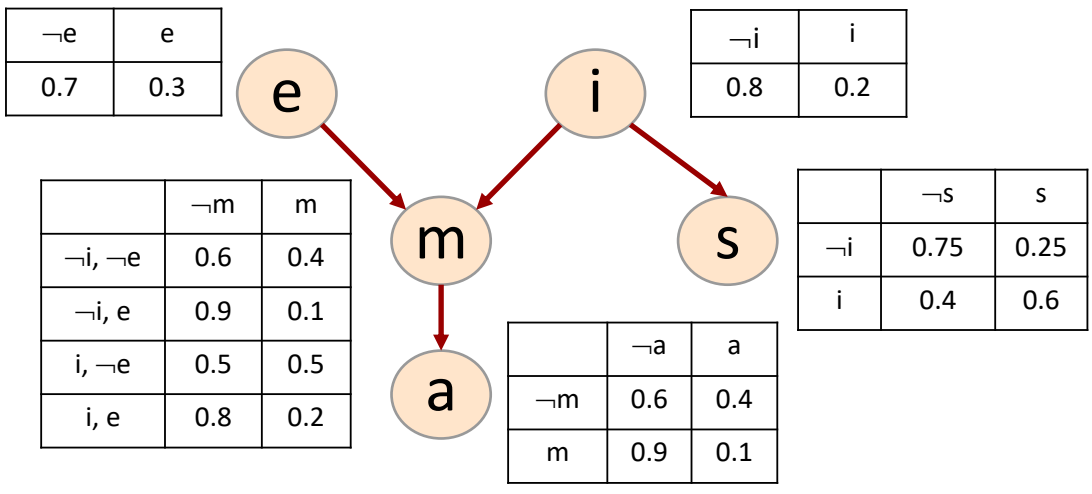
Review: Bayes' Nets

- P(a, m, i, e, s) = P(a | m) * P(m | i, e) * P(i) * P(e) * P(s | i)



www.upgrad.com/blog/bayesian-network-example/

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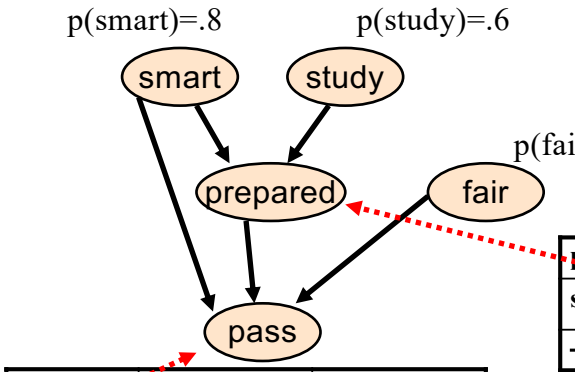
Exercise: Variable Elimination



p(prep|…)	smart	¬smart
study	.9	.7
¬study	.5	.1

p(pass|…)	smart		¬smart	
	prep	¬prep	prep	¬prep
fair	.9	.7	.7	.2
¬fair	.1	.1	.1	.1

Query: What is the probability that a student **studied**, given that they pass the exam?

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Topics: Reasoning Under Uncertainty

- How is the world represented over time?
  - Concepts: timesteps, world, observations
  - Transition model captures how the world changes
  - Sensor model capture what we see, given some world
  - Markov assumption (first-order) makes it all tractable
- What can we do with it?
  - Concepts: Filtering, predicting, smoothing, explaining

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Topics: Reasoning Under Uncertainty

- How would you represent this problem as a network and set of conditional probability tables?
  - The weather has a 30% chance of changing and a 70% chance of staying the same.
  - If it's raining, the probability of seeing someone carrying an umbrella is 90%; if it's not raining, it's 20%.
- I saw umbrellas Monday and Tuesday, but not today. What is the most likely weather pattern for those days?

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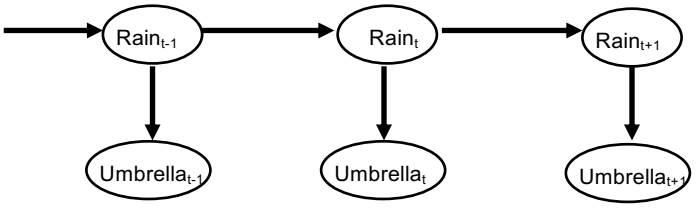
Example

R_{t-1}	$P(R_t \mid R_{t-1})$
t	0.7
f	0.3

Weather has a 30% chance of changing and a 70% chance of staying the same.



R_t	$P(U_t \mid R_t)$
t	0.9
f	0.2

BBN from: www2.isye.gatech.edu/~yxie77/isye6416_17/Lecture6.pdf

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Topics: Utility

- How should rational agents make decisions?
- Concepts: rationality, utility functions, value functions, expected value, satisficing, preferences
- Utility is a function of world states
- Must have some preferences that pertain to perceived needs or wants

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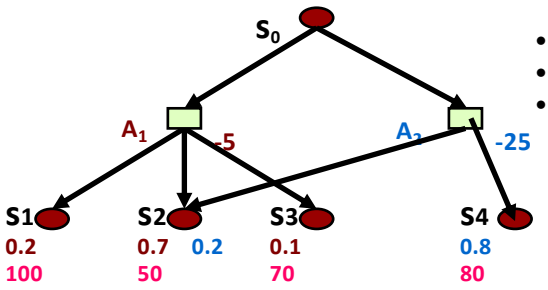
Topics: Decision Theory

- What is the expected utility of an action?
  - Broadly: its probability times its value
  - The sum of that for all possible outcomes
- Maximum Expected Utility principle



- $U(A_1, S_0) = 62 - 5 = 57$
- $U(A_2, S_0) = 74 - 25 = 49$
- $U(S_0) = \max_a\{U(a, S_0)\}$
  $= 57$

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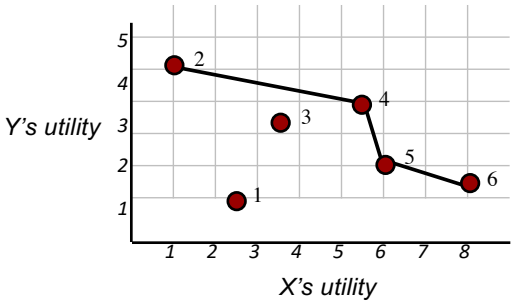
Topics: Pareto Optimality

- An outcome is Pareto optimal if there is no other outcome that all players would prefer.
- S is a Pareto-optimal solution iff
  - $\forall s' (\exists x\ Ux(s') > Ux(s) \rightarrow \exists y\ Uy(s') < Uy(s))$
  - I.e., if X is better off in s', then some Y must be worse off



Example questions:

Which solutions are Pareto-optimal?

Which solution(s) maximize global utility (social welfare)?

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Topics: Nash Equilibrium

- Occurs when each player's strategy is optimal, **given** strategies of the other players
- No player benefits by **unilaterally** changing strategy while others stay fixed
- Example questions:
  - What strategy should you choose? Why?
  - What strateg(ies) are in a Nash equilibrium?

B \ C	Confesses	Denies
Confesses	(3, 3)	(0, 5)
Denies	(5, 0)	(1, 1)

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Various Reminders

- **Everything in the readings** is fair game.
- Look at homeworks, sample problems in lectures.
- Look at lectures' "Why?" questions.
- Slides are a good source of **conceptual** understanding.
- Book goes into **detail** and explains more deeply.

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Class Project

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About the Project

- Choosing a project
  - This will be up to you!
  - We would love to discuss your project ideas with you
- Deliverables
  - Project design
  - Phase I: working code, updated design
  - Phase II: final code
  - Final writeup

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Project Ideas, Non-Exhaustively (1)

- Choose a game, and creating an agent to play that game using artificial intelligence, for example, chess, bridge, Minecraft
- Develop an agent designed to interact intelligently with people in some context, for example, a chatbot or virtual assistant
- Develop an agent that (hypothetically) interacts with some real-world phenomenon, for example, the stock market
- Develop a recommender system for some existing corpus, for example, to recommend Netflix suggestions

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Project Ideas, Non-Exhaustively (2)

- Apply machine learning techniques to some existing corpus to draw conclusions, for example, a plagiarism detector, a COVID-19 outbreak predictor
- Develop some toolkit for solving a standard type of AI problem, or extending such a toolkit with new capabilities (a software development project)
- Use NLP to analyze documents and draw intelligent conclusions, for example, a resume analyzer, a spoiler detector
- Formulate, implement, and compare a novel solution to an existing problem
- Formulate, acquire data for, and apply a sufficient baseline for a novel task

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Deliverables: Project Design

- A written document in AAAI conference format
  - Author kit information available from the project description
  - Author kit includes templates for Word and LaTeX
- ~2 pages
- Include:
  - Idea: A description and motivation of the project
  - A description of the AI technique(s) you are going to use
  - A description of what you will implement in each phase
  - How your implemented system draws on ideas from the AI literature
  - Initial references
  - Your evaluation strategy

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Deliverables: Phase I

- Updated version of project plan (~3-4 pages)
  - Progress to date, evaluation of current functionality
- Code base
  - A working, but incomplete, version of your final project
    - Examples: it plays bridge, but chooses cards unintelligently; it reads in stock market data and proposes trades, but not well; it conducts a dialog with someone, but the utterances are gibberish
    - **What this means for your specific project can be discussed with us**
  - Must work on standard Linux systems
  - Include everything necessary to run your project, including a README and a dataset if appropriate

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Deliverables: Phase II

- Final code base
  - A complete system performing a task
  - Must work on standard Linux systems
  - Include everything necessary to run your project, including a README and a dataset if appropriate
  - May include evaluation-specific data, e.g., a set of sample stock market interactions

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Deliverables: Final Writeup

- AAAI format conference paper
- 4-8 pages, not counting references
  - Includes standard paper stuff like title and abstract
- Specific sections are **recommended** in the project description:
  - Introduction – description and motivation for the project
  - Related work – how your solution fits into the landscape
  - Approach – the core description of the work you did
  - Results – your evaluation strategy, description and analysis of results
  - Conclusion – final discussion of the work, future/follow-up work

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Forming Groups

- 2-4 people
  - Get together with your group and:
  - Everyone trade names and email addresses
  - One person email group member list to me & TA **today in class**
- Pull up project description writeup
- Start talking about possible projects!

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