

## *CSCE 580: Introduction to AI* *CSCE 581: Trusted AI*

# Lecture 23 & 24: Making Decisions – Simple and Complex

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14<sup>TH</sup> NOV & 16<sup>TH</sup> NOV, 2023

**Carolinian Creed: “I will practice personal and academic integrity.”**

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# Organization of Lectures 23 & 24

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- Introduction Segment
  - Recap of Lectures 21 and 22
- Main Segment
  - Making Decisions
  - Making simple decisions - Maximum Expected Utility (MEU)
  - Making complex decisions - Markov Decision Processes (MDPs)
- Concluding Segment
  - Course Project Discussion
  - Quiz 4
  - About Next Lecture – Lecture 25
  - Ask me anything

# Introduction Section

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# Recap of Lecture 21 and 22

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- Topic discussed
  - Text Processing
  - Language Models (LMs)
  - Learning for LMs with NN
  - Large LMs

# Graduate Paper Presentation

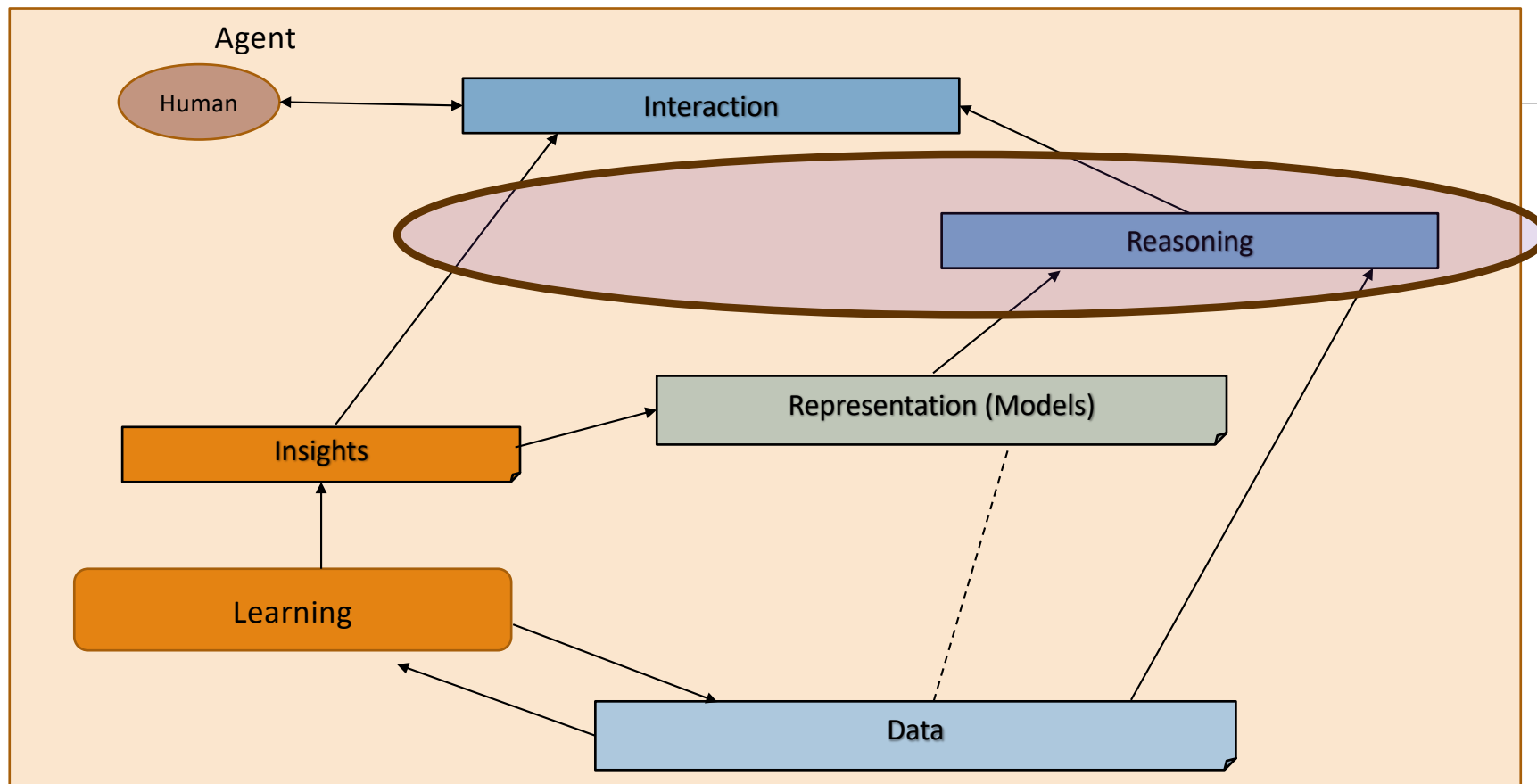
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- Papers between 2021-2023 (last 3 years)
- At top AI venues: AAAI, Neurips, IJCAI, ICML, ICLR, or discuss with instructor
- Guideline on presentation
  - Summary of the paper
  - Critique (+ves/ -ves)
  - Relevance to your and anyone else's project in the class

# Intelligent Agent Model



# Relationship Between Main AI Topics



# Where We Are in the Course

## CSCE 580/ 581 – In This Course

- Week 1: Introduction, Aim: Chatbot / Intelligence Agent
- Weeks 2-3: Data: Formats, Representation and the Trust Problem
- Week 4-5: Search, Heuristics - Decision Making
- Week 6: Constraints, Optimization – Decision Making
- Week 7: Classical Machine Learning – Decision Making, Explanation
- Week 8: Machine Learning - Classification
- Week 9: Machine Learning - Classification – Trust Issues and Mitigation Methods
- Topic 10: Learning neural network, deep learning, Adversarial attacks
- Week 11: Large Language Models – Representation, Issues
- Topic 12: Markov Decision Processes, Hidden Markov models - Decision making
- Topic 13: Planning, Reinforcement Learning – Sequential decision making
- Week 14: AI for Real World: Tools, Emerging Standards and Laws; Safe AI/ Chatbots



# Main Section

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**Credit:** Retrieved from internet

# Making Decisions

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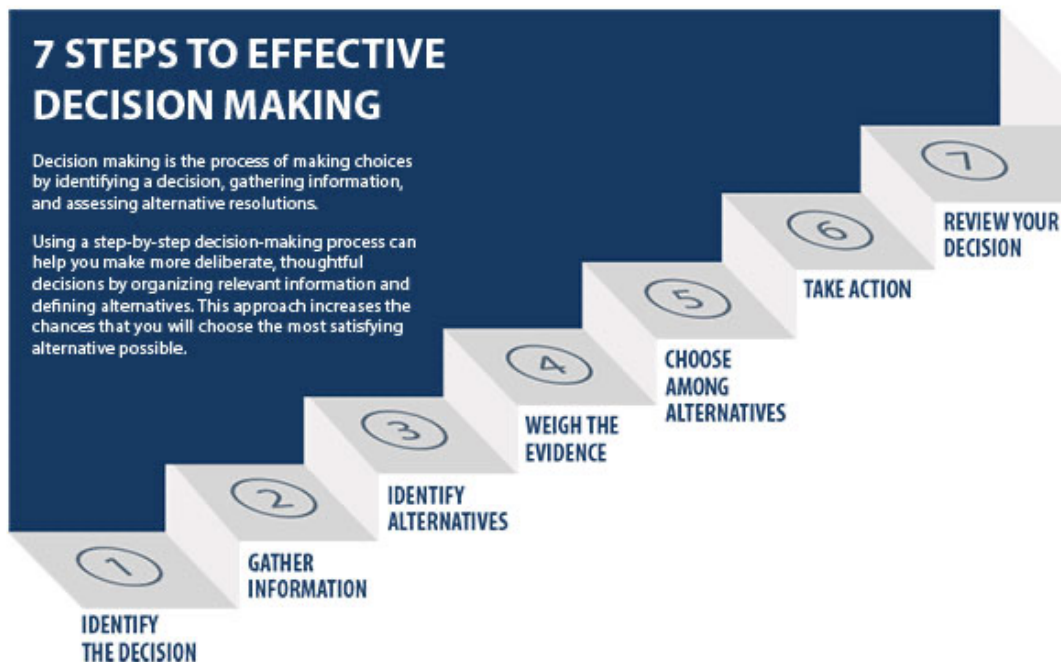
# Real World Decisions

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Decision situation: going to airport from home

- Actions:
  - Take own car
  - Take a cab/ limo
  - Take a ride-share
  - Take a bus
  - Hitch-hike
  - Walk

# The Quality of Everyday Decisions



Major variability due to:

- Emotions
- Biases
- Increasing data volume
- Cognitive ability to process
  - Decreases under stress and constraints
  - Decreases with age\*

Source: <https://www.umassd.edu/fycm/decision-making/process/>

\* Source: A Review of Decision-Making Processes: Weighing the Risks and Benefits of Aging, Mara Mather, <https://www.ncbi.nlm.nih.gov/books/NBK83778/>

## Taking medicines

- ## Impact

- causes 125,000 deaths, at least 10 percent of hospitalizations
- Costs the American health care system between \$100 billion and \$289 billion a year.

**Sources:**

- Medication Nonadherence, A Diagnosable and Treatable Medical Condition, Zachary A. Marcum, Mary Ann Seveck, Steven M. Handler, <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3976600/>, 2013.
- <https://www.nytimes.com/2017/04/17/well/the-cost-of-not-taking-your-medicine.html>

Example:  
Hard to  
understand  
medicine's  
information



## Evidence #2: Matching Demand to Supply of Jobs is Inadequate Demand-Supply Gap in Jobs Market <sup>[1]</sup> and Yet, Low Work Satisfaction/ Engagement <sup>[2]</sup>

The screenshot shows the Indeed website interface. At the top, there's a navigation bar with links like 'Find Jobs', 'Company Reviews', 'Find Salaries', 'Find Resumes', and 'Employers / Post Job'. Below this is a search bar with 'What' (Job title, keywords, or company) and 'Where' (Location) fields. The 'What' field contains 'human resources' and the 'Where' field is empty. A blue 'Find jobs' button is next to the search bar. Below the search bar, there's a tip: 'Tip: Enter your city or zip code in the "where" box to show results in your area.' The main content area shows search results for 'human resources jobs'. On the left, there's a sidebar with filters for 'Sort by: relevance - date', 'Salary Estimate' (ranging from \$30,000 to \$80,000), and 'Job Type' (Full-time, Part-time, Temporary, Contract, Internship, Commission). The main results list shows two job listings for 'Human Resources Manager' at 'Byrne Dairy' and 'Caledonia Spirits'. The 'Byrne Dairy' listing includes a star rating, number of reviews, location, and a description. The 'Caledonia Spirits' listing includes a 'Responsive employer' badge and a description. On the right, there's a section titled 'Be the first to see new human resources jobs' with an email input field and an 'Activate' button. Below that, there's a section titled 'Human Resources Manager salaries in United States' showing a bar chart and a salary of '\$75,053 per year' based on 8,263 salaries.

Job search at a portal

- Finding jobs was generally hard around the world (Dec 2019), except for in tight labor markets like US (3.5% unemployment)
- Workforce satisfaction/ engagement was generally low around the world – people did not find jobs they were match for [1,2]
- COVID-19 impact [3]:
  - Nearly half of global workforce at risk of losing livelihoods in informal sector
  - 9-12% job loss in the formal sector around the world
  - 14.7% unemployment in US by end of April 2020 [4]

1. Source: Global Skills Trends, Training Needs and Lifelong Learning Strategies for the Future of Work, ILO & OECD Report 2018, [http://www.g20.utoronto.ca/2018/g20\\_global\\_skills\\_trends\\_and\\_III\\_oecd-ilo.pdf](http://www.g20.utoronto.ca/2018/g20_global_skills_trends_and_III_oecd-ilo.pdf)
2. Source: For 2016, job satisfaction: US – 32%, Global – 13%, <https://www.gallup.com/workplace/236495/worldwide-employee-engagement-crisis.aspx>
3. [https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS\\_743036/lang--en/index.htm](https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_743036/lang--en/index.htm)
4. <https://www.bls.gov/news.release/empsit.nr0.htm>

# Decision Imperative: Corona Virus Pandemic

## Emerging Scenario Around the World\*

- Millions of cases, hundreds of thousands of deaths
- Businesses disrupted, millions going out of business
- Millions losing jobs

\* Numbers changing continuously; see reference for details

## Decisions Need to be Made

- About disease
  - Understand disease
  - Tackle disease
- Understand impact to society: economy, supply chain
- Advise on actions to take
  - Individual
  - Group
  - Societal policy

**Resource:** <https://github.com/biplav-s/covid19-info/wiki/Important-Information-About-COVID19>

# Before and After: (AI) Decision Support

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**Today's tools:** Static, non-interactive, non-contextual, lack explanations

**Future tools:** Dynamic to data, interactive, contextual, explaining with data, anywhere, multi-modal, social (group dependency), societally relevant, ...

*Future has potential to improve people's lives, promote well-being and reduce waste*



# Simple Decisions

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# Setting for a Decision

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- An agent has a set of actions available,  $A = \{a_i\}$  and is in a state  $s$
- There may be an uncertainty about current state. So, the agent assigns a probability to current state  $P(s)$  to each possible current state.
- When an action is taken, there may be uncertainty about outcome. So, resulting state is:  
 $P(s' \mid s, a)$
- The probability of reaching state  $s'$  after executing  $a$  in the current state is:  
 $P(\text{RESULT}(a) = s') = \sum_s P(s) P(s' \mid s, a)$

**Note:**  $P(\text{RESULT}(a) = s')$  requires perception, learning, knowledge representation and inference

Adapted from:  
Russell & Norvig, AI: A Modern Approach

# Making a Simple Decision

- Choose best action based on the desirability of immediate outcome
- Have a utility function  $U(s)$  expressing desirability of a state ( $s$ )
- Expected utility of an action given the evidence,  $EU(a)$ , is the average utility value of the outcome, weighted by the probability of that outcome.

$$EU(a) = \sum_{s'} P(\text{RESULT}(a) = s') U(s')$$

- Principle of maximum expected utility (MEU): rational agent chooses an action which maximizes its maximum expected utility  
action =  $\text{argmax}_a EU(a)$

**Decision situation:** going to airport from home

- Actions:
  - Take own car
  - Take a cab/ limo
  - Take a ride-share
  - Take a bus
  - Hitch-hike
  - Walk

Adapted from:  
Russell & Norvig, AI: A Modern Approach

# Utility Functions: Modeling Preferences

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- Notations
  - $A > B$ : agent (decision maker) prefers A over B
  - $A \sim B$ : agent (decision maker) is indifferent between A and B
  - $A \succeq B$ : agent (decision maker) prefers A over B or is indifferent between A and B
- Convention
  - Outcome of an action is a lottery:  $L = [p_1, S_1; p_2, S_2; \dots; p_n, S_n]$
- Utility function  $U$ 
  - $U(A) > U(B)$ , if and only if,  $A > B$
  - $U(A) = U(B)$ , if and only if,  $A \sim B$

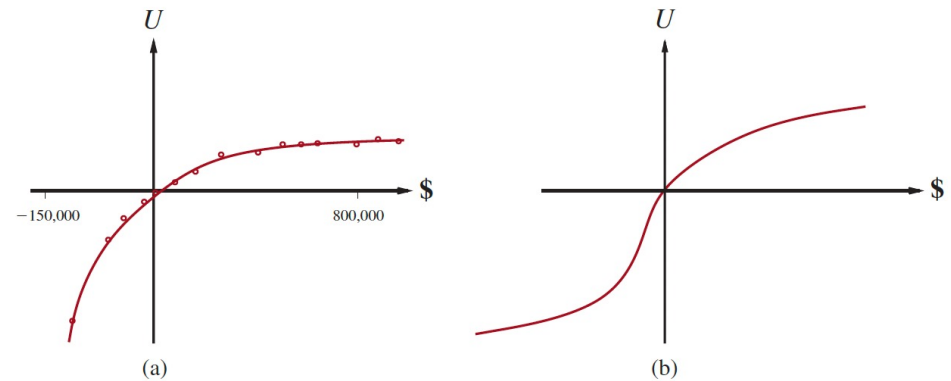
# Example: Choosing a Winning

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- Won a game and have to choose
  - Choice 1: Take \$1M
  - Choice 2: Toss coin; Heads => \$2.5 M, Tails => 0
- Expected Monetary Value (EMV)
  - Choice 1: \$1M
  - Choice 2:  $\frac{1}{2} \cdot \$2.5M + \frac{1}{2} \cdot 0 = \$1.25M$
- Expected Utility depends on current money

# Example: Choosing a Winning

- Won a game and have to choose
  - Choice 1: Take \$1M
  - Choice 2: Toss coin; Heads => \$2.5 M, Tails => 0
- Expected Utility depends on current money(k)
  - $EU(\text{Accept}) = \frac{1}{2} U(S_k) + \frac{1}{2} U(S_k + \$2.5M)$
  - $EU(\text{Decline}) = U(S_k + \$1M)$

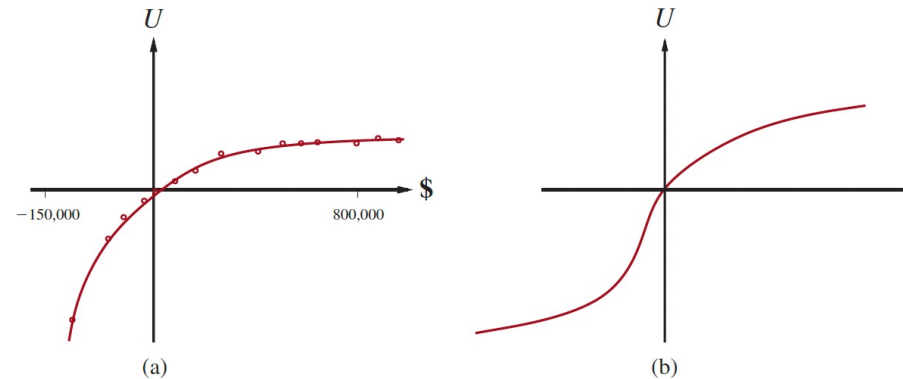


**Figure 16.2** The utility of money. (a) Empirical data for Mr. Beard over a limited range. (b) A typical curve for the full range.

Adapted from/ image credit:  
Russell & Norvig, AI: A Modern Approach

# Example: S-Curve, Risk

- S-Curve: Fig 16.2(b)
- utility of a lottery is less than a sure thing
  - $U(\text{Lottery}) < U(\text{SureThing}_{\text{EMV}(L)})$
  - **Risk averse agents:** prefer sure payoff than expected monetary value of a gamble
  - **Risk seeking agents:** (people already in debt)
  - **Certainty equivalent** of lottery: agent will accept in lieu of a lottery
- According to studies, people will accept \$400 (approx.) in lieu of a gamble than gives \$1,000 half the time and \$0 other
- **Insurance premium:** difference between EMV of a lottery and its certainty equivalent
  - Risk aversion / positive insurance premium is the basis of insurance industry



**Figure 16.2** The utility of money. (a) Empirical data for Mr. Beard over a limited range. (b) A typical curve for the full range.

Adapted from/ image credit:  
Russell & Norvig, AI: A Modern Approach

# Humans STILL Do Now Always Follow Utility Theory

- Subjects in this experiment are given a choice between lotteries A and B:

- Comparison scenario 1

- A : 80% chance of \$4000
- B : 100% chance of \$3000

- Comparison scenario 2

- C : 20% chance of \$4000
- D : 25% chance of \$3000

Tversky and Kahneman (1982) experiment

- The majority of survey respondents choose B over A and C over D.

- Comparison scenario 1:

- A:  $0.8 * 4000 + 0.2 * 0 = 3200$
- B: 3000

- Comparison scenario 2:

- C:  $0.2 * 4000 + 0.8 * 0 = 800$
- D:  $0.25 * 3000 + 0.75 * 0 = 750$

Consistent utility: A over B and C over D.

Source: Russell & Norvig, AI: A Modern Approach



# Multi-Attribute/ Objective Optimization

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Decision situation: going to airport from home

- Actions:

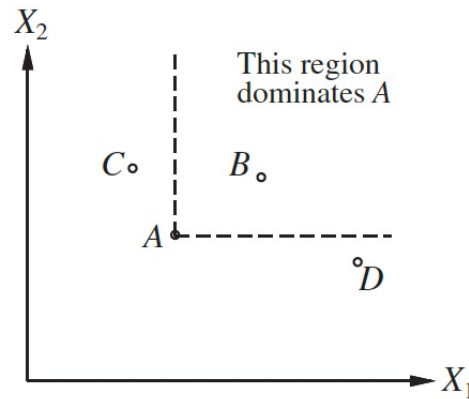
- Take own car
- Take a cab/ limo
- Take a ride-share
- Take a bus
- Hitch-hike
- Walk

**Attributes:** cost, time, comfort, certainty of arrival time, ...

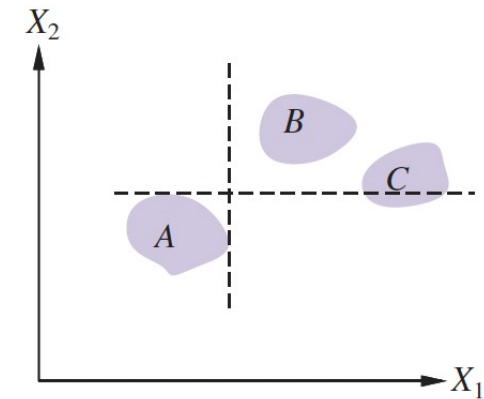
# Decision Dominance

Two attribute case shown

- Choose by dominance



(a)



(b)

**Figure 16.4** Strict dominance. (a) Deterministic: Option A is strictly dominated by B but not by C or D. (b) Uncertain: A is strictly dominated by B but not by C.

Adapted from/ image credit:  
Russell & Norvig, AI: A Modern Approach

# Complex Decisions

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# Complex Decisions

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- Making a sequence of decisions
- Making a single decision but with
  - Environment changing
  - Actions not being deterministic
  - Perception not being perfect
  - ...

# Making a Sequence of Decisions

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Decision situation: driving to airport from home

- Actions:
  - Take a LEFT at first intersection
  - ENTER a highway
  - GETOUT a highway at EXIT-X
  - Turn RIGHT at intersection
  - PARK in Premium lot
  - ..

# Optimal Decision

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- What is it? There is no absolute answer. In AI, there is the concept of a **rational** agent.
- Acting rationally: acting such that one can achieve one's goals given one's beliefs (and information)
  - But what are one's goals
  - Are the goals always of achievement?
- Some options
  - Perfect rationality: maximize expected utility at every time instant
    - Given the available information; can be computationally expensive
    - "Doing the right thing"
  - Bounded optimality: do as well as possible given computational resources
    - Expected utility as high as any other agent with similar resources
  - Calculative rationality: *eventually* returns what would have been the rational choice

# What Is It?

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- As a working principle
  - Bounded or Calculative Rationality
- In observable and deterministic scenarios
  - Maximize utility: (benefit – cost)
- In scenarios with uncertainty and/ or unobservable
  - Maximize *expected* utility: (benefit – cost)

# Example Situation – Course Selection

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- A person wants to pass an academic program in two majors: A and B
- There are three subjects: A, B and C, each with three levels (\*1, \*2, \*3). There are thus 9 courses: A1, A2, A3, B1, B2, B3, C1, C2, C3
- To graduate, at least one course at beginner (\*1) level is needed in major(s) of choice(s), and two courses at intermediate levels (\*2) are needed
- **Optimality considerations** in the problem
  - Least courses, fastest time to graduate, class size, friends attending together, ...
- **Answer questions**
  - Q1: How many minimum courses does the person have to take ?
  - Q2: Can a person graduate in 2 majors studying 3 courses only?
  - ...



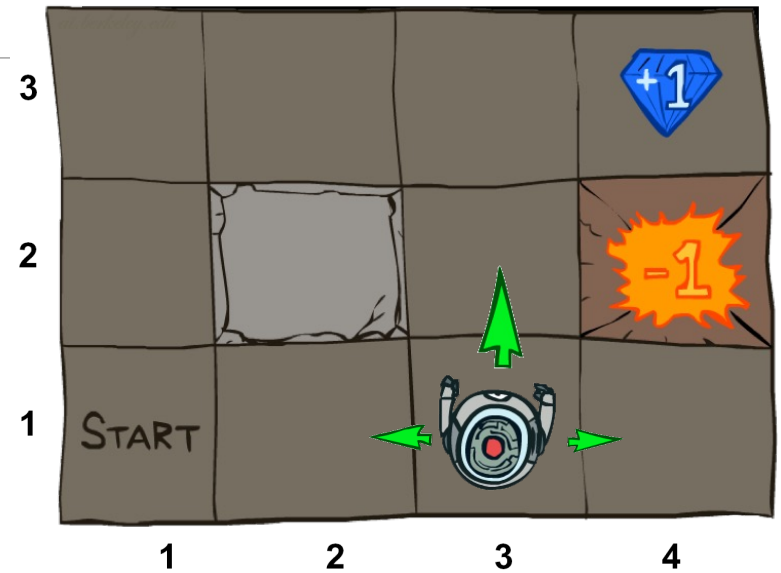
# Algorithms for Optimality

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- Problem specific methods
  - Path finding
  - Linear programming
  - Constraint satisfaction and optimization
- General Purposed - methods for optimality in search

# Synthetic Example: Grid World

- A maze-like problem
  - The agent lives in a grid
  - Walls block the agent's path
- Noisy movement: actions do not always go as planned
  - 80% of the time, the action North takes the agent North (if there is no wall there)
  - 10% of the time, North takes the agent West; 10% East
  - If there is a wall in the direction the agent would have been taken, the agent stays put
- The agent receives rewards each time step
  - Small "living" reward each step (can be negative)
  - Big rewards come at the end (good or bad)

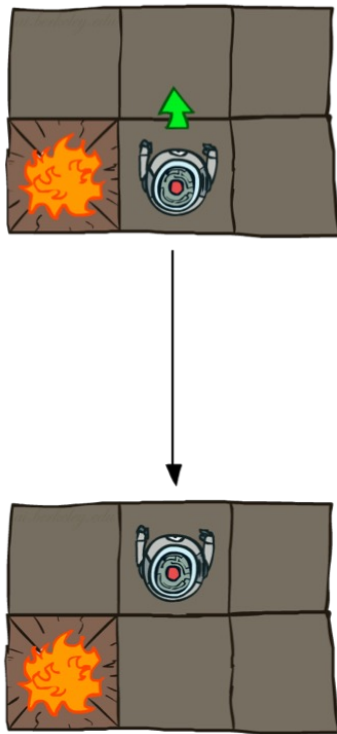


Slide adapted from: Dan Klein and Pieter Abbeel's AI lecture  
Original example in Russell & Norvig's AI book

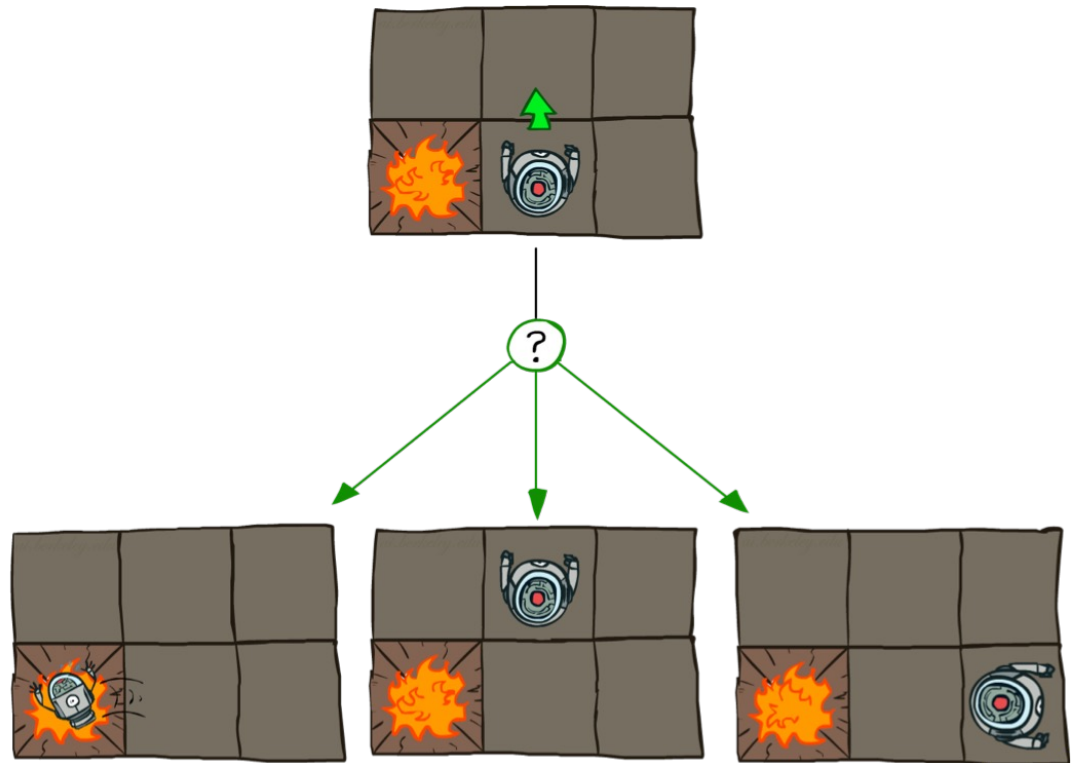
# Grid World Actions

Slide adapted from: Dan Klein and Pieter Abbeel's AI lecture  
Original example in Russell & Norvig's AI book

## Deterministic Grid World



## Stochastic Grid World

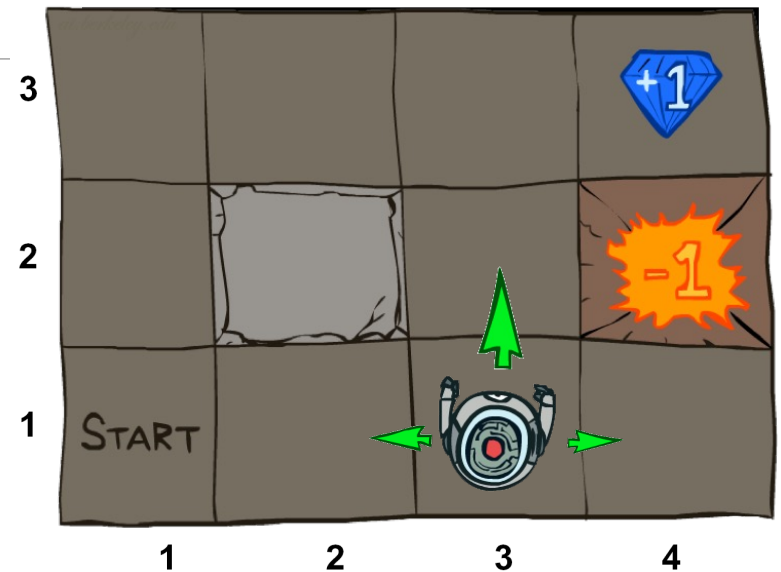


# Markov Decision Processes

An MDP is defined by:

- A **set of states**  $s \in S$
- A **set of actions**  $a \in A$
- A **transition function**  $T(s, a, s')$ 
  - Probability that  $a$  from  $s$  leads to  $s'$ , i.e.,  $P(s' | s, a)$
  - Also called the model or the dynamics
- A **reward function**  $R(s, a, s')$ 
  - Sometimes just  $R(s)$  or  $R(s')$
- A **start state**
- Maybe a **terminal state**

MDPs are non-deterministic search problems



Slide adapted from: Dan Klein and Pieter Abbeel's AI lecture  
Original example in Russell & Norvig's AI book

[Demo – gridworld manual intro (L8D1)]

# Markovian Assumption

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“Markov” generally means that given the present state, the future and the past are independent

For Markov decision processes, “Markov” means action outcomes depend only on the current state

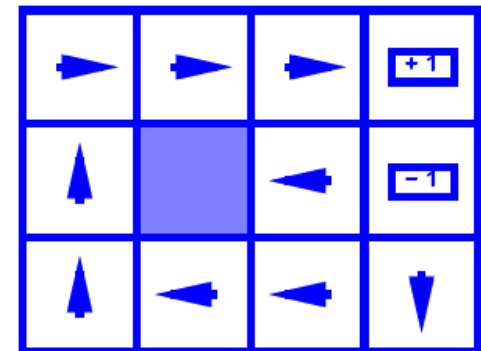
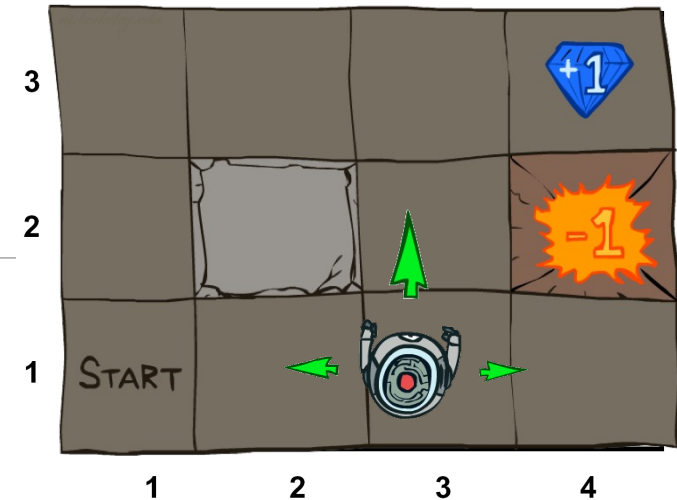
$$\begin{aligned} &P(S_{t+1} = s' | S_t = s_t, A_t = a_t, S_{t-1} = s_{t-1}, A_{t-1}, \dots, S_0 = s_0) \\ &= \\ &P(S_{t+1} = s' | S_t = s_t, A_t = a_t) \end{aligned}$$



Andrey Markov  
(1856-1922)

# Output: Policies

- In deterministic single-agent search problems, we have a **plan**, or sequence of actions, from start to a goal
- For MDPs, we want an optimal **policy**  $\pi^*: S \rightarrow A$ 
  - A policy  $\pi$  gives an action for each state
  - An optimal policy is one that maximizes expected utility if followed



$$R(s) = -0.01$$

Slide adapted from: Dan Klein and Pieter Abbeel's AI lecture

# Exercise and Code

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- MDP Solution Methods
  - From Book: AI – A Modern Approach,  
<https://github.com/aimacode/aima-python/blob/master/mdp.ipynb>

Source: Russell & Norvig, AI: A Modern Approach

# Course Project

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# Project Discussion: What Problem Fascinates You ?

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- Data
  - Water
  - Finance
  - ...
- Analytics
  - Search, Optimization, Learning, Planning, ...
- Application
  - Building chatbot
- Users
  - Diverse demographics
  - Diverse abilities
  - Multiple human languages

## Project execution in sprints

- Sprint 1: (Sep 12 – Oct 5)
  - **Solving**: Choose a decision problem, identify data, work on solution methods
  - **Human interaction**: Develop a basic chatbot (no AI), no problem focus
- Sprint 2: (Oct 10 – Nov 9)
  - **Solving**: Evaluate your solution on problem
  - **Human interaction**: Integrated your choice of chatbot (rule-based or learning-based) and methods
- Sprint 3: (Nov 14 – 30)
  - **Evaluation**: Comparison of your solver chatbot with an LLM-based alternative, like ChatGPT

# Project Discussion: Dates and Deliverables

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## Project execution in sprints

- Sprint 1: (Sep 12 – Oct 5)
  - **Solving**: Choose a decision problem, identify data, work on solution methods
  - **Human interaction**: Develop a basic chatbot (no AI), no problem focus
- Sprint 2: (Oct 10 – Nov 9)
  - **Solving**: Evaluate your solution on problem
  - **Human interaction**: Integrated your choice of chatbot (rule-based or learning-based) and methods
- Sprint 3: (Nov 14 – 30)
  - **Evaluation**: Comparison of your solver chatbot with an LLM-based alternative, like ChatGPT

- Oct 12, 2023
  - Project checkpoint
  - In-class presentation
- Nov 30, 2023
  - Project report due
- Dec 5 / 7, 2023
  - In-class presentation

# Skeleton: A Basic Chatbot

- Run in an infinite loop until the user wants to quit
- Handle any user response
  - User can quit by typing “Quit” or “quit” or just “q”
  - User can enter any other text and the program has to handle it. The program should write back what the user entered and say – “I do not know this information”.
- Handle known user query types // Depends on your project
  - “Tell me about N-queens”, “What is N ?”
  - “Solve for N=4?”
  - “Why is this a solution? ”
- Handle chitchat // Support at least 5, extensible from a file
  - “Hi” => “Hello”
  - ...
- *Store session details in a file*

## Illustrative Project

1. **Title:** Solve and explain solving of n-queens puzzle
2. **Key idea:** Show students how a course project will look like
3. **Who will care when done:** students of the course, prospective AI students and teachers
4. **Data need:** n: the size of game; interaction
5. **Methods:** search
6. **Evaluation:** correctness of solution, quality of explanation, appropriateness of chat
7. **Users:** with and without AI background; with and without chess background
8. **Trust issue:** user may not believe in the solution, may find interaction offensive (why queens, not kings? ...)

# Project Discussion: Illustration

1. Create a private Github repository called “CSCE58x-Fall2023-<studentname>-Repo”. Share with Instructor (biplav-s) and TA (kausik-l)
2. Create Google folder called “CSCE58x-Fall2023-<studentname>-SharedInfo”. Share with Instructor ([prof.biplav@gmail.com](mailto:prof.biplav@gmail.com)) and TA ([lakkarajukausik90@gmail.com](mailto:lakkarajukausik90@gmail.com))
3. Create a Google doc in your Google repo called “Project Plan” and have the following by next class (Sep 5, 2023)

1. **Title:** Solve and explain solving of n-queens puzzle
2. **Key idea:** Show students how a course project will look like
3. **Who will care when done:** students of the course, prospective AI students and teachers
4. **Data need:** n: the size of game; interaction
5. **Methods:** search
6. **Evaluation:** correctness of solution, quality of explanation, appropriateness of chat
7. **Users:** with and without AI background; with and without chess background
8. **Trust issue:** user may not believe in the solution, may find interaction offensive (why queens, not kings? ...)

# Project Illustration: N-Queens

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- Sprint 1: (Sep 12 – Oct 5)
  - **Solving**: Choose a decision problem, identify data, work on solution methods
    - Method 1: Random solution
    - Method 2: Search – BFS
    - Method 3: Search - ...
  - **Human interaction**: Develop a basic chatbot (no AI) as outlined
  - Deliverable
    - Code structure in Github
      - ./data
      - ./code
      - ./docs
      - ./test
    - Presentation: Make sprint presentation on Oct 12, 2023

# Reference: Project Rubric - NEW

- **Project report – 60%**
  - Project description: problem, related work, approach, evaluation – 40%
  - Working system demo/ video – 10%
    - Well organized Github with code (./data, ./code, ./docs, ./test) – 10%
- **Project presentation – 40%**
  - Evaluation by peers, instructor and TA
- **Bonus**
  - Instructor discretion – 10%
- **Penalty**
  - Lack of timeliness as per announced policy (right) - up to 30%

## Milestones and Penalties

- Oct 12, 2023
  - Project checkpoint
  - In-class presentation
  - **Penalty: presentation not ready by Oct 10, 2023 [-10%]**
- Nov 30, 2023
  - Project report due
  - **Project report not ready by date [-10%]**
- Dec 5 / 7, 2023
  - In-class presentation
  - **Project presentations not ready by Dec 4, 2023 [-10%]**

# Evaluation of Presentation

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1. An online form will be available during presentation
2. During a presentation, three students will be assigned to review along with instructor and TA
3. They will enter following survey questions:
  1. Their name
  2. Presentation number
  3. How useful is the system – will you use it? [1-5 scale]
  4. How well have you understood the project from the presentation? [1-5 scale]
4. Top and bottom scores will be removed. Average of remaining three will be used for final presentation marks

# Lecture 23 & 24: Summary

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- We talked about
  - Making Decisions
  - Simple Decisions
  - Complex Decisions



# Concluding Section

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# Quiz 4

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- November 14-21, 2023
  - Data Science
  - NN/ Keras with non-text media

# About Next Lecture – Lecture 25, 26

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# Lecture 25-26: Sequential Decisions

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- Planning
- Reinforcement Learning