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

# Lecture 9: Search Continued – Local Search

PROF. BIPLAV SRIVASTAVA, AI INSTITUTE

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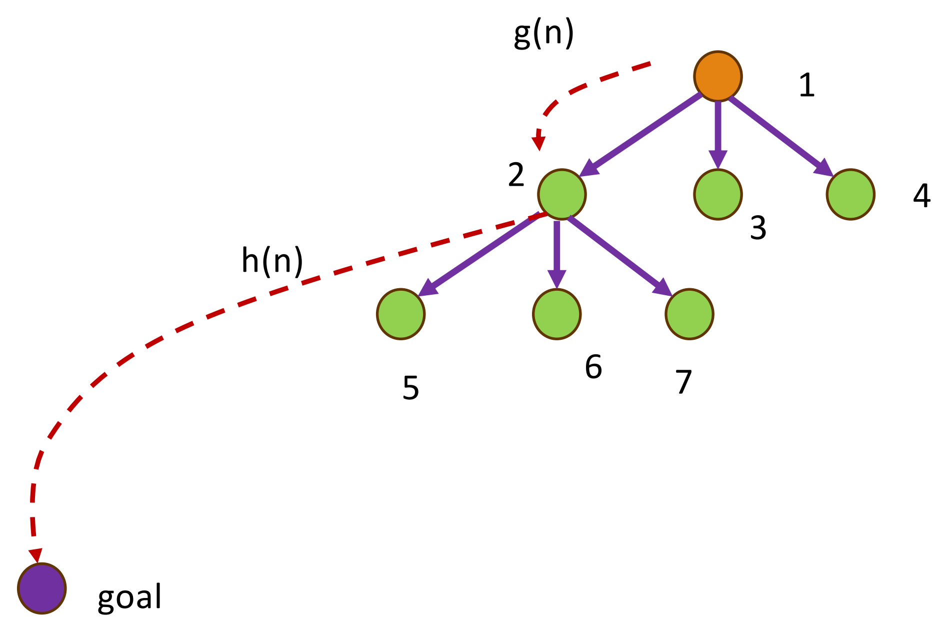
# Organization of Lecture 9

- Introduction Segment
  - Recap of Lecture 8
- Main Segment
  - Hill climbing
  - Simulated Annealing
  - Genetic programming
  - Search in complex environments
- Concluding Segment
  - Course Project Discussion
  - About Next Lecture – Lecture 9
  - Ask me anything

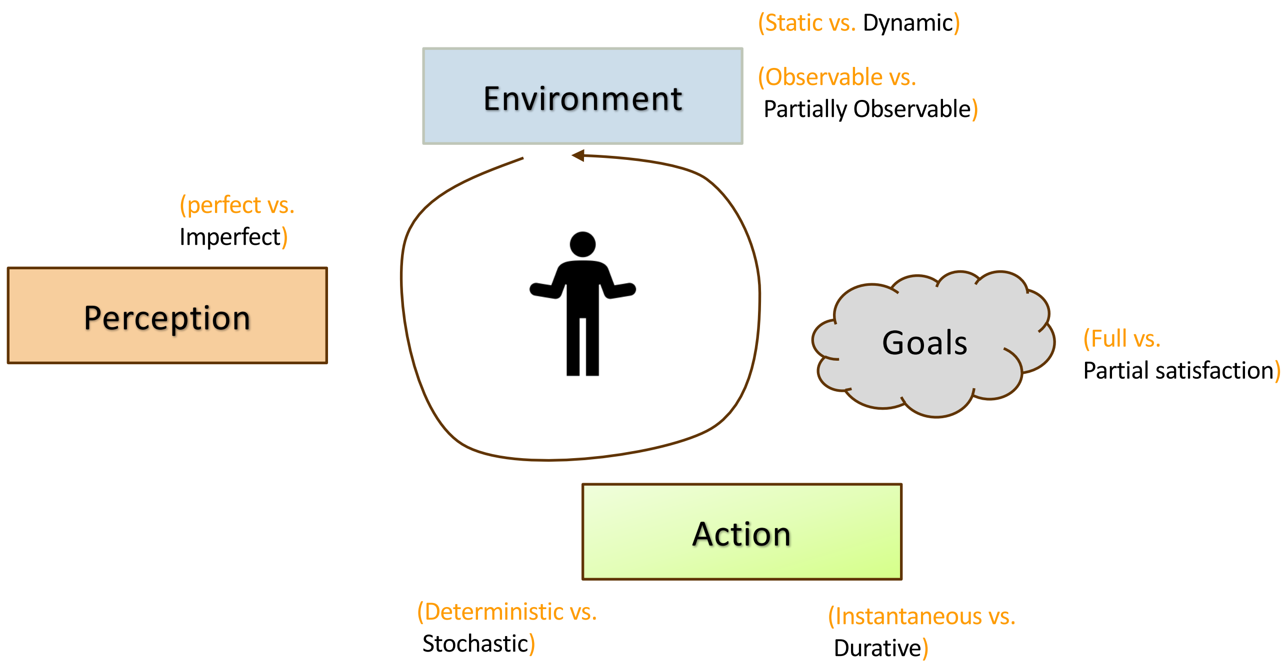
# Introduction Section

# Recap of Lecture 8

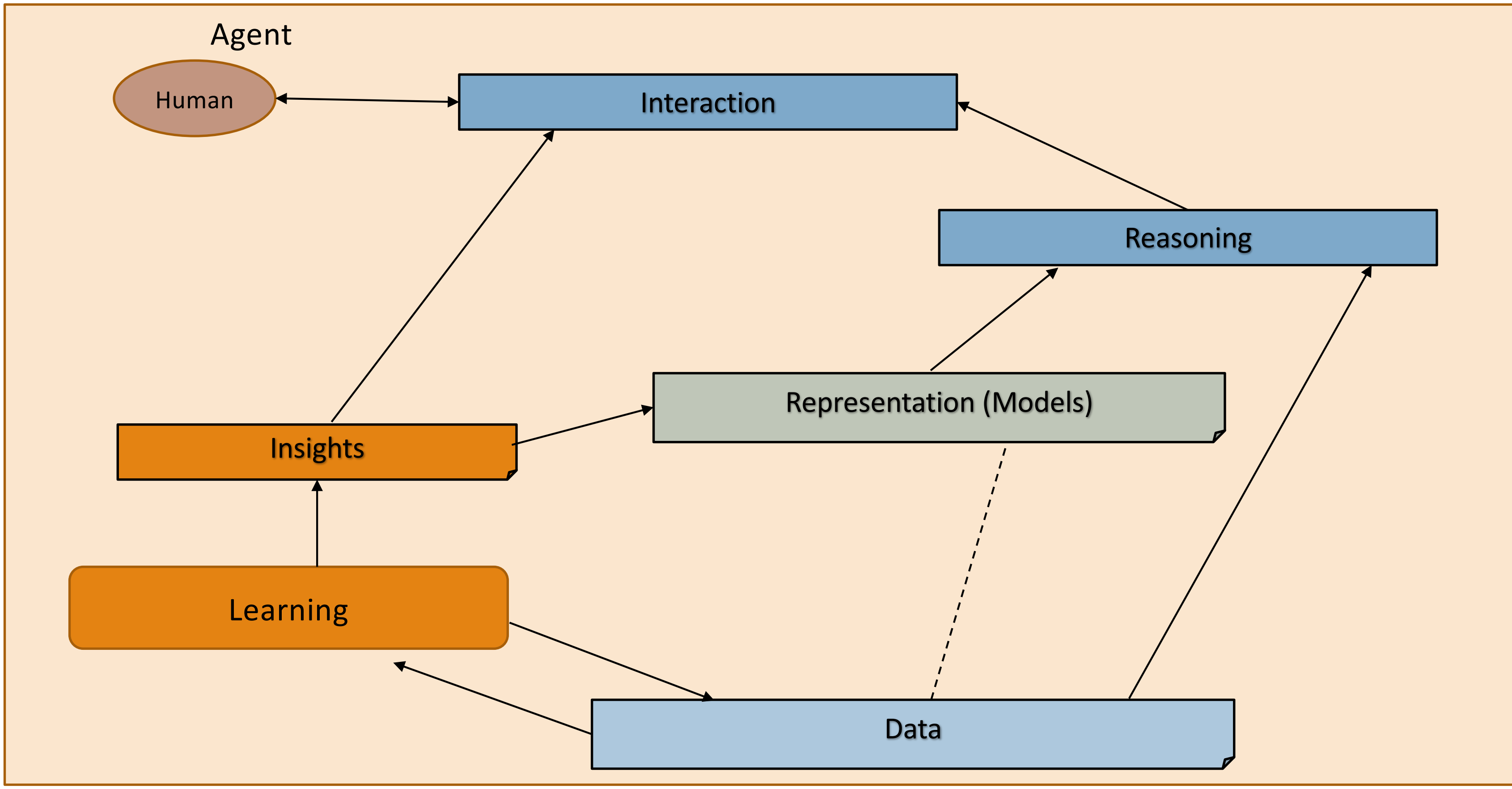
- Informed Search
- Heuristics and Properties
- Designing Heuristics



# 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

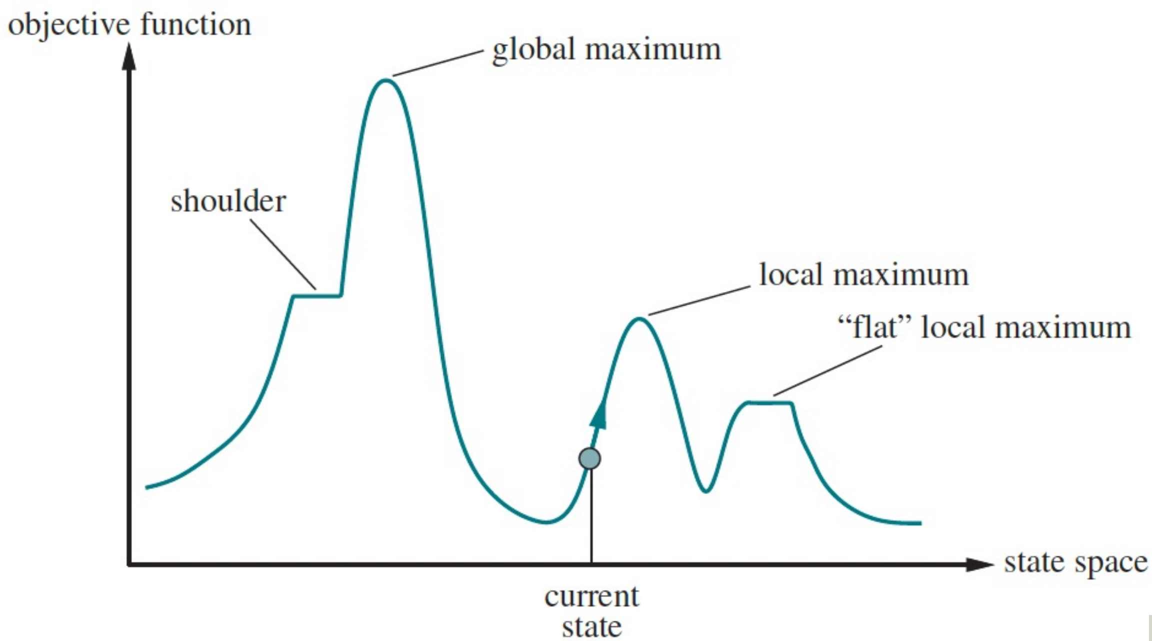
# Main Section

# Local Search

- Systematic search
  - Path matters [Store search trajectory]
- Non-systematic search
  - Solution matters, not path

- Settings
  - States: Discrete, continuous
  - Non-deterministic actions
  - Partial observability

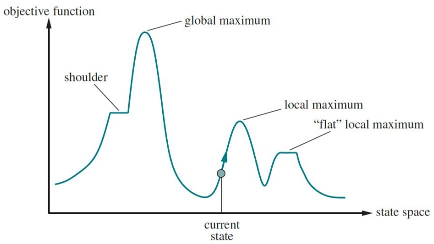
# State Space Landscape




- Setup: find maxima

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

# Hill Climbing /Greedy Local Search




**function** HILL-CLIMBING(*problem*) **returns** a state that is a local maximum
  *current* ← *problem*.INITIAL
  **while** *true* **do**
    *neighbor* ← a highest-valued successor state of *current*
    **if** VALUE(*neighbor*) ≤ VALUE(*current*) **then return** *current*
    *current* ← *neighbor*

At each step, replace the current node with the **best** neighbor.

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

# Hill Climbing Illustration

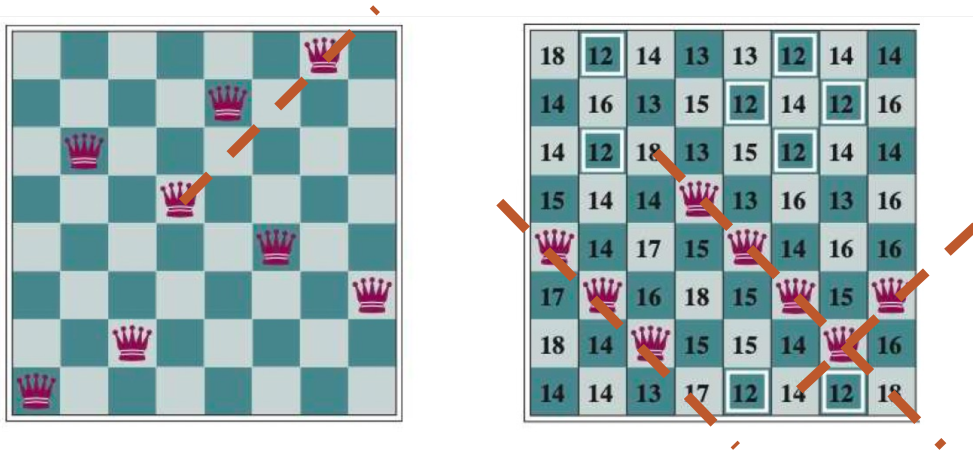



**Figure 4.3** (a) The 8-queens problem: place 8 queens on a chess board so that no queen attacks another. (A queen attacks any piece in the same row, column, or diagonal.) This position is almost a solution, except for the two queens in the fourth and seventh columns that attack each other along the diagonal. (b) An 8-queens state with heuristic cost estimate $h = 17$. The board shows the value of $h$ for each possible successor obtained by moving a queen within its column. There are 8 moves that are tied for best, with $h = 12$. The hill-climbing algorithm will pick one of these.

State representation:
- Complete state formulation

Next Action:
- Any queen in the same column (8 x 7 = 56 children)

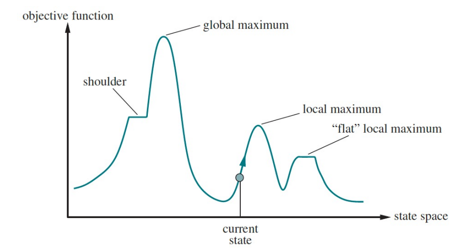
State space: 8^8 = 17 million (appx)

Steepest ascent:
* Gets stuck 86% times in 3 steps
* Solves 14% times in 4 steps

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

# Hill Climbing Variations

- **Stochastic hill climbing**: chooses an uphill node with prob. depending on steepness of increase
- **First-choice hill climbing**: choose first that is uphill
- **Random-restart hill climbing**: restart after a few tries
  - If p is chance of success. restarts needed = 1/p
  - For 8-queens, p=.14
    - Restart needed = 7 (6 failure, 1 success)
    - Total steps for finding a solution = 4 +( (1-p) / p) * 3 = 22 steps




# Simulated Annealing

**function** SIMULATED-ANNEALING(*problem*, *schedule*) **returns** a solution state
  *current* ← *problem*.INITIAL
  **for** $t$ = 1 **to** $\infty$ **do**
    $T \leftarrow schedule(t)$
    **if** $T = 0$ **then return** *current*
    *next* ← a randomly selected successor of *current*
    $\Delta E \leftarrow$ VALUE(*current*) – VALUE(*next*)
    **if** $\Delta E > 0$ **then** *current* ← *next*
    **else** *current* ← *next* only with probability $e^{-\Delta E/T}$

- Setup: find minima
- T: temperature
- A bad successor is chosen will prob. that decreases with temperature
- Schedule: cooling schedule

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

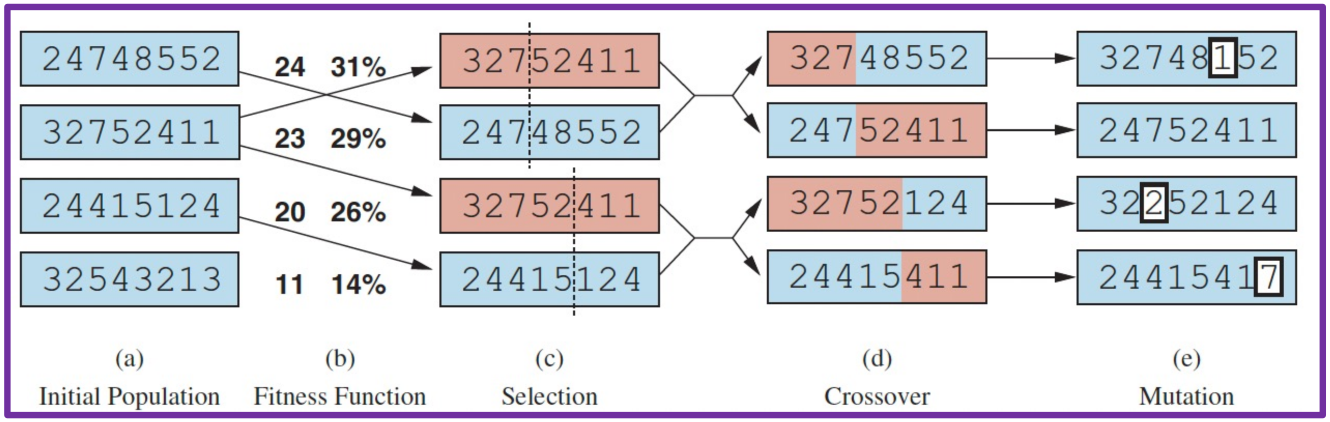
# Related Algorithms

- **Local beam search**: keeps track of **k** states rather than 1
  - Generate k randomly generated states
  - Repeat
    - Generate all successors of k states generated
    - If one is a goal, done
    - Select k best successors
- Stochastic beam search
  - Chooses k successors with probability proportional to the successors value

# Evolutionary Algorithms (EAs)

**Basic idea**

- A population of individuals (states)
- Fittest (highest value) produce offsprings (successor states) - recombination
  - Cross-over
  - mutation




*Digit strings representing 8-queens states. The initial population in (a) is ranked by a fitness function in (b) resulting in pairs for mating in (c). They produce offspring in (d), which are subject to mutation in (e).*

*Fitness function: non-attacking pairs of queens*

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

# Comparing EA with Local Search

- Idea of cross-over
  - Useful if traits of parents are useful in children
- Idea of mutation
  - Random changes can help escape local minima
- Selection of parameters (e.g., generations) affects performance
- # Parents
  - =1 : stochastic beam search
  - =2 : similar to nature
  - > 2 : not common in nature, but possible to simulate

```
function GENETIC-ALGORITHM(population, fitness) returns an individual
  repeat
     weights ← WEIGHTED-BY(population, fitness)
     population2 ← empty list
     for i = 1 to SIZE(population) do
        parent1, parent2 ← WEIGHTED-RANDOM-CHOICES(population, weights, 2)
        child ← REPRODUCE(parent1, parent2)
        if (small random probability) then child ← MUTATE(child)
        add child to population2
     population ← population2
  until some individual is fit enough, or enough time has elapsed
  return the best individual in population, according to fitness

function REPRODUCE(parent1, parent2) returns an individual
  n ← LENGTH(parent1)
  c ← random number from 1 to n
  return APPEND(SUBSTRING(parent1, 1, c), SUBSTRING(parent2, c + 1, n))
```

**Figure 4.7** A genetic algorithm. Within the function, *population* is an ordered list of individuals, *weights* is a list of corresponding fitness values for each individual, and *fitness* is a function to compute these values.

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Russell & Norvig, AI: A Modern Approach

# Local Search With Non-Deterministic Actions

- Systematic search
  - Path matters [Store search trajectory]
- Non-systematic search
  - Solution matters, not path
- Settings
  - States: Discrete, continuous
  - **Non-deterministic actions***
  - Partial observability*

**Erratic Vacuum World**

- When applied to a dirty square, the robot cleans that room and sometimes the adjacent room
- When applied to a clean square, the robot throws dirt in the room

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

* Solutions are not nodes but conditional plans/ strategies.

# Local Search With Non-Deterministic Actions

**Erratic Vacuum World**

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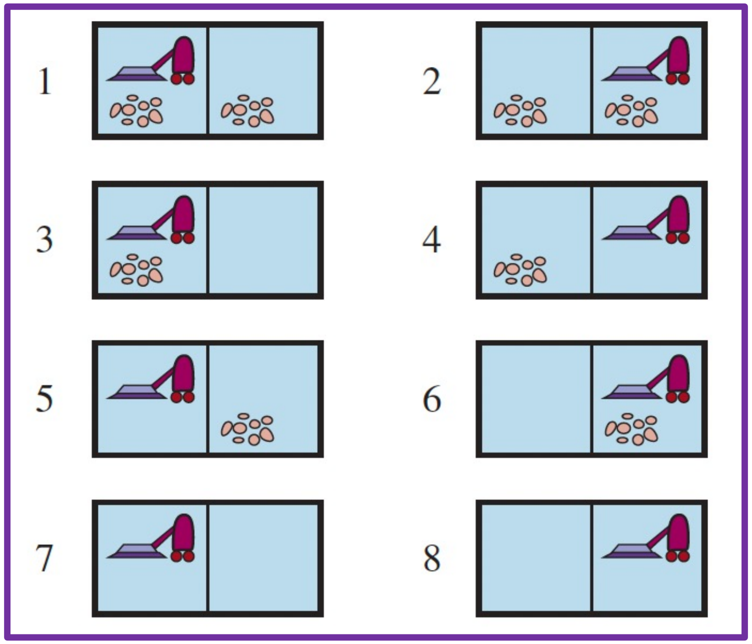


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# Local Search With Non-Deterministic Actions

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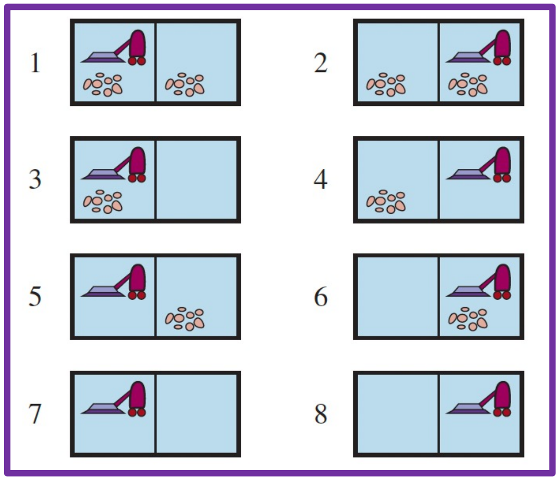


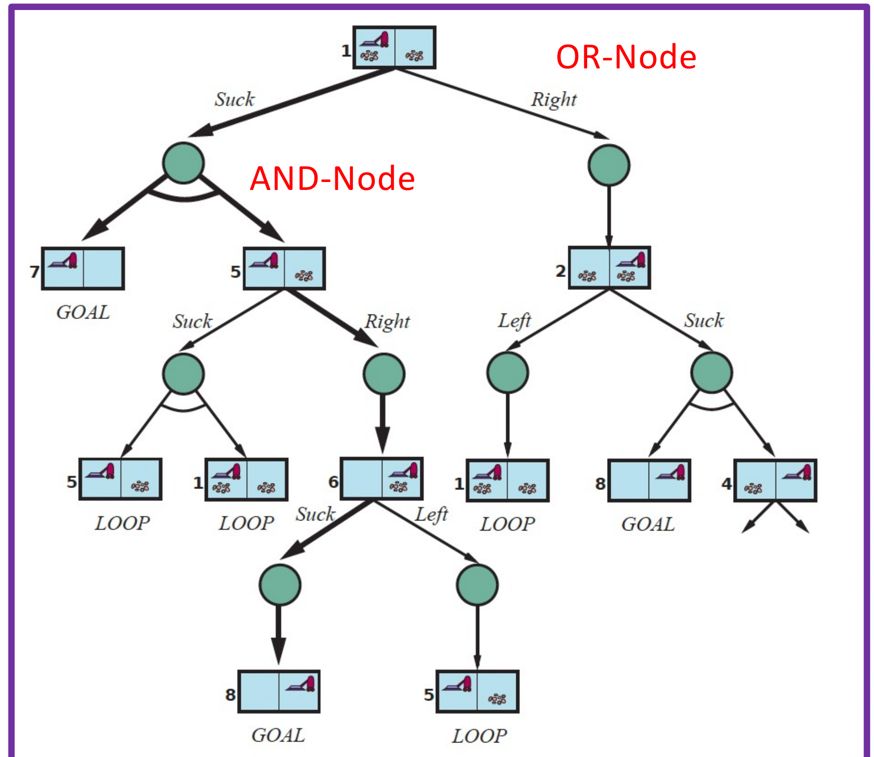


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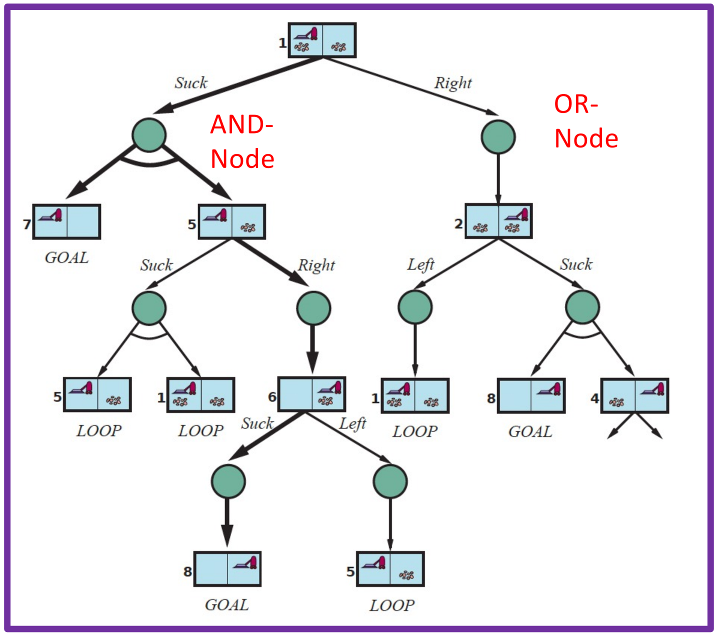
# Local Search With Non-Deterministic Actions




**function** AND-OR-SEARCH(*problem*) **returns** a conditional plan, or *failure*
  **return** OR-SEARCH(*problem*, *problem*.INITIAL, [ ])

**function** OR-SEARCH(*problem*, *state*, *path*) **returns** *a conditional plan, or failure*
  **if** *problem*.IS-GOAL(*state*) **then return** the empty plan
  **if** IS-CYCLE(*path*) **then return** *failure*
  **for each** *action* **in** *problem*.ACTIONS(*state*) **do**
    *plan* ← AND-SEARCH(*problem*, RESULTS(*state*, *action*), [*state*] + *path*])
    **if** $plan \neq failure$ **then return** [*action*] + *plan*]
  **return** *failure*

**function** AND-SEARCH(*problem*, *states*, *path*) **returns** *a conditional plan, or failure*
  **for each** $s_i$ **in** *states* **do**
    $plan_i \leftarrow$ OR-SEARCH(*problem*, $s_i$, *path*)
    **if** $plan_i = failure$ **then return** *failure*
  **return** [**if** $s_1$ **then** $plan_1$ **else if** $s_2$ **then** $plan_2$ **else** … **if** $s_{n-1}$ **then** $plan_{n-1}$ **else** $plan_n$]

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

# Coding Example

- 8-Puzzle – code notebook
  - https://github.com/biplav-s/course-ai-tai-f23/blob/main/sample-code/Class6-To-Class9-search.md

# Course Project

# Project Discussion: What Problem Fascinates You ?

- 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

Project execution in sprints

- Sprint 1: (Sep 12 – Oct 5)
  - Solving: Choose a decision problem, identify data, work on solution methods
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- 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) and TA (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
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7. **Users**: with and without AI background; with and without chess background
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# Project Illustration: N-Queens

- 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

- **Project results** – 60%
  - Working system ? – 30%
  - Evaluation with results superior to baseline? – 20%
  - Considered related work? – 10%
- **Project efforts** – 40%
  - Project report – 20%
  - Project presentation (updates, final) – 20%

- **Bonus**
  - Challenge level of problem – 10%
  - 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%]**

# Lecture 9: Summary

- We talked about
  - Hill climbing
  - Simulated Annealing
  - Genetic programming
  - Search in complex environments

# Concluding Section

# About Next Lecture – Lecture 10

# Lecture 10: Adversarial Games

- Game tree
- Adversarial games