# COMP4431 Artificial Intelligence

## Heuristic Search

Raymond Pang
Department of Computing
The Hong Kong Polytechnic University

**Largely based on Prof. Liu Slides**

# Agenda

- Rational agent
- Search agent
  - Uninformed search and informed search
  - A* search
  - Heuristics
  - Domination of heuristic functions
- Technological trends of agent

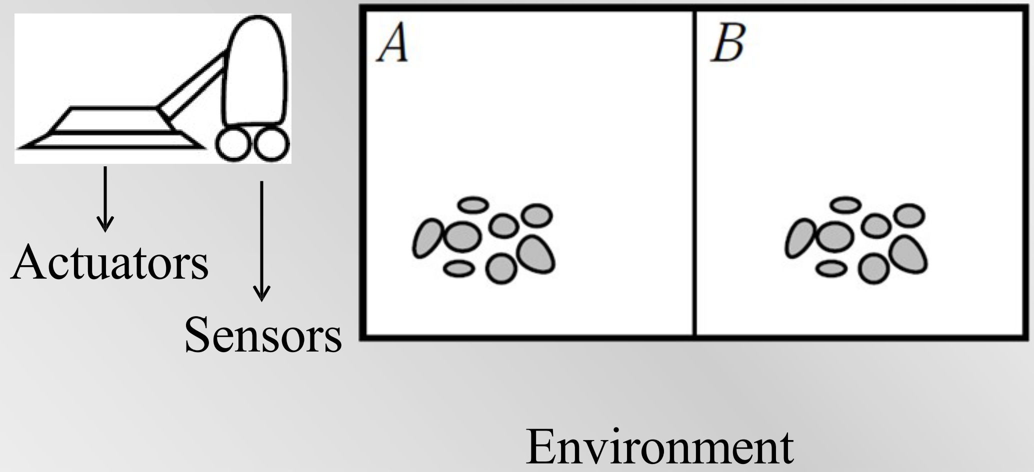
# Agenda

- Rational agent
- Search agent
  - Uninformed search and informed search
  - A* search
  - Heuristics
  - Domination of heuristic functions
- Technological trends of agent

# Agent

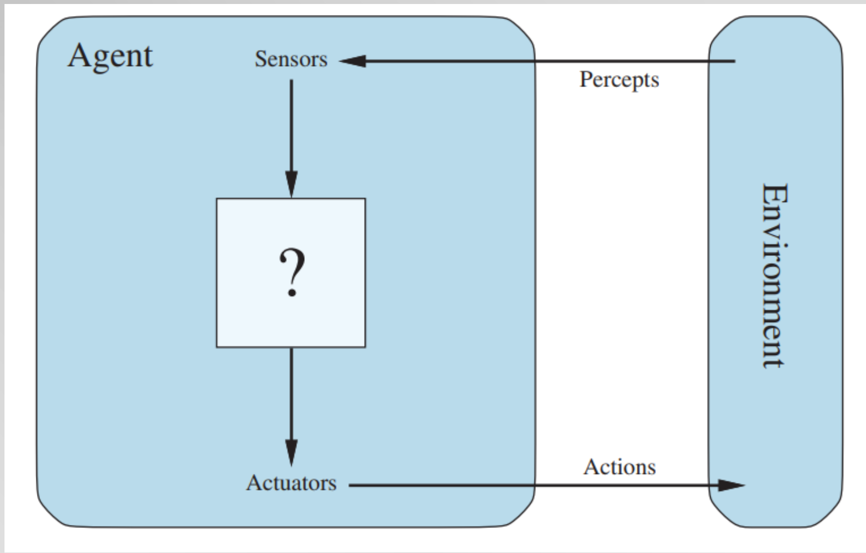
- Agents in artificial intelligence
  - Agents denotes artificial entities that are capable of perceiving their surroundings using sensors, making decisions, and then taking actions in response using actuators

- Example
  - Vacuum-Cleaner
- How to perceives the environment
  - which room, clean or dirty
- How to make the decision
  - move right or left, suck the dust
- How to make the action



# Rational Agent

- Agent
  - An agent is an entity that perceives and act with the environment




- Rational Agent
  - Agent that does the **right thing!**
  - Acts to achieve the best outcome
  - Different environment can have different agent to adopt it
  - For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance

# Rational Agent

- Characteristics of rational agent
  - Distinct from omniscience
  - An agent is autonomous if its behavior is determined by its own experience
  - Agents can perform actions in order to modify future percepts so as to obtain useful information

A real-life rational agent analogy

| Agent Type | Performance Measure | Environment | Actuators | Sensors |
|---|---|---|---|---|
| Taxi driver | Safe, fast, legal, comfortable trip, maximize profits, minimize impact on other road users | Roads, other traffic, police, pedestrians, customers, weather | Steering, accelerator, brake, signal, horn, display, speech | Cameras, radar, speedometer, GPS, engine sensors, accelerometer, microphones, touchscreen |

# Agenda

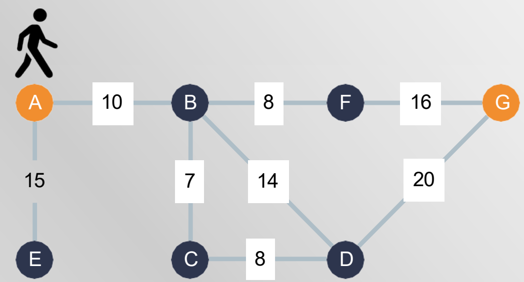
- Rational agent
- Search agent
  - Uninformed search and informed search
  - A* search
  - Heuristics
  - Domination of heuristic functions
- Technological trends of agent

# Scenario

- Students visit scientific park
  - Use intelligent information system to aid arrangement
- Real world problem
  - Students are in building A
  - Students want to go to building G
  - Find a path from building A to building G
  - Find a shortest path from building A to building G
  - Find a shortest path from any building to another building

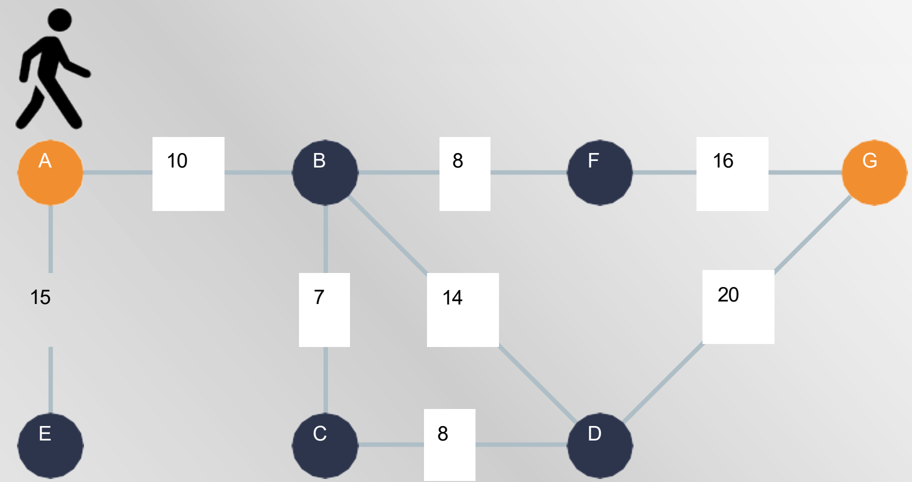
# Represent the Map using Graph

- Abstract the map to the graph
  - Ignore the detailed information
- Node
  - Location of the building
- Edge
  - The path connecting two buildings
- Value
  - The time walking from one building to another



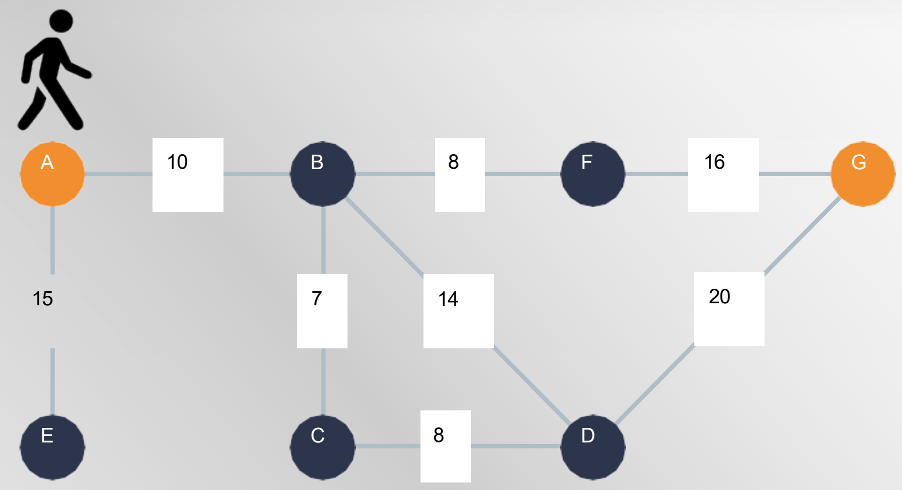

# Solve the Problem using Rational Agent

- How to perceive the environment
  - Which kind of information should be collected?
  - Which kind of information could be collected?
  - Which kind of information should be kept?
  - Which kind of information could be kept?
- How to make the action
  - Which kind of action could be taken?
  - Which kind of action should be made?
- How to optimize the performance?
  - Could we find the solution?
  - Could we find the optimal solution?
- How to make the decision
  - Check the target
  - Check the cost



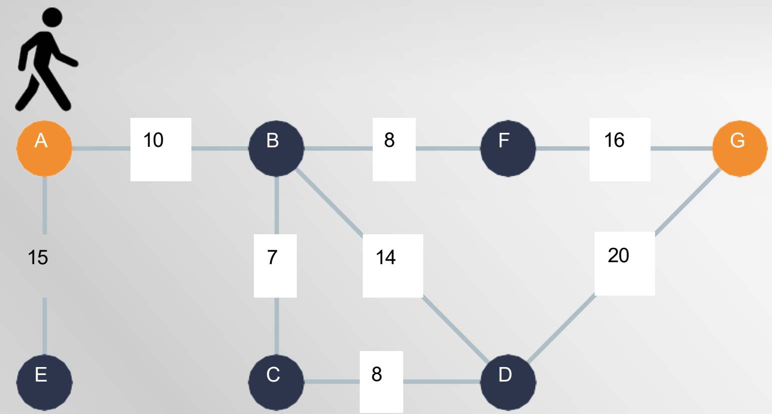
# Problem Formulation

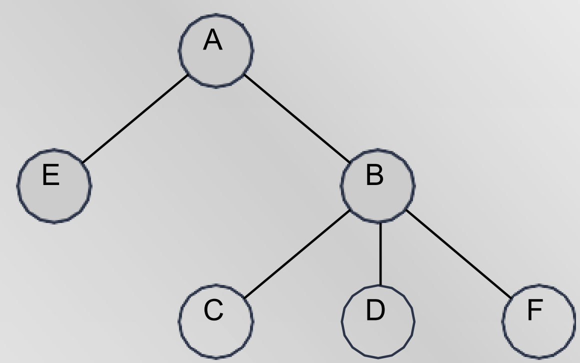
- Perception
  - State: In(B)
  - Initial state: In(A)
  - Goal state: In(G)
- Action
  - Decision result Go(B)
  - Solution: {Go(B),Go(F),Go(G)}
- Transition model
  - Action leads to the state transtition
  - Result (In(A), Go(B)) =In(B)
- Cost
  - If optimize the performance
  - c(In(A), {Go(B)}, In(B)) =10
  - The sum of the costs of the individual actions along the path
  - c(In(A), {Go(B), Go(F)}, In(F)) =10 +8 = 18



# Any Existing Methods to Model the Problem

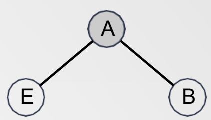
- Solution
  - An action sequence
- Search algorithm
  - Considering various possible action sequences
- Search tree
  - Nodes: states in the state space
  - Root: initial state
  - Branches: actions
- Expanding the current state
  - Apply each legal action to the current state, thereby generating a new set of states
  - Add branches from the parent node leading to child nodes
- Essence of search
  - Following up one option now and putting the others aside for later
  - In case the first choice does not lead to a solution

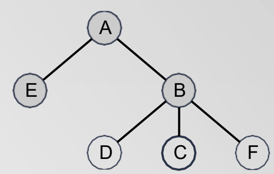


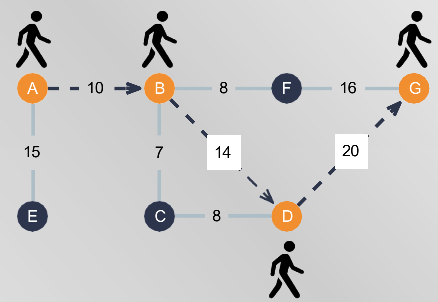



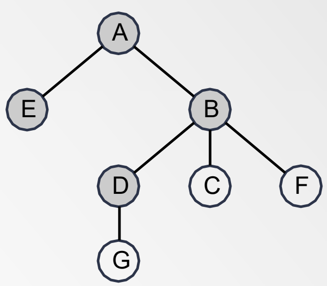
# Breadth-first Search

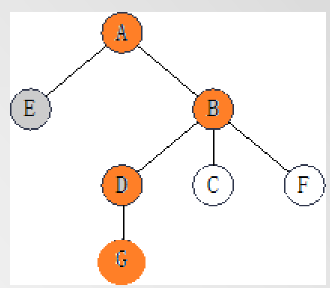
- Expand the shallowest unexpanded node
  - Cost =10+14+20=44



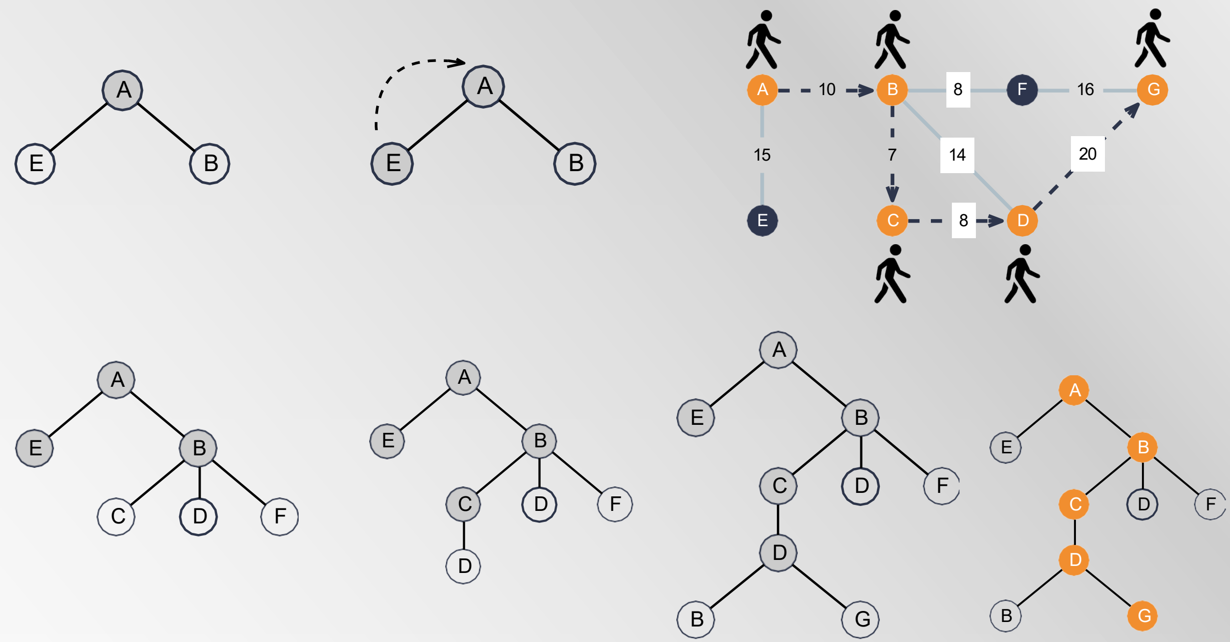



# Depth-first Search

- Expand the deepest unexpanded node
  - Cost =10+7+8+20=45

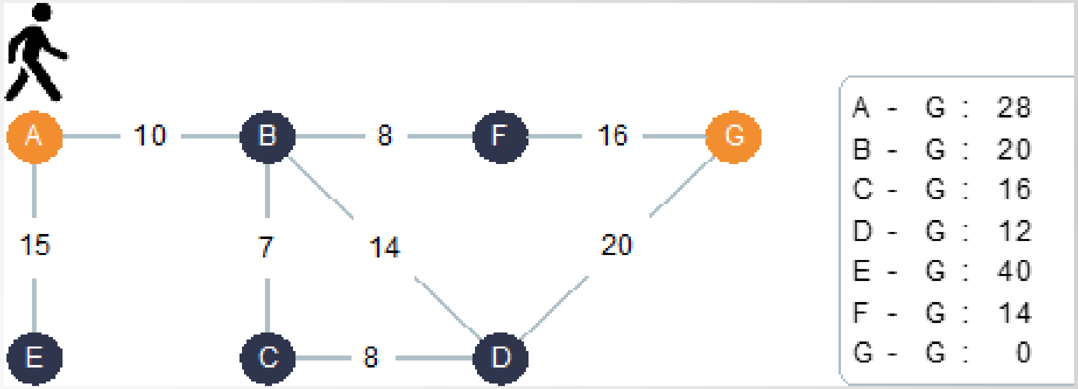


# The Search Tree

- Observe the search tree which represent the state space
  - i.e. all possible states to reach our goal
- if the problem is large, the search tree can even larger!!!
- Search will take more time.
- Search strategy is important!

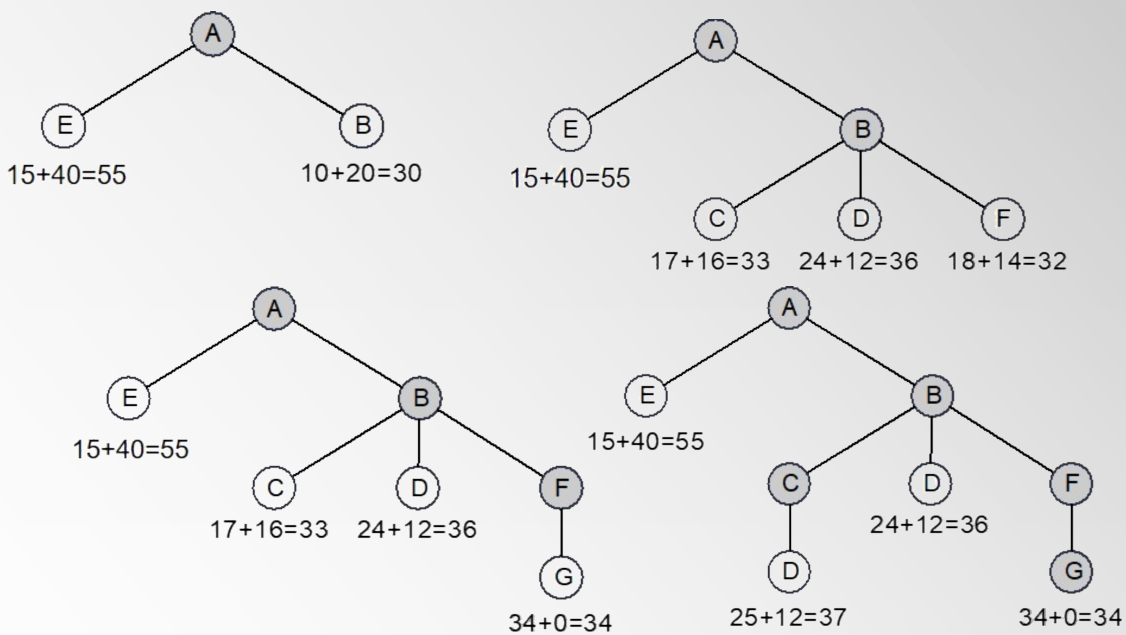
# Uninformed Search and Informed Search

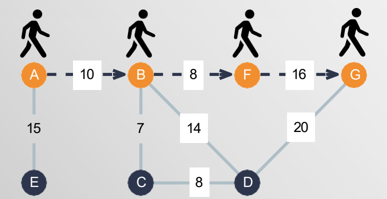
- Uninformed search
  - The strategies have no additional information about states beyond that provided in the problem definition
- Informed search
  - The strategies know whether one non-goal node is “more promising” than another
  - Heuristic information represents the relative suitability of a solution among its peers based on the intuition, experience or common sense

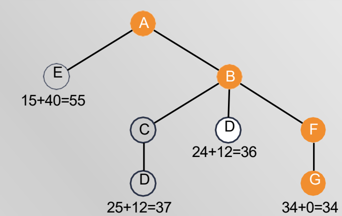


# A* Search

- Evaluation function: f(n) =g(n) +h(n).
  - g(n): the cost so far to reach the node n
  - h(n): the estimated cost to goal from the node n
  - f(n): the estimated total cost of path through the node n to goal



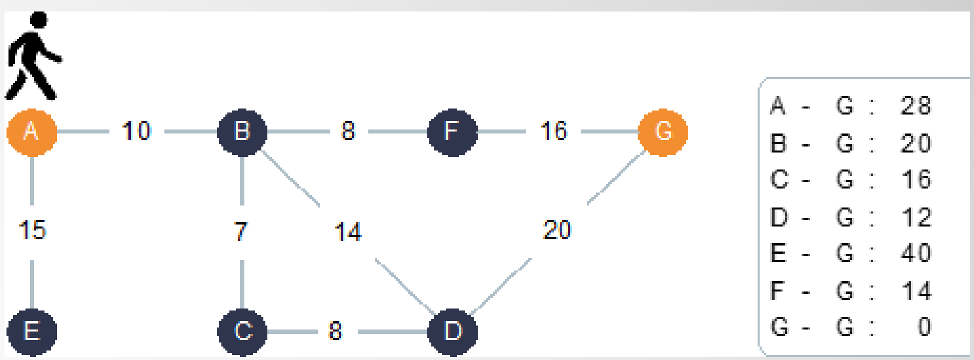




| | | | |
|---|---|---|---|
| A - | G : | 28 |
| B - | G : | 20 |
| C - | G : | 16 |
| D - | G : | 12 |
| E - | G : | 40 |
| F - | G : | 14 |
| G - | G : | 0 |

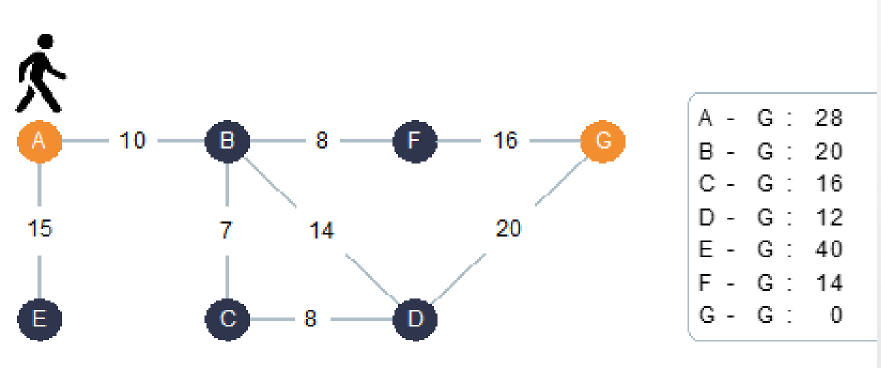
# Heuristics

- Heuristics
  - A problem-solving method
  - Uses shortcuts to produce good-enough solutions given a limited time
  - Solution may not necessarily be optimal solution
- Heuristic function in search algorithms
  - A function that ranks alternatives based on available information
- An admissible heuristic never overestimates the cost to reach the goal
  - A heuristic $h(n)$ is admissible if for every node n, $h(n) \leq h^*(n)$, where $h^*(n)$ is the true cost to reach the goal state from n



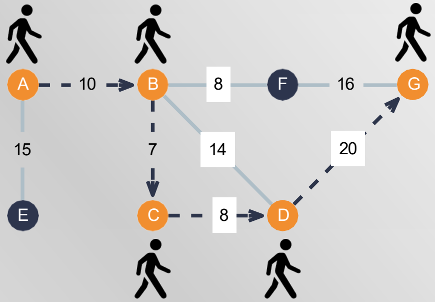
# Domination of Heuristic Functions

- If $h_2(n) \geq h_1(n)$ for all n (both admissible)
  - then $h_2$ dominates $h_1$, which indicates that $h_2$ is better for search
- Domination translates directly into efficiency
  - A* using $h_2$ will never expand more nodes than A* using $h_1$
- $h_2(S)$ and $h_1(S)$ for all both admissible
  - $h_1(S) = 8$
  - $h_2(S) = 18$
- A* using $h_2$ will never expand more nodes than A* using $h_1$
  - $A^*(h_1) = 39{,}135$ nodes
  - $A^*(h_2) = 1{,}641$ nodes



# Search Strategy

- Search strategy
  - Pick the order of node expansion
- Strategies are evaluated along the following dimensions:
  - completeness: does it always find a solution if one exists?
  - time complexity: number of nodes generated
  - space complexity: maximum number of nodes in memory
  - optimality: does it always find a least-cost solution?
- Uninformed search algorithms
  - Breadth-first search
  - Depth-first search
- Informed search algorithms
  - A* search



# 8-puzzle

- Apart from path finding problem, searching can apply to other problem, e.g. 8-puzzle/sliding-tile puzzle
- The empty space can only move in four directions viz.,
  - 1. Up
    2.Down
    3. Right or
    4. Left

Initial State

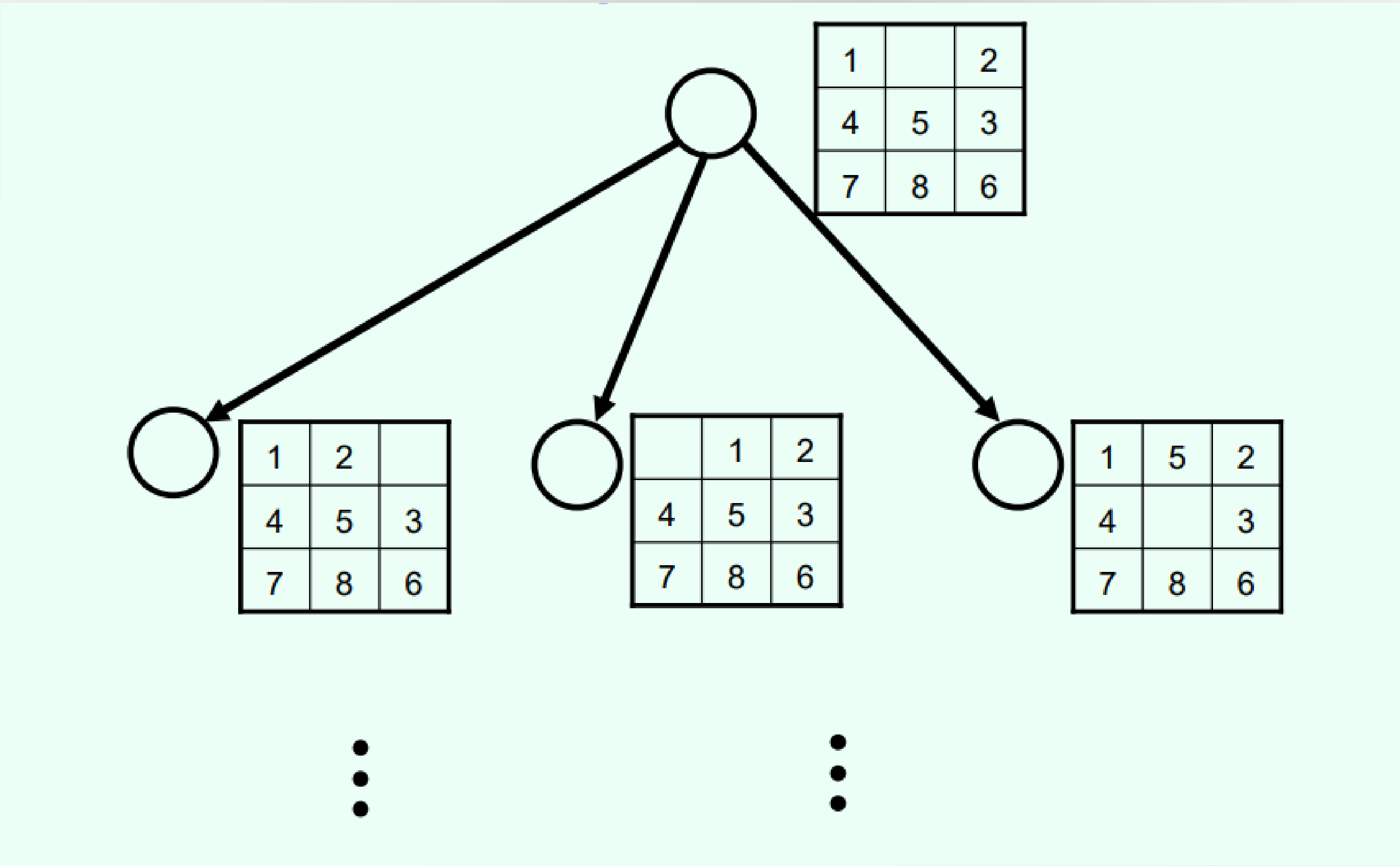
| | | |
|---|---|---|
| 1 | | 2 |
| 4 | 5 | 3 |
| 7 | 8 | 6 |

Goal State

| | | |
|---|---|---|
| 1 | 2 | 3 |
| 4 | 5 | 6 |
| 7 | 8 | |

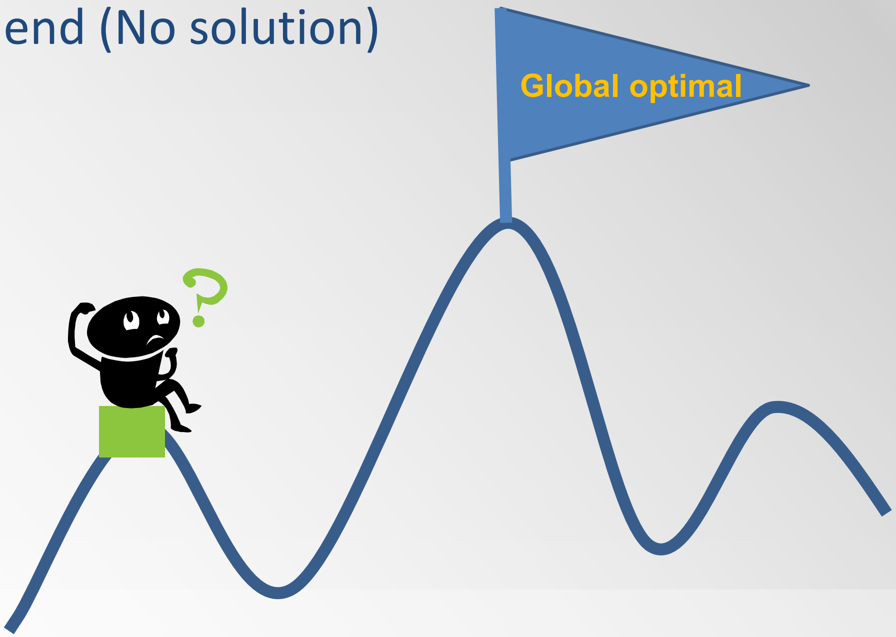
# 8-puzzle

- We can use the search strategy discussed before, e.g. BFS, A*



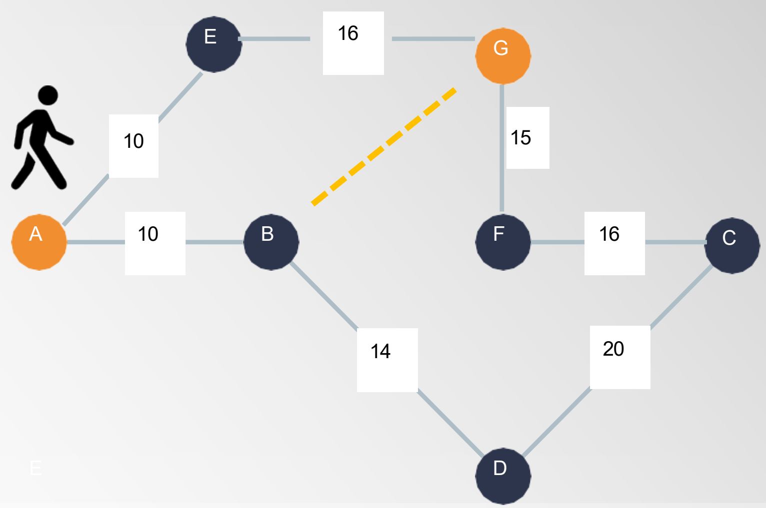
# Issues of Heuristic Search

- Heuristics may not always produce the optimum choice
  - Some times it may lead you to local minimum
  - (2nd or 3rd best solution)
  - or even dead end (No solution)



# Issues of Heuristic Search

- The definition of a heuristic function  h(n) can cause the issue
  - Since it is simply **an estimation**
- If the straight line distance of  B->G is 10,
  it will be attracted to expend node B instead of E

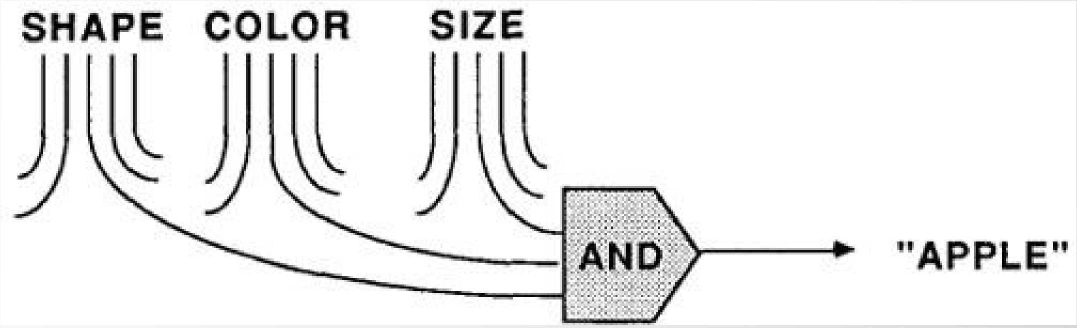


# Agenda

- Rational agent
- Search agent
  - Uninformed search and informed search
  - A* search
  - Heuristics
  - Domination of heuristic functions
- Technological trends of agent

# Technological Trends in Agent Research

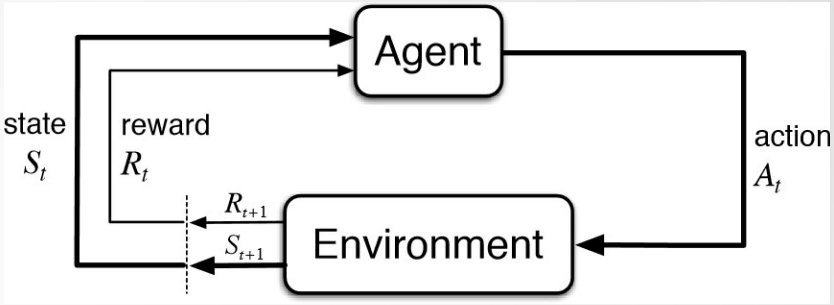
- The evolution of AI agents has undergone several stages
  - Symbolic agent stage: symbolic agent approaches employ logical rules and symbolic representations to encapsulate knowledge and facilitate reasoning processes.
  - A classic example of this approach is knowledge-based expert systems.




Minsky M. Society of mind[M]. Simon and Schuster, 1988.

# Technological Trends in Agent Research

- The evolution of AI agents has undergone several stages
  - Reinforcement learning-based agent stage: reinforcement learning-based agents utilize reinforcement learning methods to train agents to learn through interactions with their environments, enabling them to achieve maximum cumulative rewards in specific tasks.



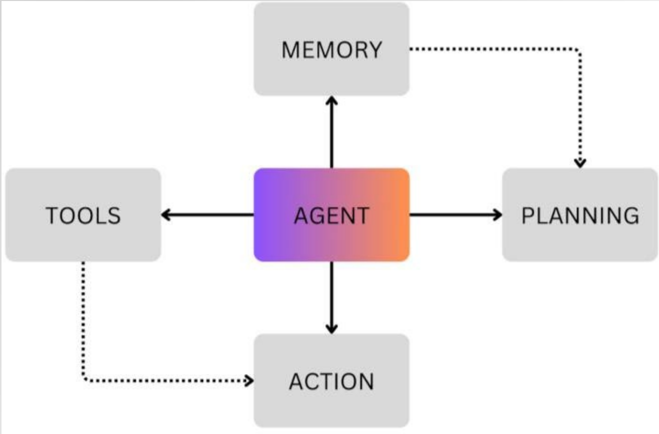

- The agent-environment interaction in reinforcement learning
  - An agent (decision maker) takes the action $A_t$ in the given state $s_t$ and receives the reward $R_t$.
  - After the reward is received, the agent update their parameters such that the total maximizing discounted expected reward.

Sutton R S, Barto A G. Reinforcement learning: An introduction[M]. MIT press, 2018.

# Technological Trends in Agent Research

- The evolution of AI agents has undergone several stages
  - Large language model-based agent stage: employ large language model as the primary component of brain or controller of agents.
    - LLMs can exhibit reasoning and planning abilities comparable to symbolic agents
    - LLMs can acquire interactive capabilities with the environment, by learning with feedback
    - LLMs undergo pre-training and demonstrate the capacity for few- and zero-shot generalization

  - Several key components in LLM
    - Memory: The primary function of the memory system is to preserve and regulate knowledge, experiential data, and historical information.
    - Planning: The planning capability defines an LLM-based agent's ability to devise action sequences based on set objectives and existing environment constraints, ensuring goal fulfillment.
    - Tool use: encompassing APIs, calculators, code interpreters, or actions within a physical environment through text-based directives.

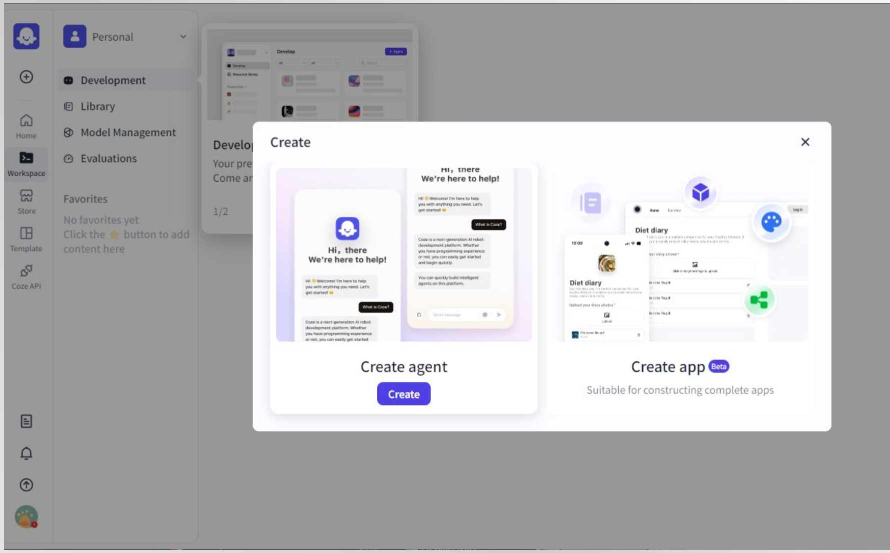



https://lilianweng.github.io/posts/2023-06-23-agent/

# Coze

- Coze is a one-stop AI chat bot development platform. Regardless of your programming skills,
- Coze allows you to swiftly create a wide range of chat bots powered by AI, capable of handling everything from simple questions to complex conversations.

- Coze facilitates and simplifies the process of AI bots development
  - Knowledge
    - Coze supports adding data from local files in the format of TXT, PDF, DOCX, Excel, and CXV, or obtaining online content and API JSON data via the specified URL.
  - Workflow
    - Coze empowers users to process intricate task flows with a set of workflow nodes such as LLMs, codes, and conditions. Regardless of your coding expertise, its intuitive drag-and-drop interface facilitates workflow creation
  - Plugins
    - Coze provides an extensive collection of plugins, enhances bot's functionality in areas such as information retrieval, travel assistance, productivity, image comprehension, and so on.



# Quiz Arrangement

- Quiz is open book and notes
- Use of mobile phone, Internet and other electronic devices are NOT ALLOWED!!
- Quiz will be held at the end of the lecture session
- Quiz time is 12 mins
- Lecture will end at 7:50pm, Quiz starts at 8:00pm

# Summary

- Search agent
- Heuristic Search
- A* Search
- NO Classes and labs on next week!
    - Be cancelled due to the Chinese New Year public holiday
- Quiz 1 after holiday!
- Happy Chinese New Year