

National University of Singapore  
School of Computing  
CS2109S: Introduction to AI and Machine Learning  
Semester 2, 2024/2025

**Tutorial 1**  
**Problem Formulation & Uninformed Search**

## Summary of Key Concepts

In this tutorial, we will discuss and explore the following key learning points/lessons:

1. Describing the problem environment with PEAS.
2. Formulating a search problem:
  - (a) State representation
  - (b) Actions
  - (c) Goal state(s)
3. Uniform-cost Search
4. Iterative Deepening Search

## A PEAS for AI chess player

1. Determine the PEAS (Performance measure, Environment, Actuators, Sensors) for an AI chess opponent in a mobile chess application.

## B Tower of Hanoi Problem

The Tower of Hanoi is a famous problem in computer science, described as follows: You are given 3 pegs (arranged left, middle, and right) and a set of  $n$  disks with holes in them (so they can slide onto the pegs). Every disk has a different diameter.

We start the problem with all the disks arranged on the left peg in order of size, with the smallest on top. The objective is to move all the disks from the left peg to the right peg in the *minimum number of moves*. This is done by:

- moving one disk at a time from one peg to another; and
- never placing a disk on top of another disk with a smaller diameter.

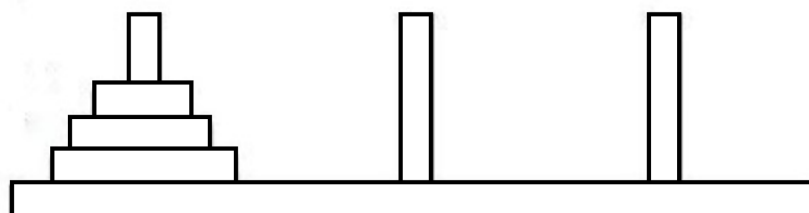


Figure 1: The initial state for  $n = 3$

Figure 1 shows the initial state for  $n = 3$ . To get a better feel for the problem, you can try it here: <https://www.mathsisfun.com/games/towerofhanoi.html>.

1. (a) Propose a state representation for this problem if we want to formulate it as a search problem.
- (b) Describe the representation invariant of your state (i.e., what condition(s) must a state satisfy to be considered valid). Compare the total number of possible configurations in the actual problem to that of your chosen state representation, with and without considering the representation invariant.
- (c) Specify the initial and goal state(s) of your state representation.
- (d) Define the actions.
- (e) Using the state representation and actions defined above, state the transition function  $T$  (i.e., upon applying each of the actions defined above to a current state, what is the resulting next state?).
2. **Additional Question:** Given the nature of the Tower of Hanoi problem, which search algorithm would be most appropriate for finding the solution? Justify your answer.
3. **Additional Question:** if there are  $k$  pegs instead of 3, what is the branching factor of the search tree?

## C Uniform-Cost Search Analysis

Consider the undirected graph shown in Figure 2. Let  $S$  be the initial state and  $G$  be the goal state. The cost of each action is as indicated.

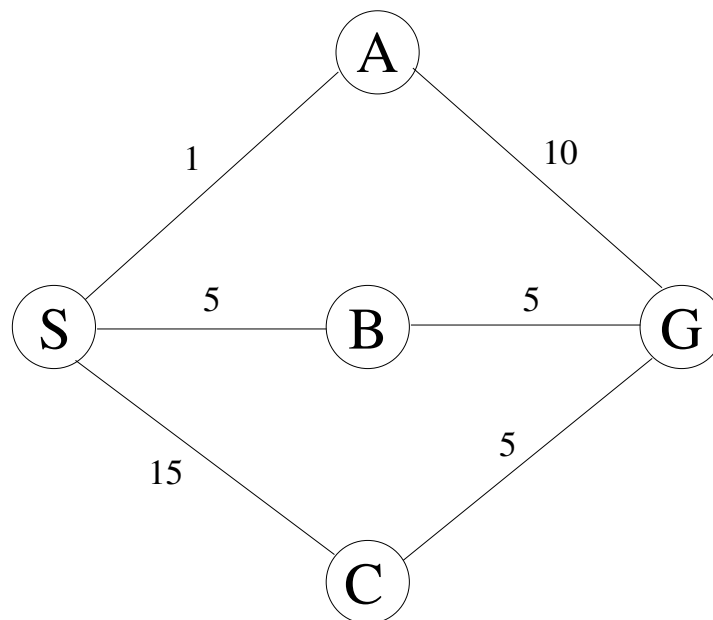


Figure 2: Graph of routes between  $S$  and  $G$ .

1. Give a trace of uniform-cost search using SEARCH (without visited memory) as implemented in Figure 3. If the costs are the same, the tiebreaker is the alphabetical ordering of the letters, with  $A < Z$ .

2. Give a trace of uniform-cost search using SEARCH WITH VISITED MEMORY as implemented in Figure 4.
3. When A generates G, the goal state, with a path cost of 11 in (b), why doesn't the algorithm halt and return the search result since the goal has been found? With your observation, discuss how uniform-cost search ensures that the shortest path solution is selected.

```

create frontier : priority queue (path cost)

insert Node(initial_state) to frontier
while frontier is not empty:
    node = frontier.pop()
    if node.state is goal: return solution

    for action in actions(node.state):
        next_state = transition(node.state, action)
        frontier.add(Node(next_state))
return failure

```

Figure 3: Uniform cost search (SEARCH implementation).

```

create frontier : priority queue (path cost)
create visited : set of states
insert Node(initial_state) to frontier
while frontier is not empty:
    node = frontier.pop()
    if node.state is goal: return solution
    if node.state in visited: continue
    visited.add(node.state)
    for action in actions(node.state):
        next_state = transition(node.state, action)
        frontier.add(Node(next_state))
return failure

```

Figure 4: Uniform cost search (SEARCH WITH VISITED MEMORY implementation).

## **D Comparison of Search Strategies**

1. Describe a problem in which iterative deepening search performs much worse than depth-first search.
2. Describe a problem where `SEARCH` performs much better than `SEARCH WITH VISITED MEMORY`.