Problems and Search

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Outline

State Space Search

Problem solving = Searching for the goal state

- State?
- Initial state
- Goal state
- Legal Moves: Current state $\rightarrow$ Next state

Problem 1: Playing Chess

- State: .....
- Initial state: .....
- Goal state: .....
- Legal Moves: Current state $\rightarrow$ Next state

Problem 2: Water Jug Problem

"You are given two jugs, a 4-litre one and a 3-litre one. Neither has any measuring markers on it. There is a pump that can be used to fill the jugs with water. How can you get exactly 2 litres of water into 4-litre jug."

- State: .....
- Initial state: .....
- Goal state: .....
- Legal Moves: Current state $\rightarrow$ Next state

Problem 2: Water Jug Problem

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- State: (x, y)
- Initial State: (0, 0)
- Goal State: (2, n)
- Legal Moves: Current state $\rightarrow$ Next State
  1. (x, y) $\rightarrow$ (4, y), if $x < 4$
  2. (x, y) $\rightarrow$ (x, 3), if $y < 3$
  3. (x, y) $\rightarrow$ (0, y), if $x > 0$
  4. (x, y) $\rightarrow$ (x, 0), if $y > 0$
  5. (x, y) $\rightarrow$ (4, y – (4 – x)), if $x + y \geq 4$, $y > 0$
  6. (x, y) $\rightarrow$ (x – (3 – y), 3), if $x + y \geq 3$, $x > 0$
  7. (x, y) $\rightarrow$ (x + y, 0), if $x + y \leq 4$, $y > 0$
  8. (x, y) $\rightarrow$ (0, x + y), if $x + y \leq 3$, $x > 0$
  9. (0, 2) $\rightarrow$ (2, 0)

State Space Search: Summary

Problem solving = Searching for the goal state

1. Define a state space that contains all the possible configurations of the relevant objects.
2. Specify the initial states.
3. Specify the goal states.
4. Specify a set of rules.

Search Strategies

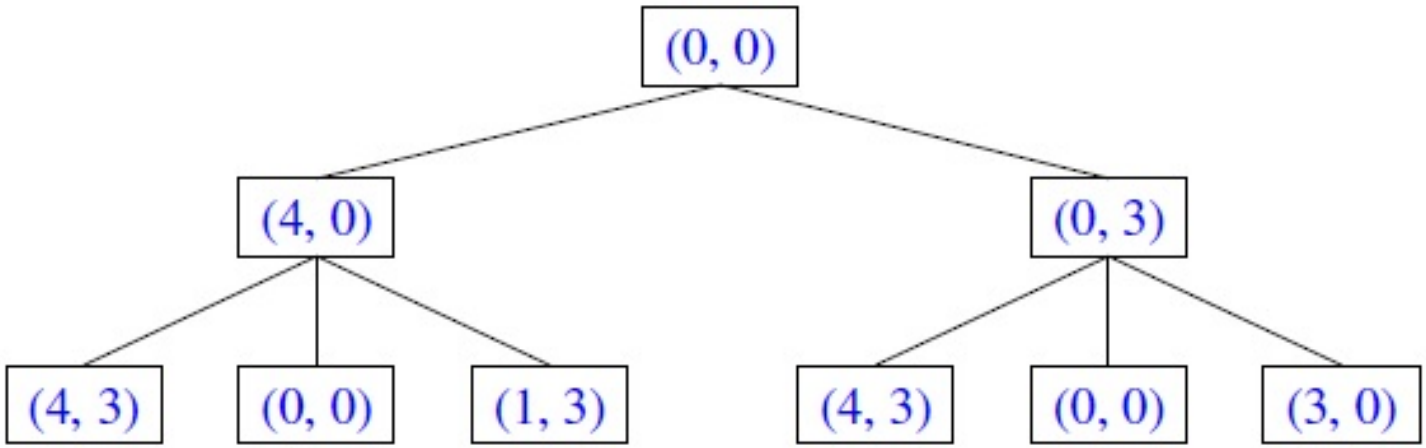
Requirements of a good search strategy.

1. It causes motion.
   Otherwise, it will never lead to a solution.
2. It is systematic.
   Otherwise, it may use more steps than necessary.
3. It is efficient.
   Find a good, but not necessarily the best, answer.

Search Strategies

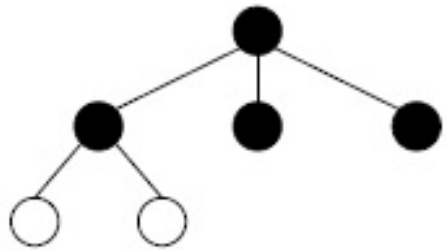
1. Uninformed search (blind search):
   Having no information about the number of steps from the current state to the goal.
2. Informed search (heuristic search):
   More efficient than uninformed search.

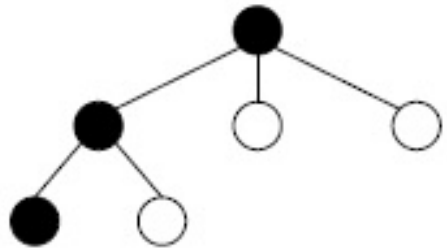
Search Strategies



Search Strategies: Blind search

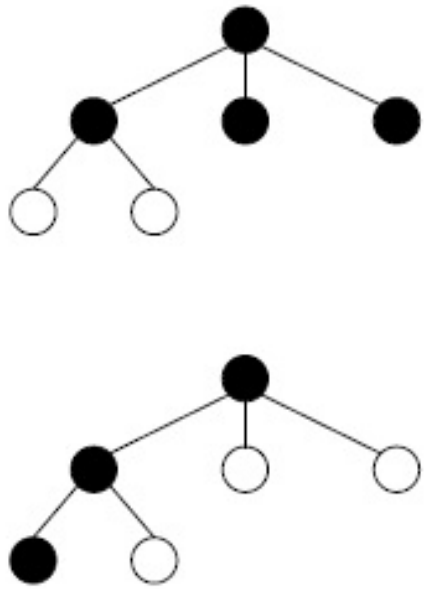
1. Breadth-first search
   Expand all the nodes of one level first.
2. Depth-first search
   Expand one of the nodes at the deepest level.





Search Strategies: Blind search

Criterion	Breadth-First	Depth-First
Time		
Space		
Optimal?		
Complete?		

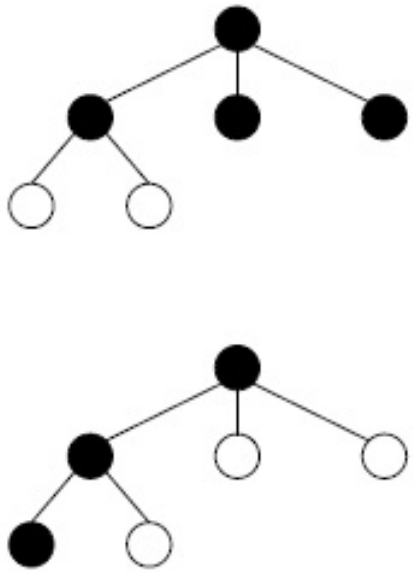


b: branching factor d: solution depth m: maximum depth

Search Strategies: Blind search

Criterion	Breadth-First	Depth-First
Time	b^d	b^m
Space	b^d	bm
Optimal?	Yes	No
Complete?	Yes	No

tốn ít biến đổi nhất



b: branching factor d: solution depth m: maximum depth

Search Strategies: Heuristic search

- Heuristic: problem-solving by experimental and especially trial-and-error methods.
- Heuristic technique improves the efficiency of a search process, possibly by sacrificing claims of completeness or optimality.

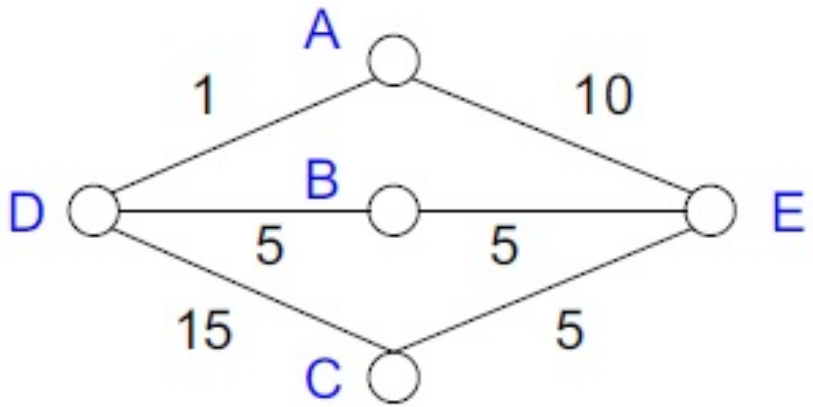
Search Strategies: Heuristic search

- Heuristic is for combinatorial explosion.
- Optimal solutions are rarely needed.

Search Strategies: Heuristic search

The Travelling Salesman Problem

"A salesman has a list of cities, each of which he must visit exactly once. There are direct roads between each pair of cities on the list. Find the route the salesman should follow for the shortest possible round trip that both starts and finishes at any one of the cities."



Search Strategies: Heuristic search

Nearest neighbour heuristic:

1. Select a starting city.
2. Select the one closest to the current city.
3. Repeat step 2 until all cities have been visited.

$$O(n^2) \text{ vs. } O(n!)$$

Search Strategies: Heuristic search

Heuristic function:

$$\text{state descriptions} \rightarrow \text{measures of desirability}$$

Problem Characteristics

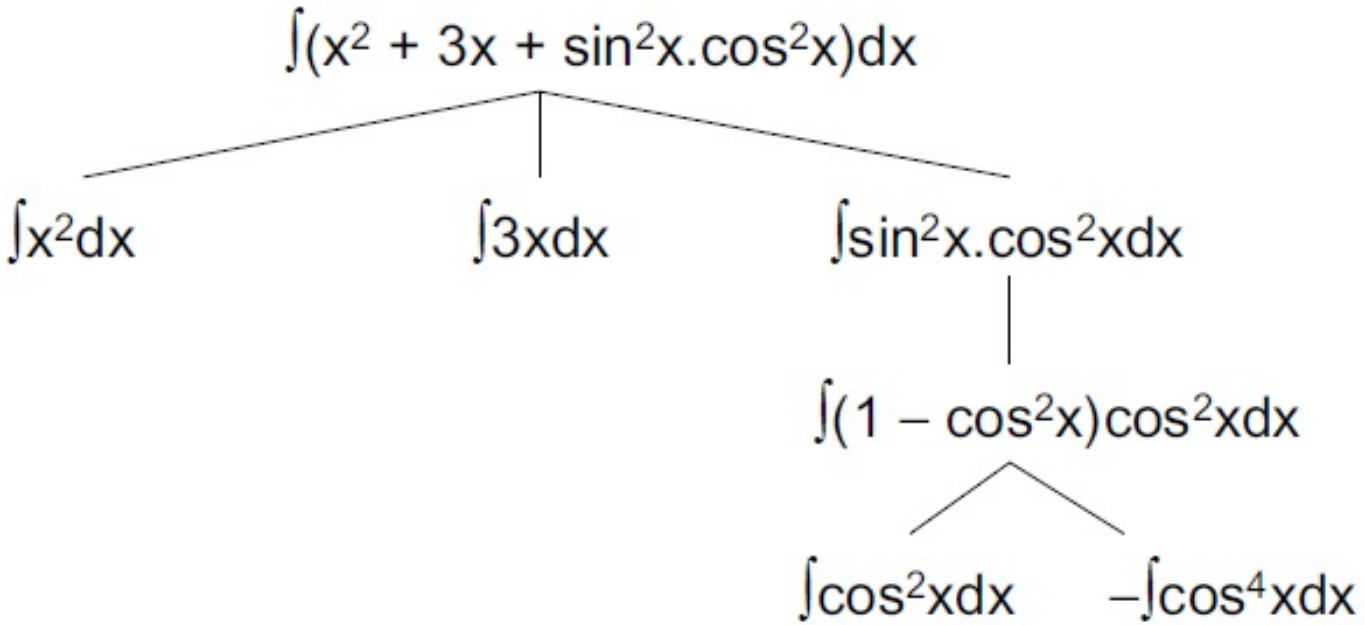
To choose an appropriate method for a particular problem:

- Is the problem decomposable?
- Can solution steps be ignored or undone?
- Is the universe predictable?
- Is a good solution absolute or relative?
- Is the solution a state or a path?
- What is the role of knowledge?
- Does the task require human-interaction?

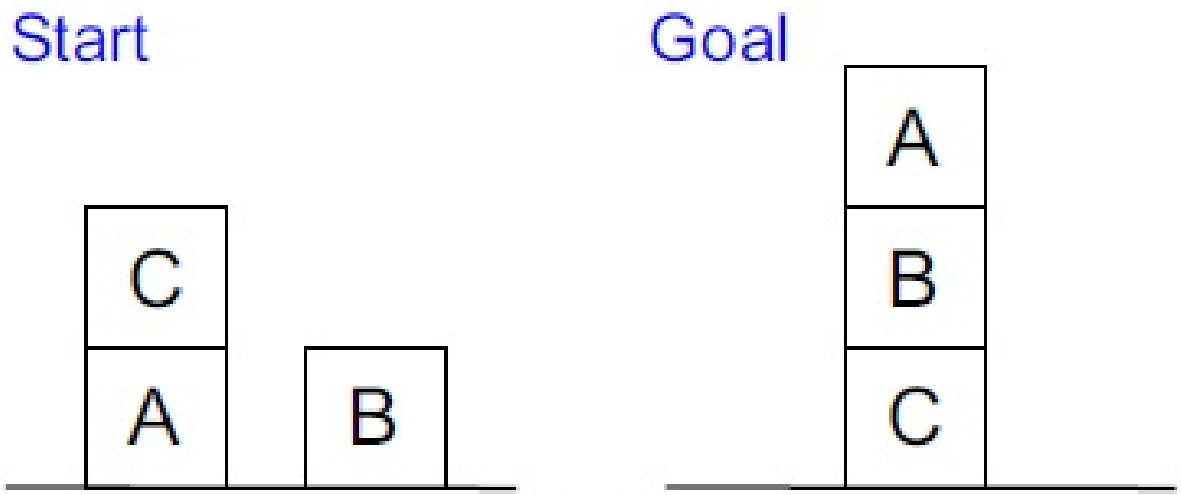
Is the problem decomposable?

- Can the problem be broken down to smaller problems to be solved independently?
- Decomposable problem can be solved easily.

Is the problem decomposable?



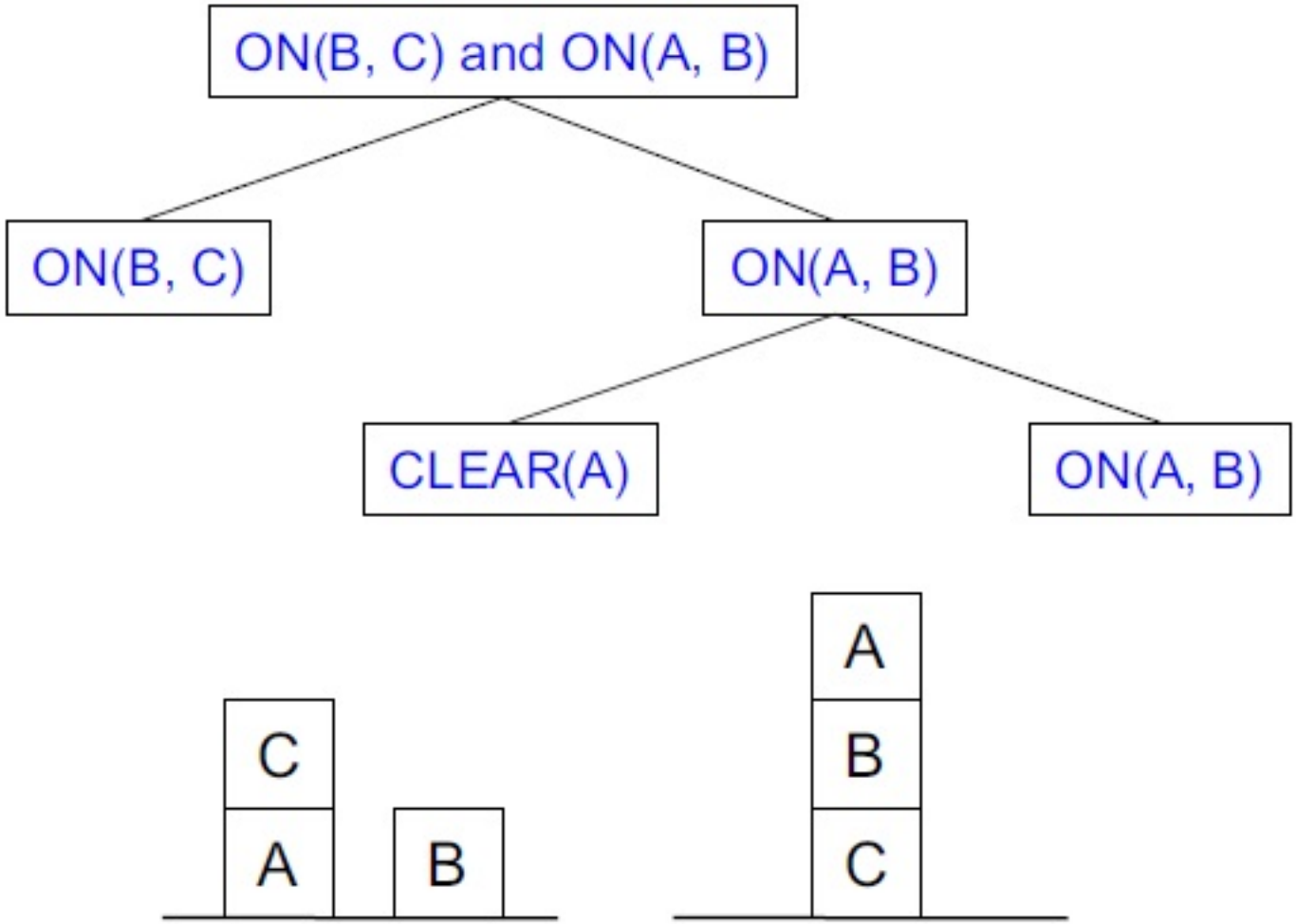
Is the problem decomposable?



CLEAR(x) $\rightarrow$ ON(x, Table)

CLEAR(x) and CLEAR(y) $\rightarrow$ ON(x, y)

Is the problem decomposable?



Can solution steps be ignored or undone?

- Theorem Proving
- 8-Puzzle
- Playing Chess

Can solution steps be ignored or undone?

Theorem Proving

A lemma that has been proved can be ignored for next steps.

Ignorable!

Can solution steps be ignored or undone?

The 8-Puzzle

Moves can be undone and backtracked.

Recoverable!

Can solution steps be ignored or undone?

Playing Chess

Moves cannot be retracted.

Irrecoverable!

Can solution steps be ignored or undone?

- Ignorable problems can be solved using a simple control structure that never backtracks.
- Recoverable problems can be solved using backtracking.
- Irrecoverable problems can be solved by recoverable style methods via planning.

Is the universe predictable?

- 8-Puzzle
- Playing Bridge

Is the universe predictable?

The 8-Puzzle

Every time we make a move, we know exactly what will happen.

Certain outcome!

Is the universe predictable?

Playing Bridge

We cannot know exactly where all the cards are or what the other players will do on their turns.

Uncertain outcome!

Is the universe predictable?

- For certain-outcome problems, planning can used to generate a sequence of operators that is guaranteed to lead to a solution.
- For uncertain-outcome problems, a sequence of generated operators can only have a good probability of leading to a solution.

  Plan revision is made as the plan is carried out and the necessary feedback is provided.

Is a good solution absolute or relative?

1. Marcus was a man.
2. Marcus was a Pompeian.
3. Marcus was born in 40 A.D.
4. All men are mortal.
5. All Pompeians died when the volcano erupted in 79 A.D.
6. No mortal lives longer than 150 years.
7. It is now 2015 A.D.

Is Marcus alive?

Is a good solution absolute or relative?

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7. It is now 2015 A.D.

Is Marcus alive?

Different reasoning paths lead to the answer. It does not matter which path we follow.

Is a good solution absolute or relative?

The Travelling Salesman Problem We have to try all paths to find the shortest one.

Is a good solution absolute or relative?

- Any-path problems can be solved using heuristics that suggest good paths to explore.
- For best-path problems, much more exhaustive search will be performed.

Is the solution a state or a path?

- Finding a consistent interpretation
- The Water Jug Problem

Is the solution a state or a path?

Finding a consistent interpretation "The bank president ate a dish of pasta salad with the fork".

No record of the processing is necessary.

Is the solution a state or a path?

The Water Jug Problem

The path that leads to the goal must be reported.

Is the solution a state or a path?

- A path-solution problem can be reformulated as a state-solution problem by describing a state as a partial path to a solution.
- The question is whether that is natural or not.

What is the role of knowledge

- Playing Chess
  Knowledge is important only to constrain the search for a solution.
- Reading Newspaper
  Knowledge is required even to be able to recognize a solution.

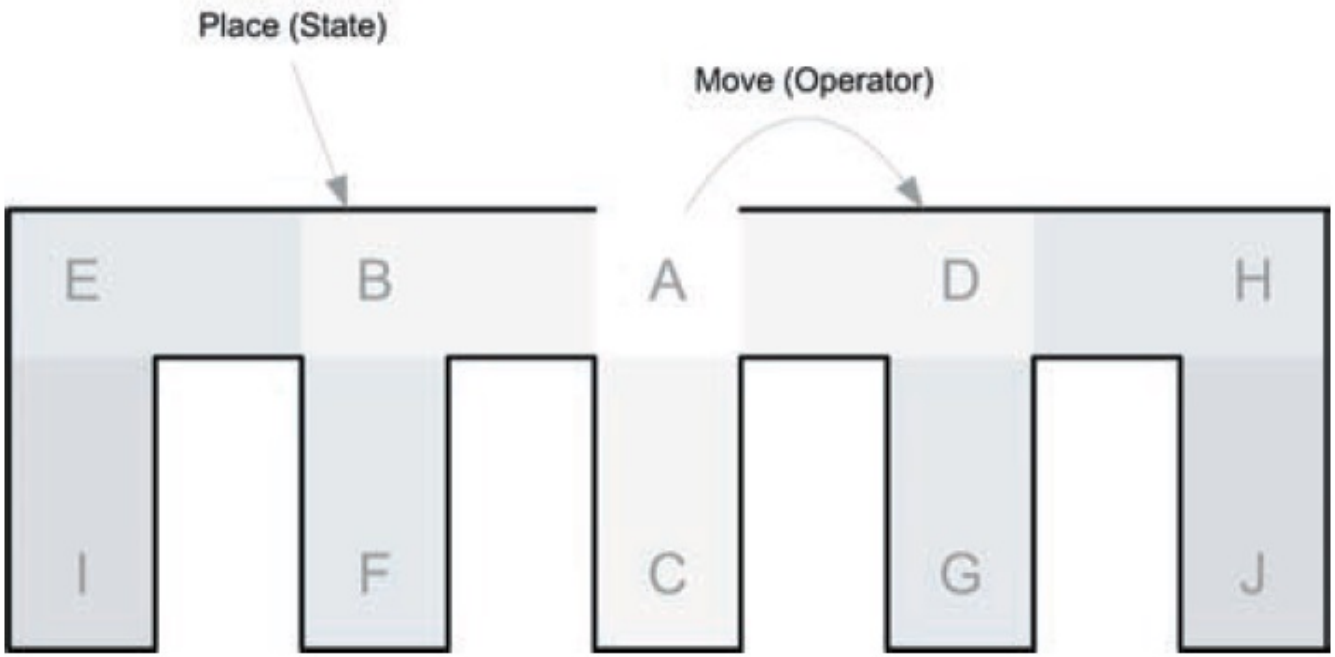
Does the task require human-interaction?

- Solitary problem, in which there is no intermediate communication and no demand for an explanation of the reasoning process.
- Conversational problem, in which intermediate communication is to provide either additional assistance to the computer or additional information to the user.

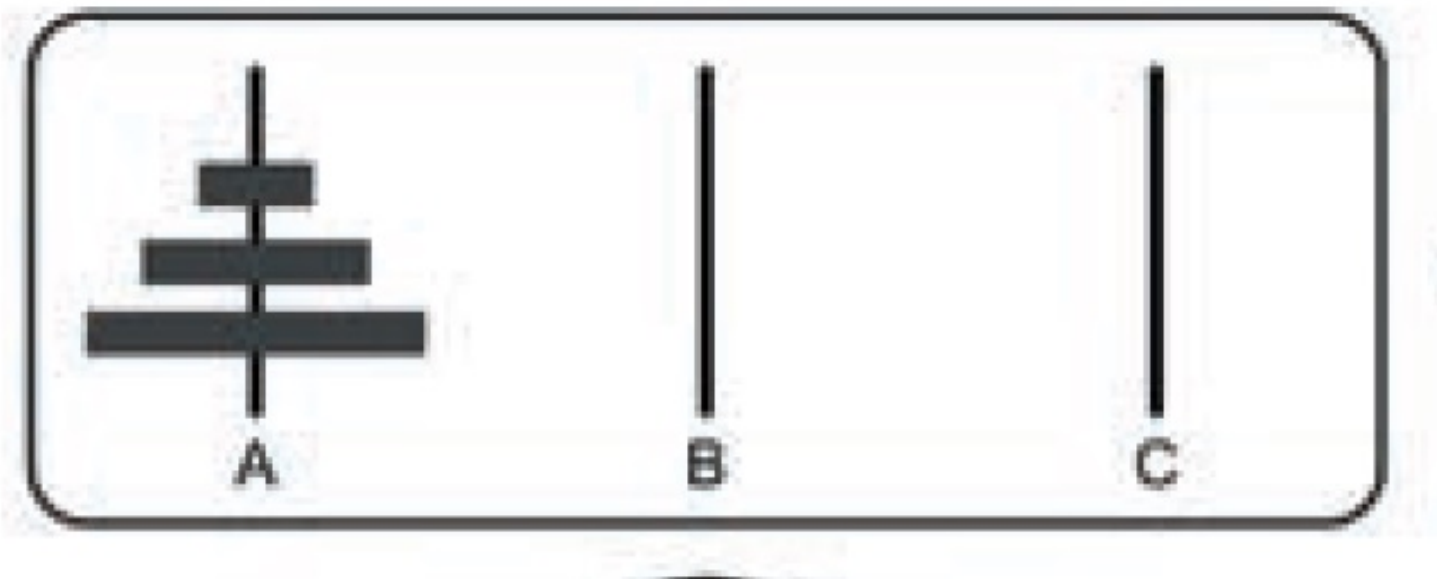
Problem Classification

- There is a variety of problem-solving methods, but there is no one single way of solving all problems.
- Not all new problems should be considered as totally new. Solutions of similar problems can be exploited.

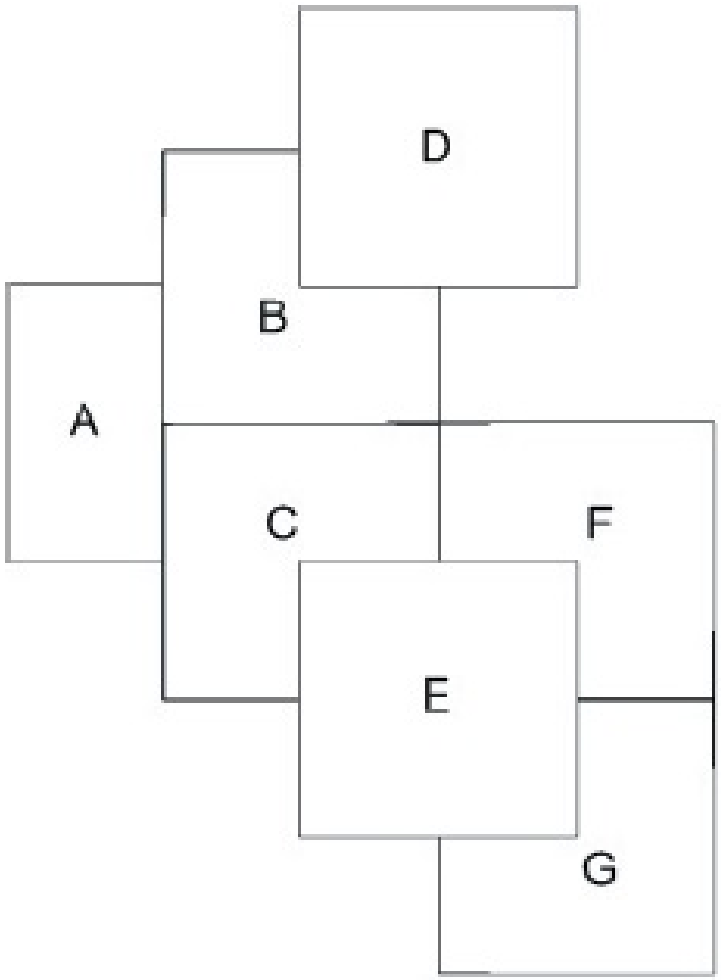
Exercise:



Exercise: The Tower of Hanoi

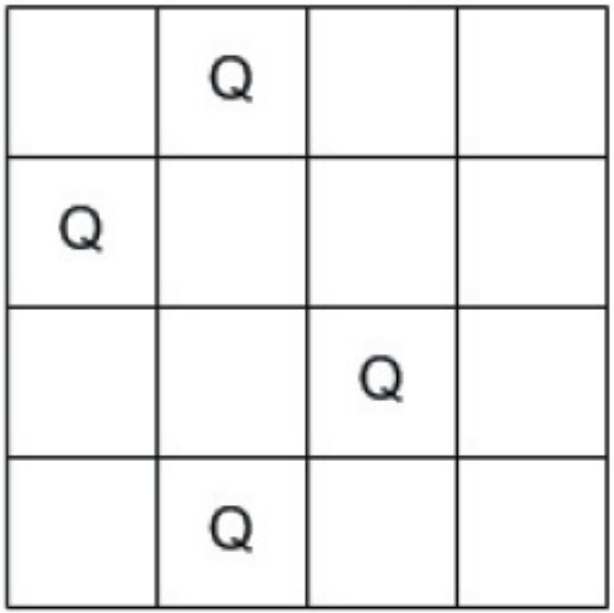


Exercise: Graph Coloring



Map

Exercise: 4-Queens



Initial Board

Homework

- Missionaries & Cannibals
- N-Queens
- Knight's Tour