Soft Computing Introduction

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AI : Definition

- *AI may be defined as the branch of computer science that is concerned with the automation of intelligence behavior"* (G.F. Luger and W.A. Stubblefield)
- *"AI is the study of computations that make possible to behave intelligently"* (Patrick H. Winston)
- *"AI is the design and study of computer programs that behave intelligently"* (Thomas Dean, et al)

Task Domains of AI

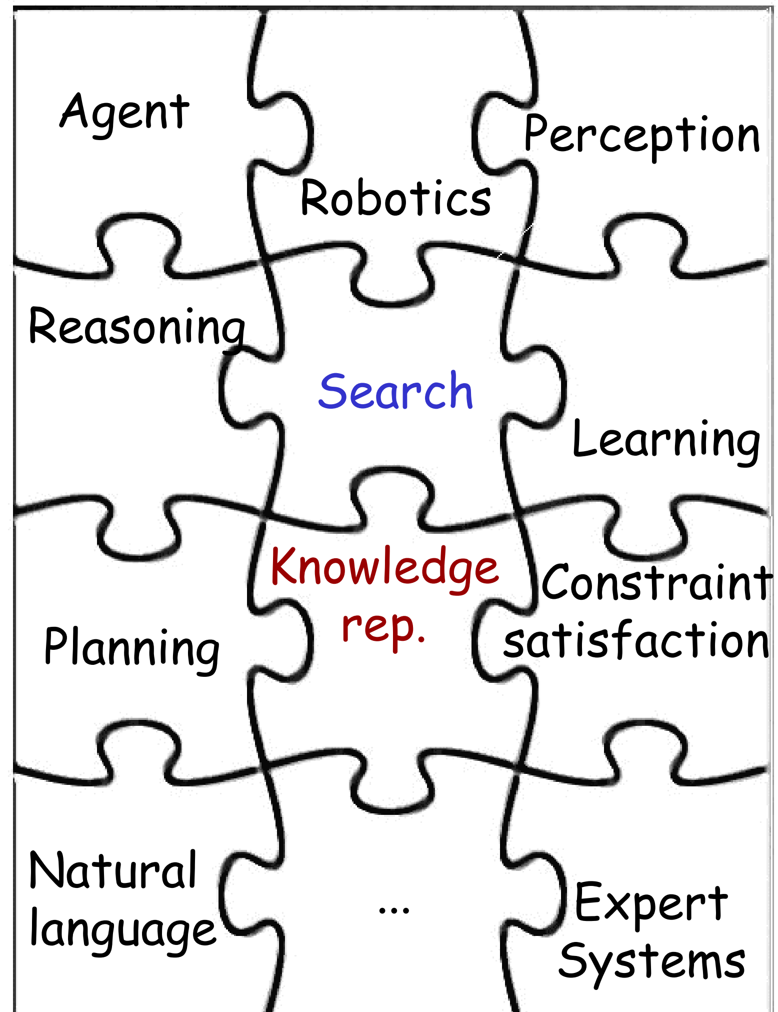
- **Mundane Tasks :**
  - Perception
  - Natural language
  - Commonsense reasoning
  - Robot Control
- **Formal Tasks :**
  - Games
  - Mathematics
- **Expert Tasks :**
  - Engineering
  - Scientific Analysis
  - Medical Diagnosis
  - Financial Analysis

Abridged History of AI

• 1943	McCulloch & Pitts: Boolean circuit model of brain
• 1950	Turing's "Computing Machinery and Intelligence"
• 1956	Dartmouth meeting: "Artificial Intelligence" adopted
• 1950s	Early AI programs, including Samuel's checkers
• 1965	Robinson's complete algorithm for logical reasoning
• 1966—73	AI discovers computational complexity Neural network research almost disappears
• 1969—79	Early development of knowledge-based systems
• 1980--	AI becomes an industry
• 1986--	Neural networks return to popularity
• 1987--	AI becomes a science
• 1995--	The emergence of intelligent agents

Main Areas of AI

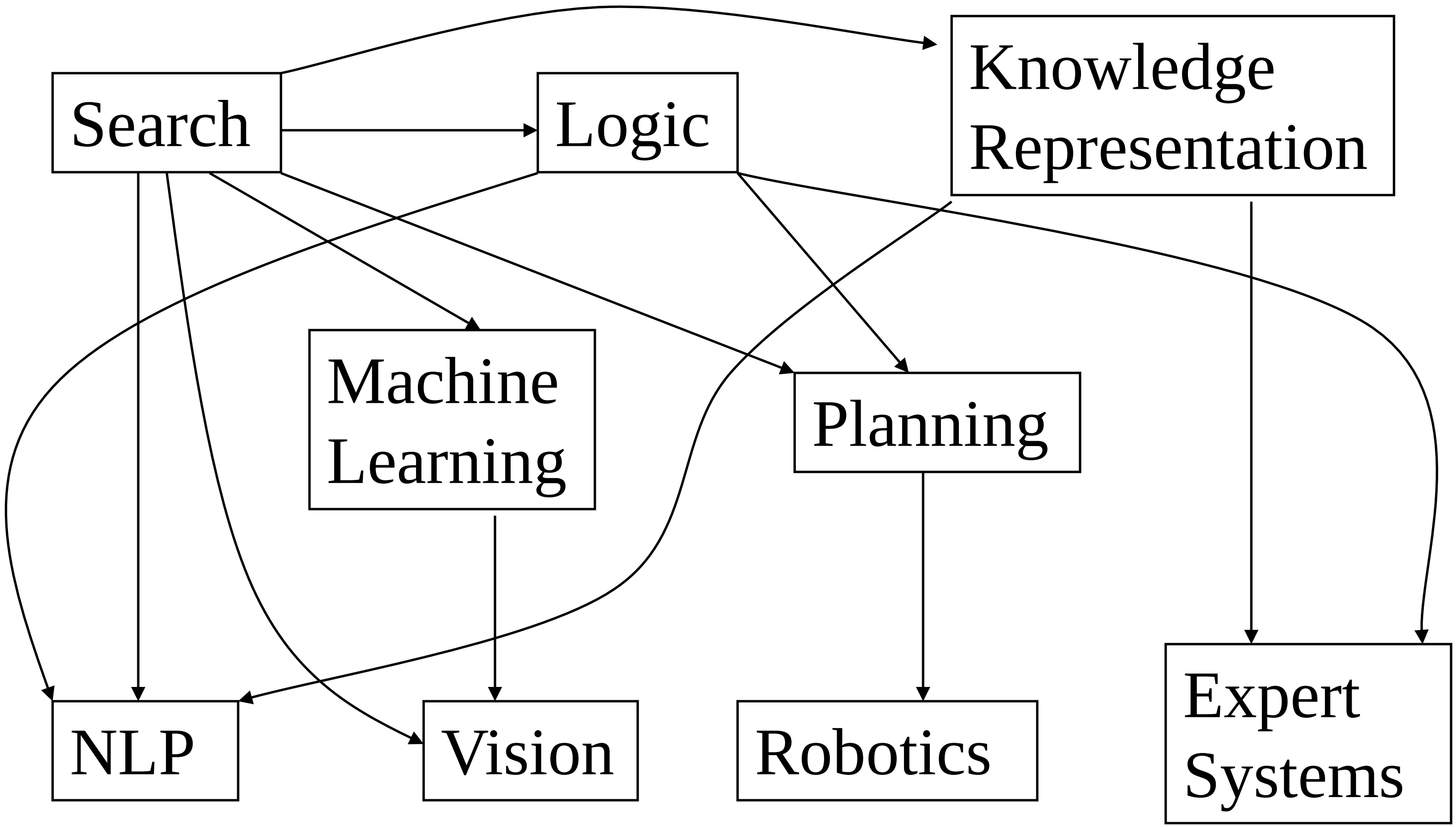
- Knowledge representation (including formal logic)
- Search, especially heuristic search (puzzles, games)
- Planning
- Reasoning under uncertainty, including probabilistic reasoning
- Learning
- Agent architectures
- Robotics and perception
- Natural language processing



Basic Techniques

- **Knowledge Representation**
  - ✓ Encoding and manipulating domain specific knowledge
  - ✓ Methods: Propositional Logic, Predicate Logic, Semantic Nets, Frames, Scripts
- **Searching**
  - ✓ Finding solutions among alternatives
  - ✓ Brute Force Search (uninformed search)
    - Generate and test every possibility
    - Often inefficient and sometimes infeasible
  - ✓ Heuristic Search (Informed Search)
    - Guiding the search with domain knowledge
    - More likely to lead to a good solution

Areas of AI and Some Dependencies



Search

- Search is a problem solving technique that systematically explores the space of problem states
- This space of alternative solutions is then searched to find an answer
- This is the essential basis of human problem solving
- Problem formulation is the process of deciding what actions and states to consider
- Go thru the set of states; Adopt a goal and aim to satisfy it

Search and AI

- Search methods are ubiquitous in AI systems. They are often the backbones of both core and peripheral modules
- An autonomous robot uses search methods:
  - To decide which actions to take and which sensing operations to perform
  - To quickly anticipate collision
  - To plan trajectories
  - To interpret large numerical datasets provided by sensors into compact symbolic representations
  - To diagnose why something did not happen as expected, etc.
- Many searches may occur concurrently and sequentially

Search and games

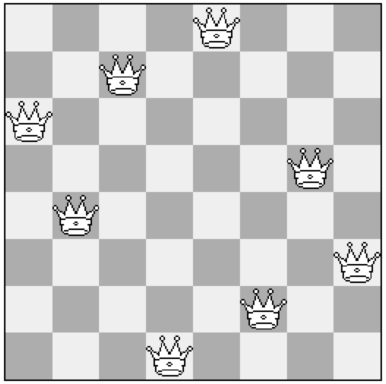
- Across history, puzzles and games requiring the exploration of alternatives have been considered a challenge for human intelligence
  - Chess originated in Persia and India about 4000 years ago
  - Checkers appeared in 3600-year-old Egyptian paintings
  - ‘Go’ originated in China over 3000 years ago
- So, it’s not surprising that AI uses games to design and test algorithms

Search problems

15 puzzle

Towers of Hanoi

Mazes



8 queens

Real life search problems

Scheduling

Route planning

Telescope scheduling

Military robot navigation

More applications

- Route finding
  - Airline travel, trains, roads etc.
  - Computer networks
- Package/mail distribution
- Pipe routing, VLSI routing
  - E.g. how to route cables and wires in a building, a car etc, or how to connect the pins of electronic chips
- Pharmaceutical drug design
  - How to find the most suitable substances that allow the active component of the drug to link to the target zone
- Video games

Search Methods

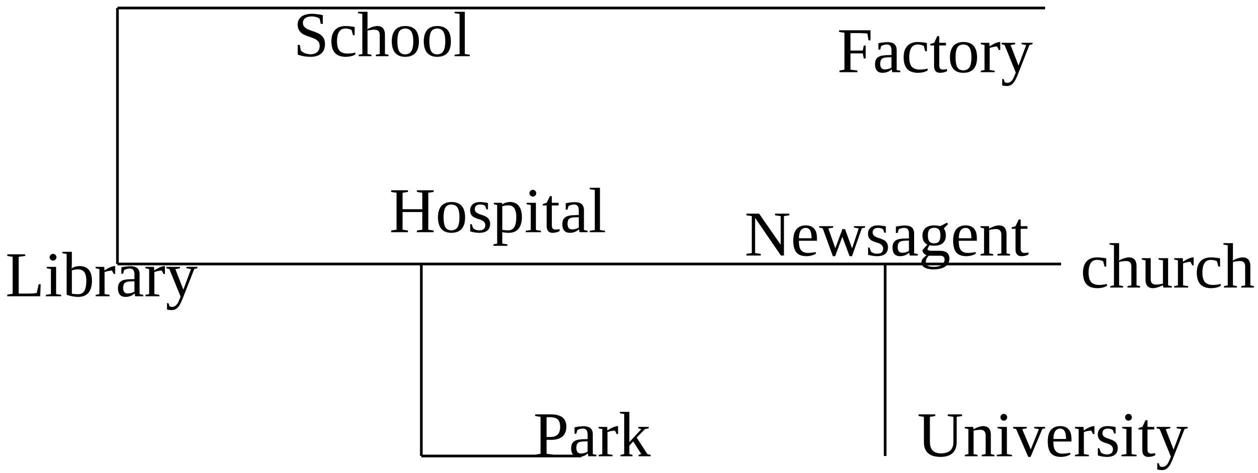
- Why search?
- Uninformed search methods
  - Breadth-first, depth-first, bidirectional, iterative deepening search
- Informed search methods
  - Greedy Hill Climbing, Best First, A Algorithm, A* search
- Conclusions

Well defined Problem

- **Initial** state is the starting position
- **Operator** is the action applied to move from one state to another. Given a state x, Succ(x) returns a set of (action, succ) ordered pairs where each action is one of the legal actions in stat x, and each successor is a state that can be reached from x by applying the action.
- **State Space** : Set of states reachable from the initial state by any sequence of actions
- **Goal** is the final state to reach
- A **path** in the state space is a sequence of actions leading from one state to another
- **Goal test** is applied to determine if it is a goal state or not
- **Path Cost** function is a function that assigns a cost to a path
- **Solution** to the problem is a path from the initial state to a goal state.

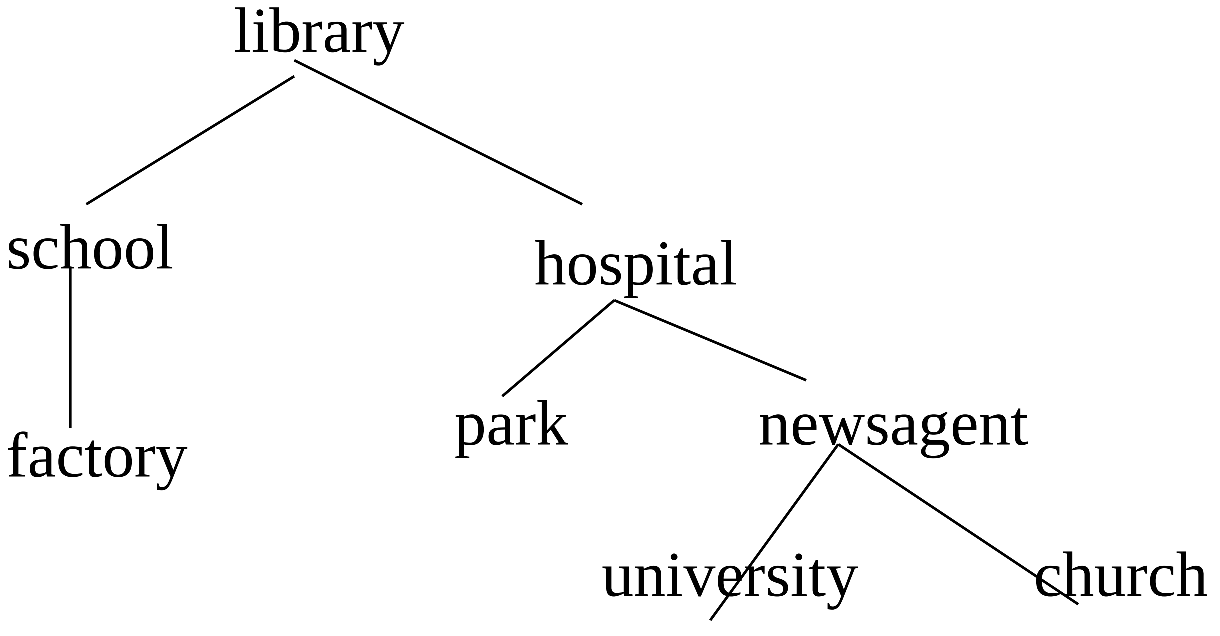
Simple Example

- Easiest to first look at simple examples based on searching for route on a map.
- How do we systematically and exhaustively search possible routes, in order to find, say, route from library to university?



Search Space

- The set of all possible states reachable from the initial state defines the *search space*.
- We can represent the search space as a tree.
- We refer to nodes connected to and "under" a node in the tree as "successor nodes".

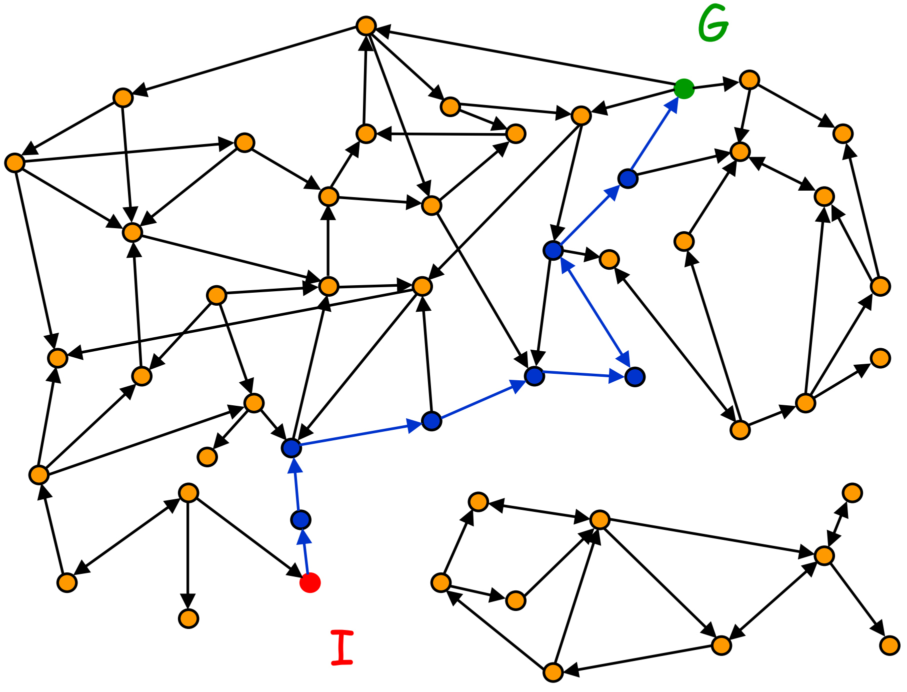


Formalization of a search problem

- **Q** is a finite set of states
- **S** $\subseteq$ Q is a non-empty set of start states
- **G** $\subseteq$ Q is a non-empty set of goal states
- **succs** : Q $\rightarrow \wp$(Q) is a function which takes a state as input and returns a set of states as output
  - succs(s) is the set of states that can be reached from s in one single step
- **cost** : $Q^2 \rightarrow R^+$ is a function which takes two states as input, and returns a positive number
  - cost(s,s') is the cost of getting from s to s'
  - cost(s,s') is only defined when s' $\in$ succs(s)

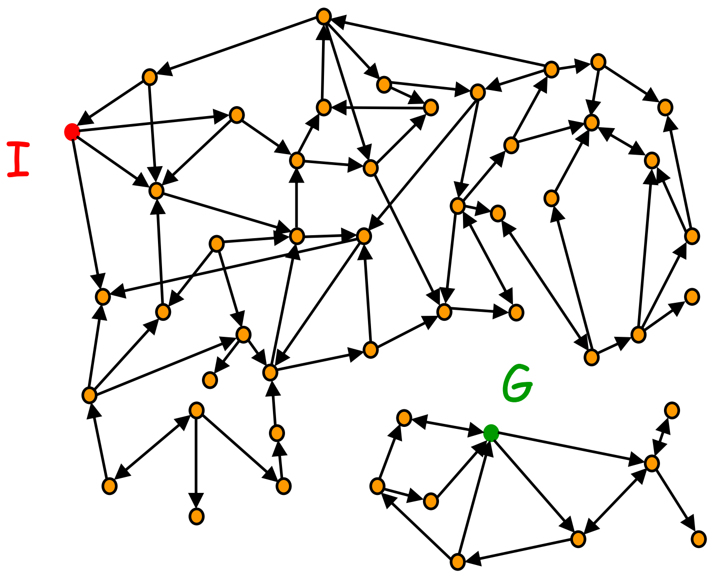
Solution to the search problem

- A solution is a path connecting the initial node to a goal node (any one)



Solution to the search problem

- A solution is a path connecting the initial node to a goal node (any one)
- The cost of a path is the sum of the arc costs along this path
- An optimal solution is a solution path of minimum cost
- There might be no solution!

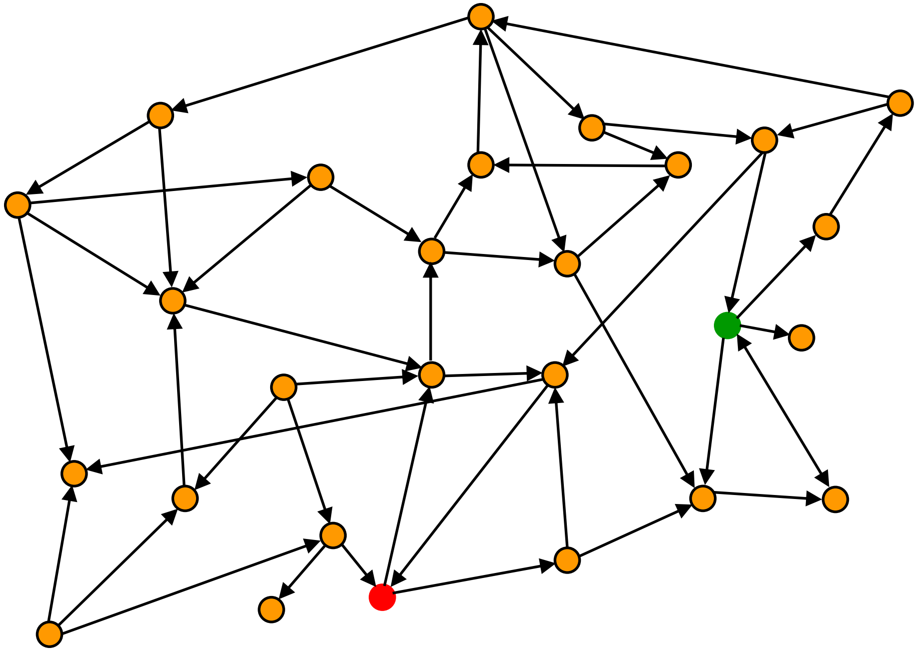


How big is the state space of the puzzle?

- 8-puzzle → 9! = 362,880 states
- 15-puzzle → 16! ≈ 2.09 x 10^{13} states
- 24-puzzle → 25! ≈ 10^{25} states

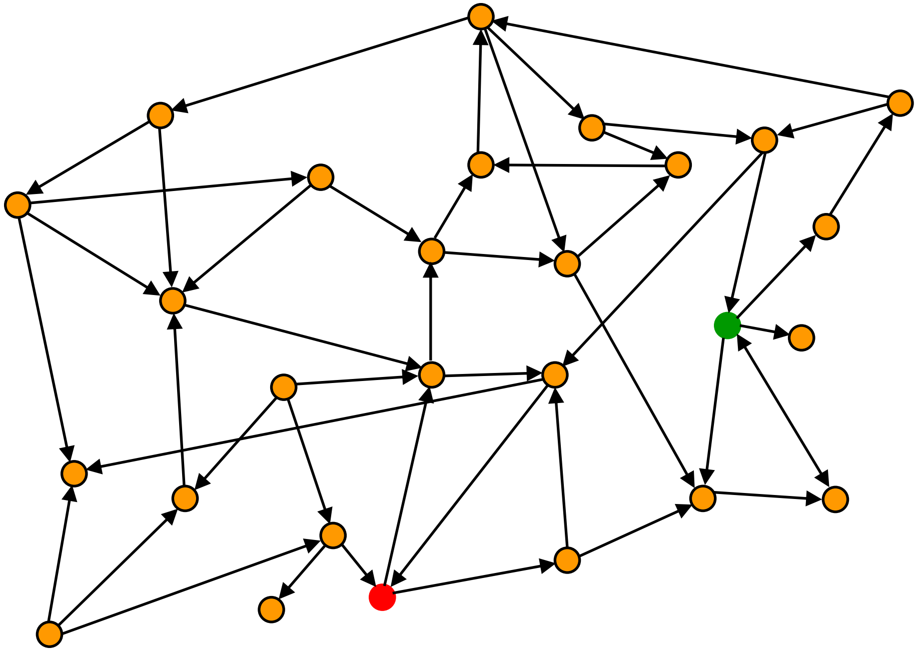
- Only half of these states are reachable from any given state
  - But that may not be known in advance

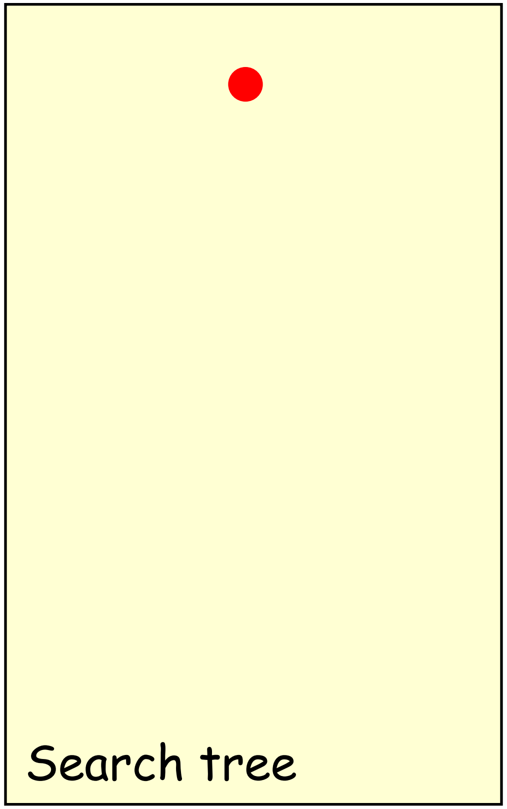
Searching the state space



- Often it is not feasible (or too expensive) to build a complete representation of the state graph
- A problem solver must construct a solution by exploring a small portion of the graph

Searching the state space





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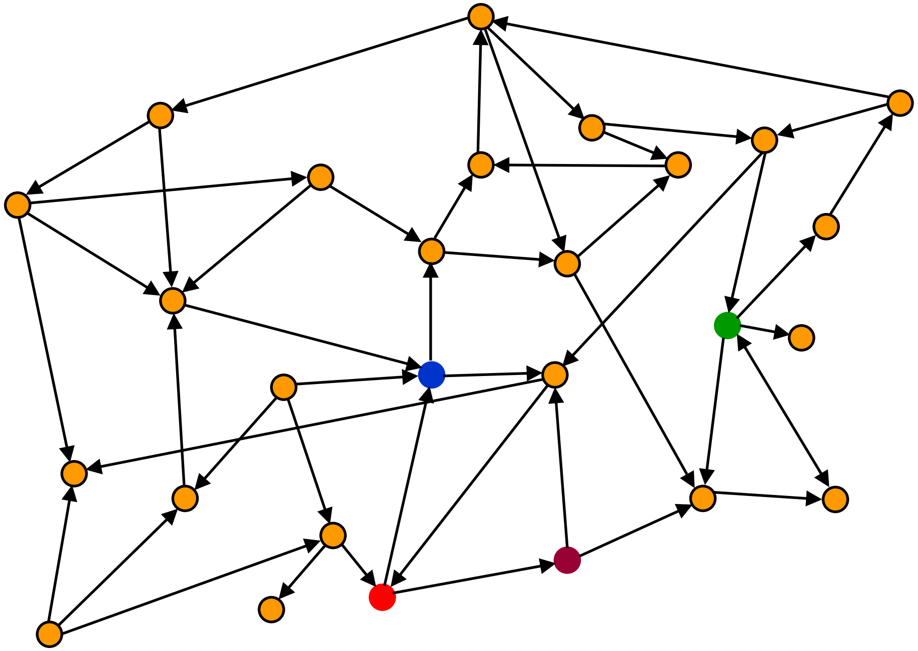

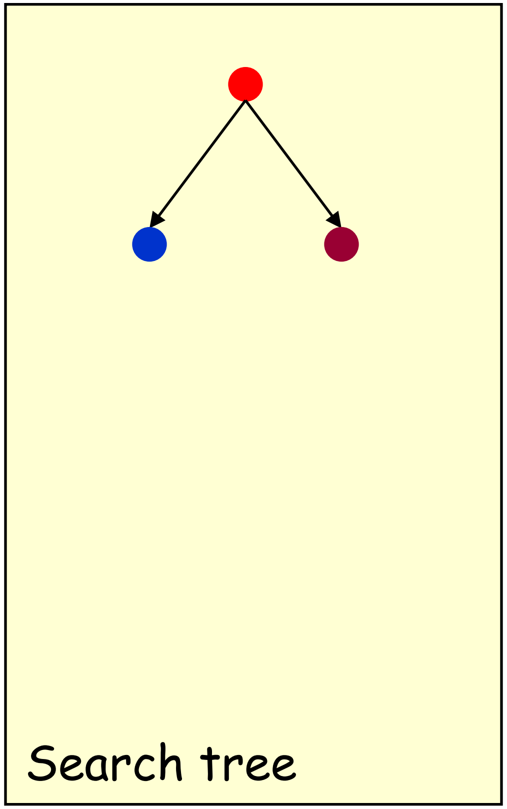

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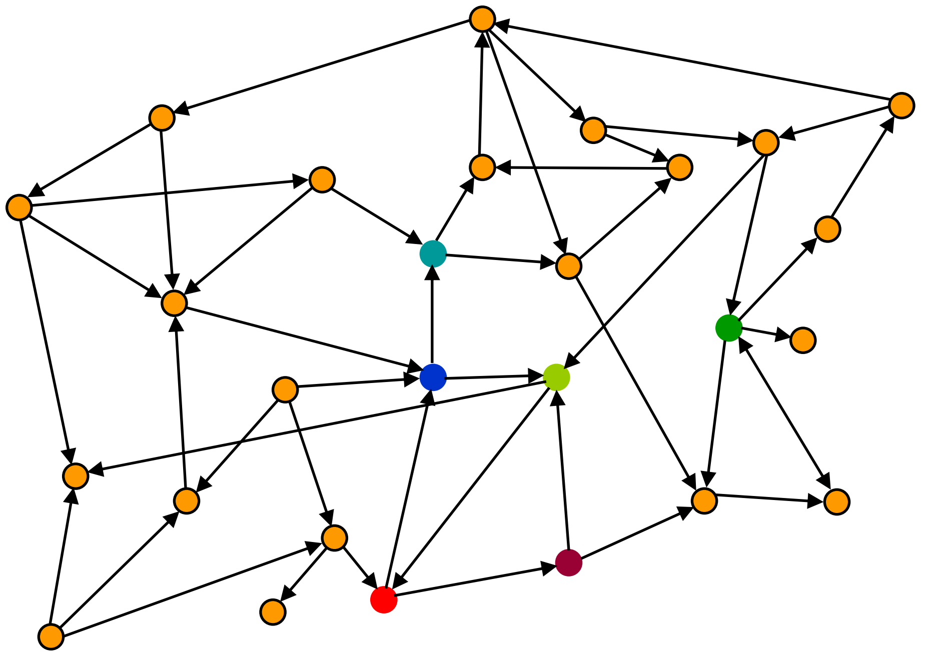

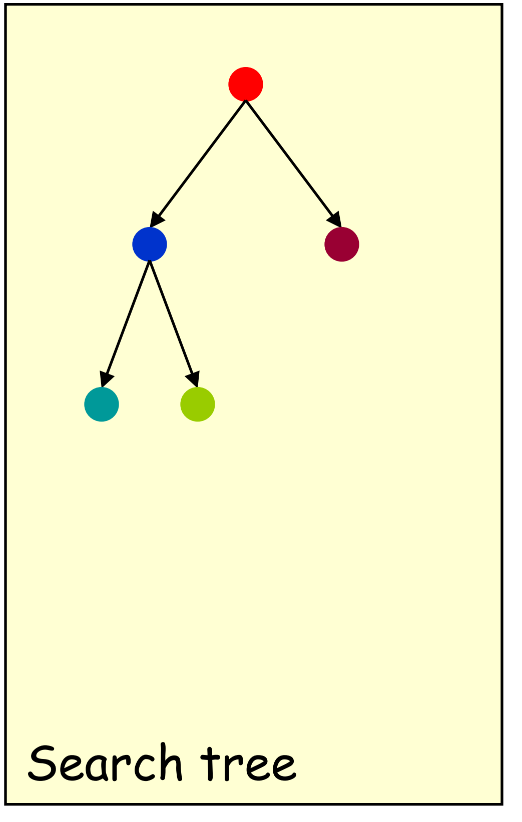

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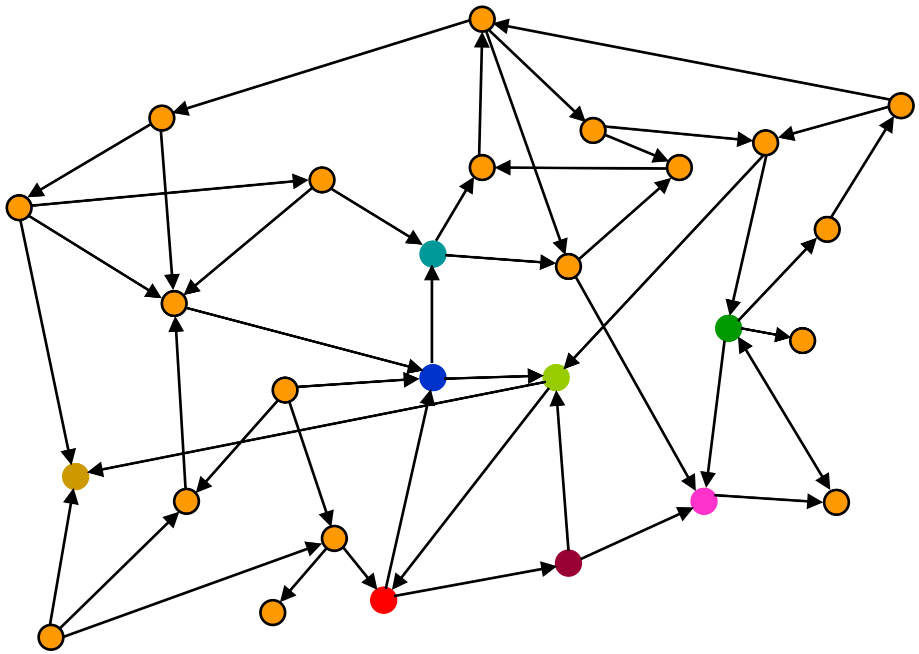

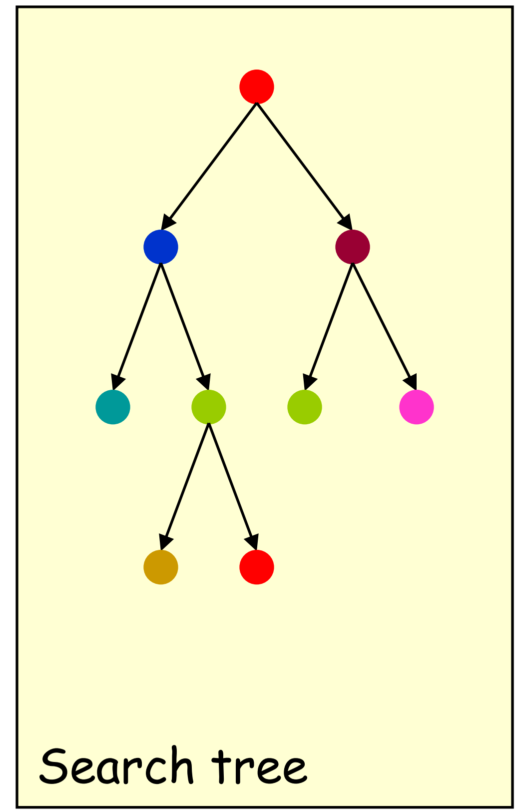

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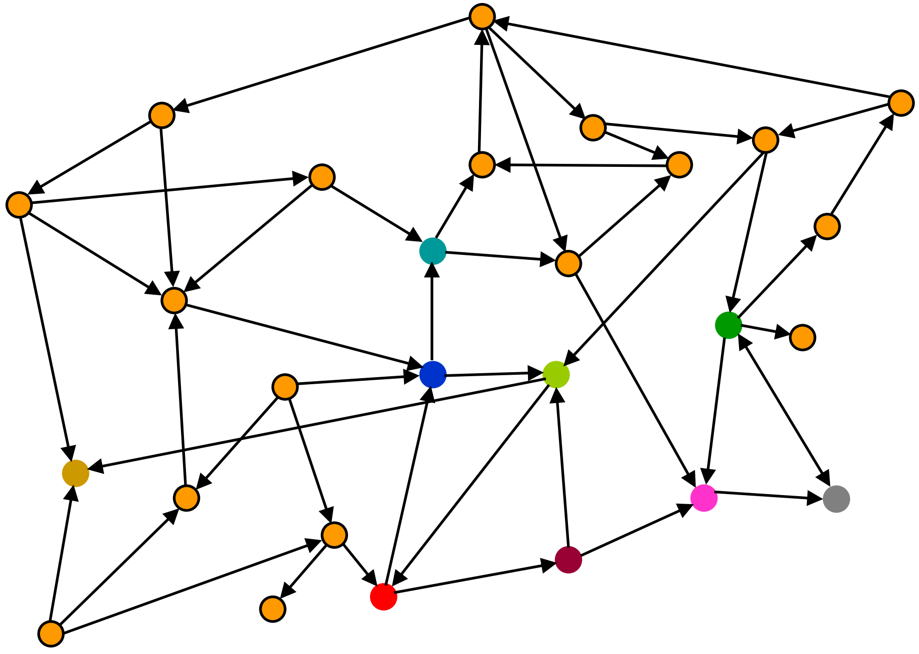

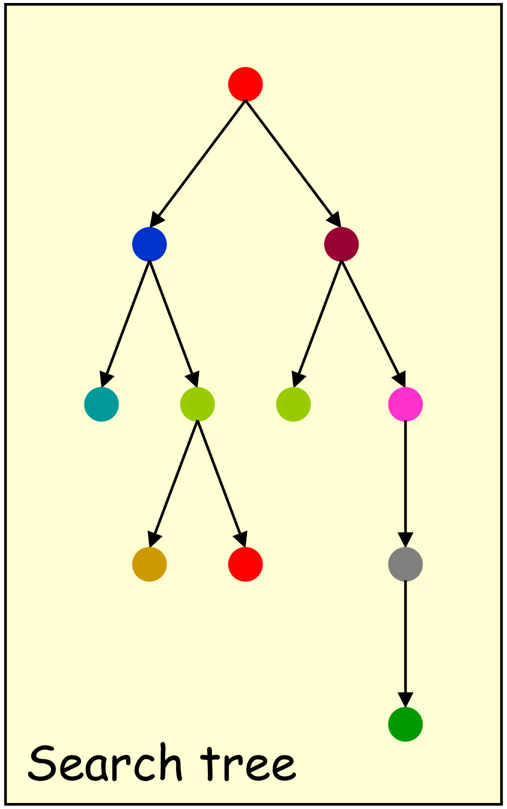

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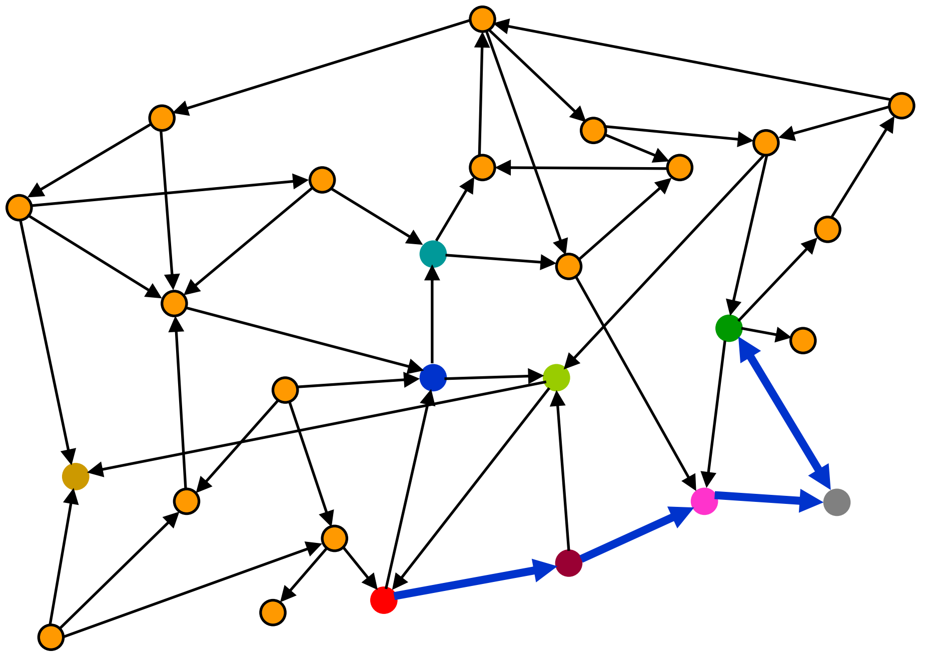
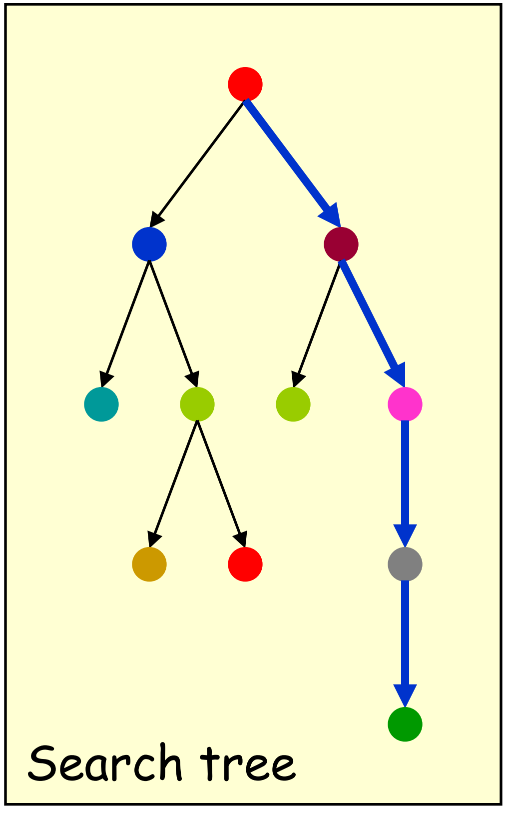




Simple Search Techniques

- How do we search this tree to find a possible route from library to University?
- May use simple systematic search techniques, which try every possibility in systematic way.
- Breadth first search - Try shortest paths first.
- Depth first search - Follow a path as far as it goes, and when reach dead end, backup and try last encountered alternative.

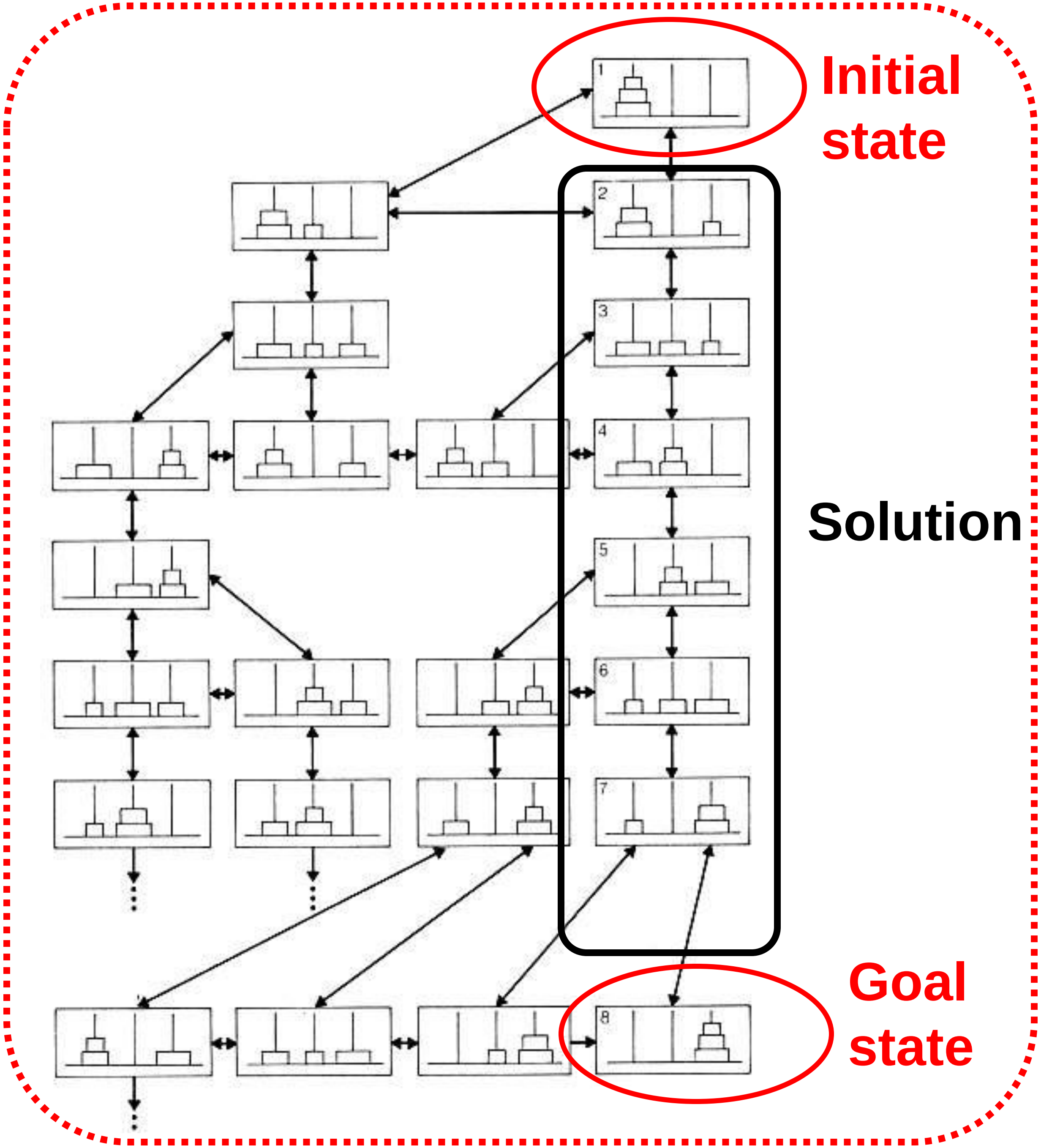
Solution to the Problem

- **Search space (Problem space)**: the set of all states that can potentially be reached by applying available operators

- **Solution**: a sequence of operators that transform the initial state into a goal state

- **A problem solving method**: a procedure for finding a solution

Problem Solving is *a search problem*



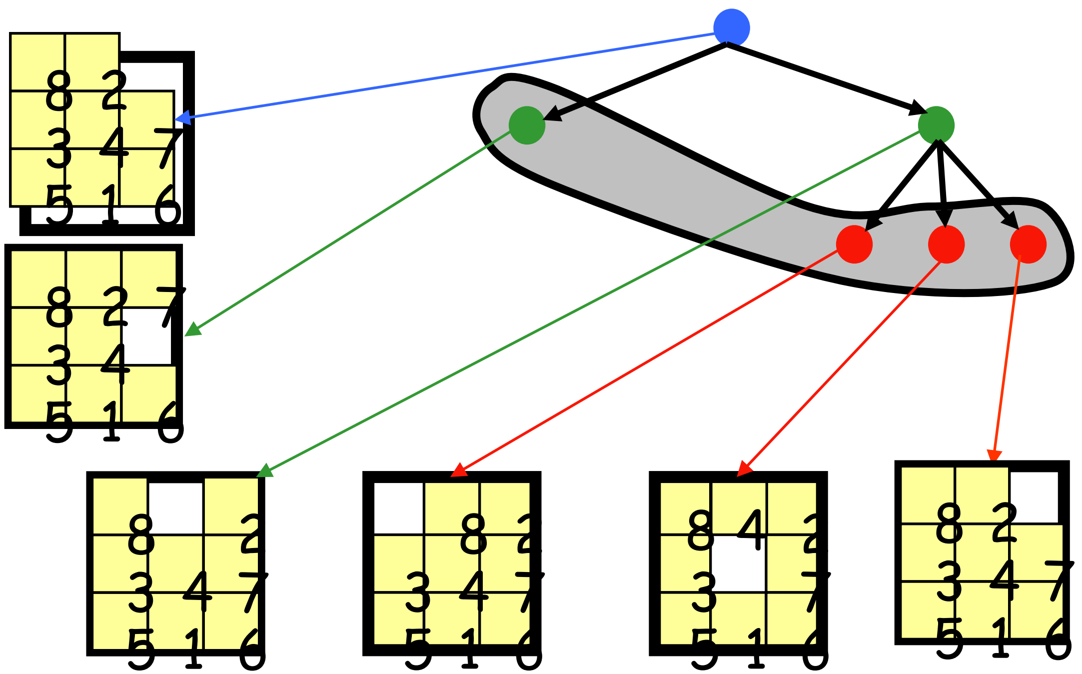
Search Space (Problem space)

Performance measures

- **Completeness**
  - A search algorithm is complete if it finds a solution whenever one exists
  - What about the case when no solution exists?
- **Optimality**
  - A search algorithm is optimal if it returns a minimum-cost path whenever a solution exists
- **Complexity**
  - It measures the time and amount of memory required by the algorithm

Fringe of a search tree

- The *fringe* is the set of all search nodes that haven't been expanded yet



Conclusion

- Search methods are useful when:
  - The search space is small, and
    - No other technique is available, or
    - Developing a more efficient technique is not worth the effort
  - The search space is large, and
    - No other available technique is available, and
    - There exist “good” heuristics

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