Problem Formulation in Artificial Intelligence

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Problem Solving

- Rational agents need to perform sequences of actions in order to achieve goals.
- Intelligent behavior can be generated by having a look-up table or reactive policy that tells the agent what to do in every circumstance, but:
  - Such a table or policy is difficult to build
  - All contingencies must be anticipated
- A more general approach is for the agent to have knowledge of the world and how its actions affect it and be able to simulate execution of actions in an internal model of the world in order to determine a sequence of actions that will accomplish its goals.
- This is the general task of problem solving and is typically performed by searching through an internally modelled space of world states.

Problem Solving Task

- Given:
  - An initial state of the world
  - A set of possible actions or operators that can be performed.
  - A goal test that can be applied to a single state of the world to determine if it is a goal state.
- Find:
  - A solution stated as a path of states and operators that shows how to transform the initial state into one that satisfies the goal test.
- The initial state and set of operators implicitly define a state space of states of the world and operator transitions between them. May be infinite.

Measuring Performance

- Path cost: a function that assigns a cost to a path, typically by summing the cost of the individual operators in the path. May want to find minimum cost solution.
- Search cost: The computational time and space (memory) required to find the solution.
- Generally there is a trade-off between path cost and search cost and one must satisfice and find the best solution in the time that is available.

Water-Jug Problem

- **Problem:**
- You are given two jugs, a 4-gallon one and a 3-gallon one. Neither has any measuring mark on it. There is a pump that can be used to fill the jugs with water. How can you get exactly 2 gallons of water into the 4-gallon jug.

Solutions Steps

- **Solution:**
- The state space for this problem can be described as the set of ordered pairs of integers (x,y)
- Where,
- X represents the quantity of water in the 4-gallon jug
  X= 0,1,2,3,4
- Y represents the quantity of water in 3-gallon jug
  Y=0,1,2,3
- **Start State:** (0,0)
- **Goal State:** (2,0)

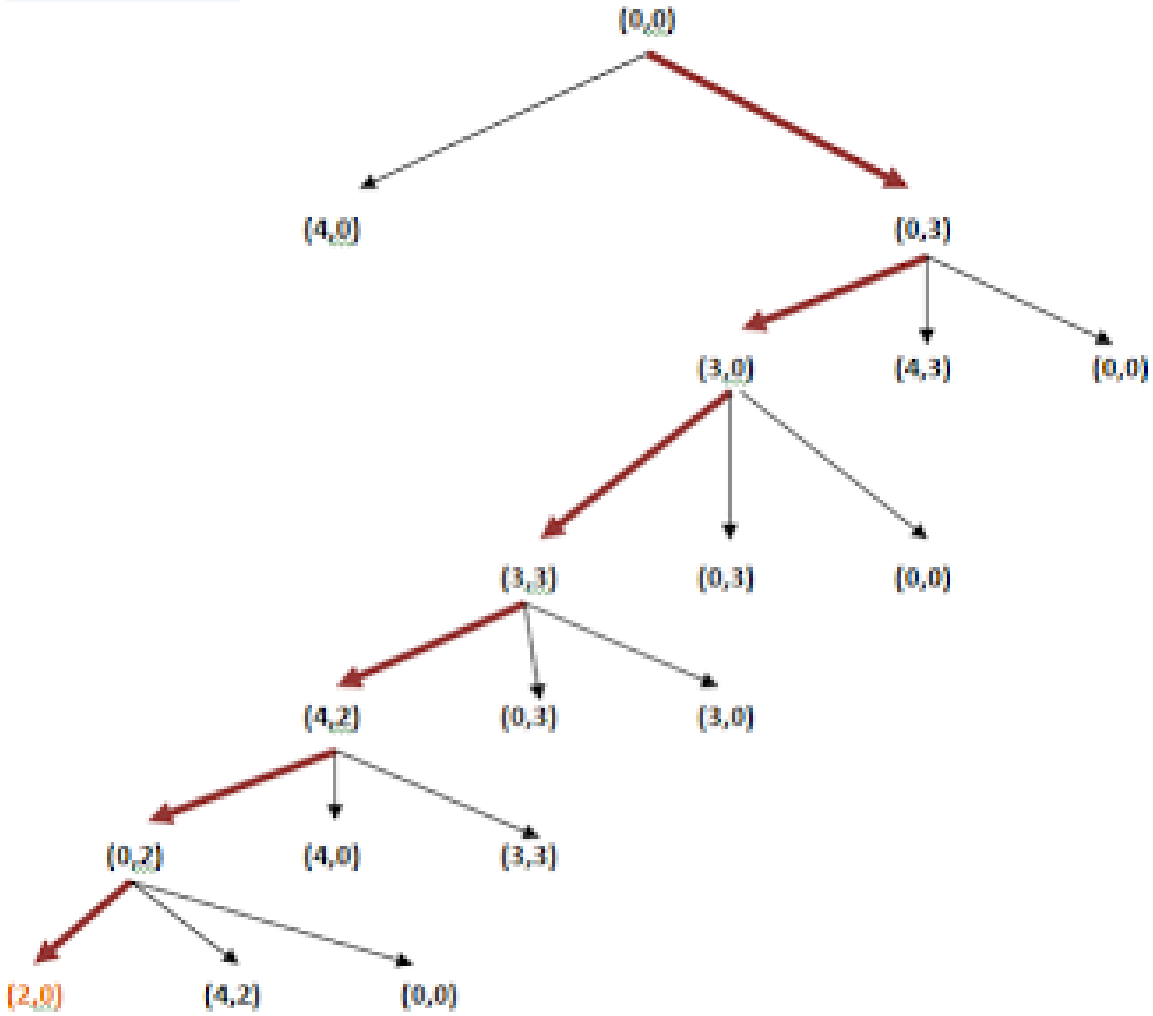
Production Rules

Rule	State	Process
1	(X,Y | X<4)	(4,Y) {Fill 4-gallon jug}
2	(X,Y |Y<3)	(X,3) {Fill 3-gallon jug}
3	(X,Y |X>0)	(0,Y) {Empty 4-gallon jug}
4	(X,Y | Y>0)	(X,0) {Empty 3-gallon jug}
5	(X,Y | X+Y>=4 ^ Y>0)	(4,Y-(4-X)) {Pour water from 3-gallon jug into 4-gallon jug until 4-gallon jug is full}
6	(X,Y | X+Y>=3 ^X>0)	(X-(3-Y),3) {Pour water from 4-gallon jug into 3-gallon jug until 3-gallon jug is full}
7	(X,Y | X+Y<=4 ^Y>0)	(X+Y,0) {Pour all water from 3-gallon jug into 4-gallon jug}
8	(X,Y | X+Y <=3^ X>0)	(0,X+Y) {Pour all water from 4-gallon jug into 3-gallon jug}
9	(0,2)	(2,0) {Pour 2 gallon water from 3 gallon jug into 4 gallon jug}

One Solution to the water jug problem

4-Gallon Jug	3 Gallon Jug	Rule Applied
0	0	2
0	3	9
3	0	8
3	3	7
4	2	5
0	2	9
2	0	

State Space Tree



Missionaries and Cannibals

- **Problem:**
- Three missionaries and three cannibals are on one side of a river that they wish to cross.
- A boat is available that can hold at most two people and at least one.
- You must never leave a group of missionaries outnumbered by cannibals on the same bank.
- Find an action sequence that brings everyone safely to the opposite bank.

Solution Steps

- State space: triple (x,y,z) with $0 \leq x,y,z \leq 3$, where x,y, and z represent the number of missionaries, cannibals and boats currently on the original bank.
- Initial State: (3,3,1)
- Goal State: (0,0,0)
- Path Costs: 1 unit per crossing

Production Rules

Rule 1 :	(0, M)	:	One missionary sailing the boat from bank-1 to bank-2
Rule 2 :	(M, 0)	:	One missionary sailing the boat from bank-2 to bank-1
Rule 3 :	(M, M)	:	Two missionaries sailing the boat from bank-1 to bank-2
Rule 4 :	(M, M)	:	Two missionaries sailing the boat from bank-2 to bank-1
Rule 5 :	(M, C)	:	One missionary and one Cannibal sailing the boat from bank-1 to bank-2
Rule 6 :	(C, M)	:	One missionary and one Cannibal sailing the boat from bank-2 to bank-1
Rule 7 :	(C, C)	:	Two Cannibals sailing the boat from bank-1 to bank-2
Rule 8 :	(C, C)	:	Two Cannibals sailing the boat from bank-2 to bank-1
Rule 9 :	(0, C)	:	One Cannibal sailing the boat from bank-1 to bank-2
Rule 10 :	(C, 0)	:	One Cannibal sailing the boat from bank-2 to bank-1

Solution

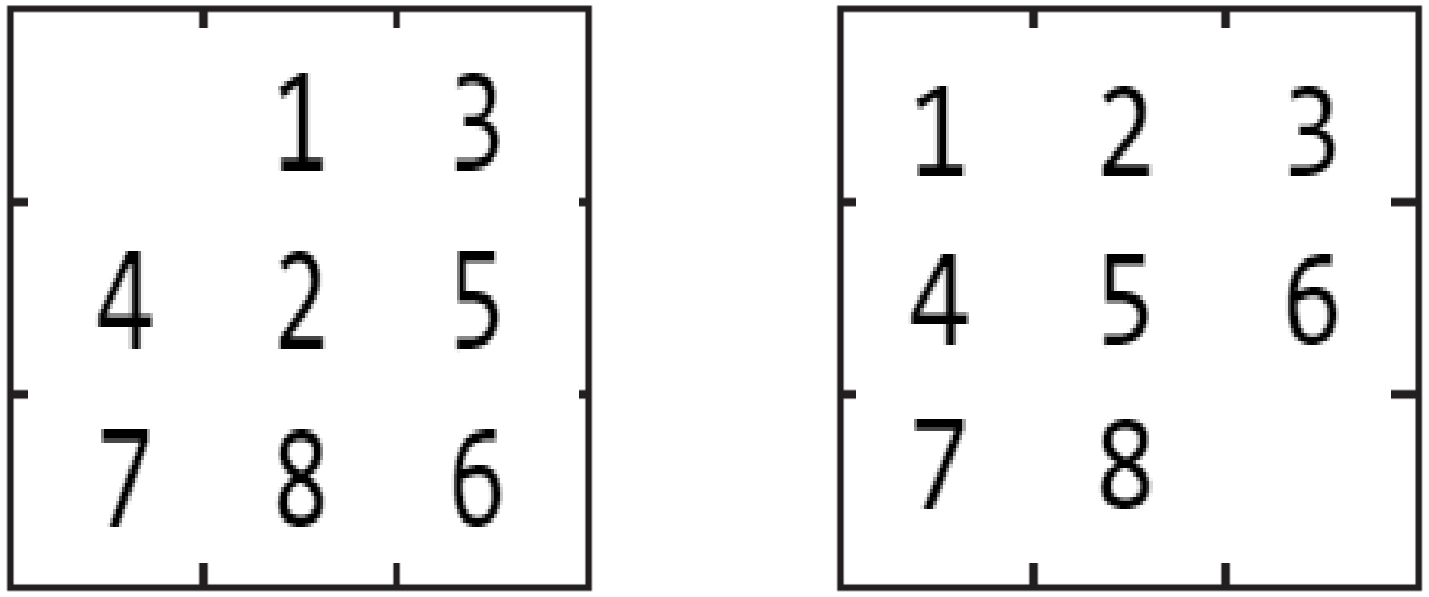
Table 2.2: Rules applied and their sequence in Missionaries and Cannibals problem

After application of rule	persons in the river bank-1	persons in the river bank-2	boat position
Start state	M, M, M, C, C, C	0	bank-1
5	M, M, C, C	M, C	bank-2
2	M, M, C, C, M	C	bank-1
7	M, M, M	C, C, C	bank-2
10	M, M, M, C	C, C	bank-1
3	M, C	C, C, M, M	bank-2
6	M, C, C, M	C, M	bank-1
3	C, C	C, M, M, M	bank-2
10	C, C, C	M, M, M	bank-1
7	C	M, M, M, C, C	bank-2
10	C, C	M, M, M, C	bank-1
7	0	M, M, M, C, C, C	bank-2

8-Puzzle Problem

- The 8-puzzle problem belongs to the category of "sliding-block puzzle" types of problems.
- It has set of a 3x3 board having 9 block spaces out of which, 8 blocks are having tiles bearing number from 1 to 8. One space is left blank. The tile adjacent to blank space can move into it. We have to arrange the tiles in a sequence.

Solution Steps



(a) Start state (b) Goal state

Fig. 2.4: Start and Goal states of 8 puzzle problem

Solution Stages

Nature of AI Problems

- **Path Finding Problems:** Traveling salesperson problem
- **Decomposable Problems:** Maths equations
- **Recoverable Problems:** 8 puzzle problem
- **Predictable Problems:** 8 puzzle problem
- **Problems Affecting the Quality of Solution:** Traveling salesperson problem
- **State Finding Problem:** Medical diagnosis problems using expert system
- **Problems Requiring Interaction:** Interacting with user
- **Knowledge Intensive Problems:** Chess or Tic Tac Toe Problem

Problem characteristics

- 1. If the problem is decomposable into independent smaller or easier sub problems.
- 2. Is backtracking possible or not.
- 3. Is the problem's universe predictable.
- 4. Is a good solution to the problem obvious without comparison to all other possible solutions.
- 5. Is the desired solution a state or a path.
- 6. Is a large amount of knowledge absolutely required to solve the problem or is knowledge important only to constrain the search.

Thank You

Any Queries ??