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Subject: Artificial Intelligence
Year & Semester: III & I
Topic: Water Jug Problem
Conventional Methods: Chalk & Talk
Teaching Methodology: Roleplay

In Artificial Intelligence subject, Water Jug Problem is basic problem that is solved using BFS or DFS Algorithm to solve the problem. Generally, the topic will be explained using chalk and board, PPT to the students. The faculty has asked to solve the problem by allocating them as buckets of their capacities.

References:

1) https://www.geeksforgeeks.org/water-jug-problem-using-bfs/

2) https://www.includehelp.com/ml-ai/water-jug-problem-in-artificial-intelligence.aspx

Water Jug Problem

Problem: You are given two jugs: one having the capacity to hold 3 gallons of water and the other has the capacity to hold 4 gallons of water. There is no other measuring equipment available and the jugs also do not have any kind of marking on them. So, the agent's task here is to fill the 4-gallon jug with 2 gallons of water by using only these two jugs and no other material. Initially, both our jugs are empty.

In the **water jug problem in Artificial Intelligence**, we are provided with two jugs: one having the capacity to hold 3 gallons of water and the other has the capacity to hold 4 gallons of water. There is no other measuring equipment available and the jugs also do not have any kind of marking on them. So, the agent's task here is to fill the 4-gallon jug with 2 gallons of water by using only these two jugs and no other material. Initially, both our jugs are empty.

So, to solve this problem, following set of rules were proposed:

Production rules for solving the water jug problem

Here, let ***x*** denote the 4-gallon jug and ***y*** denote the 3-gallon jug.

S.No.	Initial State	Condition	Final state	Description of action taken
1.	(x,y)	If x<4	(4,y)	Fill the 4 gallon jug completely
2.	(x,y)	if y<3	(x,3)	Fill the 3 gallon jug completely
3.	(x,y)	If x>0	(x-d,y)	Pour some part from the 4 gallon jug
4.	(x,y)	If y>0	(x,y-d)	Pour some part from the 3 gallon jug
5.	(x,y)	If x>0	(0,y)	Empty the 4 gallon jug
6.	(x,y)	If y>0	(x,0)	Empty the 3 gallon jug
7.	(x,y)	If (x+y)<7	(4, y-[4-x])	Pour some water from the 3 gallon jug to fill the four gallon jug
8.	(x,y)	If (x+y)<7	(x-[3-y],y)	Pour some water from the 4 gallon jug to fill the 3 gallon jug.

9.	(x,y)	If (x+y)<4	(x+y,0)	Pour all water from 3 gallon jug to the 4 gallon jug
10.	(x,y)	if (x+y)<3	(0, x+y)	Pour all water from the 4 gallon jug to the 3 gallon jug

The listed production rules contain all the actions that could be performed by the agent in transferring the contents of jugs. But, to solve the water jug problem in a minimum number of moves, following set of rules in the given sequence should be performed:

Solution of water jug problem according to the production rules

S.No.	4 gallon jug contents	3 gallon jug contents	Rule followed
1.	0 gallon	0 gallon	Initial state
2.	0 gallon	3 gallons	Rule no.2
3.	3 gallons	0 gallon	Rule no. 9
4.	3 gallons	3 gallons	Rule no. 2
5.	4 gallons	2 gallons	Rule no. 7
6.	0 gallon	2 gallons	Rule no. 5
7.	2 gallons	0 gallon	Rule no. 9

On reaching the 7th attempt, we reach a state which is our goal state. Therefore, at this state, our problem is solved.

Issues in Water Jug Problem:

It has been shown above how an informal problem state (stated in English) has been converted into a formal one (Fig. 2.4) with the help of a water jug problem.

In doing so some issues which affect the approach towards the solution are:

1. The rules should be stated explicitly and not written because they are allowable. For example, the first rule states that “Fill the 4-gallon jug”, but it should have been written as

"if the 4-gallon jug is not already full, fill it" but the rule in its stated form is not wrong as there is no condition that the already filled jug cannot be filled (may be after emptying).

No doubt this is physically possible but not wise; as this won't change the problem state. In order to increase the efficiency of the problem-solving program, it is imperative to encode some constraints in the left side of the rules so that the rules should lead to a solution that is the rules should be made more general.

2. Now consider the rules 3 and 4 should or should not these rules be included in the list of available operators? Emptying an unmeasured amount of water onto the ground is certainly allowed by the problem statement, but do these rules lead us near to a solution. The answer is 'no' so these can be ignored. So, such rules which are really applicable to the problem in arriving at the solution should be considered.

3. The rules 11 and 12 are special purpose rules, written to capture special purpose knowledge to solve this problem. This is clear from the above example solution. Consider the last two steps of the solution in Fig. 2.4 (a), once the state (4, 2) is reached it is obvious what to do next? The desired 2-gallons have been produced, but they are in a wrong jug.

Move 2-gallons of water to 4-gallon jug-rule 11 (or rule 9). But before that the water already in 4-gallon jug need to be emptied, rule 12 (or rule 5). These two special purpose rules do not help in solving the problem since the operators they describe are already provided by rules 9 and 5 respectively, so could have been avoided. Sometimes special rules improve performance if preference is given to special case rules.

To formalize a problem the following steps are needed:

(i) Define the problem precisely, giving the specification of what the initial situation (s) and the final situation (s) will be.

(ii) Analyze the problem because a few important features can have immense impact on the suitability of different techniques available for solving the problem.

(iii) Represent the knowledge completely, which is necessary to solve problem in a given domain.

(iv) Choose the best technique(s) and apply it (them) to the particular problem.

Depending upon the control strategy (Fig. 2.4) to be used the performance of problem solving procedure can be improved or degraded. It is thus clear that to create a program for solving a problem simply the formal description of the problem has to be generated using the knowledge about the given problem. This process is called operationalization.

Water jug problem is a simple illustration of solving a problem through state space search. But many difficult problems such as understanding of natural Language which need to be solved by the AI techniques, the water jug problem can act as a strong basis for such tedious problems. This was done in the case of ELIZA, an early AI program.

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