Chapter2

Problems, Problem Spaces and search

- **To build a system to solve a particular problem, we need to do four things:**
  - **Define the problem precisely**
  - **Analyse the problem**
  - **Isolate and represent the task knowledge that is necessary to solve the problem**
  - **Choose the best problem-solving technique(s) and apply it(them) to the particular problem**

Defining the problem as a State Space Search

- ## Water jug Problem
  - You are given two jugs, a 4-gallon one and a 3-gallon 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 gallons of water into 4-gallon jug?
- State space for this problem can be described as the set of ordered pair of integers (x , y)
- x = 0,1,2,3 or 4:number of gallons of water in 4-gallon jug
- y=0,1,2 or 3:number of gallons of water in 3-gallon jug

Defining the problem as a State Space Search

Start state: (0 , 0)

Goal state:(2 , n)

- **Assumptions:(Not mentioned in definition)**
  - **We can pour water out of a jug onto ground**
  - **We can pour water from one jug to another**

Production Rules

1	(x, y) if $x < 4$	$\rightarrow (4, y)$	Fill the 4-gallon jug
2	(x, y) if $y < 3$	$\rightarrow (x, 3)$	Fill the 3-gallon jug
3	(x, y) if $x > 0$	$\rightarrow (x - d, y)$	Pour some water out of the 4-gallon jug
4	(x, y) if $y > 0$	$\rightarrow (x, y - d)$	Pour some water out of the 3-gallon jug
5	(x, y) if $x > 0$	$\rightarrow (0, y)$	Empty the 4-gallon jug on the ground
6	(x, y) if $y > 0$	$\rightarrow (x, 0)$	Empty the 3-gallon jug on the ground
7	(x, y) if $x + y \geq 4$ and $y > 0$	$\rightarrow (4, y - (4 - x))$	Pour water from the 3-gallon jug into the 4-gallon jug until the 4-gallon jug is full
8	(x, y) if $x + y \geq 3$ and $x > 0$	$\rightarrow (x - (3 - y), 3)$	Pour water from the 4-gallon jug into the 3-gallon jug until the 3-gallon jug is full
9	(x, y) if $x + y \leq 4$ and $y > 0$	$\rightarrow (x + y, 0)$	Pour all the water from the 3-gallon jug into the 4-gallon jug
10	(x, y) if $x + y \leq 3$ and $x > 0$	$\rightarrow (0, x + y)$	Pour all the water from the 4-gallon jug into the 3-gallon jug
11	$(0, 2)$	$\rightarrow (2, 0)$	Pour the 2 gallons from the 3-gallon jug into the 4-gallon jug
12	$(2, y)$	$\rightarrow (0, y)$	Empty the 2 gallons in the 4-gallon jug on the ground

Solution

Gallons in the 4-Gallon Jug	Gallons in the 3-Gallon Jug	Rule Applied
0	0	
		2
0	3	
		9
3	0	
		2
3	3	
		7
4	2	
		5 or 12
0	2	
		9 or 11
2	0	

Examples

- **Two jugs: 11 gallon,4 gallon. 11 gallon must contain 1 gallon water**
- **Three jugs: 8 gallon, 5 gallon and 3 gallon.8 gallon water must be divided equally among two jugs**

Solution of Example1

11-gallon jug	4-gallon jug
0	0
0	4
4	0
4	4
8	0
8	4
11	1
0	1
1	0

Solution of Example2

8-gallon jug	5-gallon jug	3-gallon jug
8	0	0
3	5	0
3	2	3
6	2	0
6	0	2
1	5	2
1	4	3
4	4	0

Informal Def^n → Formal Def^n

- Several issues that often arise in converting an informal problem statement into a formal problem description

  1. Role of conditions that occur in left side of the rules(i.e. Rule1)
  2. Rule 3 & 4 should they or should they not be included in the list of available operators?
  3. Special purpose rules that is to capture the special case knowledge that can be used at some stage(i.e. Rule 11,12)
  4. Level of precomputation in the rule (i.e. Rule 7,8)

- Operationalization
  - A process in which program themselves produce formal descriptions from informal ones is known as operationalization

Informal Def^n → Formal Def^n

- **To provide a formal description of a problem we must do following**
  1. **Define a state space that contains all the possible configuration of the relevant objects**
  2. **Specify initial states**
  3. **Specify goal states**
  4. **Specify set of rules**

     Need to consider
     - **Unstated assumption**
     - **How general should the rule be**
     - **Level of Precomputation**

The Missionaries and Cannibals Problem

- Three Missionaries and three cannibals find themselves on one side of a river. They have agreed that they would all like to get to the the other side. But the missionaries are not sure what else the cannibals have agreed to. So the missionaries want to manage the trip across the river in such a way that number of missionaries on either side of river is never less than the number of cannibals who are on the same side. The only boat available holds only two people at a time. How can everyone get across the river without the missionaries risking being eaten?
  - The state for this problem can be defined as :{(i,j)|i=0,1,2,3, j=0,1,2,3} where i:Missionary and j:Cannibal
  - Initial state: (3,3) at bank1 (0,0) at bank2
  - Final state: (0,0) at bank1 (3,3) at bank2

Production Rules

1. (i , j):Two Missionaries can go when i-2>=j or i=0 on one side and i+2>=j on the other side
2. (i , j):Two Cannibals can go when j-2<=i or i=0 on one side and j+2<=i or i=0 on the other side
3. (i , j):One Missionary and one Cannibal can go when i-1>=j-1 or i=0 on one side and i+1>=j+1 on the other side
4. (i , j):One Missionary can go when i-1>=j or i=0 on one side and i+1>=j on the other side
5. (i , j):One cannibal can go when i>=j-1 or i=0 on one side and i>=j+1 or i=0 on the other side

Problem Solution

Bank1		Bank2
(3,3)		(0,0)
(3,1)	$\longrightarrow$	(0,2)
(3,2)	$\longleftarrow$	(0,1)
(3,0)	$\longrightarrow$	(0,3)
(3,1)	$\longleftarrow$	(0,2)
(1,1)	$\longrightarrow$	(2,2)
(2,2)	$\longleftarrow$	(1,1)
(0,2)	$\longrightarrow$	(3,1)
(0,3)	$\longleftarrow$	(3,0)
(0,1)	$\longrightarrow$	(3,2)
(0,2)	$\longleftarrow$	(3,1)
(0,0)	$\longrightarrow$	(3,3)