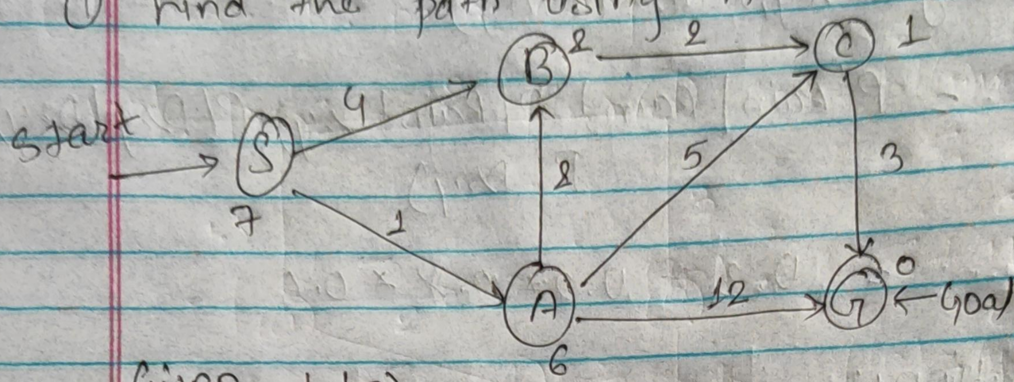
Chapter - 2

① Find the path using A^* search

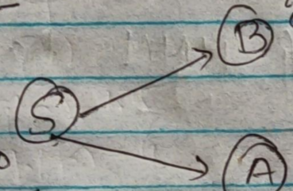


Given, $h(n)$

S - 7
A - 6
B - 2
C - 1
G - 0

We know, $f(n) = g(n) + h(n)$ (path cost: $g(n)$; heuristic value: $h(n)$)

Step1 :-

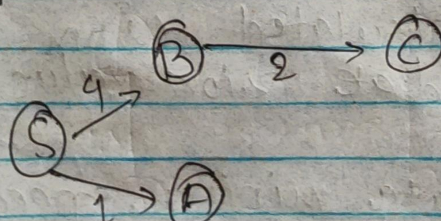


S: $g(n) = 0$, $h(n) = 7$, $f(n) = 7$

B: $g(n) = 4$, $h(n) = 2$ $\therefore f(n) = g(n) + h(n) = 4 + 2 = 6$

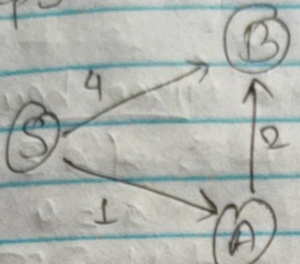
A: $g(n) = 1$, $h(n) = 6$ $\therefore f(n) = 1 + 6 = 7$

Step2 ;



C: $g(n) = 4 + 2 = 6$
$h(n) = 1$
$f(n) = 6 + 1 = 7$

Step 3:

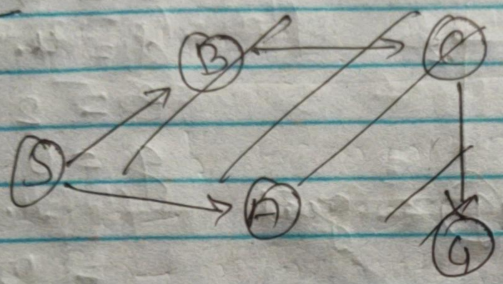


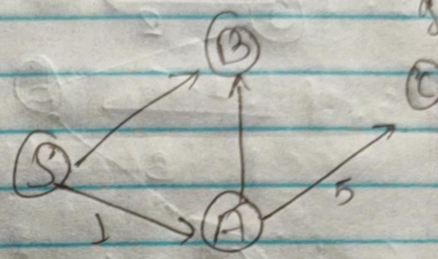
$g(n) = 1+2 = 3$

$h(n) = 2$

$\therefore f(n) = 3+2 = 5$

OR



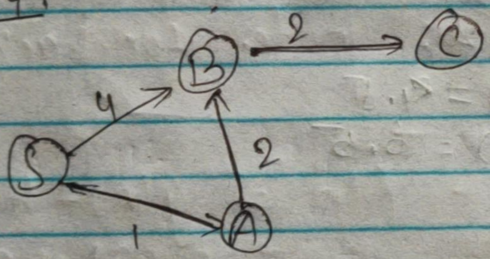


$g(n) = 6$

$h(n) = 1$

$f(n) = 7$

Step 4:

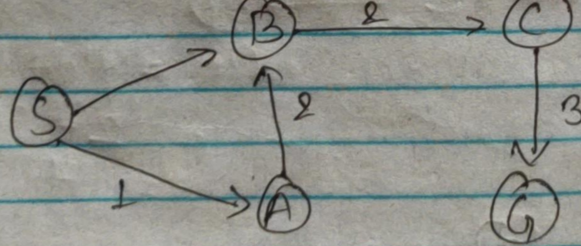


$g(n) = 1+2+2 = 5$

$h(n) = 1$

$f(n) = 5+1 = 6$

Step 5:



$g(n) = 1+2+2+3 = 8$

$h(n) = 0$

$\therefore f(n) = 8+0 = 8$

Hence,

$f(n) = 8$ is the optimal solution and the path ~~cost~~ is

$S \rightarrow A \rightarrow B \rightarrow C \rightarrow G$

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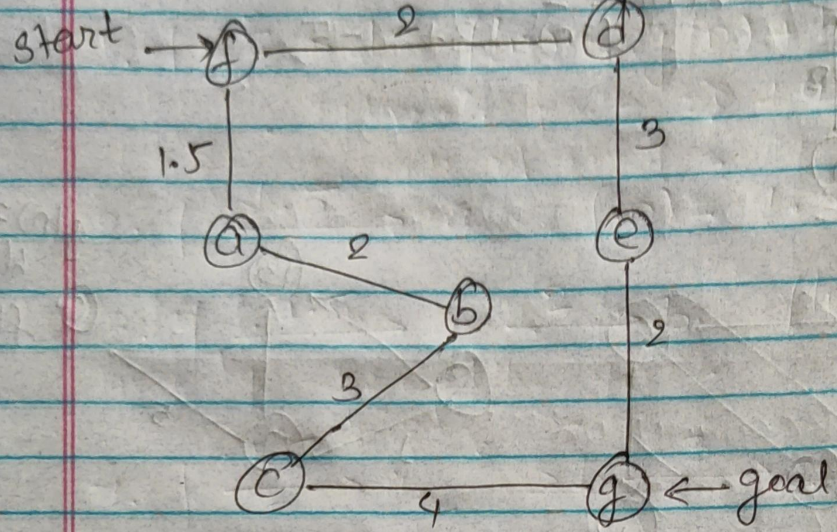
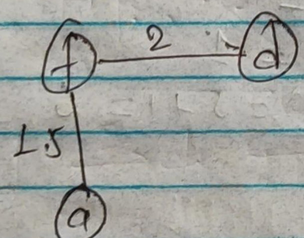
(8) Find the path using A* search.



Given heuristic

f = 3
a = 4
b = 2
c = 4
d = 4.5
e = 2
g = 0

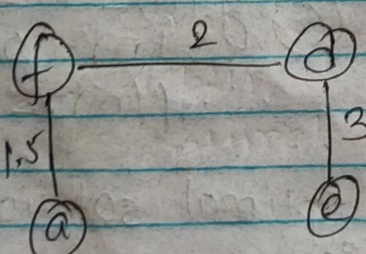
Step1



$g(n) = 2$
$h(n) = 4.5$
$f(n) = 6.5$

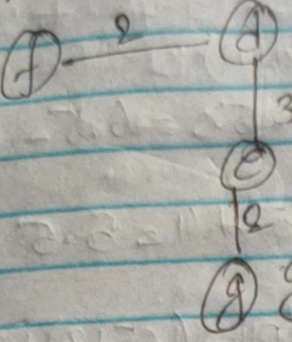
$g(n) = 1.5$
$h(n) = 4$
$f(n) = 5.5$

Step 2:



$g(n) = 5$
$h(n) = 2$
$f(n) = 7$

Step 3:

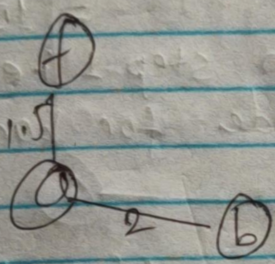


$g(n) = 2+3+2 = 7$

$h(n) = 0$

$\therefore f(n) = 7$

Step 4:

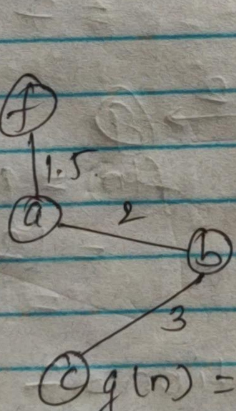


$g(n) = 3.5$

$h(n) = 2$

$f(n) = 5.5$

Step 5:

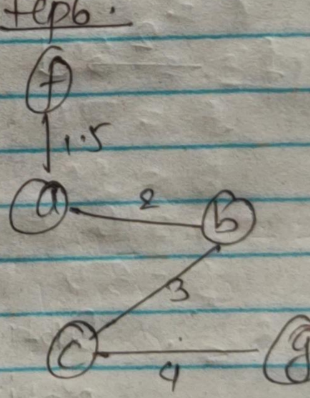


$g(n) = 6.5$

$h(n) = 4$

$f(n) = 10.5$

Step 6:



$g(n) = 10.5$

$h(n) = 0$

$\therefore f(n) = 10.5$

Hence, optimal solution is $\rightarrow$ 7

& path is : $f \rightarrow d \rightarrow e \rightarrow g$

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OR (Method II)

1. $f \xrightarrow{2} d$ $\quad f(n) = g(n) + h(n)$
$= 2 + 4.5 = 6.5$

2. $f \xrightarrow{1.5} a$ $\quad f(n) = 1.5 + 4 = 5.5$

3. $f \xrightarrow{1.5} a \xrightarrow{2} b$ $\quad f(n) = (1.5+2) + 2$
$= 5.5$

4. $f \xrightarrow{1.5} a \xrightarrow{2} b \xrightarrow{3} c$ $\quad f(n) = (1.5+2+3) + 4$
$= 10.5$

Here, 10.5 is more than step 1 i.e. $f \rightarrow d = 6.5$
A* search says, take its previous node for backtracking

5. $f \xrightarrow{2} d \xrightarrow{3} e$ $\quad f(n) = g(n) + h(n)$
$= (2+3) + 2$
$= 7$

6. $f \xrightarrow{2} d \xrightarrow{3} e \xrightarrow{2} g$
$f(n) = g(n) + h(n)$
$= (2+3+2) + 0$
$= 7$

∴ Optimal solution = 7
optimal path = $f \rightarrow d \rightarrow e \rightarrow g$

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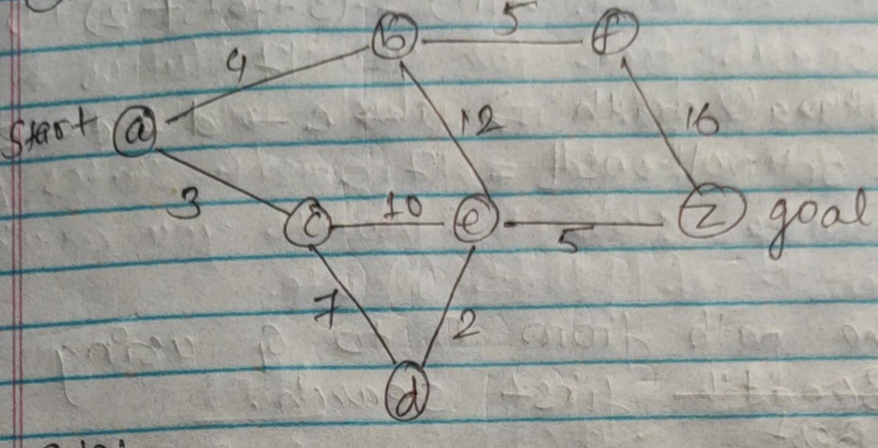
(3) Find optimal path using A^* search.



h(n)
a = 14
b = 12
c = 11
d = 6
e = 4
f = 11
z = 0

Soln:-

1. $a \xrightarrow{4} b$ $\quad f(n) = 4 + 12 = 16$

2. $a \xrightarrow{4} b \xrightarrow{5} f$ $\quad f(n) = (4+5) + 11$
$= 9 + 11 = 20$

3. $a \xrightarrow{4} b \xrightarrow{5} f \xrightarrow{16} z$
$f(n) = (4+5+16) + 0$
$= 25$

Now,
Backtracking.

4. $a \xrightarrow{3} c$ $\quad f(n) = 3 + 11 = 14$

5. $a \xrightarrow{3} c \xrightarrow{10} e$ $\quad f(n) = (3+10) + 4 = 17$

6. $a \xrightarrow{3} c \xrightarrow{7} d$ $\quad f(n) = (3+7) + 6 = 16$

7. $a \xrightarrow{3} c \xrightarrow{7} d \xrightarrow{2} e$
$f(n) = (3+7+2) + 4$
$= 16$

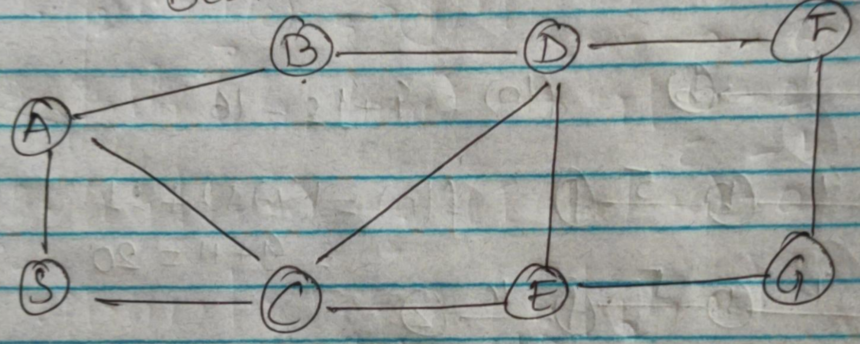
~~Now, Backtrack to steps.~~

8. $(a) \xrightarrow{3} (c) \xrightarrow{7} (d) \xrightarrow{2} (e) \xrightarrow{5} (z)$

$$f(n) = (3+7+5+2)+0$$
$$= 17$$

$\therefore$ Optimal path $\Rightarrow a \rightarrow c \rightarrow d \rightarrow e \rightarrow z$
& optimal cost = 17

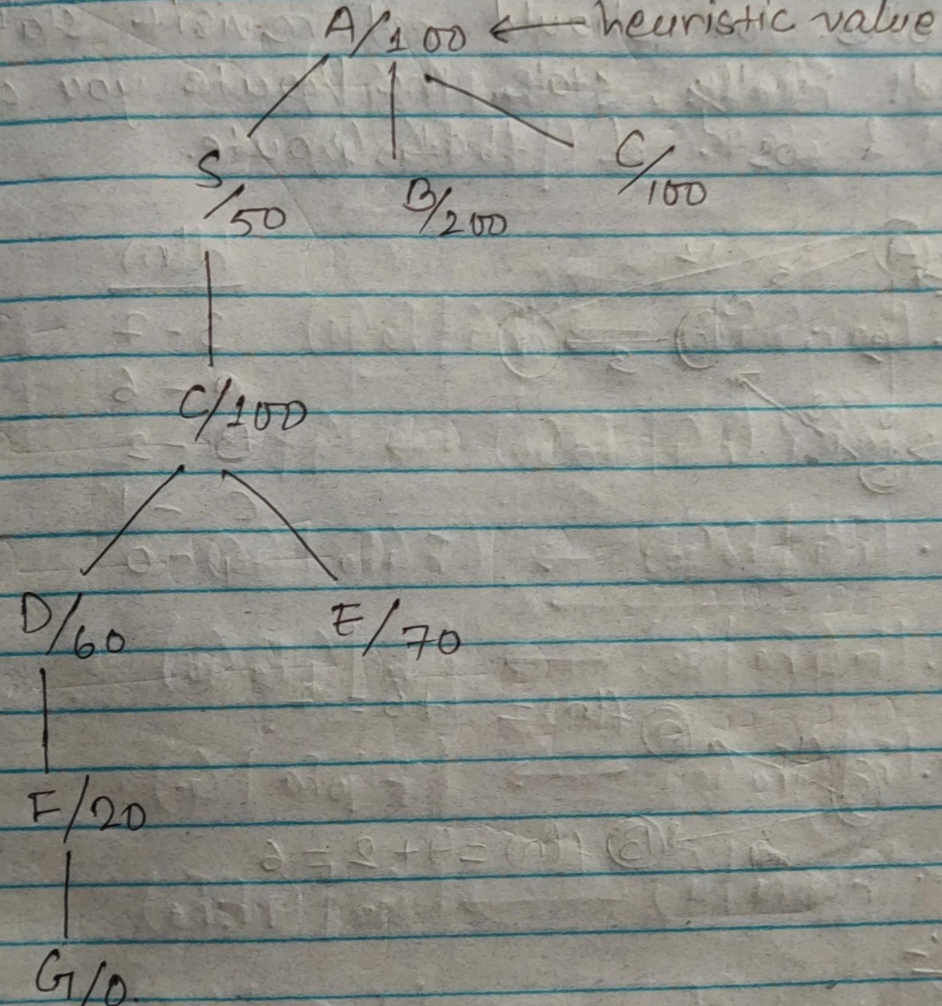
(9) Find the path from A to G using Greedy ~~Breadth~~ Best first search.



Given heuristics

A = 100
B = 200
C = 100
D = 60
E = 70
F = 20
G = 0
S = 50

We know,
Greedy breadth first search take minimum heuristic value.



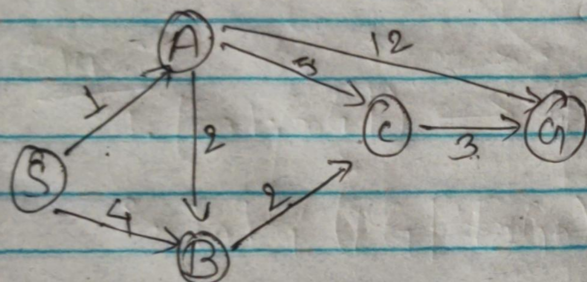
Hence,
Optimal path from A to G is:

$A \rightarrow S \rightarrow C \rightarrow D \rightarrow F \rightarrow G$

2014 (spring)

Q.2 (a)

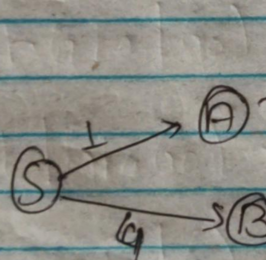
Using A^* algorithm, work out a route from town S to town G.
Provide search tree for your solution & indicate the order in which you expanded the nodes. You should not revisit states previously visited. Finally, state the route you would take & cost of that route.



H(n)	
S	7
A	6
B	2
C	1
G	0

Sol^n:-

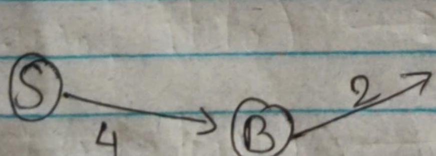
Step 1:-



A: $f(n) = 1+6 = 7$

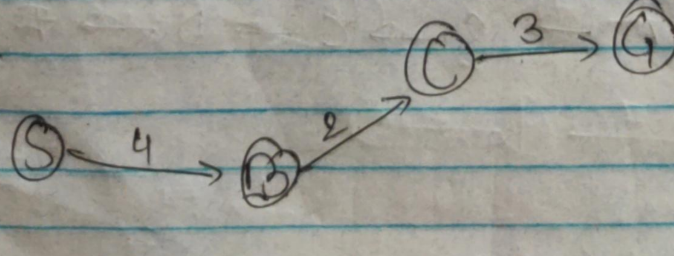
B: $f(n) = 4+2 = 6$

Step 2:-



C: $f(n) = (4+2)+1$
$= 7$

Step 3:



$f(n) = (4+2+3)+0$
$= 9$

Step 4:

$S \xrightarrow{1} A \xrightarrow{12} G$

$f(n) = (1+12)+0$
$= 13$

Step 5:

$S \xrightarrow{1} A \xrightarrow{5} C \xrightarrow{3} G$

$f(n) = (1+5+3)+0$
$= 9$

Hence,

Optimal cost = 9

Optimal path = $S \rightarrow A \rightarrow C \rightarrow G$

OR

$S \rightarrow B \rightarrow C \rightarrow G$

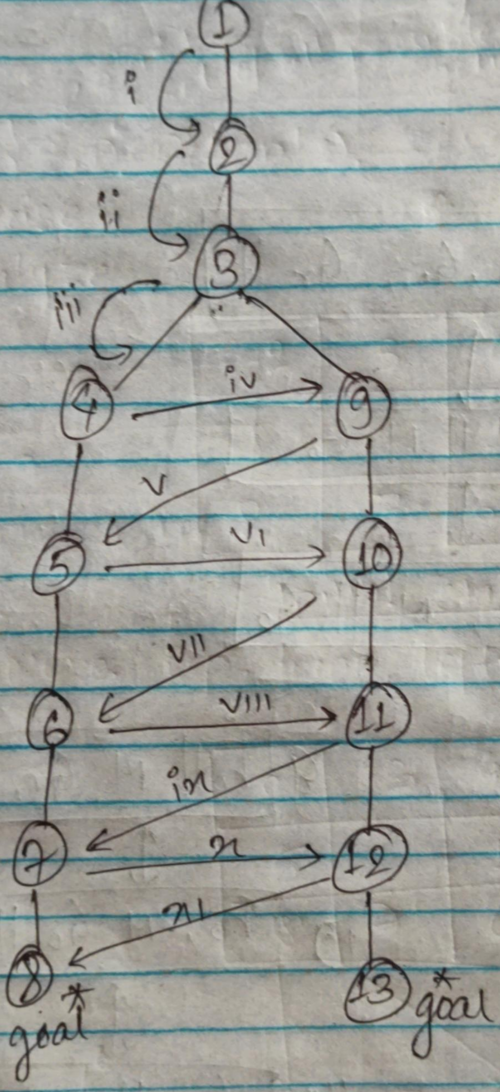
2015 (Fall)

2(a) A farmer has to cross a river with his fox, goose, grain. Each trip, his boat can ony carry himself & one of his possessions. How can he cross the river if an ungraded fox eats the goose & an ungraded goose the grain?

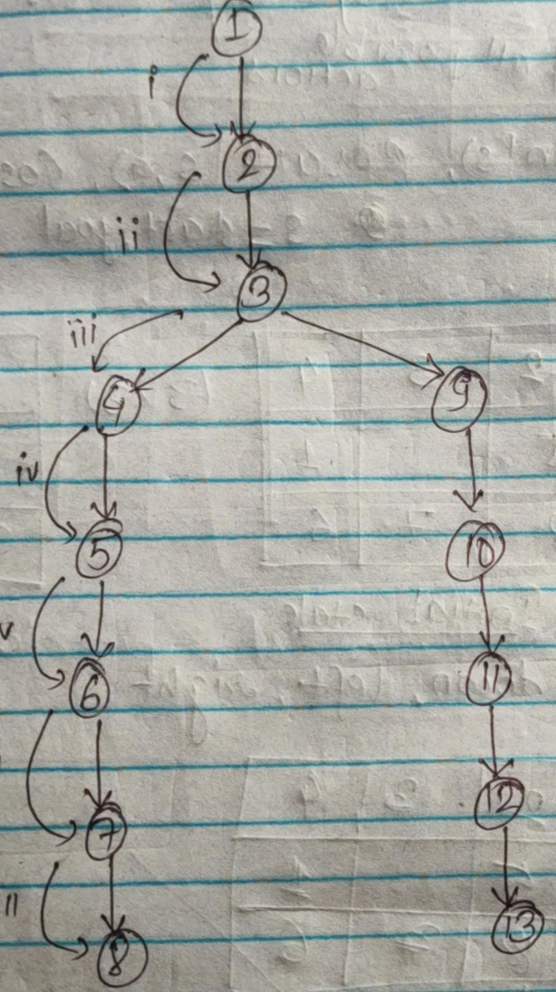
(i) ~~per~~ find a good representation for above scenario

(ii) Perform Breadth-first search for above representation.

(i) Using BFS.



Using DFS



2016 (Fall)

2(a) Model 8 puzzle game as state space search & find its solution assuming any initial position.

Soln:-

2	8	3
1	6	4
7		5

Initial state

1	2	3
8		4
7	6	5

Goal state.

2	8	3
1	6	4
7		5

2	8	3
1	6	4
	7	5

2	8	3
1		4
7	6	5

2	8	3
1	6	4
7	5	

2	8	3
	1	4
7	6	5

2		3
1	8	4
7	6	5

2	8	3
1	4	
7	6	5

	2	3
1	8	4
7	6	5

2	3	
1	8	4
7	6	5

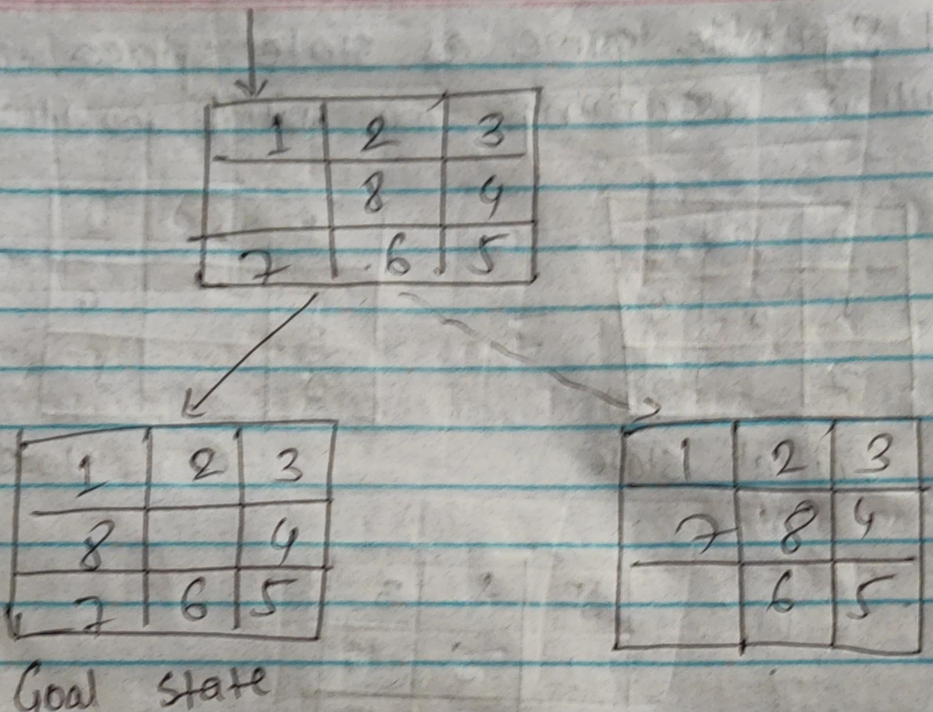
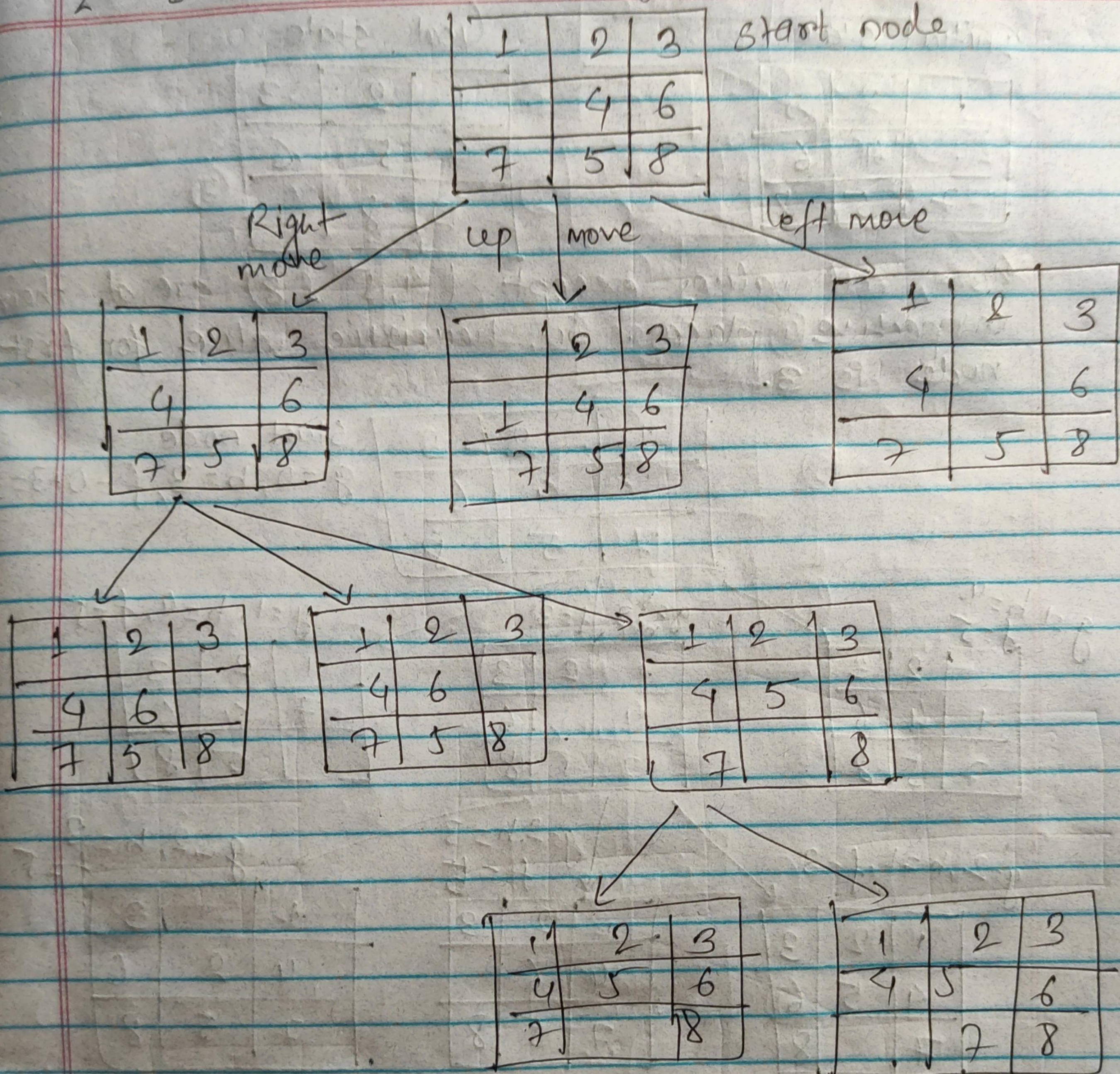


fig: solution of 8 puzzle problem.

2^{nd} solution → With uninformed search.



Using Heuristic search (Informed Search)

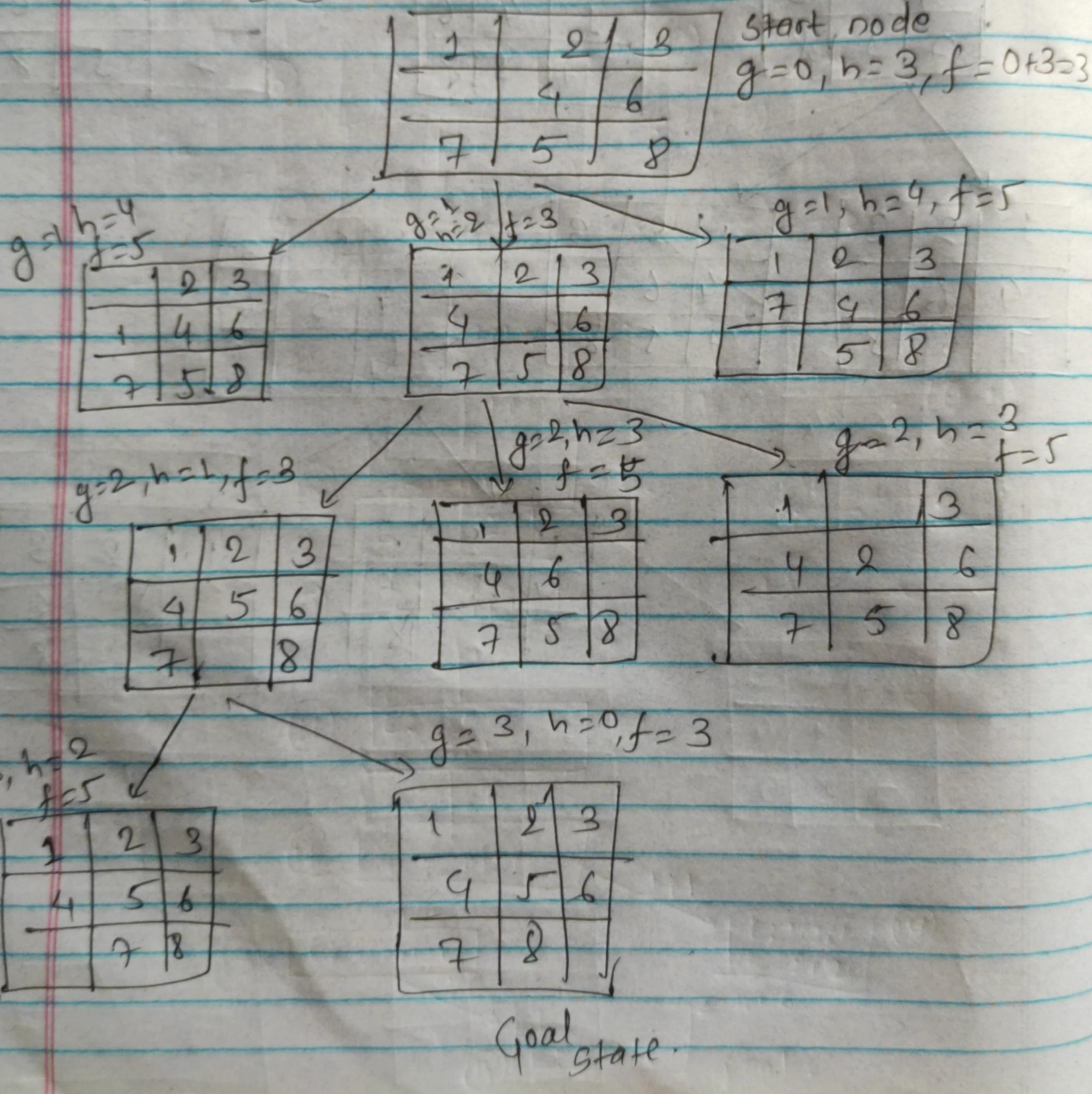
Initial state

1	2	3
	4	6
7	5	8

Goal state

1	2	3
4	5	6
7	8	

Here, all values except (4, 5 & 8) are at their respective places. So, heuristic value for first node is 3.



2018 (spring)

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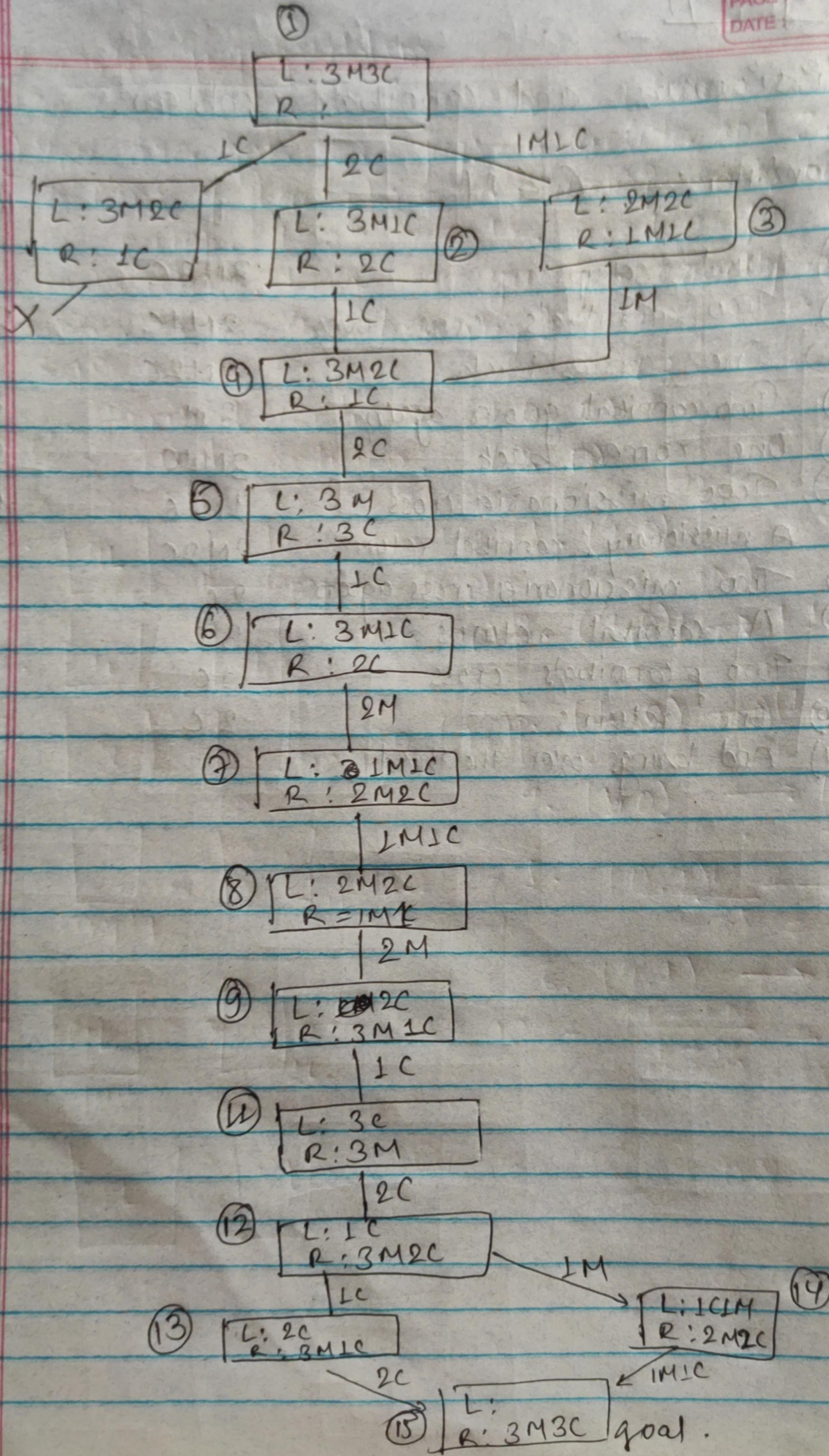
2(a) Missionaries and cannibals problem.

Condition :- $C \le M$

	L	R
0) initial setup	3M3C	—
1) Two cannibals cross over	3M1C	2C
2) One comes back	3M2C	1C
3) Two cannibals go over again	3M	3C
4) One comes back	3M1C	2C
5) Two missionaries cross	1M1C	2M2C
6) A missionary & cannibal return	2M2C	1M1C
7) Two missionaries cross again	2C	3M1C
8) A cannibal returns	3C	3M
9) Two cannibals cross	1C	3M2C
10) One returns	2C	3M1C
11) And brings over the third		3M3C

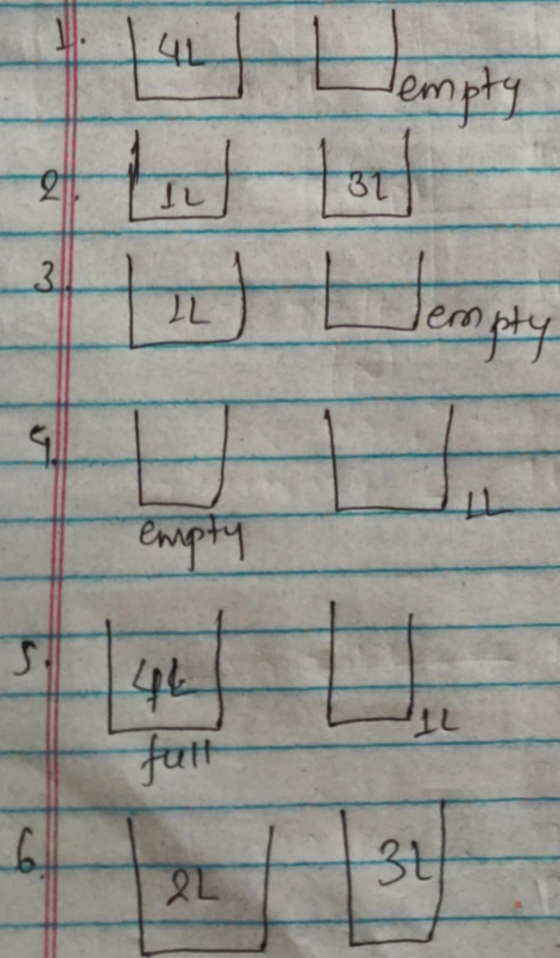

1
L: 3M3C
R:
1C
2C
1M1C
L: 3M2C
R: 1C
X
L: 3M1C
R: 2C
2
L: 2M2C
R: 1M1C
3
1C
1M
4
L: 3M2C
R: 1C
2C
5
L: 3M
R: 3C
1C
6
L: 3M1C
R: 2C
2M
7
L: 1M1C
R: 2M2C
1M1C
8
L: 2M2C
R = 1M1
2M
9
L: 2C
R: 3M1C
1C
11
L: 3C
R: 3M
2C
12
L: 1C
R: 3M2C
1M
1C
13
L: 2C
R: 3M1C
14
L: 1C1M
R: 2M2C
2C
1M1C
15
L:
R: 3M3C
goal.

Water jug problem

Q) You are give ~~3~~ 2 jugs, a 4 litre and 3 litre one. None of them have consuming marks on it. There is pump that can be used to fill the jugs with water. how can you get exactly a 2 litre of water into 4 litre jug?

Soln:-

	4 3	L3
Initial condn :	(0, 0)	
Final condition :	(2, ~~3~~)	



1. (4, 0)
2. (4, 0) → (1, 3)
3. (1, 3) → (1, 0)
4. (1, 0) → (0, 1)
5. (0, 1) → (4, 1)
6. (4, 1) → (2, 3)

Chapter - 3

system was tested on 125 male & 110 female faces

2018 (Spring)

3(a) A pattern recognition system was trained to classify between male & female faces, where the system correctly detected 100 male & 100 female faces. Find the confusion matrix for test data & calculate accuracy, error rate, true positive rate & true negative ~~neg~~ rate of pattern recognition system.

Soln:-

Confusion matrix is given as:-

Actual	Predicted: male (P)	Predicted: female (N)
male (P)	100 (TP)	25 (FN)
female (N)	10 (FP)	100 (TN)

$$\text{accuracy} = \frac{TP + TN}{\text{Total}} = \frac{100+100}{235} = \frac{200}{235}$$

$$= 0.851$$

~~Error rate~~ Error rate $= \frac{FP + FN}{P + N \text{ (total)}} = \frac{25+10}{235}$

$$= \frac{35}{235} = 0.148$$

$$\text{TP rate} = \frac{TP}{P} = \frac{100}{125} = 0.8$$

$$\text{TN rate} = \frac{TN}{N} = \frac{100}{110} = 0.90$$

Chapter-5

2019 (Spring)

5(a)

Category	Time required (min)	No. of patients
Yoga	40	42
Body massage	65	16
Steam Bath	10	13
physiotherapy	35	12
checkup	25	20

Soln:-

Category	Time required	No. of patient	Probability	Cumulative freq.	Random number
Yoga	40	42	42/103 = 0.4	0.4	0-39
Body massage	45	16	0.15	0.4+0.15=0.55	40-54
Steam bath	10	13	0.12	0.67	55-69
physiotherapy	35	12	0.11	0.78	70-79
checkup	25	20	0.19	0.97	80-99
		N=103			

Patient	Scheduled arrival	random number	category	service time required
1)	6:00	40	yoga	40 min
2)	6:30	82	Steam bath	10 min
3)	7:00	11	checkup	25 min
4)	7:30	34	yoga	40 min
5)	8:00	25	yoga	40 min
6)	8:30	66	body massage	45 min
7)	9:00	17	steam bath	10 min
8)	9:30	79	physiotherapy	35 min

Again,

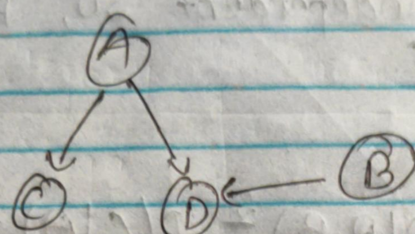
patient	Arrival time	Service start	service duration	Service ends	waiting time (service - arrival)	Idle time
1.	6:00	6:00	40 min	6:40	0	0
2.	6:30	6:40	10 min	6:50	10 min	0
3.	7:00	7:00	25 min	7:25	0	10 min
4.	7:30	7:30	40 min	8:10	0	5 min
5.	8:00	8:10	40 min	8:50	10 min	0
6.	8:30	8:50	45 min	9:35	20 min	0
7.	9:00	9:35	10 min	9:45	10 min	0
8	9:30	9:45	35 min	10:20	15 min	0
					N=65	N=15

Hence,

$$\text{Average waiting time} = \frac{65}{8} = 8.125 \text{ min}$$

$$\text{Average idle time for doctor} = \frac{15}{8} = 1.875 \text{ min}$$

4(a) Sol^n:-



given,

$P(A) = 0.3$
$P(B) = 0.7$
$P(C|A) = 0.4$
$P(C|\sim A) = 0.3$
$P(D|A, B) = 0.7$
$P(D|A, \sim B) = 0.3$
$P(D|\sim A, B) = 0.2$
$P(D|\sim A, \sim B) = 0.01$

D Conditional probability tables:-

P(A)	P(B)
0.3	0.7

A	P(C)
T	0.4
F	0.3

A	B	P(D)
T	T	0.7
T	F	0.3
F	T	0.2
F	F	0.01

we know, joint probability is,

$$P(A,B,C,D) = P(D|A,B,C) * P(C|A,B) * P(B|A) * P(A)$$

as C is not dependent on B & D is not dependent on C.

Hence,
$P(C|A,B)$ is reduced to $P(C|A)$
& $P(D|A,B,C)$ is reduced to $P(D|A,B)$

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Also, A & B are independent so, $P(B|A)$ is reduced to $P(B)$

Hence,

$$P(A,B,C,D) = P(D|A,B) * P(C|A) * P(B) * P(A)$$

$$= 0.7 * 0.4 * 0.7 * 0.3$$

$$= 0.0588$$

2016 (spring)

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Q. 4 (b) find ① $P(C)$

(ii) $P(C/S)$

(iii) $P(C| S \cap P_n)$

(iv) $P(\neg | P_n)$

(v) $P(T | P_n)$

(vi) only smoke.

Soln:-

$P(C) = P(C| P_n \cap S) \cdot P(P_n) \cdot P(S) + P(C| P_n \cap \bar{S}) \cdot$
$P\ P(n) \cdot P(\bar{S}) + P(C| \bar{P_n} \cap S) \cdot P(\bar{P_n}) \cdot P(S) +$
$P(C| \bar{P_n} \cap \bar{S}) \cdot P(\bar{P_n}) \cdot P(\bar{S})$

$= (0.95 \times 0.1 \times 0.2) + (0.8 \times 0.1 \times 0.8) +$
$(0.6 \times 0.9 \times 0.8) + (0.05 \times 0.9 \times 0.8)$

$= 0.019 + 0.064 + 0.108 + 0.036$
$= 0.227$

(ii) $P(C/S) = P(C/P_n \cap S) \cdot P(n) + P(C| \bar{P_n} \cap S) \cdot \bar{P_n}$

$= (0.95 \times 0.1) + (0.6 \times 0.9)$
$= 0.095 + 0.54$
$= 0.635$

only smoke $= P(C/\text{only smoke})$
$= P(C| P_n \cap S)$
$= 0.6$

2014 (Spring)

4(a) Solution:-

let M : set of born within 30 miles of Manchester

N : " " not born " " " "

S : set of supporter of manchester

Here,

~~again~~ given,

$$P(M) = \frac{1}{20}$$

$$P(N) = 1 - \frac{1}{20} = \frac{19}{20}$$

$$P(M|S) = \frac{7}{10}$$

$$P(N|S) = 1/10$$

$$P(S|M) = ?$$

Now,

$$P(S|M) = \frac{P(M) \cdot P(M|S)}{P(M) \cdot P(M|S) + P(N) \cdot P(N|S)}$$

$$= \frac{1/20 * \frac{7}{10}}{\frac{1}{20} * \frac{7}{10} + \frac{19}{20} * \frac{1}{20}}$$

$$= 7/26$$

→ the first step is encoding of chromosomes; use binary representations for integers, 5 bits are used to represent integers upto 31.
→ assume population size 4.

Q. Maximize the function $f(x) = x^2$ with x in interval $[0, 31]$ i.e. $x = 0, 1, \ldots, 30, 31$

1. Generate initial population at random. They are chromosomes or genotypes.
   eg: 01101 (13), 11000 (24), 01000 (8), 10011 (19)

2. Calculate fitness,
   (a) Decode into an integer (called phenotypes)
   01101 → 13, 11000 → 24, 01000 → 8, 10011 → 19

   (b) Evaluate fitness, $f(x) = x^2$
   13 → 169, 24 → 576, 8 → 64, 19 → 361

3. Select parents (2 individuals) based on their fitness in P.

$$P_i = f_i / \left(\sum_{j=1}^{n} f_j\right)$$

f_i = fitness for string i in population
P_i = probability of string i being selected
n = no. of individuals in the population

$n \times P_i$ is expected count.

$n \Rightarrow$ No. of chromosomes.

Step1:- Selecting Parent

String No.	Initial population	X value	Fitness f_i $f(x)=x^2$	P_i	Expected count n.prob.
1	01101	13	169	0.14	0.58
2	11000	24	576	0.49	1.97
3	01000	8	64	0.06	0.22
4	10011	19	361	0.31	1.23
Sum			1170	1.00	4.00
Average			293	0.25	1.00
Max			576	0.49	1.97

Step 2: Crossover Operator

- → can be of either one point or two point crossover
- → In one point crossover, selected pair of string is cut at some random position & then the segments are swapped to form new pair of strings.
- → In 2 point, there will be 2 break points

for eg:

1 0 0 | 1 1 1 0 1
1 0 1 | 0 1 0 1 1

offsprings :- 1 0 0 0 1 0 1 1
1 0 1 1 1 1 0 1

2 point :-

1 0 0 | 1 1 | 1 0 1
1 0 1 | 0 1 | 0 1 1

offsprings :- 1 0 0 0 1 1 0 1
1 0 1 1 1 0 1 1

diversity

String No.	Mating pool	Crossover pt	offspring generated after crossover	x value	fitness $f(x)=x^2$
1	0110|1	4	01100	12	144
2	1100|0	4	11001	25	625
2	11|000	2	11011	27	729
4	10|011	2	10000	16	256
Sum					1754
Average					439
Max					729

3) Mutation

→ applied to each child individually after crossover

→ Bits are changed from 0 to 1 or from 1 to 0 randomly chosen position of randomly selected strings.

String No.	offspring after crossover	offspring after mutation	x value	Fitness $f(x)=x^2$
1.	01100	11100	26	676
2.	11001	11001	25	625
2.	11011	11011	27	729
4.	10000	10100	18	324
Sum				2354
Average				588.5
Max				729

Not changed

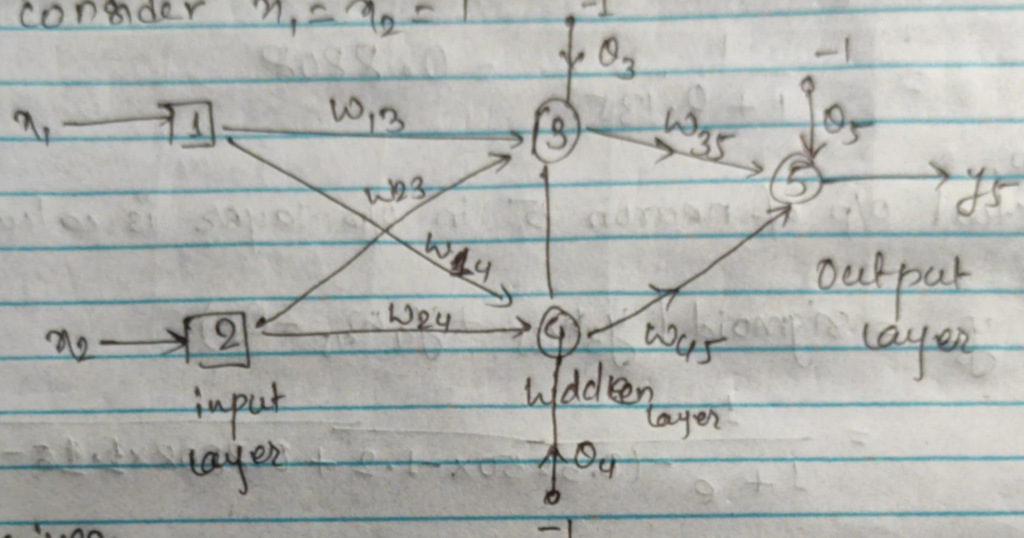
2015 (Fall)

6(b) Backpropagation.

→ perform logical operation X-OR.

→ perform single iteration.

→ consider $x_1 = x_2 = 1$



given,

Initial weights:-

$w_{13} = 0.5$, $w_{14} = 0.9$, $w_{23} = 0.4$

$w_{24} = 1.0$, $w_{35} = -1.2$, $w_{45} = 1.1$

threshold levels :-

$\theta_3 = 0.8$, $\theta_4 = -0.1$, $\theta_5 = 0.3$

Soln:-

Here,

$x_1 = x_2 = 1$, consider desired o/p $y_{d,5} = 0$.

Actual o/p of neurons 3 & 4 in hidden layers are calculated as,

~~$y_3 = \text{sigmoid}(x_1 w_{13} + x_2 w_{23} - \theta_3)$~~ sigmoid$(x) = \frac{1}{1+e^{-x}}$

$y_3 = \text{sigmoid}(x_1 w_{13} + x_2 w_{23} - \theta_3)$

$= \frac{1}{1 + e^{-(1\times0.5 + 1\times0.4 - 0.8)}} = \frac{1}{1+0.9} = 0.5250$

$$y_4 = \text{sigmoid}\,(x_1 w_{14} + x_2 w_{24} - \theta_4)$$

$$= \frac{1}{1 + e^{-(1\times 0.9 + 1\times 1 + 0.1)}}$$

$$= \frac{1}{1 + 0.135} = 0.8808$$

Now,

actual o/p of neuron 5 in o/p layer is calculated as,

$$y_5 = \text{sigmoid}\,(y_3 w_{35} + y_4 w_{45} - \theta_5)$$

$$= \frac{1}{1 + e^{-(0.5250\times -1.2 + 0.8808\times 1.1 - 0.3)}}$$

$$= 0.5097$$

Hence,

Error obtained is:-

$$e = y_{d,5} - y_5 = 0 - 0.5097 = -0.5097$$

2nd step is weight training, we propagate the error e from o/p layer to i/p layer to update weights & threshold values.

First, calculate error gradient for neuron 5 in o/p layer

$$\delta_5 = y_5(1 - y_5)e = 0.5097\times(1 - 0.5097)\times(-0.5097)$$

$$= -0.1274$$

Determine weight corrections assumming that learning rate $= \alpha = 0.1$

PAGE :
DATE : / /

$\Delta w_{35} = \alpha \times y_3 \times \delta_5 = 0.1 \times 0.5250 \times (-0.1274) = -0.0067$

$\Delta w_{45} = \alpha \times y_4 \times \delta_5 = 0.1 \times 0.8808 \times (-0.1274) = -0.0112$

$\Delta \theta_5 = \alpha \times (-1) \times \delta_5 = 0.1 \times (-1) \times (-0.1274) = 0.0127$

Now, calculate error gradients for neurons 3&4 in hidden layer.

$\delta_3 = y_3(1-y_3) \times \delta_5 \times w_{35} = 0.0381$

$\delta_4 = y_4(1-y_4) \times \delta_5 \times w_{45} = -0.0147$

Determine weight corrections:

$\Delta w_{13} = \alpha \times x_1 \times \delta_3 = 0.1 \times 1 \times 0.0381 = 0.0038$

$\Delta w_{23} = \alpha \times x_2 \times \delta_3 = 0.0038$

$\Delta \theta_3 = \alpha \times (-1) \times \delta_3 = -0.0038$

$\Delta w_{14} = \alpha \times x_1 \times \delta_4 = -0.0015$

$\Delta w_{24} = \alpha \times x_2 \times \delta_4 = -0.0015$

$\Delta \theta_4 = \alpha \times (-1) \times \delta_4 = 0.0015$

Finally, update all weight & threshold levels in our n/w.

$w_{13} = w_{13} + \Delta w_{13} = 0.5038$

$w_{14} = w_{14} + \Delta w_{14} = 0.8985$

$w_{23} = w_{23} + \Delta w_{23} = 0.4038$

$w_{24} = w_{24} + \Delta w_{24} = 0.9985$

$w_{35} = w_{35} + \Delta w_{35} = -1.2067$

$w_{45} = w_{45} + \Delta w_{45} = 1.0888$

$\theta_3 = \theta_3 + \Delta \theta_3 = 0.7962$

$\theta_4 = \theta_4 + \Delta \theta_4 = -0.0985$

$\theta_5 = \theta_5 + \Delta \theta_5 = 0.3127$

This training process is repeated until sum of squared errors is less than 0.001

Final results of 3 layer n/w learning: logical operation ~~exclusive~~ X-OR.

inputs	Desired o/p	Actual o/p	error (e)	Sum of squared errors
0 1	1	0	0.0155	0.0010
0	1	1	0.9849	
1	0	1	0.9849	
1	1	0	0.0175	