Artificial Intelligence

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Chapter 2

What we will discussed today ?

- Constraint Satisfaction Problem

- CSPs are mathematical problems defined as a set of objects whose state must satisfy a number of constraints.

  CSPs consists of

- A set of variables
- A domain for each variable
- A set of constraints

- *Examples:* Eight queens puzzle, Map coloring problem, Sudoku, **Crypt Arithmetic Problem**

• Crypt Arithmetic Problem (i)

```
  S E N D
+ M O R E
---------
M O N E Y
```

Constraints are:

i. No two digits can be assigned to same letter.

ii. Only single digit number can be assign to a letter.

iii. No two letters can be assigned to same digit.

Initial State of Problem:

D = ?, E = ?, Y = ?, N = ?, R = ?, O = ?, S = ?, M = ?

Goal State of Problem: The digits to the letters must be assigned in such a manner so that the sum is satisfied.

• Crypt Arithmetic Problem (i)

C 4 C 3 C 2 C 1

```
     S E N D
+ M O R E
- - - - - - -
M O N E Y
```

Let us suppose,

C1, C2, C3 & C4 indicates the carry bits out of the columns numbering from the right.

C4 = 1

i. Initial guess M=1, since two single digit numbers plus a carry cannot have total more than 19 i.e. M = 1

Crypt Arithmetic Problem (ii)

C 4 C 3 C 2 C 1

```
  S E N D
+ M O R E
---------
M O N E Y
```

ii. When M=1, the largest single digit number added to M (=1) can generate the sum of either 10 or 11 depend on the carry received from the carry sum i.e. on the value of C3. So the value of O is either 0 or 1.Because M is already 1 so the value of O is 0.

O	M								
0	1	2	3	4	5	6	7	8	9

C4 = 1

Crypt Arithmetic Problem (iii)

C 4 C 3 C 2 C 1

```
  S E N D
+ 1M O R E
-------
M O N E Y
1 0
```

iii. That means the value of S is either 8 or 9, depending on the value of C3.

O	M								
0	1	2	3	4	5	6	7	8	9

C4 = 1

Crypt Arithmetic Problem (iv)

C 4 C 3 C 2 C 1

```
  S E N D
+ M O R E
---------
M O N E Y
```

iv. Now E + O + C2= N

Here O = 0 and C2 at most 1.

So E = N or E + 1=N depending on the value of C2.

E = N is not possible, so **E + 1 = N** and **C2 = 1**.

O	M								
0	1	2	3	4	5	6	7	8	9

C4 = 1
C2 = 1

Crypt Arithmetic Problem (v)

C 4 C 3 C 2 C 1

```
  S E N D
+ M O R E
---------
M O N E Y
```

v. E + 1= N means E and N are in pairs and this implies that carry is not possible. So, the value of C3 is 0.

Thus,

The value of **S is 9**.

O	M								S
0	1	2	3	4	5	6	7	8	9

C4 = 1
C2 = 1
C3 = 0

Crypt Arithmetic Problem (vi)

C 4 C 3 C 2 C 1

```
  S E N D
+ M O R E
---------
M O N E Y
```

C4 = 1 ,C2 = 1, C3 = 0

vi. Since C2 = 1, we have

N + R + C1= 10 + E

From case iv, we have **E + 1 = N**

So, **E + 1** + R + C1 = 10 + E

or, 1+ R + C1 = 10

(R can be either 9 or 8, since S = 9 . So, **R = 8 and C1 = 1**)

O	M							R	S
0	1	2	3	4	5	6	7	8	9

C4 = 1, C2 = 1, C3 = 0, C1=1

Crypt Arithmetic Problem (vii)

C 4 C 3 C 2 C 1

```
  S E N D
+ M O R E
---------
M O N E Y
```

C4 = 1 , C3 = 0, C2 = 1, C1=1

O	M							R	S
0	1	2	3	4	5	6	7	8	9

vii. Now **D + E = 10 + Y** (Since, C1 = 1)

- Here, the maximum possibility of D + E is 6 + 7 i.e. 13.
- Other possibilities are 12, 11 and 10.
- If the value of D & E are either 6 or 7. Then, the value of E is either 6 or 7.

If E = 6 then D = 7

(which is not possible because E + 1 = N)

If E = 7 then D = 8

(but R = 8, so not possible)

Crypt Arithmetic Problem (vii)

C 4 C 3 C 2 C 1

S E N D

\+ M O R E

\- - - - - - -

M O N E Y

C4 = 1 , C3 = 0, C2 = 1, C1=1

O	M							R	S
0	1	2	3	4	5	6	7	8	9

D + E = 10 + Y (Since, C1 = 1)

- Again, if D + E= 11 or 10 then Y =1 or 0 which is not possible.
- So, D + E =12 i.e. **Y = 2**

  and the combination of D and E is 5 and 7.

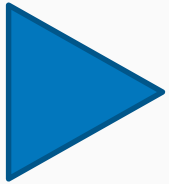
i.e. **D = 7 and E = 5 .**

Also, **N = E + 1 = 6**

O	M	Y			E	N	D	R	S
0	1	2	3	4	5	6	7	8	9

• Crypt Arithmetic Problem (viii)

```
  S E N D          9 5 6 7
+ M O R E        + 1 0 8 5
---------        ---------
M O N E Y        1 0 6 5 2
```



O	M	Y			E	N	D	R	S
0	1	2	3	4	5	6	7	8	9

THANK YOU

Any Queries ?