Constraint Satisfaction (Cryptarithmetic & Means End Analysis)

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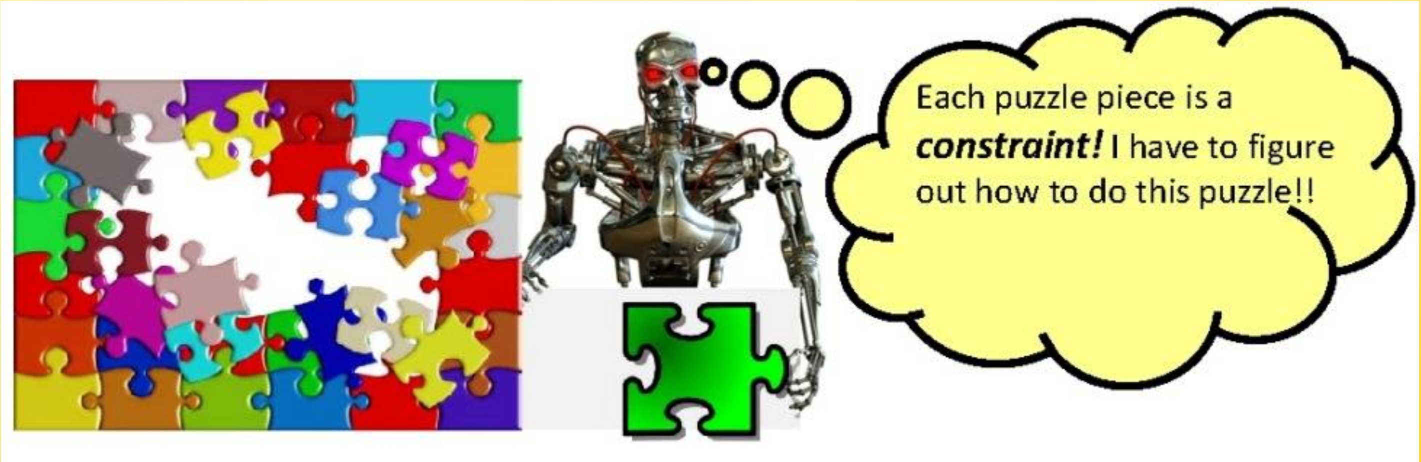
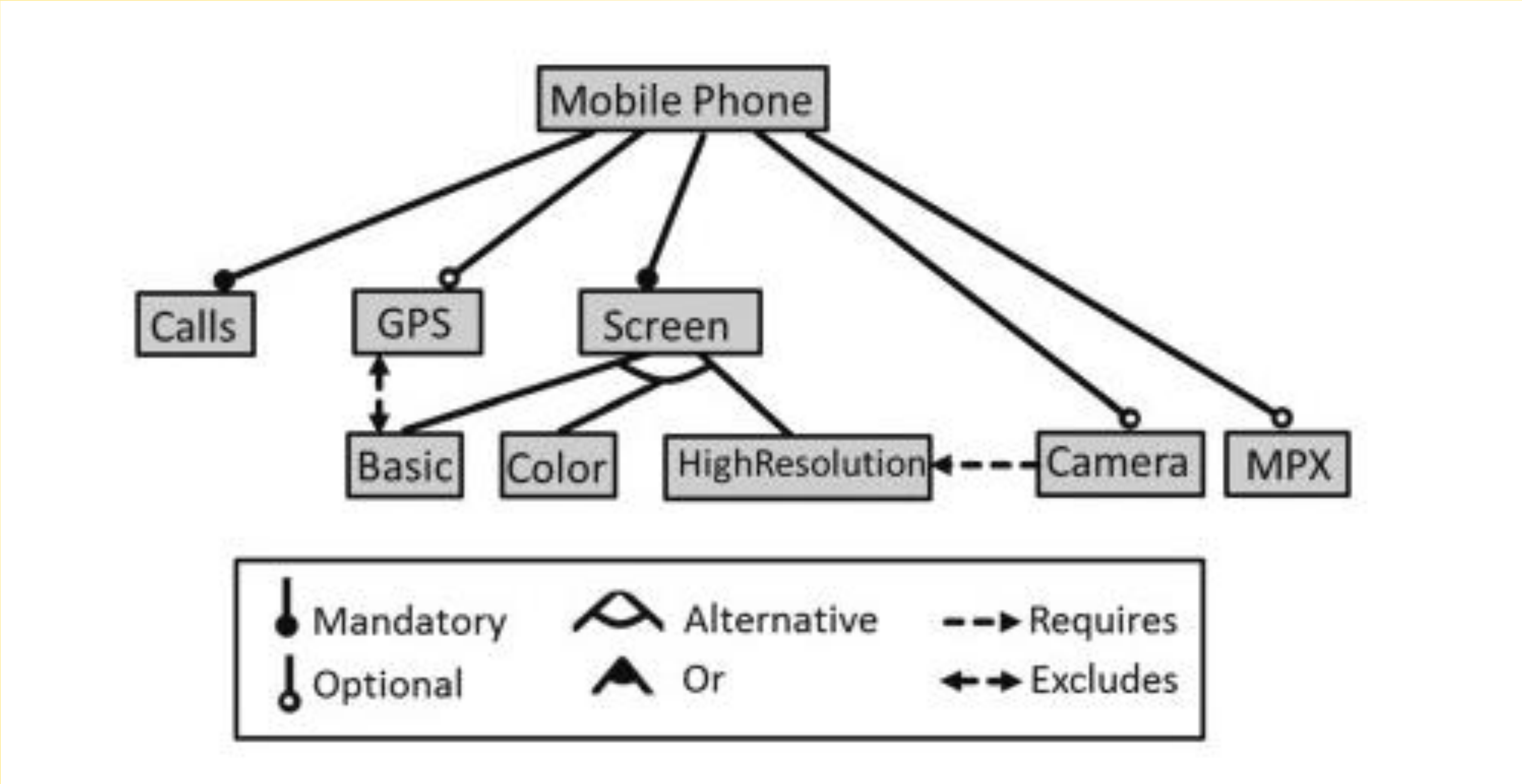
Constraint Satisfaction

- Many problems in AI can be considered as problems of constraint satisfaction, in which the goal state satisfies a given set of constraint
- **constraint satisfaction** is the process of finding a solution to a set of constraints that impose conditions that the variables must satisfy
- A solution is therefore a set of values for the variables that satisfies all constraints
- Problems that can be expressed as constraint satisfaction problems are the eight queens puzzle, the Sudoku solving problem and many other logic puzzles, the Boolean satisfiability problem, scheduling problems, bounded-error estimation problems and various problems on graphs such as the graph coloring problem



HISTORY

- Constraint satisfaction originated in the field of artificial intelligence in the 1970s ((Laurière 1978))
- During the 1980s and 1990s, embedding of constraints into a programming language were developed
- Languages often used for constraint programming are Prolog and C++

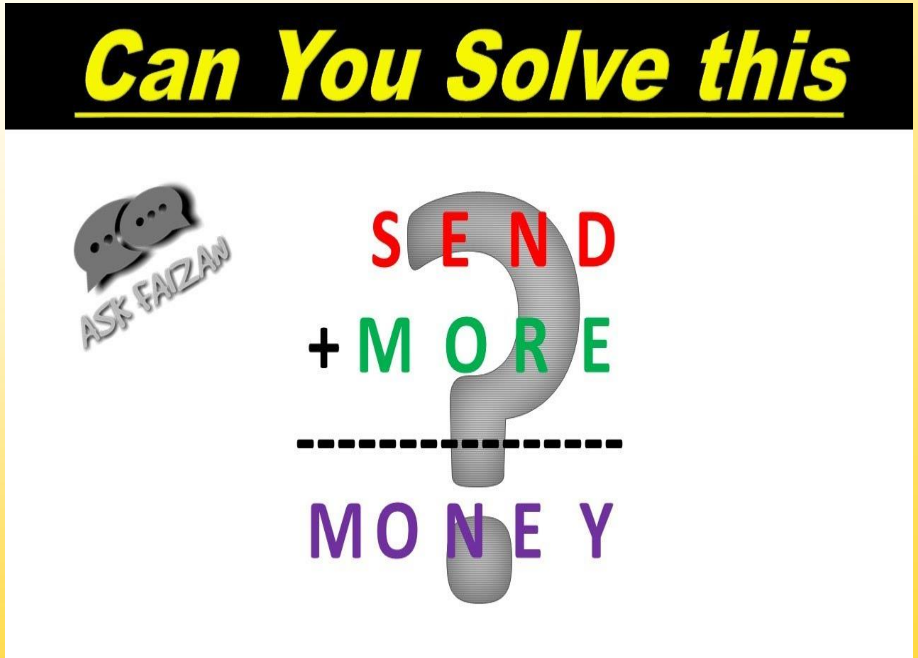

Mobile Phone
Calls
GPS
Screen
Basic
Color
HighResolution
Camera
MPX
Mandatory
Optional
Alternative
Or
Requires
Excludes

- ***The general form of the constraint satisfaction procedure is as follows:***

- Until a complete solution is found or until all paths have led to lead ends, do
- 1. select an unexpanded node of the search graph.
- 2. Apply the constraint inference rules to the selected node to generate all possible new constraints.
- 3. If the set of constraints contains a contradiction, then report that this path is a dead end.
- 4. If the set of constraints describes a complete solution then report success.
- 5. If neither a constraint nor a complete solution has been found then apply the rules to generate new partial solutions. Insert these partial solutions into the search graph

Cryptarithmetic Problem

- Cryptarithmetic Problem is a type of constraint satisfaction problem where the game is about digits and its unique replacement either with alphabets or other symbols
- In cryptarithmetic problem, the digits (0-9) get substituted by some possible alphabets or symbols
- The task in cryptarithmetic problem is to substitute each digit with an alphabet to get the result arithmetically correct.



- **S E N D + M O R E = M O N E Y**

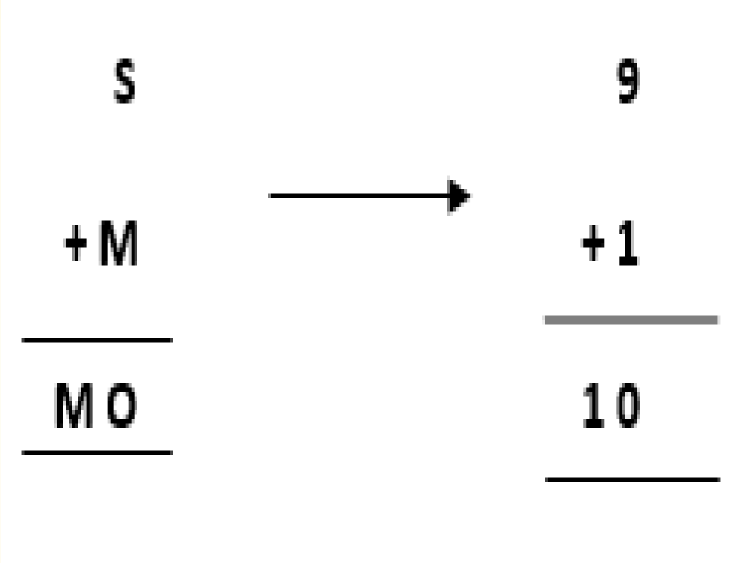
- CONSTRAINTS:-
- 1. no two digit can be assigned to same letter.
- 2. only single digit number can be assign to a letter.

- Initial state of problem.
  - D=? E=? Y=? N=? R=? O=? S=? M=?
  - C1=? C2=? C3=?
  - C1 ,C 2, C3 stands for the carry variables respectively.

- Goal State: the digits to the letters must be assigned in such a manner so that the sum is satisfied

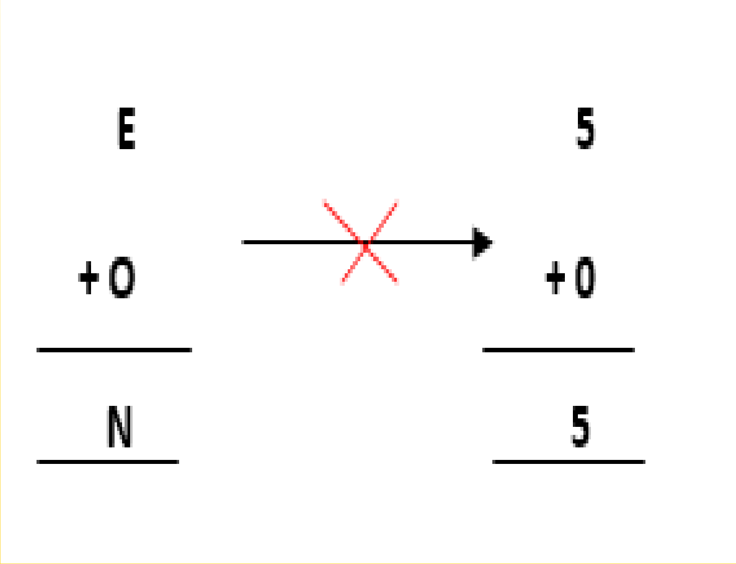
```
  SEND
+MORE
------
 MONEY
------
```

Starting from the left hand side (L.H.S) , the terms are S and M. Assign a digit which could give a satisfactory result. Let’s assign S->9 and M->1



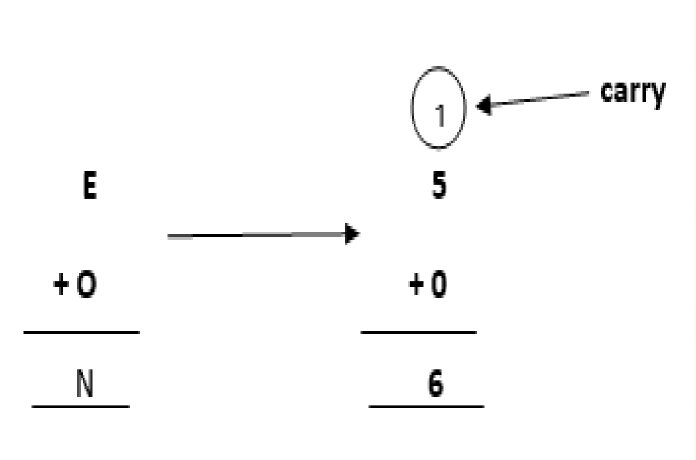
Hence, we get a satisfactory result by adding up the terms and got an assignment for O as O->0 as well.

Now, move ahead to the next terms E and O to get N as its output

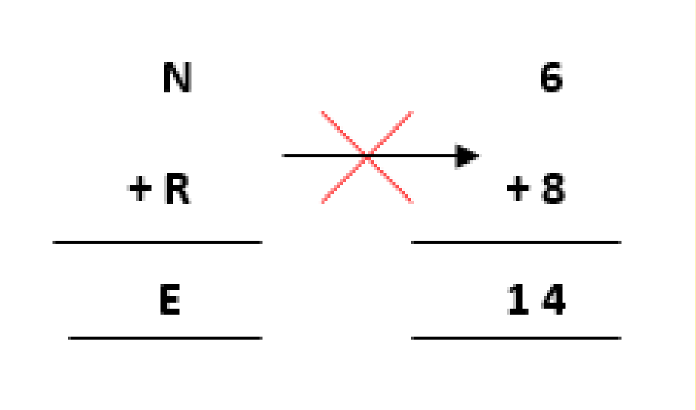


Adding E and O, which means 5+0=0, which is not possible because according to cryptarithmetic constraints, we cannot assign the same digit to two letters. So, we need to think more and assign some other value.

Note: When we will solve further, we will get one carry, so after applying it, the answer will be satisfied

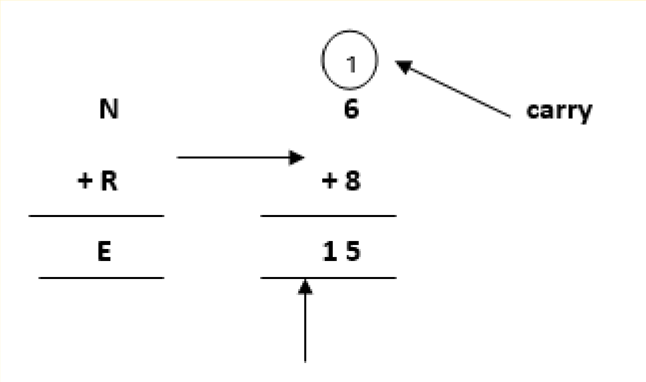


Further, adding the next two terms **N** and **R** we get,

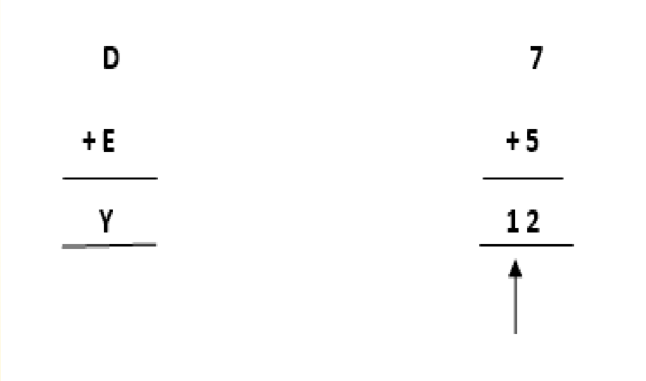


But, we have already assigned **E->5**. Thus, the above result does not satisfy the values
because we are getting a different value for **E.** So, we need to think more

Again, after solving the whole problem, we will get a carryover on this term, so our answer will be satisfied, where 1 will be carry forward to the above term

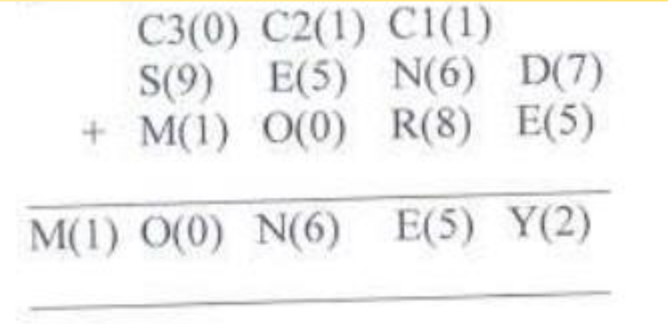


Again, on adding the last two terms, i.e., the rightmost terms **D** and **E**, we get **Y** as its result , where 1 will be carry forward to the above term



Keeping all the constraints in mind, the final resultant is as follows

S	9
E	5
N	6
D	7
M	1
O	0
R	8
y	2



Practice other Cryptarithmetic Problems

```
  BASE
 +BALL
 -----
 GAMES
```

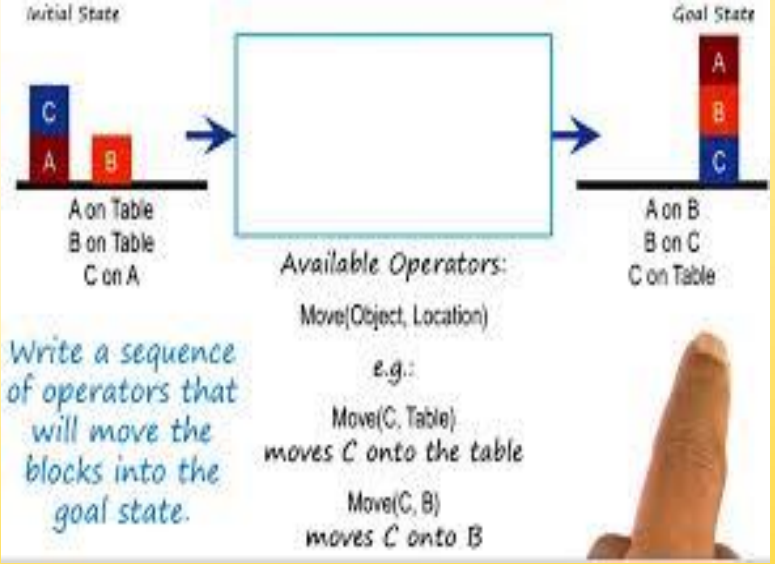
B	7
A	4
S	8
E	3
L	5
G	1
M	9

```
  YOUR
  +YOU
 -----
 HEART
```

Y	9
O	4
U	2
R	6
H	1
E	0
A	3
T	8

Means End Analysis

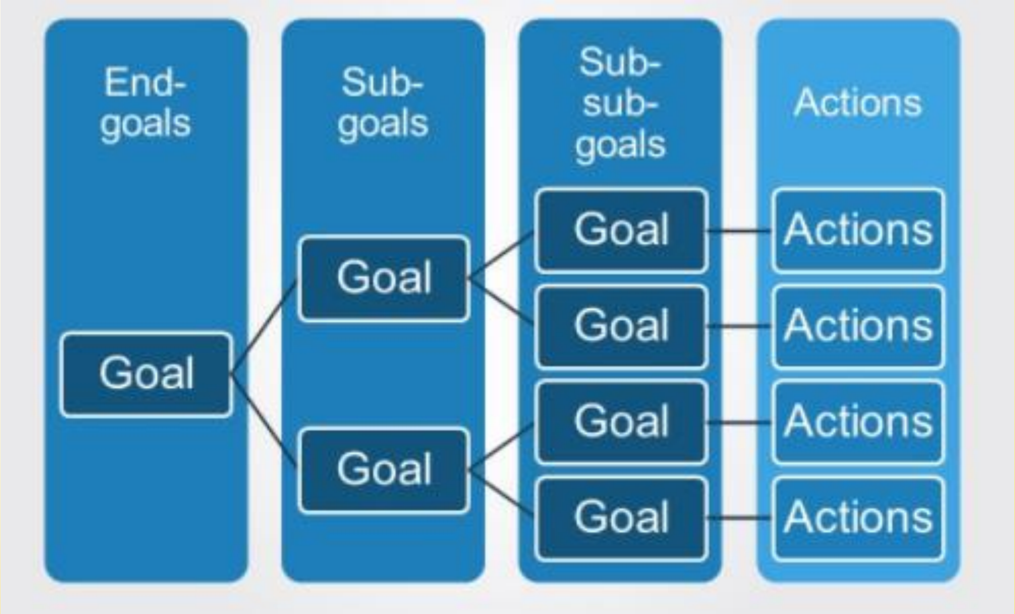
- Most of the search strategies either reason forward or backward
- However, often a mixture of the two directions is appropriate
- Such mixed strategy would make it possible to solve the major parts of problem first and solve the smaller problems that arise when combining them together. Such a technique is called "Means - Ends Analysis".



- The means -ends analysis process centers around finding the difference between current state and goal state.
- The problem space of means - ends analysis has an initial state and one or more goal state, a set of operators with a set of preconditions their application and difference functions that computes the difference between two states

- ***A problem is solved using means – ends analysis by***

- 1. Computing the current state s1 to a goal state s2 and computing their difference D12.
- 2. Satisfy the preconditions for some recommended operator *OP* is selected, then to reduce the difference D12.
- 3. The operator *OP* is applied if possible.
  - If not the current state is solved and a goal is created and means- ends analysis is applied recursively to reduce the sub goal.
- 4. If the sub goal is solved, state is restored and work resumed on the original problem



- The first AI program to use means - ends analysis was the GPS General problem solver

Algorithm

- **Step 1:** Measure the current state of things by doing as is the study and capture the status at a macro level and to a possible micro level.
- **Step 2:** Capture the deficiency in the current state and avenues for improvements (wish list) and define the goal state (to-be state). Define the to-be state at a macro level and to a possible micro level.
- **Step 3:** Compare the Current state and Goal state, and if they are at the same level, the problem is resolved.
- **Step 4:** List the differences between the current state and goal state at macro and micro levels.
- **Step 5:** Convert the differences into deletions/modifications to current state and new additions.
- **Step 6:** Define the action to implement the changes as defined in step-5.
- **Step 7:** Implement the changes and measure the actual results with the planned goals.
- **Step 8:** Do course correction and achieve the final goal.

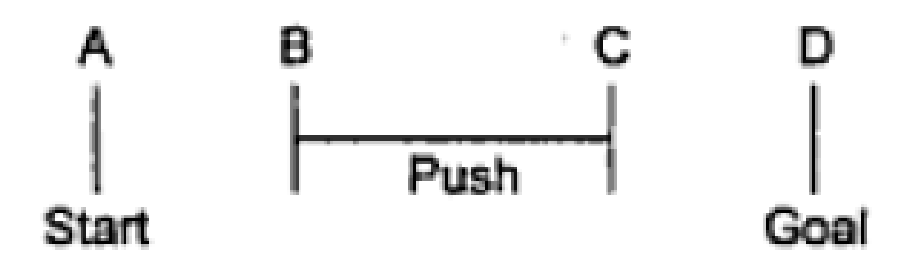
Example

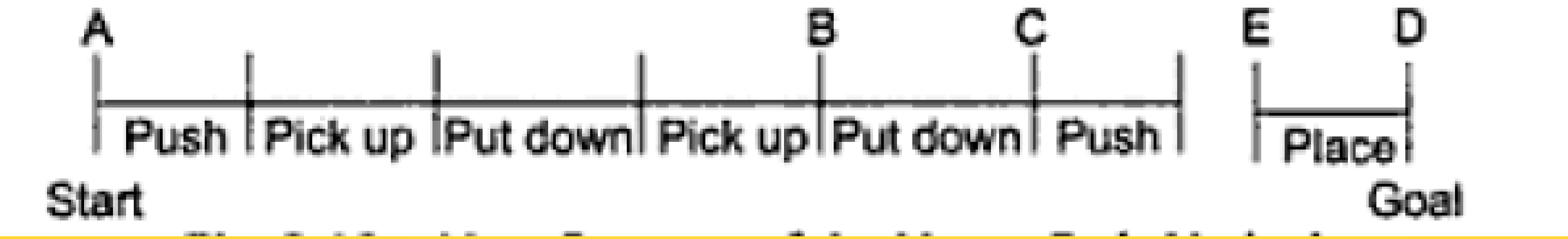
- A robot was given he problem of moving a desk with two things on it from one room to another
- The objects on top must be moved
- The main difference between the start and goal would be the location of the desk

Operator	*Preconditions*	*Results*
PUSH(obj, loc)	at(robot, obj)^ large(obj)^ clear(obj)^ armempty	at(obj, loc)^ at(robot, loc)
CARRY(obj, loc)	at(robot, obj)^ small(obj)	at(obj, loc)^ at(robot, loc)
WALK(loc)	none	at(robot, loc)
PICKUP(obj)	at(robot, obj)	holding(obj)
PUTDOWN(obj)	holding(obj)	¬holding(obj)
PLACE(obj1, obj2)	at(robot, obj2)^ holding(obj1)	on(obj1, obj2)

	Push	Carry	Walk	Pickup	Putdown	Place
Move object	*	*				
Move robot			*			
Clear object				*		
Get object on object						*
Get arm empty					*	*
Be holding object				*		

A Difference Table





- Means- ends analysis is useful for many human planning activities.
- Consider the example of planning for an office worker.
- Suppose we have a different table of three rules:
- 1. If in out current state we are hungry , and in our goal state we are not hungry , then either the "visit hotel" or "visit Canteen " operator is recommended.
- 2. If our current state we do not have money , and if in your goal state we have money, then the "Visit our bank" operator or the "Visit secretary" operator is recommended.
- 3. If our current state we do not know where something is , need in our goal state we do know, then either the "visit office enquiry" , "visit secretary" or "visit co worker " operator is recommended.


Thank
You
Obrigado
Merci
Multumesc
Asante
Spasibo
Maake
Grazie
Kiitos
Mochchakkeram
Kia Ora
Welalin
Matondo
Chokrane
Dank Je
Nirringrazzjak
Ua Tsaug Rau Koj
Vinaka
Cam on ban
Arigato
Juspaxar
Mamana
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Terma Kasih
Salamat
Matur Nuwun