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**Assignment No: 2**

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1. **Title of Assignment:** Implement A\* Algorithm for 8 puzzle game search problems.
2. **Prerequisite:** Basic knowledge of Graph, Tree, informed search, uninformed search, best first search etc.
3. **Objective:** In this experiment, we will be able to do the following:

- To understand Informed Search Strategies.
- To make use of Graph and Tree Data Structure for implementation of Informed Search strategies.
- Study how A\* Algorithm is useful for implementation of 8 puzzle game search problems

**Outcome:** Successfully able to implement 8 puzzle game search problem using A\* Algorithm

4. **Software and Hardware Requirement:**

Open Source C++ Programming tool like G++/GCC, python, Java and Ubuntu.

5. **Relevant Theory / Literature Survey:**

**Informed search**

- Informed search algorithm contains an array of knowledge such as how far we are from the goal, path cost, how to reach the goal node, etc.
- This knowledge helps agents to explore less of the search space and find the goal node.
- The informed search algorithm is more useful for large search spaces.
- Informed search algorithms use the idea of heuristic, so it is also called Heuristic search

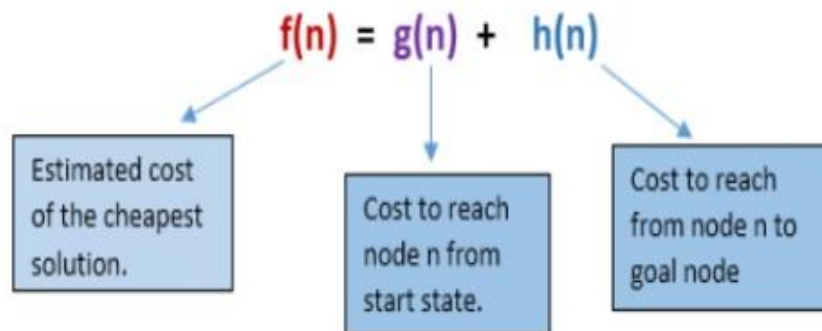
**Heuristics function:**

- Heuristic is a function which is used in Informed Search, and it finds the most promising path.
- It takes the current state of the agent as its input and produces the estimation of how close the agent is from the goal.
- The heuristic method, however, might not always give the best solution, but it guaranteed to find a good solution in reasonable time.
- Heuristic function estimates how close a state is to the goal. It is represented by  $h(n)$ , and it calculates the cost of an optimal path between the pair of states.
- The value of the heuristic function is always positive.

**A\* Search Algorithm:**

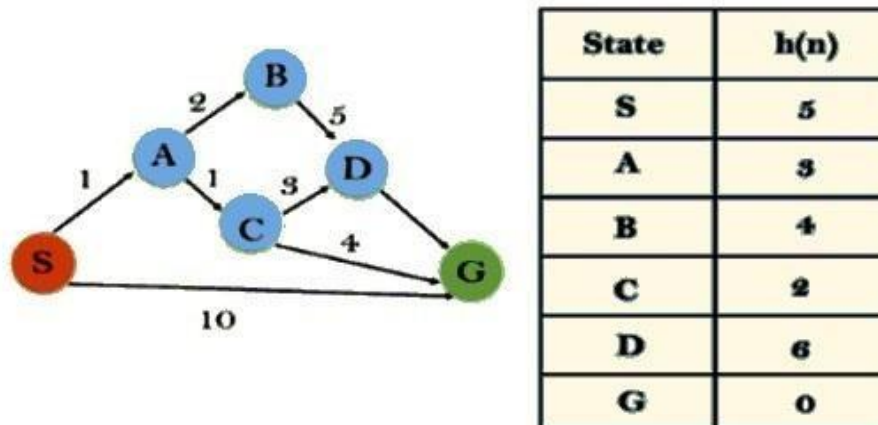
- A\* search is the most commonly known form of best-first search.
- It uses the heuristic function  $h(n)$ , and costs to reach the node  $n$  from the start state  $g(n)$ .
- It has combined features of UCS and greedy best-first search, by which it solves the problem efficiently.
- A\* search algorithm finds the shortest path through the search space using the heuristic function.
- This search algorithm expands less search tree and provides optimal results faster.
- A\* algorithm is similar to UCS except that it uses  $g(n)+h(n)$  instead of  $g(n)$ .

In A\* search algorithm, we use search heuristic as well as the cost to reach the node. Hence we can combine both costs as following, and this sum is called as a **fitness number**.



In this example, we will traverse the given graph using the A\* algorithm. The heuristic value of all states is given in the below table so we will calculate the  $f(n)$  of each state using the formula  $f(n) = g(n) + h(n)$ , where  $g(n)$  is the cost to reach any node from start state.

Here we will use OPEN and CLOSED list.



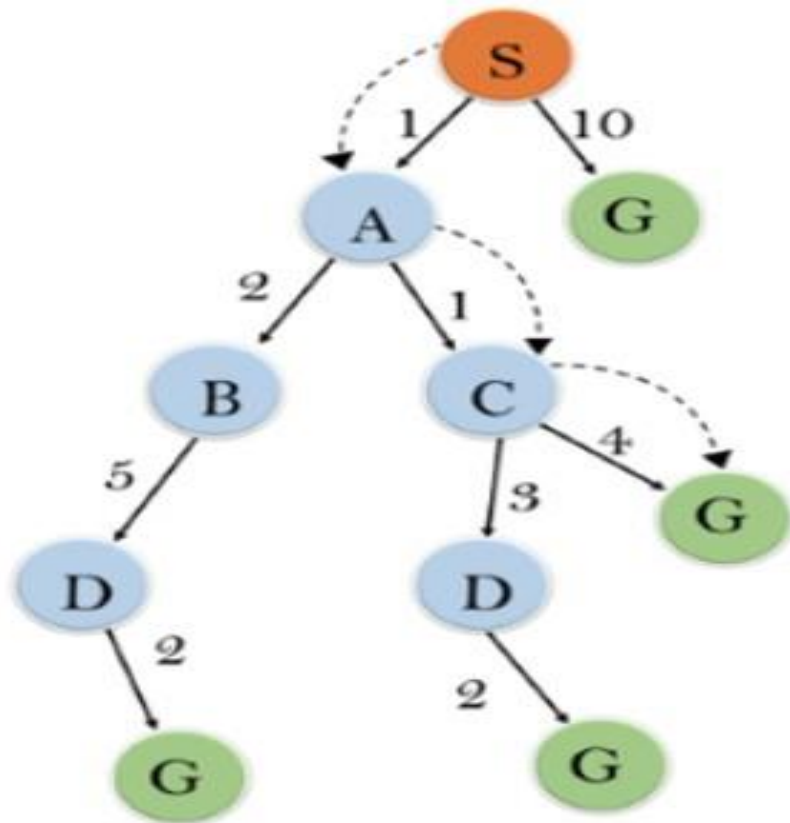
**Initialization:**  $\{(S, 5)\}$

**Iteration1:**  $\{(S \rightarrow A, 4), (S \rightarrow G, 10)\}$

**Iteration2:**  $\{(S \rightarrow A \rightarrow C, 4), (S \rightarrow A \rightarrow B, 7), (S \rightarrow G, 10)\}$

**Iteration3:**  $\{(S \rightarrow A \rightarrow C \rightarrow G, 6), (S \rightarrow A \rightarrow C \rightarrow D, 11), (S \rightarrow A \rightarrow B, 7), (S \rightarrow G, 10)\}$

**Iteration 4** will give the final result, as  $S \rightarrow A \rightarrow C \rightarrow G$  it provides the optimal path with cost 6.

**Solution:****A\* search Algorithm Advantages:**

- A\* search algorithm is the best algorithm than other search algorithms.
- A\* search algorithm is optimal and complete.
- This algorithm can solve very complex problems.

**A\* search Algorithm Disadvantages:**

- A\* search algorithm has some complexity issues.
- The main drawback of A\* is memory requirement as it keeps all generated nodes in the memory, so it is not practical for various large-scale problems.

**Complete:** A\* algorithm is complete as long as:

- Branching factor is finite.
- Cost at every action is fixed.

**Optimal:** A\* search algorithm is optimal if it follows below two conditions:

- **Admissible:** the first condition requires for optimality is that  $h(n)$  should be an admissible heuristic for A\* tree search. An admissible heuristic is optimistic in nature.
- **Consistency:** Second required condition is consistency for only A\* graph-search.

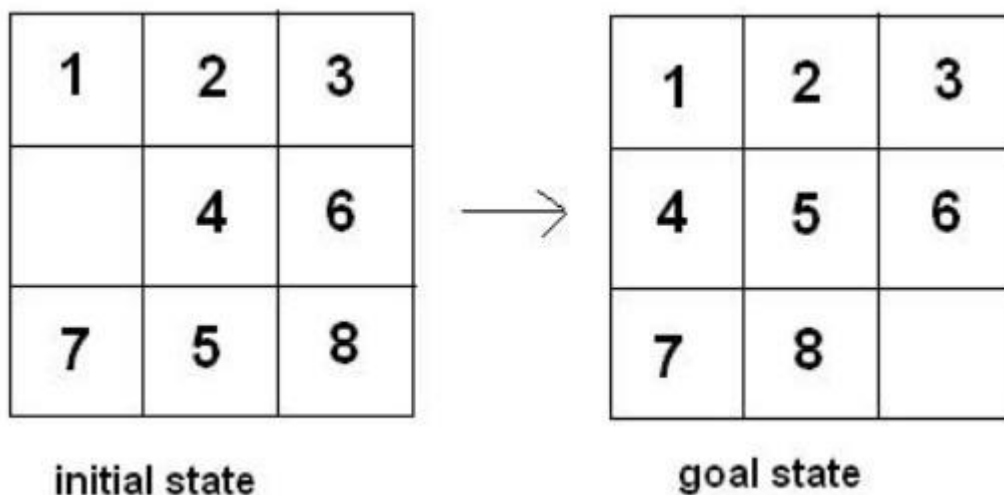
If the heuristic function is admissible, then A\* tree search will always find the least cost path.

**Time Complexity:** The time complexity of A\* search algorithm depends on heuristic function, and the number of nodes expanded is exponential to the depth of solution  $d$ . So the time complexity is  $O(b^d)$ , where  $b$  is the branching factor.

**Space Complexity:** The space complexity of A\* search algorithm is  $O(b^d)$

### 8 Puzzle Algorithm:-

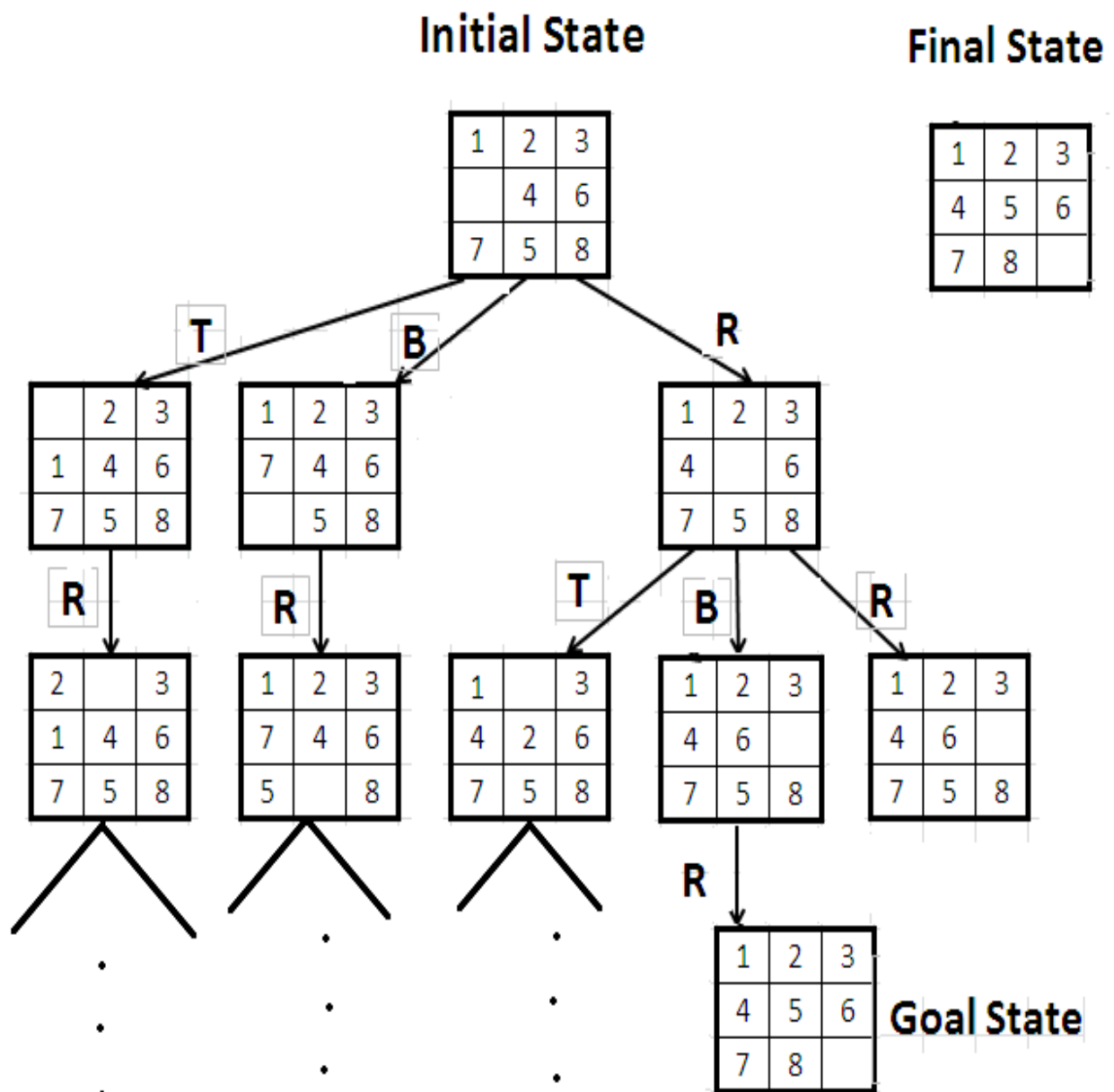
The 8-puzzle problem is a puzzle invented and popularized by Noyes Palmer Chapman in the 1870s. It is played on a 3-by-3 grid with 8 square blocks labeled 1 through 8 and a blank square. Your goal is to rearrange the blocks so that they are in order. You are permitted to slide blocks horizontally or vertically into the blank square.



There are a number of ways by which we can solve 8 puzzle problems.

- Solution without Heuristic Function
- Solution A\* Algorithm

### Solution without Heuristic Function



### Disadvantages

need to explore each node and in case of failure need to generate its child which is a very time consuming as well as space consuming process.

**Solution A\* Algorithm**

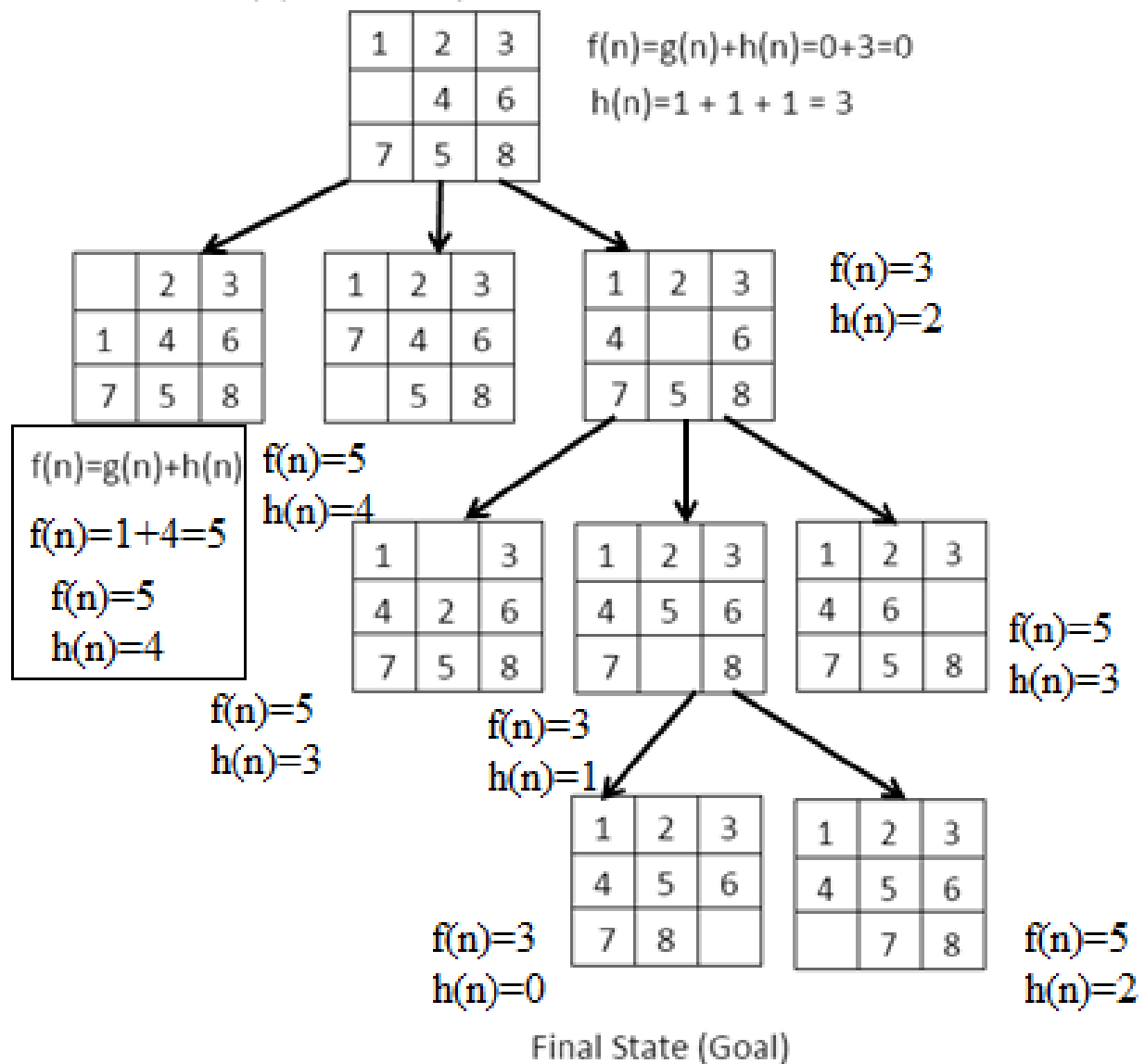
1	2	3
	4	6
7	5	8

Initial State

1	2	3
4	5	6
7	8	

Final State (Goal)

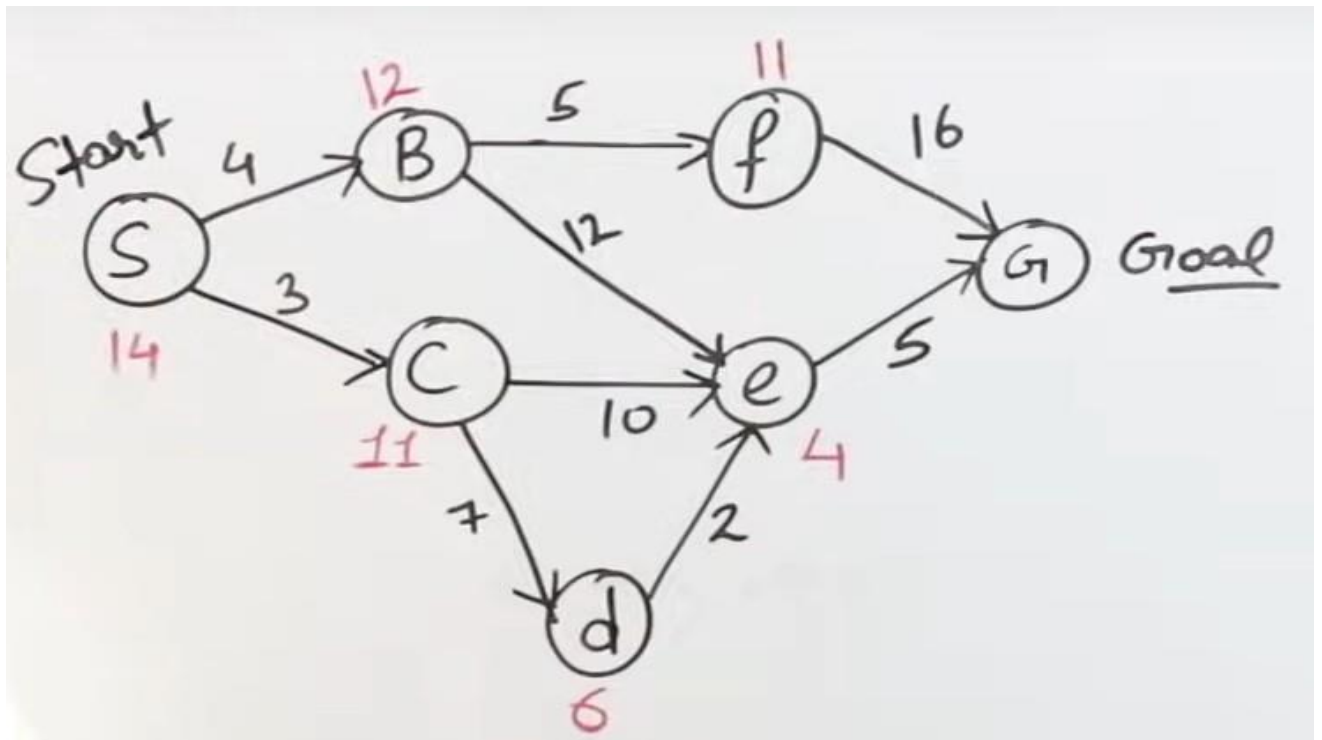
$h(n)$  = No of misplaced tiles



6. Questions:

**Q 1:** Differentiate between Best first search and A\* algorithm.

**Q 2:** Solve this problem using A\* algorithm



**Q 3:** What is the drawback to solve 8 Puzzle problem with a non-heuristic method?

### 7. Conclusion:

In This way we have studied informed search strategy, how to calculate heuristic function and implementation of 8 puzzle game search problems using A\* Algorithm.