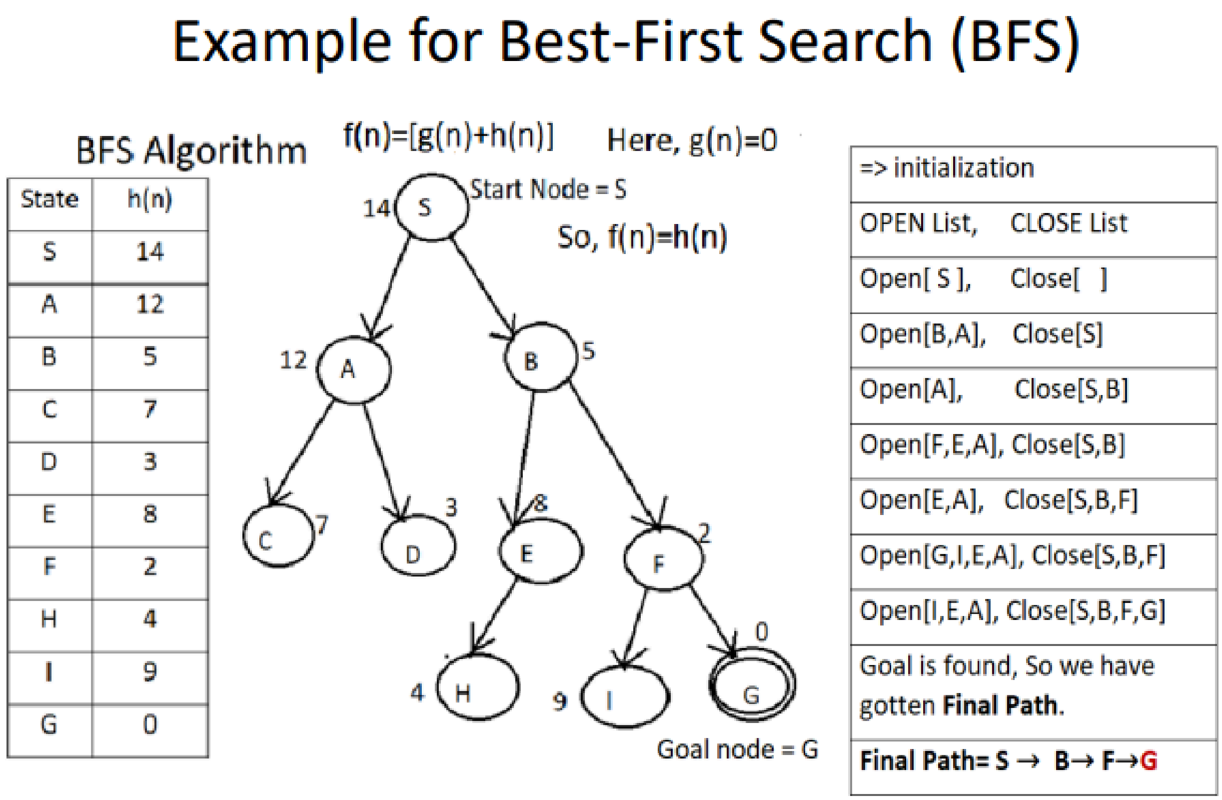
Searching Algorithms

Best First Search:

Here is the link to Best First Search: [Google Colab - Best First Search]

We implemented the algorithm using Python and illustrated it with the following example. The code is also attached to this document.



The code is given below.

```
import heapq

def best_first_search(graph, start, goal, heuristic):

    # Priority queue to store (heuristic, node)
    open_list = []
    heapq.heappush(open_list, (heuristic[start], start))
```

```
    # Dictionary to keep track of visited nodes and their parents
    close_list = []

    while open_list:
        # Get the node with the lowest heuristic value
        current_heuristic, current_node = heapq.heappop(open_list)
        close_list.append(current_node)

        # Check if we've reached the goal
        if current_node == goal:
            break

        # Explore neighbors
        for neighbor in graph[current_node]:
            if neighbor not in close_list:
                heapq.heappush(open_list, (heuristic[neighbor], neighbor))

    if goal in close_list:
      return close_list
    else:
      return None

# Program execution starts from here
if __name__ == "__main__":
    # Define a graph as an adjacency list
    graph = {
        'S': ['A', 'B'],
        'A': ['C', 'D'],
        'B': ['E', 'F'],
        'C': [],
        'D': [],
        'E': ['H'],
        'F': ['I', 'G'],
        'H': [],
        'I': [],
        'G': []
    }

    # Define heuristic values for each node
    heuristic = {
```

```python
        'S': 14,
        'A': 12,
        'B': 5,
        'C': 7,
        'D': 3,
        'E': 8,
        'F': 2,
        'G': 0,
        'H': 4,
        'I': 9
    }

    start = 'S'
    goal = 'G'

    path = best_first_search(graph, start, goal, heuristic)
    print("Best-First Search Path:", path)
```

Output: Best-First Search Path: ['S', 'B', 'F', 'G']

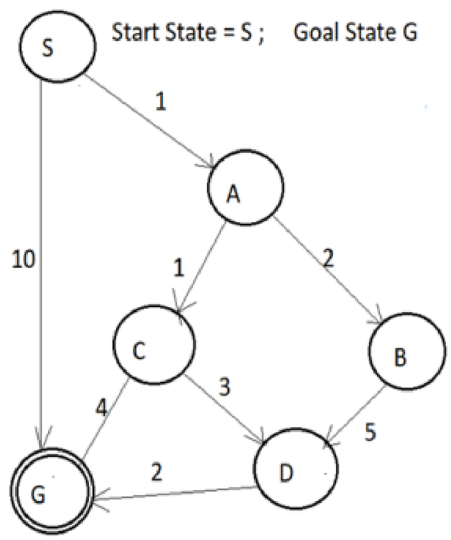
A* Search Algorithm

Here is the link to A* Search Algorithm: [Google Colab - A* Search Algorithm]()

We implemented the algorithm using Python and illustrated it with the following example. The code is also attached to this document.

Example for A* search Algorithm

State	h(n) Value
S	5
A	3
B	4
C	2
D	6
G	0



Step-1: S → A ; F(n) = g(n) + h(n) = 1 + 3 = 4 S → G ; F(n) = 10 + 0 = 10 (Hold)
Step-2: S → A→ B ; F(n) = 3 + 4 = 7 (Hold) S → A→ C ; F(n) = 2 + 2 = 4
Step-3: S → A→C→D ; F(n) = 5 + 6 = 11 (Hold) S → A→ C→G ; F(n) = 6 + 0 = 6
Final Path: S → A→ C→G ; F(n) = 6

Example for A* search Algorithm

Step-1: Initialization; Start State = S; Goal State = G;	=> initialization OPEN List, CLOSE List Open[S], Close[ ] Open[A,G], Close[S] Open[G], Close[S,A] Open[C,B,G], Close[S,A] Open[G,D,B,G], Close[S,A,C] Open[D,B,G], Close[S,A,C,G] Lower cost goal is found. So, we have gotten **Final Path**. **Final Path= S → A→ C→ G**
Step-2: S → A ; F(n) = g(n) + h(n) = 1 + 3 = 4 S → G ; F(n) = 10 + 0 = 10 (Hold)	
Step-3: S → A→ B ; F(n) = 3 + 4 = 7 (Hold) S → A→ C ; F(n) = 2 + 2 = 4	
Step-4: S → A→C →D ; F(n) = 5 + 6 = 11 (Hold) S → A→ C→G ; F(n) = 6 + 0 = 6	
Final Path: S → A→ C→ G ; F(n) = 6	

The code is given below.

```
import heapq

def a_star_search(graph, start, goal, heuristic):
    open_list = []
    heapq.heappush(open_list, (heuristic[start], start))

    close_list = []
    g_cost = {node: float('inf') for node in graph}
    g_cost[start] = 0

    while open_list:
        current_f, current_node = heapq.heappop(open_list)
        close_list.append(current_node)

        if current_node == goal:
            break

        for neighbor, step_cost in graph[current_node]:
            if neighbor not in close_list:
                temp_g = g_cost[current_node] + step_cost
                if temp_g < g_cost[neighbor]:
                    g_cost[neighbor] = temp_g
                    f_cost = temp_g + heuristic[neighbor]
                    heapq.heappush(open_list, (f_cost, neighbor))

    if goal in close_list:
      return close_list
    else:
      return None

# Program execution starts from here
if __name__ == "__main__":
    graph = {
        'S': [('A', 1), ('G', 10)],
        'A': [('B', 2), ('C', 1)],
        'B': [('D', 5)],
        'C': [('D', 3), ('G', 4)],
        'D': [('G', 2)],
```

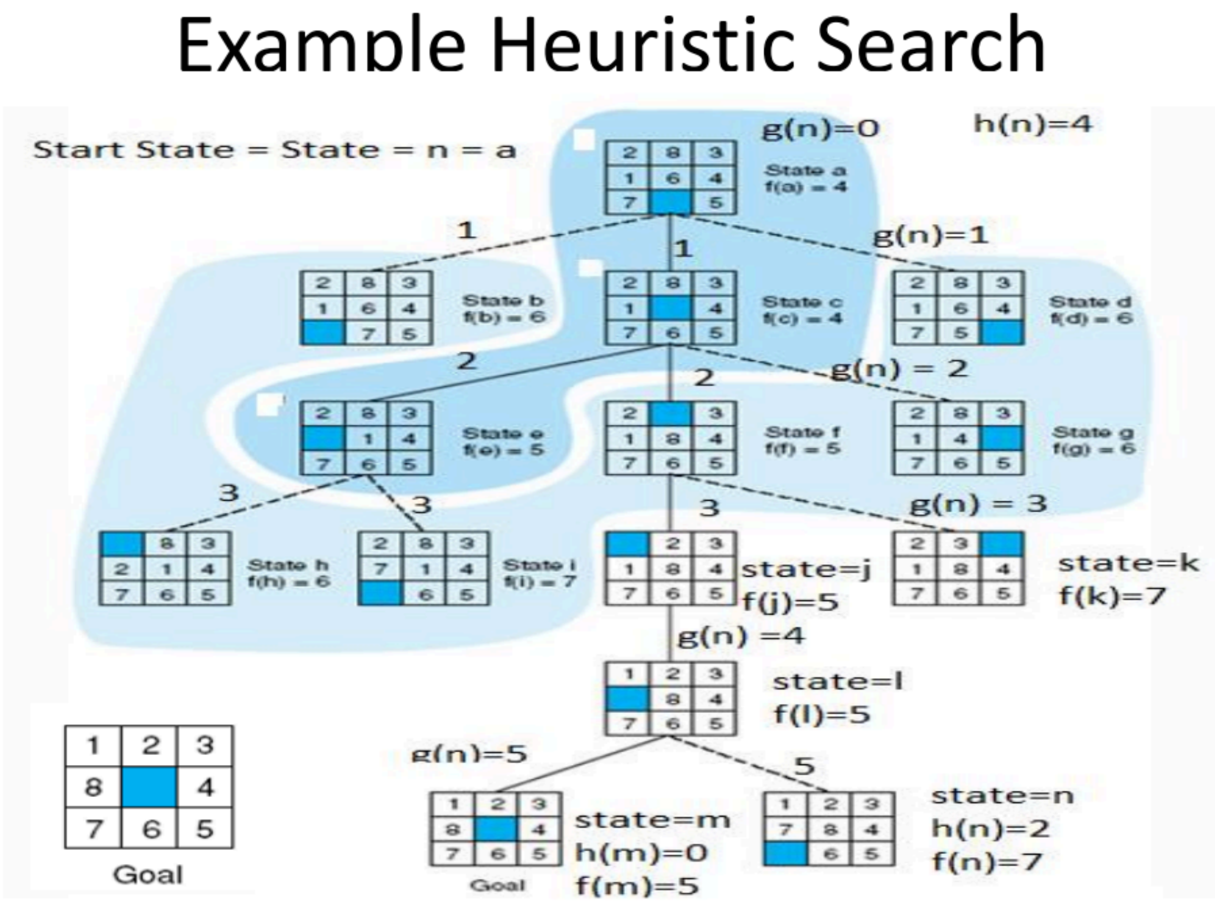
```
        'G': []
    }

    heuristic = {
        'S': 5,
        'A': 3,
        'B': 4,
        'C': 2,
        'D': 6,
        'G': 0
    }

    start = 'S'
    goal = 'G'

    path = a_star_search(graph, start, goal, heuristic)
    print("A* Search Path:", path)
```

Output: A* Search Path: ['S', 'A', 'C', 'G']

Heuristic Search

Here is the link to Heuristic Search Algorithm: [Google Colab - Heuristic Search]

We implemented the algorithm using Python and illustrated it with the following example. The code is also attached to this document.



The code is given below.

```
from heapq import heappush, heappop
import numpy as np

# Goal state of the 8-puzzle
GOAL_STATE = [
    [1, 2, 3],
    [8, 0, 4],
    [7, 6, 5]
```

```
]

# Directions for moving the blank tile (up, down, left, right)
MOVES = [(0, -1), (0, 1), (-1, 0), (1, 0)]

# Heuristic function: Manhattan distance
def heuristic(state):
    distance = 0
    for i in range(3):
        for j in range(3):
            if state[i][j] != 0 and abs(state[i][j] - GOAL_STATE[i][j]) != 
0:  # Ignore the blank tile
                distance += 1
    return distance

# Check if the current state is the goal state
def is_goal(state):
    return state == GOAL_STATE

# Find the position of the blank tile (0)
def find_blank(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
                return (i, j)
    return None

# Generate possible moves from the current state
def generate_moves(state):
    blank_row, blank_col = find_blank(state)
    moves = []
    for dr, dc in MOVES:
        new_row, new_col = blank_row + dr, blank_col + dc
        if 0 <= new_row < 3 and 0 <= new_col < 3:
            new_state = [row[:] for row in state]  # Copy the state
            new_state[blank_row][blank_col], new_state[new_row][new_col] = 
new_state[new_row][new_col], new_state[blank_row][blank_col]
            moves.append(new_state)
    return moves
```

```
# A* search algorithm
def a_star_search(start_state):
    for row in start_state:
      print(row)
    print('\nExpanding the Start State\n')
    open_list = []
    heappush(open_list, (heuristic(start_state), 0, start_state, []))  # (f(n), g(n), state, path)
    visited = set()

    while open_list:
        _, g, current_state, path = heappop(open_list)
        if is_goal(current_state):
            return path + [current_state]  # Return the solution path

        if tuple(map(tuple, current_state)) in visited:
            continue
        visited.add(tuple(map(tuple, current_state)))

        print('---------------------------------------------')

        idx = 0
        heuristic_values = []
        for move in generate_moves(current_state):
            if tuple(map(tuple, move)) not in visited:
              for row in move:
                print(row)
              print()
              idx = idx + 1
              print(f"Matrix {idx} : f(n) = {heuristic(move) + g + 1}")
              heuristic_values.append(heuristic(move) + g + 1)
              print()
              heappush(open_list, (g + 1 + heuristic(move), g + 1, move, path + [current_state]))

        print(f"Expanding Matrix: {np.argmin(heuristic_values) + 1} (lowest heuristic value)")
        print()

    return None  # No solution found
```

```python
# Program execution starts from here
if __name__ == "__main__":
    # Start state
    start_state = [
        [2, 8, 3],
        [1, 6, 4],
        [7, 0, 5]
    ]

    # Solve the puzzle
    solution = a_star_search(start_state)

    if solution:
        print('-------------------------------------------')
        print("Solution found! Steps:")
        for step in solution:
            for row in step:
                print(row)
            print()
    else:
        print("No solution found.")
```

Output:

```
[2, 8, 3]
[1, 6, 4]
[7, 0, 5]

Expanding the Start State

--------------------------------------------
[2, 8, 3]
[1, 6, 4]
[0, 7, 5]

Matrix 1 : f(n) = 6

[2, 8, 3]
[1, 6, 4]
[7, 5, 0]
```

```
Matrix 2 : f(n) = 6

[2, 8, 3]
[1, 0, 4]
[7, 6, 5]

Matrix 3 : f(n) = 4

Expanding Matrix: 3 (lowest heuristic value)

--------------------------------------------
[2, 8, 3]
[0, 1, 4]
[7, 6, 5]

Matrix 1 : f(n) = 5

[2, 8, 3]
[1, 4, 0]
[7, 6, 5]

Matrix 2 : f(n) = 6

[2, 0, 3]
[1, 8, 4]
[7, 6, 5]

Matrix 3 : f(n) = 5

Expanding Matrix: 1 (lowest heuristic value)

--------------------------------------------
[0, 2, 3]
[1, 8, 4]
[7, 6, 5]

Matrix 1 : f(n) = 5

[2, 3, 0]
[1, 8, 4]
[7, 6, 5]

Matrix 2 : f(n) = 7

Expanding Matrix: 1 (lowest heuristic value)
```

```
--------------------------------------------
[0, 8, 3]
[2, 1, 4]
[7, 6, 5]

Matrix 1 : f(n) = 6

[2, 8, 3]
[7, 1, 4]
[0, 6, 5]

Matrix 2 : f(n) = 7

Expanding Matrix: 1 (lowest heuristic value)

--------------------------------------------
[1, 2, 3]
[0, 8, 4]
[7, 6, 5]

Matrix 1 : f(n) = 5

Expanding Matrix: 1 (lowest heuristic value)

--------------------------------------------
[1, 2, 3]
[8, 0, 4]
[7, 6, 5]

Matrix 1 : f(n) = 5

[1, 2, 3]
[7, 8, 4]
[0, 6, 5]

Matrix 2 : f(n) = 7

Expanding Matrix: 1 (lowest heuristic value)

--------------------------------------------
Solution found! Steps:
[2, 8, 3]
[1, 6, 4]
[7, 0, 5]

[2, 8, 3]
[1, 0, 4]
```

```
[7, 6, 5]

[2, 0, 3]
[1, 8, 4]
[7, 6, 5]

[0, 2, 3]
[1, 8, 4]
[7, 6, 5]

[1, 2, 3]
[0, 8, 4]
[7, 6, 5]

[1, 2, 3]
[8, 0, 4]
[7, 6, 5]
```