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Solve Maze Using Breadth-First Search (BFS) Algorithm in Python

Learn how to use and implement the Breadth-First Search (BFS) algorithm to solve real-world problems.

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In my last article, we talked about Depth First Search (DFS) Algorithm and used it, in order to find the solution to a Sudoku puzzle. Today, we'll talk about another search algorithm called Breadth-First Search (BFS). After that, we will implement this algorithm in order to find a solution to the Maze problem.

Search Algorithms are used in order to find a solution to problems that can be modeled as a graph. If you do not know what a graph is please read the related article. Every node of a graph is an instance of the problem. Each search algorithm starts from a node (initial instance — state) and extends the node, creating new nodes (new instances of the problem) by applying a legal action of the problem. The whole process algorithm.

Graph Data Structure — Theory and Python Implementation
A guide on how to implement the Graph data structure in Python.
python.plainenglish.io

Breadth-First Search is a "blind" algorithm. It's called "blind" because this algorithm doesn't care about the cost between vertices on the graph. The algorithm starts from a root node (which is the initial state of the problem) and explores all nodes at the present level prior to moving on to the nodes at the next level. If the algorithm finds a solution, returns it and stops the search, otherwise extends the node and continues the search process. Breadth-First Search is "complete", which means that the algorithm always returns a solution if exists. More specifically, the algorithm returns the solution that is closest to the root, so for problems that the transition from one node to its children nodes costs one, the BFS algorithm returns the best solution. In addition, in order to explore the nodes level by level, it uses a queue data structure, so new nodes are added at the end of the queue, and nodes are removed from the start of the queue. The pseudocode of the BFS algorithm is the following.

```
procedure BFS_Algorithm(graph, initial_vertex):
  create a queue called frontier
  create a list called visited_vertex
  add the initial vertex in the frontier
  while True:
    if frontier is empty then
      print("No Solution Found")
      break

    selected_node = remove the first node of the frontier
    add the selected_node to the visited_vertex list

    // Check if the selected node is the solution
```

```
    new_nodes = extend the selected_node
    // Add the extended nodes in the frontier
    for all nodes from new_nodes do
      if node not in visited_vertex and node not in frontier then
      add node at the end of the queue
```

From the above, it's obvious that in order to solve a problem using a search algorithm like BFS, we must first model the problem in a graph form and then define the initial state of the problem (initial node). After that, we must find the rules that will be followed in order to extend nodes (instances of the problem). These rules are determined by the problem itself. The last thing we need to do is to define the target node or a mechanism so that the algorithm is able to recognize the target node.

Implementation of Queue Data Structure in Python

The theory behind the queue data structure and how the data are stored in a queue.

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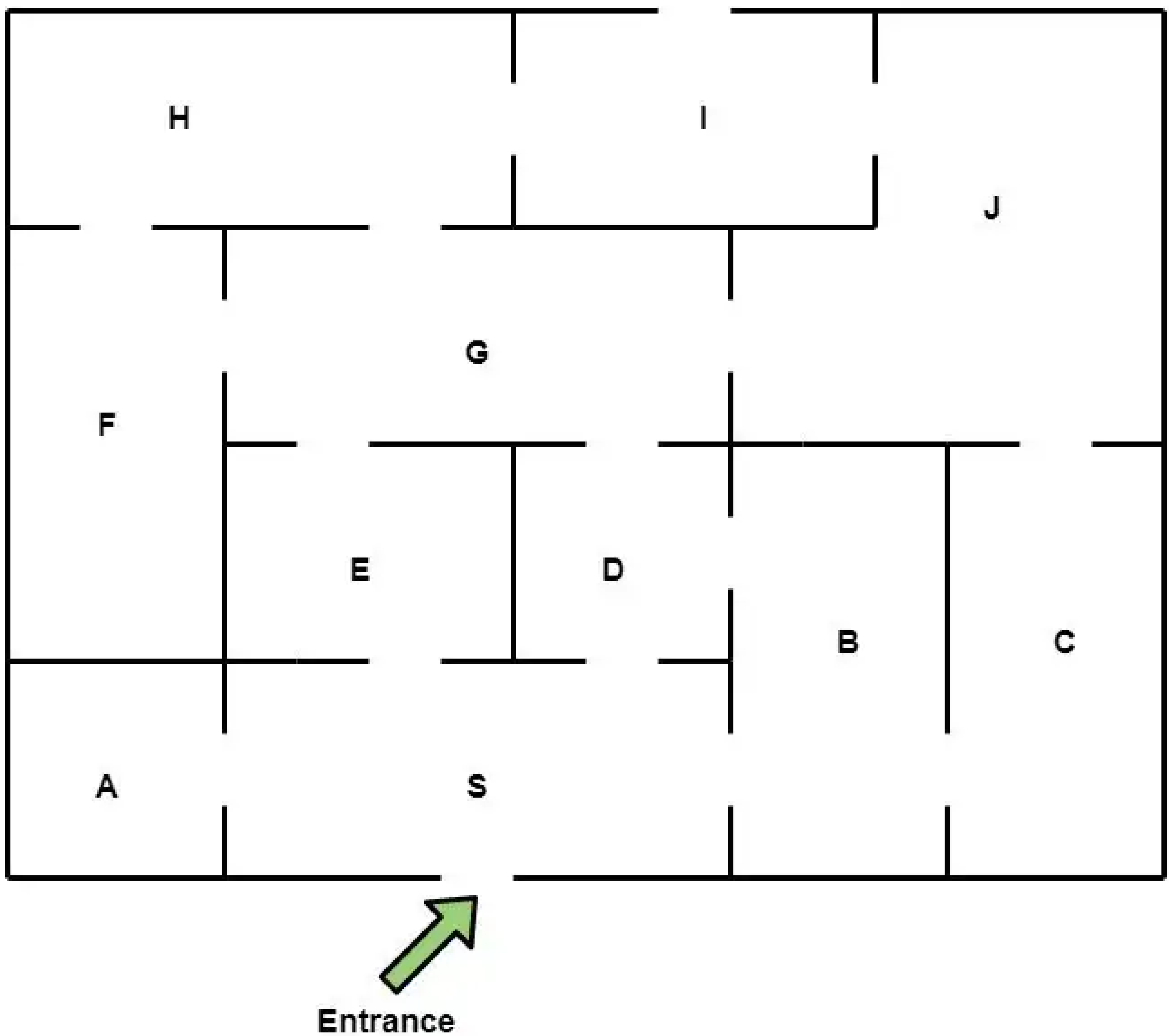
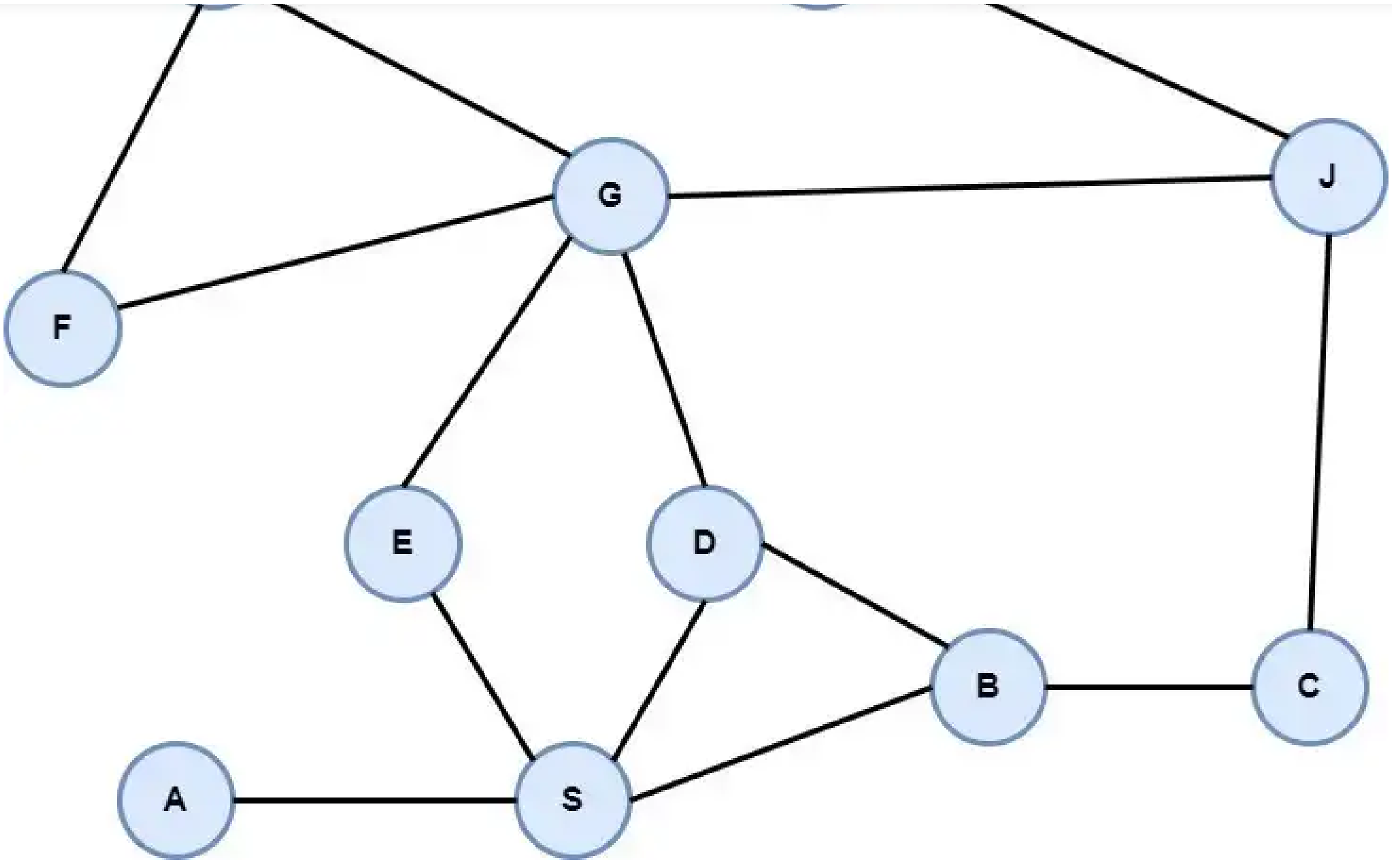
Now that we know how Breadth-First Search (BFS) works, it's time to talk about the problem that we will solve using this algorithm. Suppose there is a maze such as the image shown below and we want to navigate from the entrance to the exit with the less possible movements. As a movement, we consider each movement from one room to another. In our example, the maze consists of eleven rooms each of them has a unique name like "A", "B", etc. So, our goal is to navigate from room "S" to "I".



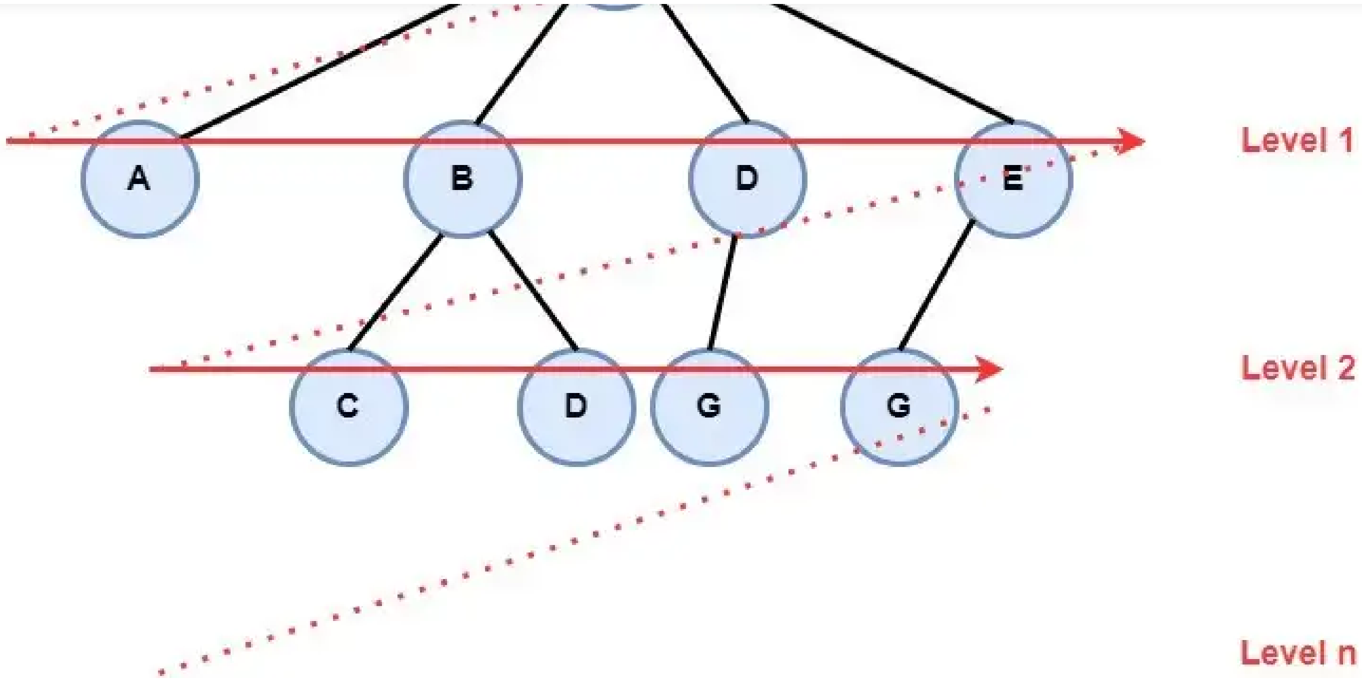
The initial maze

After defining the problem, it's time to model it into a graph. A very common way to do this is to create a *vertex for each room* and *an edge for each door* of the maze. After this modeling, the graph consists of 11 vertices and 15 edges as it seems below.



The Graph that represents the above maze

So, from each vertex we can navigate to its neighbors, starting from vertex “S” which is the initial state until the vertex “I” which is the target node of the problem. As I mentioned earlier in this article, the BFS algorithm will explore all nodes at the present level prior to moving on to the nodes at the next level, as it seems in the following image.



The way that Breadth-First Search Algorithm searches for a solution in the search space

Now that we define and model the problem, we are ready to proceed to the implementation of the algorithm. First, we must represent the maze in our program. Usually, we use an adjacent list or an adjacent table to represent a graph. In our example, we will use a dictionary, so the keys of the dictionary will be the name of the vertices and the value of each key will be a list with all the adjacent vertices of this particular vertex as it seems below.

```
graph = {
    "A": ['S'],
    "B": ['C', 'D','S'],
    "C": ['B', 'J'],
    "D": ['B', 'G', 'S'],
    "E": ['G', 'S'],
    "F": ['G', 'H'],
    "G": ['D', 'E', 'F', 'H', 'J'],
    "H": ['F', 'G', 'I'],
```

After that, it's time to create the class Node. This class will be implemented as an interface in order to use the same structure of the algorithm for other problems in the future. So, we define abstract methods that users must implement properly according to each problem.

```
from abc import ABC, abstractmethod
class Node(ABC):
  """
    This class used to represent a Node in the graph
    It's important to implement this interface in order to make the class BFS more general
    and to use it for various problems
    ...


    Methods
    -------
    __eq__(self, other)
        Determines if two nodes are equal or not

    is_the_solution(self)
        Determines if the current node is the solution of the problem

    def is_the_solution(self)
        Extends the current node according to the rules of the problem

    __str__(self)
        Prints the node data
  """

  @abstractmethod
  def __eq__(self, other):
    pass

  @abstractmethod
  def is_the_solution(self, state):
    pass
```

```python
    @abstractmethod
    def __str__(self):
      pass
```

BFS_Algorithm.py hosted with ❤ by GitHub view raw

The next step is to implement the class that represents the Breadth-First Search algorithm. This class contains all necessary methods in order to add a new node to the frontier, to remove a node from the frontier, to check if the frontier is empty and finally to search for a solution in the search space, etc.

```python
class BFS:
  """
    This class used to represent the  Breadth First Search algorithm (BFS)

    ...

    Attributes
    ----------
    start_state : Node
        represent the initial state of the problem
    final_state : Node
        represent the final state (target) of the problem
    frontier : List
        represents the stack and is initialized with the start node
    checked_nodes : List
        represents the list of nodes that have been visited throughout the algorithm execution
    number_of_steps : Integer
        Keep track of the algorithm's number of steps
    path : List
        represents the steps from the initial state to the final state

    Methods
    -------
    insert_to_frontier(self, node)
        Insert a new node to the frontier. In this algorithm the frontier is a queue, so each new

    remove_from_frontier(self)
```

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```
        search(self)
            Implements the core of algorithm. This method searches, in the search space of the proble
        """

    def __init__(self, start, final):
        self.start_state = start
        self.final_state = final
        self.frontier = [self.start_state]
        self.checked_nodes = []
        self.number_of_steps = 0
        self.path = []

    def insert_to_frontier(self, node):
        """
          Insert a node at the end of the frontier

          Parameters
          ----------
          node : Node
              The node of the problem that will be added to the frontier
        """
        self.frontier.append(node)


    def remove_from_frontier(self):
        """
          Remove a node from the beginning of the frontier
          Then add the removed node to the checked_nodes list

          Returns
          -------
          Node
            the first node of the frontier
        """
        first_node = self.frontier.pop(0)
        self.checked_nodes.append(first_node)
        return first_node


    def frontier_is_empty(self):
```

```
      Boolean
        True if the frontier is empty
        False if the frontier is not empty
    """
    if len(self.frontier) == 0:
      return True
    return False


  def search(self):
    """
      Is the main algorithm. Search for a solution in the solution space of the problem
      Stops if the frontier is empty, so no solution found or if find a solution.
    """
    while True:

      self.number_of_steps += 1

      # print(f"Step: {self.number_of_steps}, Frontier Size: {len(self.frontier)} ")
      if self.frontier_is_empty():
        print(f"No Solution Found after {self.number_of_steps} steps!!!")
        break

      selected_node = self.remove_from_frontier()

      # check if the selected_node is the solution
      if selected_node.is_the_solution(self.final_state):
        print(f"Solution Found in {self.number_of_steps} steps")
        print(selected_node)
        break

      # extend the node
      new_nodes = selected_node.extend_node()

      # add the extended nodes in the frontier
      if len(new_nodes) > 0:
        for new_node in new_nodes:
          if new_node not in self.frontier and new_node not in self.checked_nodes:
            self.insert_to_frontier(new_node)
```

```python
from BFS_Algorithm import Node
class MazeNode(Node):
  """
    This class used to represent the node of a maze
    ...
    Attributes
    ----------
    graph : Dictionary
        represent the graph
    value : String
        represents the id of the vertex
    parent : MazeNode
        represents the parent of the current node

    Methods
    -------
    __eq__(self, other)
        Determines if the current node is the same with the other
    is_the_solution(self, final_state)
        Checks if the current node is the solution
    extend_node(self)
        Extends the current node, creating a new instance of MazeNode for each edge starts from c
    _find_path(self)
        Find the path (all verticies and edges from the intitial state to the final state)
    __str__(self)
        Returns the solution of the maze, the whole path vertex by vertex in order to be printed
  """

  def __init__(self, graph, value):
    self.graph = graph
    self.value = value
    self.parent = None


  def __eq__(self, other):
    """
      Check if the current node is equal with the other node.
      Parameters
```

```
      Boolean
        True: if both verticies are the same
        False: If verticies are different
    """
    if isinstance(other, MazeNode):
      return self.value == other.value
    return self.value == other


  def is_the_solution(self, final_state):
    """
      Checks if the current node is the solution
      Parameters
      ----------
      final_state : MazeNode
          The target vertex (final state) of the graph
      Returns
      -------
      Boolean
        True: if both verticies are the same, so solution has been found
        False: If verticies are different, so solution has not been found
    """
    return self.value == final_state


  def extend_node(self):
    """
      Extends the current node, creating a new instance of MazeNode for each edge starts from the
      Returns
      -------
      List
        List with all valid new nodes
    """
    children = [MazeNode(self.graph, child) for child in self.graph[self.value]]
    for child in children:
      child.parent = self
    return children

  def _find_path(self):
    """
```

```
          List with all nodes from start to end in a row
        """
        path = []
        current_node = self
        while current_node.parent is not None:
          path.insert(0, current_node.value)
          current_node = current_node.parent
        path.insert(0, current_node.value)
        return path

    def __str__(self):
        """
          Returns the solution of the maze, the whole path vertex by vertex as well as the path lengh
          Returns
          -------
          str
            the solution of the problem
        """
        total_path = self._find_path()
        path = ""
        for index in range(len(total_path)):
          if index == len(total_path) - 1:
            path += f"{total_path[index]} "
          else:
            path += f"{total_path[index]} -> "


        return path + f"\nPath lenght: {len(total_path)-1}"
```

maze.py hosted with ❤ by GitHub view raw

The last step is to create all the necessary objects and execute the program. After that, the algorithm will compute and print the shortest path from the entrance to the exit of the maze which has a length of 4 and it's the following "S" -> "B" -> "C" -> "J" -> "I".

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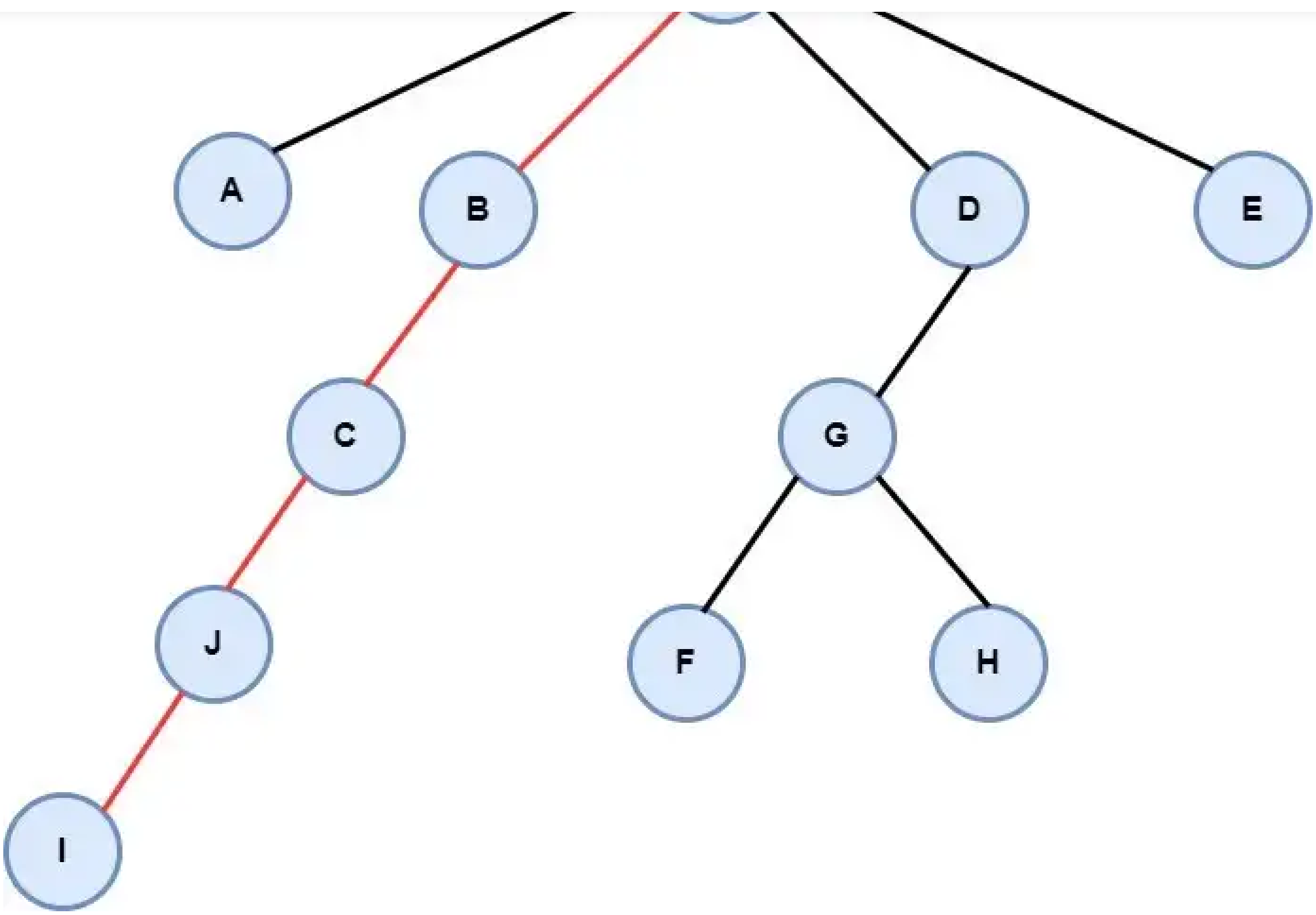

The path from node S to node I

Conclusion

In this article, we talked about Breadth-First Search (BFS) algorithm. We took a look at who this algorithm searches in the search space in order to find a solution to our problem. BFS always returns the solution that is closest to the root, which means that if the cost of each edge is the same for all edges, BFS returns the best solution.

In the second part of the article, we solved the maze problem using the BFS algorithm. Both BFS and DFS algorithms are "blind" algorithms. However, they can be used for lots of problems. In the future, we will have the opportunity to discuss and implement more "clever" algorithms such as the A* algorithm. Until then keep learning and keep

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