BÀI 2: CÁC THUẬT TOÁN TÌM KIẾM: BFS, DFS VÀ UCS(tiếp theo)

I. MỤC TIÊU:

Sau khi thực hành xong, sinh viên nắm được:

- Thuật toán BFS, DFS trên cây tìm kiếm.
- Cài đặt được các thuật toán này trên máy tính.

II. TÓM TẮT LÝ THUYẾT:

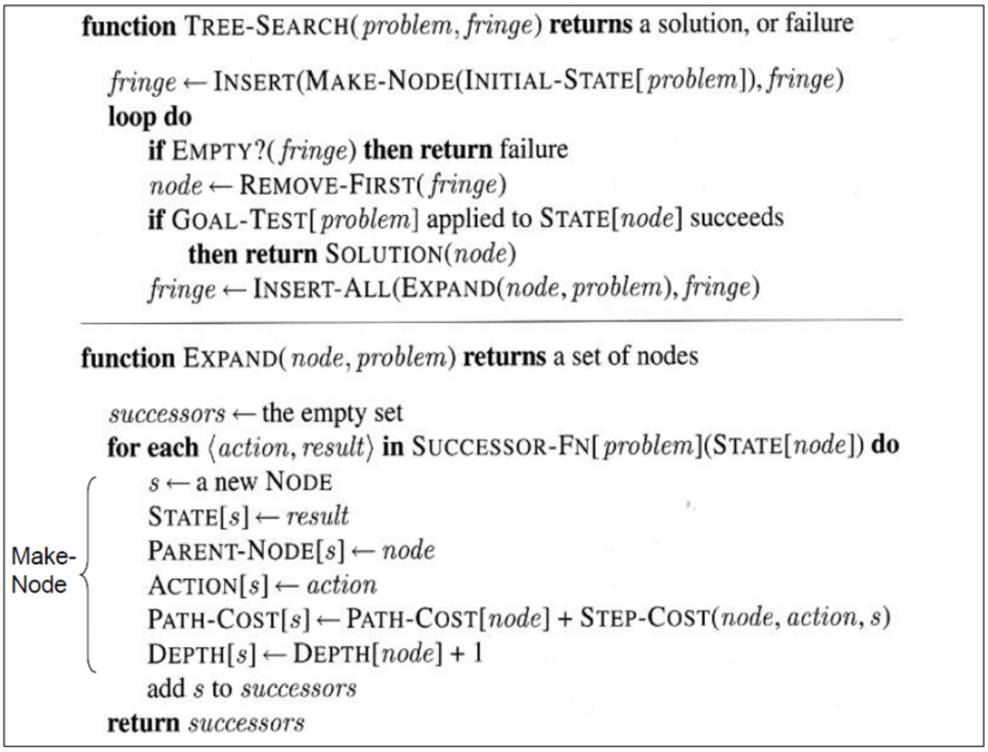
1. Cấu trúc dữ liệu của các node trong cây tìm kiếm:

- State: trạng thái trong không gian trạng thái.
- Node: chứa 1 trạng thái, con trỏ tới predecessor, độ sâu, và chi phí đường đi, hành động.
- Depth: số bước dọc theo đường đi từ trạng thái ban đầu.
- Path Cost: chi phí đường đi từ trạng thái ban đầu tới node.
- Fringe: bộ nhớ lưu trữ các node mở rộng. Ví dụ, s là stack hoặc hàng đợi.

2. Các hàm thực thi:

- Make-Node(state): khởi tạo 1 node từ 1 trạng thái (state).
- Goal-Test(state): trả về true nếu state là trạng thái kết thúc.
- Successor-Fn(state): thực thi các hàm successor (mở rộng một tập các node mới với tất cả các hành động có thể áp dụng trong trạng thái).
- Cost(state, action): trả về chi phí thực thi hành động trong trạng thái.
- Insert(node, fringe): thêm 1 node mới vào fringe.
- Remove-First(fringe): trả về node đầu tiên từ fringe.

3. General Tree-Search Procedure:



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function TREE-SEARCH(problem, fringe) returns a solution, or failure

  fringe ← INSERT(MAKE-NODE(INITIAL-STATE[problem]), fringe)
  loop do
      if EMPTY?(fringe) then return failure
      node ← REMOVE-FIRST(fringe)
      if GOAL-TEST[problem] applied to STATE[node] succeeds
          then return SOLUTION(node)
      fringe ← INSERT-ALL(EXPAND(node, problem), fringe)
-----------------------------------------------------------------------
function EXPAND(node, problem) returns a set of nodes

  successors ← the empty set
  for each ⟨action, result⟩ in SUCCESSOR-FN[problem](STATE[node]) do
      s ← a new NODE
      STATE[s] ← result
Make- PARENT-NODE[s] ← node
Node  ACTION[s] ← action
      PATH-COST[s] ← PATH-COST[node] + STEP-COST(node, action, s)
      DEPTH[s] ← DEPTH[node] + 1
      add s to successors
  return successors
```

4. Thuật toán BFS:

5. Thuật toán DFS:

III. NỘI DUNG THỰC HÀNH:

1. Bài toán:

Có 3 người truyền giáo và 3 con quỷ ở bờ bên trái của một con sông, cùng với con thuyền có thể chở được 1 hoặc 2 người. Nếu số quỷ nhiều hơn số người truyền giáo trong một bờ thì số quỷ sẽ ăn thịt số người truyền giáo. Tìm các để đưa tất cả qua bờ sông bên kia (bên phải) sao cho số người không ít hơn số quỷ ở cùng 1 bờ (bên trái hay bên phải), nghĩa là không ai bị ăn thịt. Gọi (a, b, k) với $0 \leqslant a, b \leqslant 3$, trong đó a là số người, b là số con quỷ ở bên bờ bên trái, $k = 1$ nếu thuyền ở bờ bên trái và $k = 0$ nếu thuyền ở bờ bên phải. Khi đó, không gian trạng thái của bài toán được xác định như sau:

- Trạng thái ban đầu là (3, 3, 1).
- Thuyền chở qua sông 1 người, hoặc 1 con quỷ , hoặc 1 người và 1 con quỷ, hoặc 2 người, hoặc 2 con quỷ $\Rightarrow$ các phép toán chuyển từ trạng thái này sang trạng thái khác là: (1, 0), (0, 1), (1, 1), (2, 0), (0, 2) (trong đó (x, y) là số người và số quỷ di chuyển từ bờ bên trái qua bờ bên phải hay ngược lại).
- Trạng thái kết thúc là (0, 0, 0).

2. Cây tìm kiếm(state_space_20.png):

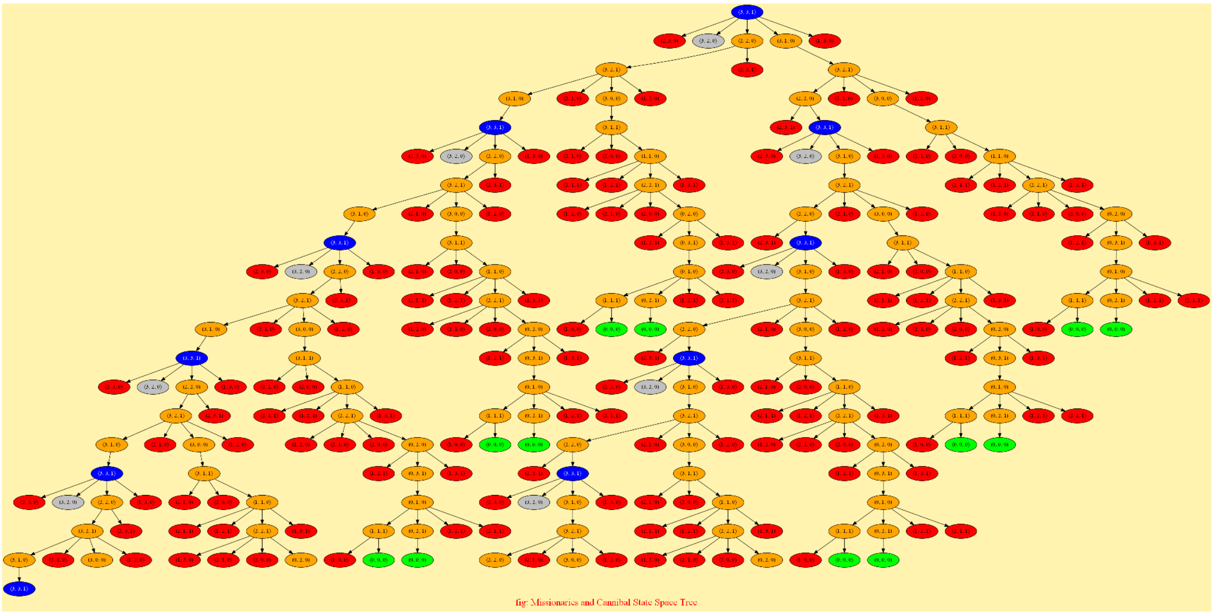
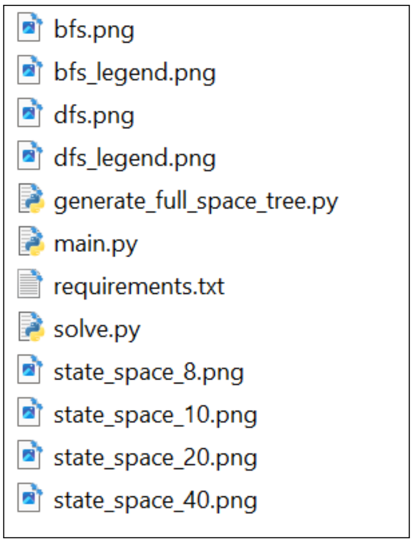
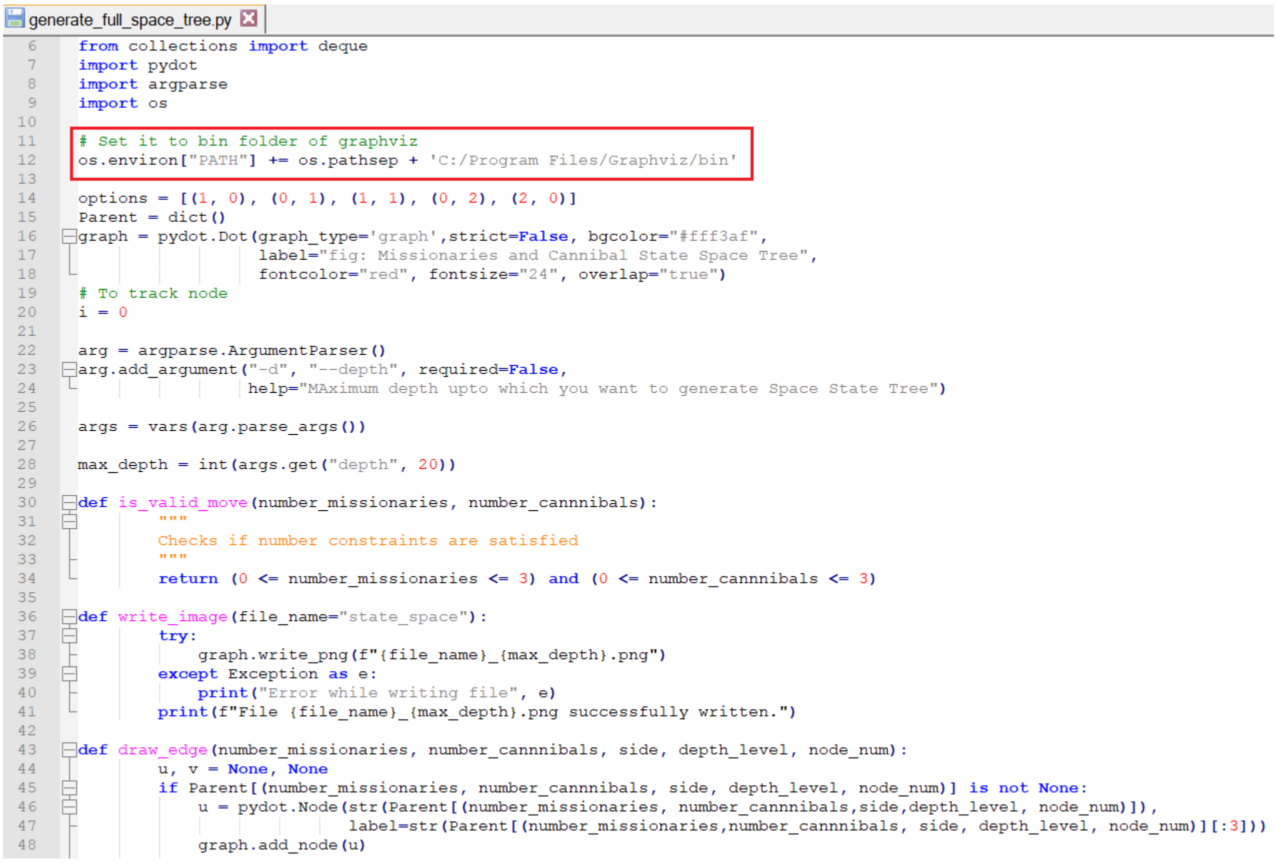


fig: Missionaries and Cannibal State Space Tree

3. Cài đặt:

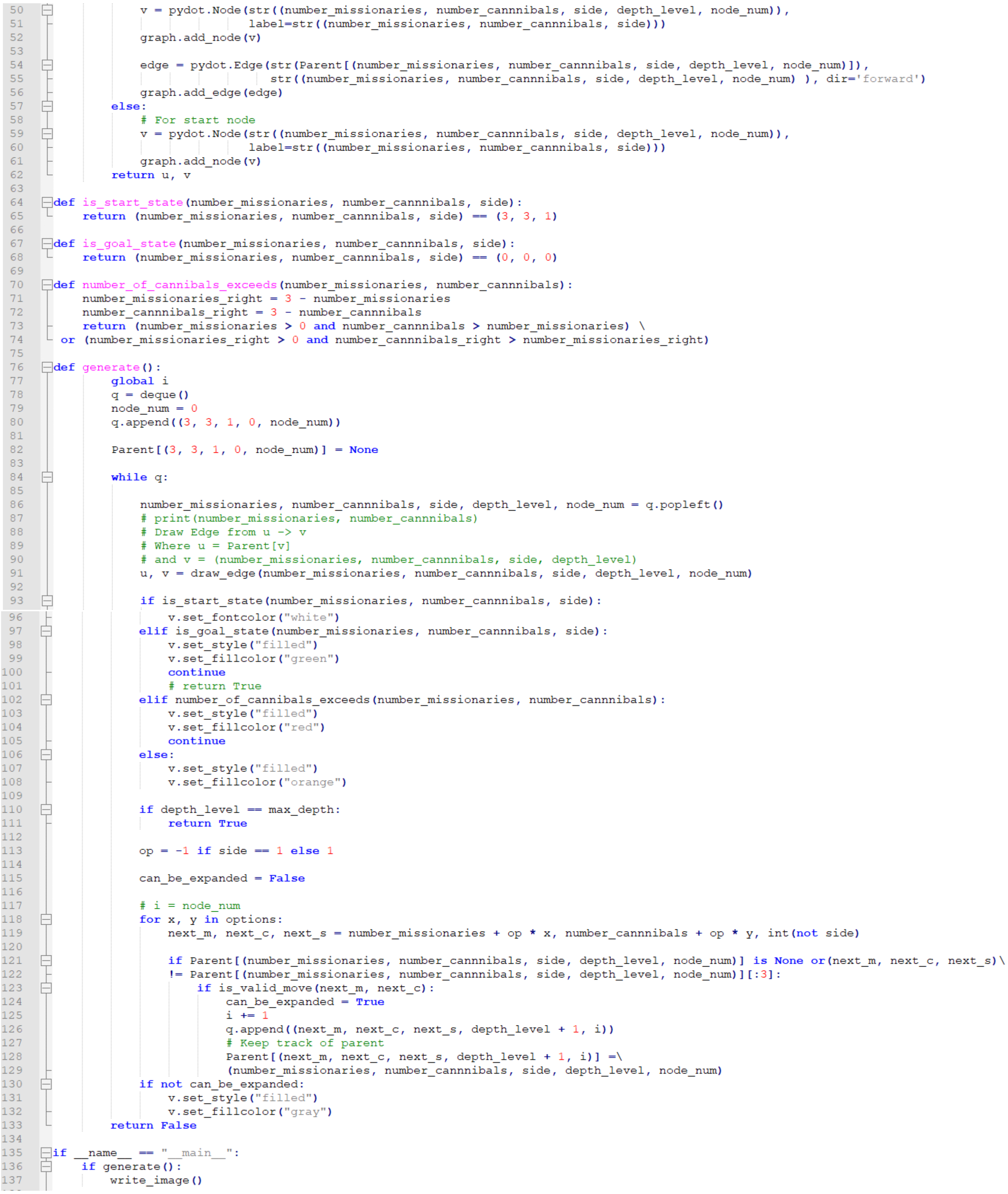


bfs.png
bfs_legend.png
dfs.png
dfs_legend.png
generate_full_space_tree.py
main.py
requirements.txt
solve.py
state_space_8.png
state_space_10.png
state_space_20.png
state_space_40.png

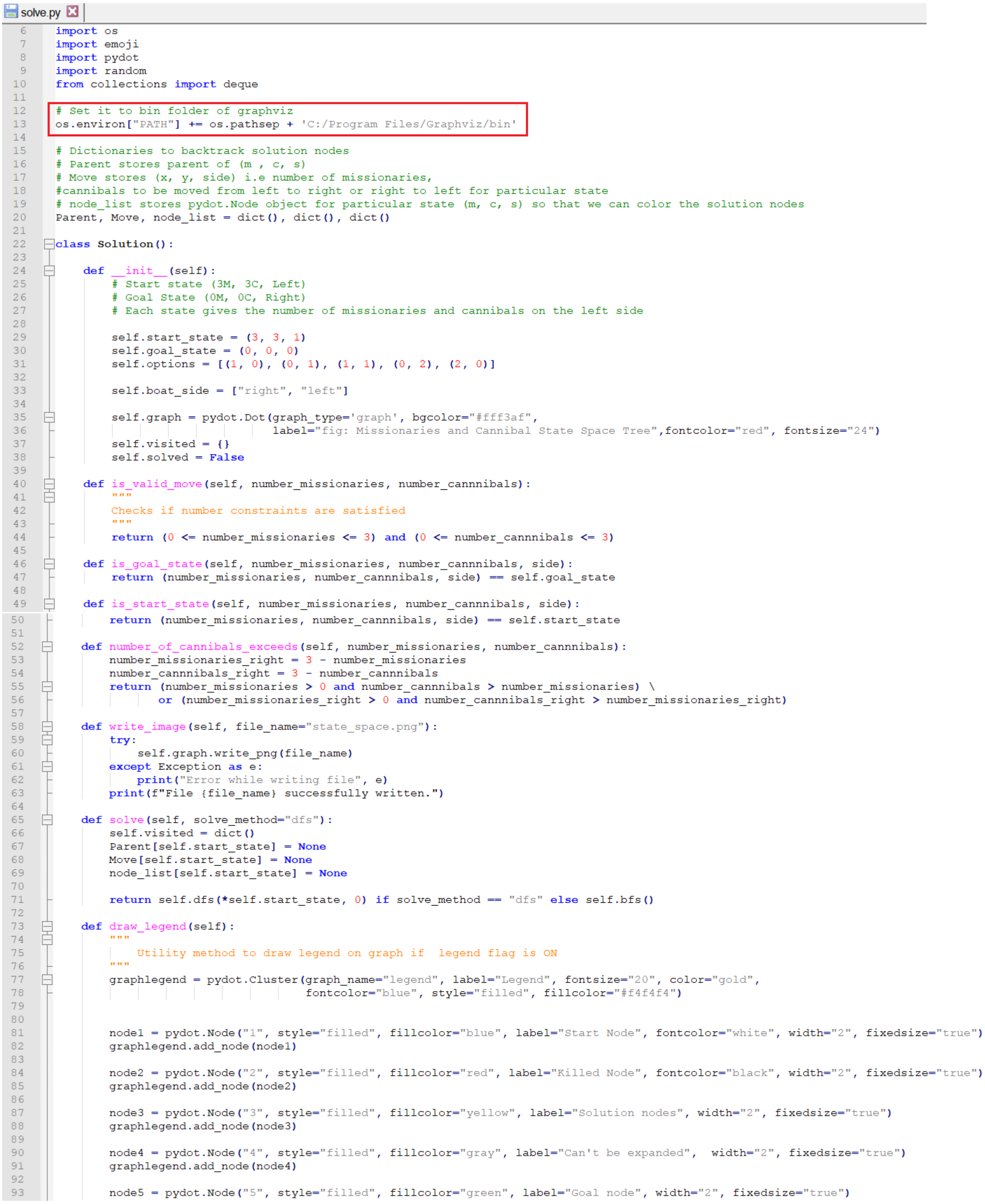


generate_full_space_tree.py

```python
from collections import deque
import pydot
import argparse
import os

# Set it to bin folder of graphviz
os.environ["PATH"] += os.pathsep + 'C:/Program Files/Graphviz/bin'

options = [(1, 0), (0, 1), (1, 1), (0, 2), (2, 0)]
Parent = dict()
graph = pydot.Dot(graph_type='graph',strict=False, bgcolor="#fff3af",
                  label="fig: Missionaries and Cannibal State Space Tree",
                  fontcolor="red", fontsize="24", overlap="true")
# To track node
i = 0

arg = argparse.ArgumentParser()
arg.add_argument("-d", "--depth", required=False,
                 help="MAximum depth upto which you want to generate Space State Tree")

args = vars(arg.parse_args())

max_depth = int(args.get("depth", 20))

def is_valid_move(number_missionaries, number_cannnibals):
        """
        Checks if number constraints are satisfied
        """
        return (0 <= number_missionaries <= 3) and (0 <= number_cannnibals <= 3)

def write_image(file_name="state_space"):
        try:
            graph.write_png(f"{file_name}_{max_depth}.png")
        except Exception as e:
            print("Error while writing file", e)
        print(f"File {file_name}_{max_depth}.png successfully written.")

def draw_edge(number_missionaries, number_cannnibals, side, depth_level, node_num):
        u, v = None, None
        if Parent[(number_missionaries, number_cannnibals, side, depth_level, node_num)] is not None:
            u = pydot.Node(str(Parent[(number_missionaries, number_cannnibals,side,depth_level, node_num)]),
                           label=str(Parent[(number_missionaries,number_cannnibals, side, depth_level, node_num)][:3]))
            graph.add_node(u)
```



```
            v = pydot.Node(str((number_missionaries, number_cannnibals, side, depth_level, node_num)),
                           label=str((number_missionaries, number_cannnibals, side)))
            graph.add_node(v)

            edge = pydot.Edge(str(Parent[(number_missionaries, number_cannnibals, side, depth_level, node_num)]),
                              str((number_missionaries, number_cannnibals, side, depth_level, node_num) ), dir='forward')
            graph.add_edge(edge)
        else:
            # For start node
            v = pydot.Node(str((number_missionaries, number_cannnibals, side, depth_level, node_num)),
                           label=str((number_missionaries, number_cannnibals, side)))
            graph.add_node(v)
        return u, v

def is_start_state(number_missionaries, number_cannnibals, side):
    return (number_missionaries, number_cannnibals, side) == (3, 3, 1)

def is_goal_state(number_missionaries, number_cannnibals, side):
    return (number_missionaries, number_cannnibals, side) == (0, 0, 0)

def number_of_cannibals_exceeds(number_missionaries, number_cannnibals):
    number_missionaries_right = 3 - number_missionaries
    number_cannnibals_right = 3 - number_cannnibals
    return (number_missionaries > 0 and number_cannnibals > number_missionaries) \
 or (number_missionaries_right > 0 and number_cannnibals_right > number_missionaries_right)

def generate():
        global i
        q = deque()
        node_num = 0
        q.append((3, 3, 1, 0, node_num))

        Parent[(3, 3, 1, 0, node_num)] = None

        while q:

            number_missionaries, number_cannnibals, side, depth_level, node_num = q.popleft()
            # print(number_missionaries, number_cannnibals)
            # Draw Edge from u -> v
            # Where u = Parent[v]
            # and v = (number_missionaries, number_cannnibals, side, depth_level)
            u, v = draw_edge(number_missionaries, number_cannnibals, side, depth_level, node_num)

            if is_start_state(number_missionaries, number_cannnibals, side):
                v.set_fontcolor("white")
            elif is_goal_state(number_missionaries, number_cannnibals, side):
                v.set_style("filled")
                v.set_fillcolor("green")
                continue
                # return True
            elif number_of_cannibals_exceeds(number_missionaries, number_cannnibals):
                v.set_style("filled")
                v.set_fillcolor("red")
                continue
            else:
                v.set_style("filled")
                v.set_fillcolor("orange")

            if depth_level == max_depth:
                return True

            op = -1 if side == 1 else 1

            can_be_expanded = False

            # i = node_num
            for x, y in options:
                next_m, next_c, next_s = number_missionaries + op * x, number_cannnibals + op * y, int(not side)

                if Parent[(number_missionaries, number_cannnibals, side, depth_level, node_num)] is None or(next_m, next_c, next_s)\
                != Parent[(number_missionaries, number_cannnibals, side, depth_level, node_num)][:3]:
                    if is_valid_move(next_m, next_c):
                        can_be_expanded = True
                        i += 1
                        q.append((next_m, next_c, next_s, depth_level + 1, i))
                        # Keep track of parent
                        Parent[(next_m, next_c, next_s, depth_level + 1, i)] =\
                        (number_missionaries, number_cannnibals, side, depth_level, node_num)
            if not can_be_expanded:
                v.set_style("filled")
                v.set_fillcolor("gray")
        return False

if __name__ == "__main__":
    if generate():
        write_image()
```



```python
import os
import emoji
import pydot
import random
from collections import deque

# Set it to bin folder of graphviz
os.environ["PATH"] += os.pathsep + 'C:/Program Files/Graphviz/bin'

# Dictionaries to backtrack solution nodes
# Parent stores parent of (m , c, s)
# Move stores (x, y, side) i.e number of missionaries,
#cannibals to be moved from left to right or right to left for particular state
# node_list stores pydot.Node object for particular state (m, c, s) so that we can color the solution nodes
Parent, Move, node_list = dict(), dict(), dict()

class Solution():

    def __init__(self):
        # Start state (3M, 3C, Left)
        # Goal State (0M, 0C, Right)
        # Each state gives the number of missionaries and cannibals on the left side

        self.start_state = (3, 3, 1)
        self.goal_state = (0, 0, 0)
        self.options = [(1, 0), (0, 1), (1, 1), (0, 2), (2, 0)]

        self.boat_side = ["right", "left"]

        self.graph = pydot.Dot(graph_type='graph', bgcolor="#fff3af",
                               label="fig: Missionaries and Cannibal State Space Tree",fontcolor="red", fontsize="24")
        self.visited = {}
        self.solved = False

    def is_valid_move(self, number_missionaries, number_cannnibals):
        """
        Checks if number constraints are satisfied
        """
        return (0 <= number_missionaries <= 3) and (0 <= number_cannnibals <= 3)

    def is_goal_state(self, number_missionaries, number_cannnibals, side):
        return (number_missionaries, number_cannnibals, side) == self.goal_state

    def is_start_state(self, number_missionaries, number_cannnibals, side):
        return (number_missionaries, number_cannnibals, side) == self.start_state

    def number_of_cannibals_exceeds(self, number_missionaries, number_cannnibals):
        number_missionaries_right = 3 - number_missionaries
        number_cannnibals_right = 3 - number_cannnibals
        return (number_missionaries > 0 and number_cannnibals > number_missionaries) \
               or (number_missionaries_right > 0 and number_cannnibals_right > number_missionaries_right)

    def write_image(self, file_name="state_space.png"):
        try:
            self.graph.write_png(file_name)
        except Exception as e:
            print("Error while writing file", e)
        print(f"File {file_name} successfully written.")

    def solve(self, solve_method="dfs"):
        self.visited = dict()
        Parent[self.start_state] = None
        Move[self.start_state] = None
        node_list[self.start_state] = None

        return self.dfs(*self.start_state, 0) if solve_method == "dfs" else self.bfs()

    def draw_legend(self):
        """
            Utility method to draw legend on graph if  legend flag is ON
        """
        graphlegend = pydot.Cluster(graph_name="legend", label="Legend", fontsize="20", color="gold",
                                    fontcolor="blue", style="filled", fillcolor="#f4f4f4")

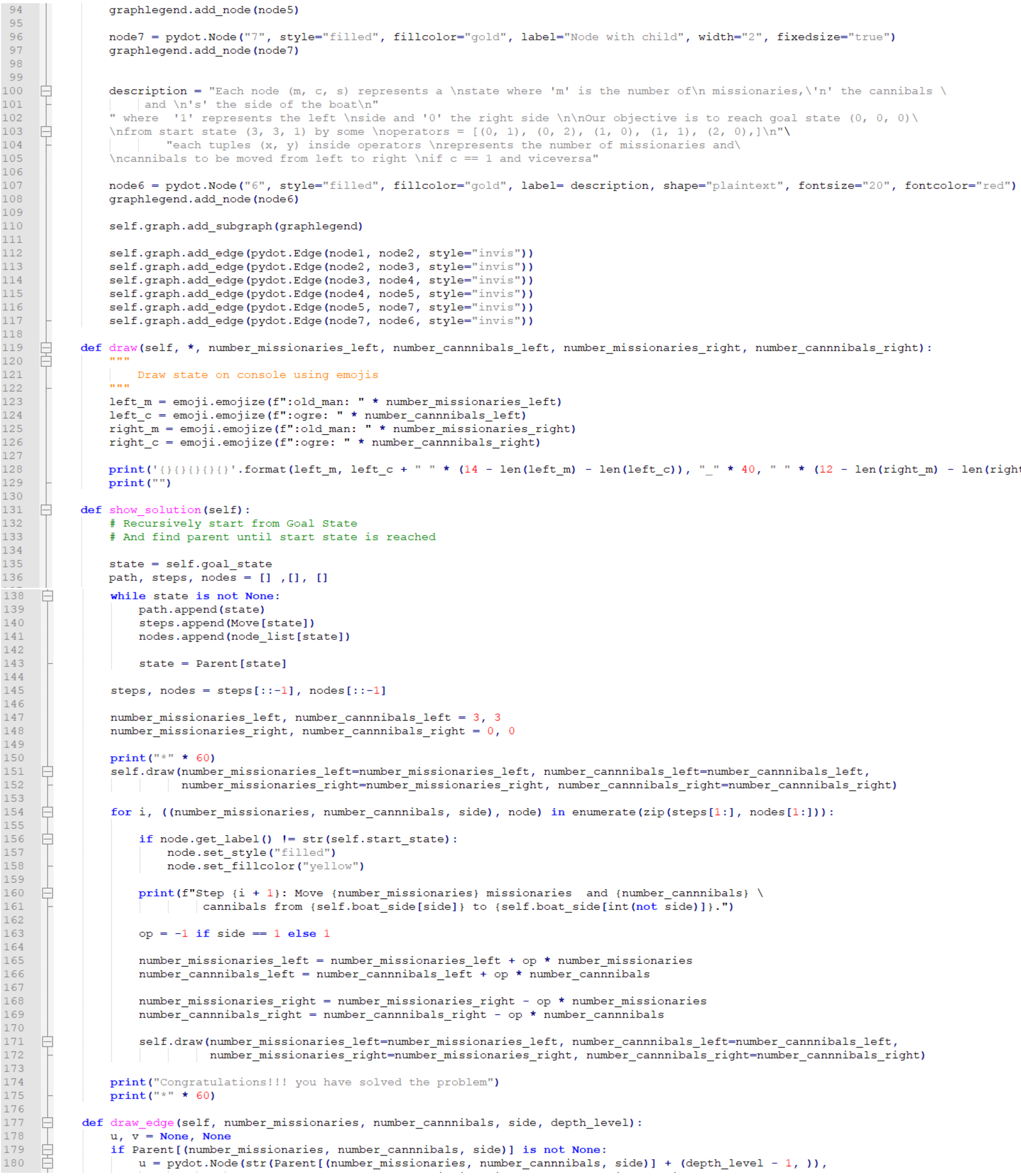

        node1 = pydot.Node("1", style="filled", fillcolor="blue", label="Start Node", fontcolor="white", width="2", fixedsize="true")
        graphlegend.add_node(node1)

        node2 = pydot.Node("2", style="filled", fillcolor="red", label="Killed Node", fontcolor="black", width="2", fixedsize="true")
        graphlegend.add_node(node2)

        node3 = pydot.Node("3", style="filled", fillcolor="yellow", label="Solution nodes", width="2", fixedsize="true")
        graphlegend.add_node(node3)

        node4 = pydot.Node("4", style="filled", fillcolor="gray", label="Can't be expanded",  width="2", fixedsize="true")
        graphlegend.add_node(node4)

        node5 = pydot.Node("5", style="filled", fillcolor="green", label="Goal node", width="2", fixedsize="true")
```



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        graphlegend.add_node(node5)

        node7 = pydot.Node("7", style="filled", fillcolor="gold", label="Node with child", width="2", fixedsize="true")
        graphlegend.add_node(node7)


        description = "Each node (m, c, s) represents a \nstate where 'm' is the number of\n missionaries,\'n' the cannibals \
            and \n's' the side of the boat\n"
        " where  '1' represents the left \nside and '0' the right side \n\nOur objective is to reach goal state (0, 0, 0)\
        \nfrom start state (3, 3, 1) by some \noperators = [(0, 1), (0, 2), (1, 0), (1, 1), (2, 0),]\n"\
                "each tuples (x, y) inside operators \nrepresents the number of missionaries and\
        \ncannibals to be moved from left to right \nif c == 1 and viceversa"

        node6 = pydot.Node("6", style="filled", fillcolor="gold", label= description, shape="plaintext", fontsize="20", fontcolor="red")
        graphlegend.add_node(node6)

        self.graph.add_subgraph(graphlegend)

        self.graph.add_edge(pydot.Edge(node1, node2, style="invis"))
        self.graph.add_edge(pydot.Edge(node2, node3, style="invis"))
        self.graph.add_edge(pydot.Edge(node3, node4, style="invis"))
        self.graph.add_edge(pydot.Edge(node4, node5, style="invis"))
        self.graph.add_edge(pydot.Edge(node5, node7, style="invis"))
        self.graph.add_edge(pydot.Edge(node7, node6, style="invis"))

    def draw(self, *, number_missionaries_left, number_cannnibals_left, number_missionaries_right, number_cannnibals_right):
        """
            Draw state on console using emojis
        """
        left_m = emoji.emojize(f":old_man: " * number_missionaries_left)
        left_c = emoji.emojize(f":ogre: " * number_cannnibals_left)
        right_m = emoji.emojize(f":old_man: " * number_missionaries_right)
        right_c = emoji.emojize(f":ogre: " * number_cannnibals_right)

        print('{}{}{}{}{}'.format(left_m, left_c + " " * (14 - len(left_m) - len(left_c)), "_" * 40, " " * (12 - len(right_m) - len(right
        print("")

    def show_solution(self):
        # Recursively start from Goal State
        # And find parent until start state is reached

        state = self.goal_state
        path, steps, nodes = [] ,[], []
        while state is not None:
            path.append(state)
            steps.append(Move[state])
            nodes.append(node_list[state])

            state = Parent[state]

        steps, nodes = steps[::-1], nodes[::-1]

        number_missionaries_left, number_cannnibals_left = 3, 3
        number_missionaries_right, number_cannnibals_right = 0, 0

        print("*" * 60)
        self.draw(number_missionaries_left=number_missionaries_left, number_cannnibals_left=number_cannnibals_left,
                  number_missionaries_right=number_missionaries_right, number_cannnibals_right=number_cannnibals_right)

        for i, ((number_missionaries, number_cannnibals, side), node) in enumerate(zip(steps[1:], nodes[1:])):

            if node.get_label() != str(self.start_state):
                node.set_style("filled")
                node.set_fillcolor("yellow")

            print(f"Step {i + 1}: Move {number_missionaries} missionaries  and {number_cannnibals} \
                 cannibals from {self.boat_side[side]} to {self.boat_side[int(not side)]}.")

            op = -1 if side == 1 else 1

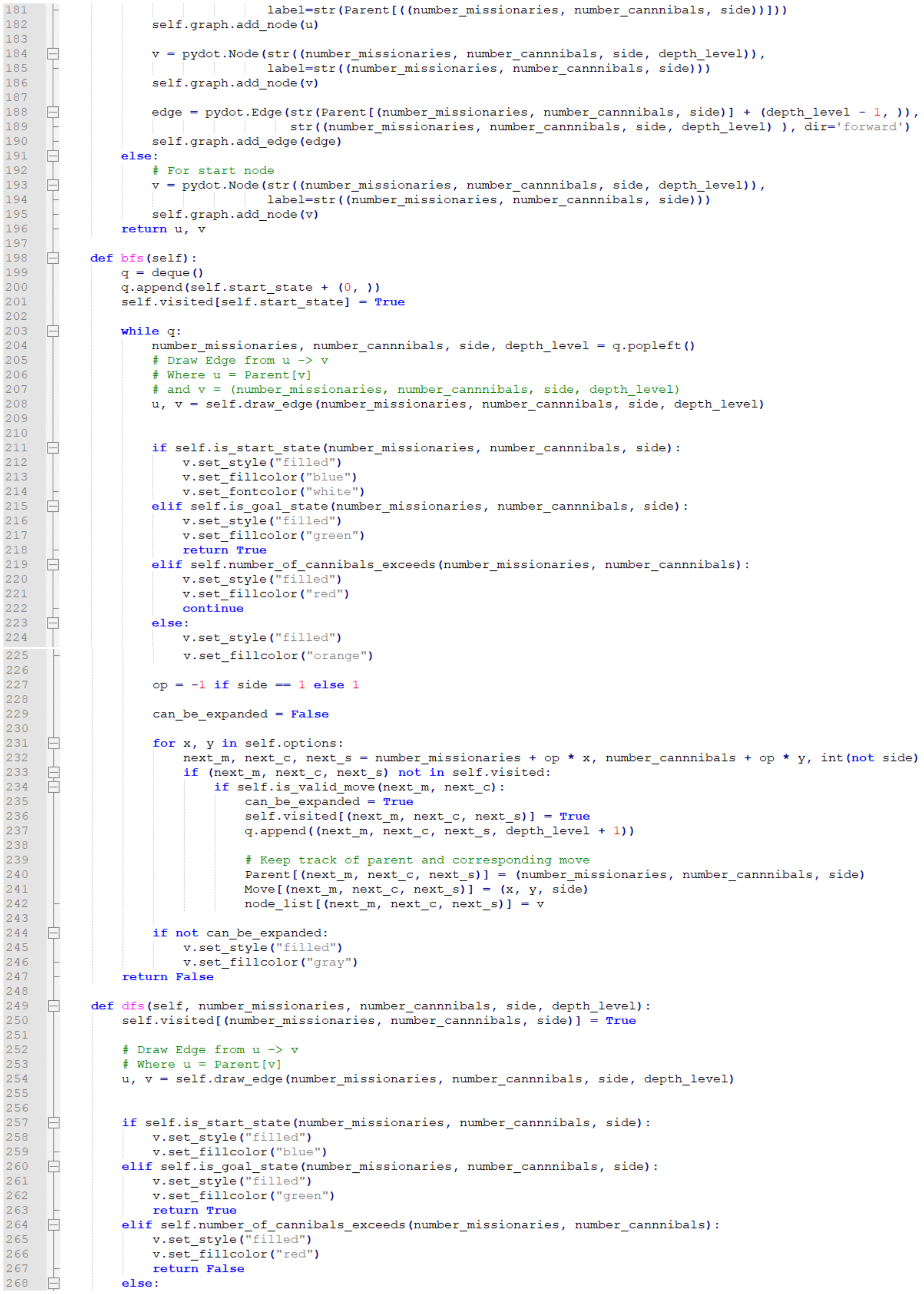
            number_missionaries_left = number_missionaries_left + op * number_missionaries
            number_cannnibals_left = number_cannnibals_left + op * number_cannnibals

            number_missionaries_right = number_missionaries_right - op * number_missionaries
            number_cannnibals_right = number_cannnibals_right - op * number_cannnibals

            self.draw(number_missionaries_left=number_missionaries_left, number_cannnibals_left=number_cannnibals_left,
                      number_missionaries_right=number_missionaries_right, number_cannnibals_right=number_cannnibals_right)

        print("Congratulations!!! you have solved the problem")
        print("*" * 60)

    def draw_edge(self, number_missionaries, number_cannnibals, side, depth_level):
        u, v = None, None
        if Parent[(number_missionaries, number_cannnibals, side)] is not None:
            u = pydot.Node(str(Parent[(number_missionaries, number_cannnibals, side)] + (depth_level - 1, )),
```



```
                           label=str(Parent[((number_missionaries, number_cannnibals, side))]))
            self.graph.add_node(u)

            v = pydot.Node(str((number_missionaries, number_cannnibals, side, depth_level)),
                           label=str((number_missionaries, number_cannnibals, side)))
            self.graph.add_node(v)

            edge = pydot.Edge(str(Parent[(number_missionaries, number_cannnibals, side)] + (depth_level - 1, )),
                              str((number_missionaries, number_cannnibals, side, depth_level) ), dir='forward')
            self.graph.add_edge(edge)
        else:
            # For start node
            v = pydot.Node(str((number_missionaries, number_cannnibals, side, depth_level)),
                           label=str((number_missionaries, number_cannnibals, side)))
            self.graph.add_node(v)
        return u, v

    def bfs(self):
        q = deque()
        q.append(self.start_state + (0, ))
        self.visited[self.start_state] = True

        while q:
            number_missionaries, number_cannnibals, side, depth_level = q.popleft()
            # Draw Edge from u -> v
            # Where u = Parent[v]
            # and v = (number_missionaries, number_cannnibals, side, depth_level)
            u, v = self.draw_edge(number_missionaries, number_cannnibals, side, depth_level)


            if self.is_start_state(number_missionaries, number_cannnibals, side):
                v.set_style("filled")
                v.set_fillcolor("blue")
                v.set_fontcolor("white")
            elif self.is_goal_state(number_missionaries, number_cannnibals, side):
                v.set_style("filled")
                v.set_fillcolor("green")
                return True
            elif self.number_of_cannibals_exceeds(number_missionaries, number_cannnibals):
                v.set_style("filled")
                v.set_fillcolor("red")
                continue
            else:
                v.set_style("filled")
                v.set_fillcolor("orange")

            op = -1 if side == 1 else 1

            can_be_expanded = False

            for x, y in self.options:
                next_m, next_c, next_s = number_missionaries + op * x, number_cannnibals + op * y, int(not side)
                if (next_m, next_c, next_s) not in self.visited:
                    if self.is_valid_move(next_m, next_c):
                        can_be_expanded = True
                        self.visited[(next_m, next_c, next_s)] = True
                        q.append((next_m, next_c, next_s, depth_level + 1))

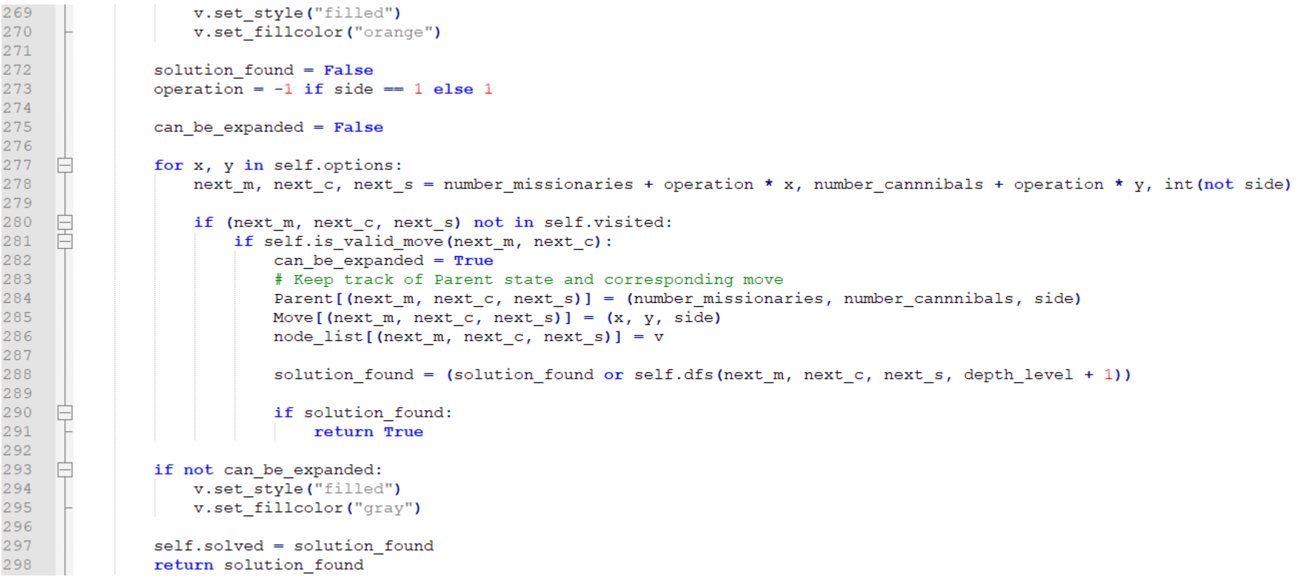
                        # Keep track of parent and corresponding move
                        Parent[(next_m, next_c, next_s)] = (number_missionaries, number_cannnibals, side)
                        Move[(next_m, next_c, next_s)] = (x, y, side)
                        node_list[(next_m, next_c, next_s)] = v

            if not can_be_expanded:
                v.set_style("filled")
                v.set_fillcolor("gray")
        return False

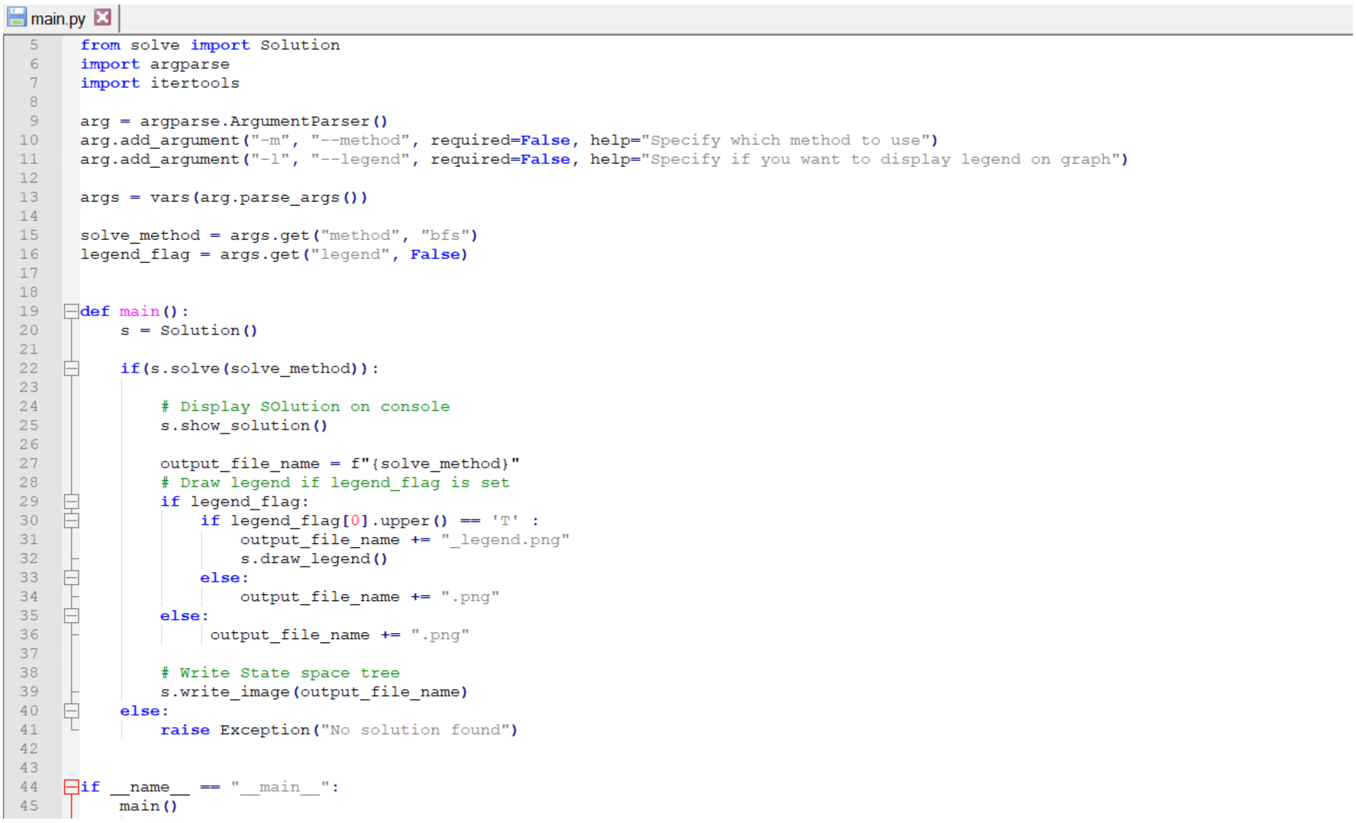
    def dfs(self, number_missionaries, number_cannnibals, side, depth_level):
        self.visited[(number_missionaries, number_cannnibals, side)] = True

        # Draw Edge from u -> v
        # Where u = Parent[v]
        u, v = self.draw_edge(number_missionaries, number_cannnibals, side, depth_level)


        if self.is_start_state(number_missionaries, number_cannnibals, side):
            v.set_style("filled")
            v.set_fillcolor("blue")
        elif self.is_goal_state(number_missionaries, number_cannnibals, side):
            v.set_style("filled")
            v.set_fillcolor("green")
            return True
        elif self.number_of_cannibals_exceeds(number_missionaries, number_cannnibals):
            v.set_style("filled")
            v.set_fillcolor("red")
            return False
        else:
```



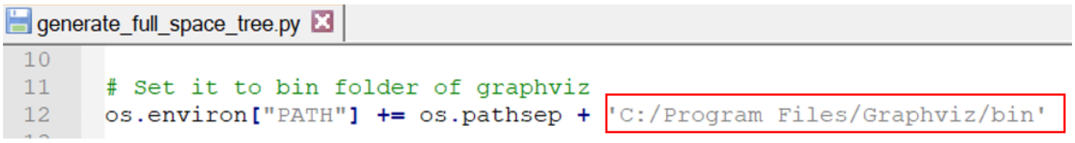
```python
            v.set_style("filled")
            v.set_fillcolor("orange")

        solution_found = False
        operation = -1 if side == 1 else 1

        can_be_expanded = False

        for x, y in self.options:
            next_m, next_c, next_s = number_missionaries + operation * x, number_cannnibals + operation * y, int(not side)

            if (next_m, next_c, next_s) not in self.visited:
                if self.is_valid_move(next_m, next_c):
                    can_be_expanded = True
                    # Keep track of Parent state and corresponding move
                    Parent[(next_m, next_c, next_s)] = (number_missionaries, number_cannnibals, side)
                    Move[(next_m, next_c, next_s)] = (x, y, side)
                    node_list[(next_m, next_c, next_s)] = v

                    solution_found = (solution_found or self.dfs(next_m, next_c, next_s, depth_level + 1))

                    if solution_found:
                        return True

        if not can_be_expanded:
            v.set_style("filled")
            v.set_fillcolor("gray")

        self.solved = solution_found
        return solution_found
```



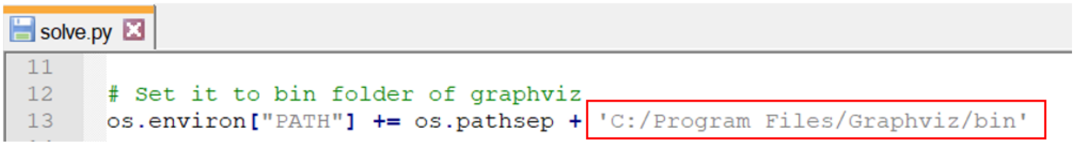
main.py

```python
from solve import Solution
import argparse
import itertools

arg = argparse.ArgumentParser()
arg.add_argument("-m", "--method", required=False, help="Specify which method to use")
arg.add_argument("-l", "--legend", required=False, help="Specify if you want to display legend on graph")

args = vars(arg.parse_args())

solve_method = args.get("method", "bfs")
legend_flag = args.get("legend", False)


def main():
    s = Solution()

    if(s.solve(solve_method)):

        # Display SOlution on console
        s.show_solution()

        output_file_name = f"{solve_method}"
        # Draw legend if legend_flag is set
        if legend_flag:
            if legend_flag[0].upper() == 'T' :
                output_file_name += "_legend.png"
                s.draw_legend()
            else:
                output_file_name += ".png"
        else:
            output_file_name += ".png"

        # Write State space tree
        s.write_image(output_file_name)
    else:
        raise Exception("No solution found")

if __name__ == "__main__":
    main()
```

a. **Cài đặt thư viện graphviz** tải về từ link: `https://graphviz.org/download/` và đặt đường dẫn tới thư mục bin của graphviz đã cài đặt trên máy tính.

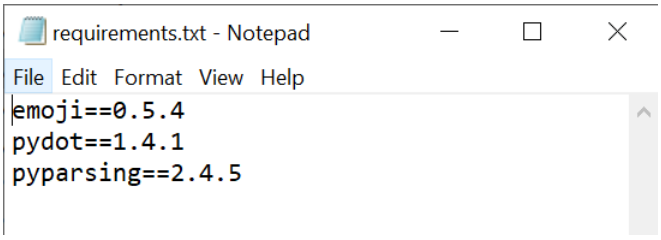


```
# Set it to bin folder of graphviz
os.environ["PATH"] += os.pathsep + 'C:/Program Files/Graphviz/bin'
```



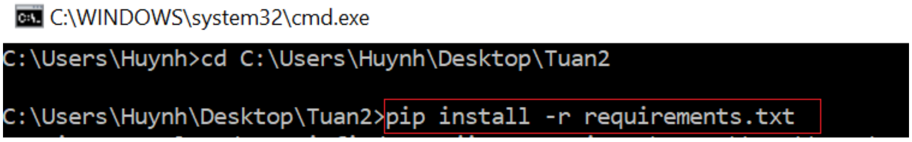
```
# Set it to bin folder of graphviz
os.environ["PATH"] += os.pathsep + 'C:/Program Files/Graphviz/bin'
```

b. Cài đặt các yêu cầu trong file "requirements.txt":



```
emoji==0.5.4
pydot==1.4.1
pyparsing==2.4.5
```

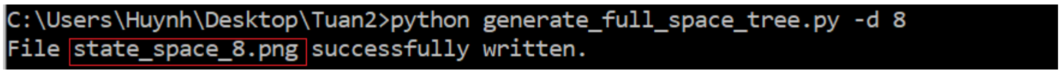
pip install -r requirements.txt



```
C:\Users\Huynh>cd C:\Users\Huynh\Desktop\Tuan2

C:\Users\Huynh\Desktop\Tuan2>pip install -r requirements.txt
```

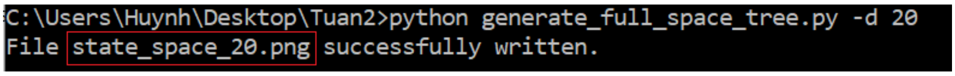
c. Khởi tạo cây không gian trạng thái:

python generate_full_space_tree.py -d 8 (với d là độ sâu (depth=8))



```
C:\Users\Huynh\Desktop\Tuan2>python generate_full_space_tree.py -d 8
File state_space_8.png successfully written.
```

python generate_full_space_tree.py -d 20 (depth = 20)



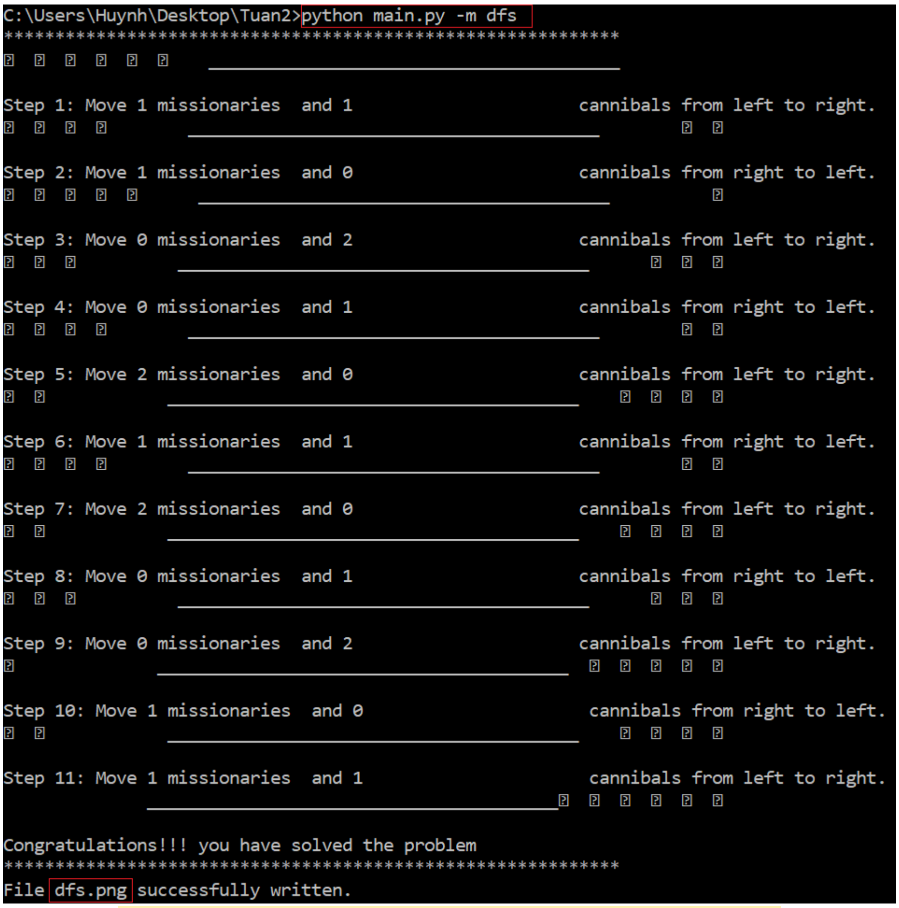
```
C:\Users\Huynh\Desktop\Tuan2>python generate_full_space_tree.py -d 20
File state_space_20.png successfully written.
```

Làm tương tự với depth = 10, depth = 40, ...

d. Cây DFS:

- DFS:

python main.py -m dfs



```
C:\Users\Huynh\Desktop\Tuan2>python main.py -m dfs
************************************************************
⍰  ⍰  ⍰  ⍰  ⍰  ⍰    ________________________________________

Step 1: Move 1 missionaries  and 1                      cannibals from left to right.
⍰  ⍰  ⍰  ⍰        ________________________________________        ⍰  ⍰

Step 2: Move 1 missionaries  and 0                      cannibals from right to left.
⍰  ⍰  ⍰  ⍰  ⍰      ________________________________________          ⍰

Step 3: Move 0 missionaries  and 2                      cannibals from left to right.
⍰  ⍰  ⍰          ________________________________________      ⍰  ⍰  ⍰

Step 4: Move 0 missionaries  and 1                      cannibals from right to left.
⍰  ⍰  ⍰  ⍰        ________________________________________        ⍰  ⍰

Step 5: Move 2 missionaries  and 0                      cannibals from left to right.
⍰  ⍰            ________________________________________    ⍰  ⍰  ⍰  ⍰

Step 6: Move 1 missionaries  and 1                      cannibals from right to left.
⍰  ⍰  ⍰  ⍰        ________________________________________        ⍰  ⍰

Step 7: Move 2 missionaries  and 0                      cannibals from left to right.
⍰  ⍰            ________________________________________    ⍰  ⍰  ⍰  ⍰

Step 8: Move 0 missionaries  and 1                      cannibals from right to left.
⍰  ⍰  ⍰          ________________________________________      ⍰  ⍰  ⍰

Step 9: Move 0 missionaries  and 2                      cannibals from left to right.
⍰              ________________________________________  ⍰  ⍰  ⍰  ⍰  ⍰

Step 10: Move 1 missionaries  and 0                      cannibals from right to left.
⍰  ⍰            ________________________________________    ⍰  ⍰  ⍰  ⍰

Step 11: Move 1 missionaries  and 1                      cannibals from left to right.
              ________________________________________⍰  ⍰  ⍰  ⍰  ⍰  ⍰

Congratulations!!! you have solved the problem
************************************************************
File dfs.png successfully written.
```

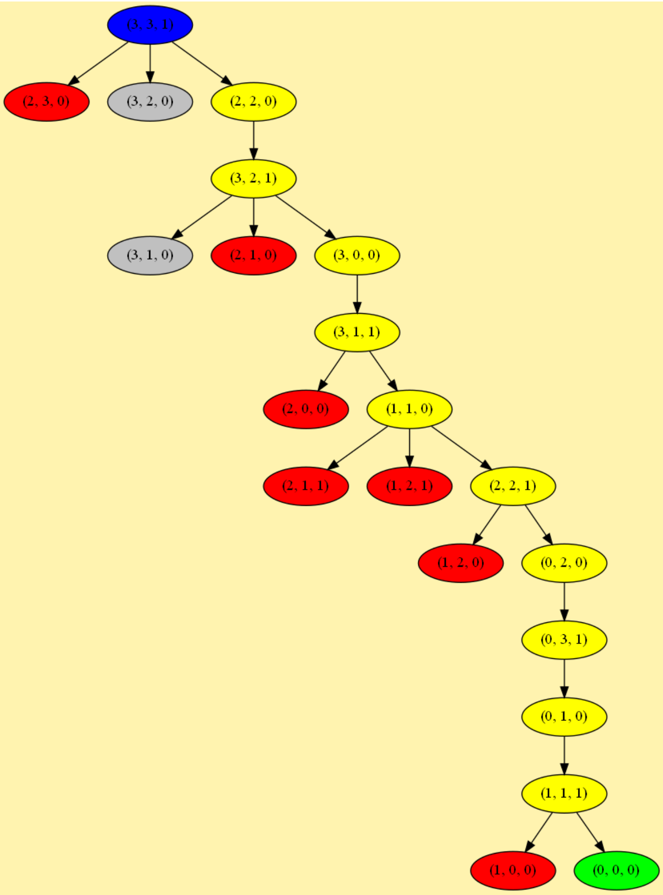
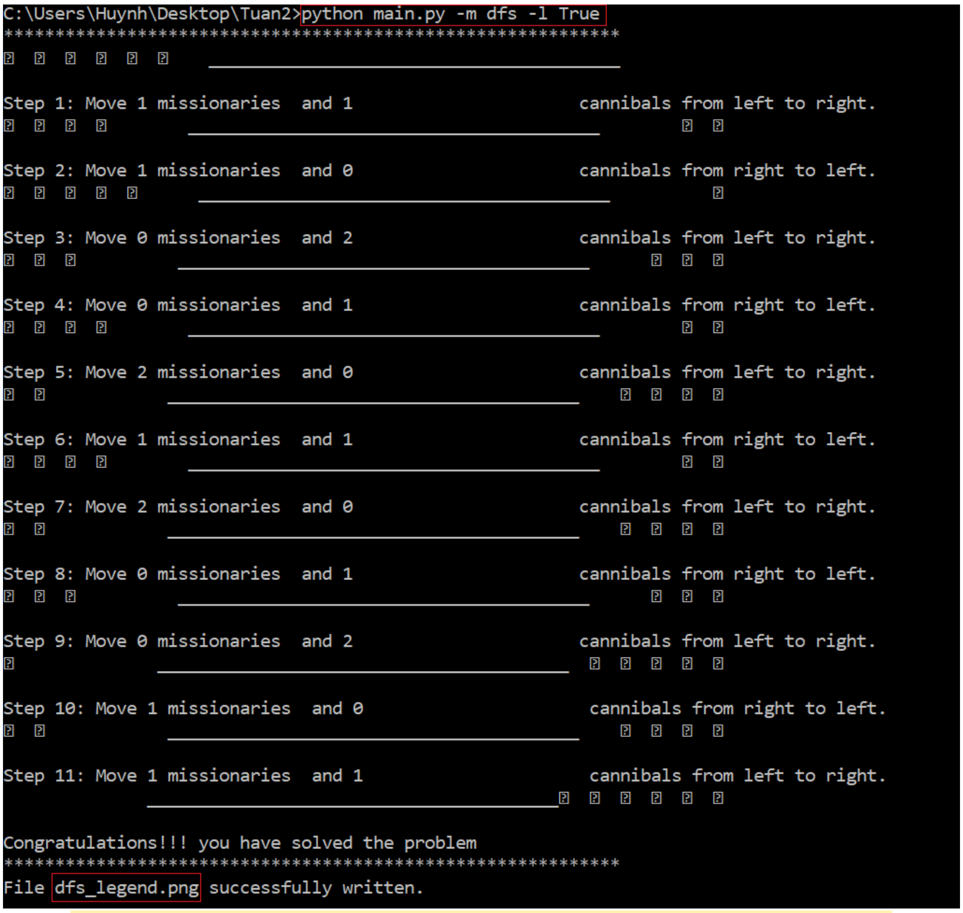


fig: Missionaries and Cannibal State Space Tree

- DFS với legend:

  python main.py -m dfs -l True



```
C:\Users\Huynh\Desktop\Tuan2>python main.py -m dfs -l True
************************************************************
⍰  ⍰  ⍰  ⍰  ⍰  ⍰    ________________________________________

Step 1: Move 1 missionaries  and 1                     cannibals from left to right.
⍰  ⍰  ⍰  ⍰         ________________________________________       ⍰  ⍰

Step 2: Move 1 missionaries  and 0                     cannibals from right to left.
⍰  ⍰  ⍰  ⍰  ⍰        ________________________________________         ⍰

Step 3: Move 0 missionaries  and 2                     cannibals from left to right.
⍰  ⍰  ⍰           ________________________________________      ⍰  ⍰  ⍰

Step 4: Move 0 missionaries  and 1                     cannibals from right to left.
⍰  ⍰  ⍰  ⍰         ________________________________________       ⍰  ⍰

Step 5: Move 2 missionaries  and 0                     cannibals from left to right.
⍰  ⍰             ________________________________________    ⍰  ⍰  ⍰  ⍰

Step 6: Move 1 missionaries  and 1                     cannibals from right to left.
⍰  ⍰  ⍰  ⍰         ________________________________________       ⍰  ⍰

Step 7: Move 2 missionaries  and 0                     cannibals from left to right.
⍰  ⍰             ________________________________________    ⍰  ⍰  ⍰  ⍰

Step 8: Move 0 missionaries  and 1                     cannibals from right to left.
⍰  ⍰  ⍰           ________________________________________      ⍰  ⍰  ⍰

Step 9: Move 0 missionaries  and 2                     cannibals from left to right.
⍰               ________________________________________  ⍰  ⍰  ⍰  ⍰  ⍰

Step 10: Move 1 missionaries  and 0                     cannibals from right to left.
⍰  ⍰             ________________________________________    ⍰  ⍰  ⍰  ⍰

Step 11: Move 1 missionaries  and 1                     cannibals from left to right.
              ________________________________________⍰  ⍰  ⍰  ⍰  ⍰  ⍰

Congratulations!!! you have solved the problem
************************************************************
File dfs_legend.png successfully written.
```

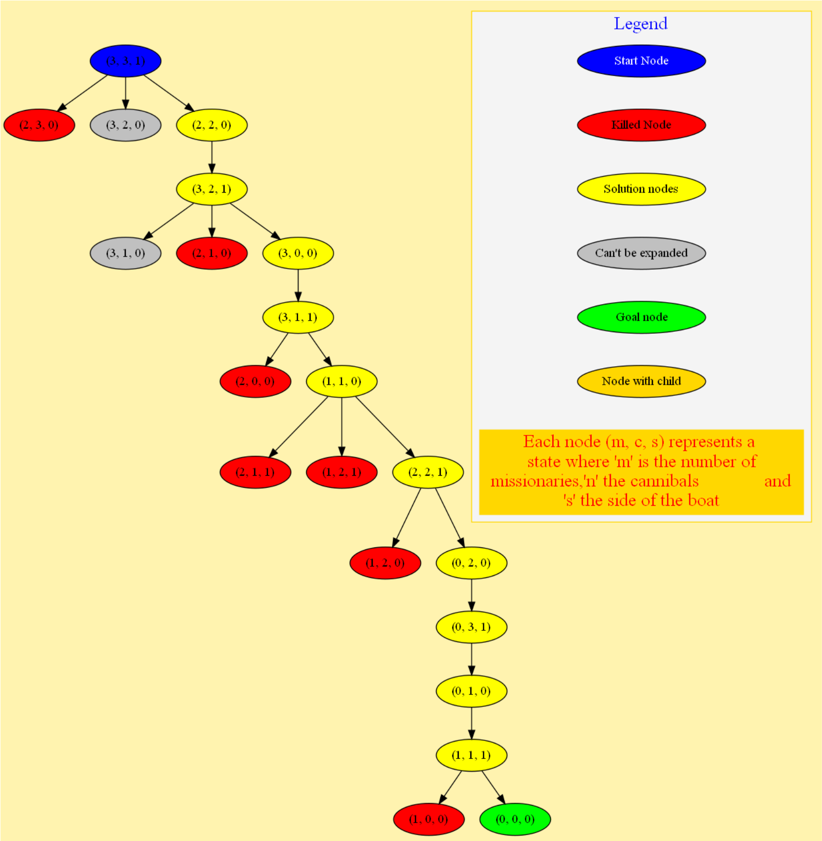
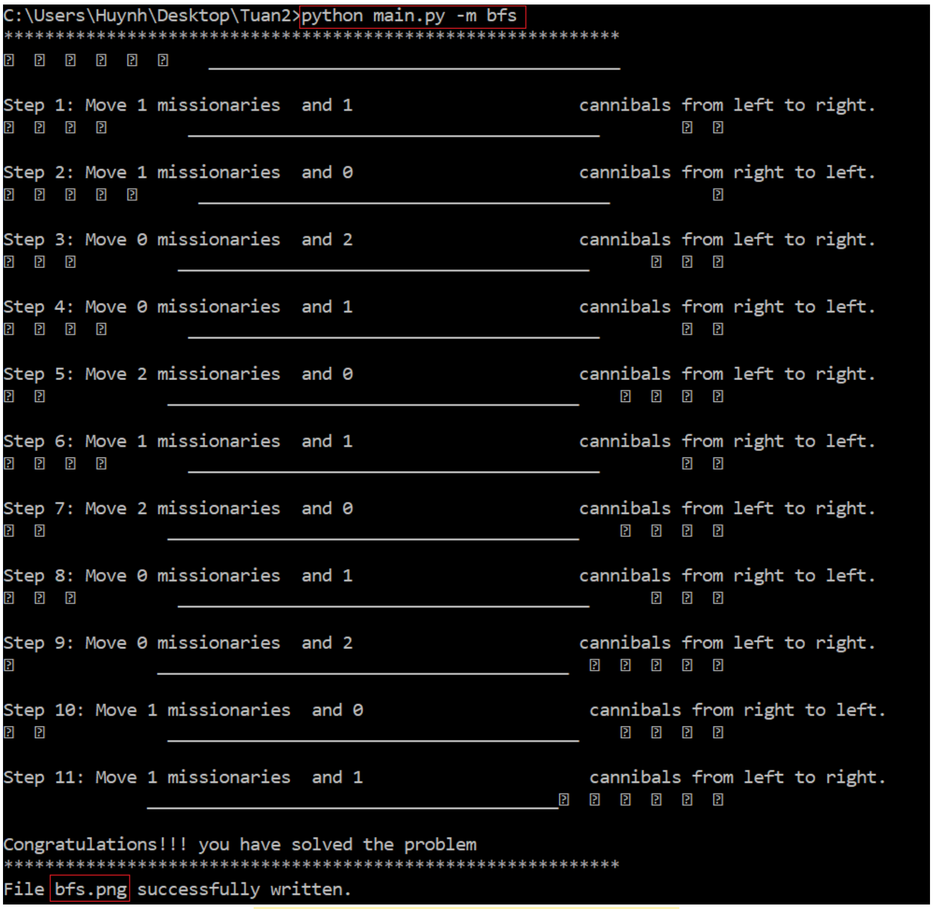


fig: Missionaries and Cannibal State Space Tree

e. Cây BFS:

- BFS:

  python main.py -m bfs



```
C:\Users\Huynh\Desktop\Tuan2>python main.py -m bfs
************************************************************
□  □  □  □  □  □    ________________________________________

Step 1: Move 1 missionaries  and 1                       cannibals from left to right.
□  □  □  □    ________________________________________          □  □

Step 2: Move 1 missionaries  and 0                       cannibals from right to left.
□  □  □  □  □   ________________________________________           □

Step 3: Move 0 missionaries  and 2                       cannibals from left to right.
□  □  □    ________________________________________          □  □  □

Step 4: Move 0 missionaries  and 1                       cannibals from right to left.
□  □  □  □    ________________________________________          □  □

Step 5: Move 2 missionaries  and 0                       cannibals from left to right.
□  □    ________________________________________          □  □  □  □

Step 6: Move 1 missionaries  and 1                       cannibals from right to left.
□  □  □  □    ________________________________________          □  □

Step 7: Move 2 missionaries  and 0                       cannibals from left to right.
□  □    ________________________________________          □  □  □  □

Step 8: Move 0 missionaries  and 1                       cannibals from right to left.
□  □  □    ________________________________________          □  □  □

Step 9: Move 0 missionaries  and 2                       cannibals from left to right.
□   ________________________________________          □  □  □  □  □

Step 10: Move 1 missionaries  and 0                       cannibals from right to left.
□  □    ________________________________________          □  □  □  □

Step 11: Move 1 missionaries  and 1                       cannibals from left to right.
              ________________________________________□  □  □  □  □  □

Congratulations!!! you have solved the problem
************************************************************
File bfs.png successfully written.
```

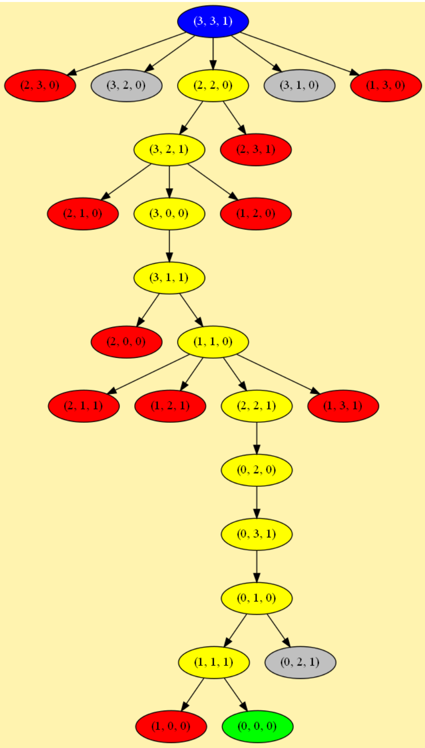
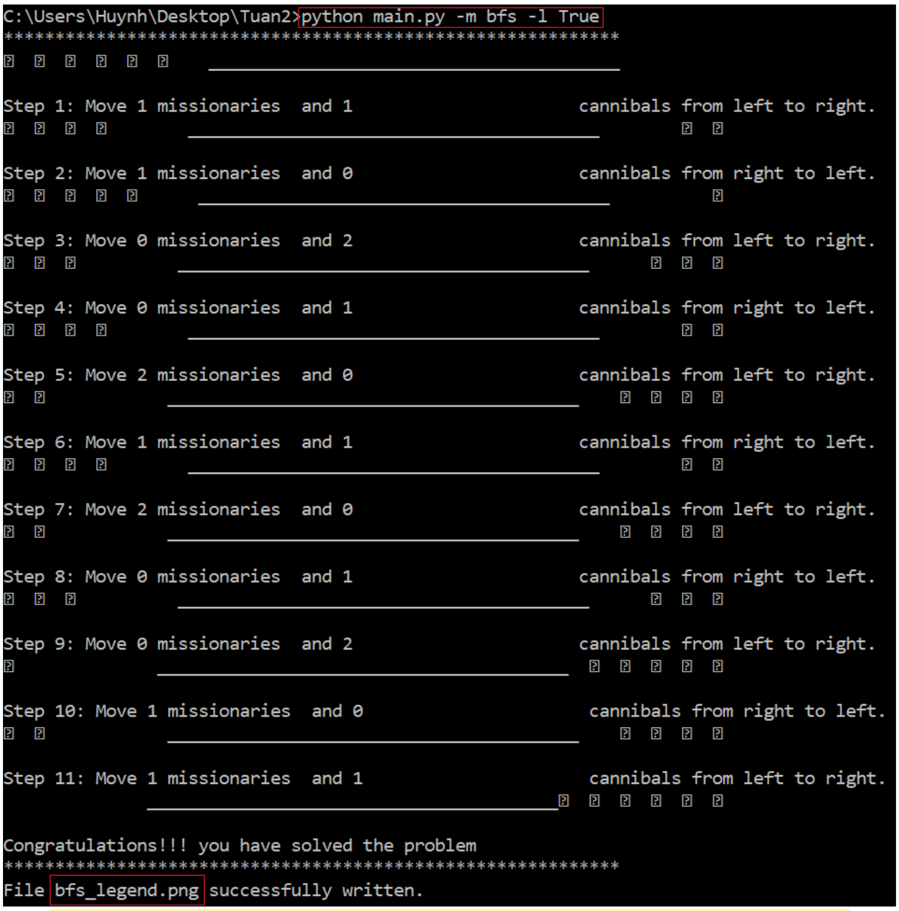


fig: Missionaries and Cannibal State Space Tree

- BFS với legend:

  python main.py -m bfs -l True



```
C:\Users\Huynh\Desktop\Tuan2>python main.py -m bfs -l True
************************************************************
□  □  □  □  □  □    ________________________________________

Step 1: Move 1 missionaries  and 1                          cannibals from left to right.
□  □  □  □    ______________________________________   □  □

Step 2: Move 1 missionaries  and 0                          cannibals from right to left.
□  □  □  □  □    ________________________________________  □

Step 3: Move 0 missionaries  and 2                          cannibals from left to right.
□  □  □    ________________________________________  □  □  □

Step 4: Move 0 missionaries  and 1                          cannibals from right to left.
□  □  □  □    ________________________________________  □  □

Step 5: Move 2 missionaries  and 0                          cannibals from left to right.
□  □    ________________________________________  □  □  □  □

Step 6: Move 1 missionaries  and 1                          cannibals from right to left.
□  □  □  □    ________________________________________  □  □

Step 7: Move 2 missionaries  and 0                          cannibals from left to right.
□  □    ________________________________________  □  □  □  □

Step 8: Move 0 missionaries  and 1                          cannibals from right to left.
□  □  □    ________________________________________  □  □  □

Step 9: Move 0 missionaries  and 2                          cannibals from left to right.
□    ________________________________________  □  □  □  □  □

Step 10: Move 1 missionaries  and 0                          cannibals from right to left.
□  □    ________________________________________  □  □  □  □

Step 11: Move 1 missionaries  and 1                          cannibals from left to right.
    ________________________________________□  □  □  □  □  □

Congratulations!!! you have solved the problem
************************************************************
File bfs_legend.png successfully written.
```

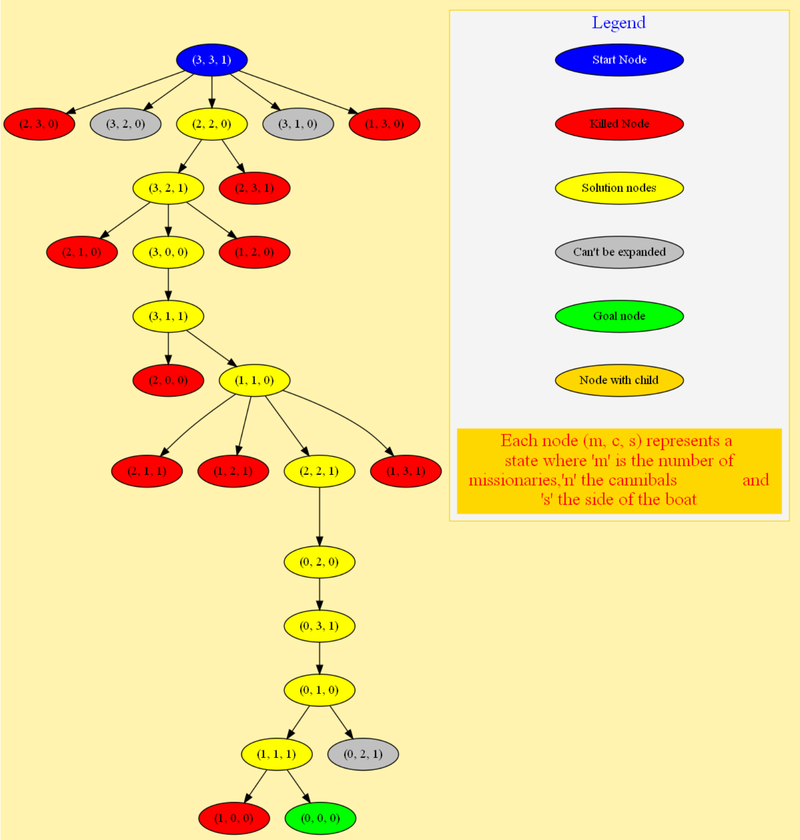


fig: Missionaries and Cannibal State Space Tree

4. Yêu cầu:

- Cài đặt và thực thi chương trình.

- Viết báo cáo trình bày:

  - ❀ Nếu chương trình bị báo lỗi thì lỗi ở dòng nào và sửa lại như thế nào? (Nếu có).

  - ❀ Đọc hiểu code đã cho và trình bày lại chi tiết hơn đoạn code cho sẵn dùng để làm gì?