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

I. MỤC TIÊU:

Sau khi thực hành xong bài này, sinh viên nắm được:

- Thuật toán tìm kiếm BFS, DFS trên cây tìm kiếm.
- Áp dụng các thuật toán này vào các bài toán thực tế.

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:

```
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)

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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                                │
    PARENT-NODE[s] ← node                            │ Make-
    ACTION[s] ← action                               │ Node
    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:

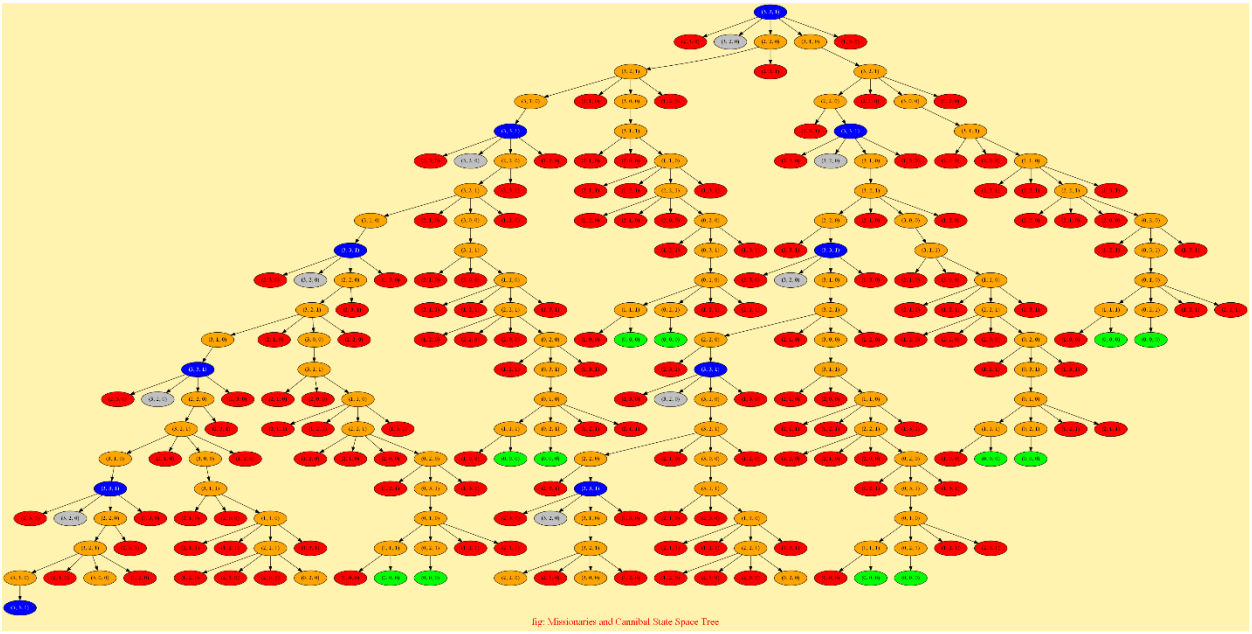
III. NỘI DUNG THỰC HÀNH:

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.

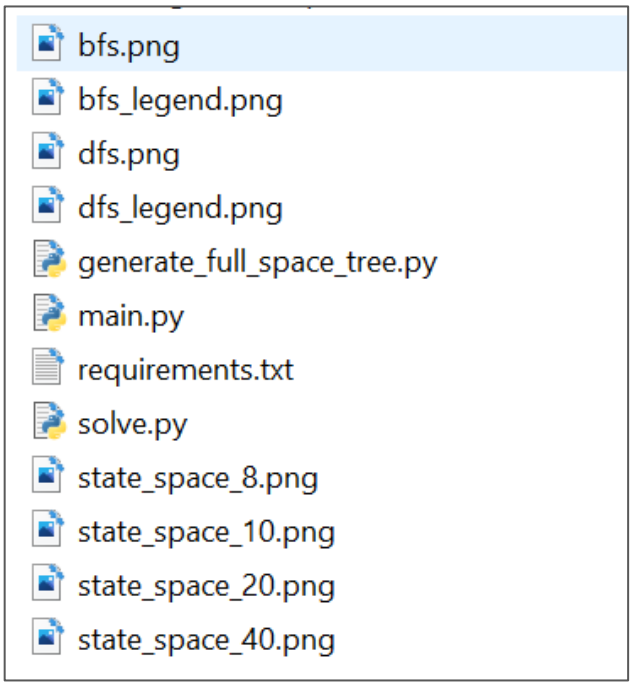
   Gọi (a, b, k) với $0 \le a, b \le 3$, trong đó a là số người, b là số con quỷ ở bên bờ bên trái, k=1 nếu thuyền ở bờ bên trái và k = 0 nếu thuyền ở bờ bên phải. Khi đó, không gian trạng thái của bài toán được xác định như sau:

   - 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):



3. **Cài đặt:**



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_style("filled")
            v.set_fillcolor("blue")
            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()
```

solve.py

```
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")
        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"
```

```
103
104         node6 = pydot.Node("6", style="filled", fillcolor="gold", label= description, shape="plaintext", fontsize="20", fontcolor="red")
105         graphlegend.add_node(node6)
106
107         self.graph.add_subgraph(graphlegend)
108
109         self.graph.add_edge(pydot.Edge(node1, node2, style="invis"))
110         self.graph.add_edge(pydot.Edge(node2, node3, style="invis"))
111         self.graph.add_edge(pydot.Edge(node3, node4, style="invis"))
112         self.graph.add_edge(pydot.Edge(node4, node5, style="invis"))
113         self.graph.add_edge(pydot.Edge(node5, node7, style="invis"))
114         self.graph.add_edge(pydot.Edge(node7, node6, style="invis"))
115
116     def draw(self, *, number_missionaries_left, number_cannnibals_left, number_missionaries_right, number_cannnibals_right):
117         """
118             Draw state on console using emojis
119         """
120         left_m = emoji.emojize(f":old_man: " * number_missionaries_left)
121         left_c = emoji.emojize(f":ogre: " * number_cannnibals_left)
122         right_m = emoji.emojize(f":old_man: " * number_missionaries_right)
123         right_c = emoji.emojize(f":ogre: " * number_cannnibals_right)
124
125         print('{}{}{}{}{}'.format(left_m, left_c + " " * (14 - len(left_m) - len(left_c)), "_" * 40, " " * (12 - len(right_m) - len(right_c)) + right_m, right_c))
126         print("")
127
128     def show_solution(self):
129         # Recursively start from Goal State
130         # And find parent until start state is reached
131
132         state = self.goal_state
133         path, steps, nodes = [] ,[], []
134
135         while state is not None:
136             path.append(state)
137             steps.append(Move[state])
138             nodes.append(node_list[state])
139
140             state = Parent[state]
141
142         steps, nodes = steps[::-1], nodes[::-1]
143
144         number_missionaries_left, number_cannnibals_left = 3, 3
145         number_missionaries_right, number_cannnibals_right = 0, 0
146
147         print("*" * 60)
148         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)
149
150         for i, ((number_missionaries, number_cannnibals, side), node) in enumerate(zip(steps[1:], nodes[1:])):
```

```
151
152             if node.get_label() != str(self.start_state):
153                 node.set_style("filled")
154                 node.set_fillcolor("yellow")
155
156             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)]}.")
157
158             op = -1 if side == 1 else 1
159
160             number_missionaries_left = number_missionaries_left + op * number_missionaries
161             number_cannnibals_left = number_cannnibals_left + op * number_cannnibals
162
163             number_missionaries_right = number_missionaries_right - op * number_missionaries
164             number_cannnibals_right = number_cannnibals_right - op * number_cannnibals
165
166             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)
167
168         print("Congratulations!!! you have solved the problem")
169         print("*" * 60)
170
171     def draw_edge(self, number_missionaries, number_cannnibals, side, depth_level):
172         u, v = None, None
173         if Parent[(number_missionaries, number_cannnibals, side)] is not None:
174             u = pydot.Node(str(Parent[(number_missionaries, number_cannnibals, side)] + (depth_level - 1, )), label=str(Parent[((number_missionaries, number_cannnibals, side))]))
175             self.graph.add_node(u)
176
177             v = pydot.Node(str((number_missionaries, number_cannnibals, side, depth_level)), label=str((number_missionaries, number_cannnibals, side)))
178             self.graph.add_node(v)
179
180             edge = pydot.Edge(str(Parent[(number_missionaries, number_cannnibals, side)] + (depth_level - 1, )), str((number_missionaries, number_cannnibals, side, depth_level) ), dir='forward')
181             self.graph.add_edge(edge)
182         else:
183             # For start node
184             v = pydot.Node(str((number_missionaries, number_cannnibals, side, depth_level)), label=str((number_missionaries, number_cannnibals, side)))
185             self.graph.add_node(v)
186         return u, v
187
188     def bfs(self):
189         q = deque()
190         q.append(self.start_state + (0, ))
191         self.visited[self.start_state] = True
192
193         while q:
194             number_missionaries, number_cannnibals, side, depth_level = q.popleft()
195             # Draw Edge from u -> v
196             # Where u = Parent[v]
197             # and v = (number_missionaries, number_cannnibals, side, depth_level)
198             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)
```

```
245
246
247         if self.is_start_state(number_missionaries, number_cannnibals, side):
248             v.set_style("filled")
249             v.set_fillcolor("blue")
250         elif self.is_goal_state(number_missionaries, number_cannnibals, side):
251             v.set_style("filled")
252             v.set_fillcolor("green")
253             return True
254         elif self.number_of_cannibals_exceeds(number_missionaries, number_cannnibals):
255             v.set_style("filled")
256             v.set_fillcolor("red")
257             return False
258         else:
259             v.set_style("filled")
260             v.set_fillcolor("orange")
261
262         solution_found = False
263         operation = -1 if side == 1 else 1
264
265         can_be_expanded = False
266
267         for x, y in self.options:
268             next_m, next_c, next_s = number_missionaries + operation * x, number_cannnibals + operation * y, int(not side)
269
270             if (next_m, next_c, next_s) not in self.visited:
271                 if self.is_valid_move(next_m, next_c):
272                     can_be_expanded = True
273                     # Keep track of Parent state and corresponding move
274                     Parent[(next_m, next_c, next_s)] = (number_missionaries, number_cannnibals, side)
275                     Move[(next_m, next_c, next_s)] = (x, y, side)
276                     node_list[(next_m, next_c, next_s)] = v
277
278                     solution_found = (solution_found or self.dfs(next_m, next_c, next_s, depth_level + 1))
279
280                     if solution_found:
281                         return True
282
283         if not can_be_expanded:
284             v.set_style("filled")
285             v.set_fillcolor("gray")
286
287         self.solved = solution_found
288         return solution_found
```

main.py

```
5   from solve import Solution
6   import argparse
7   import itertools
8
9   arg = argparse.ArgumentParser()
10  arg.add_argument("-m", "--method", required=False, help="Specify which method to use")
11  arg.add_argument("-l", "--legend", required=False, help="Specify if you want to display legend on graph")
12
13  args = vars(arg.parse_args())
14
15  solve_method = args.get("method", "bfs")
16  legend_flag = args.get("legend", False)
17
18
19  def main():
20      s = Solution()
21
22      if(s.solve(solve_method)):
23
24          # Display SOlution on console
25          s.show_solution()
26
27          output_file_name = f"{solve_method}"
28          # Draw legend if legend_flag is set
29          if legend_flag:
30              if legend_flag[0].upper() == 'T' :
31                  output_file_name += "_legend.png"
32                  s.draw_legend()
33              else:
34                  output_file_name += ".png"
35          else:
36              output_file_name += ".png"
37
38          # Write State space tree
39          s.write_image(output_file_name)
40      else:
41          raise Exception("No solution found")
42
43  if __name__ == "__main__":
44      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.

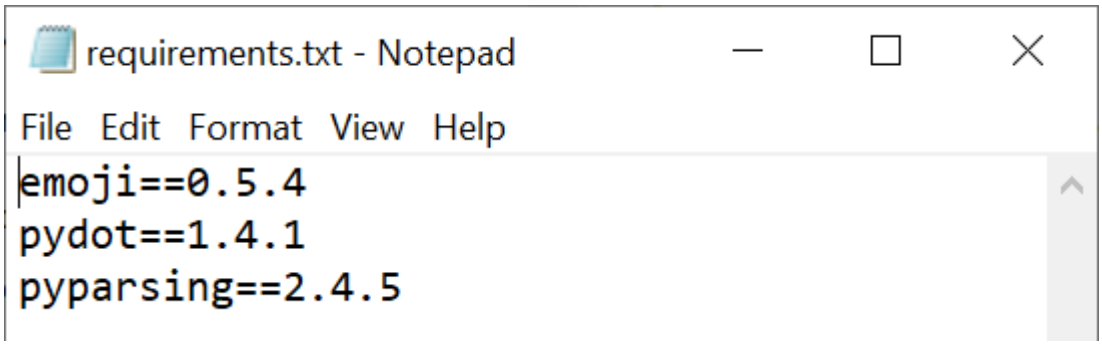
generate_full_space_tree.py

```
10
11  # Set it to bin folder of graphviz
12  os.environ["PATH"] += os.pathsep + 'C:/Program Files/Graphviz/bin'
```

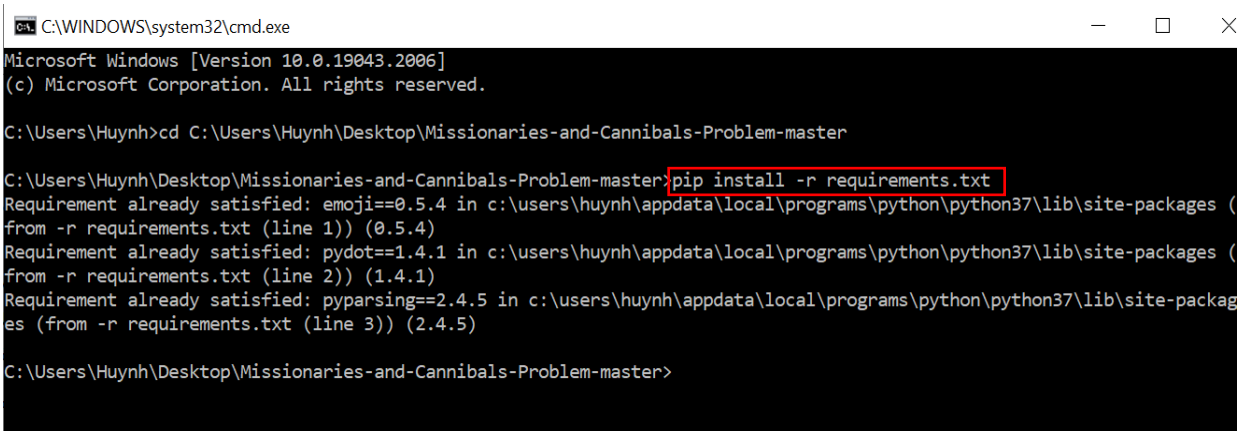
solve.py

```
11
12  # Set it to bin folder of graphviz
13  os.environ["PATH"] += os.pathsep + 'C:/Program Files/Graphviz/bin'
```

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



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\Missionaries-and-Cannibals-Problem-master>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\Missionaries-and-Cannibals-Problem-master>python generate_full_space_tree.py -d 20
File state_space_20.png successfully written.
```

……..

d. **Cây DFS:**

- DFS:

  python main.py -m dfs

```
C:\Users\Huynh\Desktop\Missionaries-and-Cannibals-Problem-master>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.
```

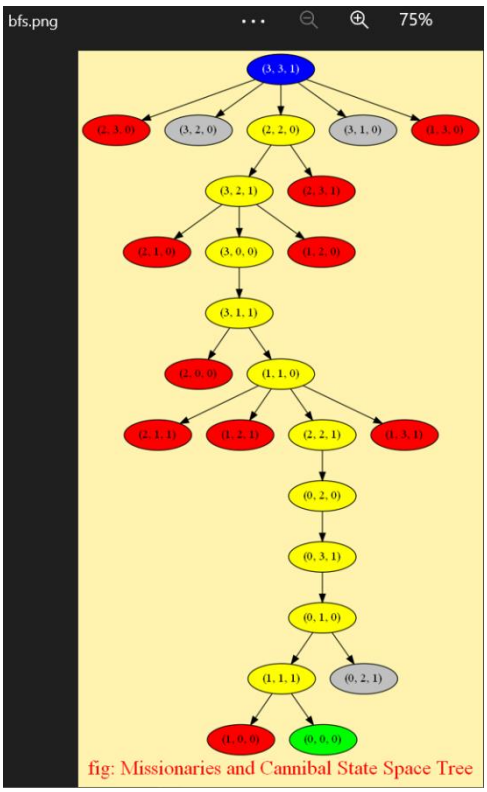


fig: Missionaries and Cannibal State Space Tree

- DFS với legends:

  python main.py -m dfs -l True

```
C:\Users\Huynh\Desktop\Missionaries-and-Cannibals-Problem-master>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.
```

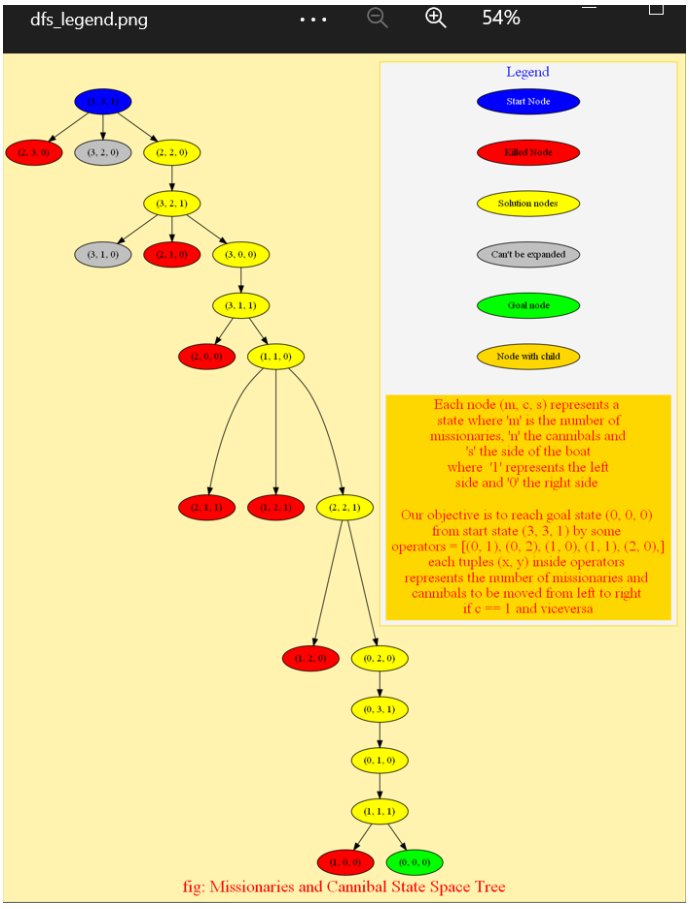


fig: Missionaries and Cannibal State Space Tree

e. Cây BFS:

- BFS

  python main.py -m bfs

```
C:\Users\Huynh\Desktop\Missionaries-and-Cannibals-Problem-master>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.
```

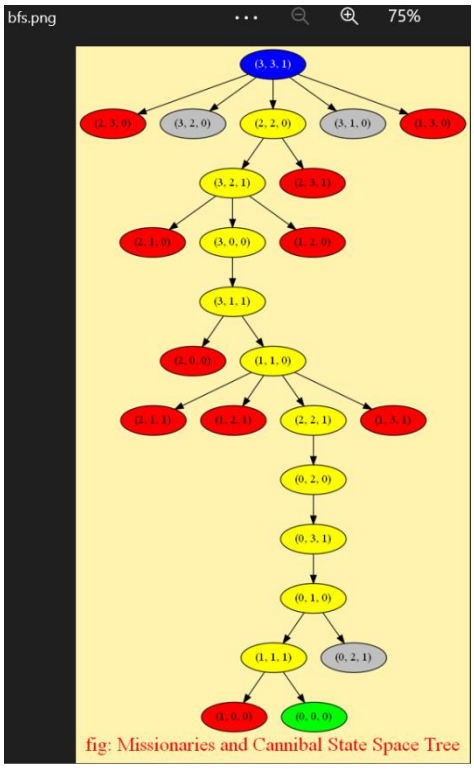


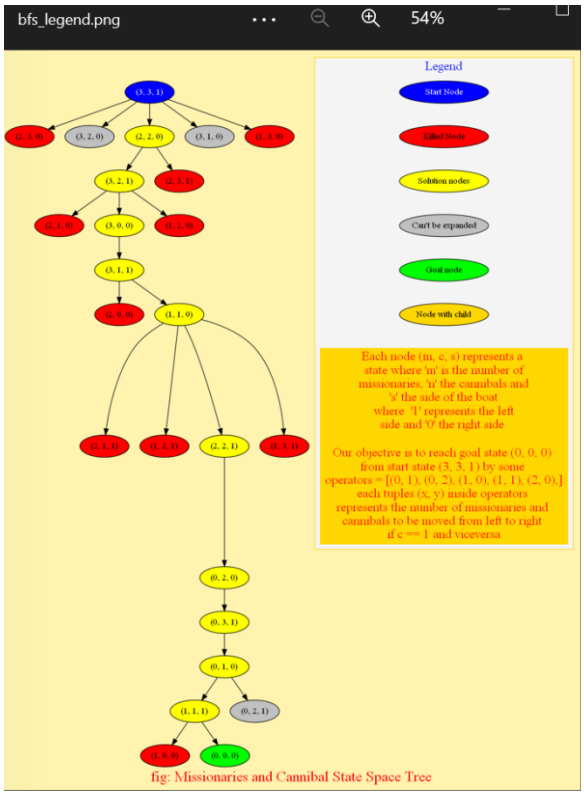
fig: Missionaries and Cannibal State Space Tree

-

- BFS với legends

  python main.py -m bfs -l True

```
C:\Users\Huynh\Desktop\Missionaries-and-Cannibals-Problem-master>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.
```



4. Yêu cầu:

- Cài đặt và thực thi chương trình. Nếu chương trình bị báo lỗi thì lỗi ở dòng nào và sửa lại như thế nào?
- Viết báo cáo trình bày lại tất cả những gì em hiểu liên quan tới bài thực hành. Nhận xét?