

Tic Tac Toe Game

WEEK-1 15/11/2023

board = [' ' for _ in range(10)]

def insertLetter(letter, pos):

global board

board[pos] = letter

def spaceIsFree(pos):

return board[pos] == ' '

def printBoard(board):

print('11')

print(' ' + board[1] + ' | ' + board[2] + ' | ' +
board[3])

print('11')

print('-----')

print('11')

print(' ' + board[4] + ' | ' + board[5] + ' | '
board[6])

print('11')

print('-----')

print('11')

print(' ' + board[7] + ' | ' + board[8] + ' | '
board[9])

print('11')

def isWinner(bd, le):

return (

(bd[7] == le and bd[8] == le and
bd[9] == le) or

(bd[4] == le and bd[5] == le and
bd[8] == le) or

(bd[1] == le and bd[2] == le and
bd[3] == le) or



$(bo[1] == 'e' \text{ and } bo[4] == 'e' \text{ and } bo[7] ==$
 $\text{or } (bo[2] == 'e' \text{ and } bo[5] == 'e' \text{ and } bo[8] ==$
 $\text{or } (bo[3] == 'e' \text{ and } bo[6] == 'e' \text{ and } bo[9] ==$
 $\text{or } (bo[1] == 'e' \text{ and } bo[5] == 'e' \text{ and } bo[9] ==$
, $(bo[3] == 'e' \text{ and } bo[5] == 'e' \text{ and } bo[7] ==$

```
def playerMove():
    global board
    run = True
    while run:
        move = input('Please select a position To
place an 'X' (1-9):')
```

try:

```
    move = int(move)
    if 1 <= move <= 9:
        if spaceIsFree(move):
            run = False
            insertLetter('X', move)
        else:
            print('Sorry, This space is occupied.')
    else:
        print('Please type a number
within the range!')
```

except ValueError:

```
    print('Please type a number
within the range!')
```

exit

def compMove():
global board
possibleMoves = [x for x, letter in enumerate
(board) if letter == ' ' and x != 0]

for let in ['O', 'X']:

for i in possibleMoves:

boardCopy = board[:]

boardCopy[i] = let

if isWinner(boardCopy, let):

return i

cornersOpen = [i for i in possibleMoves if i
in [1, 3, 7, 9]]

if cornersOpen:

return selectRandom(cornersOpen)

if 5 in possibleMoves:

return 5

edgesOpen = [i for i in possibleMoves if i
in [2, 4, 6, 8]]

if edgesOpen:

return selectRandom(edgesOpen)

if 5 in possibleMoves:

return 5

return None

edgesOpen = [i for i in possibleMoves if i
in

def selectRandom(li):

m = len(li)

x = random.randrange(m)

return li[x]

def isBoardFull(board):

return board.count(' ') <= 1

det main():
 global board
 print('Welcome to Tic Tac Toe!')
 printBoard(board)
 while not isBoardFull(board):
 if not isWinner(board, 'O'):
 playerMove()
 printBoard(board)
 else:
 print('Sorry, O\'s won this time!')
 break
 if not isWinner(board, 'X'): if move == None:
 move = compMove()
 if move in None:
 print('Tie Game!')
 else:
 insertLetter('O', move)
 print('Computer placed an O\'
 in position', move, ':')
 printBoard(board)
 else:
 print('X\'s won this time! Good Job!')
 break
 if isBoardFull(board):
 print('Tie Game!')
 while True:
 answer = input('Do you want to play
 again? (Y/N)')
 if answer.lower() == 'y' or answer.lower() == 'yes':

```
board = ' ' for - in range(10):
print('.....')
main()
else
break;
main()
```

Output:

X |

- |

- |

- |

- |

- |

- |

- |

- |

- |

- |

- |

- |

- |

- |

- |

- |

- |

- |

- |

- |

- |

- |

- |

- |

- |

computer placed an 'O' in position 3:

X | | O

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

Please select a position to place an 'X' (Tie)

X | | O

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

computer placed an 'O' in position 9:

X | | O | O

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

- | | -

Please select a position to place an 'X'

X | | O | O

- | | -

- | | -

- | | -

tie Game 1



```
print(...)  
main()  
the  
break;  
main()
```

Output:

~~X~~ | | |
- | | |
- | | |
~~X~~ | | O

computer place an 'O' in position 3:

~~X~~ | | |
- | | |
- | | |
~~X~~ | | O

Please select a position to place an 'X':

~~X~~ | | O
- | X | |
| | | |

computer placed an 'O' in position 9:

~~X~~ | | O
- | X | |
| | | |

Please select a position to place an 'X':

~~X~~ | | O
- | X | |
| | | |

computer placed an 'O' in position 4:

~~O~~ | X | X
- | | | |
| | | |

Please select a position to place an 'X':

~~X~~ | O | O
- | T | X
| | | |

2 Vacuum Cleaner Agent

22/4/2023

```
def vacuum_world():
    goal_state = {'A': '0', 'B': '0'}
    cost = 0
    location_input = input('Enter Location of
                           Vacuum')
    status_input = input('Enter status of +
                         location_input')
    status_input_complement = input('Enter
                                    status of other room')
    print('Initial Location Condition' +
          str(goal_state))

    if location_input == 'A':
        print('Vacuum is placed in Location A')
        if status_input == '1':
            print('Location A is dirty')
            goal_state['A'] = '0'
            cost += 1
            print('cost for cleaning A' +
                  str(cost))
            print('Location A has been cleaned')

        if status_input_complement == '1':
            print('Location B is dirty')
            print('Moving right to the location
                  B')
            cost += 1
            print('cost for moving Right' +
                  str(cost))
            goal_state['B'] = '0'
            cost += 1
```



Scanned with OKEN Scanner

```

print('lost for suck') + str(cost))
print('Location B has been cleaned')
else:
    print('No action') + str(cost)
    print('Location B is already clean')
if status_input == '0':
    print('Location A is already clean')
    if status_input & complement == 1:
        print('Location B is Dirty')
        print('Moving Right To The Location')
        cost += 1
        print('lost for moving Right' +
              str(cost)))
        goal_state['B'] = '0'
        cost += 1
        print('lost for suck') + str(cost))
        print('Location B has been cleaned')
    else:
        print('No action') + str(cost)
        print(cost)
        print('Location B is already clean')
else:
    print('Vacuum is placed in location B')
    if status_input == '1':
        print('Location B is Dirty')
        goal_state['B'] = '0'
        cost += 1
        print('lost for cleaning') + str(cost))
        print('Location B has been cleaned')

```

if status_input_complement = '1'
print('Location A is Dirty')
print('Moving Left To The Location A')
cost += 1
print('cost for moving Left' + str(cost))
goal_state['A'] = '0'
cost += 1
print('cost for suck' + str(cost))
print('Location A has been cleaned')

else:

print(wst)
print('Location B is already clean')

if if status_input_complement = '1':

print('Location A is Dirty')
print('Moving Left To The Location A')

cost += 1
print('cost for moving Left' + str(cost))
goal_state['A'] = '0'

cost += 1

print('cost for suck' + str(cost))
print('Location A has been cleaned')

else:

print('No action' + str(cost))
print('Location A is already clean')

print('Goal State:')

print(goal_state)

print('Performance Measurement' + str(cost))

vacuum_world()

Sample Output:

Enter Location of Vacuum A

Enter status of A 0

Enter status of other room 0

Initial Location Condition {'A': '0', 'B': '0'}

Vacuum is placed in location B

Location B is already clean

No action 0

Location A is already clean

Goal state:

{'A': '0', 'B': '0'}

Performance Measurement: 0

WEEK - 3

3 8 - Puzzle Problem using BFS

29/11/2023

```

import numpy as np
import pandas as pd
import os
def bfs(src, Target):
    queue = []
    queue.append(src)
    print(queue)
    exp = []
    while len(queue) > 0:
        source = queue.pop(0)
        exp.append(source)
        print(source)
        if source == target:
            print('succ')
            return
        pos_moves_to_do = []
        pos_moves_to_do = possible_moves(source, exp)
        for move in pos_moves_to_do:
            if move not in exp and move not in queue:
                queue.append(move)
    def possible_moves(state, visited_states):
        b = state.index(0)
        d = []
        if b not in [0, 1, 2]:
            d.append('u')
        if b not in [6, 7, 8]:
            d.append('d')
        if b not in [2, 5, 8]:
            d.append('l')
        if b not in [0, 3, 6]:
            d.append('r')
        return d
    
```

if b not in [2, 5, 8]:
 d.append('r')
 pos_moves_it_can = []
 for i in d:
 pos_moves_it_can.append(gen(state, i, b))
 return [move_it_can for move_it_can
 in pos_moves_it_can if move_it_can
 not in visited_states]

def gen(state, m, b):

Temp = state.copy()

if m == 'd':

Temp[b+3], Temp[b] = Temp[b],
Temp[b+3]

Part 6(12/23) if m == 'u':
Temp[b-3], Temp[b] = Temp[b],
Temp[b-3]

if m == 'l':

Temp[b-1], Temp[b] = Temp[b],
Temp[b-1]

if m == 'r':

Temp[b+1], Temp[b] = Temp[b],
Temp[b+1]

return Temp

sample output:

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

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

bfs(src, target)

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

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

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

success

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

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

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

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



4 8-Puzzle Problem WEEK-4 using Iterative Deepening Search

```
import numpy as np
import pandas as pd
def dfs(src, Target, limit, visited_states):
    if src == Target:
        return True
    if limit <= 0:
        return False
    visited_states.append(src)
    moves = possible_moves(src, visited_states)
    for move in moves:
        if dfs(move, Target, limit - 1, visited_states):
            return True
    return False
def possible_moves(state, visited_states):
    b = state.index(-1)
    d = []
    if b not in [0, 1, 2]:
        d += 'u'
    if b not in [6, 7, 8]:
        d += 'd'
    if b not in [2, 5, 8]:
        d += 'r'
    if b not in [0, 3, 6]:
        d += 'l'
    pos_moves = []
    for move in d:
        pos_moves.append(gen(state, move, b))
    for move in pos_moves:
        if move
```

```

def gen(state, move, blank):
    Temp = state.copy()
    if move == 'u':
        Temp[blank-3], Temp[blank] = Temp[blank],
        Temp[blank-3]
    if move == 'd':
        Temp[blank+3], Temp[blank] = Temp[blank],
        Temp[blank+3]
    if move == 's':
        Temp[blank+1], Temp[blank] = Temp[blank],
        Temp[blank+1]
    if move == 'l':
        Temp[blank-1], Temp[blank] = Temp[blank],
        Temp[blank-1]
    return Temp

def iddfs(src, target, depth):
    for i in range(depth):
        visited_states = []
        if dfr(src, target, i+1, visited_states):
            return True
    return False

```

Output:

$$src = [1, 2, 3, -1, 4, 5, 6, 7, 8]$$

~~$$target = [1, 2, 3, 4, 5, -1, 6, 7, 8]$$~~

$$depth = 1$$

iddfs(src, target, depth)

False

5 8-Puzzle Problem Using Best First Search

import heapq

class Node:

def __init__(self, state, level, heuristic):

self.state = state

self.level = level

self.heuristic = heuristic

def generate_child(node):

x, y = find_blank(node.state)

moves = [(x-1, y), (x+1, y), (x, y-1), (x, y+1)]

children = []

for move in moves:

child_state = move_blank(node.state,
(x, y), move)

if child_state is not None:

h = calculate_heuristic(child_state)

child_node = Node(child_state,
node.level + 1, h)

children.append(child_node)

return children

def find_blank(state):

for i in range(3):

for j in range(3):

if state[i][j] == 0:

return i, j

def move_blank(state, src, dest):

x1, y1 = src

x2, y2 = dest

if 0 <= x2 and 0 <= y2 < 3:

be Problem using Best First Search
heapq

f_(self, state, level, heuristic):

state = state

level = level

heuristic = heuristic

rate_child(node):

= find_blank(node.state)

os = [(x-1, y), (x+1, y), (x, y-1), (x, y+1)]

then = []

move in moves:

child_state = move_blank(node.state,
(x, y), move)

if child_state is not None:

h = calculate_heuristic(child_state)
child_node = Node(child_state,
node.level + 1, h)

children.append(child_node)

children

blank(state):

in range(3):

in range(3):

state[i][j] == 0:

return i, j

rank(state, src, dest):

rc

est

x2 and 0 <= y2 < 3;

new_state = [row[:] for row in state]
new_state[x1][y1], new_state[x2][y2] =
newstate[x2][y2], new_state[x1][y1]

return new_state

else:
return None

def calculate_heuristic(state):

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

h = 0

for i in range(3):

for j in range(3):

if state[i][j] != goal_state[i][j]

and state[i][j] != 0:

h += 1

return h

def best_first_search(initial_state):

start_node = Node(initial_state)

calculate_heuristic(initial_state)

open_list = [start_node]

while open_list:

wcurrent_node = heapq.heappop(open_list)

if wcurrent_node.state == [[1, 2, 3], [4, 5, 6],

[7, 8, 0]]:

return wcurrent_node

closed_set.add(Tuple(mup, Tuple(wcurrent_node.state)))

for child in generate_child(current_node):

if Tuple(mup(Tuple, child.state)) not

in closed_set:

return heapq.heappush(open_list, child)

return None



```

initial_state = [[1, 2, 3], [4, 5, 6], [7, 8, 0]]
solution_node = best_first_search(initial_state)

if solution_node:
    print("solution found in", solution_node.moves, "moves")
    print("Path:")
    for row in solution_node.state:
        print(row)
else:
    print("No solution found")

```

Output:

Solution found in 3 moves.

Path:

```

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

```

Time complexity:

→ BFS using a priority queue for 8-puzzle problem with a simple misplaced tiles heuristic is generally $O(b^d)$, where:

- b is The average no. of paths
- d is The depth or length of The path from the start to The solution in The maze.

6 8-Puzzle Problem using A* Algorithm

```
import heapq
```

```
class Node:
```

```
    def __init__(self, data, level, fval):
```

```
        self.data = data
```

```
        self.level = level
```

```
        self.fval = fval
```

```
    def generate_child(self):
```

```
        x, y = self.find(self.data, '_')
```

```
        val_list = [[x, y-1], [x, y+1], [x-1, y],  
                   [x+1, y]]
```

```
        children = []
```

```
        for i in val_list:
```

```
            child = self.shuffle(self.data, x, y,  
                                 i[0], i[1])
```

```
            if child is not None:
```

```
                child_node = Node(child, self.level  
                                   + 1, 0)
```

```
                children.append(child_node)
```

```
        return children
```

~~```
def shuffle(self, puz, x1, y1, x2, y2):
```~~~~```
    if x2 >= 0 and x2 < len(self.data) and  
        y2 >= 0 and y2 < len(self.data);
```~~~~```
 Temp_puz = self.copy(puz)
```~~~~```
        Temp = Temp_puz[x2][y2]
```~~~~```
 Temp_puz[x][y] = Temp
```~~~~```
        return Temp_puz
```~~

```
else:  
    return None
```

```
def copy(self, root):
    Temp = []
    for i in root:
        T = []
        for j in i:
            T.append(j)
        Temp.append(T)
    return Temp
```

```
def find(self, puz, x):
    for i in range(0, len(self.data)):
        for j in range(0, len(self.data)):
            if puz[i][j] == x:
                return i, j
```

```
class Puzzle:
    def __init__(self, size):
        self.n = size
        self.open = []
        self.closed = []
```

```
def f(self, start, goal):
    return self.h(start.data, goal) + start.level
```

```
def h(self, start, goal):
    Temp = 0
    for i in range(0, self.n):
        for j in range(0, self.n):
            if start[i][j] == goal[i][j] and
               start[i][j] != '_':
                Temp += 1
    return Temp
```

```

def process(self, start_data, goal_data):
    start = Node(start_data, 0, 0)
    start.fval = self.f(start, goal_data)
    self.open.append(start)
    print("n\n")
    while True:
        cur = self.open[0]
        print("n")
        for i in cur.data:
            for j in i:
                print(j, end = " ")
            print("n")
        if self.h(cur.data, goal_data) == 0:
            break
        for i in cur.generate_children():
            i.fval = self.f(i, goal_data)
            self.open.append(i)
        self.closed.append(cur)
        del self.open[0]
    self.open.sort(key = lambda x:
                    x.fval, reverse = False)

start_state = [[1, 2, 3], [-4, 5, 6],
               [7, 8, -1]]
goal_state = [[1, 2, 3], [4, 5, 6],
              [7, 8, -1]]
puz = Puzzle(3)
puz.process(start_state, goal_state)

```

Output:

1 2 3
- 4 6
7 5 8

1 2 3
4 - 5
7 5 8

1 2 3
4 5 6
7 - 8

1 2 3
4 5 6
7 8 -

Q
D/121

- Time complexity can be exponential in the worst case, usually denoted as $O(b^d)$
- b represents The average branching factor from a given state.
- d is The depth of the solution

7 Create KB using propositional logic and show if the given KB entails query def evaluate-first(premise, conclusion):

models = [

{'p': False, 'q': False, 'r': False},
{'p': False, 'q': False, 'r': True},
{'p': False, 'q': True, 'r': False},
{'p': False, 'q': True, 'r': True},
{'p': True, 'q': False, 'r': False},
{'p': True, 'q': False, 'r': True},
{'p': True, 'q': True, 'r': False},
{'p': True, 'q': True, 'r': True}]

]

entails = True

for model in models:

if evaluate_expression(premise, model) == True
evaluate_expression(conclusion, model) == True:

entails = False

break

return entails

def evaluate-second(premise, conclusion):

models = [

{'p': p, 'q': q, 'r': r}

for p in [True, False]

for q in [True, False]

for r in [True, False]

True

x0 x1 x2

entails = all(evaluate_expression(premise, model) for
model in models if evaluate_expression(conclusion,
model) and evaluate_expression(premise, model))



return entiah

```
def evaluate_expression(expression, model):
    if isinstance(expression, str):
        return model.get(expression)
    elif isinstance(expression, tuple):
        op = expression[0]
        if op == 'not':
            return not evaluate_expression(expression[1], model)
        elif op == 'and':
            return evaluate_expression(expression[1], model) and
                   evaluate_expression(expression[2], model)
        elif op == 'if':
            return (not evaluate_expression(expression[1], model)) or evaluate_expression(expression[2], model)
        elif op == 'or':
            return evaluate_expression(expression[1], model) or evaluate_expression(expression[2], model)
```

~~((~q ∨ ~p ∨ r) ∧ (~q ∨ p) ∧ q) model~~

~~first-premise = ('and', ('or', ('not', 'q'), ('not', 'p')), ('not', 'q'))~~

~~first-conclusion = ('and', ('p'), ('r'))~~

~~second-premise = ('and', ('or', ('not', 'q'), ('not', 'p')), ('and', ('not', 'q'), ('p')))~~

~~second-conclusion = ('r', 'q')~~

~~result-first = evaluate-first(first-premise, first-conclusion)~~

result-second = evaluate-second(second-premise,
second-conclusion)

if result-first:

print("For the first input: The knowledge
base entails the query.")

else:

print("For the first input: The knowledge
base does not entail the query.")

if result-second:

print("For the second input: The knowledge
base entails the query.")

else:

print("For the second input: The knowledge
base does not entail the query.")

Output:

For the first input: The knowledge base does
not entail the query.

For the second input: The knowledge base entails
the query.

8 Create a KB using propositional logic and prove the given query using resolution

import re

def main(rules, goal):

rules = rules.split()

steps = resolve(rules, goal)

print('\\\\nStep' + str(i) + 'Claimed ' + T + ' Derivation ' + T)

print('-' * 30)

i = 1

for step in steps:

print(f' {i}. {T} a step {T} | {steps[i]} {T}')

i += 1

def negate(term):

return f'~{term}' if term[0] == '~' else

Term[1]

def reverse(clause):

if len(clause) > 2:

T = split_Terms(clause)

return f'{T[1]} \vee {T[0]}'

return ''

def split_Terms(sentence):

exp = '(~* [PQRS])'

Terms = re.findall(exp, sentence)

return Terms

split_Terms('~PVR')

['~P', 'R']

def contradiction(goal, clause):

contradictions = [f'~goal \vee ~negate(goal)',

f'~negate(goal) \vee ~goal']



returns clause in contradictions or reverse
(clauses) in contradictions

def resolve(rules, goal):

Temp = rules.copy()

Temp + = [negate(goal)]

steps = dict()

for rule in Temp:

steps[rule] = "Given"

steps[negate(goal)] = "Negated conclusion"

i = 0 while i < len(Temp):

n = len(Temp)

j = (i+1) % n

clauses = []

while j < i = i + 1:

Terms1 = split(Temp[i])

Terms2 = split(Temp[j])

for c in Terms1:

if negative(c) in Terms2:

T1 = [t for t in Terms1 if

t1 = c]

T2 = [t for t in Terms2 if

t1 = negative(c)]

gen = T1 + T2

if len(gen) == 2:

if gen[0] != negate(gen[1]):

clauses += [{"f": gen[0], "g": gen[1]}]

v q gen[1] g gen[0]}

else:

if contradiction(goal,

- f1 q gen[0] v {gen[1]}

Temp.append({-f1 q gen[0]})

v {gen[1]} v {gen[0]}

$\text{steps}[""] = f'' \text{Resolved } \{\text{Temp}[i]\} \text{ and,}$
 $\{\text{Temp}[j]\} \text{ To } \{\text{Temp}[-1]\},$
which is in turn null.

return steps
else len(goal) == 1:
 clauses + = $[f' \text{dgen}[0]]$

else:
 if contradiction(goal, $f' \{\text{Terms1}[0]\} \vee$
 $\{\text{Terms2}[0]\})$:

 Temp.append($f' \{\text{Terms1}[0]\} \vee \{\text{Terms2}[0]\}$)

 steps[""] = $f'' \text{Resolved } \{\text{Temp}[i]\} \vee$
 and $\{\text{Temp}[j]\} \text{ To } \{\text{Temp}[-1]\},$

return steps

for clause in clauses:

 if clause not in Temp and clause =
 reverse(clause) and reverse(clause)
 not in Temp:

 Temp.append(clause)

 steps["clause"] = $f' \text{Resolved from}$
 $j = (j+1) \% n \quad \{\text{Temp}[i]\} \vee \{\text{Temp}[j]\}$

$i+1$

return steps

rules = 'RV~P RV~Q ~RVP ~RVQ'

goal = 'R'

main(rules, goal)

Output:

| Step | Change | Derivation |
|------|-------------|-------------------------------|
| 1. | $RV \sim P$ | Given |
| 2. | $RV \sim Q$ | Given |
| 3. | $\sim RVP$ | Given |
| 4. | $\sim RVQ$ | Given |
| 5. | $\sim R$ | Negated conclusion |
| 6. | Resolved | $RV \sim P$ and $\sim RVP$ To |

A contradiction is found when $\sim R$ is assumed as True. Hence, R is False.

9 Implement unification in first order logic

WEEK-8

```
import re

def getAttributes(expression):
    expression = expression.split("(")[1:]
    expression = " ".join(expression)
    expression = expression[:-1]
    expression = re.split("(,|<|,>|,|.|,|.)", expression)
    return expression

def getInitialPredicate(expression):
    return expression.split("(")[0]

def isConstant(char):
    return char.isupper() and len(char) == 1

def isVariable(char):
    return char.islower() and len(char) == 1

def replaceAttributes(exp, old, new):
    attributes = getAttributes(exp)
    for index, val in enumerate(attributes):
        if val == old:
            attributes[index] = new
    predicate = getInitialPredicate(exp)
    return predicate + "(" + " ".join(attributes) + ")"

def apply(exp, substitutions):
    for substitution in substitutions:
        new, old = substitution
        exp = replaceAttributes(exp, old, new)
    return exp
```

```

def checkOccurs(var, exp):
    if exp.find(var) == -1:
        return False
    return True

def getFirstPart(expression):
    attributes = getAttributes(expression)
    return attributes[0]

def getRemainingPart(expression):
    predicate = getInitialPredicate(expression)
    attributes = getAttributes(expression)
    newExpression = predicate + " (" + ", ".join(
        attributes[1:]) + ")"

    return newExpression

def unify(exp1, exp2):
    if exp1 == exp2:
        return []
    if isConstant(exp1) and isConstant(exp2):
        if exp1 != exp2:
            return False
        else:
            return []
    if isConstant(exp1):
        return [(exp1, exp2)]
    if isVariable(exp1):
        if checkOccurs(exp1, exp2):
            return False
        else:
            return [(exp2, exp1)]
    if isVariable(exp2):
        if checkOccurs(exp2, exp1):
            return False
        else:
            return [(exp1, exp2)]

```

if getInitialPredicate(exp1) != getInitialPredicate(exp2):
point ("Predicates do not match. Cannot be unified")

return False

attributeCount1 = len(getAttributes(exp1))

attributeCount2 = len(getAttributes(exp2))

if attributeCount1 == attributeCount2:

return False

head1 = getFirstPart(exp1)

head2 = getFirstPart(exp2)

initialSubstitution = unify(head1, head2)

if not initialSubstitution:

return False

if attributeCount1 == 1:

return initialSubstitution

tail1 = getRemainingPart(exp1)

tail2 = getRemainingPart(exp2)

if initialSubstitution1 == []:

Tail1 = apply(tail1, initialSubstitution)

Tail2 = apply(tail2, initialSubstitution)

remainingSubstitution = extend(remaining

= unify(Tail1, Tail2, ^{Substitution})

if not remainingSubstitution:

return False

initialSubstitution, extend(remaining

return initialSubstitution, ^{Substitution}

substitutions = unify(exp1, exp2)



print substitutions
print('substitutions')

Output:

exp1 = "knows(A, x)"

exp2 = "knows(y, y)"

substitutions:

[('A', 'y'), ('y', 'x')]

exp1 = "like(A, y)"

exp2 = "like(K, g(x))"

substitutions:

False



Convert given first order logic statement into
 conjunctive Normal Form (CNF)

def getAttributes(string):
 $\text{exp} = '([^\wedge])^+]$
 $\text{matches} = \text{re.findall(expr, string)}$
 return [m for m in matches if
 $m.isalpha()]]$

def getPredicated(string):
 $\text{expr} = '[a-z\wedge]^+([A-Z\alpha\wedge]^+)^+'$
 return re.findall(expr, string)

def skolemization(statement):
 $\text{SKOLEM_CONSTANTS} = [f'_{\text{chr}(c)}y' \text{ for } c \text{ in}$
 $\text{range(ord('A'), ord('z') + 1))}]$
 $\text{matches} = \text{re.findall('}\exists\text{', statement)}$
 for match in matches[:-1]:
 $\text{statement} = \text{statement.replace(match, }$
 for predicate in getPredicates(statement):
 $\text{attributes} = \text{getAttributes(predicate)}$
 $\text{if u.join(attributes).isupper():}$
 $\text{statement} = \text{statement.replace($
~~match[1], SKOLEM_CONSTANTS.pop()~~
 return statement

import re

def fol_to_cnf(fol):
 $\text{statement} = \text{fol.replace('}\Rightarrow\text{', '}\rightarrow\text{')}$
 $\text{expr} = 'V([^\wedge])^+)]'$

statements = re.findall(expr, statement)
for i, s in enumerate(statements):
 if '[' in s and ']' not in s:
 statements[i] += ']'

for s in statements:

 statement = statement.replace(s, fol_to_cnf(s))

 while '-' in statement:

 i = statement.index('-')

 br = statement.index('[') if

 '[' in statement else 0

 new_statement = '~' + statement[br:i]

 statement = statement[:br] + new_statement

 if br > 0 else new_statement

 return skolemization(statement)

Output
print(skolemization(fol_to_cnf(" ∀x food(x) ⇒ likes(John, x)")))

~ food(A) | likes(John, A)

print(skolemization(fol_to_cnf(" ∀x [∃y [loves(x, y)]] ")))

[loves(x, B(x))]

print(fol_to_cnf(" ∀ [american(x) & weapon(y) & settle(x, y, z) & hostile(z)] ⇒ criminal(x) "))

american(x) | ~ weapon(y) | ~ settle(x, y, z) |
 ~ hostile(z)] | criminal(x)

WEEK -10

Create a knowledge base consisting of first order logic statements and prove the given query using forward reasoning.

```

import re

def isVariable(x):
    return len(x) == 1 and x.islower() and
           x.isalpha()

def getAttributes(string):
    expr = '[^ ]+' + ')'
    matches = re.findall(expr, string)
    return matches

def getPredicates(string):
    expr = '([a-zA-Z]+)\[(^\&|)]+'
    return re.findall(expr, string)

class Fact:
    def __init__(self, expression):
        self.expression = expression
        predicate, params = self.splitExpression(expression)
        self.predicate = predicate
        self.params = params
        self.result = any(self.getConstants(c))
        self.result = any(self.getConstants(c))

    def splitExpression(self, expression):
        predicate = getPredicates(expression)[0]
        params = getAttributes(expression)[0].strip(')').split(',')
        return [predicate, params]

```

```

def getResults(self):
    return self.result

def getConstants(self):
    return [None if isVariable(c) else c for c
            in self.params]

def getVariables(self):
    return [v if isVariable(v) else None for
            v in self.params]

def getSubstitute(self, constants):
    c = constants.copy()
    f = f' & self.predicate(q).join([
        constants.pop(0) if isVariable(p)
        else p for p in self.params])
    return Fact(f)

class Implication:
    def __init__(self, expression):
        self.expression = expression
        l = expression.split('=>')
        self.lhs = [Fact(f) for f in l[0].split('&')]
        self.rhs = Fact(l[1])

    def evaluate(self, facts):
        constants = {}
        new_lhs = []
        for fact in facts:
            for val in self.lhs:
                if val.predicate == fact.predicate:
                    for i, v in enumerate(val):
                        getVariables():
                            if v:
                                constants[v] = fact.get

```

constants()

new_rhs.append(fail)

predicate_attributes = getPredicates(self,

rhs.expression[0],

str(getAttributes(self.rhs.expression)[0]))

for key in constants:

if constants[key]:

attribute = attribute.replace(key, constants[key])

class KB:

def __init__(self):

self.facts = set()

self.implications = set()

def query(self, e):

facts = set([f.expression for f in

i=1 self.facts])

print(f'Querying {e}')

def display(self):

print('All facts:')

for i, f in enumerate(self.facts):

for f in self.facts):

print(f'{f}\n{i+1}, {ff}')

kb_ = KB()

kb_.tell('missile(x) \Rightarrow weapon(x)')

kb_.tell('missile(M)')

kb_.tell('enemy(x, America) \Rightarrow hostile(x)')

kb_.tell('enemy (Nono, America)')

kb_.tell('owns (Nono, MI)')

kb_.tell('missile (x) & owns (Nono, x) \Rightarrow
sell (West, x, Nono)')

kb_.tell('american (x) & weapon (y) & sell (x,y,z)
& hostile (z) \Rightarrow criminal (x)')

kb_.query('criminal (x)')
kb_.display()

Output:

Querying criminal (x);
1. criminal (West)

All facts:

1. sell (West, MI, Nono)
2. criminal (West)
3. hostile (Nono)
4. owns (Nono, MI)
5. enemy (Nono, America)
6. weapon (MI)
7. american (West)
8. ~~missile (MI)~~

Paul
1/2/20

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LAB REPORT

on

ARTIFICIAL INTELLIGENCE (22CS5PCAIN)

Submitted by

SHRAVANI SHEKAR (1BM21CS205)

in partial fulfillment for the award of the degree of
BACHELOR OF ENGINEERING
in
COMPUTER SCIENCE AND ENGINEERING



B.M.S. COLLEGE OF ENGINEERING

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November-2023 to Febraruay-2024

B. M. S. College of Engineering,

Bull Temple Road, Bangalore 560019
(Affiliated To Visvesvaraya Technological University, Belgaum)
Department of Computer Science and Engineering



CERTIFICATE

This is to certify that the Artificial Intelligence (22CS5PCAIN) laboratory has been carried out by Shravani Shekar (1BM21CS205) during the 5th Semester November-February 2024.

Signature of the Faculty Incharge:

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Index Sheet

| Lab Program | Program Details | Page No. |
|--------------------|---|-----------------|
| 1 | Analyse and implement Tic-Tac-Toe game | 5 |
| 2 | Analyse and implement vacuum cleaner agent | 9 |
| 3 | Analyse 8 Puzzle problem and implement the same using Breadth First Search Algorithm | 14 |
| 4 | Analyse Iterative Deepening Search Algorithm. Demonstrate how 8 Puzzle problem could be solved using this algorithm. Implement the same. | 17 |
| 5 | Analyse best first search and A* algorithm. Implement 8 puzzle problem using both algorithms. | 20 |
| 6 | Create a knowledgebase using propositional logic and show that the given query entails the knowledge base or not. | 27 |
| 7 | Create a knowledgebase using propositional logic and prove the given query using resolution. | 30 |
| 8 | Implement unification in first order logic. | 34 |
| 9 | Convert given first order logic statement into Conjunctive Normal Form (CNF). | 38 |

| | | |
|----|---|----|
| 10 | Create a knowledgebase consisting of first order logic statements and prove the given query using forward reasoning. | 40 |
|----|---|----|

WEEK-2

1.Analyse and implement Tic-Tac-Toe game

```
import random

# Initialize the game board
board = [' ' for _ in range(10)]

def insertLetter(letter, pos):
    global board
    board[pos] = letter

def spaceIsFree(pos):
    return board[pos] == ' '

def printBoard(board):
    print(' | ')
    print(' ' + board[1] + ' | ' + board[2] + ' | ' + board[3])
    print(' | ')
    print('-----')
    print(' | ')
    print(' ' + board[4] + ' | ' + board[5] + ' | ' + board[6])
    print(' | ')
    print('-----')
    print(' | ')
    print(' ' + board[7] + ' | ' + board[8] + ' | ' + board[9])
    print(' | ')

def isWinner(bo, le):
    return (
        (bo[7] == le and bo[8] == le and bo[9] == le) or
        (bo[4] == le and bo[5] == le and bo[6] == le) or
        (bo[1] == le and bo[2] == le and bo[3] == le) or
        (bo[1] == le and bo[4] == le and bo[7] == le) or
        (bo[2] == le and bo[5] == le and bo[8] == le) or
        (bo[3] == le and bo[6] == le and bo[9] == le) or
        (bo[1] == le and bo[5] == le and bo[9] == le) or
        (bo[3] == le and bo[5] == le and bo[7] == le)
    )

def playerMove():
    global board
    run = True
    while run:
        move = input('Please select a position to place an \'X\' (1-9): ')
```

```

try:
    move = int(move)
    if 1 <= move <= 9:
        if spaceIsFree(move):
            run = False
            insertLetter('X', move)
        else:
            print('Sorry, this space is occupied!')
    else:
        print('Please type a number within the range!')
except ValueError:
    print('Please type a number!')


def compMove():
    global board
    possibleMoves = [x for x, letter in enumerate(board) if letter == ' ' and x != 0]

    for let in ['O', 'X']:
        for i in possibleMoves:
            boardCopy = board[:]
            boardCopy[i] = let
            if isWinner(boardCopy, let):
                return i

    cornersOpen = [i for i in possibleMoves if i in [1, 3, 7, 9]]
    if cornersOpen:
        return selectRandom(cornersOpen)

    if 5 in possibleMoves:
        return 5

    edgesOpen = [i for i in possibleMoves if i in [2, 4, 6, 8]]
    if edgesOpen:
        return selectRandom(edgesOpen)

    return None # Indicates a tie


def selectRandom(li):
    ln = len(li)
    r = random.randrange(ln)
    return li[r]


def isBoardFull(board):
    return board.count(' ') <= 1


def main():

```

```

global board
print('Welcome to Tic Tac Toe!')
printBoard(board)

while not isBoardFull(board):
    if not isWinner(board, 'O'):
        playerMove()
        printBoard(board)
    else:
        print('Sorry, O\'s won this time!')
        break

    if not isWinner(board, 'X'):
        move = compMove()
        if move is None:
            print('Tie Game!')
        else:
            insertLetter('O', move)
            print('Computer placed an \'O\' in position', move, ':')
            printBoard(board)
    else:
        print('X\'s won this time! Good Job!')
        break

if isBoardFull(board):
    print('Tie Game!')

while True:
    answer = input('Do you want to play again? (Y/N)')
    if answer.lower() == 'y' or answer.lower() == 'yes':
        board = [' ' for _ in range(10)]
        print('-----')
        main()
    else:
        break

# Run the game
main()

```

OUTPUT:

```
-----  
| | |  
-----  
Computer placed an 'O' in position 3 :  
X | | O  
-----  
| | |  
-----  
| | |  
Please select a position to place an 'X' (1-9): 5  
X | | O  
-----  
| X | |  
-----  
| | |  
Computer placed an 'O' in position 9 :  
X | | O  
-----  
| X | |  
-----  
| | | O  
Please select a position to place an 'X' (1-9): 6  
X | | O  
-----  
| X | X |  
-----  
| | | O  
Computer placed an 'O' in position 4 :  
X | | O  
-----  
O | X | X |  
-----  
| | | O  
Please select a position to place an 'X' (1-9): 8  
X | | O  
-----  
O | X | X |  
-----  
| X | O |  
Computer placed an 'O' in position 2 :  
X | O | O  
-----  
O | X | X |  
-----  
| X | O |  
Please select a position to place an 'X' (1-9): 7  
X | O | O  
-----  
O | X | X |  
-----  
X | X | O  
Tie Game!
```

2.Analyse and implement vacuum cleaner agent

```
def vacuum_world():

    # initializing goal_state
    # 0 indicates Clean and 1 indicates Dirty
    goal_state = {'A': '0', 'B': '0'}
    cost = 0

    location_input = input("Enter Location of Vacuum") #user_input of location vacuum is placed
    status_input = input("Enter status of " + location_input) #user_input if location is dirty or clean
    status_input_complement = input("Enter status of other room")
    print("Initial Location Condition" + str(goal_state))

    if location_input == 'A':
        # Location A is Dirty.
        print("Vacuum is placed in Location A")
        if status_input == '1':
            print("Location A is Dirty.")
            # suck the dirt and mark it as clean
            goal_state['A'] = '0'
            cost += 1           #cost for suck
            print("Cost for CLEANING A " + str(cost))
            print("Location A has been Cleaned.")

        if status_input_complement == '1':
            # if B is Dirty
            print("Location B is Dirty.")
            print("Moving right to the Location B. ")
            cost += 1           #cost for moving right
            print("COST for moving RIGHT" + str(cost))
```

```

# suck the dirt and mark it as clean
goal_state['B'] = '0'

cost += 1           #cost for suck

print("COST for SUCK " + str(cost))
print("Location B has been Cleaned. ")

else:

    print("No action" + str(cost))

    # suck and mark clean

    print("Location B is already clean.")


if status_input == '0':

    print("Location A is already clean ")

if status_input_complement == '1';# if B is Dirty

    print("Location B is Dirty.")

    print("Moving RIGHT to the Location B. ")

    cost += 1           #cost for moving right

    print("COST for moving RIGHT " + str(cost))

    # suck the dirt and mark it as clean

    goal_state['B'] = '0'

    cost += 1           #cost for suck

    print("Cost for SUCK" + str(cost))

    print("Location B has been Cleaned. ")

else:

    print("No action " + str(cost))

    print(cost)

    # suck and mark clean

    print("Location B is already clean.")


else:

    print("Vacuum is placed in location B")

```

```

# Location B is Dirty.

if status_input == '1':
    print("Location B is Dirty.")
    # suck the dirt and mark it as clean
    goal_state['B'] = '0'
    cost += 1 # cost for suck
    print("COST for CLEANING " + str(cost))
    print("Location B has been Cleaned.")

if status_input_complement == '1':
    # if A is Dirty
    print("Location A is Dirty.")
    print("Moving LEFT to the Location A. ")
    cost += 1 # cost for moving right
    print("COST for moving LEFT" + str(cost))
    # suck the dirt and mark it as clean
    goal_state['A'] = '0'
    cost += 1 # cost for suck
    print("COST for SUCK " + str(cost))
    print("Location A has been Cleaned.")

else:
    print(cost)
    # suck and mark clean
    print("Location B is already clean.")

if status_input_complement == '1': # if A is Dirty
    print("Location A is Dirty.")
    print("Moving LEFT to the Location A. ")
    cost += 1 # cost for moving right

```

```
print("COST for moving LEFT " + str(cost))

# suck the dirt and mark it as clean

goal_state['A'] = '0'

cost += 1 # cost for suck

print("Cost for SUCK " + str(cost))

print("Location A has been Cleaned. ")

else:

    print("No action " + str(cost))

    # suck and mark clean

    print("Location A is already clean.")

# done cleaning

print("GOAL STATE: ")

print(goal_state)

print("Performance Measurement: " + str(cost))

vacuum_world()
```

OUTPUT:

```
Enter Location of VacuumA
Enter status of A1
Enter status of other room1
Initial Location Condition('A': '0', 'B': '0')
Vacuum is placed in Location A
Location A is Dirty.
Cost for CLEANING A 1
Location A has been Cleaned.
Location B is Dirty.
Moving right to the Location B.
COST for moving RIGHT2
COST for SUCK 3
Location B has been Cleaned.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 3
```

```
Enter Location of Vacuum A
Enter status of A 0
Enter status of other room 0
Initial Location Condition('A': '0', 'B': '0')
Vacuum is placed in location B
0
Location B is already clean.
No action 0
Location A is already clean.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 0
```

WEEK-3

3.Analyse 8 Puzzle problem and implement the same using Breadth First Search Algorithm

```
import numpy as np
import pandas as pd
import os

def bfs(src, target):
    queue = []
    queue.append(src)

    exp = []

    while len(queue) > 0:
        source = queue.pop(0)
        exp.append(source)

        print(source)

        if source == target:
            print("success")
            return

    poss_moves_to_do = possible_moves(source, exp)
    for move in poss_moves_to_do:
        if move not in exp and move not in queue:
            queue.append(move)

def possible_moves(state, visited_states):
    b = state.index(0)
```

```

d = []

if b not in [0, 1, 2]:
    d.append('u')
if b not in [6, 7, 8]:
    d.append('d')
if b not in [0, 3, 6]:
    d.append('l')
if b not in [2, 5, 8]:
    d.append('r')

pos_moves_it_can = []

for i in d:
    pos_moves_it_can.append(gen(state, i, b))

return [move_it_can for move_it_can in pos_moves_it_can if move_it_can not in
visited_states]

def gen(state, m, b):
    temp = state.copy()

    if m == 'd':
        temp[b + 3], temp[b] = temp[b], temp[b + 3]

    if m == 'u':
        temp[b - 3], temp[b] = temp[b], temp[b - 3]

    if m == 'l':
        temp[b - 1], temp[b] = temp[b], temp[b - 1]

```

```

if m == 'r':
    temp[b + 1], temp[b] = temp[b], temp[b + 1]

return temp

```

OUTPUT:

```

▶ src = [1,0,3,4,2,6,7,5,8]
      target = [1,2,3,4,5,6,7,8,0]
      bfs(src, target)

```

```

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

```

```

[10] src=[2,0,3,1,8,4,7,6,5]
      target=[1,2,3,8,0,4,7,6,5]
      bfs(src, target)

```

```

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

```

WEEK-4

4.Analyse Iterative Deepening Search Algorithm. Demonstrate how 8 Puzzle problem could be solved using this algorithm. Implement the same.

```
import numpy as np
```

```
import pandas as pd
```

```
def dfs(src, target, limit, visited_states):
```

```
    if src == target:
```

```
        return True
```

```
    if limit <= 0:
```

```
        return False
```

```
    visited_states.append(src)
```

```
    moves = possible_moves(src, visited_states)
```

```
    for move in moves:
```

```
        if dfs(move, target, limit - 1, visited_states):
```

```
            return True
```

```
    return False
```

```
def possible_moves(state, visited_states):
```

```
    b = state.index(-1)
```

```
    d = []
```

```
    if b not in [0, 1, 2]:
```

```
        d += 'u'
```

```
    if b not in [6, 7, 8]:
```

```
        d += 'd'
```

```
    if b not in [2, 5, 8]:
```

```
        d += 'r'
```

```

if b not in [0, 3, 6]:
    d += 'l'

pos_moves = []

for move in d:
    pos_moves.append(gen(state, move, b))

return [move for move in pos_moves if move not in visited_states]

def gen(state, move, blank):
    temp = state.copy()

    if move == 'u':
        temp[blank - 3], temp[blank] = temp[blank], temp[blank - 3]
    elif move == 'd':
        temp[blank + 3], temp[blank] = temp[blank], temp[blank + 3]
    elif move == 'r':
        temp[blank + 1], temp[blank] = temp[blank], temp[blank + 1]
    elif move == 'l':
        temp[blank - 1], temp[blank] = temp[blank], temp[blank - 1]

    return temp

def iddfs(src, target, depth):
    for i in range(depth):
        visited_states = []
        if dfs(src, target, i + 1, visited_states):
            return True
    return False

```

OUTPUT:

```
src = [1,2,3,-1,4,5,6,7,8]
target = [1,2,3,4,5,-1,6,7,8]

depth = 1
iddfs(src, target, depth)

False
```

```
src = [3,5,2,8,7,6,4,1,-1]
target = [-1,3,7,8,1,5,4,6,2]

depth = 1
iddfs(src, target, depth)
```

False

```
src = [1,2,3,-1,4,5,6,7,8]
target=[1,2,3,6,4,5,-1,7,8]

depth = 1
iddfs(src, target, depth)
```

True

WEEK-5

5.Analyse best first search and A* algorithm. Implement 8 puzzle problem using both algorithms.

```
import heapq
```

```
class Node:
```

```
    def __init__(self, state, level, heuristic):
```

```
        self.state = state
```

```
        self.level = level
```

```
        self.heuristic = heuristic
```

```
    def __lt__(self, other):
```

```
        return self.heuristic < other.heuristic
```

```
def generate_child(node):
```

```
    x, y = find_blank(node.state)
```

```
    moves = [(x - 1, y), (x + 1, y), (x, y - 1), (x, y + 1)]
```

```
    children = []
```

```
    for move in moves:
```

```
        child_state = move_blank(node.state, (x, y), move)
```

```
        if child_state is not None:
```

```
            h = calculate_heuristic(child_state)
```

```
            child_node = Node(child_state, node.level + 1, h)
```

```
            children.append(child_node)
```

```
    return children
```

```
def find_blank(state):
```

```
    for i in range(3):
```

```
        for j in range(3):
```

```

if state[i][j] == 0:
    return i, j

def move_blank(state, src, dest):
    x1, y1 = src
    x2, y2 = dest

    if 0 <= x2 < 3 and 0 <= y2 < 3:
        new_state = [row[:] for row in state]
        new_state[x1][y1], new_state[x2][y2] = new_state[x2][y2], new_state[x1][y1]
        return new_state
    else:
        return None

def calculate_heuristic(state):
    goal_state = [[1, 2, 3], [4, 5, 6], [7, 8, 0]]
    h = 0

    for i in range(3):
        for j in range(3):
            if state[i][j] != goal_state[i][j] and state[i][j] != 0:
                h += 1

    return h

def best_first_search(initial_state):
    start_node = Node(initial_state, 0, calculate_heuristic(initial_state))
    open_list = [start_node]
    closed_set = set()

```

```

while open_list:
    current_node = heapq.heappop(open_list)

    if current_node.state == [[1, 2, 3], [4, 5, 6], [7, 8, 0]]:
        return current_node

    closed_set.add(tuple(map(tuple, current_node.state)))

    for child in generate_child(current_node):
        if tuple(map(tuple, child.state)) not in closed_set:
            heapq.heappush(open_list, child)

return None

initial_state = [[1, 2, 3], [0, 4, 6], [7, 5, 8]]
solution_node = best_first_search(initial_state)

if solution_node:
    print("Solution found in", solution_node.level, "moves.")
    print("Path:")
    for row in solution_node.state:
        print(row)
else:
    print("No solution found.")

```

OUTPUT:

```

[+] Solution found in 3 moves.
  Path:
  [1, 2, 3]
  [4, 5, 6]
  [7, 8, 0]

```

A* Algorithm:

```
import heapq

class Node:

    def __init__(self, data, level, fval):
        self.data = data
        self.level = level
        self.fval = fval

    def generate_child(self):
        x, y = self.find(self.data, '_')
        val_list = [[x, y-1], [x, y+1], [x-1, y], [x+1, y]]
        children = []

        for i in val_list:
            child = self.shuffle(self.data, x, y, i[0], i[1])
            if child is not None:
                child_node = Node(child, self.level+1, 0)
                children.append(child_node)

        return children

    def shuffle(self, puz, x1, y1, x2, y2):
        if 0 <= x2 < len(self.data) and 0 <= y2 < len(self.data):
            temp_puz = self.copy(puz)
            temp = temp_puz[x2][y2]
            temp_puz[x2][y2] = temp_puz[x1][y1]
            temp_puz[x1][y1] = temp
            return temp_puz
        else:
            return None
```

```

def copy(self, root):
    temp = []
    for i in root:
        t = []
        for j in i:
            t.append(j)
        temp.append(t)
    return temp

def find(self, puz, x):
    for i in range(0, len(self.data)):
        for j in range(0, len(self.data)):
            if puz[i][j] == x:
                return i, j

class Puzzle:
    def __init__(self, size):
        self.n = size
        self.open = []
        self.closed = []

    def f(self, start, goal):
        return self.h(start.data, goal) + start.level

    def h(self, start, goal):
        temp = 0
        for i in range(0, self.n):
            for j in range(0, self.n):
                if start[i][j] != goal[i][j] and start[i][j] != '_':

```

```

        temp += 1

    return temp


def process(self, start_data, goal_data):
    start = Node(start_data, 0, 0)
    start.fval = self.f(start, goal_data)
    self.open.append(start)
    print("\n\n")

    while True:
        cur = self.open[0]
        print("")
        for i in cur.data:
            for j in i:
                print(j, end=" ")
            print("")

        if self.h(cur.data, goal_data) == 0:
            break

        for i in cur.generate_child():
            i.fval = self.f(i, goal_data)
            self.open.append(i)
            self.closed.append(cur)

        del self.open[0]
        self.open.sort(key=lambda x: x.fval, reverse=False)

    start_state = [['1', '2', '3'], ['_', '4', '6'], ['7', '5', '8']]
    goal_state = [['1', '2', '3'], ['4', '5', '6'], ['7', '8', '_']]

```

```
puz = Puzzle(3)  
puz.process(start_state, goal_state)
```

OUTPUT:

1 2 3
4 6
7 5 8

1 2 3
4 6
7 5 8

1 2 3
4 5 6
7 _ 8

1 2 3
4 5 6
7 8 _

WEEK-6

6.Create a knowledgebase using prepositional logic and show that the given query entails the knowledge base or not.

```
def evaluate_first(premise, conclusion):  
    # Create all possible models for the variables p, q, and r  
    models = [  
        {'p': False, 'q': False, 'r': False},  
        {'p': False, 'q': False, 'r': True},  
        {'p': False, 'q': True, 'r': False},  
        {'p': False, 'q': True, 'r': True},  
        {'p': True, 'q': False, 'r': False},  
        {'p': True, 'q': False, 'r': True},  
        {'p': True, 'q': True, 'r': False},  
        {'p': True, 'q': True, 'r': True}  
    ]  
  
    # Check if the premise logically entails the conclusion  
    entails = True # Initially assume the premise entails the conclusion  
    for model in models:  
        if evaluate_expression(premise, model) != evaluate_expression(conclusion, model):  
            entails = False # If any model disagrees, premise does not entail conclusion  
            break  
  
    # Return the result  
    return entails  
  
# Define a function to evaluate logical expressions for the second input  
def evaluate_second(premise, conclusion):  
    # Generate all possible truth assignments to p, q, and r  
    models = [  
        {'p': p, 'q': q, 'r': r}
```

```

for p in [True, False]
    for q in [True, False]
        for r in [True, False]
    ]

# Check if the conclusion holds in every model where the premise is true
entails = all(evaluate_expression(premise, model) for model in models if
evaluate_expression(conclusion, model) and evaluate_expression(premise, model))

# Return the result
return entails

# Define a function to evaluate logical expressions based on the given expression and model
def evaluate_expression(expression, model):
    # Evaluate the logical expression recursively using the given model
    if isinstance(expression, str):
        # Base case: if it's a single variable or literal
        return model.get(expression)
    elif isinstance(expression, tuple):
        op = expression[0] # Get the operator
        if op == 'not':
            return not evaluate_expression(expression[1], model) # Negation
        elif op == 'and':
            return evaluate_expression(expression[1], model) and
evaluate_expression(expression[2], model) # Conjunction
        elif op == 'if':
            return (not evaluate_expression(expression[1], model)) or
evaluate_expression(expression[2], model) # Implication
        elif op == 'or':
            return evaluate_expression(expression[1], model) or
evaluate_expression(expression[2], model) # Disjunction (OR)

```

```

# Premise and conclusion for the first and second inputs

first_premise = ('and', ('or', 'p', 'q'), ('or', ('not', 'r'), 'p')) # (p OR q) AND (NOT r OR p)
first_conclusion = ('and', 'p', 'r') # p AND r

second_premise = ('and', ('or', ('not', 'q'), ('not', 'p')), 'r'), ('and', ('not', 'q'), 'p'), 'q')
second_conclusion = 'r'

# Evaluate both inputs using the merged function

result_first = evaluate_first(first_premise, first_conclusion)
result_second = evaluate_second(second_premise, second_conclusion)

# Print the results for both inputs

if result_first:
    print("For the first input: The knowledge base entails the query.")
else:
    print("For the first input: The knowledge base does not entail the query.")

if result_second:
    print("For the second input: The knowledge base entails the query.")
else:
    print("For the second input: The knowledge base does not entail the query.")

```

OUTPUT:

```

>>> ===== RESTART: C:/Users/Admin/Desktop/1BM21CS205 AI LAB/p5.py ======
For the first input: The knowledge base does not entail the query.
For the second input: The knowledge base entails the query.
>>>

```

WEEK-7

7.Create a knowledgebase using prepositional logic and prove the given query using resolution.

```
import re
```

```
def main(rules, goal):
    rules = rules.split(' ')
    steps = resolve(rules, goal)
    print('\nStep\tClause\tDerivation\t')
    print('-' * 30)
    i = 1
    for step in steps:
        print(f'{i}. {step}\t{steps[step]}\t')
        i += 1
def negate(term):
    return f'~{term}' if term[0] != '~' else term[1]

def reverse(clause):
    if len(clause) > 2:
        t = split_terms(clause)
        return f'{t[1]}v{t[0]}'
    return ""
def split_terms(rule):
    exp = '(~*[PQRS])'
    terms = re.findall(exp, rule)
    return terms
def contradiction(goal, clause):
    contradictions = [f'{goal}v{negate(goal)}', f'{negate(goal)}v{goal}']
    return clause in contradictions or reverse(clause) in contradictions
def resolve(rules, goal):
    temp = rules.copy()
```

```

temp += [negate(goal)]
steps = dict()
for rule in temp:
    steps[rule] = 'Given.'
    steps[negate(goal)] = 'Negated conclusion.'
i = 0
while i < len(temp):
    n = len(temp)
    j = (i + 1) % n
    clauses = []
    while j != i:
        terms1 = split_terms(temp[i])
        terms2 = split_terms(temp[j])
        for c in terms1:
            if negate(c) in terms2:
                t1 = [t for t in terms1 if t != c]
                t2 = [t for t in terms2 if t != negate(c)]
                gen = t1 + t2
                if len(gen) == 2:
                    if gen[0] != negate(gen[1]):
                        clauses += [f'{gen[0]} v {gen[1]}']
                else:
                    if contradiction(goal, f'{gen[0]} v {gen[1]}'):
                        temp.append(f'{gen[0]} v {gen[1]}')
                        steps[""] = f'Resolved {temp[i]} and {temp[j]} to {temp[-1]}, which is in turn null.\n'
    return steps
elif len(gen) == 1:
    clauses += [f'{gen[0]}']

```

```

else:
    if contradiction(goal,f{terms1[0]}v{terms2[0]})':
        temp.append(f{terms1[0]}v{terms2[0]}'')
        steps[""] = f'Resolved {temp[i]} and {temp[j]} to {temp[-1]}, which is in
turn null.\n
\nA contradiction is found when {negate(goal)} is assumed as true. Hence,
{goal} is true."
    return steps

for clause in clauses:
    if clause not in temp and clause != reverse(clause) and reverse(clause) not in temp:
        temp.append(clause)
        steps[clause] = f'Resolved from {temp[i]} and {temp[j]}.''
        j = (j + 1) % n
        i += 1
    return steps

```

OUTPUT

rules = 'Rv~P Rv~Q ~RvP ~RvQ' #(P^Q)<=>R : (Rv~P)v(Rv~Q)^(~RvP)^(~RvQ)

goal = 'R'

main(rules, goal)

```

Step | Clause | Derivation
-----
1. | Rv~P | Given.
2. | Rv~Q | Given.
3. | ~RvP | Given.
4. | ~RvQ | Given.
5. | ~R | Negated conclusion.
6. |   | Resolved Rv~P and ~RvP to Rv~R, which is in turn null.
A contradiction is found when ~R is assumed as true. Hence, R is true.
> |

```

```

rules = 'PvQ PvR ~PvR RvS Rv~Q ~Sv~Q' # (P=>Q)=>Q, (P=>P)=>R, (R=>S)=>~(S=>Q)
main(rules, 'R')

```

| Step | Clause | Derivation |
|--|--------|---|
| 1. | PvQ | Given. |
| 2. | PvR | Given. |
| 3. | ~PvR | Given. |
| 4. | RvS | Given. |
| 5. | Rv~Q | Given. |
| 6. | ~Sv~Q | Given. |
| 7. | ~R | Negated conclusion. |
| 8. | QvR | Resolved from PvQ and ~PvR. |
| 9. | Pv~S | Resolved from PvQ and ~Sv~Q. |
| 10. | P | Resolved from PvR and ~R. |
| 11. | ~P | Resolved from ~PvR and ~R. |
| 12. | Rv~S | Resolved from ~PvR and Pv~S. |
| 13. | R | Resolved from ~PvR and P. |
| 14. | S | Resolved from RvS and ~R. |
| 15. | ~Q | Resolved from Rv~Q and ~R. |
| 16. | Q | Resolved from ~R and QvR. |
| 17. | ~S | Resolved from ~R and Rv~S. |
| 18. | | Resolved ~R and R to ~RvR, which is in turn null. |
| A contradiction is found when ~R is assumed as true. Hence, R is true. | | |

WEEK-8

8.Implement unification in first order logic.

```
import re
```

```
def getAttributes(expression):
    expression = expression.split("(")[1:]
    expression = (".".join(expression)
    expression = expression[:-1]
    expression = re.split("(?<!\\(.),(?!\\))", expression)
    return expression
```

```
def getInitialPredicate(expression):
    return expression.split("(")[0]
```

```
def isConstant(char):
    return char.isupper() and len(char) == 1
```

```
def isVariable(char):
    return char.islower() and len(char) == 1
```

```
def replaceAttributes(exp, old, new):
    attributes = getAttributes(exp)
    for index, val in enumerate(attributes):
        if val == old:
            attributes[index] = new
    predicate = getInitialPredicate(exp)
    return predicate + "(" + ",".join(attributes) + ")"
```

```
def apply(exp, substitutions):
    for substitution in substitutions:
```

```

new, old = substitution
exp = replaceAttributes(exp, old, new)
return exp

def checkOccurs(var, exp):
    if exp.find(var) == -1:
        return False
    return True

def getFirstPart(expression):
    attributes = getAttributes(expression)
    return attributes[0]

def getRemainingPart(expression):
    predicate = getInitialPredicate(expression)
    attributes = getAttributes(expression)
    newExpression = predicate + "(" + ",".join(attributes[1:]) + ")"
    return newExpression

def unify(exp1, exp2):
    if exp1 == exp2:
        return []
    if isConstant(exp1) and isConstant(exp2):
        if exp1 != exp2:
            return False
    if isConstant(exp1):
        return [(exp1, exp2)]

```

```

if isConstant(exp2):
    return [(exp2, exp1)]


if isVariable(exp1):
    if checkOccurs(exp1, exp2):
        return False
    else:
        return [(exp2, exp1)]


if isVariable(exp2):
    if checkOccurs(exp2, exp1):
        return False
    else:
        return [(exp1, exp2)]


if getInitialPredicate(exp1) != getInitialPredicate(exp2):
    print("Predicates do not match. Cannot be unified")
    return False


attributeCount1 = len(getAttributes(exp1))
attributeCount2 = len(getAttributes(exp2))
if attributeCount1 != attributeCount2:
    return False


head1 = getFirstPart(exp1)
head2 = getFirstPart(exp2)
initialSubstitution = unify(head1, head2)
if not initialSubstitution:
    return False
if attributeCount1 == 1:

```

```

return initialSubstitution

tail1 = getRemainingPart(exp1)
tail2 = getRemainingPart(exp2)

if initialSubstitution != []:
    tail1 = apply(tail1, initialSubstitution)
    tail2 = apply(tail2, initialSubstitution)

remainingSubstitution = unify(tail1, tail2)
if not remainingSubstitution:
    return False

initialSubstitution.extend(remainingSubstitution)
return initialSubstitution

```

OUTPUT

```

exp1 = "knows(A,x)"
exp2= "knows(y,Y)"

```

```

Substitutions:
[('A', 'y'), ('Y', 'x')]
> |

```

```

exp1 = "like(A,y)"
exp2 = "like(K,g(x))"

```

```

Substitutions:
False
> |

```

WEEK-9

9. Convert given first order logic statement into Conjunctive Normal Form (CNF).

```
def getAttributes(string):
    expr = '\([^\)]+\)'
    matches = re.findall(expr, string)
    return [m for m in str(matches) if m.isalpha()]

def getPredicates(string):
    expr = '[a-zA-Z~]+\\([A-Za-z,]+\\)'
    return re.findall(expr, string)

def Skolemization(statement):
    SKOLEM_CONSTANTS = [f'{chr(c)}' for c in range(ord('A'), ord('Z')+1)]
    matches = re.findall('(\exists).', statement)
    for match in matches[::-1]:
        statement = statement.replace(match, "")
        for predicate in getPredicates(statement):
            attributes = getAttributes(predicate)
            if ''.join(attributes).islower():
                statement = statement.replace(match[1], SKOLEM_CONSTANTS.pop(0))
    return statement

import re

def fol_to_cnf(fol):
    statement = fol.replace("=>", "-")
    expr = '\([^\)]+\)'
    statements = re.findall(expr, statement)
    for i, s in enumerate(statements):
        if '[' in s and ']' not in s:
            statements[i] += ']'
```

```
for s in statements:
```

```
    statement = statement.replace(s, fol_to_cnf(s))
```

```
while '-' in statement:
```

```
    i = statement.index('-')
```

```
    br = statement.index('[') if '[' in statement else 0
```

```
    new_statement = '~' + statement[br:i] + '|' + statement[i+1:]
```

```
    statement = statement[:br] + new_statement if br > 0 else new_statement
```

```
return Skolemization(statement)
```

OUTPUT:

```
[12] print(Skolemization(fol_to_cnf("∀x food(x) => likes(John, x)")))
      ~ food(A) | likes(John, A)

[13] print(Skolemization(fol_to_cnf("∀x[∃z[loves(x,z)]]")))
      [loves(x,B(x))]

[14] print(fol_to_cnf("[american(x)&weapon(y)&sells(x,y,z)&hostile(z)]=>criminal(x)"))
      [~american(x)|~weapon(y)|~sells(x,y,z)|~hostile(z)]|criminal(x)
```

WEEK-10

10.Create a knowledgebase consisting of first order logic statements and prove the given query using forward reasoning.

```
import re

def isVariable(x):
    return len(x) == 1 and x.islower() and x.isalpha()

def getAttributes(string):
    expr = '\([^\)]+\)'
    matches = re.findall(expr, string)
    return matches

def getPredicates(string):
    expr = '([a-z~]+)([^&]+)'
    return re.findall(expr, string)

class Fact:
    def __init__(self, expression):
        self.expression = expression
        predicate, params = self.splitExpression(expression)
        self.predicate = predicate
        self.params = params
        self.result = any(self.getConstants())

    def splitExpression(self, expression):
        predicate = getPredicates(expression)[0]
        params = getAttributes(expression)[0].strip(')').split(',')
        return [predicate, params]

    def getResult(self):
        return self.result

    def getConstants(self):
        return [None if isVariable(c) else c for c in self.params]

    def getVariables(self):
        return [v if isVariable(v) else None for v in self.params]

    def substitute(self, constants):
        c = constants.copy()
        f = f'{self.predicate}({",".join([constants.pop(0) if isVariable(p) else p for p in self.params])})'
        return Fact(f)

class Implication:
```

```

def __init__(self, expression):
    self.expression = expression
    l = expression.split('=>')
    self.lhs = [Fact(f) for f in l[0].split('&')]
    self.rhs = Fact(l[1])

def evaluate(self, facts):
    constants = {}
    new_lhs = []
    for fact in facts:
        for val in self.lhs:
            if val.predicate == fact.predicate:
                for i, v in enumerate(val.getVariables()):
                    if v:
                        constants[v] = fact.getConstants()[i]
                new_lhs.append(fact)
    predicate, attributes = getPredicates(self.rhs.expression)[0],
    str(getAttributes(self.rhs.expression)[0])
    for key in constants:
        if constants[key]:
            attributes = attributes.replace(key, constants[key])
    expr = f'{predicate} {attributes}'
    return Fact(expr) if len(new_lhs) and all([f.getResult() for f in new_lhs]) else None

class KB:
    def __init__(self):
        self.facts = set()
        self.implications = set()

    def tell(self, e):
        if '=>' in e:
            self.implications.add(Implication(e))
        else:
            self.facts.add(Fact(e))
        for i in self.implications:
            res = i.evaluate(self.facts)
            if res:
                self.facts.add(res)

    def query(self, e):
        facts = set([f.expression for f in self.facts])
        i = 1
        print(f'Querying {e}:')
        for f in facts:
            if Fact(f).predicate == Fact(e).predicate:
                print(f'\t{i}. {f}')
                i += 1

```

```
def display(self):
    print("All facts: ")
    for i, f in enumerate(set([f.expression for f in self.facts])):
        print(f'\t{i+1}'. {f}'')
```

OUTPUT

```
Shell
Querying criminal(x):
  1. criminal(West)
All facts:
  1. sells(West,M1,Nono)
  2. criminal(West)
  3. hostile(Nono)
  4. owns(Nono,M1)
  5. enemy(Nono,America)
  6. weapon(M1)
  7. american(West)
  8. missile(M1)
> |
```

