VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence LAB

Submitted by

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

B.M.S. COLLEGE OF ENGINEERING
(Autonomous Institution under VTU)
BENGALURU-560019
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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 Lab work entitled "Artificial Intelligence lab" carried out by **SAMARTH M SHETTY (1BM21CS184),** who is a bonafide student of **B. M. S. College of Engineering.** It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum during the year 2023. The Lab report has been approved as it satisfies the academic requirements in respect of a **Artificial Intelligence lab (22CS5PCAIN)**work prescribed for the said degree.

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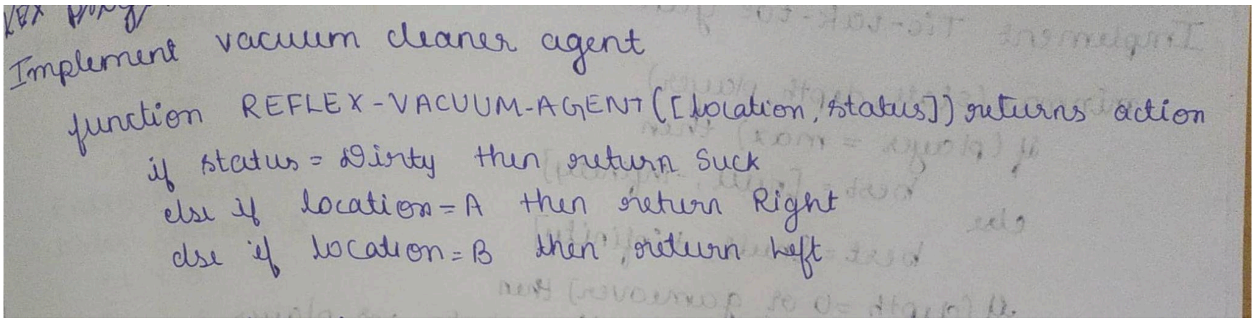
Program-1

Implement Vacuum cleaner problem for 2 rooms ,any type of agent can be considered simple reflex or model based etc.

Algorithm:



Implement vacuum cleaner agent

function REFLEX-VACUUM-AGENT([location, status]) returns action

if status = Dirty then return Suck

else if location = A then return Right

else if location = B then return Left

Code:

```
def vacuum_world():
    # Initializing goal_state for four rooms
    # 0 indicates Clean and 1 indicates Dirty
    goal_state = {'A': 0, 'B': 0, 'C': 0, 'D': 0}
    cost = 0

    # User input for initial vacuum location and status of each room
    location_input = input("Enter Initial Location of Vacuum (A/B/C/D): ")
    print("Enter status of each room (1 - dirty, 0 - clean):")
    for room in goal_state:
        goal_state[room] = int(input(f"Status of Room {room}: "))

    print("Initial Location Condition: " + str(goal_state))

    # Function to clean a room
    def clean_room(room):
        nonlocal cost
        if goal_state[room] == 1:
            print(f"Cleaning Room {room}...")
            goal_state[room] = 0
            cost += 1  # Cost for cleaning
            print(f"Room {room} has been cleaned. Current cost: {cost}")
        else:
            print(f"Room {room} is already clean.")

    # Cleaning logic
    rooms = ['A', 'B', 'C', 'D']
    current_index = rooms.index(location_input)

    # Clean all rooms starting from the initial location
    for i in range(current_index, len(rooms)):
        clean_room(rooms[i])
```

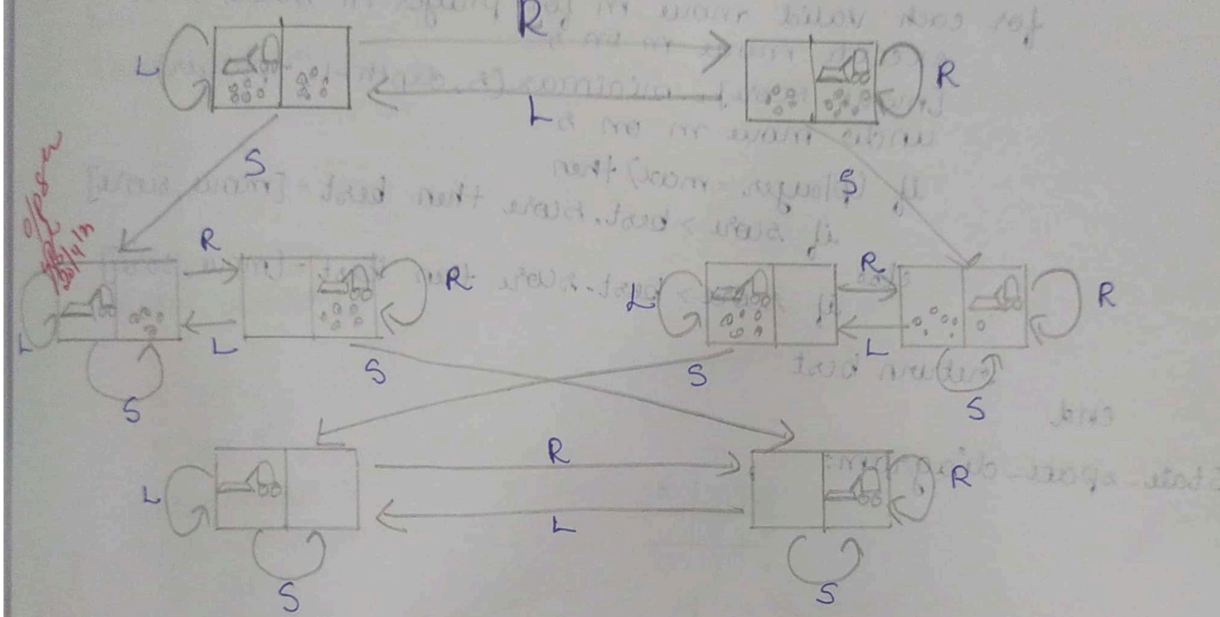
```
    # Clean remaining rooms (if the initial location was not 'A')
    for i in range(0, current_index):
        clean_room(rooms[i])

    # Output final state and performance measure
    print("Final State of Rooms: " + str(goal_state))
    print("Performance Measurement (Total Cost): " + str(cost+4))

vacuum_world()
```

Output:

```
Enter clean status for Room at (1, 1) (1 for dirty, 0 for clean): 1
Enter clean status for Room at (1, 2) (1 for dirty, 0 for clean): 0
Enter clean status for Room at (2, 1) (1 for dirty, 0 for clean): 1
Enter clean status for Room at (2, 2) (1 for dirty, 0 for clean): 1
Cleaning Room at (1, 1) (Room was dirty)
Room is now clean.
Room at (1, 2) is already clean.
Cleaning Room at (2, 1) (Room was dirty)
Room is now clean.
Cleaning Room at (2, 2) (Room was dirty)
Room is now clean.
Returning to Room at (1, 1) to check if it has become dirty again:
Room at (1, 1) is already clean.
```

State-Space Diagram:

state space for the vacuum world



Program-2

Explore the working of Tic Tac Toe using Min max strategy

Algorithm:

```
Implement Tic-tak-toe game
  minmax (state, depth, player)
      if (player = max) then
           best = [null, -infinity]
      else
           best = [null, +infinity]
      if (depth = 0 or gameover) then
           score = evaluate this state for player
           return [null, score]
      for each valid move m for player in state s do
           execute move m on s
           [move, score] = minimax(s, depth-1, -player)
           undo move m on s
           if (player = max) then
                if score > best.score then best = [move, score]
           else
                if score > best.score then best = [move, sore]
        return best
  end
```

Code:

```
tic=[]
import random
def board(tic):
    for i in range(0,9,3):
        print("+"+"-"*29+"+")
        print("|"+" "*9+"|"+" "*9+"|"+" "*9+"|")
        print("|"+" "*3,tic[0+i]," "*3+"|"+" "*3,tic[1+i]," "*3+"|"+"
"*3,tic[2+i]," "*3+"|")
        print("|"+" "*9+"|"+" "*9+"|"+" "*9+"|")
    print("+"+"-"*29+"+")




def update_comp():
    global tic,num
    for i in range(9):
        if tic[i]==i+1:
            num=i+1
```

```
            tic[num-1]='X'
            if winner(num-1)==False:
                #reverse the change
                tic[num-1]=num
            else:
                return
    for i in range(9):
        if tic[i]==i+1:
            num=i+1
            tic[num-1]='O'
            if winner(num-1)==True:
                tic[num-1]='X'
                return
            else:
                tic[num-1]=num
    num=random.randint(1,9)
    while num  not in tic:
        num=random.randint(1,9)
    else:
        tic[num-1]='X'




def update_user():
    global tic,num
    num=int(input("enter a number on the board :"))
    while num not in tic:
        num=int(input("enter a number on the board :"))
    else:
        tic[num-1]='O'


def winner(num):
    if tic[0]==tic[4] and tic[4]==tic[8] or tic[2]==tic[4] and
tic[4]==tic[6]:
        return True
    if tic[num]==tic[num-3] and tic[num-3]==tic[num-6]:
        return True
    if tic[num//3*3]==tic[num//3*3+1] and
tic[num//3*3+1]==tic[num//3*3+2]:
        return True
    return False




try:
    for i in range(1,10):
        tic.append(i)
    count=0
    #print(tic)
    board(tic)
```

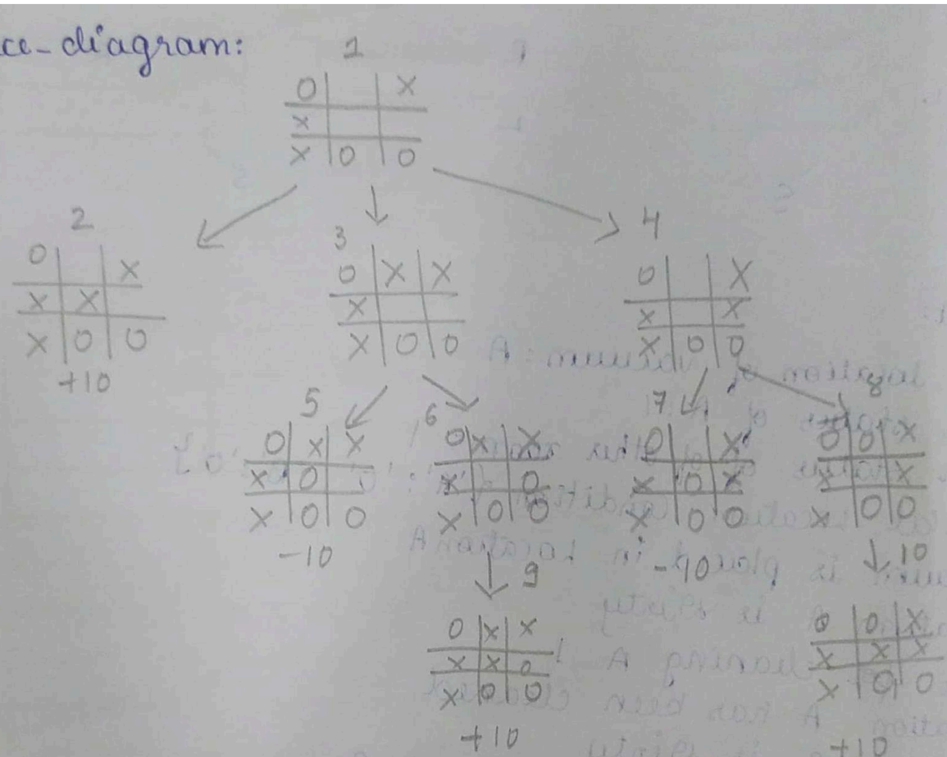
```
    while count!=9:
        if count%2==0:
            print("computer's turn :")
            update_comp()
            board(tic)
            count+=1
        else:
            print("Your turn :")
            update_user()
            board(tic)
            count+=1
        if count>=5:
            if winner(num-1):
                print("winner is ",tic[num-1])
                break
            else:
                continue
except:
    print("\nerror\n")
```

Output:

```
[1, 2, 3, 4, 5, 6, 7, 8, 9]
+-----------------------------+
|         |         |         |
|    1    |    2    |    3    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    4    |    5    |    6    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    7    |    8    |    9    |
|         |         |         |
+-----------------------------+
computer's turn :
+-----------------------------+
|         |         |         |
|    1    |    2    |    3    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    4    |    X    |    6    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    7    |    8    |    9    |
|         |         |         |
+-----------------------------+
Your turn :
enter a number on the board :1
```

State-Space Diagram:

State-space-diagram:



Program-3

Implement the 8 Puzzle Breadth First Search Algorithm.

Algorithm:

```
Algorithm:
  function BFS-8-Puzzle (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 = possible_moves(source, exp)
```

Code:

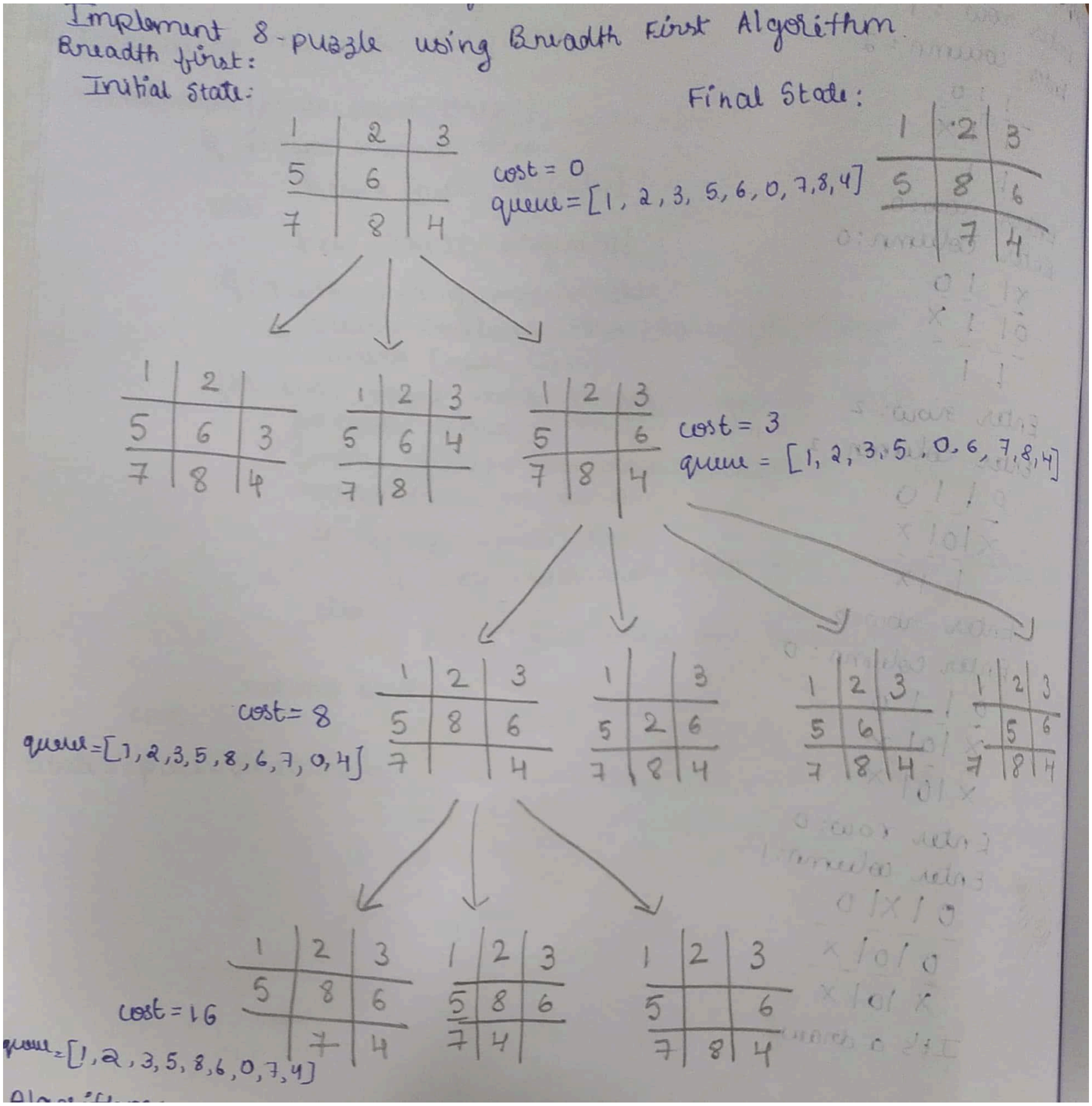
```
def bfs(src,target):
    queue=[]
    queue.append(src)
    exp=[]
    while len(queue)>0:
        source=queue.pop(0)
        #print("queue",queue)
        exp.append(source)

        print(source[0],'|',source[1],'|',source[2])
        print(source[3],'|',source[4],'|',source[5])
        print(source[6],'|',source[7],'|',source[8])
        print("-----------")
        if source==target:
            print("Success")
            return
        poss_moves_to_do=[]
        poss_moves_to_do=possible_moves(source,exp)
        #print("possible moves",poss_moves_to_do)
        for move in poss_moves_to_do:
            if move not in exp and move not in queue:
              #print("move",move)
              queue.append(move)
```

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

    #direction array
    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

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

Output:

```
1 | 2 | 3
4 | 5 | 6
0 | 7 | 8

1 | 2 | 3
0 | 5 | 6
4 | 7 | 8

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

1 | 2 | 3
4 | 5 | 6
7 | 8 | 0

success
```

State-Space Diagram:



Program-4

Implement Iterative deepening search algorithm.

Algorithm:

Program 4 18/12/2023

Implement Iterative Deepening Search algorithm

function ITERATIVE-DEEPENING-SEARCH(problem) returns a sol or failure
 for depth = 0 to ∞ do
  result ← DEPTH-LIMITED-SEARCH(problem, depth)
  if result ≠ cutoff then return result

function DEPTH-LIMITED-SEARCH(problem, depth) returns a sol or failure/cutoff
 return DLS(MAKE-NODE(problem.INITIAL-STATE), problem, limit)

function DLS(node, problem, limit) returns a sol or failure/cutoff
 if problem.GOAL-STATE (node.STATE) then return SOLUTION(node)
 else if limit=0 then return cutoff
 else
  cutoff-occurred? ← false
  for each action in problem.ACTIONS(node.STATE) do
   child ← CHILD-NODE(problem, node, action)
   result ← DLS(child, problem, limit-1)
   if result=cutoff then cutoff-occurred? ← true
   else if result ≠ failure then return result
  if cutoff-occurred? then return cutoff else return failure

Code:

```
# 8 Puzzle problem using Iterative deepening depth first search algorithm

def id_dfs(puzzle, goal, get_moves):
    import itertools
#get_moves -> possible_moves
    def dfs(route, depth):
        if depth == 0:
            return
        if route[-1] == goal:
            return route
        for move in get_moves(route[-1]):
            if move not in route:
                next_route = dfs(route + [move], depth - 1)
```

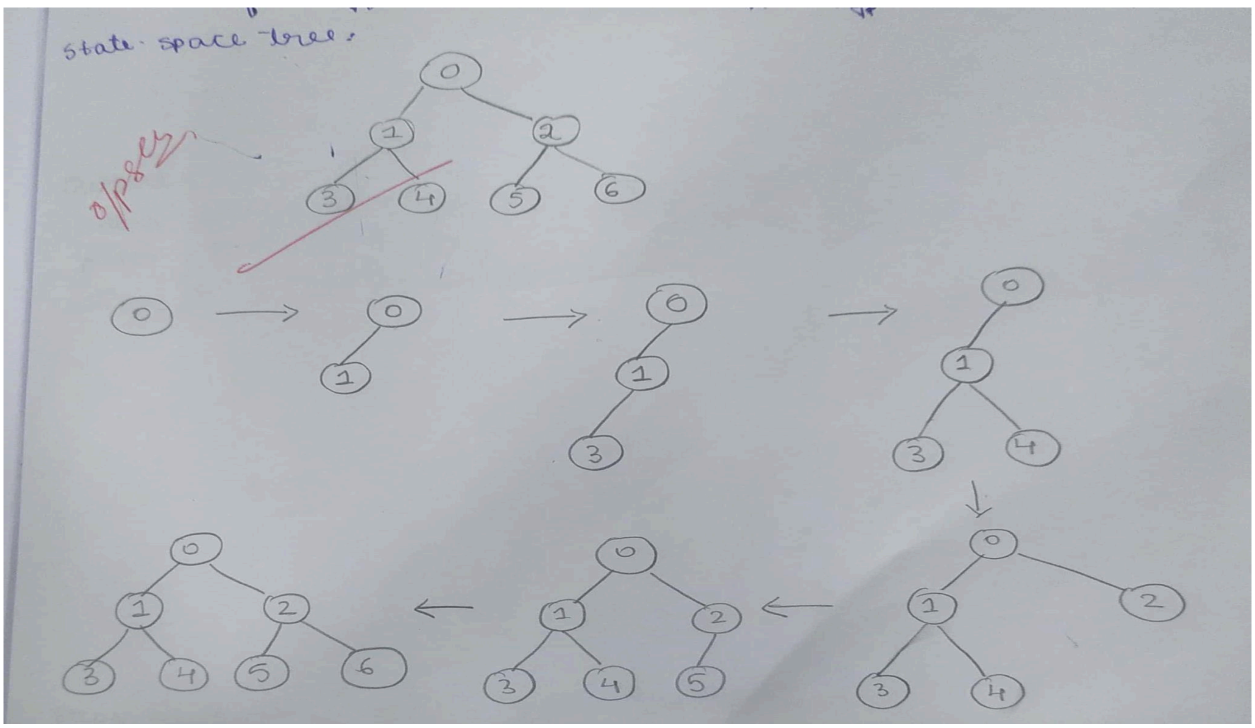
```python
                if next_route:
                    return next_route

    for depth in itertools.count():
        route = dfs([puzzle], depth)
        if route:
            return route


def possible_moves(state):
    b = state.index(0)  # ) indicates White space -> so b has index of it.
    d = []  # direction

    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 = []
    for i in d:
        pos_moves.append(generate(state, i, b))
    return pos_moves


def generate(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


# calling ID-DFS
initial = [1, 2, 3, 0, 4, 6, 7, 5, 8]
goal = [1, 2, 3, 4, 5, 6, 7, 8, 0]

route = id_dfs(initial, goal, possible_moves)

if route:
    print("Success!! It is possible to solve 8 Puzzle problem")
    print("Path:", route)
```

```
else:
    print("Failed to find a solution")
```

Output:

```
Success!! It is possible to solve 8 Puzzle problem
Path: [[1, 2, 3, 0, 4, 6, 7, 5, 8], [1, 2, 3, 4, 0, 6, 7, 5, 8], [1, 2, 3, 4, 5, 6, 7, 0, 8], [1, 2, 3, 4, 5, 6, 7, 8, 0]]
```

State-Space Diagram:



Program-5

Implement A* for 8 puzzle problem

Algorithm:

- Initialize the open list
- Initialize the closed list
  put the starting node on the open list
- while the open list is not empty
  - a) find the node with the least f on the open list, call it 'q'
  - b) pop q off the open list
  - c) generate q's 8 successors and set their parents to q
  - d) for each successor
    - i) if successor is the goal, stop search
    - ii) else, compute both g & h for successor
      successor.g = q.g + distance b/w successor and q
      successor.h = distance from goal to successor
      successor.f = successor.g + successor.h
    - iii) if a node with the same position as successor is in the OPEN list which has a lower f than successor, skip this successor
    - iv) if a node with the same position as successor is in the CLOSED list

    end (for loop)
  - e) push q on the closed list

  end (while loop)

Code:

```
class Node:
    def __init__(self,data,level,fval):
        """ Initialize the node with the data, level of the node and the
calculated fvalue """
        self.data = data
        self.level = level
        self.fval = fval

    def generate_child(self):
        """ Generate child nodes from the given node by moving the blank
space
```

```
            either in the four directions {up,down,left,right} """
        x,y = self.find(self.data,'_')
        """ val_list contains position values for moving the blank space
in either of
            the 4 directions [up,down,left,right] respectively. """
        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):
        """ Move the blank space in the given direction and if the
position value are out
            of limits the return None """
        if x2 >= 0 and x2 < len(self.data) and y2 >= 0 and y2 <
len(self.data):
            temp_puz = []
            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):
        """ Copy function to create a similar matrix of the given node"""
        temp = []
        for i in root:
            t = []
            for j in i:
                t.append(j)
            temp.append(t)
        return temp

    def find(self,puz,x):
        """ Specifically used to find the position of the blank space """
        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):
        """ Initialize the puzzle size by the specified size,open and
closed lists to empty """
        self.n = size
```

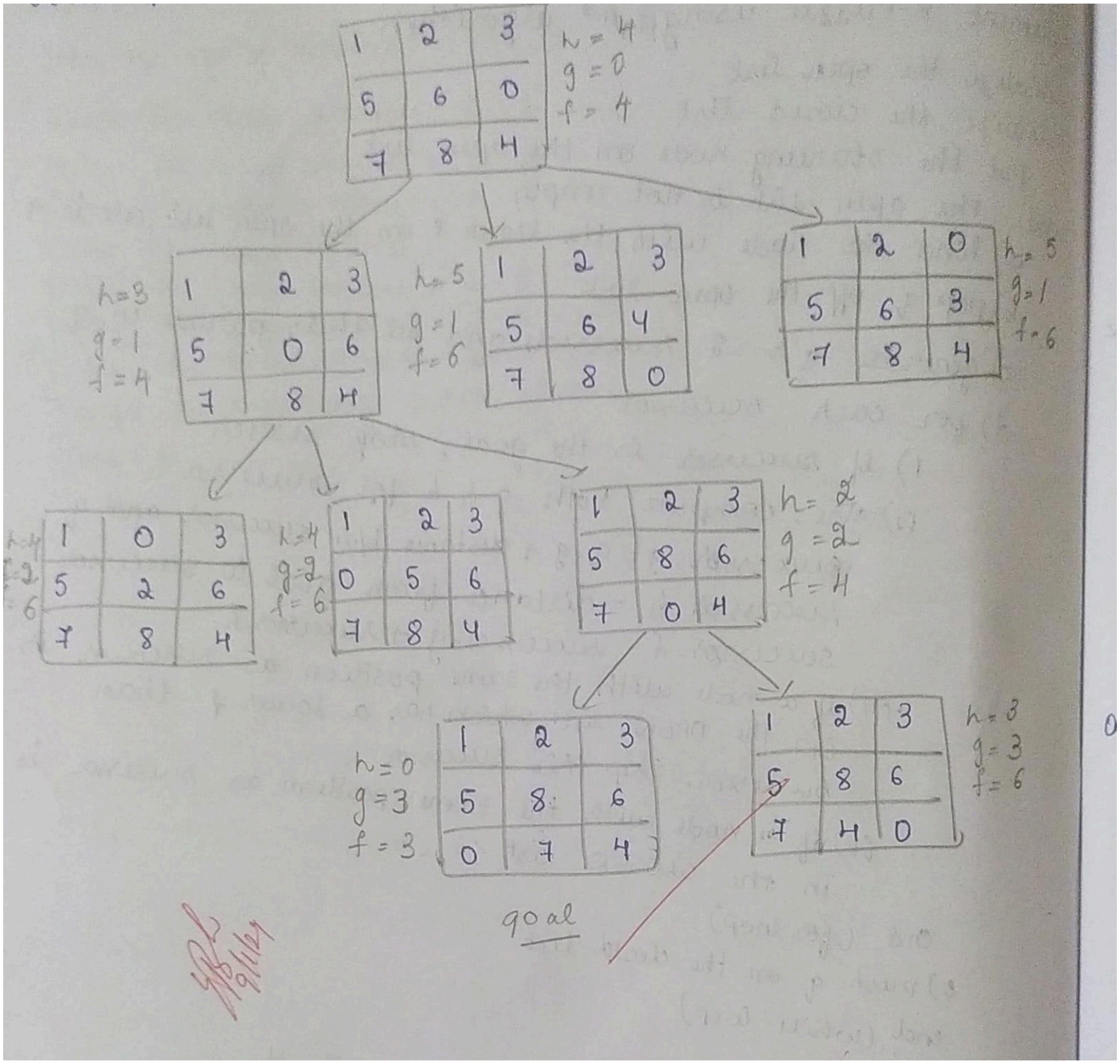
```
        self.open = []
        self.closed = []

    def accept(self):
        """ Accepts the puzzle from the user """
        puz = []
        for i in range(0,self.n):
            temp = input().split(" ")
            puz.append(temp)
        return puz

    def f(self,start,goal):
        """ Heuristic Function to calculate hueristic value f(x) = h(x) +
g(x) """
        return self.h(start.data,goal)+start.level

    def h(self,start,goal):
        """ Calculates the different between the given puzzles """
        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):
        """ Accept Start and Goal Puzzle state"""
        print("Enter the start state matrix \n")
        start = self.accept()
        print("Enter the goal state matrix \n")
        goal = self.accept()

        start = Node(start,0,0)
        start.fval = self.f(start,goal)
        """ Put the start node in the open list"""
        self.open.append(start)
        print("\n\n")
        while True:
            cur = self.open[0]
            print("")
            print("  | ")
            print("  | ")
            print(" \\\'/ \n")
            for i in cur.data:
                for j in i:
                    print(j,end=" ")
                print("")
            """ If the difference between current and goal node is 0 we
have reached the goal node"""
            if(self.h(cur.data,goal) == 0):
                break
            for i in cur.generate_child():
```

```
                i.fval = self.f(i,goal)
                self.open.append(i)
            self.closed.append(cur)
            del self.open[0]

            """ sort the opne list based on f value """
            self.open.sort(key = lambda x:x.fval,reverse=False)


puz = Puzzle(3)
puz.process()
```

Output:

```
Enter the start state matrix

1 2 3
4 5 6
_ 7 8
Enter the goal state matrix

1 2 3
4 5 6
7 8 _



  |
  |
 \'/

1 2 3
4 5 6
_ 7 8

  |
  |
 \'/

1 2 3
4 5 6
7 _ 8

  |
  |
 \'/

1 2 3
4 5 6
7 8 _
```

State-Space Diagram:


1 2 3 / 5 6 0 / 7 8 4
h = 4
g = 0
f = 4
h = 3
g = 1
f = 4
1 2 3 / 5 0 6 / 7 8 4
h = 5
g = 1
f = 6
1 2 3 / 5 6 4 / 7 8 0
1 2 0 / 5 6 3 / 7 8 4
h = 5
g = 1
f = 6
1 0 3 / 5 2 6 / 7 8 4
h = 4
g = 2
f = 6
1 2 3 / 0 5 6 / 7 8 4
1 2 3 / 5 8 6 / 7 0 4
h = 2
g = 2
f = 4
h = 0
g = 3
f = 3
1 2 3 / 5 8 6 / 0 7 4
goal
1 2 3 / 5 8 6 / 7 4 0
h = 3
g = 3
f = 6

Program-6

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

Algorithm:

```
function TT-ENTAILS? (KB, a) returns true or false
    inputs: KB, the knowledge base
            a, the query
    symbols: a list of the proposition symbols in KB and a
function TT-CHECK-ALL (KB, a, symbols, model) returns true or false
    if EMPTY? (symbols) then
        if PL-TRUE? (KB, model) then return PL-TRUE? (a, model)
        else return true
    else do
        P = FIRST(symbols); rest = REST(symbols)
        return TT-CHECK-ALL (KB, a, rest, EXTEND (P, true, model)) and
               TT-CHECK-ALL (KB, a, rest, EXTEND (P, false, model))
```

Code:

```
from sympy import symbols, And, Not, Implies, satisfiable

def create_knowledge_base():
    # Define propositional symbols
    p = symbols('p')
    q = symbols('q')
    r = symbols('r')

    # Define knowledge base using logical statements
    knowledge_base = And(
        Implies(p, q),          # If p then q
        Implies(q, r),          # If q then r
        Not(r)                  # Not r
    )

    return knowledge_base

def query_entails(knowledge_base, query):
    # Check if the knowledge base entails the query
    entailment = satisfiable(And(knowledge_base, Not(query)))

    # If there is no satisfying assignment, then the query is entailed
    return not entailment
```

```
if __name__ == "__main__":
    # Create the knowledge base
    kb = create_knowledge_base()

    # Define a query
    query = symbols('p')

    # Check if the query entails the knowledge base
    result = query_entails(kb, query)

    # Display the results
    print("Knowledge Base:", kb)
    print("Query:", query)
    print("Query entails Knowledge Base:", result)
```

Output:

```
Knowledge Base: ~r & (Implies(p, q)) & (Implies(q, r))
Query: p
Query entails Knowledge Base: False
```

Proof:

Truth table:

p	q	p ∨ q
T	T	T
T	F	T
F	T	T
F	F	F

$p \vee q \not\vdash q$

Program-7

Create a knowledge base using prepositional logic and prove the given query using resolution

Algorithm:

function PL-RESOLUTION(KB, α) returns true or false
inputs: KB, the knowledge base, a sentence in propositional logic
α, the query, a sentence in PL
clauses $\leftarrow$ the set of clauses in the CNF representation KB $\wedge \neg\alpha$
new $\leftarrow \{\}$
loop do
for each pair of clauses C_i, C_j in clauses do
resolvents $\leftarrow$ PL-RESOLVE(C_i, C_j)
if resolvents contains the empty clause then return true
new $\leftarrow$ new $\cup$ resolvents
if new $\subseteq$ clauses then return false
clauses $\leftarrow$ clauses $\cup$ new

Code:

```
import re

def main(rules, goal):
    rules = rules.split(' ')
    steps = resolve(rules, goal)
    print('\nStep\t|Clause\t|Derivation\t')
    print('-' * 30)
    i = 1
    for step in steps:
        print(f' {i}.\t| {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)
```

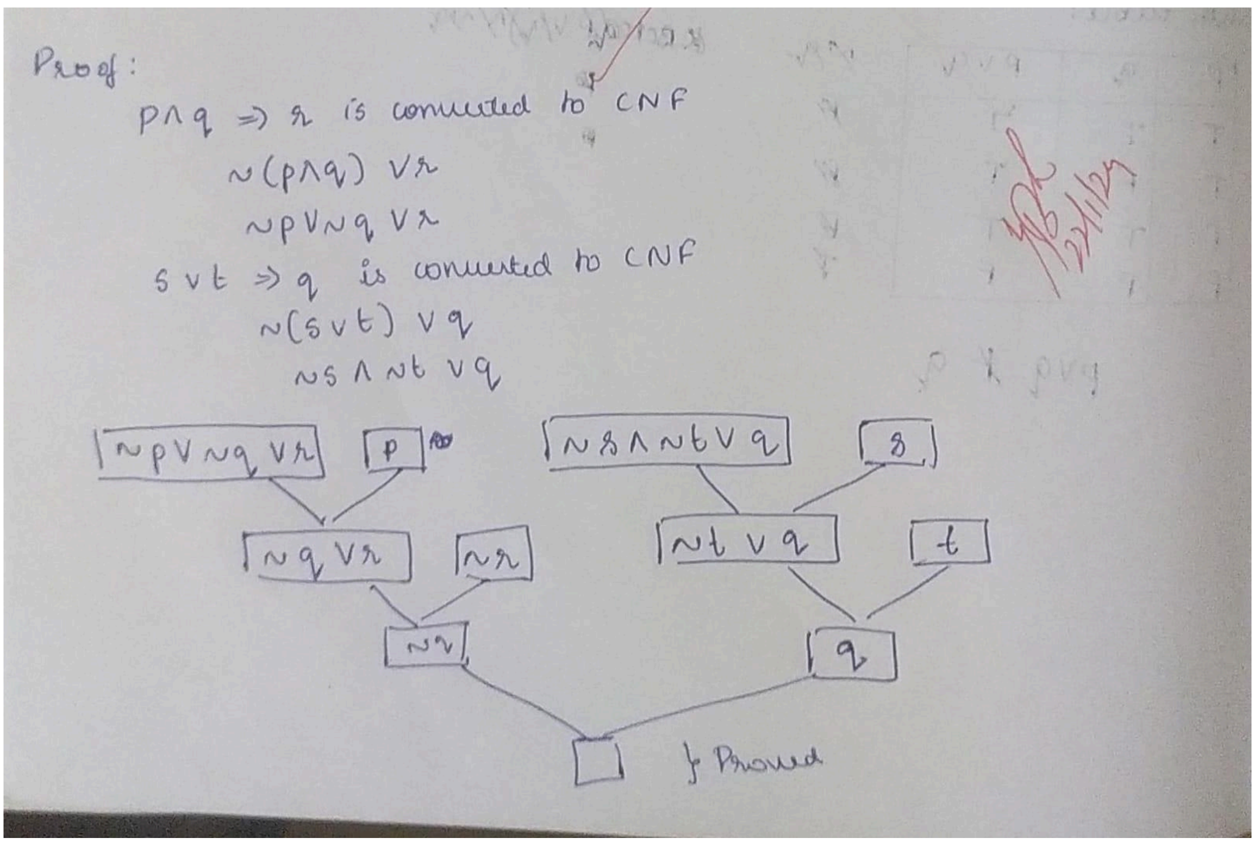
```
    return terms

split_terms('~PvR')
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. \
                                \nA contradiction is found when
{negate(goal)} is assumed as true. Hence, {goal} is true."
                                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. \
                            \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
rules = 'Rv~P Rv~Q ~RvP ~RvQ' #(P^Q)<=>R : (Rv~P)v(Rv~Q)^(~RvP)^(~RvQ)
goal = 'R'
main(rules, goal)
```

Output:

```
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.
```

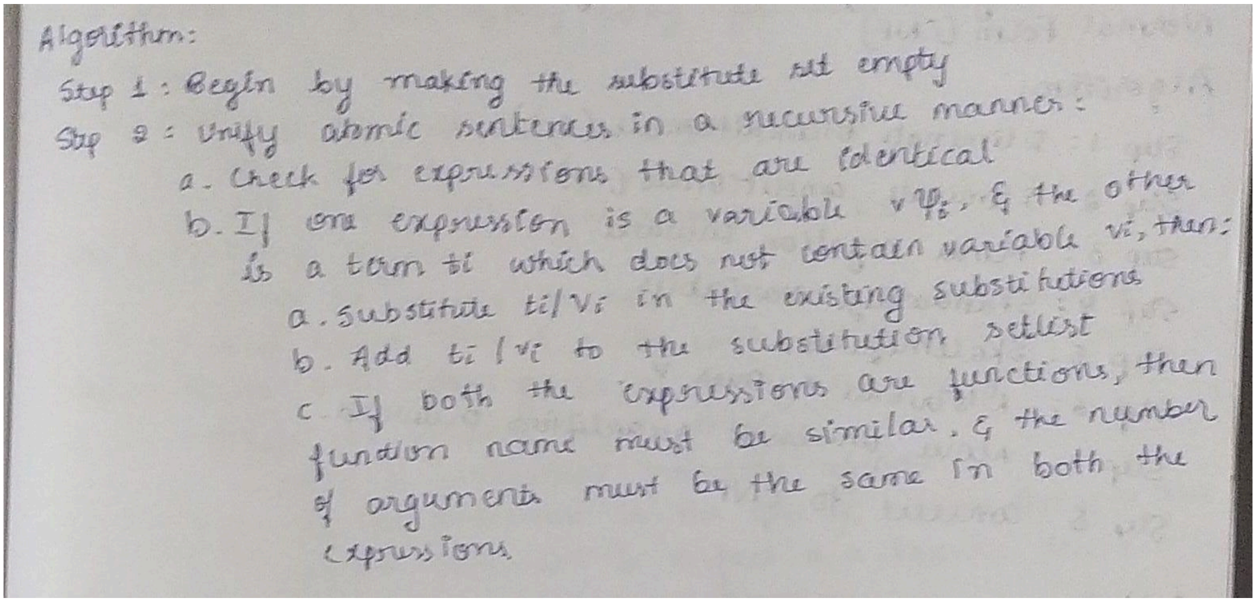
Proof:



Program-8

Implement unification in first order logic

Algorithm:



Algorithm:

Step 1: Begin by making the substitute set empty

Step 2: Unify atomic sentences in a recursive manner:

a. Check for expressions that are identical

b. If one expression is a variable $v\Psi_i$, & the other is a term t_i which does not contain variable v_i, then:

a. Substitute t_i/v_i in the existing substitutions

b. Add t_i/v_i to the substitution setlist

c. If both the expressions are functions, then function name must be similar, & the number of arguments must be the same in both the expressions.

Code:

```
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
exp1 = "knows(X)"
exp2 = "knows(Richard)"
substitutions = unify(exp1, exp2)
print("Substitutions:")
print(substitutions)
```

Output:

```
Enter the first expression
knows(y,f(x))
Enter the second expression
knows(nithin,N)
The substitutions are:
['nithin / y', 'N / f(x)']
```

Proof:

Proof :

Here, predicate is same

So, by replacing y with nithin, we can unify both statements

Replace f(x) with N, unification is possible

Program-9

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

Algorithm:

Algorithm:

Step 1: Eliminate biconditionals ($\leftrightarrow$)

Step 2: Eliminate conditionals ($\rightarrow$)

Step 3: Move negation inward

Step 4: Standardize variables

Step 5: Skalemization

Step 6: Distribute $\wedge$ over $\vee$

Step 7: Move universal quantifiers outward

Step 8: Convert to CNF

Code:

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

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

def DeMorgan(sentence):
    string = ''.join(list(sentence).copy())
    string = string.replace('~~','')
    flag = '[' in string
    string = string.replace('~[','')
    string = string.strip(']')
    for predicate in getPredicates(string):
        string = string.replace(predicate, f'~{predicate}')
    s = list(string)
    for i, c in enumerate(string):
        if c == '|':
            s[i] = '&'
        elif c == '&':
            s[i] = '|'
    string = ''.join(s)
    string = string.replace('~~','')
    return f'[{string}]' if flag else string
```

```
def Skolemization(sentence):
    SKOLEM_CONSTANTS = [f'{chr(c)}' for c in range(ord('A'), ord('Z')+1)]
    statement = ''.join(list(sentence).copy())
    matches = re.findall('[∀∃].', statement)
    for match in matches[::-1]:
        statement = statement.replace(match, '')
        statements = re.findall('\[\[[^]]+\]]', statement)
        for s in statements:
            statement = statement.replace(s, s[1:-1])
        for predicate in getPredicates(statement):
            attributes = getAttributes(predicate)
            if ''.join(attributes).islower():
                statement =
statement.replace(match[1],SKOLEM_CONSTANTS.pop(0))
            else:
                aL = [a for a in attributes if a.islower()]
                aU = [a for a in attributes if not a.islower()][0]
                statement = statement.replace(aU,
f'{SKOLEM_CONSTANTS.pop(0)}({aL[0] if len(aL) else match[1]})')
    return statement

import re

def fol_to_cnf(fol):

    statement = fol.replace("<=>", "_")
    while '_' in statement:
        i = statement.index('_')
        new_statement = '[' + statement[:i] + '=>' + statement[i+1:] +
']&['+ statement[i+1:] + '=>' + statement[:i] + ']'
        statement = new_statement
    statement = statement.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
    while '~∀' in statement:
        i = statement.index('~∀')
        statement = list(statement)
        statement[i], statement[i+1], statement[i+2] = '∃',
statement[i+2], '~'
        statement = ''.join(statement)
    while '~∃' in statement:
```

```
        i = statement.index('~∃')
        s = list(statement)
        s[i], s[i+1], s[i+2] = '∀', s[i+2], '~'
        statement = ''.join(s)
    statement = statement.replace('~[∀','[~∀')
    statement = statement.replace('~[∃','[~∃')
    expr = '(~[∀|∃].)'
    statements = re.findall(expr, statement)
    for s in statements:
        statement = statement.replace(s, fol_to_cnf(s))
    expr = '~\[[^]]+\]'
    statements = re.findall(expr, statement)
    for s in statements:
        statement = statement.replace(s, DeMorgan(s))
    return statement
print(Skolemization(fol_to_cnf("animal(y)<=>loves(x,y)")))
print(Skolemization(fol_to_cnf("∀x[∀y[animal(y)=>loves(x,y)]]=>[∃z[loves(z
,x)]]")))
print(fol_to_cnf("[american(x)&weapon(y)&sells(x,y,z)&hostile(z)]=>crimina
l(x)"))
```

Output:

```
[~animal(y)|loves(x,y)]&[~loves(x,y)|animal(y)]
[animal(G(x))&~loves(x,G(x))]|[loves(F(x),x)]
[~american(x)|~weapon(y)|~sells(x,y,z)|~hostile(z)]|criminal(x)
```

Proof:

Proof :

food (x) ⇒ likes (pooja, x)

Remove conditionals by using

if P ⇒ Q

then ~P ∨ Q.

∴ ~food(x) ∨ likes(pooja, x)

Program-10

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

Algorithm:

Algorithm:

Step 1 : Initialize the knowledge base (KB):
- Start with an empty KB
- Add known FOL statements to the KB

Step 2 : Initialize Agenda:
- create an agenda to store statements to be processed
- Add known facts & rules with satisfied antecedents

Step 3 : Repeat until convergence or query is answered:
- while the agenda is non empty;
  - Pop a statement from the agenda
  - If the statement is the query, return 'Query is true'
  - If the statement is a fact or a known truth:
    - Skip to the next iteration
  - If the statement is a rule with satisfied antecedents:
    - Apply the rule to generate a new consequent
    - Add the new consequent to the agenda

Step 4 : Termination
- If the agenda is empty & the query is not answered, return 'Query is false'

Code:

```
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
```

```python
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}')

kb = KB()
kb.tell('missile(x)=>weapon(x)')
kb.tell('missile(M1)')
kb.tell('enemy(x,America)=>hostile(x)')
kb.tell('american(West)')
kb.tell('enemy(Nono,America)')
kb.tell('owns(Nono,M1)')
kb.tell('missile(x)&owns(Nono,x)=>sells(West,x,Nono)')
kb.tell('american(x)&weapon(y)&sells(x,y,z)&hostile(z)=>criminal(x)')
kb.query('criminal(x)')
kb.display()
```

Output:

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

Proof:

Proof:

Agend:

1. missile (m1)
2. enemy (china, america)

Iterations:

Iteration 1:

pop: missile (m1) (Fact, skip)

pop: enemy (china, america) (Fact, skip)

Iteration 2:

pop: missile (x) ⇒ weapon (x) (Rule, add weapon (m1) to agenda)

Iteration 3:

pop: weapon(m1) (Fact, skip)

Iteration 4:

pop: owns (china, m1) (fact, skip)

Iteration 5:

pop: missile (x) & owns (china, x) ⇒ sells (west, x, china) (Rule, add sells (west, m1, china) to agen)

Iteration 6:

pop: sells (west, m1, china) (Fact, skip)

Iteration 7:

pop: american (west) (Fact, skip)

Iteration 8:

pop: american(x) & weapon (y) & sells (x, y, z) & hostile (z) ⇒ criminal (x) (Rule, add criminal (west) to agenda)

Iteration 9:

pop: criminal (west) (Query found, return "Query is true")