B.M.S. COLLEGE OF ENGINEERING BENGALURU
Autonomous Institute, Affiliated to VTU

Lab Record

Artificial Intelligence

Submitted in partial fulfillment for the 5th Semester Laboratory

Bachelor of Technology
in
Computer Science and Engineering

Submitted by:

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Nov 2023 - Feb 2024

B.M.S. COLLEGE OF ENGINEERING

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

CERTIFICATE

This is to certify that the Artificial Intelligence (22CS5PCAIP) laboratory has been carried out by **Likhith G S** (1BM21CS096) during the 5th Semester Nov 2023 - Feb 2024.

Signature of the Faculty Incharge:

Dr. Asha G R
Assistant Professor
Department of Computer Science and Engineering
B.M.S. College of Engineering, Bangalore

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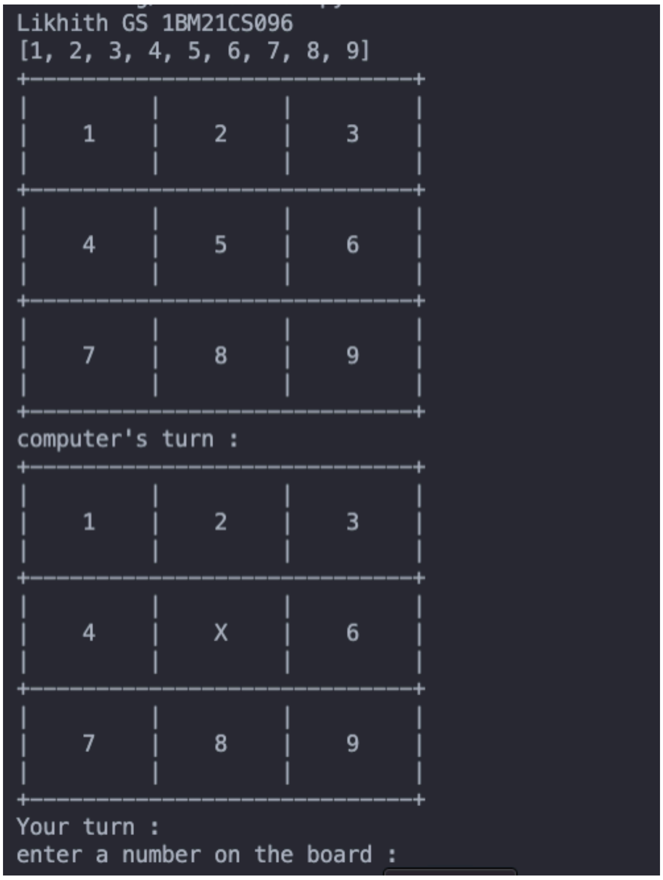
Program 1: Implement Tic Tac Toe

Code:

```
board = [' ' for x in range(10)]

def insertLetter(letter, pos):
    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():
    run = True
    while run:
        move = input('Please select a position to place an \'X\' (1-9):
')
        try:
            move = int(move)
            if move > 0 and move < 10:
                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:
            print('Please type a number!')

def compMove():
    possibleMoves = [x for x, letter in enumerate(board) if letter == ' ' and x
    != 0]
    move = 0
    for let in ['O', 'X']:
        for i in possibleMoves:
            boardCopy = board[:]
            boardCopy[i] = let
            if isWinner(boardCopy, let):
                move = i
                return move
    cornersOpen = []
    for i in possibleMoves:
        if i in [1, 3, 7, 9]:
            cornersOpen.append(i)
    if len(cornersOpen) > 0:
        move = selectRandom(cornersOpen)
        return move
    if 5 in possibleMoves:
        move = 5
        return move
    edgesOpen = []
    for i in possibleMoves:
        if i in [2, 4, 6, 8]:
            edgesOpen.append(i)
    if len(edgesOpen) > 0:
        move = selectRandom(edgesOpen)
        return move

def selectRandom(li):
    import random
    ln = len(li)
    r = random.randrange(0, ln)
    return li[r]

def isBoardFull(board):
    if board.count(' ') > 1:
        return False
    else:
        return True

def main():
    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 == 0:
            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!')
    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 x in range(10)]
        print('-----------------------------------')
        main()
    else:
        break
```

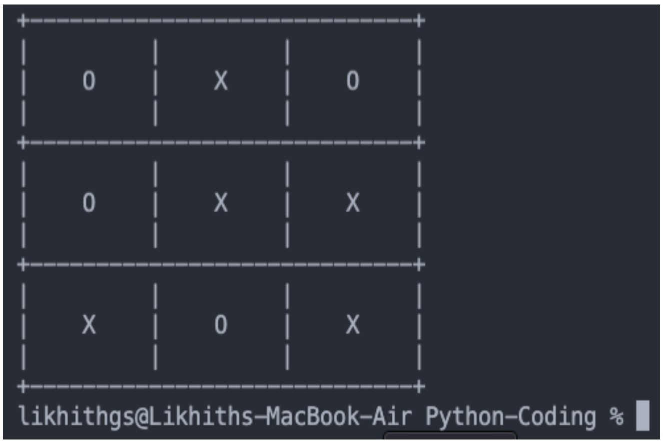
Output:

In the Beginning:



```
Likhith GS 1BM21CS096
[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 :
```

At the End:



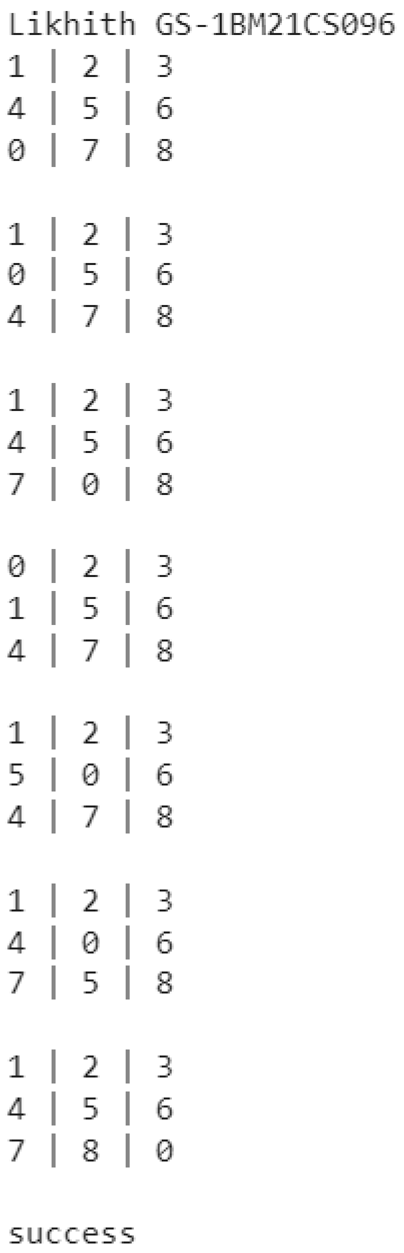
```
+-----------------------------+
|         |         |         |
|    O    |    X    |    O    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    O    |    X    |    X    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    X    |    O    |    X    |
|         |         |         |
+-----------------------------+
likhithgs@Likhiths-MacBook-Air Python-Coding %
```

Program 2 : 8 Puzzle Breadth First Search Algorithm

Code:

```
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 = []
        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):
    #index of empty spot
    b = state.index(-1)

    #directions array
    d = []
    #Add all the possible directions

    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')
    # If direction is possible then add state to move
    pos_moves_it_can = []

    # for all possible directions find the state if that move is played
    ### Jump to gen function to generate all possible moves in the given directions

    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 new state with tested move to later check if "src == target"
    return temp
src = [1,2,3,-1,4,5,6,7,8]
target = [1,2,3,4,5,-1,6,7,8]
bfs(src, target)
```

Output:



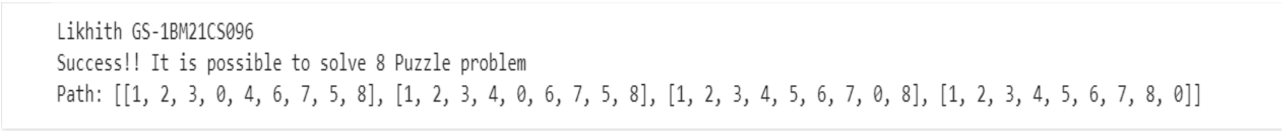
```
Likhith GS-1BM21CS096
1 | 2 | 3
4 | 5 | 6
0 | 7 | 8

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
```

Program 3 : 8 Puzzle Iterative Deepening Search Algorithm

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)
                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:



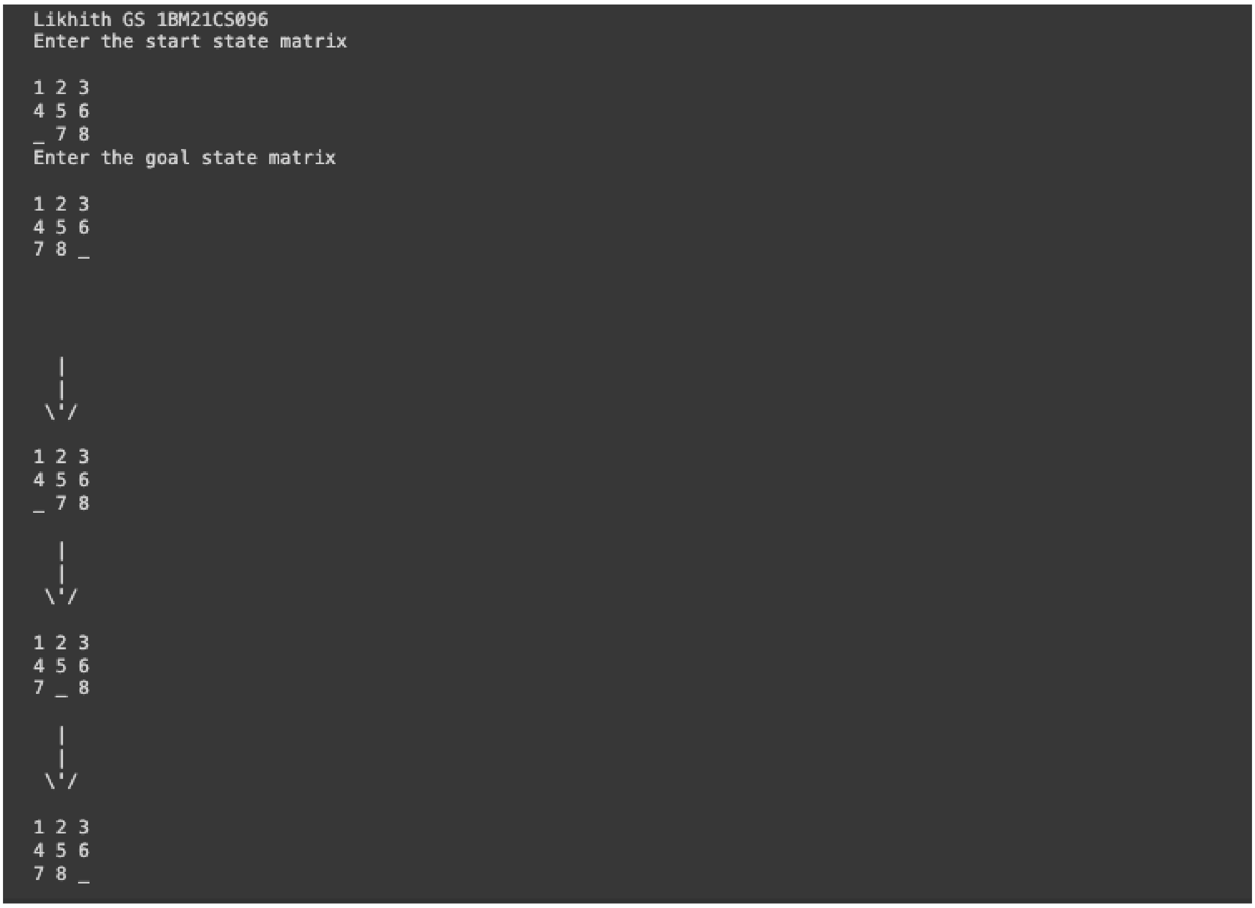
```
Likhith GS-1BM21CS096
Success!! It is possible to solve 8 Puzzle problem
Path: [[1, 2, 3, 0, 4, 6, 7, 5, 8], [1, 2, 3, 4, 0, 6, 7, 5, 8], [1, 2, 3, 4, 5, 6, 7, 0, 8], [1, 2, 3, 4, 5, 6, 7, 8, 0]]
```

Program 4 : 8 Puzzle A* Search Algorithm

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 :



```
Likhith GS 1BM21CS096
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 _
```

Program 5 : Vacuum Cleaner

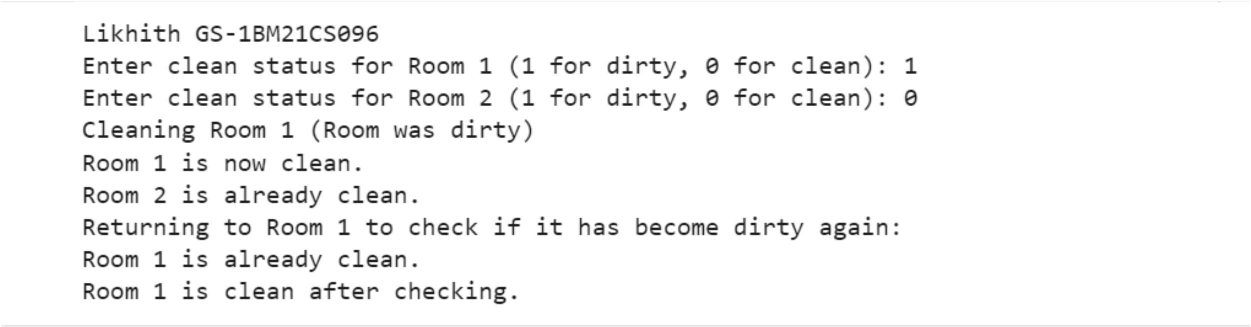
Code:

```
def clean_room(floor, room_row, room_col):
    if floor[room_row][room_col] == 1:
        print(f"Cleaning Room at ({room_row + 1}, {room_col + 1}) (Room was dirty)")
        floor[room_row][room_col] = 0
        print("Room is now clean.")
    else:
        print(f"Room at ({room_row + 1}, {room_col + 1}) is already clean.")

def main():
    rows = 2
    cols = 2
    floor = [[0, 0], [0, 0]]  # Initialize a 2x2 floor with clean rooms

    for i in range(rows):
        for j in range(cols):
            status = int(input(f"Enter clean status for Room at ({i + 1}, {j + 1}) (1 for dirty,
0 for clean): "))
            floor[i][j] = status

    for i in range(rows):
        for j in range(cols):
            clean_room(floor, i, j)

    print("Returning to Room at (1, 1) to check if it has become dirty again:")
    clean_room(floor, 0, 0)  # Checking Room at (1, 1) after cleaning all rooms

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

Four rooms:

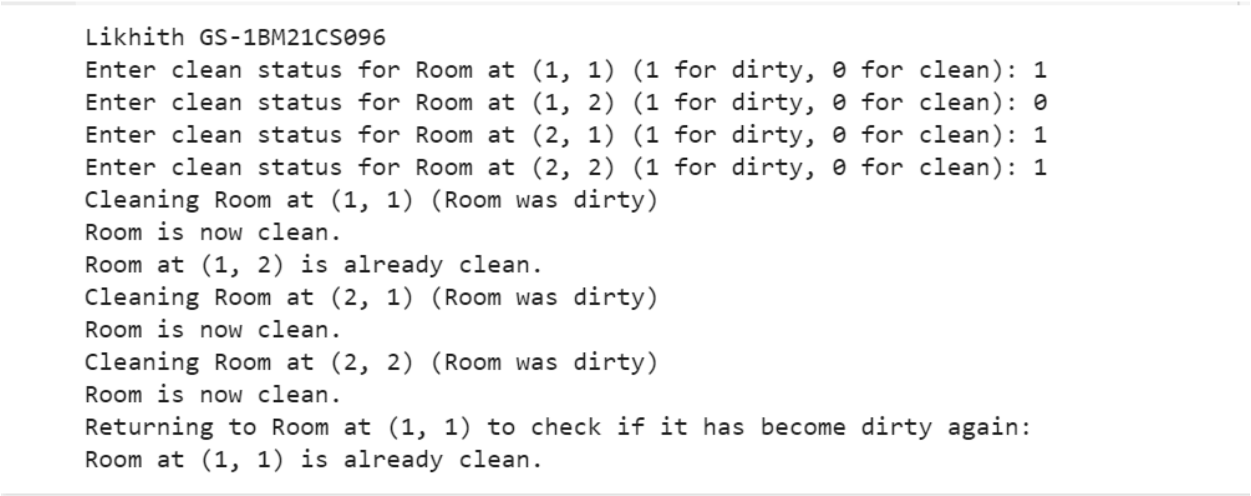
```
def clean_room(room_name, is_dirty):
    if is_dirty:
        print(f"Cleaning {room_name} (Room was dirty)")
        print(f"{room_name} is now clean.")
        return 0  # Updated status after cleaning
    else:
        print(f"{room_name} is already clean.")
        return 0  # Status remains clean

def main():
    rooms = ["Room 1", "Room 2"]
    room_statuses = []
    for room in rooms:
        status = int(input(f"Enter clean status for {room} (1 for dirty, 0 for clean): "))
        room_statuses.append((room, status))
    print(room_statuses)

    for i, (room, status) in enumerate(room_statuses):
        room_statuses[i] = (room,clean_room(room, status)) # Update status after cleaning

    print(f"Returning to {rooms[0]} to check if it has become dirty again:")
    room_statuses[0]=status = (rooms[0],clean_room(rooms[0], room_statuses[0][1])) # Checking
Room 1 after cleaning all rooms

    print(f"{rooms[0]} is {'dirty' if room_statuses[0][1] else 'clean'} after checking.")

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

Output:



```
Likhith GS-1BM21CS096
Enter clean status for Room 1 (1 for dirty, 0 for clean): 1
Enter clean status for Room 2 (1 for dirty, 0 for clean): 0
Cleaning Room 1 (Room was dirty)
Room 1 is now clean.
Room 2 is already clean.
Returning to Room 1 to check if it has become dirty again:
Room 1 is already clean.
Room 1 is clean after checking.
```

Vacuum cleaner 2 rooms



```
Likhith GS-1BM21CS096
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.
```

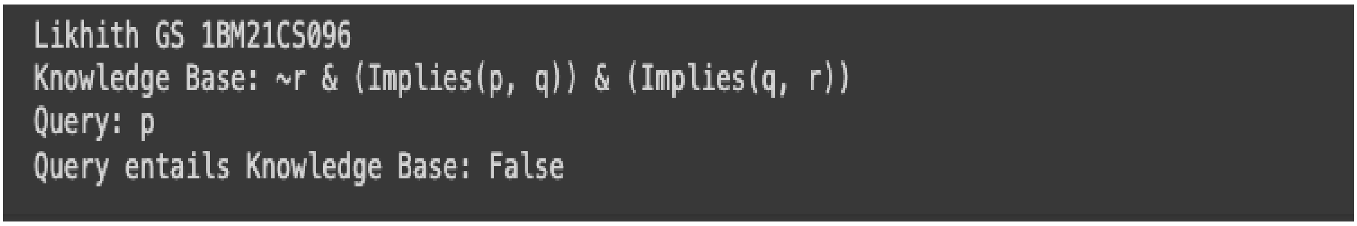
Vacuum cleaner 4 rooms

Program 6 : Knowledge Base Entailment

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:



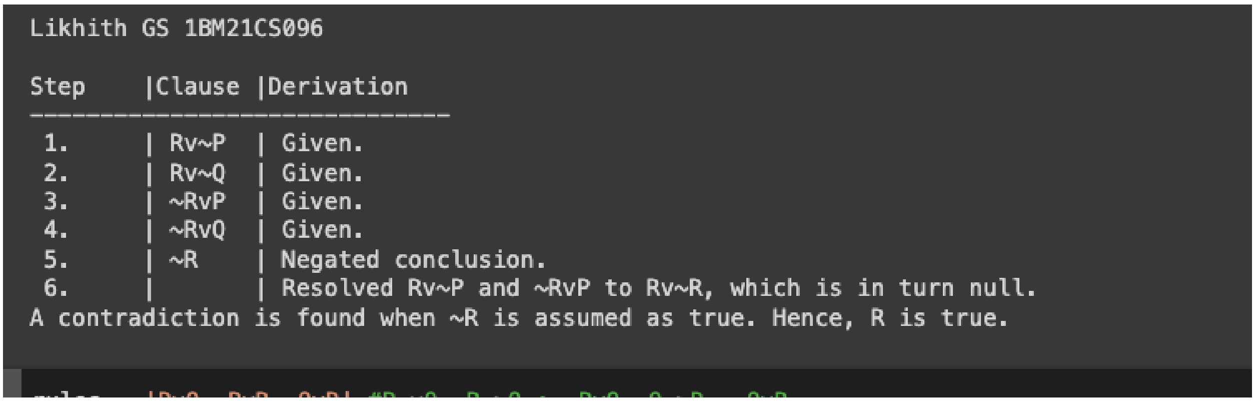
```
Likhith GS 1BM21CS096
Knowledge Base: ~r & (Implies(p, q)) & (Implies(q, r))
Query: p
Query entails Knowledge Base: False
```

Program 7 : Knowledge Base Resolution

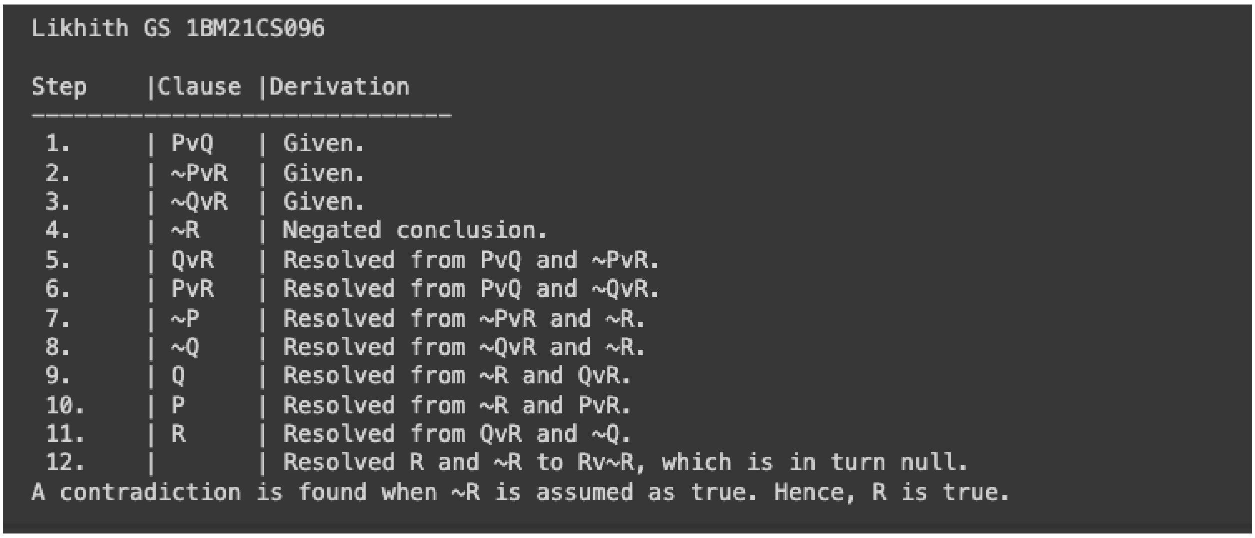
Code:

```
def tell(kb, rule):
    kb.append(rule)

combinations = [(True, True, True), (True, True, False),
                (True, False, True), (True, False, False),
                (False, True, True), (False, True, False),
                (False, False, True), (False, False, False)]



def ask(kb, q):
    for c in combinations:
        s = all(rule(c) for rule in kb)
        f = q(c)
        print(s, f)
        if s != f and s != False:
            return 'Does not entail'
    return 'Entails'



kb = []

# Get user input for Rule 1
rule_str = input("Enter Rule 1 as a lambda function (e.g., lambda x: x[0] or x[1] and (x[0] and
x[1]): ")
r1 = eval(rule_str)
tell(kb, r1)

# Get user input for Query
query_str = input("Enter Query as a lambda function (e.g., lambda x: x[0] and x[1] and (x[0] or
x[1]): ")
q = eval(query_str)

# Ask KB Query
result = ask(kb, q)
print(result)
```

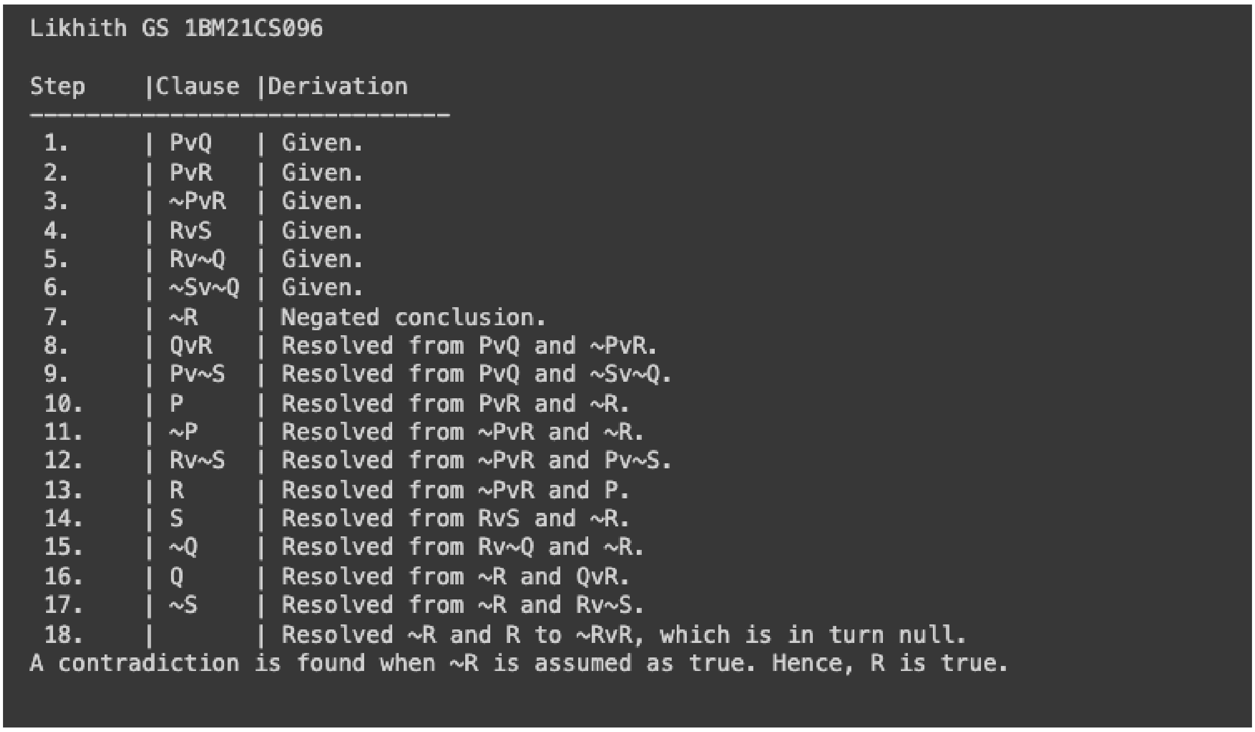
Output:



```
Likhith GS 1BM21CS096

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.
```



```
Likhith GS 1BM21CS096

Step    |Clause |Derivation
------------------------------
 1.     | PvQ   | Given.
 2.     | ~PvR  | Given.
 3.     | ~QvR  | Given.
 4.     | ~R    | Negated conclusion.
 5.     | QvR   | Resolved from PvQ and ~PvR.
 6.     | PvR   | Resolved from PvQ and ~QvR.
 7.     | ~P    | Resolved from ~PvR and ~R.
 8.     | ~Q    | Resolved from ~QvR and ~R.
 9.     | Q     | Resolved from ~R and QvR.
 10.    | P     | Resolved from ~R and PvR.
 11.    | R     | Resolved from QvR and ~Q.
 12.    |       | Resolved R and ~R to Rv~R, which is in turn null.
A contradiction is found when ~R is assumed as true. Hence, R is true.
```



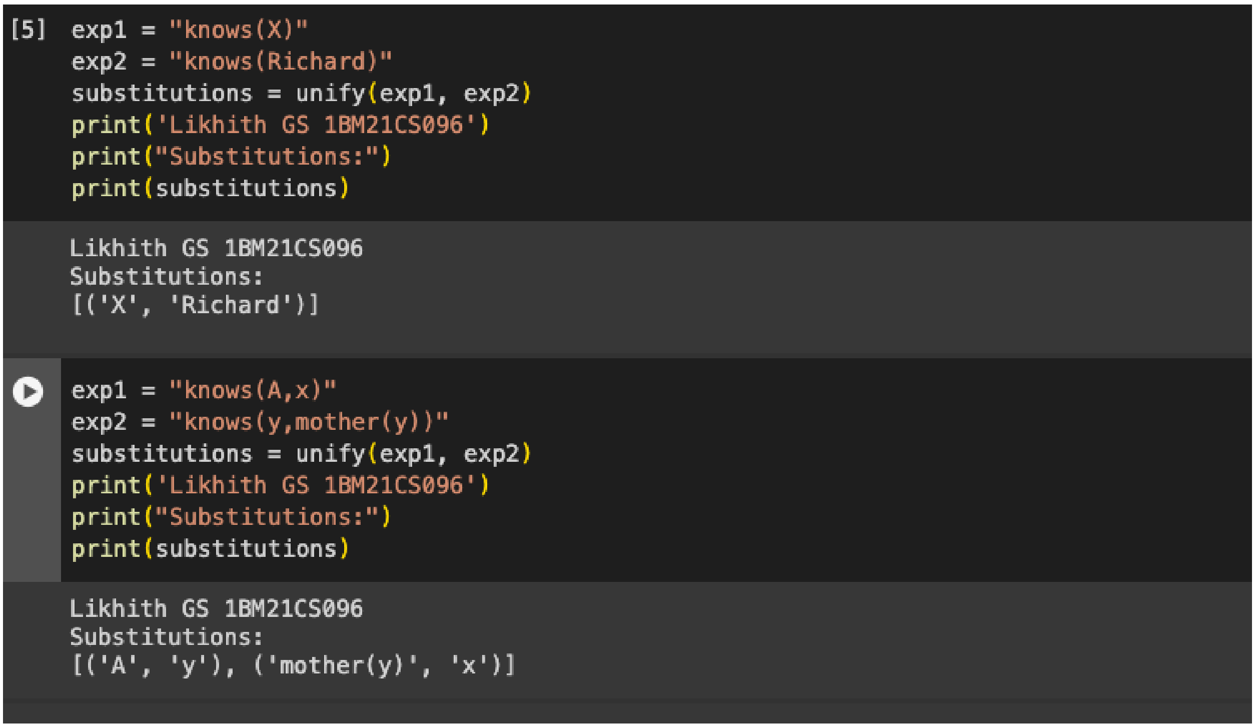
```
Likhith GS 1BM21CS096

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.
```

Program 8 : Unification

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("Likhith G S - 1BM21CS096")
print("Substitutions:")
print(substitutions)
exp1 = "knows(A,x)"
exp2 = "knows(y,mother(y))"
substitutions = unify(exp1, exp2)
print("Substitutions:")
print(substitutions)
```

Output:



```
[5] exp1 = "knows(X)"
    exp2 = "knows(Richard)"
    substitutions = unify(exp1, exp2)
    print('Likhith GS 1BM21CS096')
    print("Substitutions:")
    print(substitutions)
```

```
Likhith GS 1BM21CS096
Substitutions:
[('X', 'Richard')]
```

```
exp1 = "knows(A,x)"
exp2 = "knows(y,mother(y))"
substitutions = unify(exp1, exp2)
print('Likhith GS 1BM21CS096')
print("Substitutions:")
print(substitutions)
```

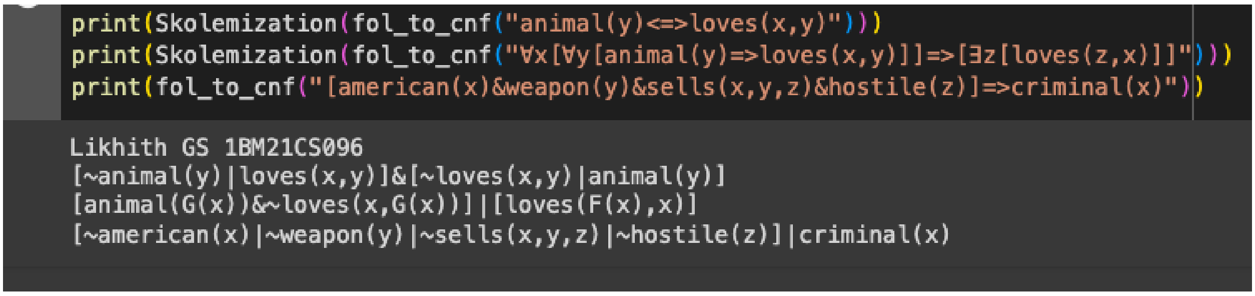
```
Likhith GS 1BM21CS096
Substitutions:
[('A', 'y'), ('mother(y)', 'x')]
```

Program 9 : FOL 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("Likhith G S - 1BM21CS096")
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)]=>criminal(x)"))
```

Output:



```
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)]=>criminal(x)"))
```

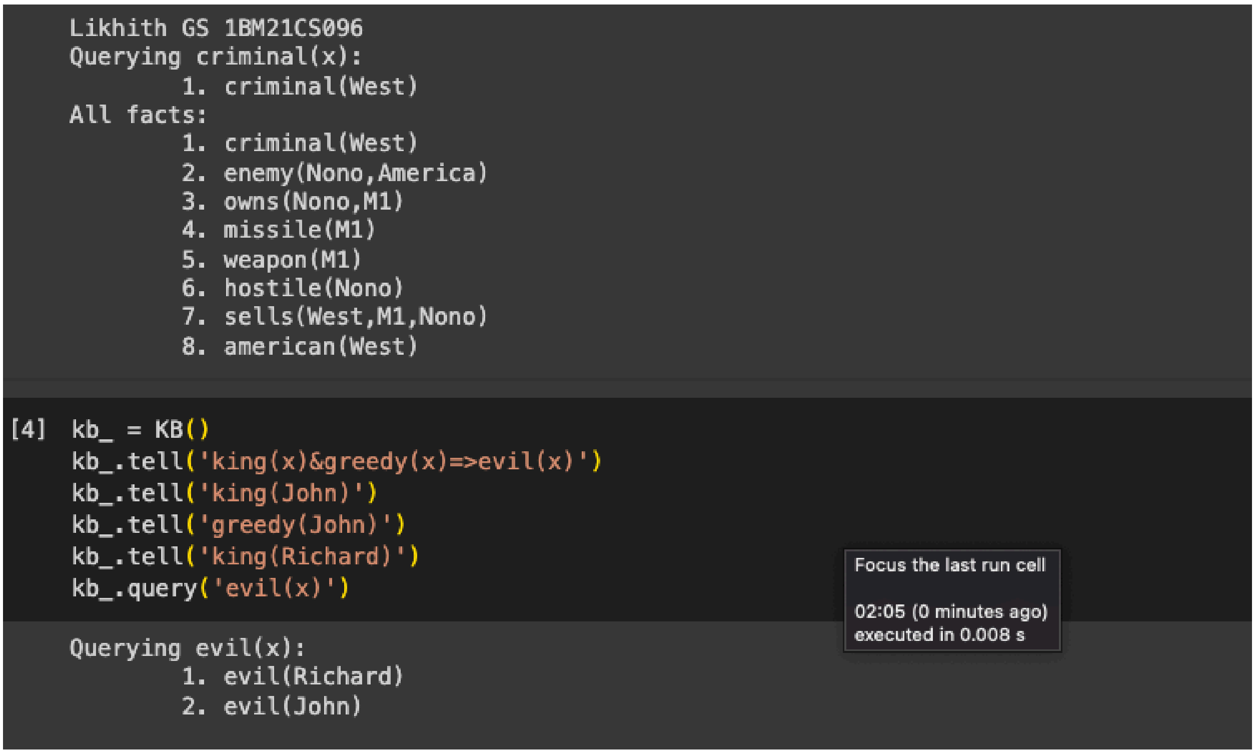
```
Likhith GS 1BM21CS096
[~animal(y)|loves(x,y)]&[~loves(x,y)|animal(y)]
[animal(G(x))&~loves(x,G(x))]|[loves(F(x),x)]
[~american(x)|~weapon(y)|~sells(x,y,z)|~hostile(z)]|criminal(x)
```

Program 10 : Forward Reasoning

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

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}')
print("Likhith G S - 1BM21CS096")
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()
print("Likhith G S - 1BM21CS096")

kb_ = KB()
kb_.tell('king(x)&greedy(x)=>evil(x)')
kb_.tell('king(John)')
kb_.tell('greedy(John)')
kb_.tell('king(Richard)')
kb_.query('evil(x)')
```

Output:



```
Likhith GS 1BM21CS096
Querying criminal(x):
        1. criminal(West)
All facts:
        1. criminal(West)
        2. enemy(Nono,America)
        3. owns(Nono,M1)
        4. missile(M1)
        5. weapon(M1)
        6. hostile(Nono)
        7. sells(West,M1,Nono)
        8. american(West)
```

```
[4] kb_ = KB()
    kb_.tell('king(x)&greedy(x)=>evil(x)')
    kb_.tell('king(John)')
    kb_.tell('greedy(John)')
    kb_.tell('king(Richard)')
    kb_.query('evil(x)')
```

```
Querying evil(x):
        1. evil(Richard)
        2. evil(John)
```