VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT

on

ARTIFICIAL INTELLIGENCE

Submitted by

MADHUSOODAN REDDY(1BM21CS099)

Under the Guidance of
Prof. Sneha S Bagalkot
Assistant Professor, BMSCE

in partial fulfilment 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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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**" carried out by **Madhusoodan Reddy(1BM21CS099)** , who is bonafide student of **B. M. S. College of Engineering.** It is in partial fulfilment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum during the year 2023-24.

The Lab report has been approved as it satisfies the academic requirements in respect of **Artificial Intelligence- (22CS5PCAIN)** work prescribed for the said degree.

Prof. Sneha S Bagalkot	Dr. Jyothi Nayak
Assistant professor	Professor and Head
Department of CSE	Department of CSE
BMSCE, Bengaluru	BMSCE, Bengaluru

B. M. S. COLLEGE OF ENGINEERING

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

DECLARATION

I, Madhusoodan Reddy (1BM21CS099), student of 5th Semester, B.E, Department of Computer Science and Engineering, B. M. S. College of Engineering, Bangalore, here by declare that, this lab report entitled " **Artificial Intelligence**" has been carried out by me under the guidance of **Prof. Sneha S Bagalkot**, Assistant Professor, Department of CSE, B. M. S. College of Engineering, Bangalore during the academic semester November-2023-February-2024.

I also declare that to the best of my knowledge and belief, the development reported here is not from part of any other report by any other students.

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Program 1

Implementation of tic tac toe

Code

```
# Create a 3x3 tic tac toe board of "" strings for each value
board = [' '] * 9

# Create a function to display your board
def display_board(board):
    print(f" {board[0]} | {board[1]} | {board[2]} ")
    print("---+---+---")
    print(f" {board[3]} | {board[4]} | {board[5]} ")
    print("---+---+---")
    print(f" {board[6]} | {board[7]} | {board[8]} ")



#Create a function to check if anyone won, Use marks "X" or "O"
def check_win(player_mark, board):
    win = [f'{player_mark}'] * 3
    return board[:3] == win or board[3:6] == win or board[6:9] == win or \
        [board[0], board[4], board[8]] == win or [board[2], board[4], board[6]] == win or \
        [board[0], board[3], board[6]] == win or [board[1], board[4], board[7]] == win or
[board[2], board[5], board[8]] == win


def check_draw(board):
    return ' ' not in board


# Create a Function that makes a copy of the board
def board_copy(board):
    new_board = []
```

```
    for c in board:
        new_board += c
    return new_board

def test_win_move(move, player_mark, board):
    copy = board_copy(board)
    copy[move] = player_mark
    return check_win(player_mark, copy)

def win_strategy(board):
    if board[4] == ' ':
        return 4
    for i in [0, 2, 6, 8]:
        if board[i] == ' ':
            return i
    for i in [1, 3, 5, 7]:
        if board[i] == ' ':
            return i

def get_agent_move(board):
    for i in range(9):
        if board[i] == ' ' and test_win_move(i, 'X', board):
            return i
    for i in range(9):
        if board[i] == ' ' and test_win_move(i, 'O', board):
            return i
    return win_strategy(board)

def tictactoe():
    playing = True
```

```
while playing:
    in_game = True
    board = [' '] * 9
    print('Would you like to go first or second? (1/2)')
    choice = input()
    player_marker = 'O' if choice == '1' else 'X'
    display_board(board)

    while in_game:
        print('\n')
        if player_marker == 'O':
            print('Player move: (0-8)')
            move = int(input())
            if board[move] != ' ':
                print('Invalid move')
                continue
        else:
            move = get_agent_move(board)
        board[move] = player_marker
        if check_win(player_marker,board):
            in_game = False
            display_board(board)
            if player_marker == 'O':
                print('O won')
            else:
                print('X won')
            break
        if check_draw(board):
            in_game = False
            display_board(board)
```

```
            print('The game was a draw.')
            break
        display_board(board)
        if player_marker == 'O':
            player_marker = 'X'
        else:
            player_marker = 'O'
    print('Continue playing? (y/n)')
    ans = input()
    if ans not in 'yY':
        playing = False

# Play!!!
tictactoe()
```

Output

```
PS C:\Users\Hp\Desktop\Madhusoodan> python -u "c:\Users\Hp\Desktop\Madhusoodan\lab.py"
Would you like to go first or second? (1/2)
1
   |   |
---+---+---
   |   |
---+---+---
   |   |


Player move: (0-8)
0
 O |   |
---+---+---
   |   |
---+---+---
   |   |


 O |   |
---+---+---
   | X |
---+---+---
   |   |


Player move: (0-8)
3
 O |   |
---+---+---
 O | X |
---+---+---
   |   |


 O |   |
---+---+---
 O | X |
---+---+---
 X |   |
```

```
Player move: (0-8)
2
 O |   | O
---+---+---
 O | X |
---+---+---
 X |   |


 O | X | O
---+---+---
 O | X |
---+---+---
 X |   |


Player move: (0-8)
7
 O | X | O
---+---+---
 O | X |
---+---+---
 X | O |


 O | X | O
---+---+---
 O | X |
---+---+---
 X | O | X


Player move: (0-8)
5
 O | X | O
---+---+---
 O | X | O
---+---+---
 X | O | X
The game was a draw.
Continue playing? (y/n)
```

Program 2

8 Puzzle Breadth First Search Algorithm

Code

```
#import numpy as np

#import pandas as pd

import os


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


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


    return temp  # Return the modified state


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

    exp = []

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

    for move in poss_moves_to_do:
        if move not in exp and move not in queue:
            queue.append(move)

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

Output

```
PS C:\Users\Hp\Desktop\Madhusoodan> python -u "c:\Users\Hp\Desktop\Madhusoodan\lab.py"
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

```
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

```
PS C:\Users\Hp\Desktop\Madhusoodan> python -u "c:\Users\Hp\Desktop\Madhusoodan\lab.py"
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]]
PS C:\Users\Hp\Desktop\Madhusoodan>
```

Program 4

8 Puzzle A* 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

```
PS C:\Users\Hp\Desktop\Madhusoodan> python -u "c:\Users\Hp\Desktop\Madhusoodan\lab.py"
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
PS C:\Users\Hp\Desktop\Madhusoodan>
```

Program 5

Vacuum Cleaner

Code

```
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]= (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

```
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): 1
[('Room 1', 1), ('Room 2', 1)]
Cleaning Room 1 (Room was dirty)
Room 1 is now clean.
Cleaning Room 2 (Room was dirty)
Room 2 is now clean.
Returning to Room 1 to check if it has become dirty again:
Room 1 is already clean.
Room 1 is clean after checking.
```

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

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

Program 7

Knowledge base resolution

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.
```

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(A,x)"
exp2 = "knows(y,Y)"
substitutions = unify(exp1, exp2)
print("Substitutions:")
print(substitutions)
```

Output

```
PS C:\Users\Hp\Desktop\Madhusoodan> python -u "c:\Users\Hp\Desktop\Madhusoodan\lab.py"
Substitutions:
[('A', 'y'), ('Y', 'x')]
PS C:\Users\Hp\Desktop\Madhusoodan>
```

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 Skolemization(statement):
    SKOLEM_CONSTANTS = [f'{chr(c)}' for c in range(ord('A'), ord('Z')+1)]
    matches = re.findall('[∃].', 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)

print(fol_to_cnf("bird(x)=>~fly(x)"))
print(fol_to_cnf("∃x[bird(x)=>~fly(x)]"))
```

Output

```
PS C:\Users\Hp\Desktop\Madhusoodan> python -u "c:\Users\Hp\Desktop\Madhusoodan\lab.py"
~bird(x)|~fly(x)
[~bird(A)|~fly(A)]
PS C:\Users\Hp\Desktop\Madhusoodan>
```

Program 10

Forward Chaining

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}')

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

```
PS C:\Users\Hp\Desktop\Madhusoodan> python -u "c:\Users\Hp\Desktop\Madhusoodan\lab.py"
Querying criminal(x):
        1. criminal(West)
All facts:
        1. american(West)
        2. missile(M1)
        3. enemy(Nono,America)
        4. owns(Nono,M1)
        5. weapon(M1)
        6. sells(West,M1,Nono)
        7. hostile(Nono)
        8. criminal(West)
PS C:\Users\Hp\Desktop\Madhusoodan>
```