VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
On

ARTIFICIAL INTELLIGENCE

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
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Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled **"ARTIFICIAL INTELLIGENCE"** carried out by **J Hanuma Kaushik (1BM21CS078)**, who is 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 2022-23. The Lab report has been approved as it satisfies the academic requirements in respect of Artificial Intelligence Lab - **(22CS5PCAIN)**work prescribed for the said degree.

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1.Implement Tic –Tac –Toe Game.

```
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")
```

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1. 1) 2 Arrays for 2 players

* It takes input from player 1 & 2.
* If ~~Print~~ Prepare a board of 3 x 3 size.

* If x state has win conditions
[0,1,2], [3,4,5], [6,7,8], ...
~~Print~~ x won the match

* If y state has win conditions
[0,1,2], [3,4,5], [2,58], ...
~~Print~~ y won the match

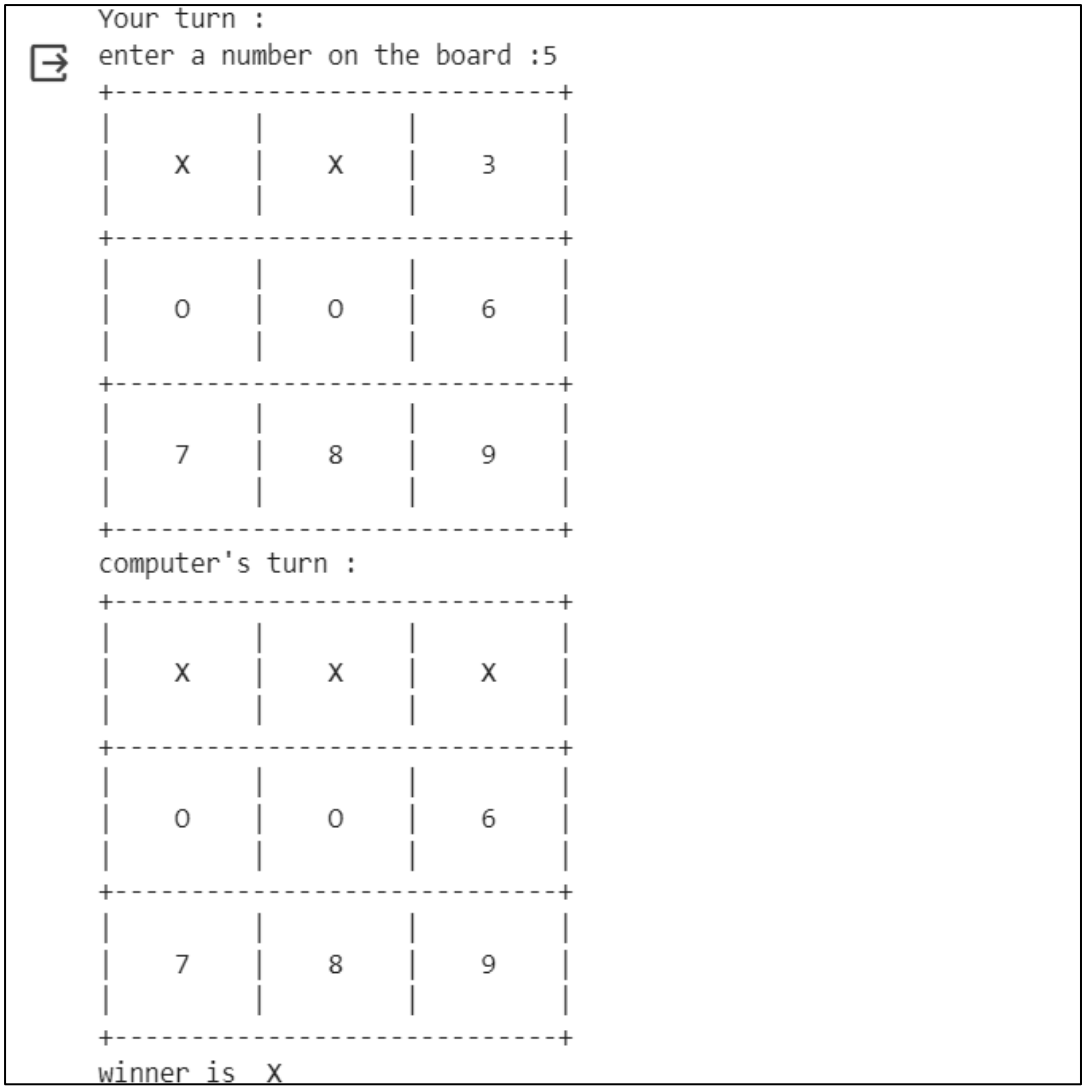
* If no win conditions are there,
Match over.

```
for win in wins:
    if (sum (xstate [win[0]], xstate [win[1]],
        xstate [win [2]]) == 3):
        print ("x won the match")
        return 1

    if (sum (zstate [win[0], zstate [win[1]],
        zstate [win[2]] == 3):
        print ("0 won the match")
        return 0
    return -1
def main():
    x state = [0,0,0,0,0,0,0,0,0]
    z state = [0,0,0,0,0,0,0,0,0]
    turn = 1
    print ("Let's Play Tic Tac Toe")
    while (true):
        if (turn == 1):
            print ("x's turn")
        choice = int (input ("Enter choice"))
        xstate [choice] = 1

    elsee
        print ("0's turn")
        choice = int (input ("Enter choice"))
        zstate [choice] = 1

    c win = Check win (x state, z State)
        if ((win! = -1)
        print ("Match over")
        break,
```

OUTPUT

```
[1, 2, 3, 4, 5, 6, 7, 8, 9]
+-----------------------------+
|         |         |         |
|    1    |    2    |    3    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    4    |    5    |    6    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    7    |    8    |    9    |
|         |         |         |
+-----------------------------+
computer's turn :
+-----------------------------+
|         |         |         |
|    1    |    X    |    3    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    4    |    5    |    6    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    7    |    8    |    9    |
|         |         |         |
+-----------------------------+
Your turn :
```

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


Your turn :
enter a number on the board :5
+---+---+---+
| X | X | 3 |
+---+---+---+
| O | O | 6 |
+---+---+---+
| 7 | 8 | 9 |
+---+---+---+
computer's turn :
+---+---+---+
| X | X | X |
+---+---+---+
| O | O | 6 |
+---+---+---+
| 7 | 8 | 9 |
+---+---+---+
winner is X

2 .Solve 8 puzzle problems.

```
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)
```

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Algorithm:

2. Create a puzzle class.
Define the initial board state & final state. (Final output of the solved puzzle)

Initial state is the shuffled numbers (Randomly set).

Initial state(random)

	2	3
	4	6
7	5	8

Goal State

1	2	3
4	5	6
7	8	

* By moving the tiles one by one to the empty state, the goal state can be achieved.

* The empty state can be moved in only 4 directions. (right, left, up, down). It cannot be moved diagonally.

* Implement a method to check current board configuration matches with the goal state.

* The puzzle is considered as solved if all the tiles are in correct positions.

2.

```
from queue import Queue

class puzzle8:
    def __init__(self, initial_state):
        self.initial_state = initial_state
        self.goal = [1,2,3,4,5,6,7,8,0]
        self.moves = [(0,1),(1,0),(0,-1),(-1,0)]

    def print_state(self, state):
        for i in range(0,9,3):
            print(state[i:i+3])

    def is_solved(self, state):
        return state == self.goal

    def get_blank_index(self, state):
        return state.index(0)

    def apply_move(self, state, move):
        blank_index = self.get_blank_index(state)
        row, col = blank_index // 3, blank_index % 3
        new_row, new_col = row + move[0], col + move[1]
        if 0 <= new_row < 3 and 0 <= new_col < 3:
            new_blank_index = new_row * 3 + new_col
            new_state = state[:]
            new_state[blank_index], new_state[new_blank_index] = new_state[new_blank_index], new_state[blank_index]
            return new_state
        else:
```

```
        return None

    def bfs(self):
        visited = set()
        queue = Queue()
        queue.put((self.initial_state, []))
        while not queue.empty():
            current_state, path = queue.get()
            if self.is_solved(current_state):
                print("Solution Found!")
                print("No. of moves:", len(path))
                for move in path:
                    print(move)
                break

            if tuple(current_state) not in visited:
                visited.add(tuple(current_state))
                blank_index = self.get_blank_index(current_state)
                row, col = blank_index // 3, blank_index % 3

                for move in self.moves:
                    new_state = self.apply_move(current_state, move)
                    if new_state is not None:
                        new_state = path + [move]
                        queue.put((new_state, new_path))

initial_state = [0, 3, 2, 4, 5, 6, 1, 7, 8]
puzzle = puzzle8(initial_state)
puzzle.bfs()
```

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
-----------
```

3. Implement Iterative deepening 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")
```

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3. Puzzle iterative deepening search algorithm.

Algorithm:

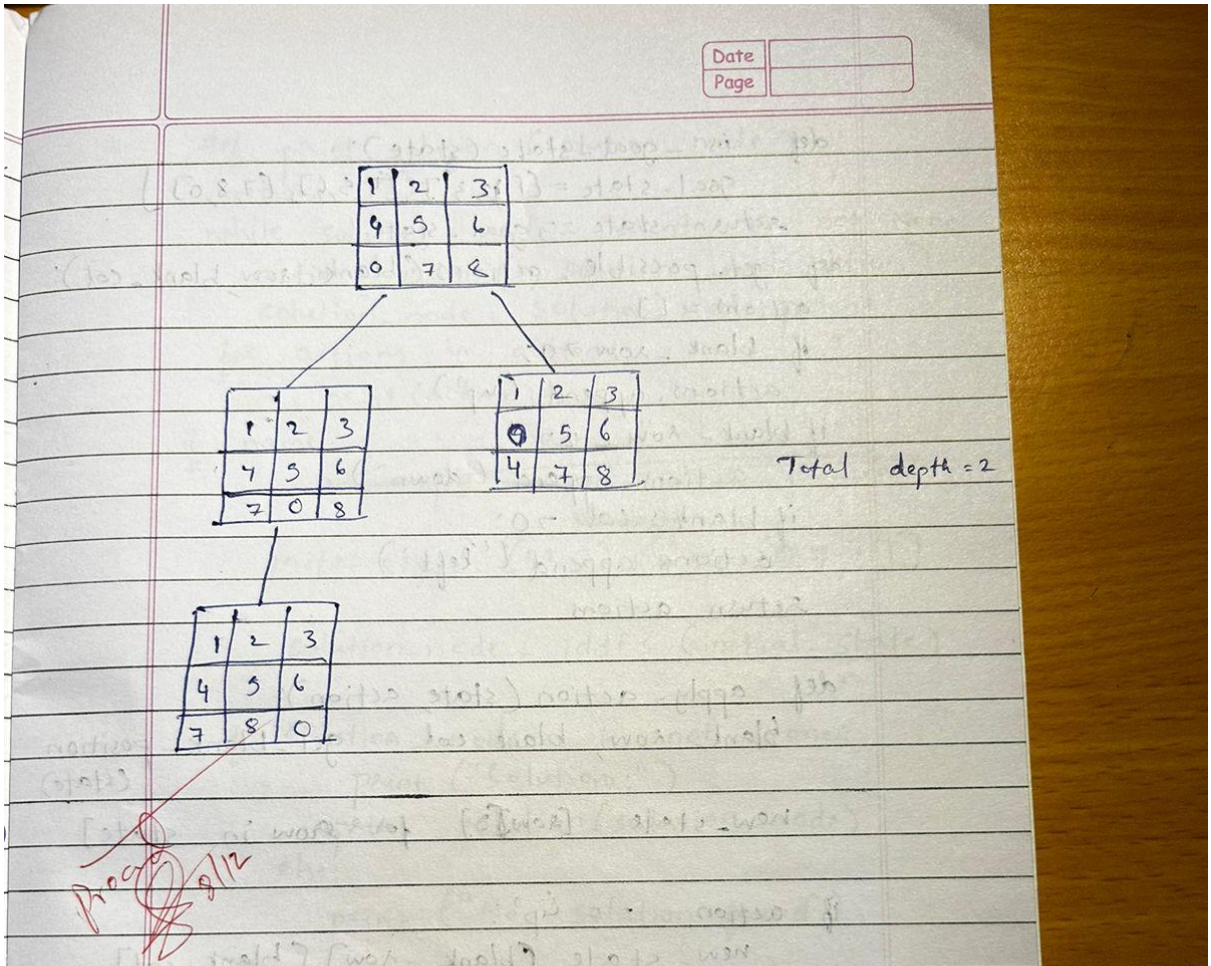
1) Initialize the initial state : [ ] and the goal state for the 8 puzzle.
goal_state = [1, 2, 3, 4, 5, 6, 7, 8].
0 is blank space.

2) Set the depth = 1 and expand the initial state. The depth-limited-search (depth) is performed
if node.state = goal.
return node
else
for neighbour in get.neighbour node (state)
child = puzzlenode (neighbour, node)
result = depth_limited_search (depth-1)
if result = True,
return result.

3) After one iteration where depth = 1 increment the depth by 1 and perform depth_limited_search again.

4) Here get_neighbours will generate the possible moves by swapping the zero.

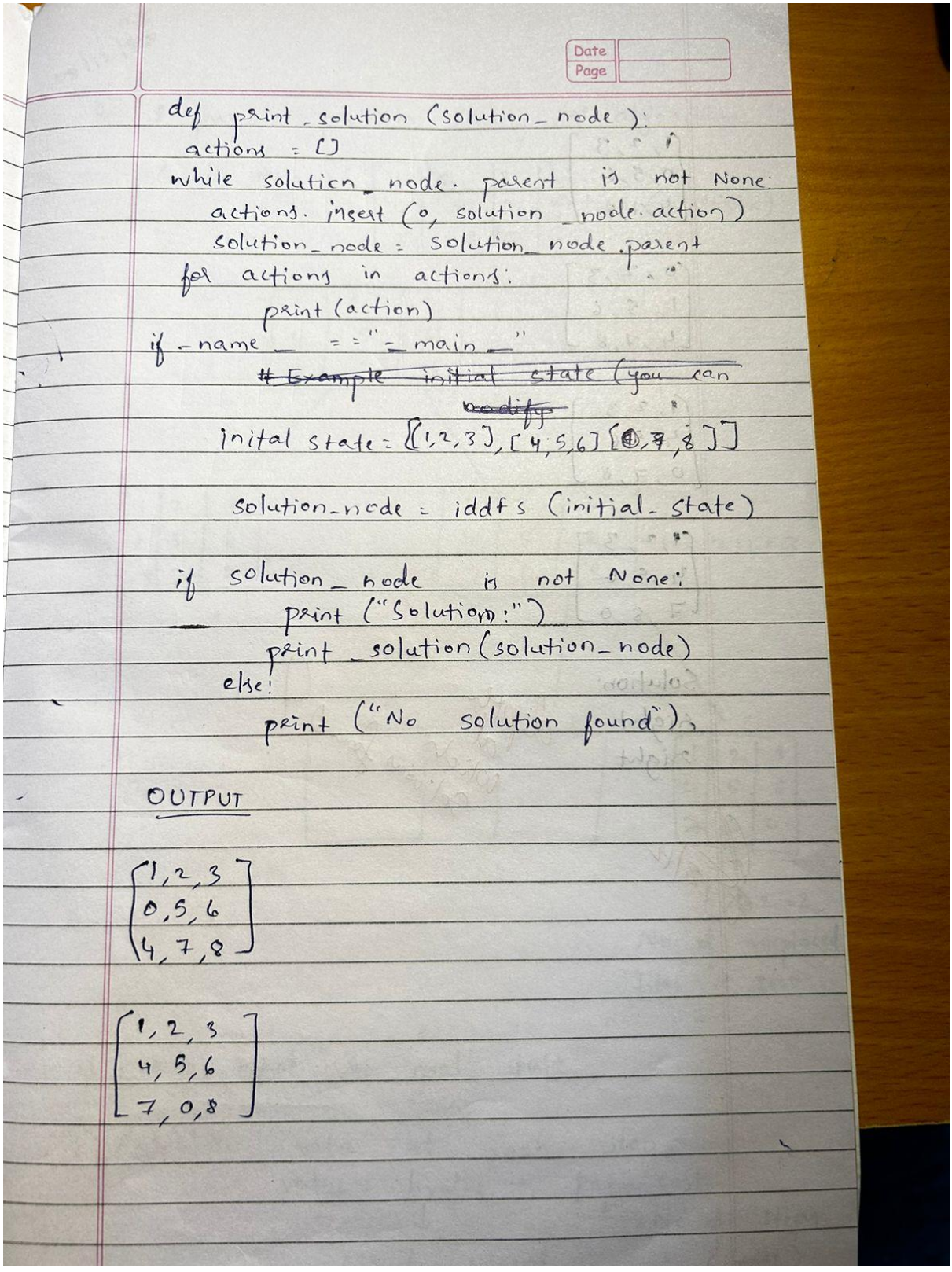
5) The path traversed is printed to reach the goal state.



Code:

```
Class PuzzleNode:
    def __init__(self, state, parent = None, action = None):
        self.state = state
        self.parent = parent
        self.action = action

def get_blank_position(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
                return i, j
```



```
def print_solution (solution_node ):
 actions = []
while solution_node. parent is not None:
    actions. insert (0, solution _node. action)
    solution_ node = solution_ node .parent
for actions in actions:
        print (action)
if - name __ = = "= main _"
        # Example initial state (you can
          modify)
    inital state = [[1,2,3], [4,5,6] [0,7,8]]

    solution_node = iddfs (initial_ state)

if solution_ node is not None:
        print ("Solution:")
        print _solution (solution_node)
    else:
        print ("No solution found").
```

OUTPUT

$$\begin{bmatrix} 1,2,3 \\ 0,5,6 \\ 4,7,8 \end{bmatrix}$$

$$\begin{bmatrix} 1,2,3 \\ 4,5,6 \\ 7,0,8 \end{bmatrix}$$

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]]
```

4. Implement A* search algorithm.

```
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.processs
```

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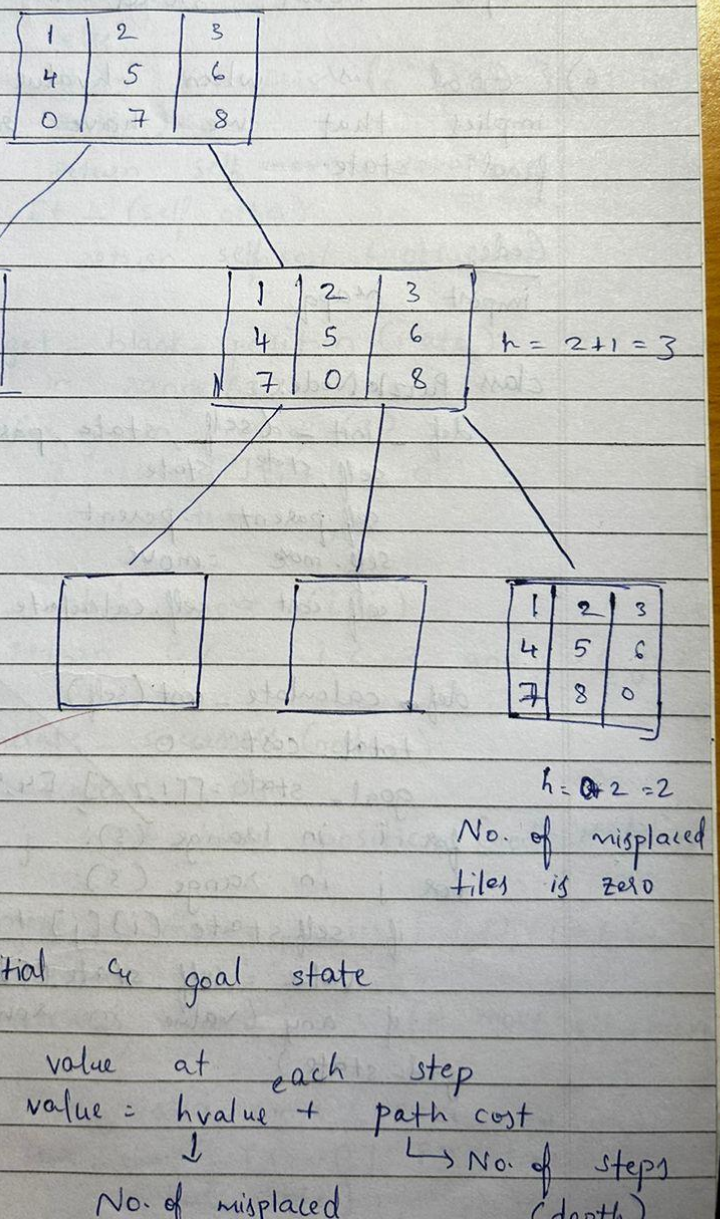
4. 8-puzzle problem using A* algorithm.

Goal state

1	2	3
4	5	6
7	8	0

=> h=0 (heuristic)



1) Create initial & goal state

2) Calculate value at each step

value = hvalue + path cost

hvalue → No. of misplaced

path cost → No. of steps (depth)

3) Goes to direction where value is less.

4) All nodes are stored in open list (Keep track of all nodes).

5) Explore nodes stored in closed lists.

6) Goal is when hvalue is 0. This implies that we have reached the final state.

Code:

```
import heapq

class PuzzleNode:
    def __init__(self, state, parent=None, move=0):
        self.state = state
        self.parent = parent
        self.move = move
        self.cost = self.calculate_cost()

    def calculate_cost(self):
        total_cost = 0
        goal_state = [[1,2,3] [4,5,6], [7,8,0]]
        for i in range(3):
            for j in range(3):
                if self.state[i][j] != 0:
                    value = self.state[i][j]
                    if any(value in row for row in
goal_state):
```

```
row, col = divmod(next(idx for idx, row
in enumerate(goal_state) if value in row),
None), 3)
        if row is not None:
            total_cost += abs(i - row) +
abs(j - col)
        else:
        raise ValueError(f"{value} is not
in goal state").
        return self.move + total_cost.
    def __lt__(self, other):
        return self.cost < other.cost

def get_blank_position(state):
for i in range(3):
    for j in range(3):
        if state[i][j] == 0:
            return i, j

def is_valid_move(i,j):
    return 0 <= i < 3 and 0 <= j < 3.

def generate_successors(node):
    successors = []
    i, j = get_blank_position(node.state)

for move_i, move_j in [(0,1),(1,0),(0,-1),
(-1,0)]:
    new_i, new_j = i + move_i, j + move
                                  _j
    if is_valid_move(new_i, new_j):
        new_state = [row[:] for row in
                     node.state]
```

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 _
```

5. Implement vaccum cleaner agent.

```
def vacuum_world():
    # 0 indicates Clean and 1 indicates Dirty
    goal_state = {'A': '0', 'B': '0'}
    cost = 0

    location_input = input("Enter Location of Vacuum")
    status_input = input("Enter status of " + location_input)
    status_input_complement = input("Enter status of other room")

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

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

```
        else:
            print("No action" + str(cost))
            # suck and mark clean
            print("Location B is already clean.")
        if status_input == '0':
        print("Location A is already clean ")
        if status_input_complement == '1':# if B is Dirty
            print("Location B is Dirty.")
            print("Moving RIGHT to the Location B. ")
            cost += 1                     #cost for moving right
            print("COST for moving RIGHT " + str(cost))
            # suck the dirt and mark it as clean
            cost += 1                     #cost for suck
            print("Cost for SUCK" + str(cost))
            print("Location B has been Cleaned. ")
        else:
            print("No action " + str(cost))
            print(cost)
            # suck and mark clean
            print("Location B is already clean.")

else:
    print("Vacuum is placed in location B")
    # Location B is Dirty.
    if status_input == '1':
        print("Location B is Dirty.")
        # suck the dirt  and mark it as clean
        cost += 1  # cost for suck
        print("COST for CLEANING " + str(cost))
        print("Location B has been Cleaned.")
```

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

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

    if status_input_complement == '1':  # if A is Dirty
        print("Location A is Dirty.")
        print("Moving LEFT to the Location A. ")
        cost += 1  # cost for moving right
        print("COST for moving LEFT " + str(cost))
        # suck the dirt and mark it as clean
        cost += 1  # cost for suck
        print("Cost for SUCK " + str(cost))
        print("Location A has been Cleaned. ")
    else:
        print("No action " + str(cost))
        # suck and mark clean
        print("Location A is already clean.")
```

```
    # done cleaning
    print("GOAL STATE: ")
    print(goal_state)
    print("Performance Measurement: " + str(cost))

print("0 indicates clean and 1 indicates dirty")
vacuum_world()
```

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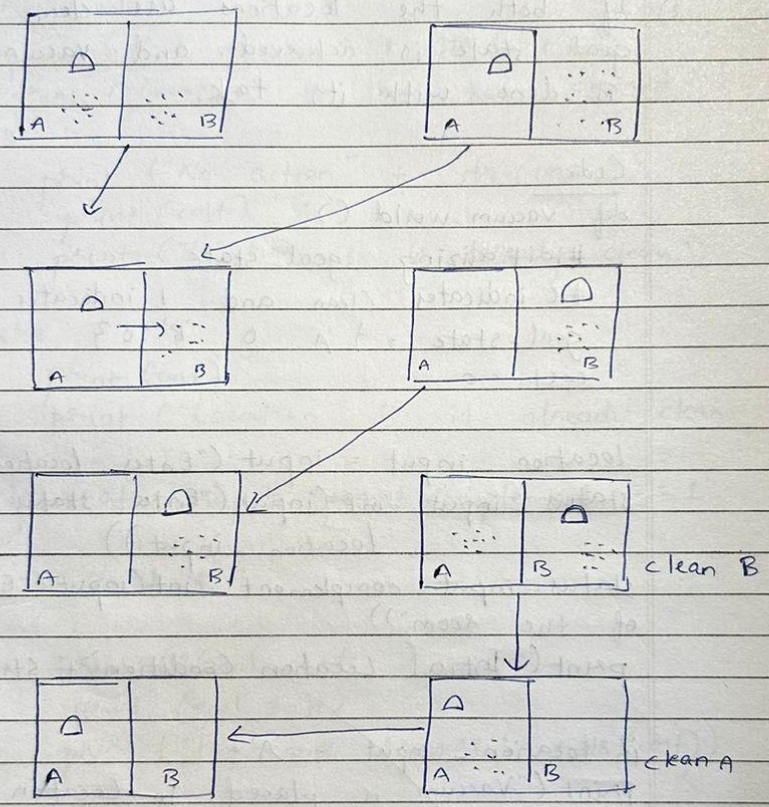
5. Vacuum Cleaner problem.



Algorithm

1) Initialize the starting and goal state, the goal is to clean both rooms A & B,

2) If status = Dirty then clean
else if location = A and status = clean
then return right else if location = B and

Status = clean then return left else exit

3) If both the locations are clean the goal state is achieved and vaccum cleaner is done with its task.

Code:

```
def vaccum_world():
    #initializing goal_state
    #0 indicates Clean and 1 indicates dirty
    goal_state = {'A': 0, 'B': 0}
    cost = 0.

location_input = input("Enter location of vaccum")
status_input = int(input("Enter status of" +
                location_input))
status_input_complement = int(input("Enter status
of the room"))
print("Initial Location Condition" + str(goal_state)

if location_input == 'A':
print("Vaccum is placed in Location A")
if status_input == 1
    print("Location A is Dirty.")
goal_state['A'] = 0
cost += 1
print("Location A is cleaned.")

if status_input == 0:
print("Location A is already clean")
if status_input_complement == 1:
```

```
        print ("Location B is dirty.")
        print ("Moving RIGHT to Location B.")
        cost += 1
        print ("cost of SUCK" + str(cost))
        print ("Location B has been cleaned.")
    else:
        print ("No action" + str(cost))
        print (cost)
        print ("Location B is already clean.")

else:
    print (cost)
    print ("Location B is already clean.

if status_input_complement == 1

    else += 1

    print ("Goal state:")
    print (goal_state)
    print ("Performance Measure:" + str(cost))

vaccum_world()
```

OUTPUT

```
Enter Location of Vaccum: A
Enter states of A: 1
Enter states of the room: 1
Initial located condition {'A': 0, 'B': 0}
Vaccum is placed in Location A
Location A is dirty.
Cost for cleaning A: 1
Location A has been cleaned
```

OUTPUT:

```
0 indicates clean and 1 indicates dirty
Enter Location of Vacuumb
Enter status of b1
Enter status of other room1
Vacuum is placed in location B
Location B is Dirty.
COST for CLEANING 1
Location B has been Cleaned.
Location A is Dirty.
Moving LEFT to the Location A.
COST for moving LEFT2
COST for SUCK 3
Location A has been Cleaned.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 3
```

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

```
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)
```

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Inputs:-

6. Knowledge base (set of logical rules)
   Query statement

Steps:-

1) Negate the query:
   Obtain the negation

2) Combine with knowledge base:

3) Check if the negation is satisfying the rules. (Satisfiability)

4) Determine entailment
   if conjunction is not satisfiable → True
   if conjunction is satisfiable → False

Code

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

def create_knowledge_base():

    P = symbols('s')
    q = symbols('q')
    r = symbols('r')

knowledge_base = And(
                    Implies(P, q),
                    Implies(q, r),
                ) Not(r)
```

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return knowledge_base

```
def query_entails(knowledge_base, query):
entailment = satisfiable(And(knowledge_base, Not(query)))
return not entailment

if __name__ == "__main__":
kb = create_knowledge_base()

query = symbols('not p')

result = query_entails(kb, query)

print("Knowledge base:" kb)
print("Query:", query)
print("Query entails knowledge Base:", result)
```

OUTPUT

Knowledge Base : ~R & Implies (P,Q) & Implies (Q, R))

Query : (not, P)

Query entails Knowledge Base : False

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OUTPUT:

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

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

```
import re


def main(rules, goal):
    rules = rules.split(' ')
    steps = resolve(rules, goal)
    print('\nStep\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')
```

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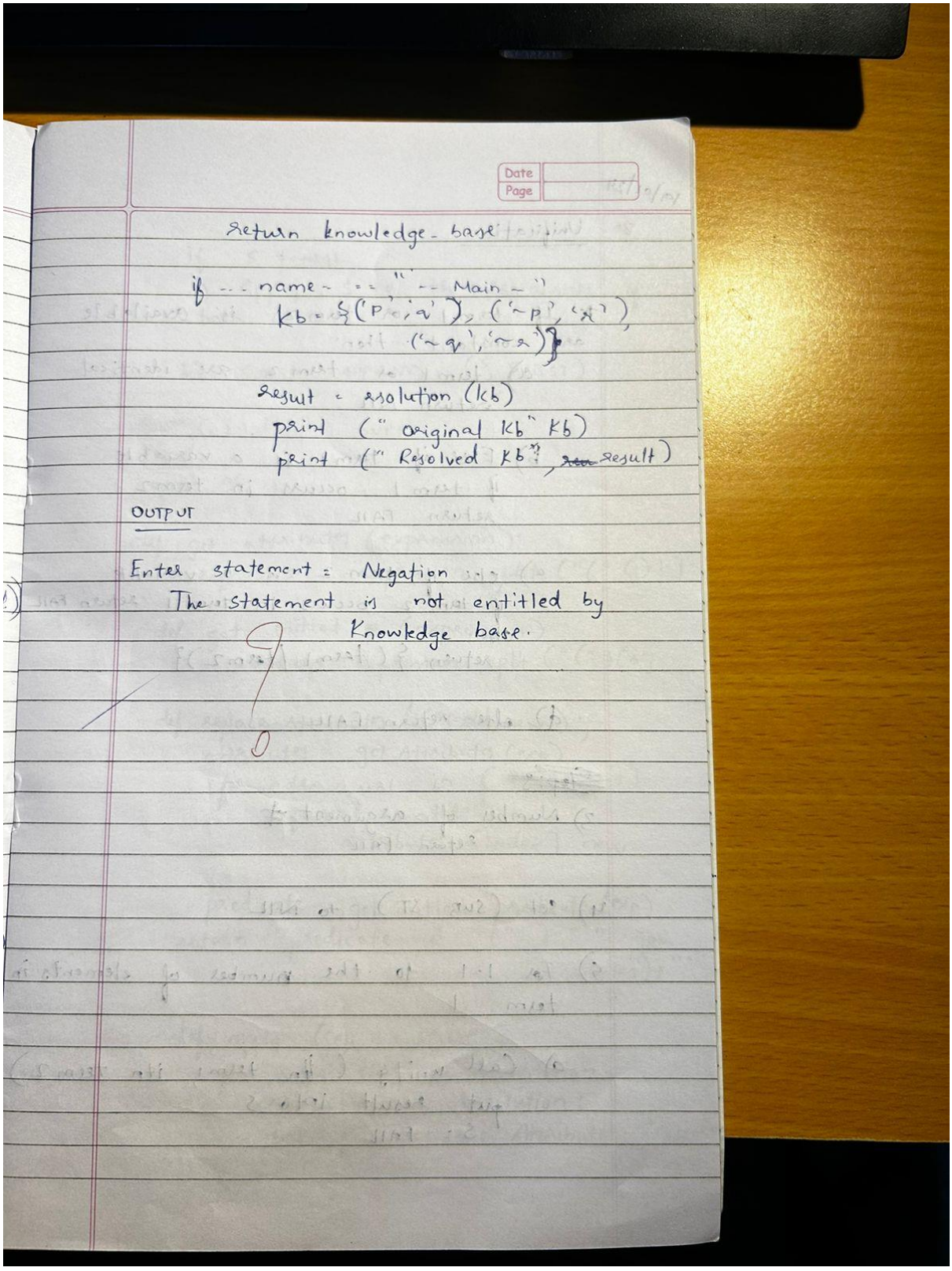
7. Knowledge base Resolution

```
def negate_literal(literal)
    if literal[0] == '~':
        return literal[1:]
    else:
        return '~' + literal

def resolve(c1, c2):
    resolved_clause = set(c1) | set(c2)

    for literal in c1:
        if negate_literal(literal) in c2:
            resolved_clause.remove(literal)
            resolved_clause.remove(negate_literal(literal))

    return tuple(resolved_clause)

def resolution(knowledge_base):

    while True:

        new_clauses = set()

        for i, c1 in enumerate(knowledge_base)
        for j, c2 in enumerate(knowledge_base)

            for i != j:
                new_clause.add(new_clause)
        if not new_clause
            break

        knowledge_base != new_clause
```



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return knowledge_base

if __name__ == "__main__":
    kb = {('P', 'Q'), ('~P', 'R'),
          ('~Q', '~R')}

    result = resolution(kb)
    print("original kb" kb)
    print("Resolved kb", result)

OUTPUT

Enter statement : Negation
The statement is not entitled by
Knowledge base.

OUTPUT:

```
['~P', 'R']
```

```
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)
```

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

rules = 'PvQ ~PvR ~QvR' #P=vQ, P=>Q : ~PvQ, Q=>R, ~QvR

goal = 'R'

main(rules, goal)

```
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.
```

8. Implement unification in first order logic

```
import re

def getAttributes(expression):
    expression = expression.split("(")[1:]
    expression = "(".join(expression)
    expression = expression[:-1]
    expression = re.split("(?

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)
```

19/01/24

8. Unification

1) If term 1 or term 2 is available are constant then:

a) term 1 or term 2 are identical.
return NIL

b) Else if term 1 is a variable
if term 1 occurs in term 2
return FAIL

c) else if term 2 is a variable
if term 2 occurs in term 1 return FAIL
else
return {(term1 / term2)}

d) else return FAIL

~~Steps~~

3) Number of argument ≠
return FAIL

4) Set (SUBST) to NIL

5) For I=1 to the number of elements in term 1

a) Call unify (ith term1, ith term2)
put result into S
S: FAIL

if S ≠ NIL

a) Apply S to the remainder of both L_1 & L_2

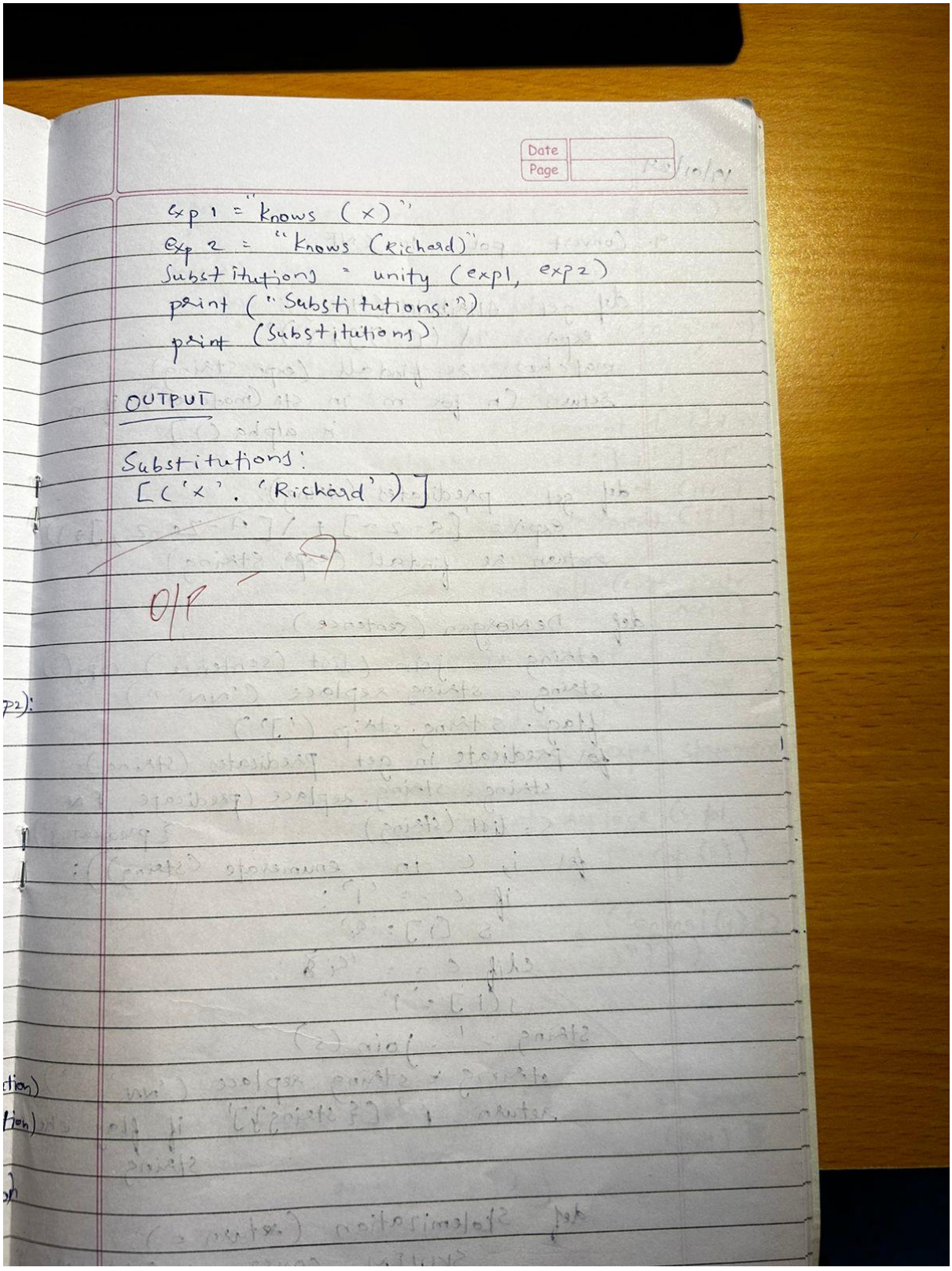
b). SUBST. APPEND (S, SUBST)

~~Step~~ 6) Return SUBST

CODE

```
import re

def get attributes (expression):
    expression = expression.split ("(") ()[]

def get initial (expression)
    return expression.split ("(")[0]

def replace Attributes (exp,old,new);
    attributes = get Attributes (exp)
    for index, val in (attributes):
        if val == old:
            attributes [index] new.

predicate = get initial predicate (exp)
return predicate + "(" + ",".join
                    (attributes) + ")"

def apply (exp, subtitution
    for substitution in substitution:
        new, old = substitution:
        exp = replace Attributes (exp,
                    old, new)
```

```
return exp.

def check (var, exp):
    if exp.find(var) == -1:
        return False
    return true.

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

def unify(exp1, exp2):
    if exp1 == exp2:
        return []

    if is_constant(exp1) and is_constant(exp2):
        if exp1 != exp2:
            return False.

    if is_constant(exp1)
        return [(exp2, exp1)]

    ~~if is_variable(exp1):~~
        ~~if check_occurs~~

    if initial_Substitution != []:
        tail1 = apply(tail2, initial_Substitution
        tail2 = apply(tail2, initial_Substitution

    initial_substitution.extend(remaining_substitution)
    return initial_Substitution
```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exp1 = "knows (x)"
exp2 = "knows (Richard)"
Substitutions = unity (exp1, exp2)
print ("Substitutions:")
print (Substitutions)

OUTPUT

Substitutions:
[('x', 'Richard')]

O/P

OUTPUT

```
Substitutions:
[('X', 'Richard')]
```

exp1 = "knows(A,x)"

exp2 = "knows(y,mother(y))"

substitutions = unify(exp1, exp2)

print("Substitutions:")

print(substitutions)

```
Substitutions:
[('A', 'y'), ('mother(y)', 'x')]
```

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

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


def getPredicates(string):
    expr = '[a-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)]=>criminal(x)"))
```

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9. Convert FOL to CNF.

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

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 = string.strip('~')
    for predicate in getpredicates(string):
        string = string.replace(predicate, f'~
        s = list(string)                  {predicate}')
    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(return c):
    SKULEM_CONSTANTS = [f'{chal(c)}
```

```
for c in range(ord('A'), ord('Z')+1):

import re
    def fol_to_cnf(fol):
        statement = fol.replace("<=>", "_")
        while '_' in statement:
            i = statement.index('_')
            new_st = '[' + statement[:i] + '=>'
                + statement[i+1:] + ']' & '['
                + statement[i+1:]
                + '=>' + statement[:i] + ']'
        statement = newst
        statements = re.findall(expr, state
                                ment)
    statement = statement.replace('~[∀.'
                                  '[~∀')
    expr = '(~[∀|∃,)'
    statements = re.findall(expr, statement)
    for s in statements:
        statement = statement.replace(s, fol_
                                      to_cnf(s))

print(Skolemization(fol_to_cnf('animal(y)<=>
                               loves(x,y)')))
```

OUTPUT

[~animal(y) | Loves(x,y)] & [~Loves(x,y) | animal(y)]

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)
```

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

```
import re


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


def getAttributes(string):
    expr = '
'
    matches = re.findall(expr, string)
    return matches


def getPredicates(string):
    expr = '([a-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()
```

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10. Create KB consisting of FOL statements & prove given query using forward reasoning.

```
import re
def is_variable(x):
    return len(x) == 1 and x is lowercase

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

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

class Implication:
    def __init__(self, expression):
        self.expression = expression
        l = expression.split('=>')
        if rhs = Fact(l[1])

    def evaluate(self, facts):
        constants = {}
        new = lhs = []
        for fact in facts:
            for val in self:
```

```
for key in constants:
    if constant[key]:
        attributes = attributes.replace(key,
                                        constants[key])
    expr = f'{predicate}({attributes})'
return fact(expr) if len(new.lhs)
and all(if.get_result() for f in
        new.lhs)
    else None.

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

    def (self, e):
        if '=>' in e:
            self.implications.add(Implications
                                  [e])
        else:
            self.facts.add(Fact(e))
            for i in self.implication:
            res = i.evaluate(self.facts)
            if res:
                self.facts.add(res)

for f in facts:
    if fact(f).predicate = Fact(e).
                           predicate:

print(f'\t{i}. {f}')
    i += 1
```

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

OUTPUT

```
Querying criminal(x):
1. criminal(west)
All facts:
1. American(west)
2. Sell(West, M1, Nono)
3. Missile(M1)
4. Enemy(Nono, America)
5. Criminal(west)
6. Weapon(M1)
7. Owns(Nono, M1)
8. Hostile(Nono)
```

OUTPUT

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