**VISVESVARAYA TECHNOLOGICAL UNIVERSITY “JnanaSangama”, Belgaum -590014, Karnataka.**

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**LAB REPORT**

**On**

**ARTIFICIAL INTELLIGENCE**

**Submitted by**

**ANSHU MOHANDAS (1BM21CS025)**

**in partial fulfillment for the award of the degree of**

**BACHELOR OF ENGINEERING**

**in**

**COMPUTER SCIENCE AND ENGINEERING**

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**B.M.S. COLLEGE OF ENGINEERING**

**(Autonomous Institution under VTU)**

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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**

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CERTIFICATE

This is to certify that the Lab work entitled **“ARTIFICIAL INTELLIGENCE”** carried out by **ANSHU MOHANDAS(1BM21CS025)**, 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 2023-24. 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

1

num=int(input("enter a number on the board :"))

while num not in tic:

num=int(input("enter a number on the board :"))

else:

tic[num-1]='O'

def winner(num):

if tic[0]==tic[4] and tic[4]==tic[8] or tic[2]==tic[4] and tic[4]==tic[6]: return True

if tic[num]==tic[num-3] and tic[num-3]==tic[num-6]:

return True

if tic[num//3\*3]==tic[num//3\*3+1] and tic[num//3\*3+1]==tic[num//3\*3+2]: return True

return False

try:

for i in range(1,10):

tic.append(i)

count=0

#print(tic)

board(tic)

while count!=9:

if count%2==0:

print("computer's turn :")

update\_comp()

board(tic)

count+=1

else:

print("Your turn :")

update\_user()

board(tic)

count+=1

if count>=5:

if winner(num-1):

print("winner is ",tic[num-1])

break

else:

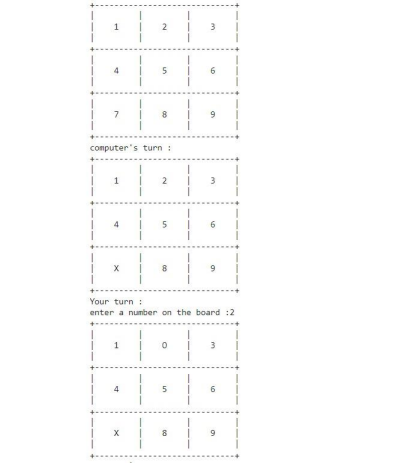
continue

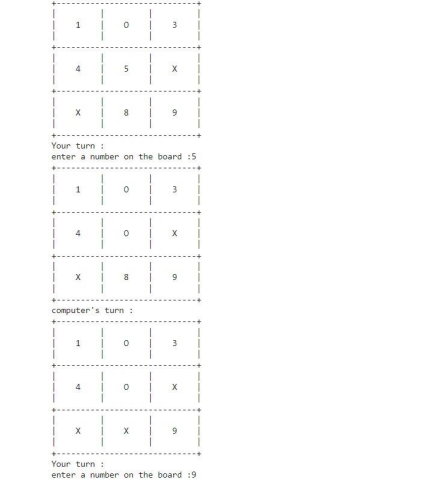
except:

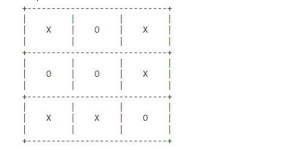
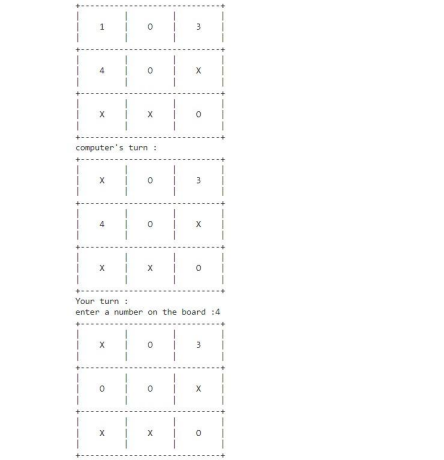
print("\nerror\n")

Output:

2

3

4



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2. 8 Puzzle Breadth First Search Algorithm 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))

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return [move\_it\_can for move\_it\_can in pos\_moves\_it\_can if move\_it\_can not in visited\_states]

def gen(state,m,b):

temp=state.copy()

if m=='d':

temp[b+3],temp[b]=temp[b],temp[b+3]

if m=='u':

temp[b-3],temp[b]=temp[b],temp[b-3]

if m=='l':

temp[b-1],temp[b]=temp[b],temp[b-1]

if m=='r':

temp[b+1],temp[b]=temp[b],temp[b+1]

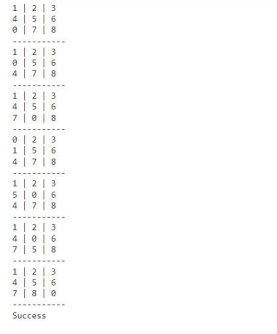
return temp

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

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

bfs(src,target)

Output:



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3. 8 Puzzle 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()

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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:

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4. 8 Puzzle 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:

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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"""

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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 """

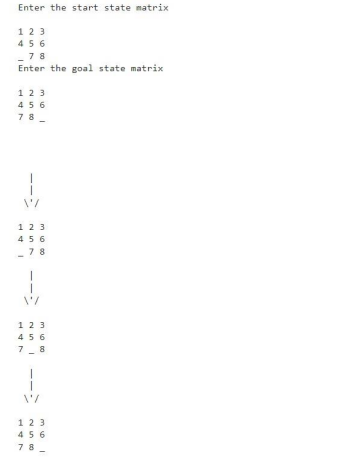
self.open.sort(key = lambda x:x.fval,reverse=False)

puz = Puzzle(3)

puz.process()

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Output:

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5. Vacuum Cleaner

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

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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. ")

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else:

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

# suck and mark clean

print("Location A is already clean.")

# done cleaning

print("GOAL STATE: ")

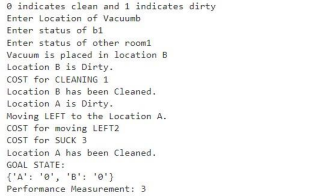
print(goal\_state)

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

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

vacuum\_world()

Output:

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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)

Output:

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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')

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

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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)

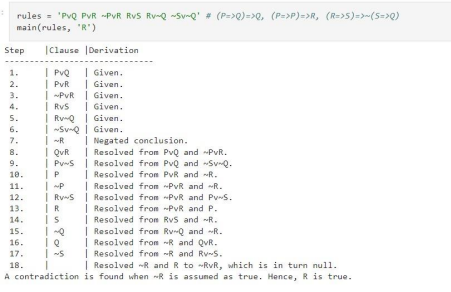
steps[clause] = f'Resolved from {temp[i]} and {temp[j]}.' j = (j + 1) % n

i += 1

return steps

Output:

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8. Implement unification in first order logic import re

def getAttributes(expression):

expression = expression.split("(")[1:]

expression = "(".join(expression)

expression = expression[:-1]

expression = re.split("(?<!\(.),(?!.\))", expression) return expression

def getInitialPredicate(expression):

return expression.split("(")[0]

def isConstant(char):

return char.isupper() and len(char) == 1

def isVariable(char):

return char.islower() and len(char) == 1

def replaceAttributes(exp, old, new):

attributes = getAttributes(exp)

for index, val in enumerate(attributes):

if val == old:

attributes[index] = new

predicate = getInitialPredicate(exp)

return predicate + "(" + ",".join(attributes) + ")"

def apply(exp, substitutions):

for substitution in substitutions:

new, old = substitution

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

def checkOccurs(var, exp):

if exp.find(var) == -1:

return False

return True

def getFirstPart(expression):

attributes = getAttributes(expression)

return attributes[0]

def getRemainingPart(expression):

predicate = getInitialPredicate(expression)

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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:

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return initialSubstitution

tail1 = getRemainingPart(exp1)

tail2 = getRemainingPart(exp2)

if initialSubstitution != []:

tail1 = apply(tail1, initialSubstitution)

tail2 = apply(tail2, initialSubstitution)

remainingSubstitution = unify(tail1, tail2)

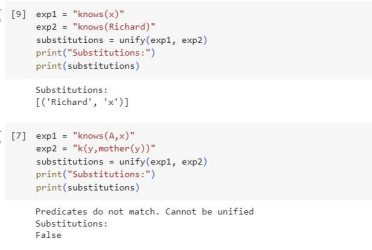
if not remainingSubstitution:

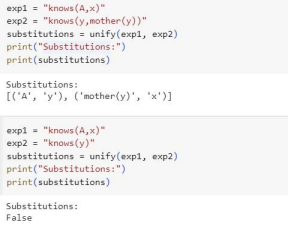
return False

initialSubstitution.extend(remainingSubstitution)

return initialSubstitution

Output:

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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~]+\([A-Za-z,]+\)'

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()]

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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))

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expr = '~\[[^]]+\]'

statements = re.findall(expr, statement)

for s in statements:

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

return statement

Output:

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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)

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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

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print(f'Querying {e}:')

for f in facts:

if Fact(f).predicate == Fact(e).predicate:

print(f'\t{i}. {f}')

i += 1

def display(self):

print("All facts: ")

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

Output:

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