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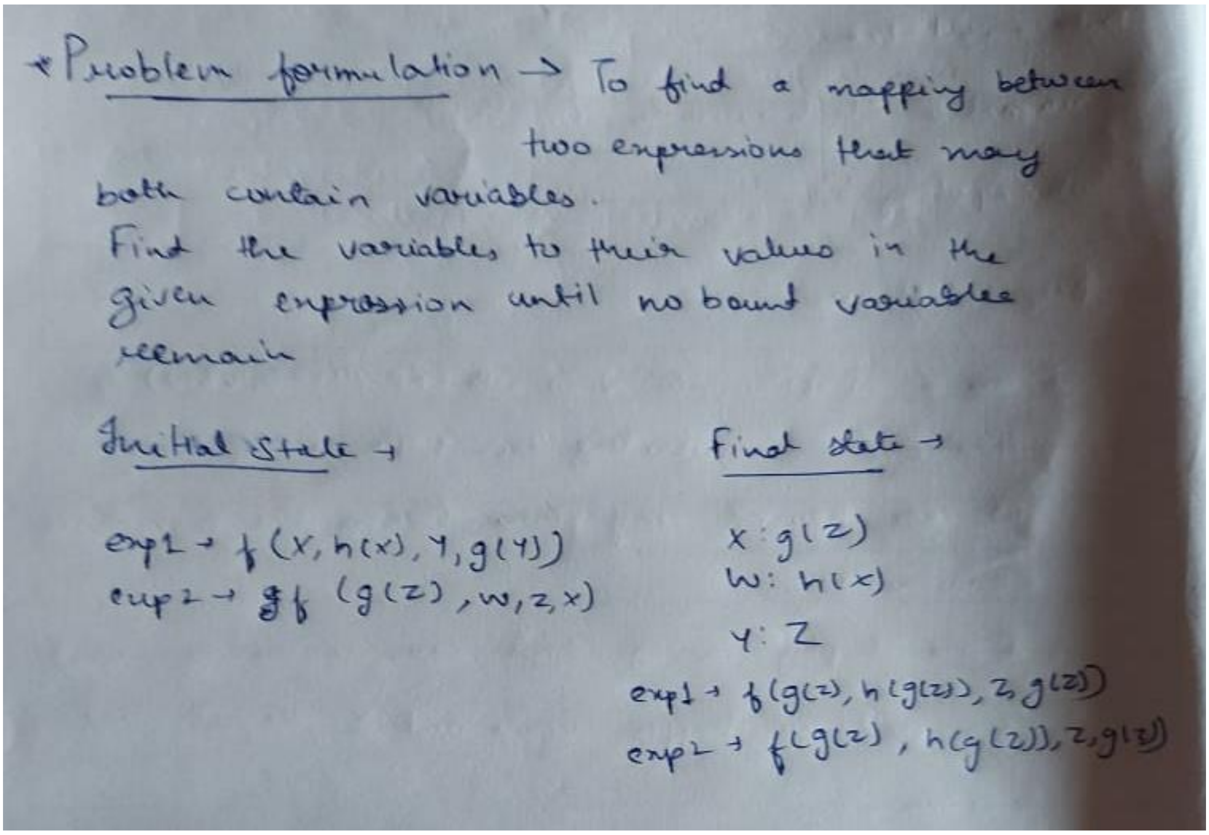
AI LAB-7

Aim- Implementation of Unification and Resolution in real world applications

i) Unification (Pattern Matching)



* Problem formulation → To find a mapping between two expressions that may both contain variables.

Find the variables to their values in the given expression until no bound variables remain

Initial State →

exp1 → f(x, h(x), y, g(y))

exp2 → f(g(z), w, z, x)

Final state →

x : g(z)

w : h(x)

y : z

exp1 → f(g(z), h(g(z)), z, g(z))

exp2 → f(g(z), h(g(z)), z, g(z))

- Problem Solving →

→ Unify $f(x, h(x), y, g(y))$ and $f(g(z), w, z, x)\}$

→ It would loop through each argument

→ Unify $(x, g(z))$ is invoked

x is a variable, ∴ substitute $x = g(z)$

→ Unify $(h(x), w)$ is invoked

↳ w is variable ∴ substitute $w = h(x)$

→ $\{x = g(z), W = h(x)\}$

→ Unify (y, z) is invoked

Both y and z are variables ∴ added directly to the dictionary

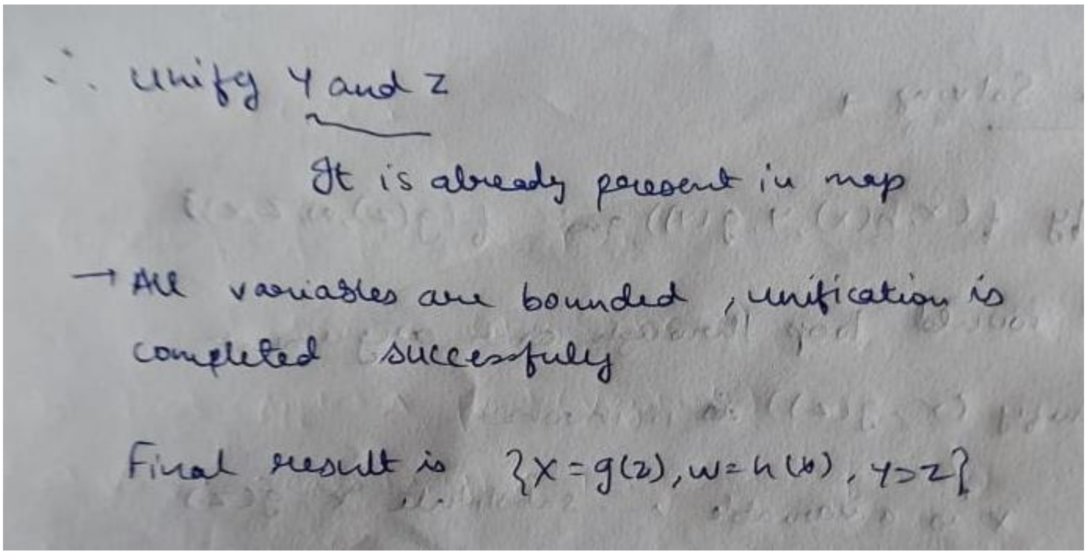
→ $\{x = g(z), W = h(x), y = z\}$

→ Unify $(g(y), x)$ is invoked

x is a variable but is already present in the dictionary

∴ the unify would be on the substituted value if it is not a variable

unify $(\underbrace{g(y), g}_{\text{Both terms have } g}(z))$



∴ unify Y and Z

It is already present in map

→ All variables are bounded, unification is completed succesfuly

Final result is {X=g(z), W=h(b), Y=Z}

Algorithm-

Step-1: Start

Step-2: Declare a Python dict mapping variable names to terms

Step-3: When either side is a variable, it calls unify_variable.

Step-4: Otherwise, if both sides are function applications, it ensures they apply the same function (otherwise there's no match) and then unifies their arguments one by one, carefully carrying the updated substitution throughout the process.

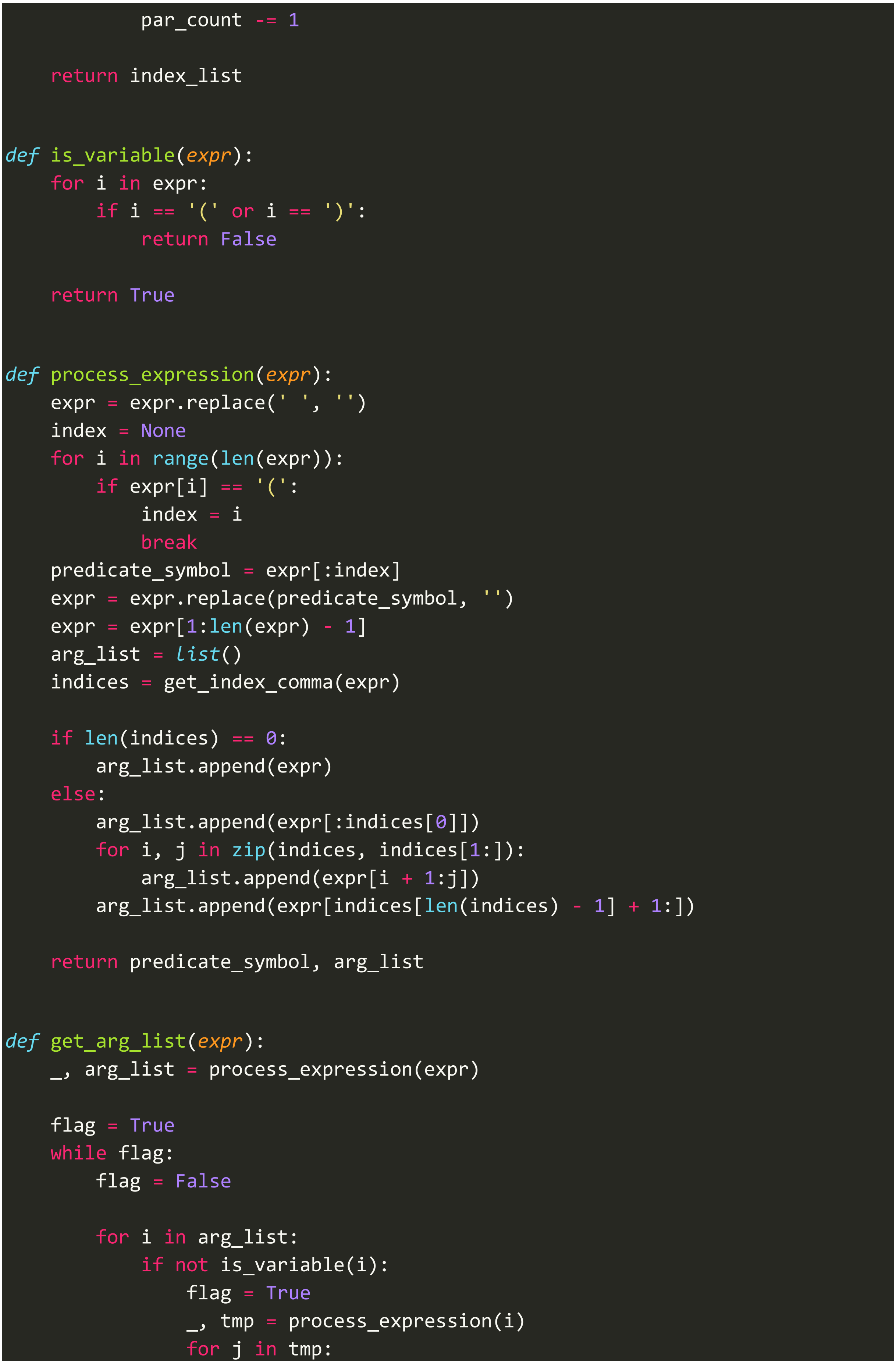
Step-5: If v is bound in the substitution, we try to unify its definition with x to guarantee consistency throughout the unification process (and vice versa when x is a variable).

Step-6: occurs_check, is to guarantee that we don't have self-referential variable bindings like X=f(X) that would lead to potentially infinite unifiers.

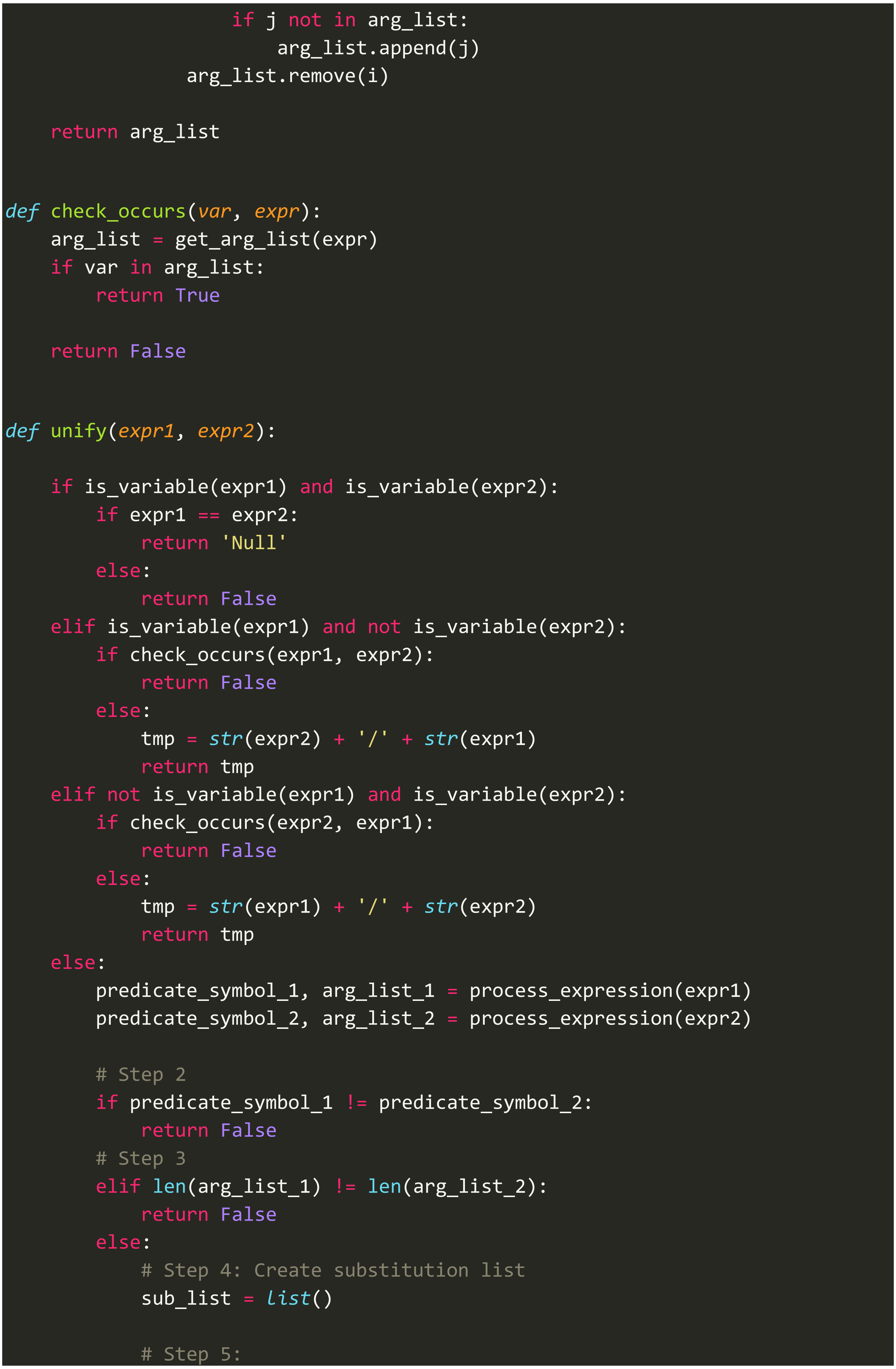
Step-7: Stop

Code-

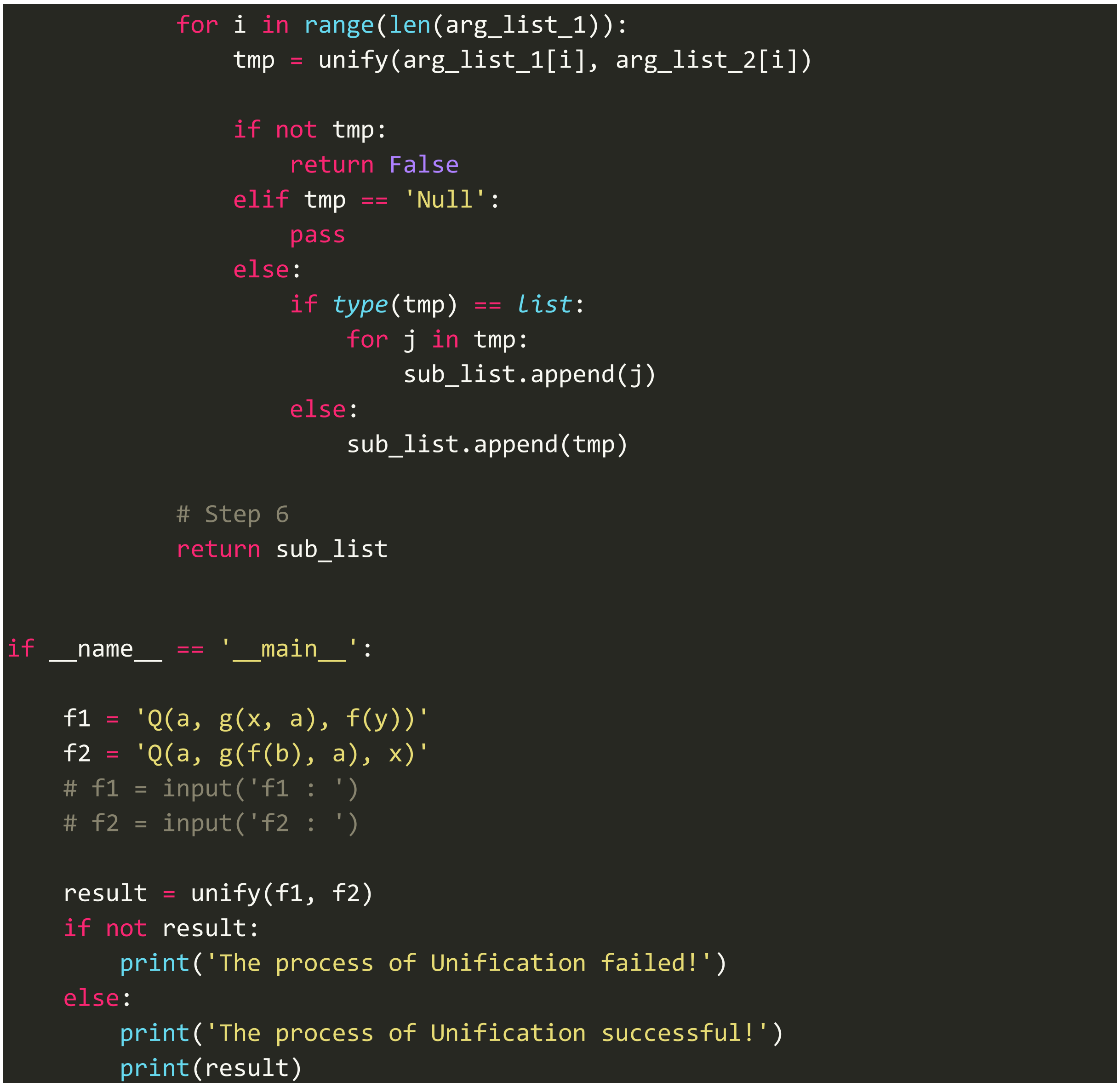
```python
def get_index_comma(string):
    index_list = list()
    par_count = 0

    for i in range(len(string)):
        if string[i] == ',' and par_count == 0:
            index_list.append(i)
        elif string[i] == '(':
            par_count += 1
        elif string[i] == ')':
```



```
            par_count -= 1

    return index_list


def is_variable(expr):
    for i in expr:
        if i == '(' or i == ')':
            return False

    return True


def process_expression(expr):
    expr = expr.replace(' ', '')
    index = None
    for i in range(len(expr)):
        if expr[i] == '(':
            index = i
            break
    predicate_symbol = expr[:index]
    expr = expr.replace(predicate_symbol, '')
    expr = expr[1:len(expr) - 1]
    arg_list = list()
    indices = get_index_comma(expr)

    if len(indices) == 0:
        arg_list.append(expr)
    else:
        arg_list.append(expr[:indices[0]])
        for i, j in zip(indices, indices[1:]):
            arg_list.append(expr[i + 1:j])
        arg_list.append(expr[indices[len(indices) - 1] + 1:])

    return predicate_symbol, arg_list


def get_arg_list(expr):
    _, arg_list = process_expression(expr)

    flag = True
    while flag:
        flag = False

        for i in arg_list:
            if not is_variable(i):
                flag = True
                _, tmp = process_expression(i)
                for j in tmp:
```

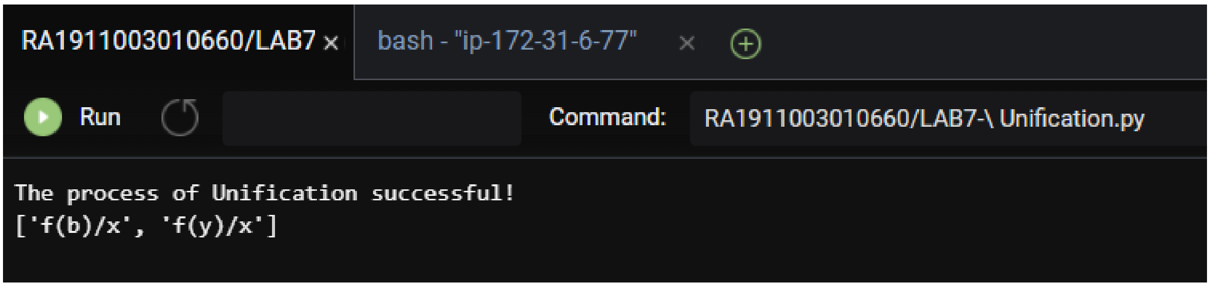


```
                    if j not in arg_list:
                        arg_list.append(j)
                arg_list.remove(i)

    return arg_list


def check_occurs(var, expr):
    arg_list = get_arg_list(expr)
    if var in arg_list:
        return True

    return False


def unify(expr1, expr2):

    if is_variable(expr1) and is_variable(expr2):
        if expr1 == expr2:
            return 'Null'
        else:
            return False
    elif is_variable(expr1) and not is_variable(expr2):
        if check_occurs(expr1, expr2):
            return False
        else:
            tmp = str(expr2) + '/' + str(expr1)
            return tmp
    elif not is_variable(expr1) and is_variable(expr2):
        if check_occurs(expr2, expr1):
            return False
        else:
            tmp = str(expr1) + '/' + str(expr2)
            return tmp
    else:
        predicate_symbol_1, arg_list_1 = process_expression(expr1)
        predicate_symbol_2, arg_list_2 = process_expression(expr2)

        # Step 2
        if predicate_symbol_1 != predicate_symbol_2:
            return False
        # Step 3
        elif len(arg_list_1) != len(arg_list_2):
            return False
        else:
            # Step 4: Create substitution list
            sub_list = list()

            # Step 5:
```



```
            for i in range(len(arg_list_1)):
                tmp = unify(arg_list_1[i], arg_list_2[i])

                if not tmp:
                    return False
                elif tmp == 'Null':
                    pass
                else:
                    if type(tmp) == list:
                        for j in tmp:
                            sub_list.append(j)
                    else:
                        sub_list.append(tmp)

            # Step 6
            return sub_list


if __name__ == '__main__':

    f1 = 'Q(a, g(x, a), f(y))'
    f2 = 'Q(a, g(f(b), a), x)'
    # f1 = input('f1 : ')
    # f2 = input('f2 : ')

    result = unify(f1, f2)
    if not result:
        print('The process of Unification failed!')
    else:
        print('The process of Unification successful!')
        print(result)
```

Output-



Command: RA1911003010660/LAB7-\ Unification.py

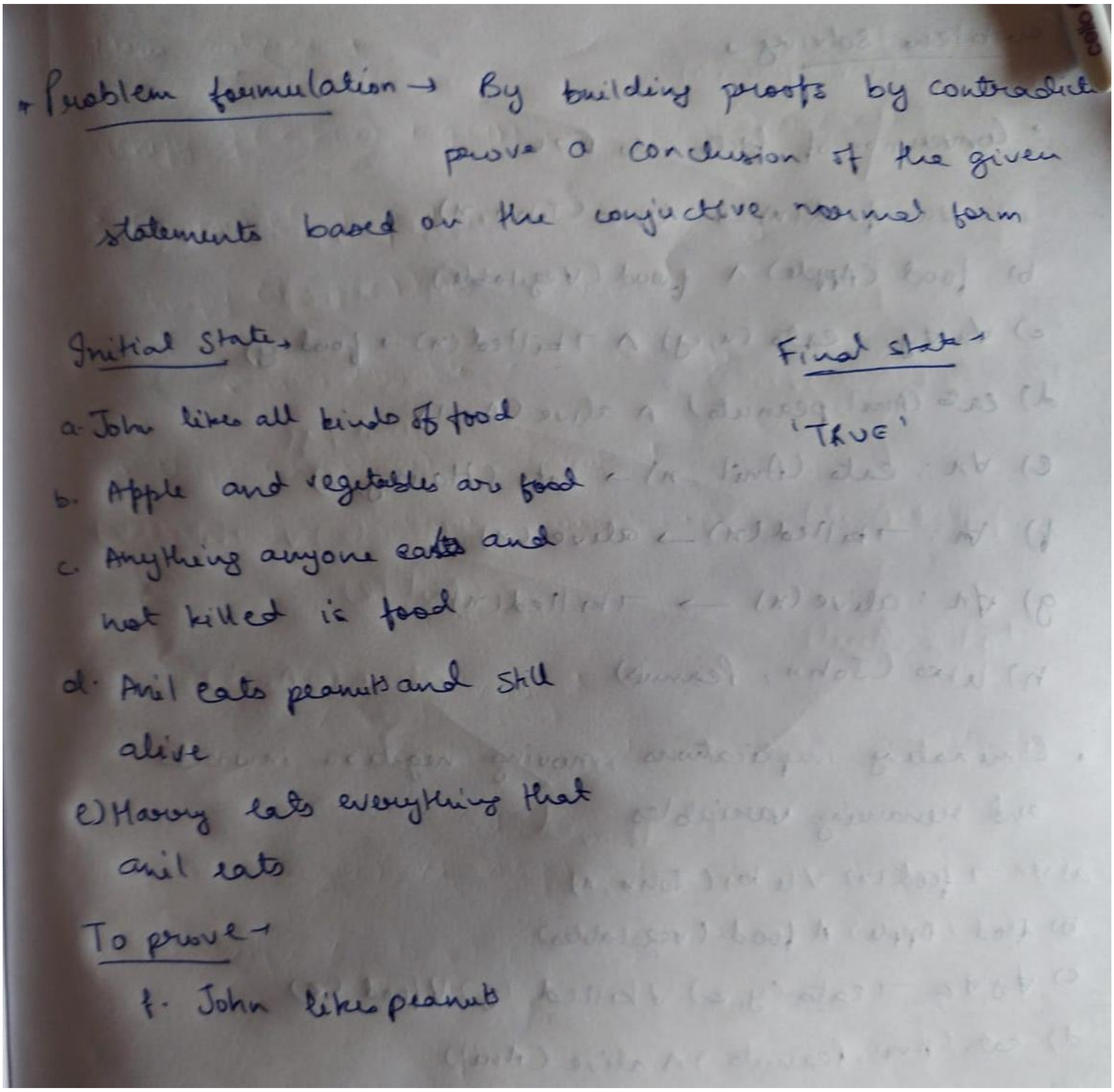
```
The process of Unification successful!
['f(b)/x', 'f(y)/x']
```

Result-

Hence, the Implementation of unification algorithm for Pattern Matching is done

Successfully.

ii) Resolution (Predicate Logic)



* Problem formulation → By building proofs by contradicti prove a conclusion of the given statements based on the conjuctive normal form

Initial State →

Final state → 'TRUE'

a. John likes all kinds of food

b. Apple and vegetables are food

c. Anything anyone eats and not killed is food

d. Anil eats peanuts and still alive

e) Harry eats everything that anil eats

To prove →

f. John likes peanuts

* Problem solving →

- Conversion of facts into FOL

a) $\forall x: food(x) \rightarrow likes(John, x)$

b) $food(Apple) \wedge food(Vegetable)$

c) $\forall x \forall y : eats(x, y) \wedge \neg killed(x) \rightarrow food(y)$

d) $eats(Anil, peanuts) \wedge alive(Anil)$

e) $\forall x: eats(Anil, x) \rightarrow eats(Harry, x)$

f) $\forall x: \neg killed(x) \rightarrow alive(x)$

g) $\forall x : alive(x) \rightarrow \neg killed(x)$

h) $likes(John, Peanuts)$

- Eliminating implications, moving negation inwards and renaming variables

a) $\forall x \neg food(x) \vee likes(John, x)$

b) $food(Apple) \wedge food(vegetables)$

c) $\forall y \forall z \neg eats(y, z) \vee killed(y) \vee food(z)$

d) $eats(Anil, Peanuts) \wedge alive(Anil)$

e) $\forall w \neg eats(Anil, w) \vee eats(Harry, w)$

f) $\forall g \neg killed(g) \vee alive(g)$

g) $\forall k \neg alive(k) \vee killed(k)$

h) $likes(John, Peanuts)$

- Drop existential quantifiers -

a) food (x) v likes (John, x)

b) food (Apple)

c) food (Vegetables)

d) ¬ eats (y, z) v killed(y) v food (z)

e) eats (Anil, peanuts)

f) alive (Anil)

g) ¬ eats (Anil, w) v eats (Harry, w)

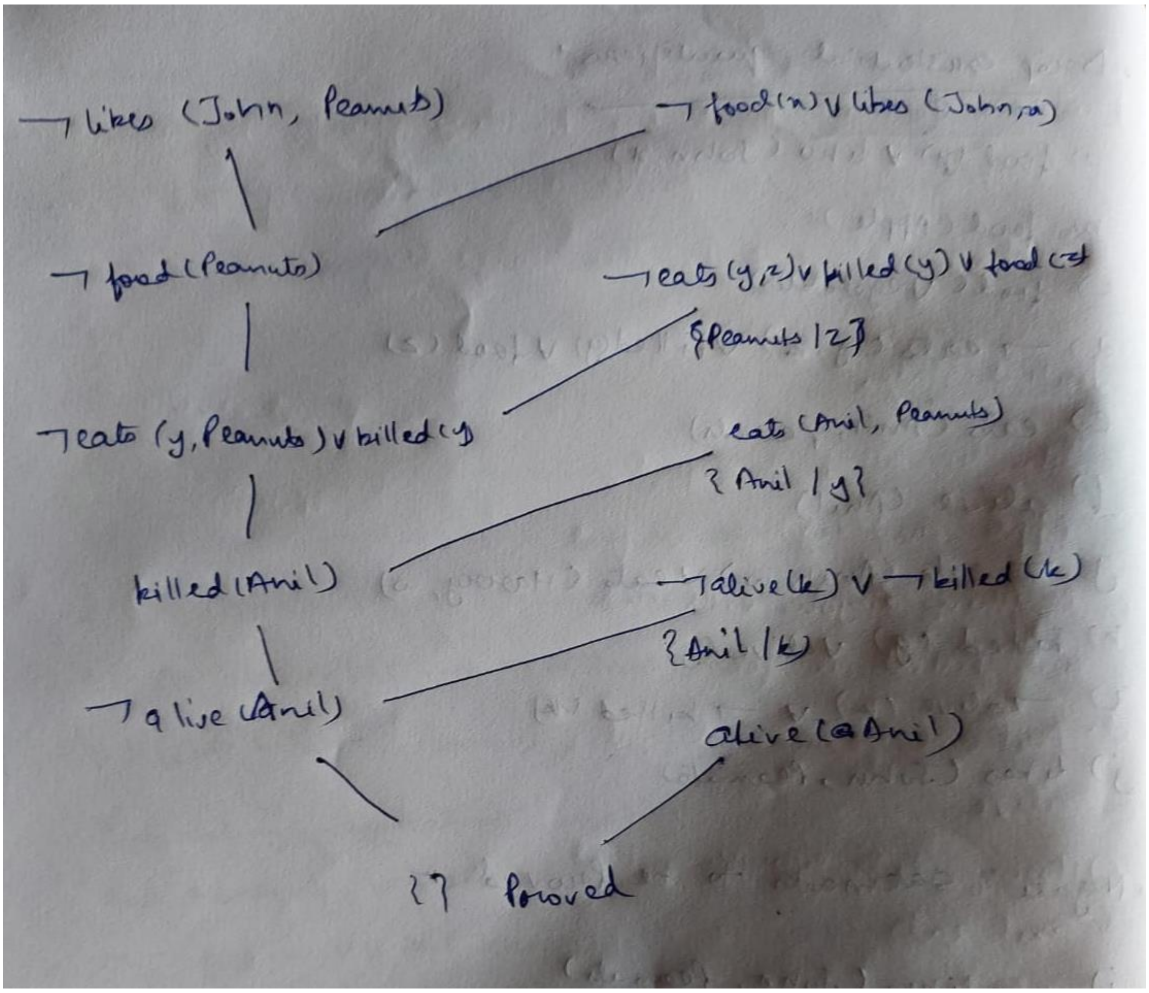
h) killed (g) v alive (g)

i) ¬ alive (k) v ¬ killed (k)

j) likes (John, Peanuts)

- Negate statements to be proved -

i) ¬ likes (John, Peanuts)



Algorithm-

```
Step-1: Start
Step-2: if L1 or L2 is an atom part of same thing do
(a) if L1 or L2 are identical then return NIL
(b) else if L1 is a variable then do
(i) if L1 occurs in L2 then return F else return (L2/L1)
else if L2 is a variable then do
(i) if L2 occurs in L1 then return F else return (L1/L2)
else return F.
Step-3: If length (L!) is not equal to length (L2) then return F.
Step-4: Set SUBST to NIL
( at the end of this procedure , SUBST will contain all the substitutions used
to unify L1 and L2).
```

Step-5: For I = 1 to number of elements in L1 do

i) call UNIFY with the i th element of L1 and I'th element of L2, putting the

result in S

ii) if S = F then return F

iii) if S is not equal to NIL then do

(A) apply S to the remainder of both L1 and L2

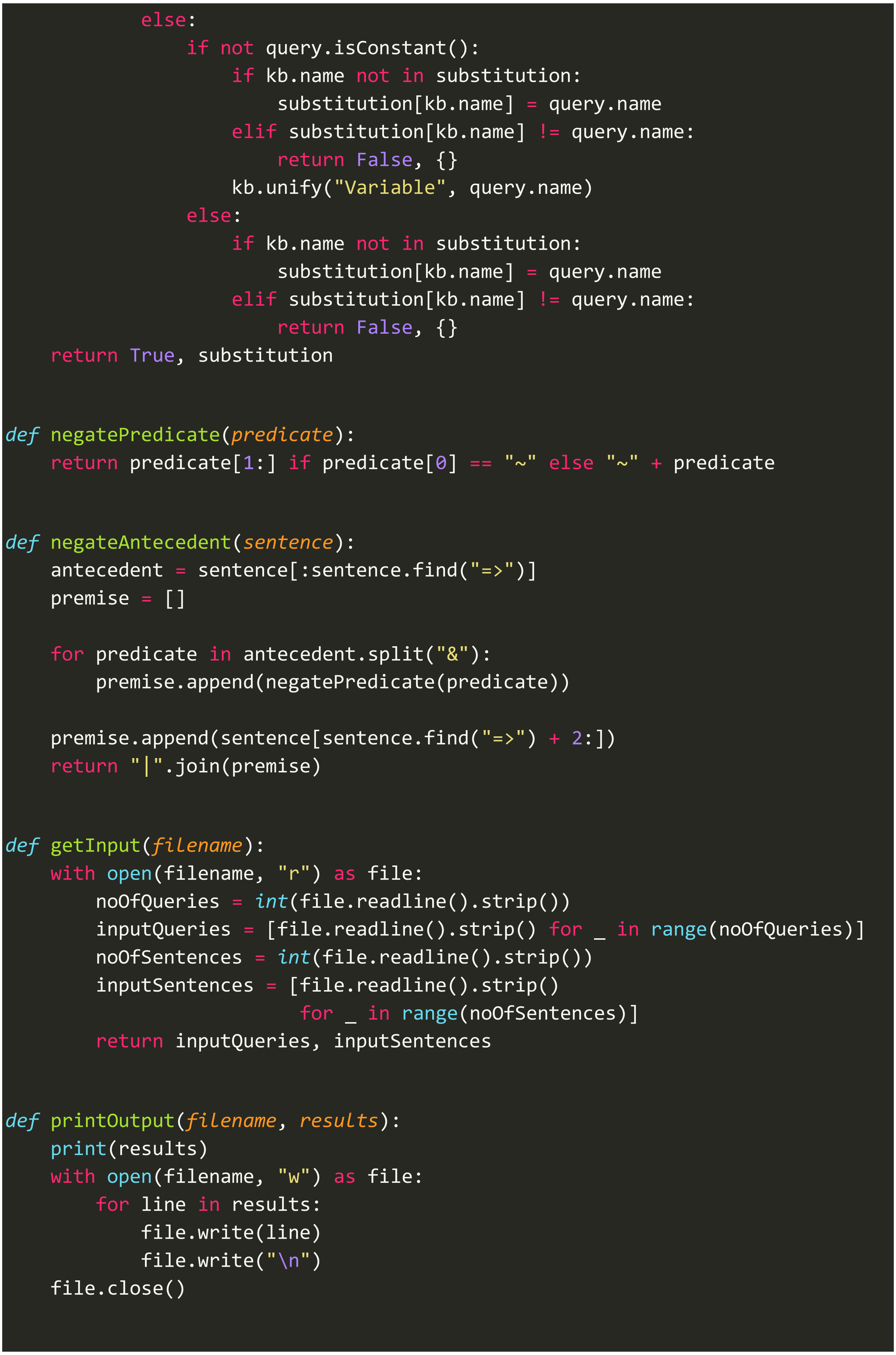
(B) SUBST := APPEND (S, SUBST) return SUBST.

Step-6: Stop.

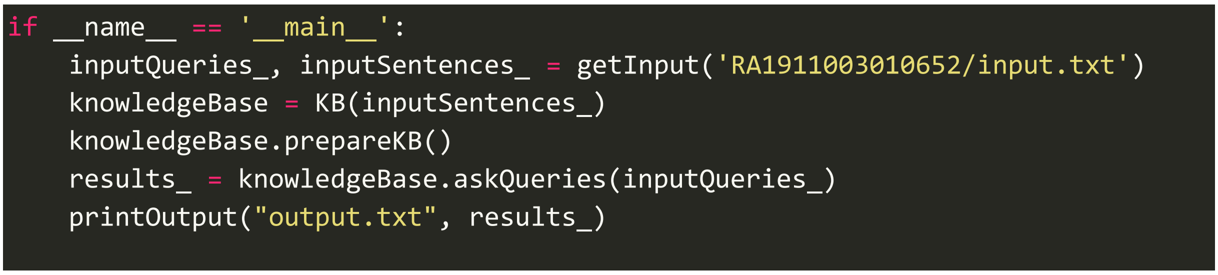
Code-

```
#Resolution
import copy
import time


class Parameter:
    variable_count = 1

    def __init__(self, name=None):
        if name:
            self.type = "Constant"
            self.name = name
        else:
            self.type = "Variable"
            self.name = "v" + str(Parameter.variable_count)
            Parameter.variable_count += 1

    def isConstant(self):
        return self.type == "Constant"

    def unify(self, type_, name):
        self.type = type_
        self.name = name

    def __eq__(self, other):
        return self.name == other.name

    def __str__(self):
        return self.name


class Predicate:
    def __init__(self, name, params):
        self.name = name
        self.params = params

    def __eq__(self, other):
        return self.name == other.name and all(a == b for a, b in zip(self.params, other.params))

    def __str__(self):
        return self.name + "(" + ",".join(str(x) for x in self.params) + ")"

    def getNegatedPredicate(self):
        return Predicate(negatePredicate(self.name), self.params)


class Sentence:
    sentence_count = 0

    def __init__(self, string):
        self.sentence_index = Sentence.sentence_count
        Sentence.sentence_count += 1
        self.predicates = []
        self.variable_map = {}
        local = {}

        for predicate in string.split("|"):
            name = predicate[:predicate.find("(")]
            params = []

            for param in predicate[predicate.find("(") + 1: predicate.find(")")].split(","):
                if param[0].islower():
                    if param not in local:  # Variable
                        local[param] = Parameter()
                        self.variable_map[local[param].name] = local[param]
                    new_param = local[param]
                else:
                    new_param = Parameter(param)
                    self.variable_map[param] = new_param

                params.append(new_param)

            self.predicates.append(Predicate(name, params))

    def getPredicates(self):
        return [predicate.name for predicate in self.predicates]

    def findPredicates(self, name):
        return [predicate for predicate in self.predicates if predicate.name == name]
    def removePredicate(self, predicate):
        self.predicates.remove(predicate)
        for key, val in self.variable_map.items():
            if not val:
                self.variable_map.pop(key)

    def containsVariable(self):
        return any(not param.isConstant() for param in
self.variable_map.values())

    def __eq__(self, other):
        if len(self.predicates) == 1 and self.predicates[0] == other:
            return True
        return False

    def __str__(self):
        return "".join([str(predicate) for predicate in self.predicates])


class KB:
    def __init__(self, inputSentences):
        self.inputSentences = [x.replace(" ", "") for x in inputSentences]
        self.sentences = []
        self.sentence_map = {}

    def prepareKB(self):
        self.convertSentencesToCNF()
        for sentence_string in self.inputSentences:
            sentence = Sentence(sentence_string)
            for predicate in sentence.getPredicates():
                self.sentence_map[predicate] = self.sentence_map.get(
                    predicate, []) + [sentence]

    def convertSentencesToCNF(self):
        for sentenceIdx in range(len(self.inputSentences)):
            # Do negation of the Premise and add them as literal
            if "=>" in self.inputSentences[sentenceIdx]:
                self.inputSentences[sentenceIdx] = negateAntecedent(
                    self.inputSentences[sentenceIdx])

    def askQueries(self, queryList):
        results = []

        for query in queryList:
            negatedQuery = Sentence(negatePredicate(query.replace(" ", "")))
            negatedPredicate = negatedQuery.predicates[0]
            prev_sentence_map = copy.deepcopy(self.sentence_map)
            self.sentence_map[negatedPredicate.name] = self.sentence_map.get(
                negatedPredicate.name, []) + [negatedQuery]
            self.timeLimit = time.time() + 40

            try:
                result = self.resolve([negatedPredicate], [
                                      False]*(len(self.inputSentences) + 1))
            except:
                result = False

            self.sentence_map = prev_sentence_map

            if result:
                results.append("TRUE")
            else:
                results.append("FALSE")

        return results

    def resolve(self, queryStack, visited, depth=0):
        if time.time() > self.timeLimit:
            raise Exception
        if queryStack:
            query = queryStack.pop(-1)
            negatedQuery = query.getNegatedPredicate()
            queryPredicateName = negatedQuery.name
            if queryPredicateName not in self.sentence_map:
                return False
            else:
                queryPredicate = negatedQuery
                for kb_sentence in self.sentence_map[queryPredicateName]:
                    if not visited[kb_sentence.sentence_index]:
                        for kbPredicate in
kb_sentence.findPredicates(queryPredicateName):

                            canUnify, substitution = performUnification(
                                copy.deepcopy(queryPredicate),
copy.deepcopy(kbPredicate))

                            if canUnify:
                                newSentence = copy.deepcopy(kb_sentence)
                                newSentence.removePredicate(kbPredicate)
                                newQueryStack = copy.deepcopy(queryStack)

                                if substitution:
                                    for old, new in substitution.items():
                                        if old in newSentence.variable_map:
                                            parameter =
newSentence.variable_map[old]
```

```
                                            newSentence.variable_map.pop(old)
                                            parameter.unify(
                                                "Variable" if new[0].islower()
else "Constant", new)
                                            newSentence.variable_map[new] =
parameter

                                    for predicate in newQueryStack:
                                        for index, param in
enumerate(predicate.params):
                                            if param.name in substitution:
                                                new = substitution[param.name]
                                                predicate.params[index].unify(
                                                    "Variable" if
new[0].islower() else "Constant", new)

                                for predicate in newSentence.predicates:
                                    newQueryStack.append(predicate)

                                new_visited = copy.deepcopy(visited)
                                if kb_sentence.containsVariable() and
len(kb_sentence.predicates) > 1:
                                    new_visited[kb_sentence.sentence_index] =
True

                                if self.resolve(newQueryStack, new_visited,
depth + 1):
                                    return True
                return False
        return True


def performUnification(queryPredicate, kbPredicate):
    substitution = {}
    if queryPredicate == kbPredicate:
        return True, {}
    else:
        for query, kb in zip(queryPredicate.params, kbPredicate.params):
            if query == kb:
                continue
            if kb.isConstant():
                if not query.isConstant():
                    if query.name not in substitution:
                        substitution[query.name] = kb.name
                    elif substitution[query.name] != kb.name:
                        return False, {}
                    query.unify("Constant", kb.name)
                else:
                    return False, {}
```

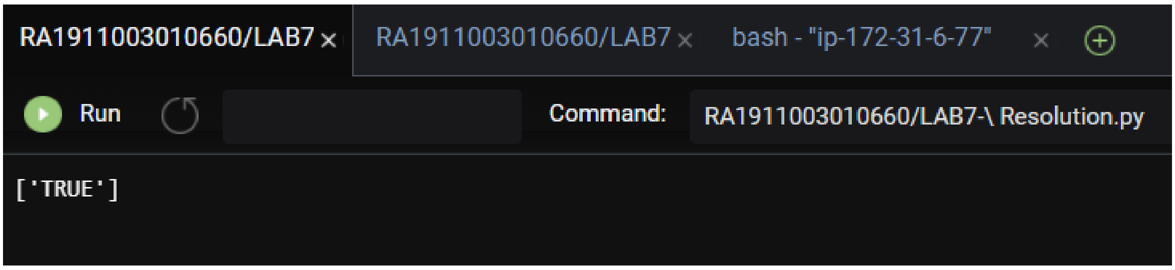


```
            else:
                if not query.isConstant():
                    if kb.name not in substitution:
                        substitution[kb.name] = query.name
                    elif substitution[kb.name] != query.name:
                        return False, {}
                    kb.unify("Variable", query.name)
                else:
                    if kb.name not in substitution:
                        substitution[kb.name] = query.name
                    elif substitution[kb.name] != query.name:
                        return False, {}
    return True, substitution


def negatePredicate(predicate):
    return predicate[1:] if predicate[0] == "~" else "~" + predicate


def negateAntecedent(sentence):
    antecedent = sentence[:sentence.find("=>")]
    premise = []

    for predicate in antecedent.split("&"):
        premise.append(negatePredicate(predicate))

    premise.append(sentence[sentence.find("=>") + 2:])
    return "|".join(premise)


def getInput(filename):
    with open(filename, "r") as file:
        noOfQueries = int(file.readline().strip())
        inputQueries = [file.readline().strip() for _ in range(noOfQueries)]
        noOfSentences = int(file.readline().strip())
        inputSentences = [file.readline().strip()
                          for _ in range(noOfSentences)]
        return inputQueries, inputSentences


def printOutput(filename, results):
    print(results)
    with open(filename, "w") as file:
        for line in results:
            file.write(line)
            file.write("\n")
    file.close()
```



```python
if __name__ == '__main__':
    inputQueries_, inputSentences_ = getInput('RA1911003010652/input.txt')
    knowledgeBase = KB(inputSentences_)
    knowledgeBase.prepareKB()
    results_ = knowledgeBase.askQueries(inputQueries_)
    printOutput("output.txt", results_)
```

Output-



Command: RA1911003010660/LAB7-\ Resolution.py

```
['TRUE']
```

Result-

Hence, the Implementation of resolution algorithm for Predicate logic is done successfully.