AI LAB 7

UNIFICATION & RESOLUTION

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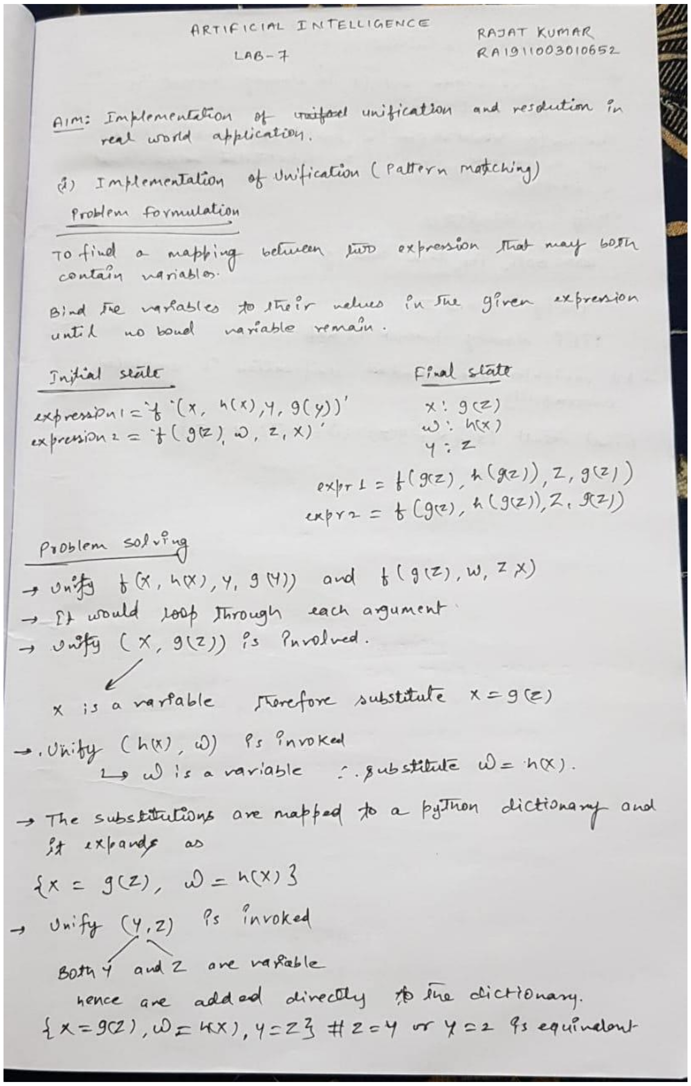
1. UNIFICATION:



ARTIFICIAL INTELLIGENCE

LAB-7

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Aim: Implementation of unification and resdution in real world application.

(i) Implementation of Unification (Pattern matching)

Problem formulation

To find a mapping between two expression that may both contain variables.

Bind the variables to their values in the given expression until no boud variable remain.

Initial state

expression1 = 'f (x, h(x), y, g(y))'
expression2 = 'f (g(z), ω, z, x)'

Final state

x : g(z)
ω : h(x)
y : z

expr1 = f(g(z), h(g(z)), Z, g(z))
expr2 = 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 involved.

x is a variable therefore substitute x = g(z)

→ Unify (h(x), ω) is invoked
↳ ω is a variable ∴ substitute ω = h(x).

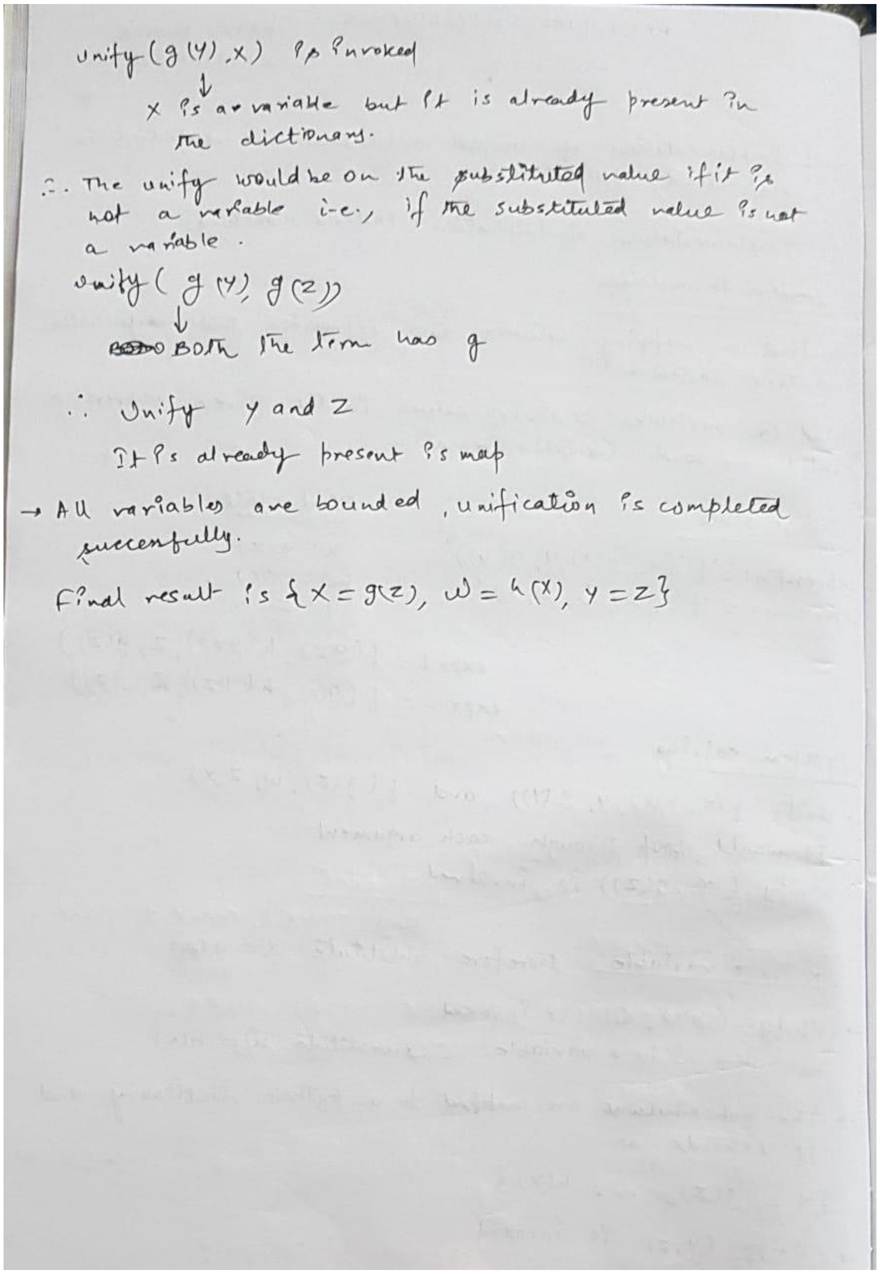
→ The substitutions are mapped to a python dictionary and it expands as

{x = g(z), ω = h(x)}

→ Unify (y, z) is invoked

Both y and z are variable
hence are added directly to the dictionary.

{x = g(z), ω = h(x), y = z} # z = y or y = z is equivalent



unify (g(Y), X) is invoked

↓

X is a variable but it is already present in the dictionary.

∴ The unify would be on the substituted value if it is not a variable i.e., if the substituted value is not a variable.

unify (g(Y), g(Z))

↓

BOTH the term has g

∴ Unify Y and Z

It is already present is map

→ All variables are bounded , unification is completed succenfully.

Final result is $\{X = g(Z), W = h(X), Y = Z\}$

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.

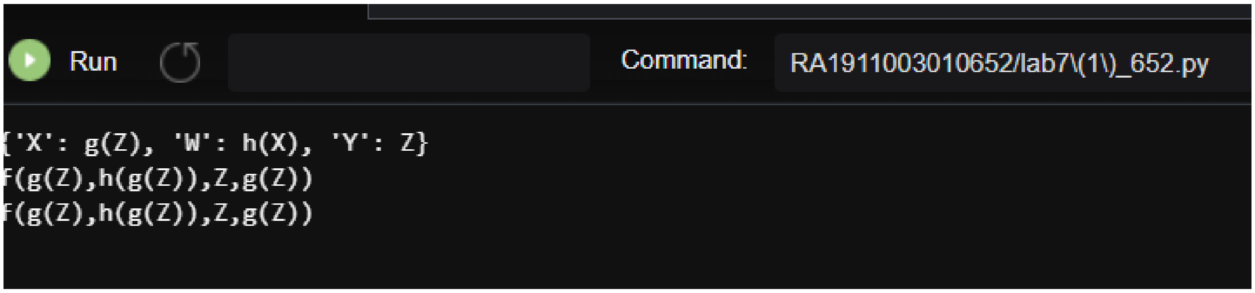
Step-7: Stop

SOURCE CODE:

```
#Unification

import lexer



class Term:

  pass





# In App, function names are always considered to be constants, not variables.

# This simplifies things and doesn't affect expressivity. We can always model

# variable functions by envisioning an apply(FUNCNAME, ... args ...).

class App(Term):

  def __init__(self, fname, args=()):

    self.fname = fname

    self.args = args



  def __str__(self):

     return '{0}({1})'.format(self.fname, ','.join(map(str, self.args)))
    def __eq__(self, other):
        return (type(self) == type(other) and
                self.fname == other.fname and
                all(self.args[i] == other.args[i] for i in range(len(self.args))))

    __repr__ = __str__


class Var(Term):
    def __init__(self, name):
        self.name = name

    def __str__(self):
        return self.name

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

    __repr__ = __str__


class Const(Term):
    def __init__(self, value):
        self.value = value

    def __str__(self):
        return self.value
    def __eq__(self, other):
        return type(self) == type(other) and self.value == other.value

    __repr__ = __str__


class ParseError(Exception): pass


def parse_term(s):
    """Parses a term from string s, returns a Term."""
    parser = TermParser(s)
    return parser.parse_term()


class TermParser:
    """Term parser.

    Use the top-level parse_term() instead of instantiating this class directly.
    """
    def __init__(self, text):
        self.text = text
        self.cur_token = None
        lexrules = (
            ('\d+',           'NUMBER'),
            ('[a-zA-Z_]\w*',    'ID'),
            (',',             'COMMA'),
            ('\(',          'LP'),
            ('\)',          'RP'),
        )
        self.lexer = lexer.Lexer(lexrules, skip_whitespace=True)
        self.lexer.input(text)
        self._get_next_token()

    def _get_next_token(self):
        try:
            self.cur_token = self.lexer.token()

            if self.cur_token is None:
                self.cur_token = lexer.Token(None, None, None)
        except lexer.LexerError as e:
            self._error('Lexer error at position %d' % e.pos)

    def _error(self, msg):
        raise ParseError(msg)

    def parse_term(self):
        if self.cur_token.type == 'NUMBER':
            term = Const(self.cur_token.val)
            # Consume the current token and return the Const term.
            self._get_next_token()
            return term
        elif self.cur_token.type == 'ID':
            # We have to look at the next token to distinguish between App and
            # Var.
            idtok = self.cur_token
            self._get_next_token()
            if self.cur_token.type == 'LP':
                if idtok.val.isupper():
                    self._error("Function names should be constant")
                self._get_next_token()
                args = []
                while True:
                    args.append(self.parse_term())
                    if self.cur_token.type == 'RP':
                        break
                    elif self.cur_token.type == 'COMMA':
                        # Consume the comma and continue to the next arg
                        self._get_next_token()
                    else:
                        self._error("Expected ',' or ')' in application")
                # Consume the ')'
                self._get_next_token()
                return App(fname=idtok.val, args=args)
            else:
                if idtok.val.isupper():
                    return Var(idtok.val)
                else:
                    return Const(idtok.val)


def occurs_check(v, term, subst):
    """Does the variable v occur anywhere inside term?
    Variables in term are looked up in subst and the check is applied

    recursively.

    """

    assert isinstance(v, Var)

    if v == term:

        return True

    elif isinstance(term, Var) and term.name in subst:

        return occurs_check(v, subst[term.name], subst)

    elif isinstance(term, App):

        return any(occurs_check(v, arg, subst) for arg in term.args)

    else:

        return False



def unify(x, y, subst):

    """Unifies term x and y with initial subst.


    Returns a subst (map of name->term) that unifies x and y, or None if

    they can't be unified. Pass subst={} if no subst are initially

    known. Note that {} means valid (but empty) subst.

    """

    if subst is None:

        return None

    elif x == y:

        return subst

    elif isinstance(x, Var):

        return unify_variable(x, y, subst)
    elif isinstance(y, Var):
        return unify_variable(y, x, subst)
    elif isinstance(x, App) and isinstance(y, App):
        if x.fname != y.fname or len(x.args) != len(y.args):
            return None
        else:
            for i in range(len(x.args)):
                subst = unify(x.args[i], y.args[i], subst)
            return subst
    else:
        return None


def apply_unifier(x, subst):
    """Applies the unifier subst to term x.

    Returns a term where all occurrences of variables bound in subst
    were replaced (recursively); on failure returns None.
    """
    if subst is None:
        return None
    elif len(subst) == 0:
        return x
    elif isinstance(x, Const):
        return x
    elif isinstance(x, Var):
        if x.name in subst:
            return apply_unifier(subst[x.name], subst)
        else:
            return x
    elif isinstance(x, App):
        newargs = [apply_unifier(arg, subst) for arg in x.args]
        return App(x.fname, newargs)
    else:
        return None


def unify_variable(v, x, subst):
    """Unifies variable v with term x, using subst.

    Returns updated subst or None on failure.
    """
    assert isinstance(v, Var)
    if v.name in subst:
        return unify(subst[v.name], x, subst)
    elif isinstance(x, Var) and x.name in subst:
        return unify(v, subst[x.name], subst)
    elif occurs_check(v, x, subst):
        return None
    else:
        # v is not yet in subst and can't simplify x. Extend subst.
        return {**subst, v.name: x}


if __name__ == '__main__':
    s1 = 'f(X,h(X),Y,g(Y))'
```

```
s2 = 'f(g(Z),W,Z,X)'

subst = unify(parse_term(s1), parse_term(s2), {})

print(subst)


print(apply_unifier(parse_term(s1), subst))

print(apply_unifier(parse_term(s2), subst))
```

OUTPUT:

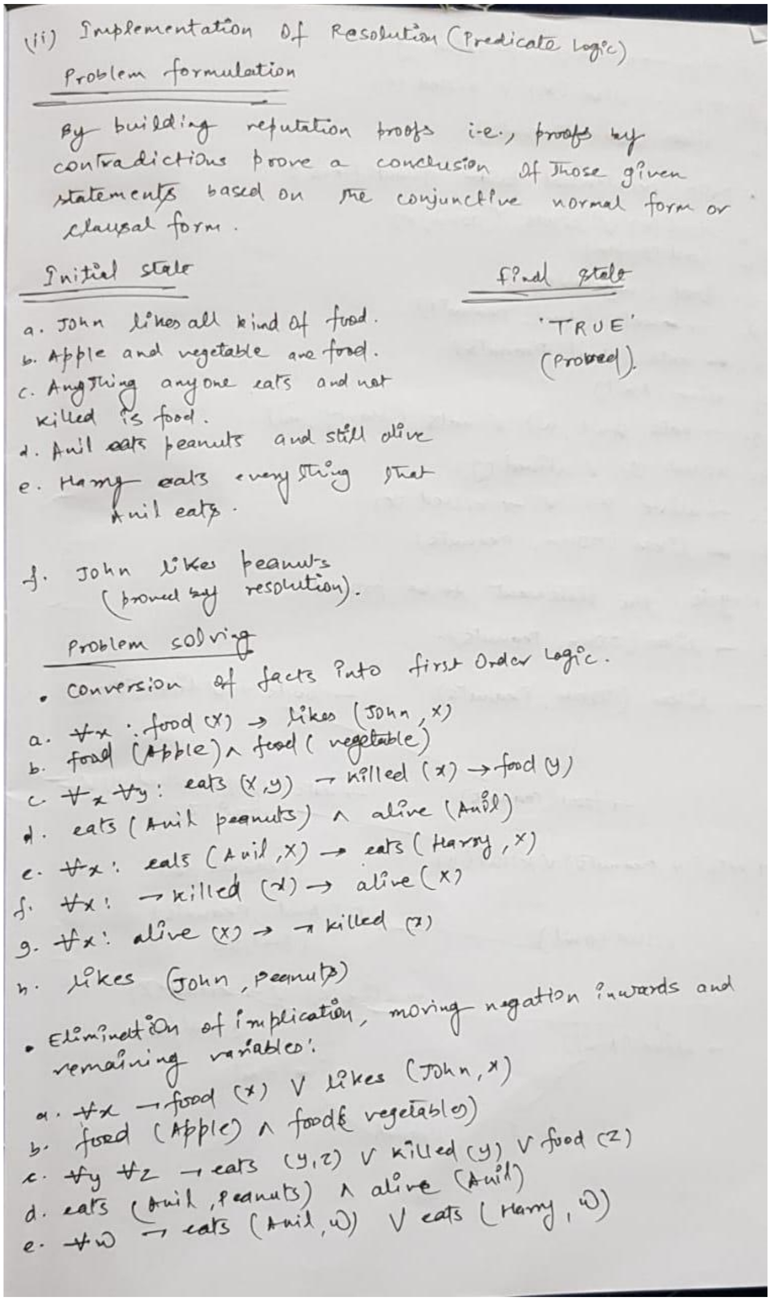


Command: RA1911003010652/lab7\(1\)_652.py

```
{'X': g(Z), 'W': h(X), 'Y': Z}
f(g(Z),h(g(Z)),Z,g(Z))
f(g(Z),h(g(Z)),Z,g(Z))
```

RESULT: Hence, the implementation of Unification is done successfully

2. RESOLUTION:



(ii) Implementation Of Resolution (Predicate Logic)

Problem formulation

By building refutation proofs i.e., proofs by contradictions prove a conclusion of those given statements based on the conjunctive normal form or clausal form.

Initial state

a. John likes all kind of food.
b. Apple and vegetable 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.

f. John likes peanuts (proved by resolution).

Final state

'TRUE' (Proved).

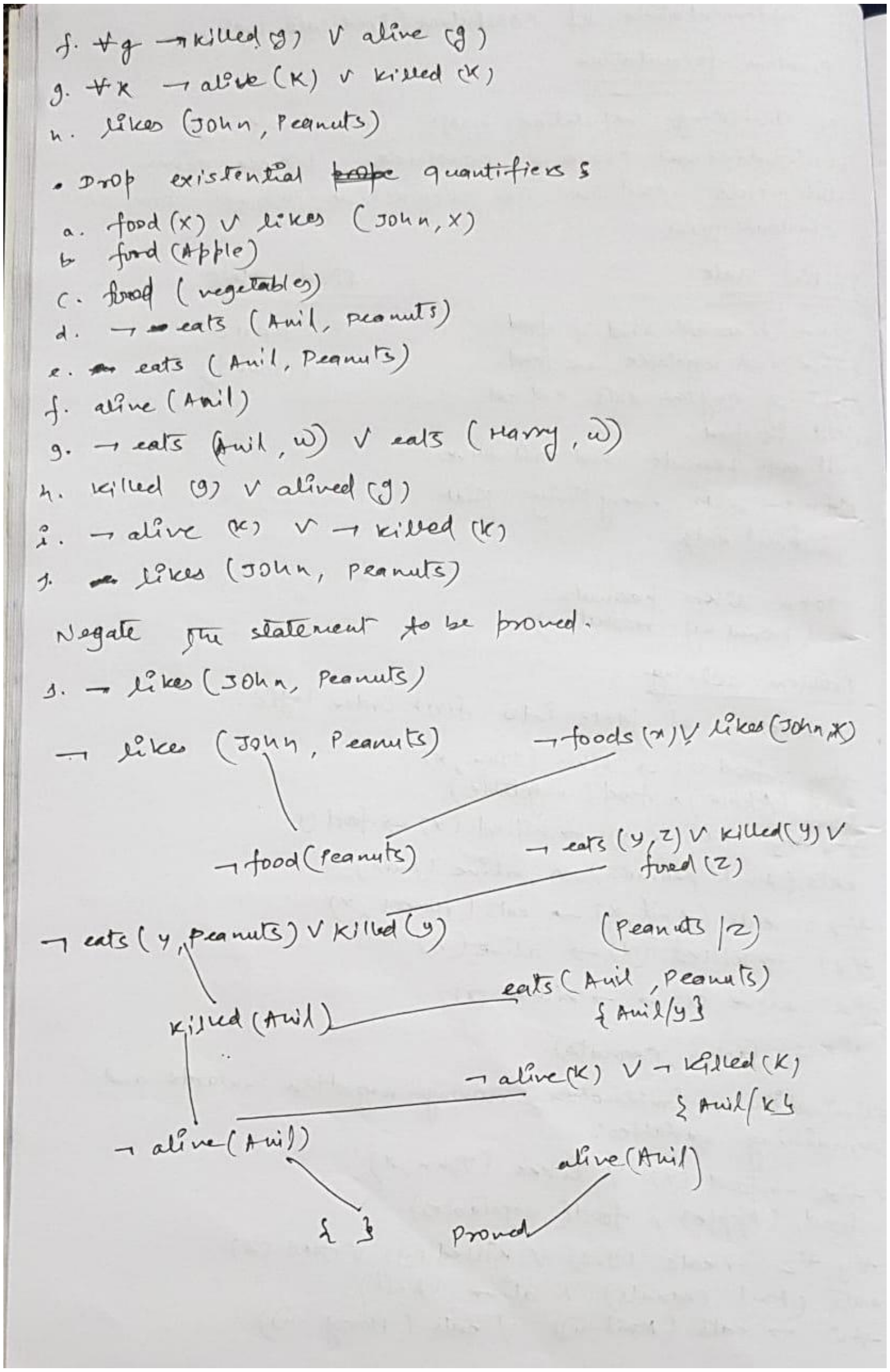
Problem solving

- Conversion of facts into first Order logic.

a. $\forall x : \text{food}(x) \rightarrow \text{likes}(\text{John}, x)$
b. $\text{food}(\text{Apple}) \wedge \text{food}(\text{vegetable})$
c. $\forall x \forall y : \text{eats}(x, y) \neg \text{killed}(x) \rightarrow \text{food}(y)$
d. $\text{eats}(\text{Anil peanuts}) \wedge \text{alive}(\text{Anil})$
e. $\forall x : \text{eats}(\text{Anil}, x) \rightarrow \text{eats}(\text{Harry}, x)$
f. $\forall x : \neg \text{killed}(x) \rightarrow \text{alive}(x)$
g. $\forall x : \text{alive}(x) \rightarrow \neg \text{killed}(x)$
h. $\text{likes}(\text{John}, \text{peanuts})$

- Elimination of implication, moving negation inwards and remaining variables:

a. $\forall x \neg \text{food}(x) \vee \text{likes}(\text{John}, x)$
b. $\text{food}(\text{Apple}) \wedge \text{food}(\text{vegetables})$
c. $\forall y \forall z \neg \text{eats}(y, z) \vee \text{killed}(y) \vee \text{food}(z)$
d. $\text{eats}(\text{Anil}, \text{peanuts}) \wedge \text{alive}(\text{Anil})$
e. $\forall w \neg \text{eats}(\text{Anil}, w) \vee \text{eats}(\text{Harry}, w)$



f. ∀g ¬killed(g) ∨ alive(g)

g. ∀x ¬alive(K) ∨ killed(K)

h. likes(John, Peanuts)

- Drop existential ~~prope~~ quantifiers s

a. food(x) ∨ likes(John, x)

b. food(Apple)

c. food(vegetables)

d. ¬ eats(Anil, peanuts)

e. eats(Anil, Peanuts)

f. alive(Anil)

g. ¬eats(Anil, w) ∨ eats(Harry, w)

h. killed(g) ∨ alived(g)

i. ¬alive(K) ∨ ¬killed(K)

j. likes(John, peanuts)

Negate the statement to be proved.

1. ¬likes(John, Peanuts)

¬likes(John, Peanuts)

¬foods(x) ∨ likes(John, x)

¬food(peanuts)

¬eats(y, z) ∨ killed(y) ∨ food(z)

¬eats(y, peanuts) ∨ killed(y)

(Peanuts/z)

eats(Anil, Peanuts)

{Anil/y}

killed(Anil)

¬alive(K) ∨ ¬killed(K)

{Anil/K}

¬alive(Anil)

alive(Anil)

{ }

Proved

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.
```

SOURCE 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])
```

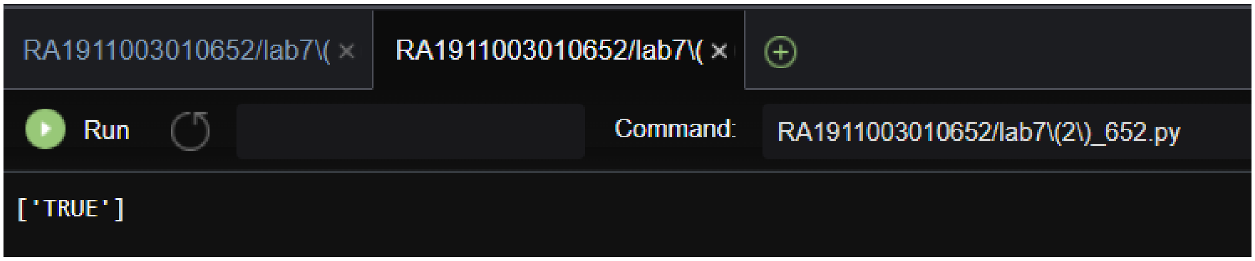
```
class KB:
    def __init__(self, inputSentences):
        self.inputSentences = [x.replace(" ", "") for x in inputSentences]
        self.sentences = []
        self.sentence_map = {}

    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()



if __name__ == '__main__':
    inputQueries_, inputSentences_ = getInput('RA1911003010652/input.txt')
```

```
knowledgeBase = KB(inputSentences_)

knowledgeBase.prepareKB()

results_ = knowledgeBase.askQueries(inputQueries_)

printOutput("output.txt", results_)
```

OUTPUT:



RA1911003010652/lab7\(2\)_652.py

```
['TRUE']
```

RESULT: Hence, the implementation of Resolution is successfully done.