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AI Lab -7

Aim :- Implementation of unification & resolution in real world application

Implementation of unification (Pattern Matching)

To find a mapping between 2 expression that may both contain variables.

Bind the variables to their values in the expression until no bound variables remain

Initial State

exp 1 = 'f(x, h(x), y, g(y))'

exp 2 = f(g(z), w, z, x)'

Final State

x : g(z)

w : h(x)

y : z

exp 1 = f(g(z), h(g(z)), z)

exp 2 = 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 argument

→ unify (x, g(z)) is invoked.

↳ x is a variable Substitute x = g(z)

→ unify (h(x), w) is invoked

↳ w is a variable ∴ Substitute w = h(x)

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

{ x = g(z) , w = h(x) }

→ Unify (Y, Z) is invoked.

Both Y and Z are variable

hence are added directly to the dictionary.

$\{ x = g(z), w = h(x), Y = z \}$

$z = Y$ or $Y = z$ is equivalent.

→ 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 i.e if the substituted value is not a variable unify $(\underbrace{g(Y), g(z)}_{L})$

Both the terms have g

∴ Unify $\underbrace{Y \text{ and } z}$

Z to R already present as map

→ All variables are bounded, unification is completed succesfully -

Final result is $\{ x = g(z), w = h(x), Y = z \}$

Implementation of Resolution (Predicate logic).

Problem Formulation →

By building reputation proofs ie proofs by contradiction.
prove a conclusion of those given statements based on the conjuctive normal form or clausal form.

Initial State

a. John likes all kinds of food.
b. Apple and Vegetable are food.
c. Anything anyone eats and not killed is food.
d. Anil eats peanuts & still alive.
e. Harry eats everything that Anil eats.

Prove by resolution :

f. John like peanuts.

Final State

('TRUE')
(proved)

Problem Solving →

- Conversion of facts into first order logic.

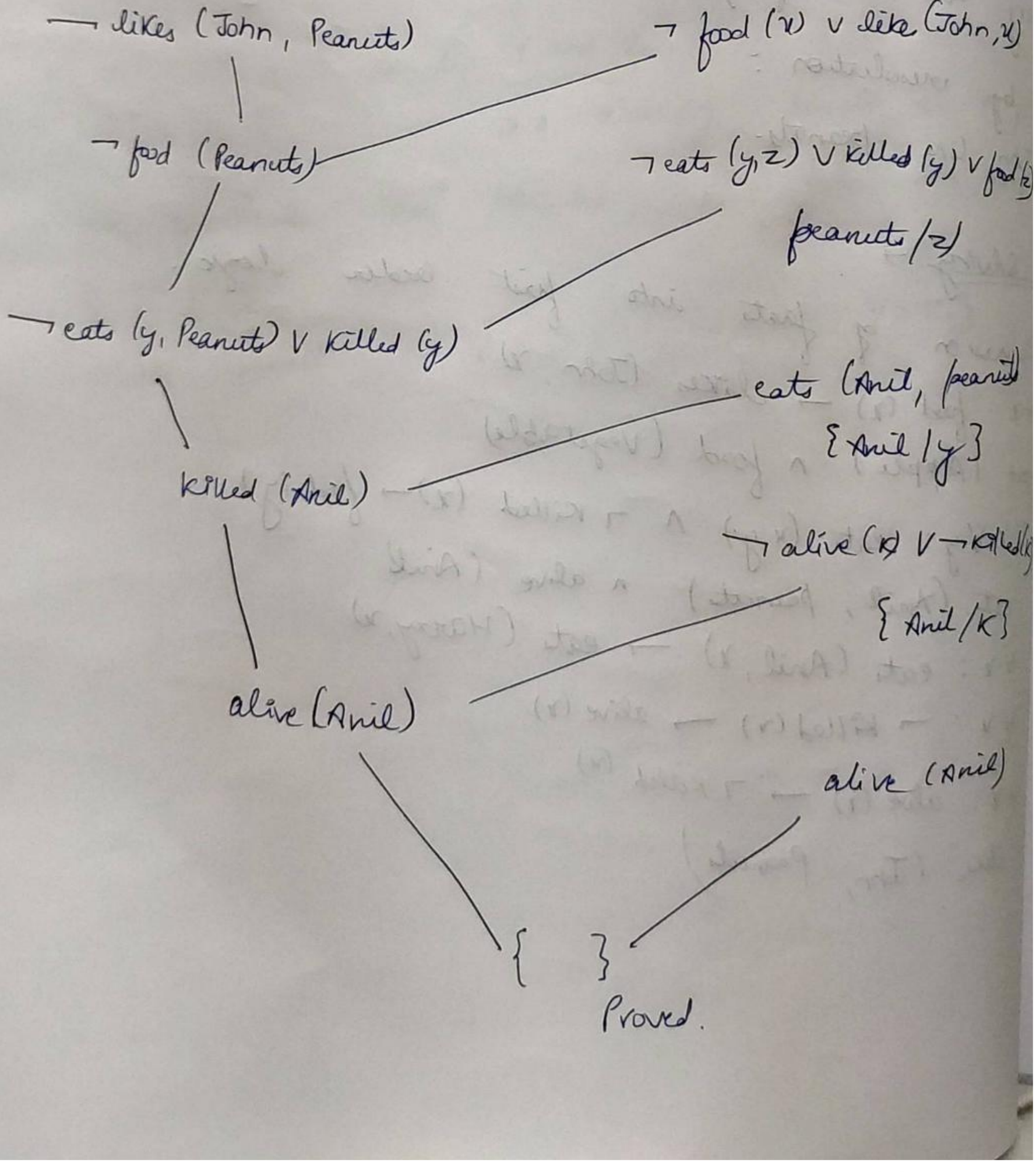
a. $\forall x$: food (x) → likes (John, x)
b. food (Apple) ∧ food (Vegetable)
c. $\forall x \forall y$: eats (x,y) ∧ ¬ killed (x) → food (y)
d. eats (Anil, peanuts) ∧ alive (Anil)
e. $\forall x$: eats (Anil, x) → eats (Harry, x)
f. $\forall x$: ¬ killed (x) → alive (x)
g. $\forall x$: alive (x) → ¬ killed (x)
h. likes (John, Peanuts)

- Drop existential quantifiers

a. food (x) ∨ likes (John, x)
b. food (Apple)
c. food (vegetables)
d. ¬ eats (y, z) ∨ killed (y) ∨ food (z)
e. eats (Anil, peanuts)
f. alive (Anil)
g ¬ eats (Anil, w) ∨ eats (Harry, w)
h killed (g) ∨ alive (g)
i ¬ alive (k) ∨ ¬ killed (k)
j likes (John, Peanuts)

- Negate the statement to be proved

j. ¬ likes (John, Peanuts)



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AI LAB 7

❖ Unification (Pattern matching):

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:

```
# Python 3.6
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)
```

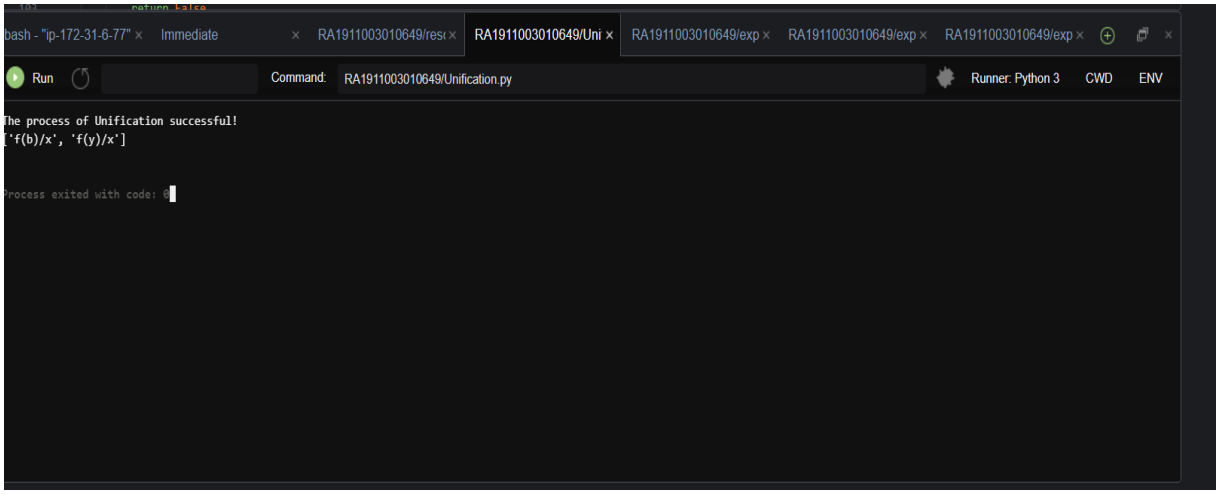
```
# Consume the current token and return the Const term.
self._get_next_token()
return term
elif self.cur_token.type == 'ID':

# 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 –



Result:

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

❖ Resolution (Predicate logic):

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:

```
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")
```

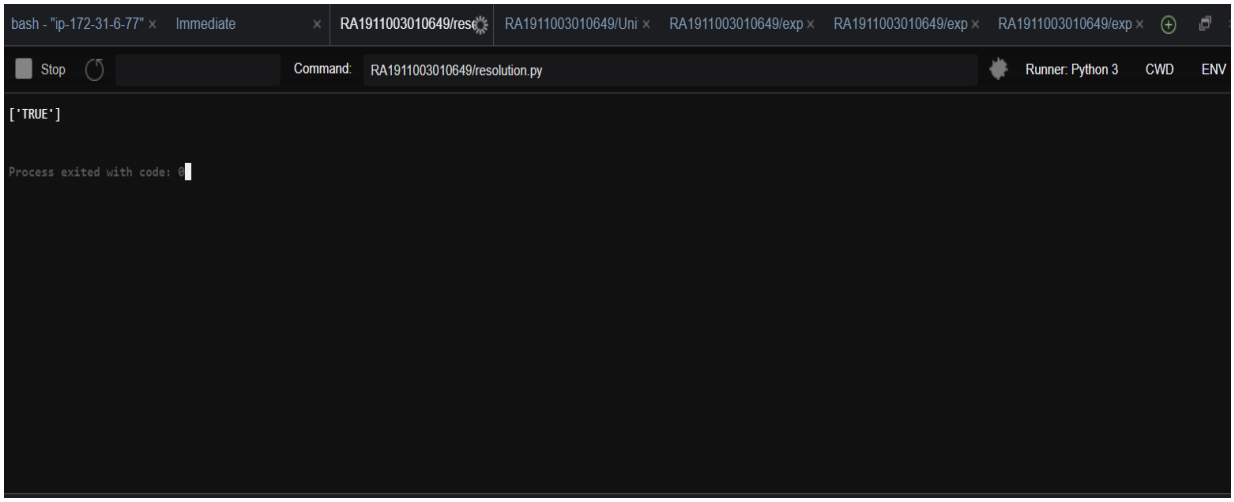
```
return results
def resolve(self, queryStack, visited, depth=0):
if time.time() > self.timeLimit:
raise Exception
if queryStack:
query = queryStack.pop(-1)
negatedQuery = query.getNegatedPredicate()
queryPredicateName = negatedQuery.name
if queryPredicateName not in self.sentence_map:
return False
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('RA1911003010633/input1.txt')
knowledgeBase = KB(inputSentences_)
knowledgeBase.prepareKB()
results_ = knowledgeBase.askQueries(inputQueries_)
printOutput("output.txt", results_)
```

Output:



Result:

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