Akshat Agarwal - 646

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STUDY BUDDIES

Artificial Intelligence
Lab - 7

Aim: Implementation of unification & resolution in real world application

(i) Implementation of unification

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 bound variables remain.

Initial state

expression 1 = 'f(x, h(x), y, g(y))'
expression 2 = 'g(g(z), w, z, x)'

Final state

x : g(z)
w : h(x)
y : z

expr 1 = f(g(z), h(g(z)), z, g(z))
expr 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 each arg.
- unify(x, g(z)) is invoked.

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- 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 as
  {X = g(z), W = h(x)}

- unify(Y, Z) is invoked
  Both Y & Z are variable
  hence are added directly to dictionary
  {X = g(z), W = h(x), Y = Z} # Z = Y or Y = Z

- unify(g(Y), X) is invoked
  ↓
  X is a variable but already in dict.

∴ 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 terms have g

∴ unify Y & Z
  ↓
  already present

- all variables are bounded, unification is completed successfully.

final result is {X = g(z), W = h(x), Y = Z}

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(ii) Implementation of Resolution (Predicate logic)

Problem Formulation

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

Initial State

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

Final State

'TRUE' (proved)

Prove by resolution:
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)

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- Elimination of implication, moving negation inwards & 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. $food(x) \vee likes(John, x)$
b. $food(Apple)$
c. $food(vegetables)$
d. $\neg eats(y, z) \vee Killed(y) \vee food(z)$
e. $eats(Anil, Peanuts)$
f. $alive(Anil)$
g. $\neg eats(Anil, w) \vee eats(Harry, w)$
h. $Killed(g) \vee alive(g)$
i. $\neg alive(k) \vee \neg Killed(k)$
j. $likes(John, Peanuts)$

- Negate the statement to be proved.

j- $\neg likes(John, Peanuts)$

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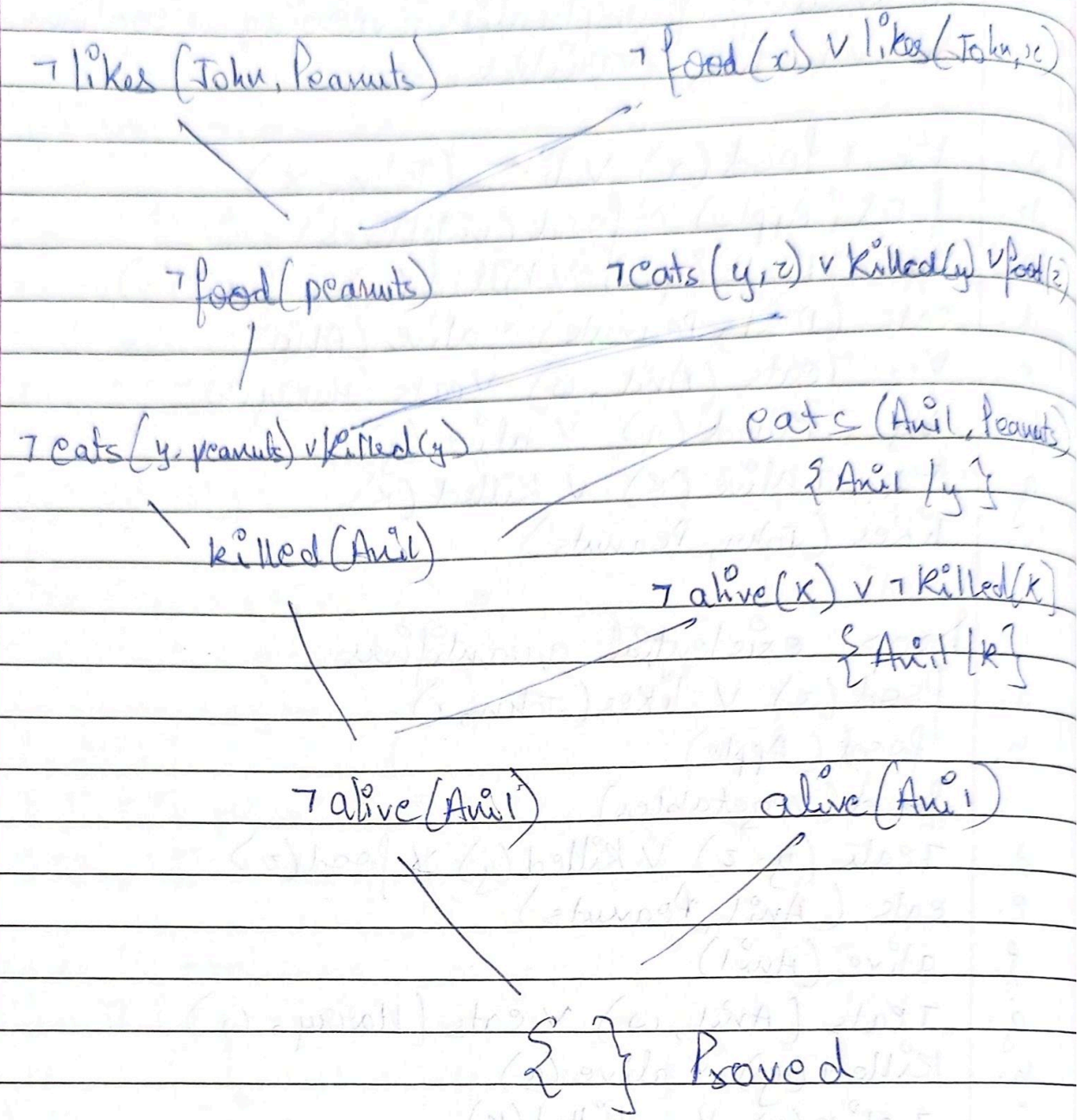
¬ Likes (John, Peanuts)
¬ food(x) ∨ Likes(John, x)
¬ food(peanuts)
¬ Eats(y, z) ∨ Killed(y) ∨ food(z)
¬ Eats(y, peanuts) ∨ Killed(y)
Eats(Anil, Peanuts)
{Anil / y}
killed(Anil)
¬ alive(x) ∨ ¬ Killed(x)
{Anil / x}
¬ alive(Anil)
alive(Anil)
{ } Proved

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Artificial Intelligence
Lab - 7

Aim : Implementation of unification and resolution in real world problems

UNIFICATION

Algorithm :

1. Start
2. Declare a Python dict mapping variable names to terms
3. When either side is a variable, it calls unify_variable.
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.
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).
6. **occurs_check** , is to guarantee that we don't have self-referential variable bindings like that would lead to potentially infinite unifiers.
7. Stop

Code :

```
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
```

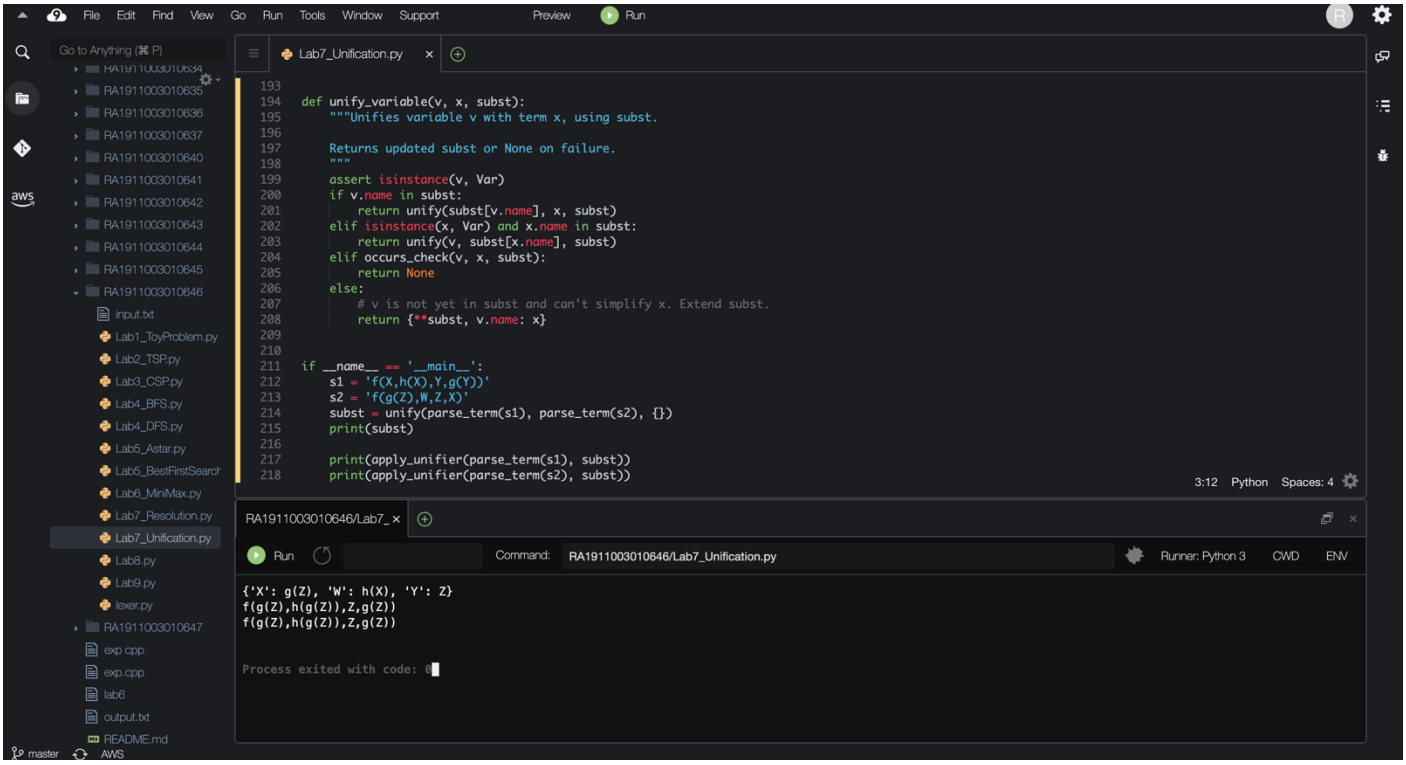
```
    def __eq__(self, other):
        return type(self) == type(other) and self.value == other.value

    __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 :



RESOLUTION

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:
```

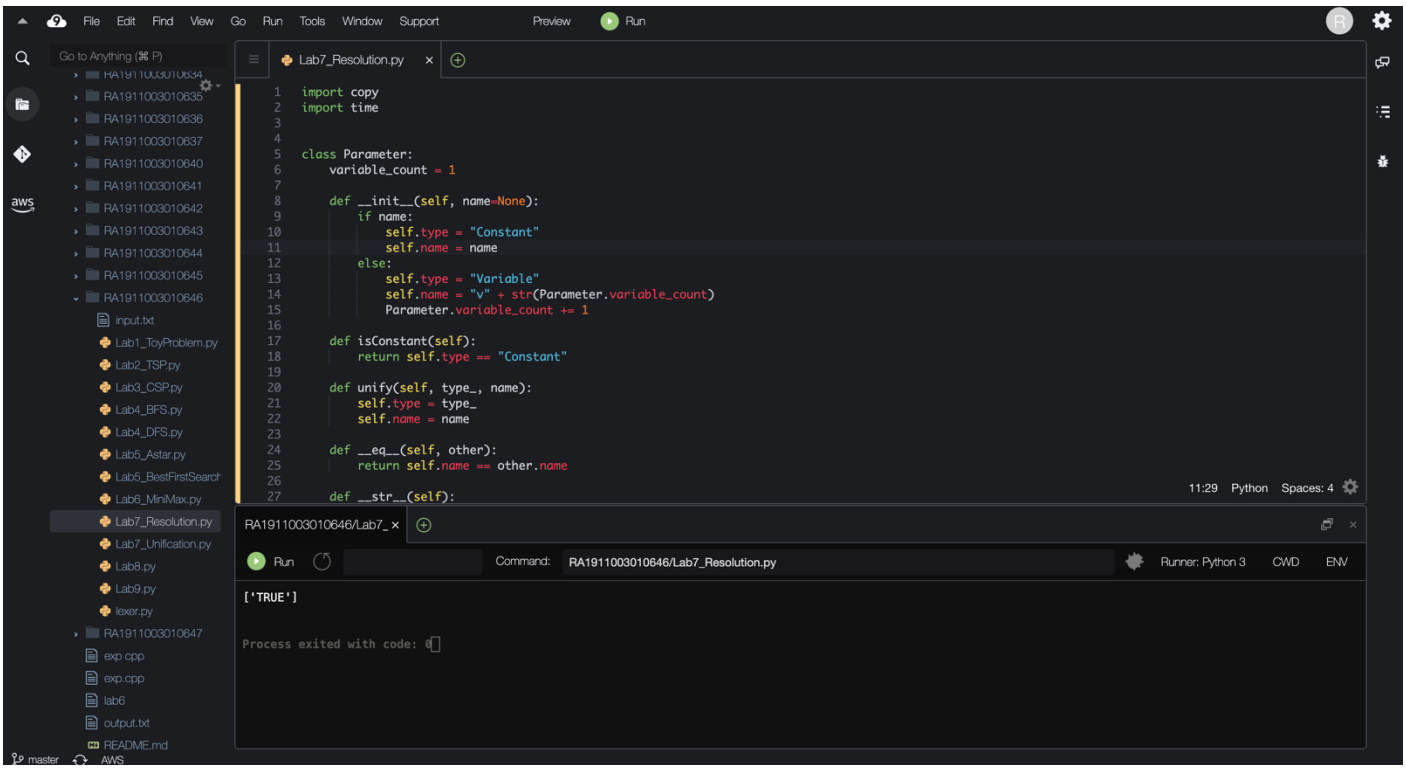
```
newSentence = copy.deepcopy(kb_sentence)
newSentence.removePredicate(kbPredicate)
newQueryStack = copy.deepcopy(queryStack)

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('RA1911003010646/input.txt')
    knowledgeBase = KB(inputSentences_)
    knowledgeBase.prepareKB()
    results_ = knowledgeBase.askQueries(inputQueries_)
    printOutput("output.txt", results_)
```

Output :


File Edit Find View Go Run Tools Window Support
Preview
Run
Lab7_Resolution.py
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):
11:29 Python Spaces: 4
RA1911003010646/Lab7_
Run
Command: RA1911003010646/Lab7_Resolution.py
Runner: Python 3
CWD
ENV
['TRUE']
Process exited with code: 0
input.txt
Lab1_ToyProblem.py
Lab2_TSP.py
Lab3_CSP.py
Lab4_BFS.py
Lab4_DFS.py
Lab5_Astar.py
Lab6_MiniMax.py
Lab7_Resolution.py
Lab7_Unification.py
Lab8.py
Lab9.py
lexer.py
exp.cpp
exp.cpp
lab6
output.txt
README.md
master
AWS