Expt 7- Unification & Resolution On Real World Problems

Aim:- Implementation of unification and resolution in real world applications.

(i) Implementation of unification (Pattern matching)

Problem Formulation:-

* To find a mapping between the two expressions 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(z))'

expression 2 = 'f (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)), i, g(x))

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, therefore substitute.

$x = g(z)$.

- Unify $(h(x), w)$ is invoked

w is a variable.

∴ substitute $w = h(x)$.

- The substitution are mapped to a python dictionary and it expands as

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

- Unify (Y, z) is invoked.

Both Y and z are variable, hence a added directly to one 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 (g(Y), g(2))

↓

Both the terms have g.

∴ Unify Y & 2.

↓

It is already present in map.

• All the variables are bounded, unification is completed successfully.

final result {X = g(2), W = h(X), Y = 2}

(ii) Implementation of Resolution (Predictive Logic)

Problem Formulation:-

By building repatation proofs, i.e. proofs by contradictions. prove a conclusion of mose given statements. based on me conjunctive normal form (CNF). or clausal form.

Initial State:-

a. John likes all kind of food.
b. Apple and vegetasles are food.
c. Anything anyone eats and not kills is food.
d. Anil eats peanats and still alive.
e. Harry eats everything mat Anil eats.

Prove by resolution:-

f. John likes peanats.

Problem Soluing:-

- Conversion of facts into first order logic.
- $\forall x$. food (x) $\longrightarrow$ likes (John, x)
- food. (Apples) $\wedge$ food (Vegeta ble).

- $\forall x \forall y$: eats $(x, y) \wedge$ killed $(x) \rightarrow$ food (y)
- eats (Anil, peanuts) $\wedge$ alive (Anil)
- $\forall x$: eats (Anil, x) $\rightarrow$ eats (Harry, x)
- $\forall z$: $\neg$ killed $(x) \rightarrow$ alive (x)
- $\forall x$: alive $(x) \rightarrow \neg$ killed (x)
- Likes (John, peanuts)

* Elimination of implication, 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: $\forall y : \neg$ killed $(y) \vee$ alive (y)

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

h: likes (John, peanuts)

• Drop existential equations:

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).

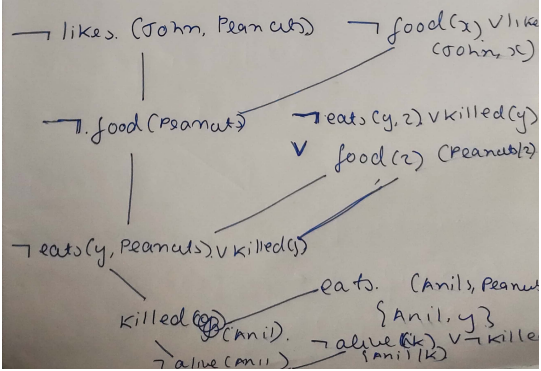
h. killed (g) V alive (g).

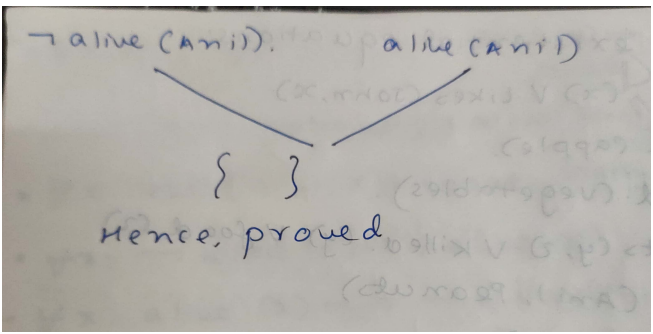
i. ¬ alive (k) V ¬ killed (k)

j. likes (John, Peanuts).

• Negate the statement to be proved.

j: ¬ likes (John, Peanuts)




¬ alive (Ami).
alive (Ami)
{ }
Hence, proved

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

CODE:-

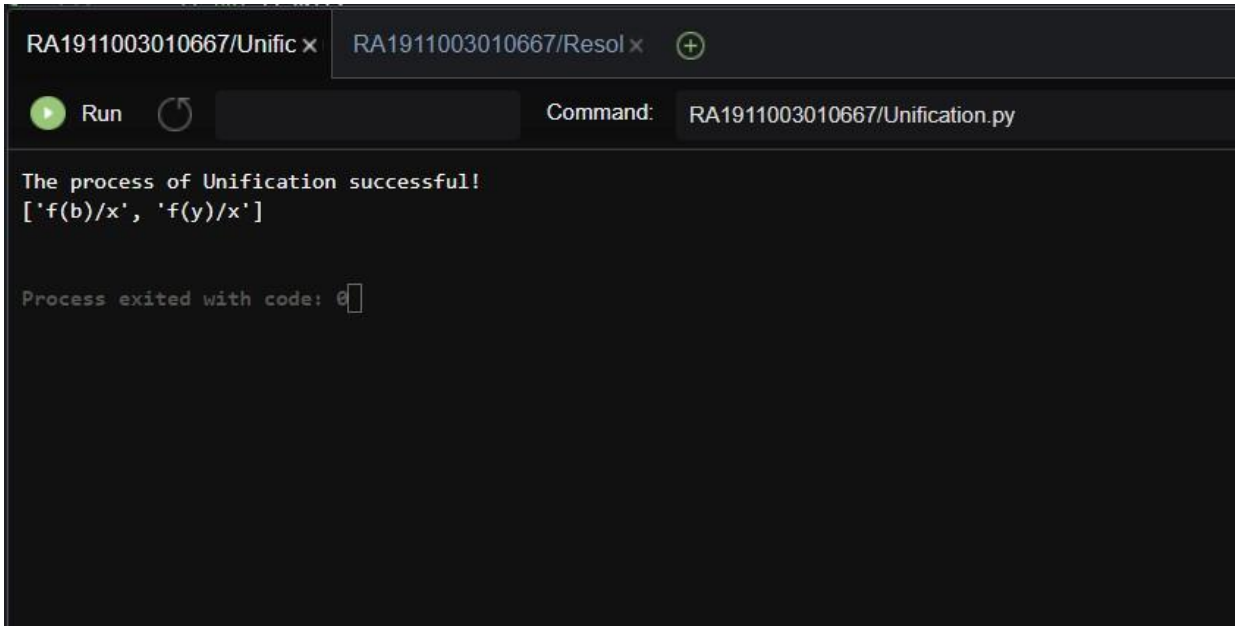
```
def get_index_comma(string):
    index_list  = list()
    par_count = 0

    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:-



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

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:
```

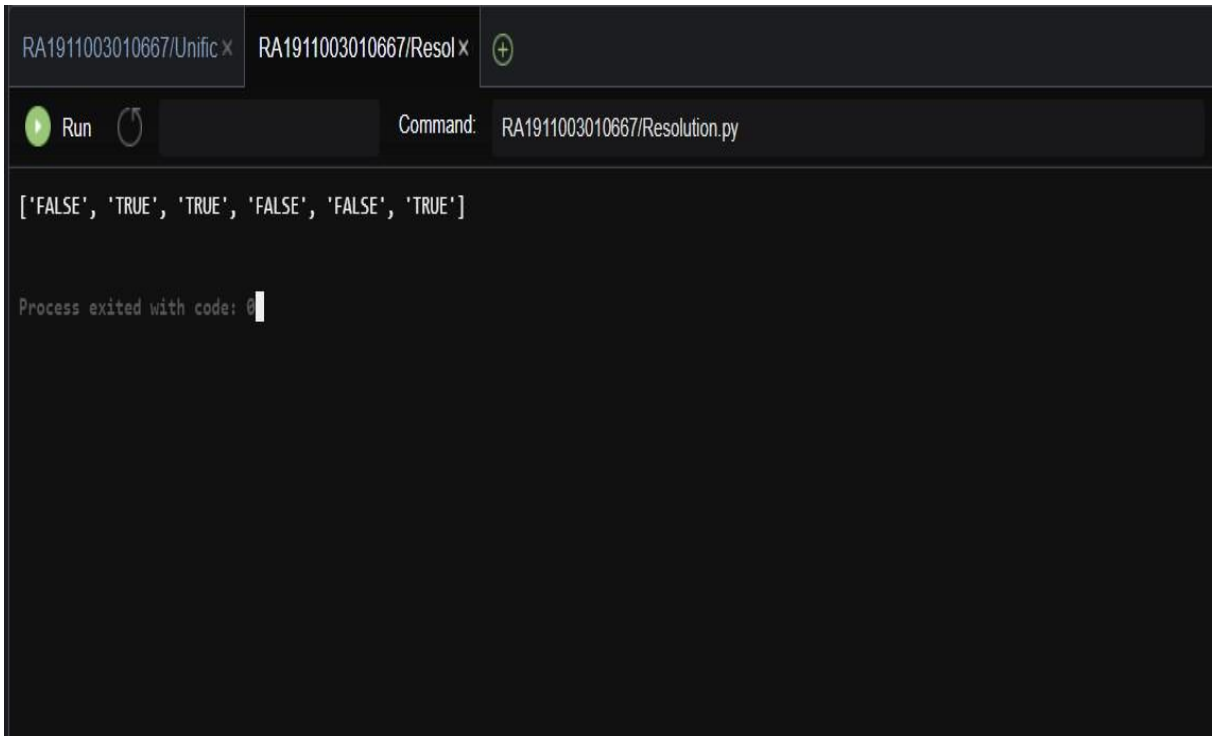
```
            if not query.isConstant():
                if kb.name not in substitution:
                    substitution[kb.name] = query.name
                elif substitution[kb.name] != query.name:
                    return False, {}
                kb.unify("Variable", query.name)
            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("RA1911003010667/Input.txt")
    knowledgeBase = KB(inputSentences_)
    knowledgeBase.prepareKB()
    results_ = knowledgeBase.askQueries(inputQueries_)
    printOutput("RA1911003010667/output.txt", results_)
```

INPUT:-

```
6
F(Joe)
H(John)
~H(Alice)
~H(John)
G(Joe)
G(Tom)
14
~F(x) | G(x)
~G(x) | H(x)
~H(x) | F(x)
~R(x) | H(x)
~A(x) | H(x)
~D(x,y) | ~H(y)
~B(x,y) | ~C(x,y) | A(x)
B(John,Alice)
B(John,Joe)
~D(x,y) | ~Q(y) | C(x,y)
D(John,Alice)
Q(Joe)
D(John,Joe)
R(Tom)
```

OUTPUT:-



RESULT:-

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