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EXP-6 Implementation of unification and resolution for real-world problems

AIM

To implement a program for unification and resolution of real-world problems.

UNIFICATION:

It is a process of making two different logical atomic expressions identical by finding a substitution.
Unification depends on the substitution process.
It takes two literals as input and makes them identical using substitution.
Let Ψ1 and Ψ2 be two atomic sentences and σ be a unifier such that, Ψ1σ = Ψ2σ, then it can be expressed as UNIFY(Ψ1, Ψ2)

Example: Find the MGU for Unify{King(x), King(John).
Let Ψ1 = King(x), Ψ2 = King(John),
Substitution θ = {John/x} is a unifier for these atoms and applying this substitution, both expressions will be identical.

CONDITION FOR UNIFICATION:

Following are some basic conditions for unification:
Predicate symbols must be the same, atoms or expressions with different predicate symbols can never be unified.
The number of Arguments in both expressions must be identical.
Unification will fail if there are two similar variables present in the same expression.

Algorithm

Step 1: If Ψ1 or Ψ2 is a variable or constant, then:
a) If Ψ1 or Ψ2 are identical, then return NIL.
b) Else if Ψ1 is a variable,
i) then if Ψ1 occurs in Ψ2, then return FAILURE
ii) Else return { (Ψ2/ Ψ1)}.
c) Else if Ψ2 is a variable,
i) If Ψ2 occurs in Ψ1 then return FAILURE,
ii) Else return {(Ψ1/ Ψ2)}.
d) Else return FAILURE.

Step 2: If the initial Predicate symbol in Ψ1 and Ψ2 are not same, then return FAILURE.

Step 3: IF Ψ1 and Ψ2 have a different number of arguments, then return FAILURE.

Step 4: Set Substitution set(SUBST) to NIL.

Step 5: For i=1 to the number of elements in Ψ1.

a) Call Unify function with the ith element of Ψ1 & ith element of Ψ2, & put the result into S.

b) If S = failure then returns Failure

c) If S ≠ NIL then do,

i) Apply S to the remainder of both L1 and L2.

ii) SUBST= APPEND(S, SUBST).

Step.6: Return SUBST.

Program

```
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)'

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

Input & Output

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

```
RA1911026010021:~/environment/RA1911026010029/exp6 $ python3 exp6-uni.py
The process of Unification successful!
['f(b)/x', 'f(y)/x']
```

AWS Screenshot

bash - "ip-172-31-2-88" | exp6-uni.py | exp6-res.py

```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:
```

RESOLUTION:

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Resolution method is an inference rule which is used in both Propositional as well as First-order Predicate Logic in different ways. This method is basically used for proving the satisfiability of a sentence. In the resolution method, we use the Proof by Refutation technique to prove the given statement. The key idea for the resolution method is to use the knowledge base and negated goal to obtain a null clause (which indicates contradiction). The resolution method is also called Proof by Refutation.

Method for Resolution

The process followed to convert the propositional logic into resolution method contains the below steps:

- Convert the given axiom into clausal form, i.e., disjunction form.
- Apply and proof the given goal using negation rule.
- Use those literals which are needed to prove.
- Solve the clauses together and achieve the goal.

Conjunctive Normal Form (CNF)

1) Eliminate bi-conditional implication by replacing A ? B with (A ? B) ? (B ?A)
2) Eliminate implication by replacing A ? B with ¬A V B.
3) In CNF, negation(¬) appears only in literals, therefore we move it inwards
4) Finally, using distributive law on the sentences, and form the CNF

Program

```
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]
```

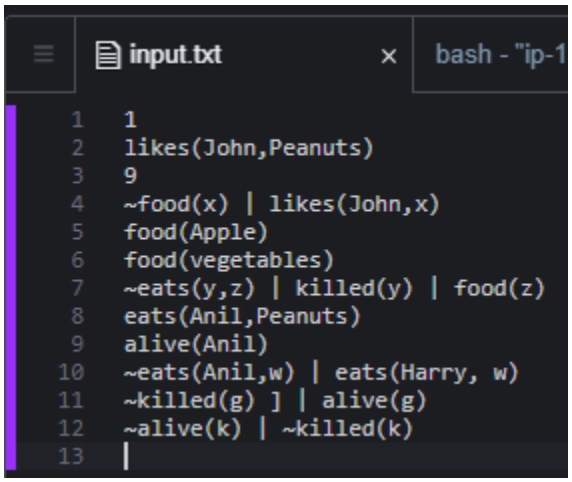
```
def convertSentencesToCNF(self):
    for sentenceIdx in range(len(self.inputSentences)):
        # Do negation of the Premise and add them as literal
        if "=>" in self.inputSentences[sentenceIdx]:
            self.inputSentences[sentenceIdx] = negateAntecedent(
                self.inputSentences[sentenceIdx])

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]:
```

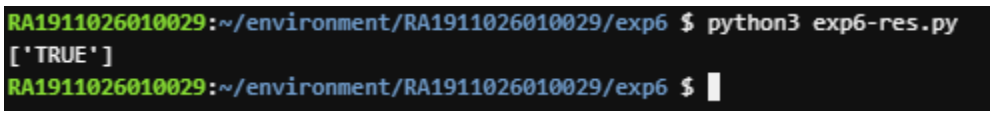
```
                for kbPredicate in
kb_sentence.findPredicates(queryPredicateName):

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

Input & Output





AWS Output

```
    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)
```

Observation

The concept of unification and resolution has been studied and understood through this experiment.

Result

Thus the program for unification and resolution has been successfully implemented and verified with manual calculation.