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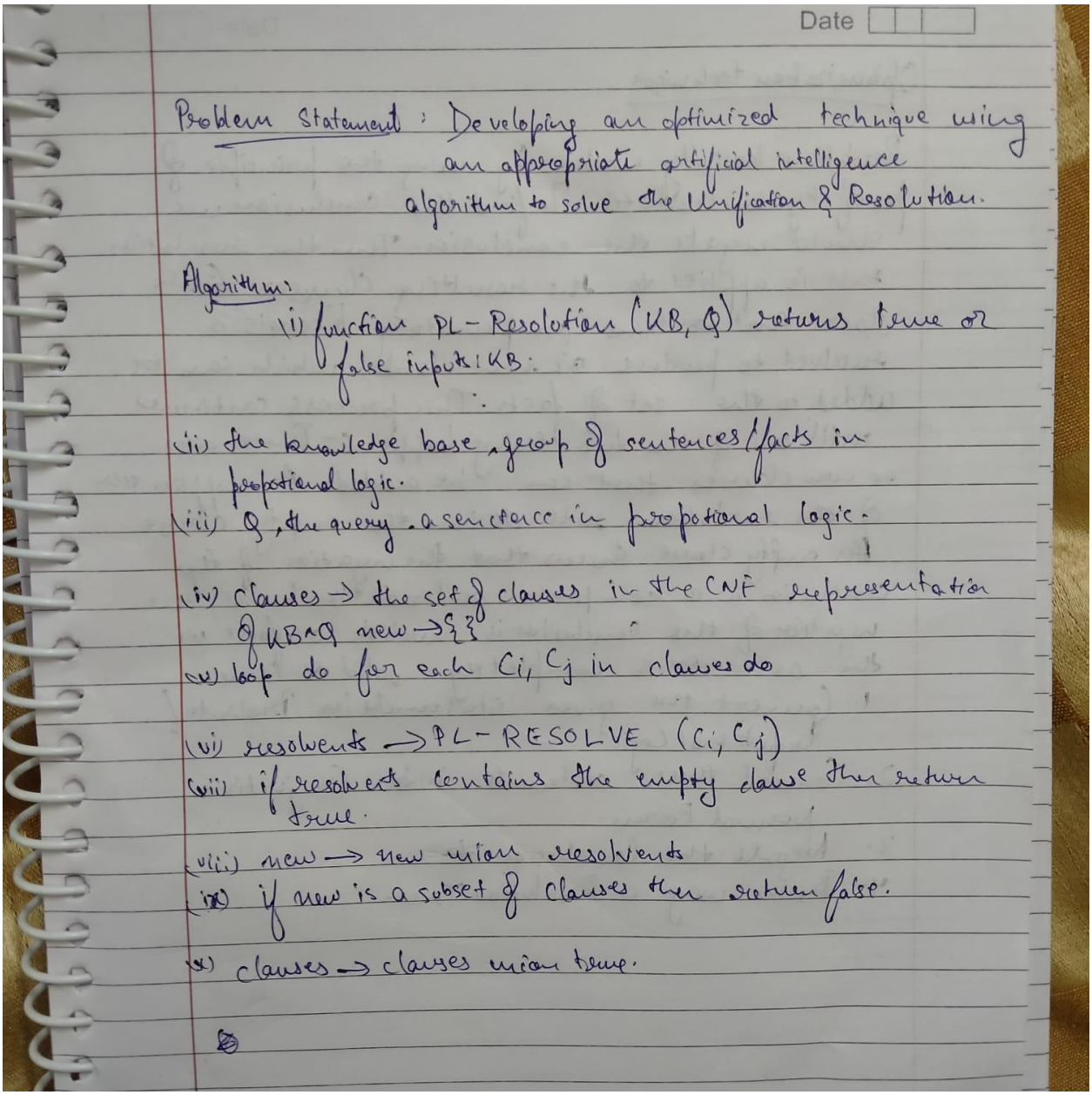

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Problem Statement : Developing an optimized technique using an appropriate artificial intelligence algorithm to solve the Unification & Resolution.

Algorithm:

(i) function PL-Resolution (KB, Φ) returns true or false inputs: KB:

(ii) the knowledge base, group of sentences/facts in propotional logic.

(iii) Φ, the query, a sentence in propotional logic.

(iv) clauses → the set of clauses in the CNF representation of KB^Φ new → {}

(v) loop do for each C_i, C_j in clauses do

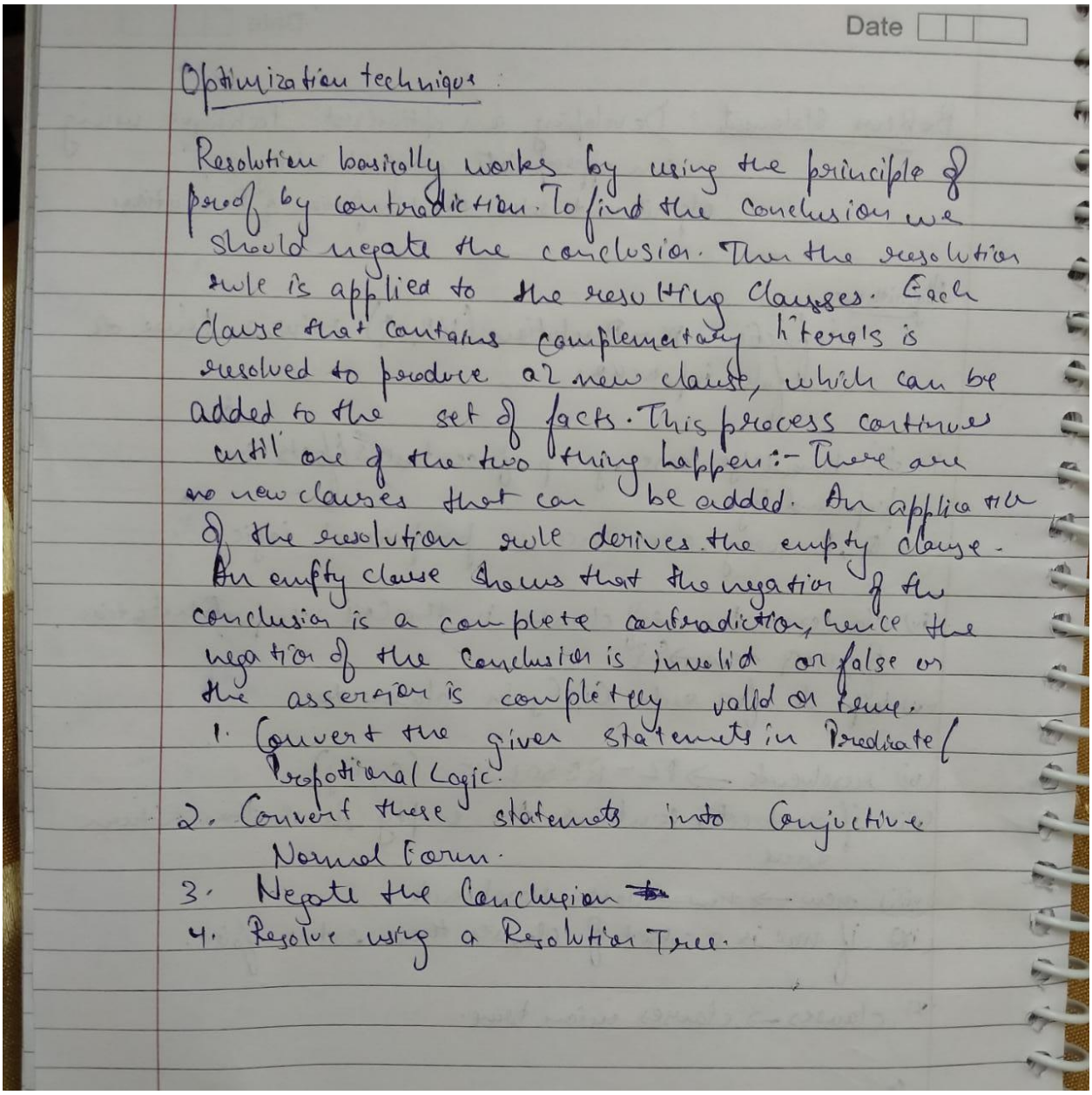
(vi) resolvents → PL-RESOLVE (C_i, C_j)

(vii) if resolvents contains the empty clause then return true.

(viii) new → new union resolvents

(ix) if new is a subset of clauses then return false.

(x) clauses → clauses union true.



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Optimization techniques:

Resolution basically works by using the principle of proof by contradiction. To find the conclusion we should negate the conclusion. Then the resolution rule is applied to the resulting clauses. Each clause that contains complementary literals is resolved to produce a new clause, which can be added to the set of facts. This process continues until one of the two thing happen:- There are no new clauses that can be added. An application of the resolution rule derives the empty clause. An empty clause shows that the negation of the conclusion is a complete contradiction, hence the negation of the conclusion is invalid or false or the assertion is completely valid or true.

1. Convert the given statements in Predicate/ Propotional Logic.
2. Convert these statements into Conjuctive Normal Form.
3. Negate the Conclusion
4. Resolve using a Resolution Tree.

```
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:
```

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        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])

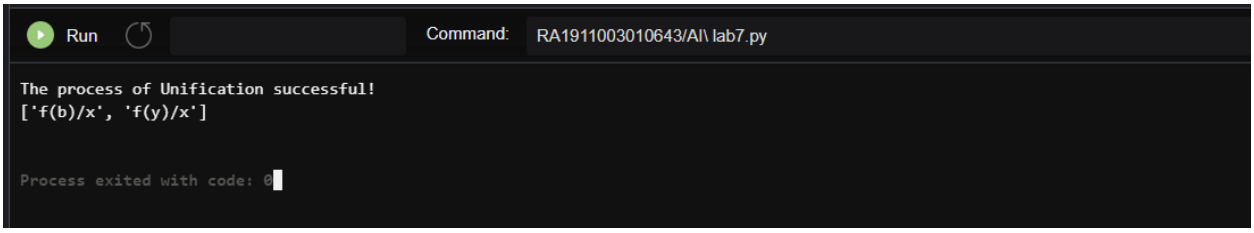
        if not tmp:
            return False
        elif tmp == 'Null':
            pass
        else:
            if type(tmp) == list:
                for j in tmp:
                    sub_list.append(j)
            else:
                sub_list.append(tmp)

    # 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)
```




```
import copy
import time



class Parameter:
    variable_count = 1

    def __init__(self, name=None):
        if name:
            self.type = "Constant"
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            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
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```
            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(
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            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:
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```
                    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('C:/shushrut/studies/SRM University/SEM 6/AI/7-
Unification Resolutiion/Resolution/Input/input_1.txt')
    knowledgeBase = KB(inputSentences_)
    knowledgeBase.prepareKB()
    results_ = knowledgeBase.askQueries(inputQueries_)
    printOutput("output.txt", results_)
```