Computational Problem

In this project, I intend to construct a program that decides the DFA emptiness problem.

Program Documentation

String Encoding Spec

We define a valid string as the following:

A string should consist of 5 sections:

1. A list of semicolon separated unique strings indicating state names.
2. A string of unique ASCII characters indicating the alphabet. The end is marked with a semicolon.
3. A list of semicolon separated list transition definitions, formatted as such: `<from_state>-<to_state>,<input>;`
4. A single string from the set of defined state names.
5. A list of semicolon separated strings from the defined states in item 1. Repeats are ignored.

Each of these sections are separated by the string `END_SECTION`, which is a reserved word and cannot be used as a state name.

Note that on top of the reserved word `END_SECTION`, the symbol `;` also cannot be used in state names or the alphabet. Note that all whitespaces are ignored, so a defining a state as `state name;` will be interpreted as `statename;`

Thus an example string would look like such:

```
q1;
q2;
END_SECTION
abc;
END_SECTION
q1-q2,a;
q1-q1,b;
```

```
q1-q2,c;
q2-q1,a;
q2-q2,b;
q2-q2,c;
END_SECTION
q1;
END_SECTION
q2;
END_SECTION
```

How the Program Works

The program is self-contained in the script main.py. The script takes a filename, reads the contents inside, and executes several steps.

1. Lexing: The program has a simple Lexer object which splits up string in the input file into tokens, returned as a list of strings to the program. For the string above, the lexer output would look something like `["q1", "q2", "END_SECTION", "abc", ...and more]`.

2. DFA Construction: Here, the program constructs an instance of a DFA. It defines 5 variables each corresponding to a variable in the formal definition of a DFA. From there, we populate the variables by looking through the tokens. Each set of strings between `END_SECTION` s represents a certain set of information. For example, the first set of strings designate state names. The second designates our input alphabet. The third designates the transitions between states.

Notably, the data structure of state transitions was designed to make lookup as easy as possible. To find the next state starting from a given state s, and given a character input x, you can query the state transitions dictionary first for another dictionary storing all of transitions going out from s, and then after querying this dictionary by the input x, you are given the exact destination state. This makes creating the graph traversal algorithms much easier.

The last two variables are pretty self explanatory, a string specifying the start state name, and a set of states designating accept states.

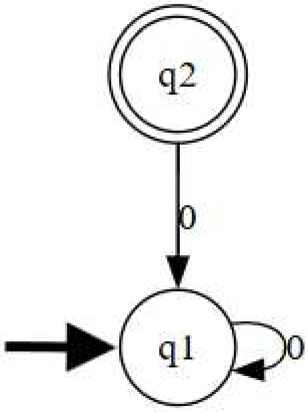
3. Checking Emptiness: This program checks DFA emptiness by running graph search on the state diagram of the DFA, starting from the given start state. After this graph search, we have a set of all reachable states, which we then check whether this set shares no elements

with the designated accept states. If there are no shared elements, then the DFA must recognize an empty set.

Example Strings

Example in the Set of Empty DFAs

```
q1;q2;END_SECTION
0;END_SECTION
q1-q1,0;q2-q1,0;END_SECTION
q1;END_SECTION
q2;END_SECTION
```

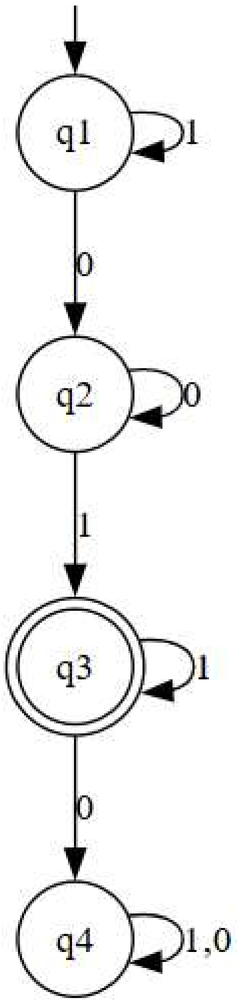


There is no way to reach the accept state `q2` from the start state `q1`, so we know that this DFA must recognize the empty set.

Example not in the Set of Empty DFAs

```
q1;q2;q3;q4;END_SECTION
01;END_SECTION
q1-q1,1;q1-q2,0;
q2-q2,0;q2-q3,1;
q3-q3,1;q3-q4,0;
q4-q4,0;q4-q4,1;END_SECTION
```

```
q1;END_SECTION
q3;END_SECTION
```

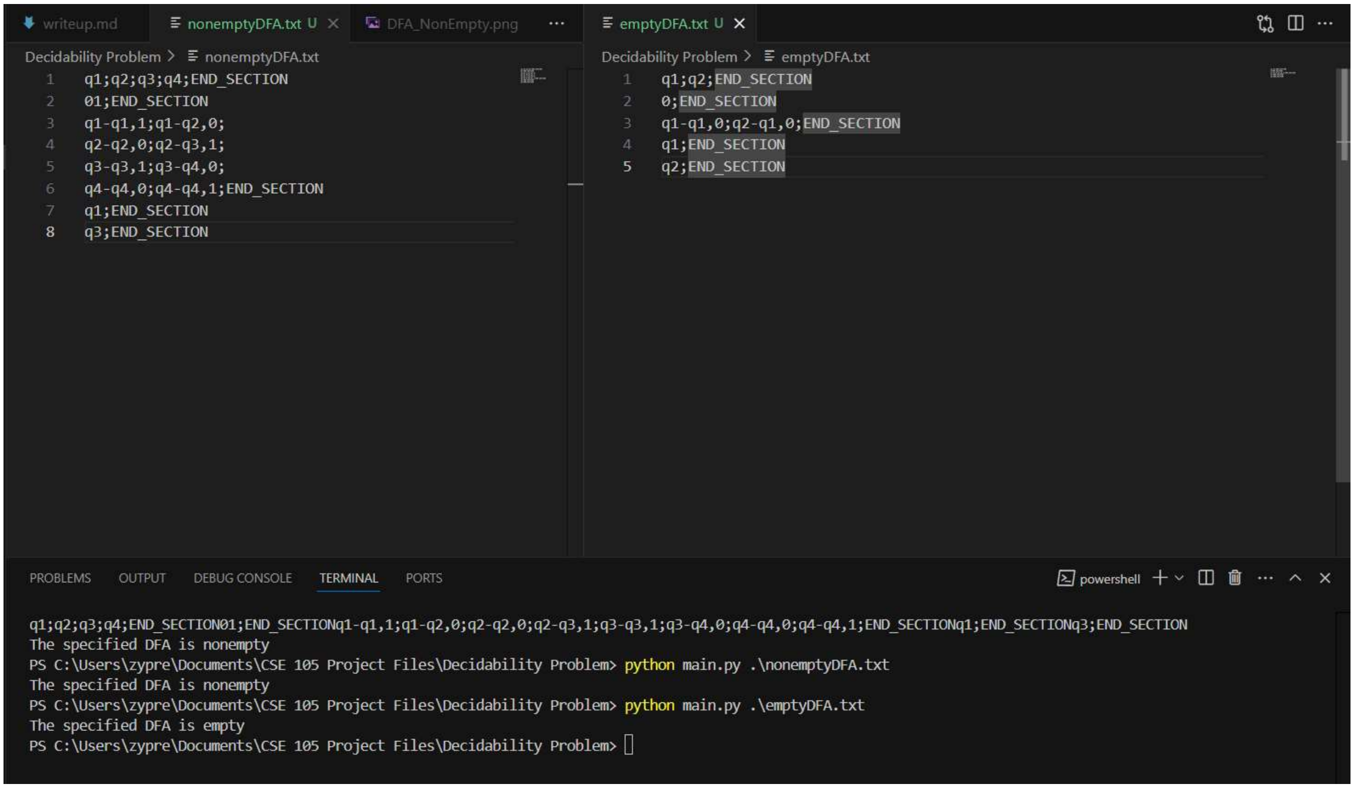


This DFA recognizes the language defined by the Regular Expression: `1*0+1+`. One example of a string accepted is "01". Thus it is not in the Set E_DFA.

Source Code

Screenshot Example of Running Script

To test the code yourself, simply install main.py, and create a .txt file describing a valid DFA. Then run `python main.py <yourfile>.txt`



```
q1;q2;q3;q4;END_SECTION
01;END_SECTION
q1-q1,1;q1-q2,0;
q2-q2,0;q2-q3,1;
q3-q3,1;q3-q4,0;
q4-q4,0;q4-q4,1;END_SECTION
q1;END_SECTION
q3;END_SECTION
```

```
q1;q2;END_SECTION
0;END_SECTION
q1-q1,0;q2-q1,0;END_SECTION
q1;END_SECTION
q2;END_SECTION
```

```
q1;q2;q3;q4;END_SECTION01;END_SECTIONq1-q1,1;q1-q2,0;q2-q2,0;q2-q3,1;q3-q3,1;q3-q4,0;q4-q4,0;q4-q4,1;END_SECTIONq1;END_SECTIONq3;END_SECTION
The specified DFA is nonempty
PS C:\Users\zypre\Documents\CSE 105 Project Files\Decidability Problem> python main.py .\nonemptyDFA.txt
The specified DFA is nonempty
PS C:\Users\zypre\Documents\CSE 105 Project Files\Decidability Problem> python main.py .\emptyDFA.txt
The specified DFA is empty
PS C:\Users\zypre\Documents\CSE 105 Project Files\Decidability Problem> 
```

```
import sys
import re

class Lexer:
    def __init__(self, string):
        self.string = string.replace('\n','').replace('\r','').replace(' ', '')
        self.line = 0
        self.index = 0

    def readToken(self):
        startIndex = self.index
        while (not self.atEnd() and self.next() != ";" and
self.string[startIndex:self.index+1] != "END_SECTION"):
            self.index = self.index + 1
        out = self.string[startIndex:self.index + 1]
        if out == "END_SECTION":
            self.index = self.index + 1
        else:
            self.index = self.index + 2
        if (self.atEnd() and not out == "END_SECTION"): return "EOF"
        return out

    def atEnd(self):
        return self.index + 1 >= len(self.string)
    def next(self):
        if not self.atEnd():
            return self.string[self.index + 1]
        else:
            return "EOF"

    def run(self):
        token = self.readToken()
        out = []
        while (token != "EOF"):
            out.append(token)
            token = self.readToken()
        return out

def run(file):
    lex = Lexer(file.read())
    tokens = lex.run()
    state = 1
    definedStates = set()
    stateTransitions = {}
    alphabet = set()
    start = ""
    acceptStates = set()
    for token in tokens:
        if (token == "END_SECTION"):
            state = state + 1
            continue
        match state:
            case 1: # defining states
                definedStates.add(token)
                stateTransitions[token] = {}
            case 2: # defining alphabet
                alphabet = set(token)
            case 3: # defining state transitions
                transition = re.split('-|,', token)
                if (len(transition) != 3):
                    raise Exception("Error! Transition token had incorrect format "+
token)
                else:
                    if transition[0] in definedStates and transition[1] in
definedStates and transition[2] in alphabet:
                        stateTransitions[transition[0]][transition[2]] =
transition[1]
                    else:
                        raise Exception("Error! Transition token tried to specify a
transition using an undefined state or invalid input character")
            case 4: # defining start state
                if len(start) != 0:
                    raise Exception("Error! More than one start state defined")
                    continue
                start = token
            case 5: # defining accept states
                if (token in definedStates):
                    acceptStates.add(token)
                else:
                    raise Exception("Error! Specified accept state " + token + " is
not defined!")
    for state in stateTransitions:
        if len(stateTransitions[state].keys()) != len(alphabet):
            raise Exception("Error! not enough transitions defined for state " +
state)
    return (definedStates, alphabet, stateTransitions, start, acceptStates)


def isEmpty(dfa):
    (definedStates, alphabet, stateTransitions, start, acceptStates) = dfa
    explored = set()
    unexplored = [start]
    while len(unexplored) > 0:
        currState = unexplored.pop()
        explored.add(currState)
        for key in stateTransitions[currState]:
            if stateTransitions[currState][key] not in explored:
                unexplored.append(stateTransitions[currState][key])

    intersection = acceptStates.intersection(explored)

    return len(intersection) == 0

def main():
    if len(sys.argv) != 2:
       print("Invalid Number of Arguments " + str(len(sys.argv)) + " received, 2
expected.")
       return
    filename = sys.argv[1]
    try:
        with open(filename, "r") as file:
            dfa = run(file)
            if isEmpty(dfa):
                print("The specified DFA is empty")
            else:
                print("The specified DFA is nonempty")
    except FileNotFoundError:
        print("Specified file not found.")
    except Exception as e:
        print("Program failed with error: \"" + str(e) + "\"")

main()
```