COCKE-KASAMI-YOUNGER ALGORITHM

A PYTHON IMPLEMENTATION

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CYK ALGORITHM

In this project, we will implement the Cocke-Kasami-Younger (CYK) Algorithm using the Python programming language. In fact, the CYK Algorithm is a membership algorithm for context-free grammar. Thus, using the CYK algorithm, it is possible to check whether a particular string is generated by the grammar of a language.

IMPLEMENTATION

We implemented a version of the CYK algorithm using the python programming language and hosted the code source on github (see repository: https://github.com/kandersonko/cyk_algorithm). The version of the algorithm we implemented is the following:

CYK ($\mathcal{G}, w$)
$\mathcal{G} = (\mathcal{V}, \Sigma, \mathcal{R}, \mathsf{S})$, $\Sigma \cup \mathcal{V} = \{\mathsf{X}_1, \ldots, \mathsf{X}_r\}$, $w = w_1 w_2 \ldots w_n$.
begin
Initialize the 3d array $\mathsf{B}[1 \ldots n, 1 \ldots n, 1 \ldots r]$ to FALSE
for $i = 1$ to n **do**
  for $(\mathsf{X}_j \rightarrow x) \in \mathcal{R}$ **do**
    if $x = w_i$ **then** $\mathsf{B}[i, i, j] \leftarrow$ TRUE.
for $i = 2$ to n **do** /* Length of span */
  for $L = 1$ to $n - i + 1$ **do** /* Start of span */
    $R = L + i - 1$ /* Current span $s = w_L w_{L+1} \ldots w_R$ */
    for $M = L + 1$ to R **do** /* Partition of span */
      /* $x = w_L w_{L+1} \ldots w_{M-1}$, $y = w_M w_{M+1} \ldots w_R$, and $s = xy$ */
      for $(\mathsf{X}_\alpha \rightarrow \mathsf{X}_\beta \mathsf{X}_\gamma) \in \mathcal{R}$ **do**
        /* Can we match X_β to x and X_γ to y? */
        if $\mathsf{B}[L, M-1, \beta]$ and $\mathsf{B}[M, R, \gamma]$ **then**
          $\mathsf{B}[L, R, \alpha] \leftarrow$ TRUE /* If so, then can generate s by X_α! */
for $i = 1$ to r **do**
  if $\mathsf{B}[1, n, i]$ **then return** TRUE
return FALSE

Figure 1: The CYK algorithm.

Our code sources can be found in the appendix.

RESULTS

Using our implementation, we were able to check the membership of different string for the following grammar:

$S \rightarrow \varepsilon \mid AB \mid XB$

$T \rightarrow AB \mid XB$

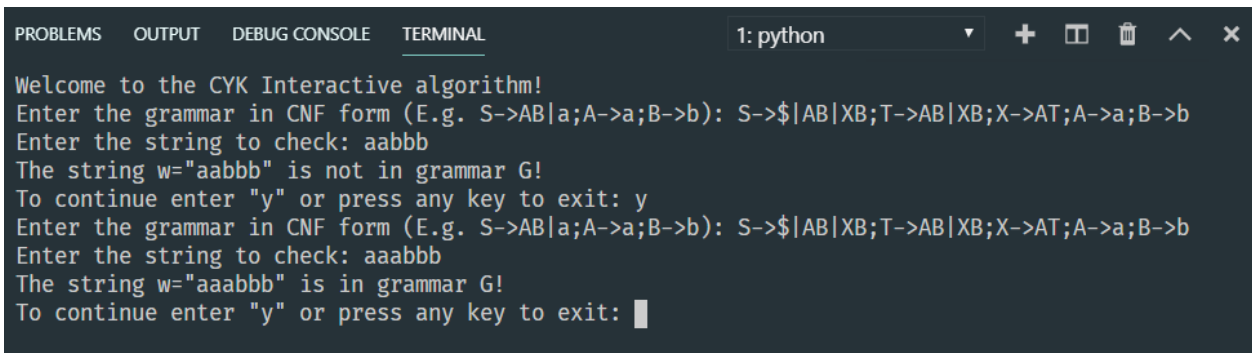
$X \rightarrow AT$

$A \rightarrow a$

$B \rightarrow b$

Figure 2: Grammar G

We found that the string w="aabbb" is not in L(G), but the string w="aaabbb" is in L(G) (see figure 3).



This result agrees with our findings when we apply manually the algorithm.

CONCLUSION

In this project, we implemented the CYK Algorithm in Python programming language. Our implementation can correctly check the membership of a string in the language generated by a grammar. The importance of the CYK Algorithm clearly be seen as it can be applied to check whether a keyword in a programming language.

APPENDIX

main.py

```
from grammar import Grammar
from CYKAlgo import CYKAlgo


def main():

    print("Welcome to the CYK Interactive algorithm!")

    command = "y"
    while(command == "y"):
        grammar_text = input("Enter the grammar in CNF form (E.g. S->AB|a;A-
>a;B->b): ")
        if grammar_text == "": break
        G = Grammar(grammar_text.strip())

        w = input("Enter the string to check: ")

        cykAlgo = CYKAlgo(G)
        if (cykAlgo.membership(w.strip())):
            print("The string w=\"{}\" is in grammar G!".format(w))
        else:
            print("The string w=\"{}\" is not in grammar G!".format(w))

        command = input("To continue enter \"y\" or press any key to exit: ")
    print("Bye!")


if __name__ == '__main__':
    main()
```

gammar.py

```
class Grammar(object):

    def __init__(self, G):
        """ __init__ takes a string G
            and parses parses the productions into an array of productions
        """
        self.rules = G.split(';');
        self.productions = dict()
        for rule in self.rules:
            startVar = rule.split('->')[0]
            varSet = rule.split("->")[1]
            variables = [x for x in varSet.split('|') if x.isupper()]
            terminals = [x for x in varSet.split('|') if x.islower()]
            self.productions[startVar] = {"variables": variables,
"terminals": terminals}
```

CYKAlgo.py

```
class CYKAlgo:
    def __init__(self, G):
        """ initilizes with the grammar G
        """
        self.G = G

    def membership(self, w):
        B = dict()
        X = dict()
        V = [i for i in self.G.productions.keys()]
        for k,v in enumerate(self.G.productions.keys()):
            X[v]=k
        n = len(w)
        r = len(X)

        # case where S->a is the only production
        if(r==1 and w in self.G.productions[V[0]]["terminals"]):
            return True

        # initialize all items in B to false
        for i in range(n):
            for j in range(n):
                for k in range(r):
                    B[i, j, k] = False
```

```python
# production A->a
for i in range(n):
    for j,v in enumerate(X):
        if w[i] in self.G.productions[v]["terminals"]:
            B[i, i, j] = True

# production A -> BC
for i in range(1, n):
    for L in range(n-i+1):
        R = L + i - 1
        for M in range(L+1, R):
            for v in range(r):
                P=self.G.productions[V[v]]
                variables = P["variables"]
                if(len(variables)):
                    b, c = tuple(variables[0])
                    s, t = X[b],X[c]
                    if(B[L, M-1, s] and B[M, R, t]):
                        B[L, R, v] = True

r = n-1
for i in range(r):
    if(B[r, n-1, i]):
        return True
return False
```

REFERENCES:

"Lecture 15." *Ethics and Engineering*, courses.engr.illinois.edu/cs373/sp2009/lectures/.