

# Computer Programming 1 Lab

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# Outline

- Tree
- Binary Tree
- Expression
- Exercise 10

# Tree

Tree is a graph.

- node
- edge

# Tree

- Tree is a hierarchical structure.
- Tree is a connected graph without cycles.
- Tree only has one root.
- Each node only has one parent.

# Tree - Element

- degree
- root
- leaf
- internal node

# Tree - Element

- parent  $\leftrightarrow$  child
- siblings
- descendant
- ancestor
- path
- level
- height of node
- height of tree
- depth

# Tree - Properties

- Each node can be a root.
- There is only one path from root to certain node.
- There are  $(n-1)$  edges in a  $n$  vertices tree.

# Tree - How to build a tree?

- linked list
- dynamic array



# Tree - How to build a tree? (other)

- array

# Tree - traversal

Time complexity  $O(n)$

- DFS
- BFS

# Binary Tree

- Two children (left child and right child)
- There are  $2^k$  nodes in the kth layer.

# Binary Tree - Order

- Preorder
- Inorder
- Postorder

# Binary Tree - Complete Binary Tree

- Every layer is full except last one.

# Binary Tree - Complete Binary Tree

- Use array storage
- Let the left child of the  $k$ st node is the  $(2k)$ st nodes.
- Let the right child of the  $k$ st node is the  $(2k + 1)$ st nodes.
- Let the parent of the  $k$ st node is the  $\lceil \frac{k}{2} \rceil$ st nodes.
- The height of a complete binary tree is  $\log n$ .

# Binary Tree - Binary Search Tree

- left child's value is smaller than node's value.
- right child's value is larger than node's value.

# Expression

$a+(b+c)*d$

- Prefix Notation `+a*+bcd`
- Infix Notation `a+(b+c)*d`
- Postfix Notation `abc+d*+`



## Exercise 10 - Syntax Tree

# Exercise 10

## Description

Convert an expression to an abstract syntax tree (AST).

The expression only has  $+$ ,  $-$ ,  $*$ ,  $/$ ,  $($ ,  $)$  and variables (a to z and A to Z).

Ensure that each operator will be enclosed in parentheses regardless of the four fundamental operations of arithmetic.

## Exercise 10

### Input

Input has one line.

First line has a expression of length  $L(1 \leq L \leq 2 \cdot 10^5)$ .

## Exercise 10

### Output

Output the prefix notation of the AST.  
There is no '\n' in the end.

# Exercise 10

## Sample1

Input sample	Output sample
$((a+b)*(c+d))$	*+ab+cd

# Exercise 10

## Sample2

Input sample	Output sample
$((a+b)*(c+d))+e$	$+*+ab+cde$

## Exercise 10

### Hint

Syntax Tree is a Tree.

You must use struct to construct a AST, if you don't use your score will be 0.

# Exercise 10

## Constraints

For 20%:

- $1 \leq L \leq 2 \cdot 10$

For 60%:

- $1 \leq L \leq 2 \cdot 10^3$

For 100%:

- $1 \leq L \leq 2 \cdot 10^5$