

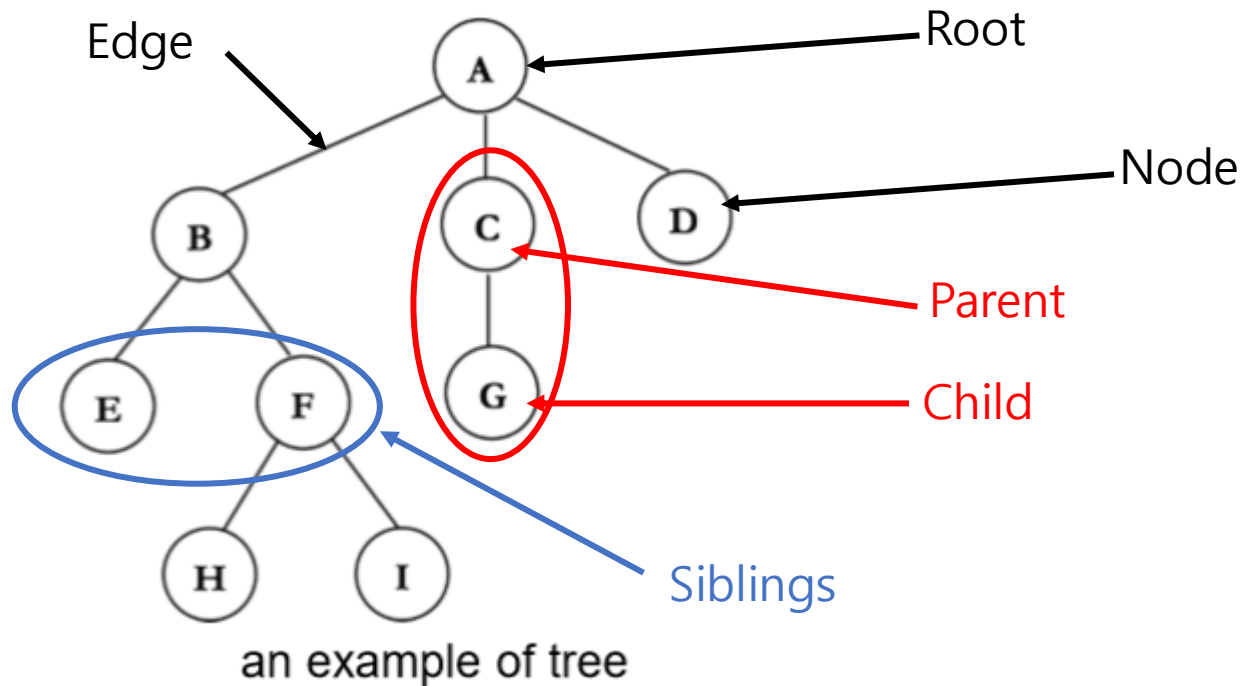
Data Structures

박영준 교수님

Lab4:Tree

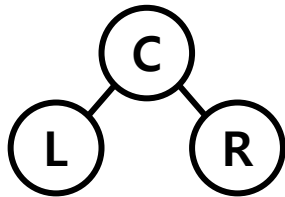
Tree

- A collection of nodes connected by edges without a cycle

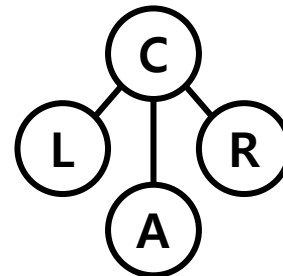


Binary Tree

- Tree data structure in which each node has two children, which are referred to as the left child and the right child.



Binary Tree



Binary Tree X

Binary Tree ADT

- `TreeNode *MakeTree(void);`
 - Create binary tree node
 - Return tree node
- `void SaveData(TreeNode *tree, DATATYPE data);`
 - Save data into node
- `DATATYPE RetData(TreeNode *tree);`
 - Return data from node

Binary Tree ADT

- `void MakeSubTreeLeft(TreeNode *tree, TreeNode *subtree);`
 - Link subtree node with left edge of tree node
- `void MakeSubTreeRight(TreeNode *tree, TreeNode *subtree);`
 - Link subtree node with right edge of tree node

Binary Tree ADT

- `TreeNode *RetSubTreeLeft(TreeNode *tree);`
 - Return left subtree node from tree node
- `TreeNode *RetSubTreeRight(TreeNode *tree);`
 - Return right subtree node from tree node

Binary Tree

Linked List

```
1 #include <stdio.h>
2 #include <stdlib.h>
3
4 typedef int DATATYPE;
5
6 typedef struct TreeNode
7 {
8     DATATYPE data;
9     struct TreeNode *Left;
10    struct TreeNode *Right;
11 } TreeNode;
12
13 TreeNode *MakeTree(void);
14 DATATYPE RetData(TreeNode *tree);
15 void SaveData(TreeNode *tree, DATATYPE data);
16
17 TreeNode *RetSubTreeLeft(TreeNode *tree);
18 TreeNode *RetSubTreeRight(TreeNode *tree);
19
20 void MakeSubTreeLeft(TreeNode *tree, TreeNode *subtree);
21 void MakeSubTreeRight(TreeNode *tree, TreeNode *subtree);
22
```

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61
62 TreeNode *MakeTree(void)
63 {
64     TreeNode *tree = (TreeNode*)malloc(sizeof(TreeNode));
65     tree->Left = NULL;
66     tree->Right = NULL;
67
68     return tree;
69 } //change to pass by argument
70
71 DATATYPE RetData(TreeNode *tree)
72 {
73     return tree->data;
74 }
75
76 void SaveData(TreeNode *tree, DATATYPE data)
77 {
78     tree->data = data;
79 }
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```

Binary Tree

Linked List

```
81 TreeNode *RetSubTreeLeft(TreeNode *tree)
82 {
83     return tree->Left;
84 }
85
86 TreeNode *RetSubTreeRight(TreeNode *tree)
87 {
88     return tree->Right;
89 }
90
```

```
91 void MakeSubTreeLeft(TreeNode *tree, TreeNode *subtree)
92 {
93     if(tree->Left != NULL)
94     {
95         free(tree->Left);
96     }
97     tree->Left = subtree;
98 }
99
100 void MakeSubTreeRight(TreeNode *tree, TreeNode *subtree)
101 {
102     if(tree->Right != NULL)
103     {
104         free(tree->Right);
105     }
106     tree->Right = subtree;
107 }
108
109
110
```


Binary Tree

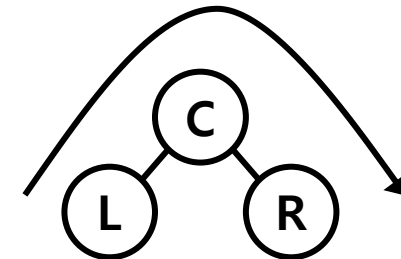
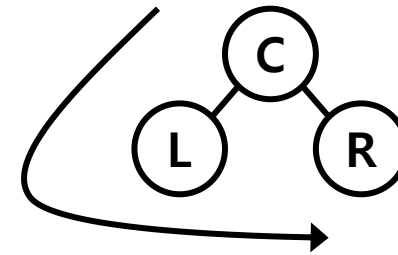
Linked List

```
23 int main(int argc, char *argv[])
24 {
25     TreeNode *tree1 = MakeTree();
26     TreeNode *tree2 = MakeTree();
27     TreeNode *tree3 = MakeTree();
28     TreeNode *tree4 = MakeTree();
29     TreeNode *tree5 = MakeTree();
30
31     SaveData(tree1, 1);
32     SaveData(tree2, 2);
33     SaveData(tree3, 3);
34     SaveData(tree4, 4);
35     SaveData(tree5, 5);
36
37     MakeSubTreeLeft(tree1, tree2);
38     MakeSubTreeRight(tree1, tree3);
39     MakeSubTreeLeft(tree2, tree4);
40     MakeSubTreeRight(tree2, tree5);
41 }
```

```
37     MakeSubTreeLeft(tree1, tree2);
38     MakeSubTreeRight(tree1, tree3);
39     MakeSubTreeLeft(tree2, tree4);
40     MakeSubTreeRight(tree2, tree5);
41
42     //print tree
43     printf("%d ", RetData(tree1));
44
45     //print left subtree data of tree1
46     printf("%d ", RetData(RetSubTreeLeft(tree1)));
47
48     //print left subtree data of tree2
49     printf("%d ", RetData(RetSubTreeLeft(RetSubTreeLeft(tree1))));
50
51     //print right subtree data of tree2
52     printf("%d ", RetData(RetSubTreeRight(RetSubTreeLeft(tree1))));
53
54     //print right subtree data of tree1
55     printf("%d ", RetData(RetSubTreeRight(tree1)));
56
57     printf("\n");
58
59     return 0;
60 }
```

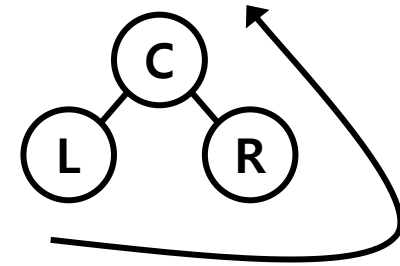
Tree Traversal

- Preorder traversal
 - Access current node
 - Traverse left subtree recursively
 - Traverse right subtree recursively
- Inorder traversal
 - Traverse left subtree recursively
 - Access current node
 - Traverse right subtree recursively



Tree Traversal

- Postorder traverse
 - Traverse left subtree recursively
 - Traverse right subtree recursively
 - Access current node



Binary Tree Traversal ADT

- void PreorderTraversal(TreeNode *tree);
 - Traverse tree by preorder
- void InorderTraversal(TreeNode *tree);
 - Traverse tree by inorder
- void PostorderTraversal(TreeNode *tree);
 - Traverse tree by postorder

Binary Tree Traversal

Linked List

```
1 #include <stdio.h>
2 #include <stdlib.h>
3
4 typedef int DATATYPE;
5
6 typedef struct TreeNode
7 {
8     DATATYPE data;
9     struct TreeNode *Left;
10    struct TreeNode *Right;
11 } TreeNode;
12
13 void PreorderTraversal(TreeNode *tree);
14 void InorderTraversal(TreeNode *tree);
15 void PostorderTraversal(TreeNode *tree);
16
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```

Binary Tree Traversal

Linked List

```
58 void PreorderTraversal(TreeNode *tree)
59 {
60     if(tree == NULL)
61     {
62         return ;
63     }
64     printf("%d ", tree->data);
65     PreorderTraversal(tree->Left);
66     PreorderTraversal(tree->Right);
67 }
68
69 void InorderTraversal(TreeNode *tree)
70 {
71     if(tree == NULL)
72     {
73         return ;
74     }
75     InorderTraversal(tree->Left);
76     printf("%d ", tree->data);
77     InorderTraversal(tree->Right);
78 }
79
80
81
```

```
82 void PostorderTraversal(TreeNode *tree)
83 {
84     if(tree == NULL)
85     {
86         return ;
87     }
88     PostorderTraversal(tree->Left);
89     PostorderTraversal(tree->Right);
90     printf("%d ", tree->data);
91 }
92
```

Binary Tree Traversal

Linked List

```
--
62 TreeNode *MakeTree(void)
63 {
64     TreeNode *tree = (TreeNode*)malloc(sizeof(TreeNode));
65     tree->Left = NULL;
66     tree->Right = NULL;
67
68     return tree;
69 }//change to pass by argument
70
71 DATATYPE RetData(TreeNode *tree)
72 {
73     return tree->data;
74 }
75
76 void SaveData(TreeNode *tree, DATATYPE data)
77 {
78     tree->data = data;
79 }
on
```

```
--
81 TreeNode *RetSubTreeLeft(TreeNode *tree)
82 {
83     return tree->Left;
84 }
85
86 TreeNode *RetSubTreeRight(TreeNode *tree)
87 {
88     return tree->Right;
89 }
90
```

Binary Tree Traversal

Linked List

```
91 void MakeSubTreeLeft(TreeNode #tree, TreeNode #subtree)
92 {
93     if(tree->Left != NULL)
94     {
95         free(tree->Left);
96     }
97     tree->Left = subtree;
98 }
99
100
101 void MakeSubTreeRight(TreeNode #tree, TreeNode #subtree)
102 {
103     if(tree->Right != NULL)
104     {
105         free(tree->Right);
106     }
107     tree->Right = subtree;
108 }
109
110
```


Binary Tree Traversal

Linked List

```
--
27 int main(int argc, char *argv[])
28 {
29     TreeNode *tree1 = MakeTree();
30     TreeNode *tree2 = MakeTree();
31     TreeNode *tree3 = MakeTree();
32     TreeNode *tree4 = MakeTree();
33     TreeNode *tree5 = MakeTree();
34
35     SaveData(tree1, 1);
36     SaveData(tree2, 2);
37     SaveData(tree3, 3);
38     SaveData(tree4, 4);
39     SaveData(tree5, 5);
40
```

```
41     MakeSubTreeLeft(tree1, tree2);
42     MakeSubTreeRight(tree1, tree3);
43     MakeSubTreeLeft(tree2, tree4);
44     MakeSubTreeRight(tree2, tree5);
45
46     //print tree
47     printf("preorder : ");
48     PreorderTraversal(tree1);
49     printf("\n");
50
51     printf("inorder : ");
52     InorderTraversal(tree1);
53     printf("\n");
54
55     printf("postorder : ");
56     PostorderTraversal(tree1);
57     printf("\n");
58
59
60     return 0;
61 }
62
```

Lab4: Calculator(tree)

- Submit on GitLab
- Postfix calculator using tree & expression printer
- Create Lab4 directory on your own GitLab project
- Submit file : source code(c only, run on linux)
- Filename : StudentID_lab4.c
- Input file : no

Lab4: Calculator(tree)

- Postfix calculator & expression printer using tree & linked list based stack
- ex) Input postfix equation : $12+7*$
 - Answer : 21
 - Prefix expression : $*+127$
 - Infix expression : $1+2*7$
 - Postfix expression : $12+7*$

Lab4: Calculator(tree) ADT

- `TreeNode *MakeExpTree(char exp[]);`
 - Pass the postfix equation as an argument
 - Make exp a tree using linked list based stack
 - Return root node of the tree
- `int EvalExpTree(TreeNode *tree);`
 - Pass the tree returned by `MakeExpTree()`
 - Calculate postfix equation stored as tree
 - Return answer
 - Using recursive calls

Lab4: Calculator(tree)

- Output example

```
prefix : * + 1 2 7
infix  : 1 + 2 * 7
postfix : 1 2 + 7 *
result : 21
```

Lab4: Calculator(tree)

```
80 TreeNode #MakeExpTree(char exp[])
81 {
82     ListStack stack;
83     TreeNode #tree;
84
85     int ExpLen = strlen(exp);
86
87     InitStack(&stack);
88
89     for(int i = 0; i < ExpLen; i++)
90     {
91         tree = MakeTree();
92
93         if(isdigit(exp[i]))
94         {
95             //Note, make tree node with integer data
96
97         }
98         else
99         {
100             //Note, make tree, root - operator, childs - integers inserted in stack
101         }
102     }
103     Push(&stack, tree);
104 }
105
106
107 return Pop(&stack);
108 }
109
```

exp[] = 127*+

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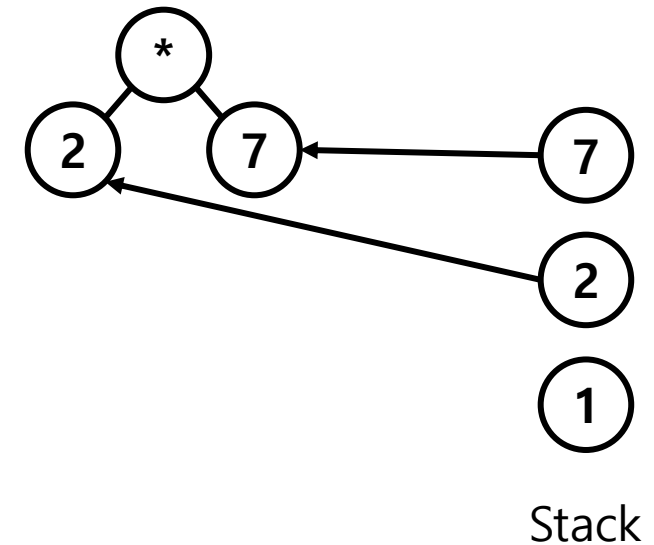
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Stack

Lab4: Calculator(tree)

```
80 TreeNode #MakeExpTree(char exp[])
81 {
82     ListStack stack;
83     TreeNode #tree;
84
85     int ExpLen = strlen(exp);
86
87     InitStack(&stack);
88
89     for(int i = 0; i < ExpLen; i++)
90     {
91         tree = MakeTree();
92         if(isdigit(exp[i]))
93         {
94             //Note, make tree node with integer data
95
96         }
97         else
98         {
99             //Note, make tree, root - operator, childs - integers inserted in stack
100
101         }
102     }
103     Push(&stack, tree);
104 }
105
106 return Pop(&stack);
107 }
108
109
```

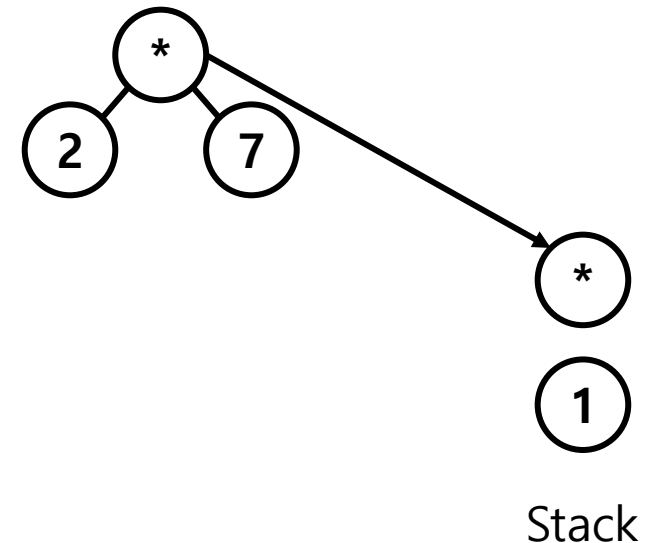
exp[] = 127*+



Lab4: Calculator(tree)

```
80 TreeNode #MakeExpTree(char exp[])
81 {
82     ListStack stack;
83     TreeNode #tree;
84
85     int ExpLen = strlen(exp);
86
87     InitStack(&stack);
88
89     for(int i = 0; i < ExpLen; i++)
90     {
91         tree = MakeTree();
92         if(isdigit(exp[i]))
93         {
94             //Note, make tree node with integer data
95
96         }
97         else
98         {
99             //Note, make tree, root - operator, childs - integers inserted in stack
100
101         }
102     }
103     Push(&stack, tree);
104 }
105
106 return Pop(&stack);
107 }
108
109
```

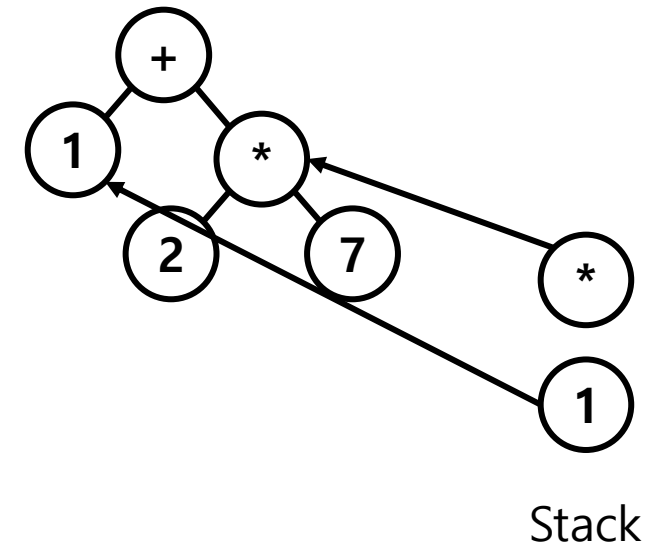
exp[] = 127*+



Lab4: Calculator(tree)

```
80 TreeNode #MakeExpTree(char exp[])
81 {
82     ListStack stack;
83     TreeNode #tree;
84
85     int ExpLen = strlen(exp);
86
87     InitStack(&stack);
88
89     for(int i = 0; i < ExpLen; i++)
90     {
91         tree = MakeTree();
92
93         if(isdigit(exp[i]))
94         {
95             //Note, make tree node with integer data
96
97         }
98         else
99         {
100             //Note, make tree, root - operator, childs - integers inserted in stack
101         }
102     }
103     Push(&stack, tree);
104 }
105
106
107 return Pop(&stack);
108 }
109
```

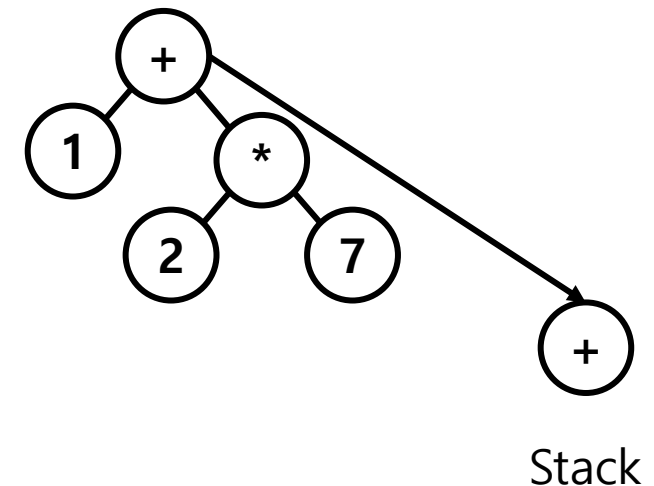
exp[] = 127*+



Lab4: Calculator(tree)

```
80 TreeNode #MakeExpTree(char exp[])
81 {
82     ListStack stack;
83     TreeNode #tree;
84
85     int ExpLen = strlen(exp);
86
87     InitStack(&stack);
88
89     for(int i = 0; i < ExpLen; i++)
90     {
91         tree = MakeTree();
92
93         if(isdigit(exp[i]))
94         {
95             //Note, make tree node with integer data
96         }
97         else
98         {
99             //Note, make tree, root - operator, childs - integers inserted in stack
100
101         }
102     }
103     Push(&stack, tree);
104 }
105
106 return Pop(&stack);
107 }
108
109
```

exp[] = 127*+

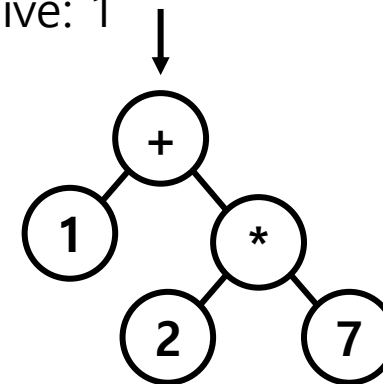


Lab4: Calculator(tree)

```
110 int EvalExpTree(TreeNode *tree)
111 {
112     //Note, if tree reached one end
113     if( )
114     {
115         return RetData(tree);
116     }
117
118     int op1 = EvalExpTree(RetSubTreeLeft(tree)); ←
119     int op2 = EvalExpTree(RetSubTreeRight(tree));
120
121     switch(RetData(tree))
122     {
123         case '+':
124             return op1 + op2;
125         case '-':
126             return op1 - op2;
127         case '*':
128             return op1 * op2;
129         case '/':
130             return op1 / op2;
131     }
132
133     return 0;
134 }
135
```

exp[] = 127*+

Recursive: 1



Lab4: Calculator(tree)

```
110 int EvalExpTree(TreeNode *tree)
111 {
112     //Note, if tree reached one end
113     if( )
114     {
115         return RetData(tree);
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117
118     int op1 = EvalExpTree(RetSubTreeLeft(tree));
119     int op2 = EvalExpTree(RetSubTreeRight(tree));
120
121     switch(RetData(tree))
122     {
123         case '+':
124             return op1 + op2;
125         case '-':
126             return op1 - op2;
127         case '*':
128             return op1 * op2;
129         case '/':
130             return op1 / op2;
131     }
132
133     return 0;
134 }
135
```

exp[] = 127*+

Recursive: 2

