Data structure and algorithms lab

TREE TRAVERSAL

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Topics of this week

- How to build programs using makefile utility
- Tree traversal
  - Depth first search
    - Preorder traversal
    - Inorder traversal
    - Postorder traversal
  - Breadth first search.
- Exercises

Makefile - motivation

- Small programs ⟶ single file
- “Not so small” programs :
  - Many lines of code
  - Multiple components
  - More than one programmer

- Problems:
  - Long files are harder to manage (for both programmers and machines)
  - Every change requires long compilation
  - Many programmers cannot modify the same file simultaneously

Makefile - motivation

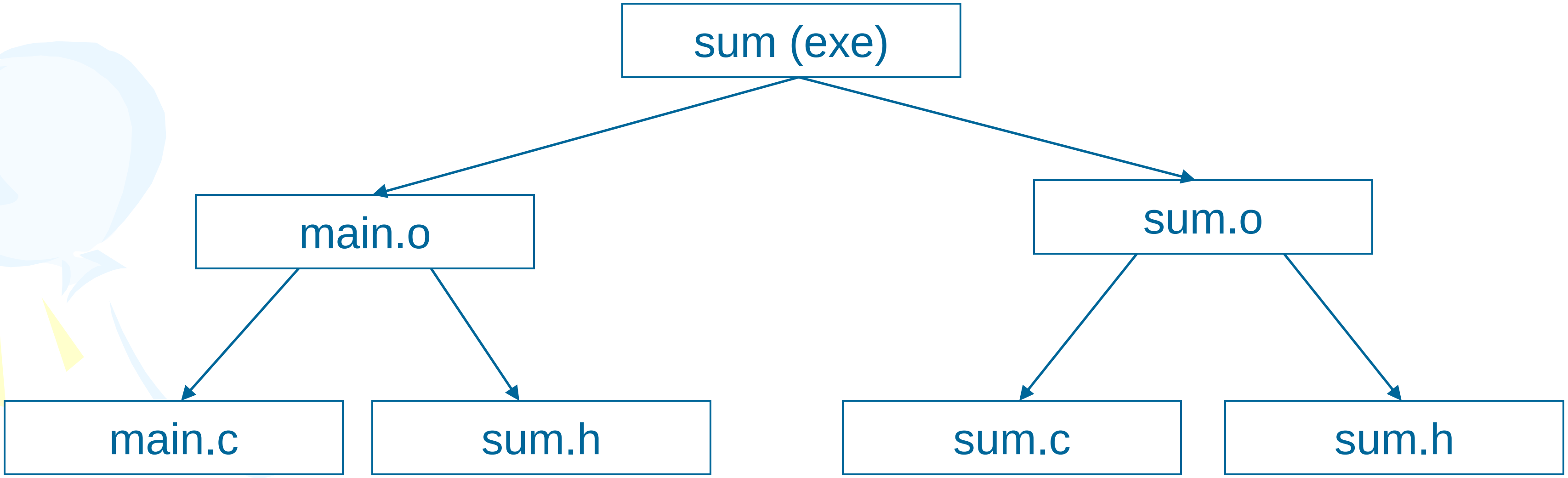
- Solution : divide project to multiple files
- Targets:
  - Good division to components
  - Minimum compilation when something is changed
  - Easy maintenance of project structure, dependencies and creation

Project maintenance

- Done in Unix by the Makefile mechanism
- A makefile is a file (script) containing :
  - Project structure (files, dependencies)
  - Instructions for files creation
- The make command reads a makefile, understands the project structure and makes up the executable
- Note that the Makefile mechanism is not limited to C programs

Project structure

- Project structure and dependencies can be represented as a DAG (= Directed Acyclic Graph)
- Example :
  - Program contains 3 files
  - main.c., sum.c, sum.h
  - sum.h included in both .c files
  - Executable should be the file sum



sum (exe)

main.o

sum.o

main.c

sum.h

sum.c

sum.h

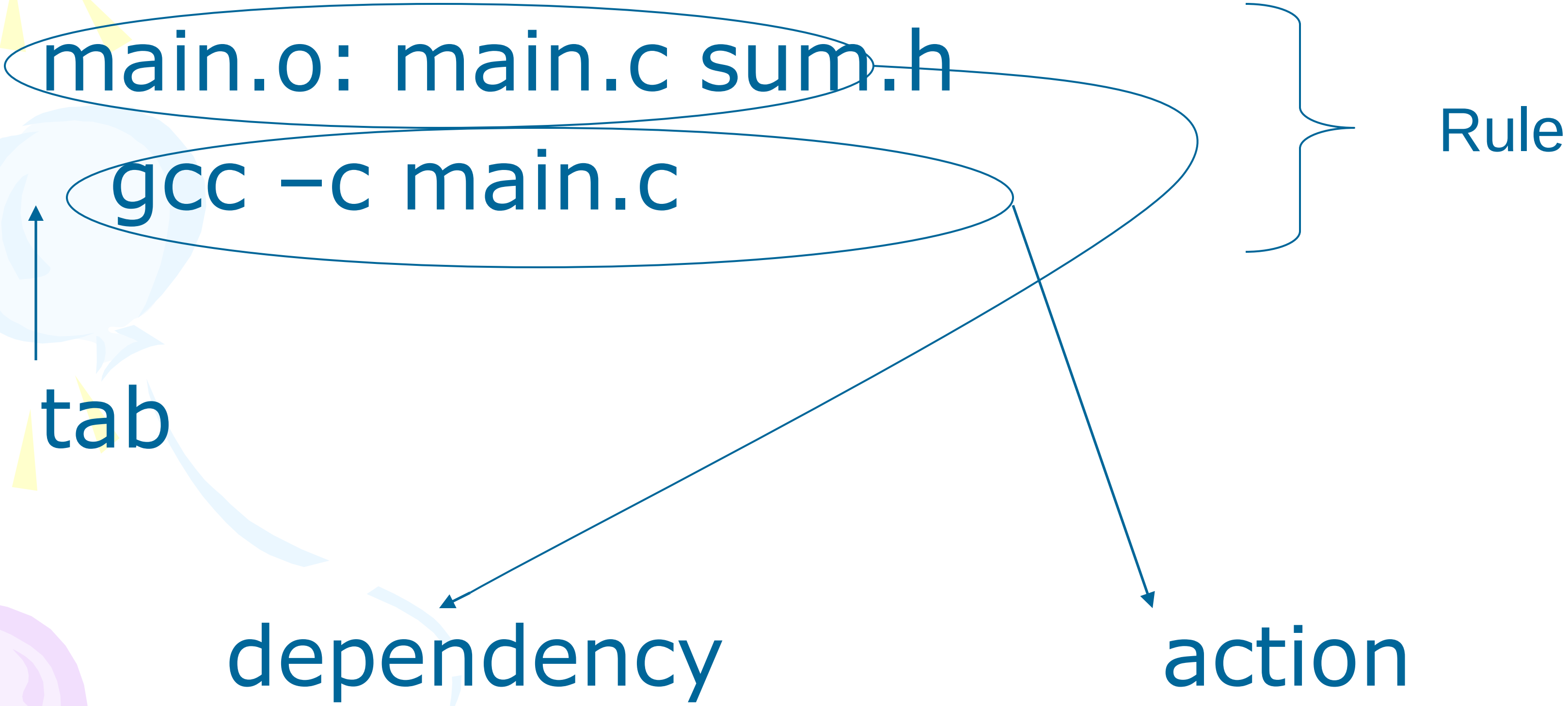
makefile

```
sum: main.o sum.o
    gcc –o sum main.o sum.o

main.o: main.c sum.h
    gcc –c main.c

sum.o: sum.c sum.h
    gcc –c sum.c
```

Rule syntax



```
main.o: main.c sum.h
	gcc –c main.c
```

Rule

tab

dependency

action

Equivalent makefiles

- .o depends (by default) on corresponding .c file. Therefore, equivalent makefile is:

```
sum: main.o sum.o
    gcc –o sum main.o sum.o

main.o: sum.h
    gcc –c main.c

sum.o: sum.h
    gcc –c sum.c
```

Equivalent makefiles - continued

- We can compress identical dependencies and use built-in macros to get another (shorter) equivalent makefile :

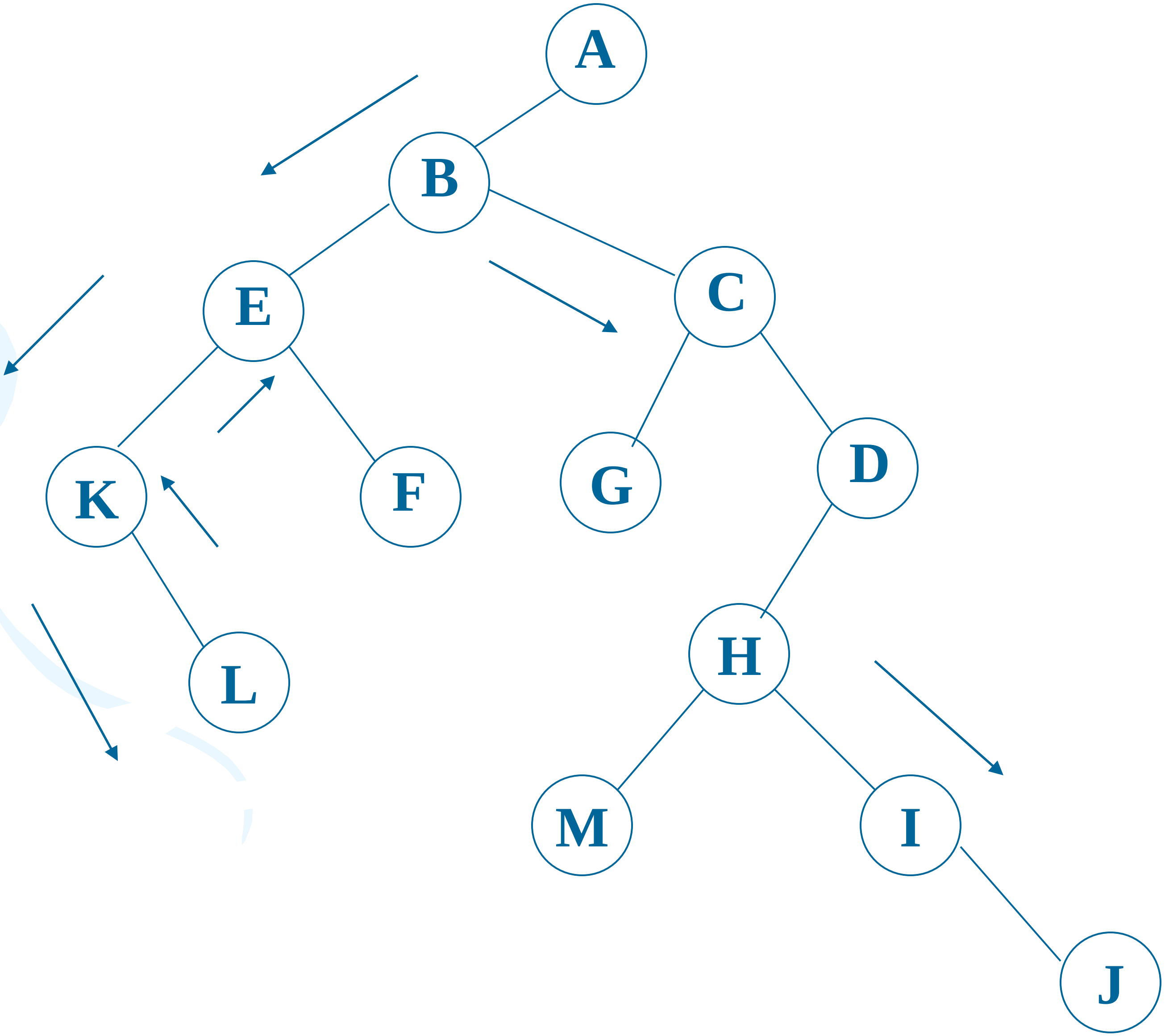
```
sum: main.o sum.o
   gcc –o $@ main.o sum.o

main.o sum.o: sum.h
   gcc –c $*.c
```

Binary Tree Traversal

- Many binary tree operations are done by performing a traversal of the binary tree
- In a traversal, each element of the binary tree is visited exactly once
- During the visit of an element, all action (make a clone, display, evaluate the operator, etc.) with respect to this element is taken

Binary Tree Traversal

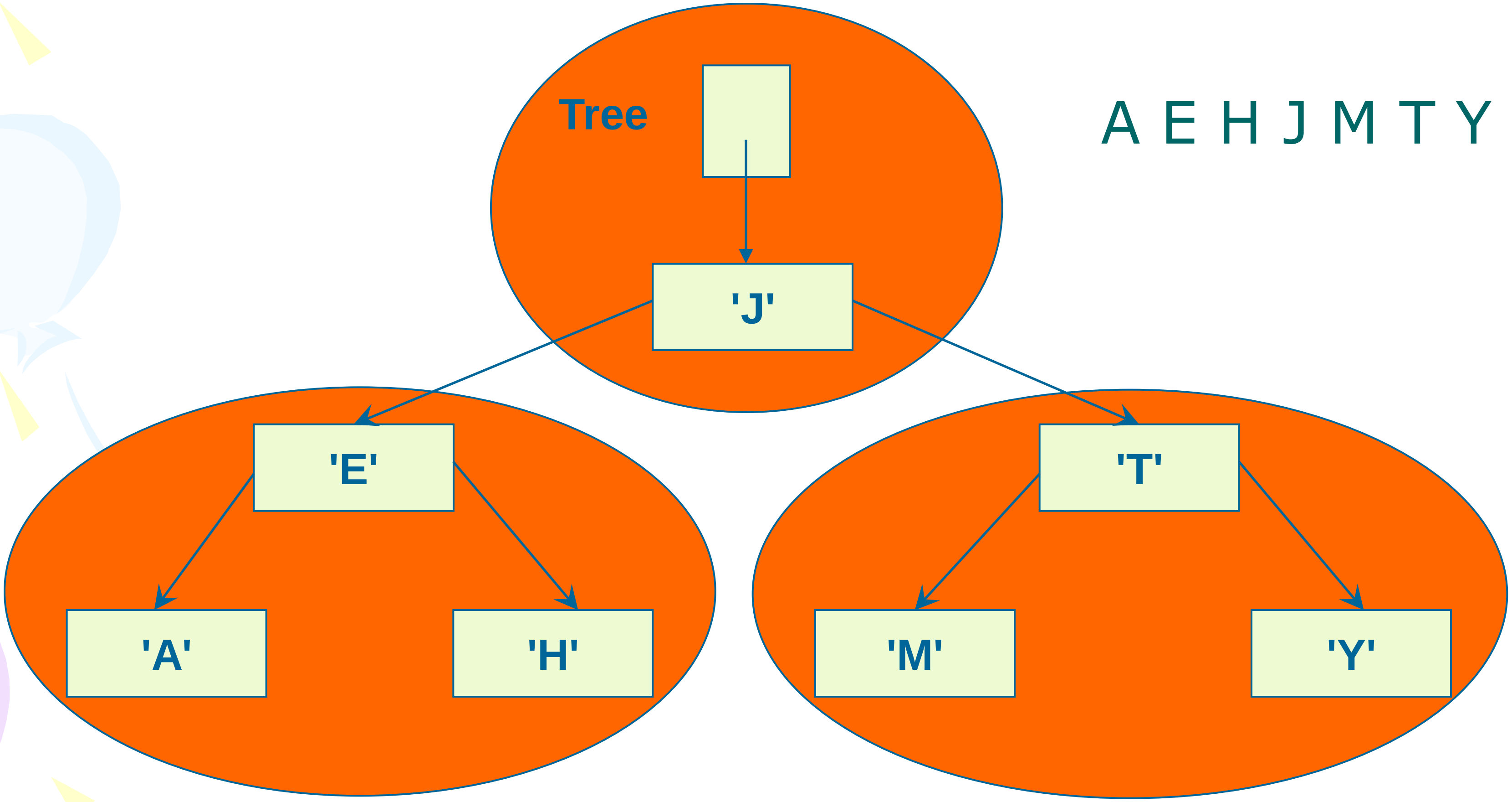


DFS

- Depth-first search (traversal): This strategy consists of searching deeper in the tree whenever possible.
- Tree types:
  - Preorder
  - Inorder
  - Postorder

Inorder Traversal

- Visit the nodes in the left subtree, then visit the root of the tree, then visit the nodes in the right subtree



A E H J M T Y

Print left subtree first

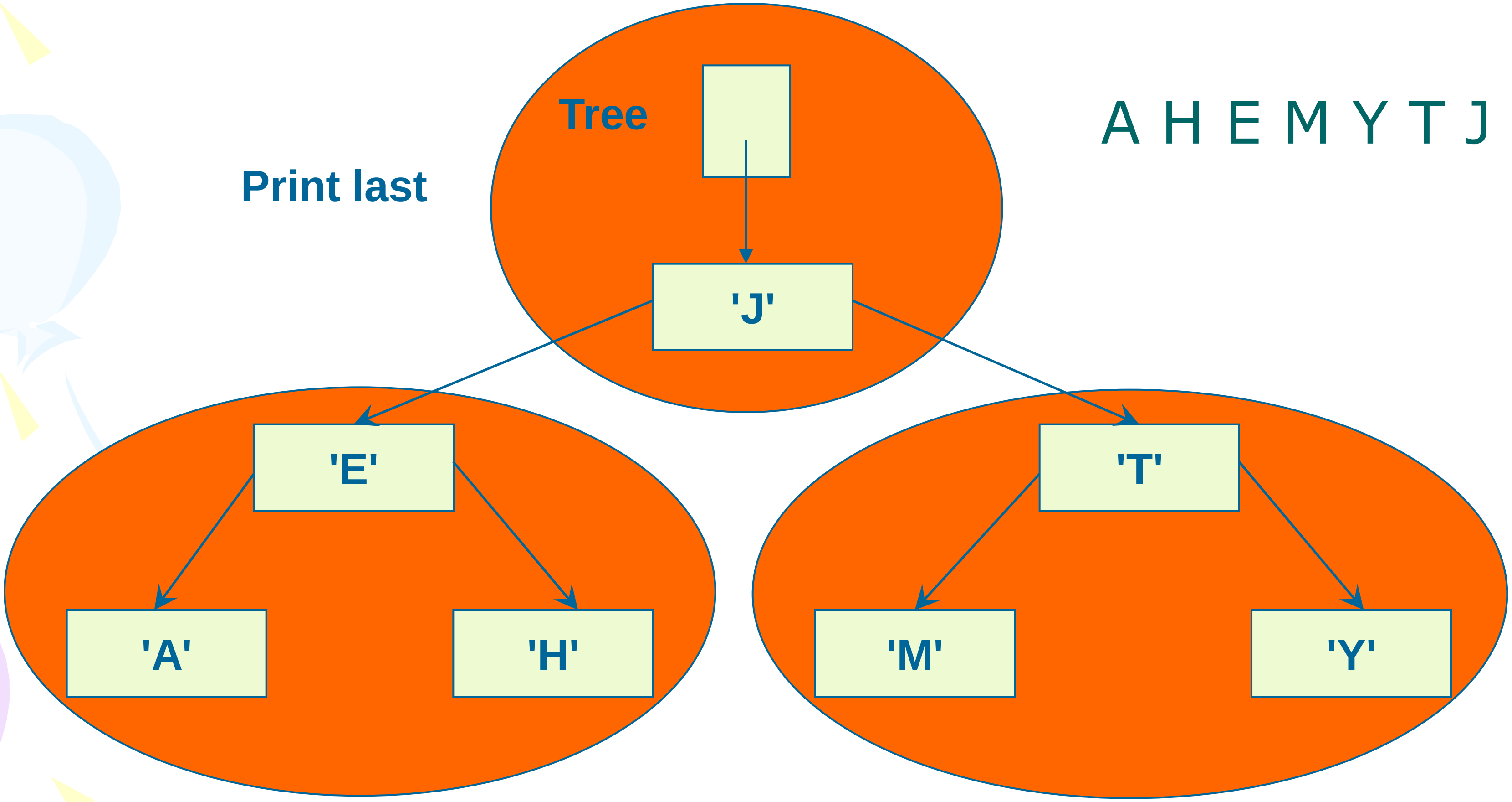
Print right subtree last

Function inorderprint

```
void inorderprint(TreeType tree)
{
  if (tree!=NULL)
  {
     inorderprint(tree->left);
     printf("%4d\n",tree->Key);
     inorderprint(tree->right);
  }
}
```

Postorder Traversal

- Visit the nodes in the left subtree, then visit the nodes in the right subtree, then visit the root of the tree



Print last

A H E M Y T J

Print left subtree first

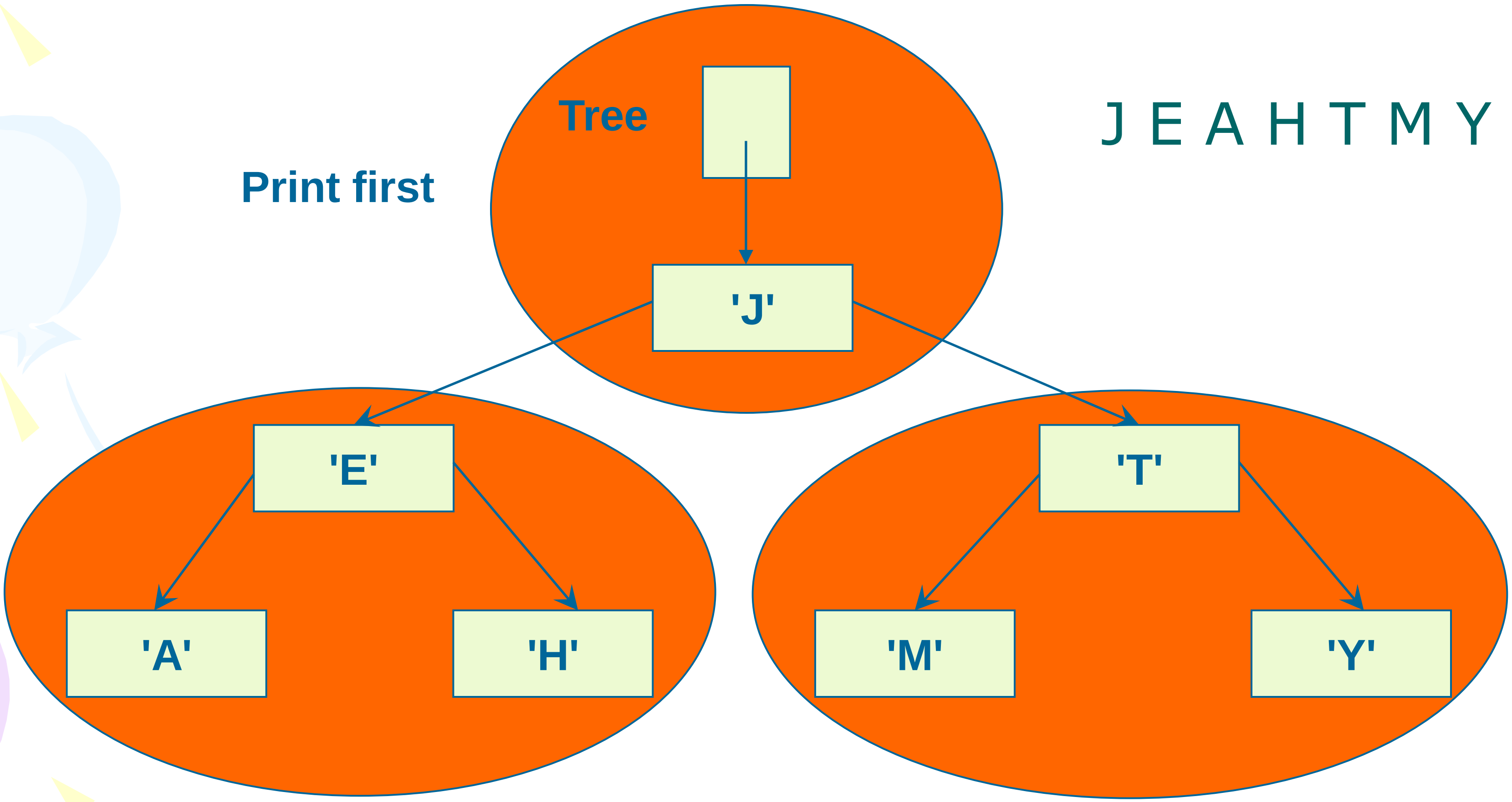
Print right subtree second

Function postorderprint

```
void postorderprint(TreeType tree)
{
  if (tree!=NULL)
  {
     postorderprint(tree->left);
     postorderprint(tree->right);
     printf("%4d\n",tree->Key);
  }
}
```

Preorder Traversal

- Visit the root of the tree first, then visit the nodes in the left subtree, then visit the nodes in the right subtree



Print first

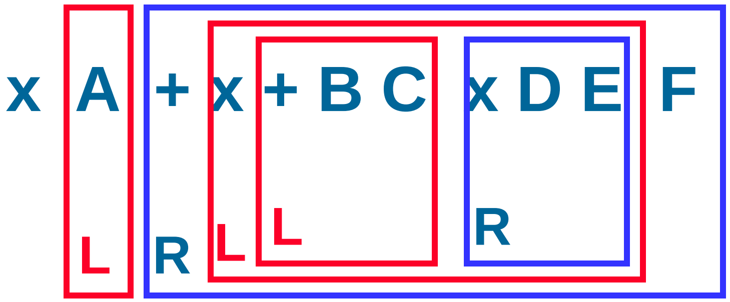
J E A H T M Y

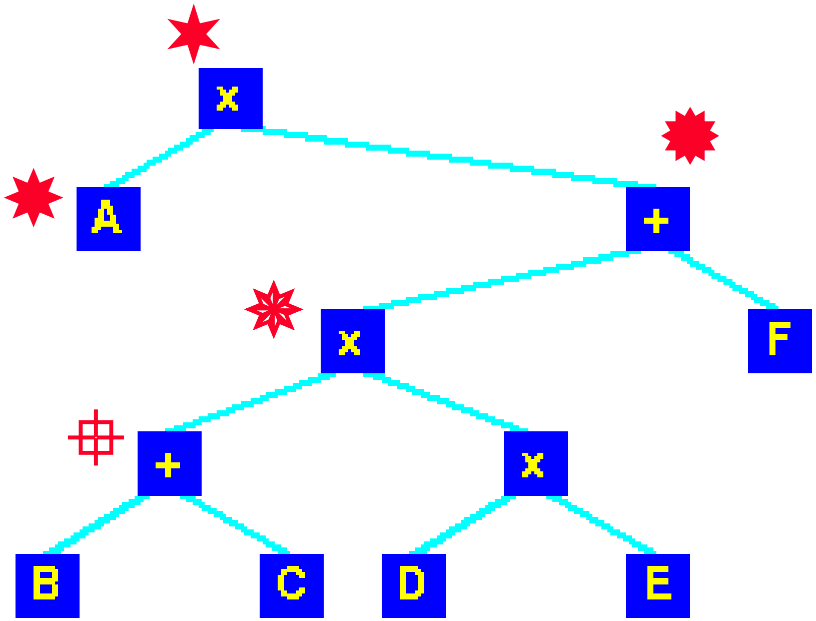
Print left subtree second

Print right subtree last

Pre_order

- Pre-order
  - Root
  - Left sub-tree
  - Right sub-tree





Function preorderprint

```
void preorderprint(TreeType tree)
{
  if (tree!=NULL)
  {
     printf("%4d\n",tree->Key);
     preorderprint(tree->left);
     preorderprint(tree->right);
  }
}
```

Exercise

- Add API to your BinaryTree Lib
- void freeTree(TreeType tree);

Hint

- Just use the traversal algorithm

```
freeTree (node):
    //do nothing if passed a non-existent node
    if node is null
        return

    //now onto the recursion
    freeTree(left subTree)
    freeTree (right subTree)

    free node
```

Exercise

- Return to the exercise lastweek. We have already a tree for storing Phone address book.
- Now output all the data stored in the binary tree in ascending order for the e-mail address.

Hint

- Just use the InOrderTraversal()

Iterative Inorder Traversal

```
void iter_inorder(TreeType node)
{
  int top= -1; /* initialize stack */
  TreeType stack[MAX_STACK_SIZE];
  for (;;) {
   for (; node; node=node->left)
     add(&top, node);/* add to stack */
   node= delete(&top);/*delete from stack*/

   if (node==NULL) break;/* stack is empty */
   printf(“%d”, node->key);
   node = node->right;
 }
}
```

Exercise

- Output all the data stored in the binary tree in ascending dictionnary order for the name in the Phone Book Tree:
  - to screen.
  - to a file.

Exercise

- Return to the arithmetic expression tree exercise.
- Use postfix order traversal procedure to display equivalent postfix expression

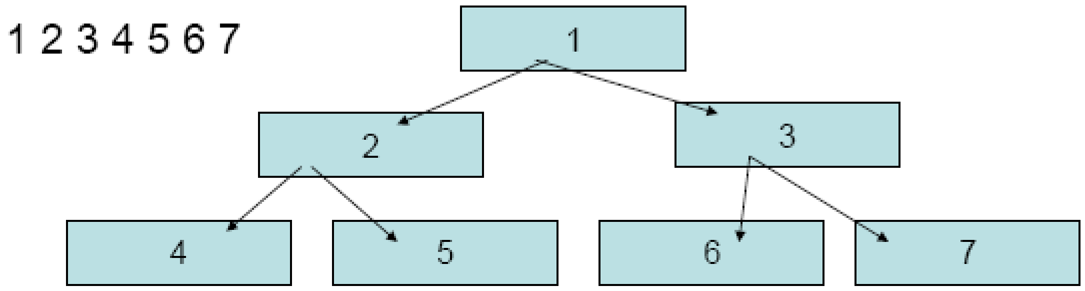
Exercise : Reverse Tree

- Write a recursive function that take the pointer root of a tree and modify it as follow:
  - all left-child -> right child
  - left – subtree → right subtree
  - and inversely.

  - Test it with an arithmetic expression tree.

Breadth First Traversal

- Instead of going down to children first, go across to siblings
- Visits all nodes on a given level in left-to-right order



Breadth First Traversal

- To handle breadth-first search, we need a queue in place of a stack
- Add root node to queue
- For a given node from the queue
  - Visit node
  - Add nodes left child to queue
  - Add nodes right child to queue

Pseudo Algorithm

```
void breadth_first(TreeType node)
{
   QueueType queue; // queue of pointers
   if (node!=NULL) {
       enq(node,queue);
       while (!empty(queue)) {
          node=deq(queue);
          printf(node->key);
          if (node->left !=NULL)
             enq(node->left,queue);
          if (node->right !=NULL)
             enq(node->right,queue);
         }
     }
}
```

Exercise

- Implement BFS algorithm in C language
- Add this function to the binary tree library
- Test it the Phone Book management program to print all the names in the tree.
- Output the results to a file

Homework: PrintTree

- Based on the idea of a breadth first tree traversal algorithm, write a procedure:vertical_print_tree(root,..)
- Use the function in the arithmethic tree exercise. The program should have the following menu driven interface:
  - 1. Create Tree (Automatically instead of manual input)
  - 2. Depth First Traversal(Pre – In – Post Order)
  - 3. Reverse Tree
  - 4. Vertical Print Tree.

Tree of officers

- This tree is meant to represent who is in charge of lower-ranking officers. For example, Commander Riker is directly responsible for Worf and LaForge. People of the same rank are at the same level in the tree. However, to distinguish between people of the same rank, those with more experience are on the left and those with less on the right.
- Suppose a fierce battle with an enemy ensues. If officers start dropping like flies, we need to know who is the next person to take over command. Use BFS to display the list.

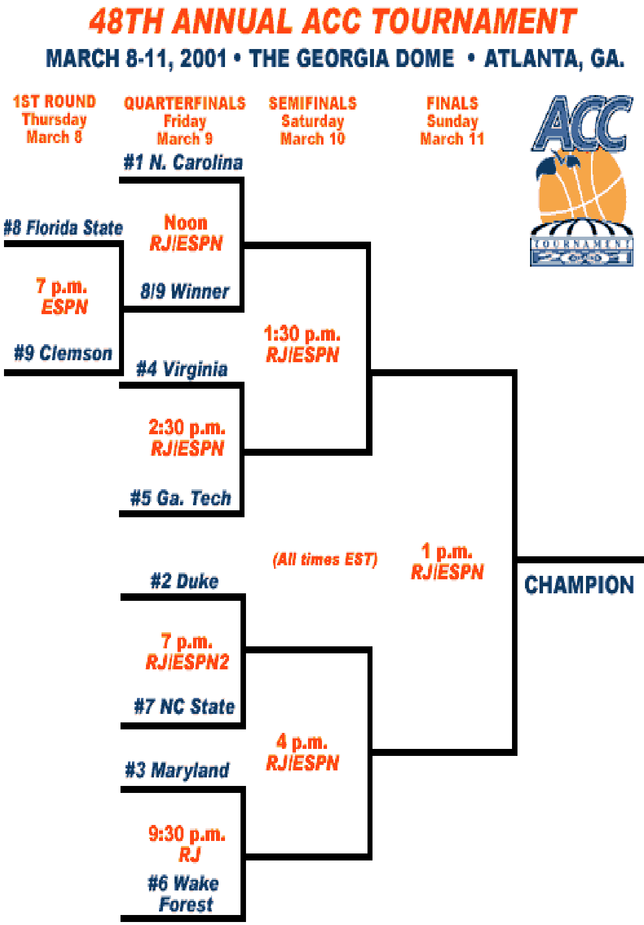
```
               Captain Picard
             /                \
    Commander Riker       Commander Data
      /         \               |
 Lt. Cmdr.   Lt. Cmdr.      Lt. Cmdr.
 Worf        LaForge        Crusher
     |                          |
Lieutenant                  Lieutenant
Cameo-Appearance            Selar
```

Homework

- Implement Breadth First Traversal for PhoneDB Management Program.

Exercise

- Write a program to build a tournament: a binary tree where the item in every internal node is a copy of the larger of the items in its two children. So the root is a copy of largest item in the tournament. The items in the leaves constitute the data of interest.
- The input items are stored in an array.
- Hint: Uses a divide and conquer strategy



Solution

```
typedef struct node *link;
struct node { Item item; link l, r };
link NEW(Item item, link l, link r)
  { link x = malloc(sizeof *x);
    x->item = item; x->l = l; x->r = r;
    return x;
  }
link max(Item a[], int l, int r)
  { int m = (l+r)/2; Item u, v;
    link x = NEW(a[m], NULL, NULL);
    if (l == r) return x;
    x->l = max(a, l, m);
    x->r = max(a, m+1, r);
    u = x->l->item; v = x->r->item;
    if (u > v)
      x->item = u; else x->item = v;
    return x;
  }
```

Exercise: Calculate word frequencies

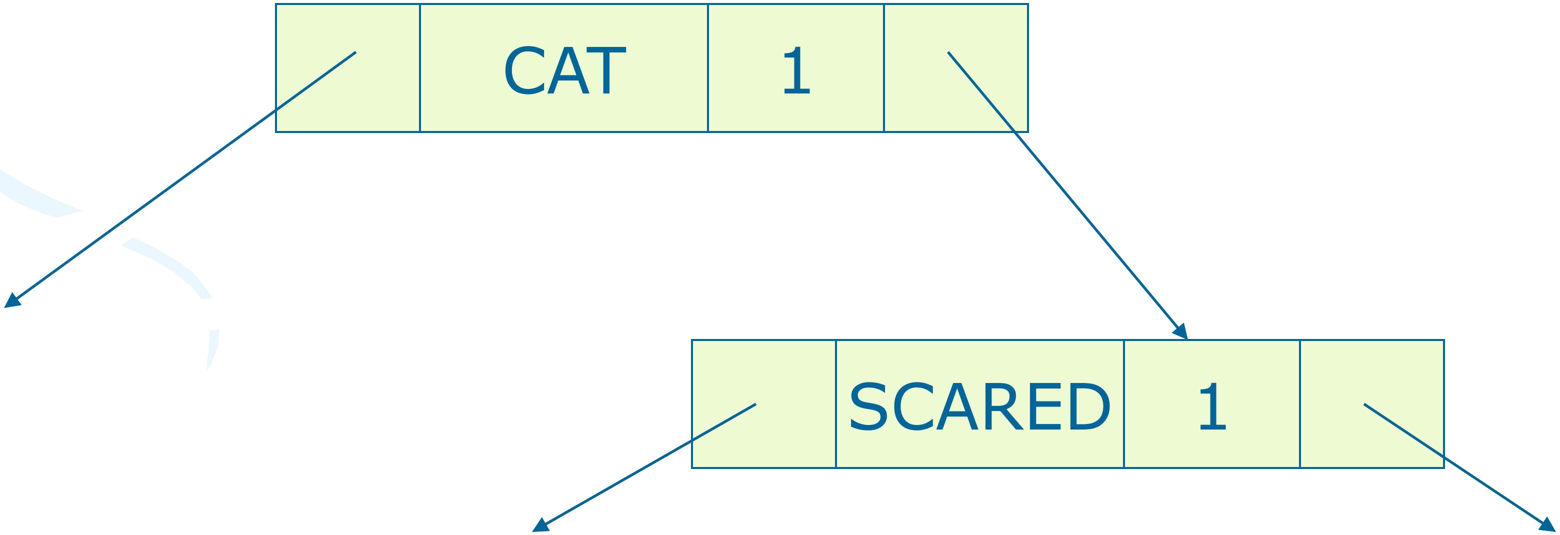
- Write to a program WordCount which reads a text file, then analyzes the word frequencies. The result is stored in a file. When user provide a word, program should return the number of occurrences of this word in the file.
- For example, suppose the input files has the following contents: *A black black cat saw a very small mouse and a very scared mouse.*
- The word frequencies in this file are as follows:

AND 1
CAT 1
SAW 1
SCARED 1

SMALL 1
BLACK 2
MOUSE 2
VERY 2
A 3

Hint

- Use a binary search tree (it's even better with AVL) to store data.
- A node in this tree should contain at least two fields:
  - word: string
  - count: int
- Words are stored in nodes in the dictionary order.



Another solution

```
#include <stdio.h>
#include <ctype.h>
#include <string.h>
#define MAXWORD 100
struct tnode {
 char *word; /* points to the text */
 int count;     /* number of occurrences */
 struct tnode *left;   /* left child */
 struct tnode *right;  /* right child */
};
struct tnode *addtree(struct tnode *, char *);
void treeprint(struct tnode *);
int getword(char *, int);
```

Another solution

```
main()
   {
       struct tnode *root;
       char word[MAXWORD];
       root = NULL;
       while (getword(word, MAXWORD) != EOF)
           if (isalpha(word[0]))
               root = addtree(root, word);
       treeprint(root);
       return 0;
   }
   struct tnode *talloc(void);
   char *strdup(char *);
/* treeprint:  in-order print of tree p */
   void treeprint(struct tnode *p)
   {
       if (p != NULL) {
           treeprint(p->left);
           printf("%4d %s\n", p->count, p->word);
           treeprint(p->right);
       }
   }
```

Another solution

```
/* addtree:  add a node with w, at or below p */
   struct treenode *addtree(struct tnode *p, char *w)
   {
       int cond;

       if (p == NULL) {     /* a new word has arrived */
           p = talloc();    /* make a new node */
           p->word = strdup(w);
           p->count = 1;
           p->left = p->right = NULL;
       } else if ((cond = strcmp(w, p->word)) == 0)
           p->count++;      /* repeated word */
       else if (cond < 0)   /* less than into left subtree */
           p->left = addtree(p->left, w);
       else             /* greater than into right subtree */
           p->right = addtree(p->right, w);
       return p;
   }
```

Homework

- Modify the above exercise so that it takes the text file as command arguments.
- Output the result (list all word with its frequency) as a file named wordcounting.txt.

Homework

- Write 2 functions in BST library:
  - int lowerThanKey(key X, Tree root)
  - int higherThanKey(key X, Tree root)
- each does the following tasks:
  - list all node(info data) of which key is smaller (bigger) than X
  - return the number of these nodes.
- Use these functions in Student management program. Program should allow to see students whose grade is higher a value inputted by user