C Programming Basic – week 9

Tree

Lecturers :

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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 - motivatio

- 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

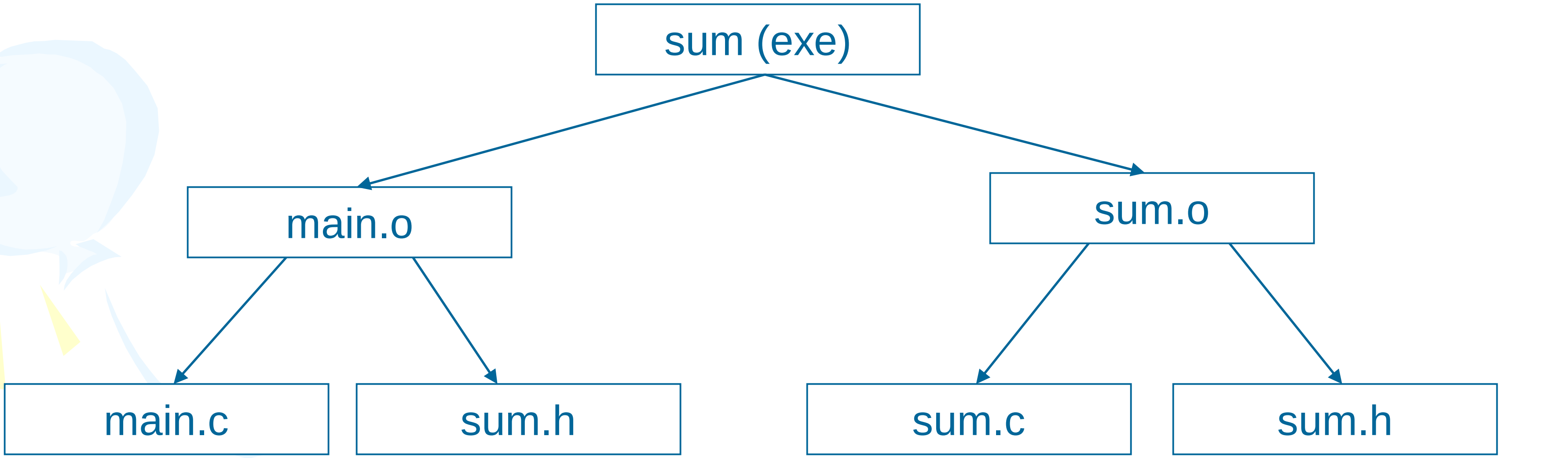
- Solution : divide project to multiple files
- Targets:
  - Good division to components
  - Minimum compilation when something is changed
  - Easy maintenance of project structure, dependencies and creation

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 :

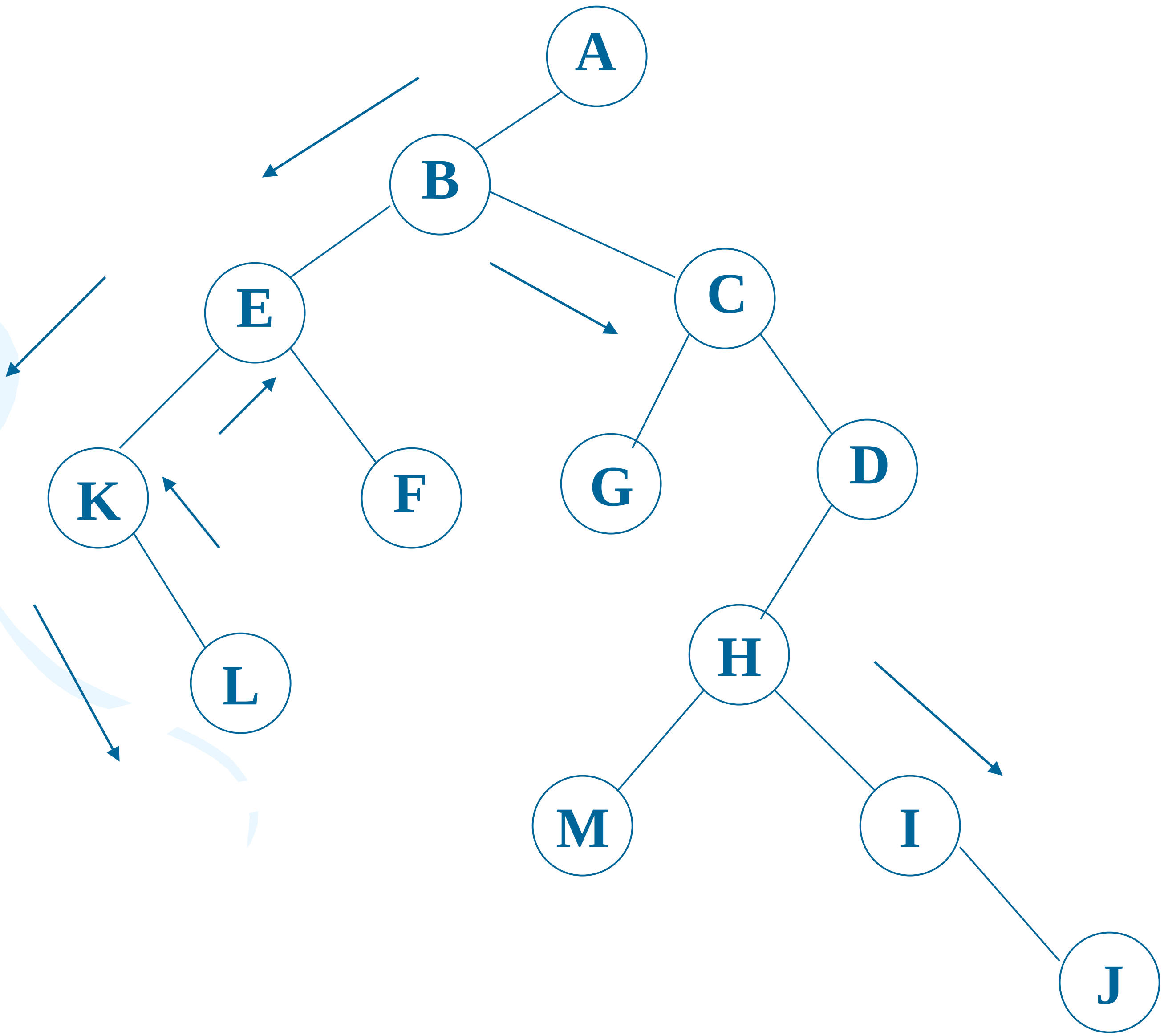
```
sum: main.o sum.o
    gcc –o $@ main.o sum.o

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

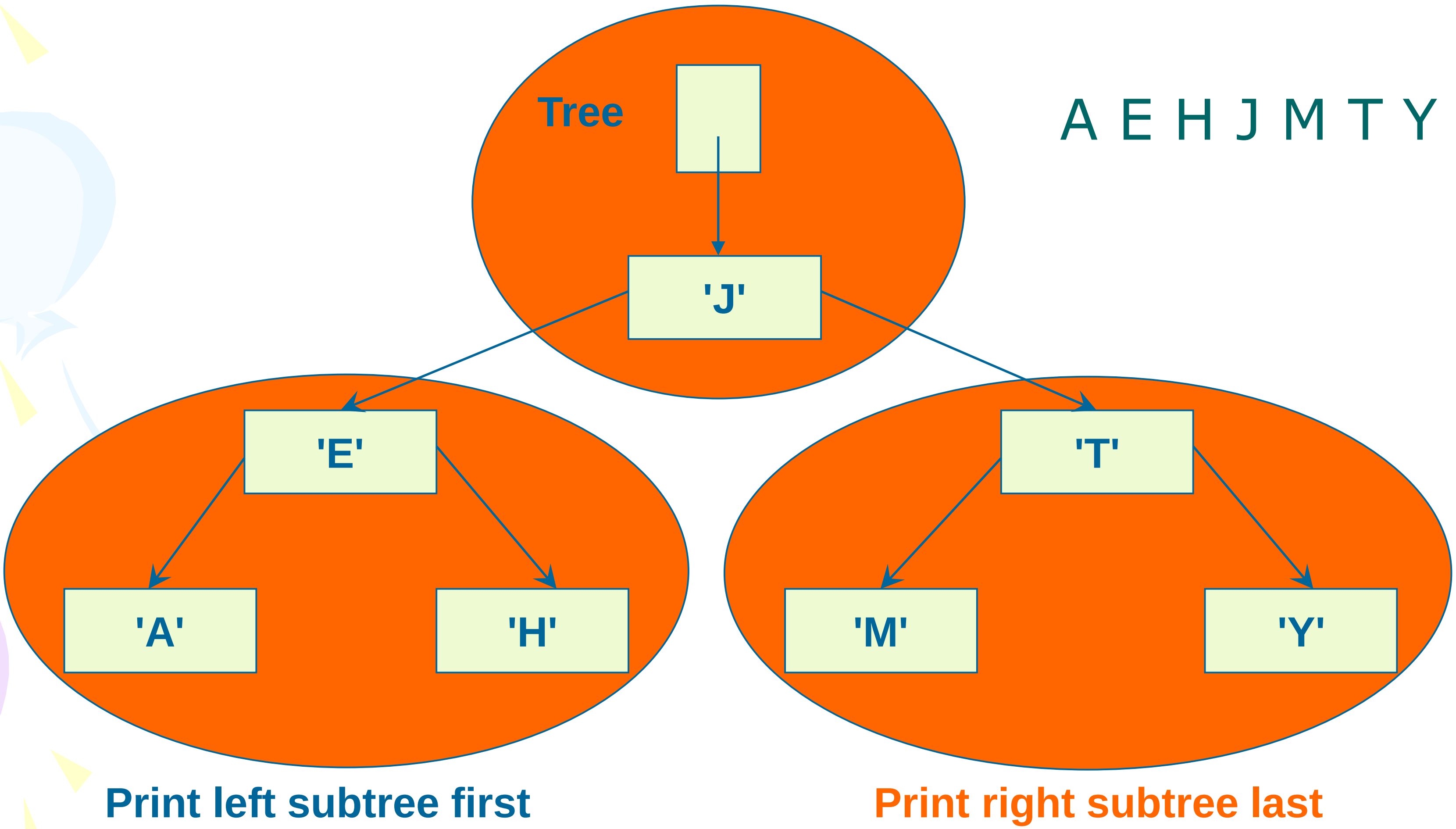


DFS

- 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



Function inorderprint

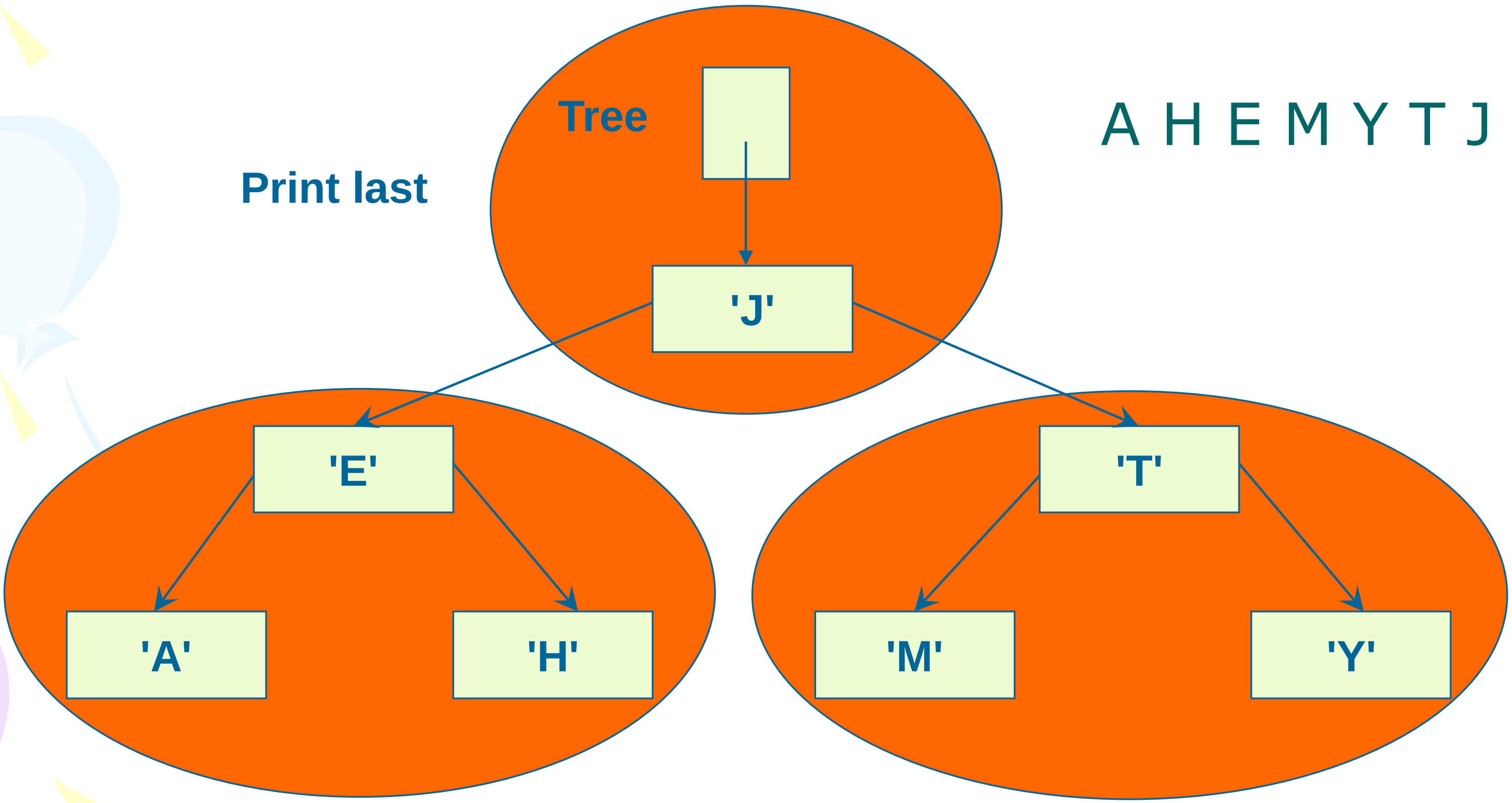
```
void inorderprint(TreeType tree)
{
  if (tree!=NULL)
  {
     inorderprint(tree->left);
     printf("%4d\n",tree->Key);
     inorderprint(tree->right);
  }
}
```

Postorder Traversal

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

A H E M Y T J

Print last



Print left subtree first

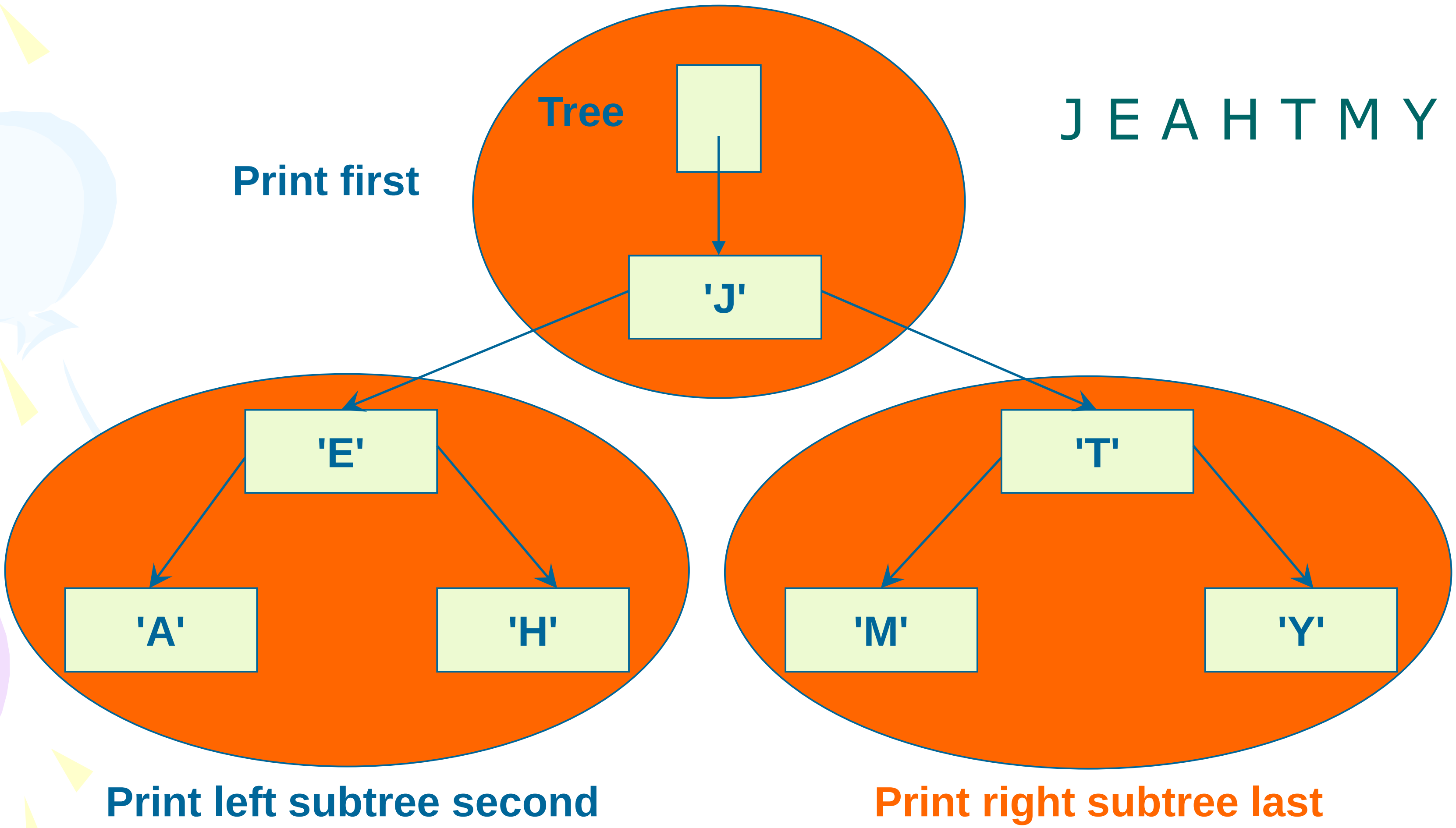
Print right subtree second

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

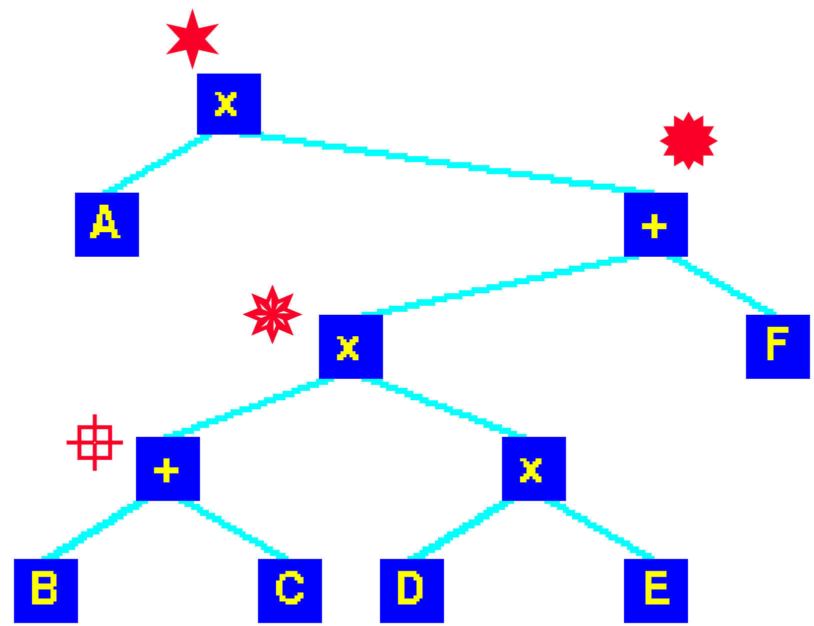


Pre_order

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

x A + x + B C x D E F

L R L L R



Function preorderprint

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

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;
 }
}
```

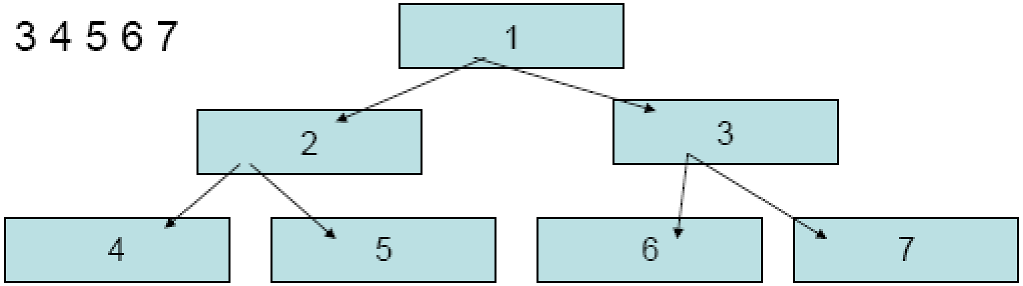
Exercise

- 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.

Breadth First Search

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

1 2 3 4 5 6 7



Breadth First Search

- 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

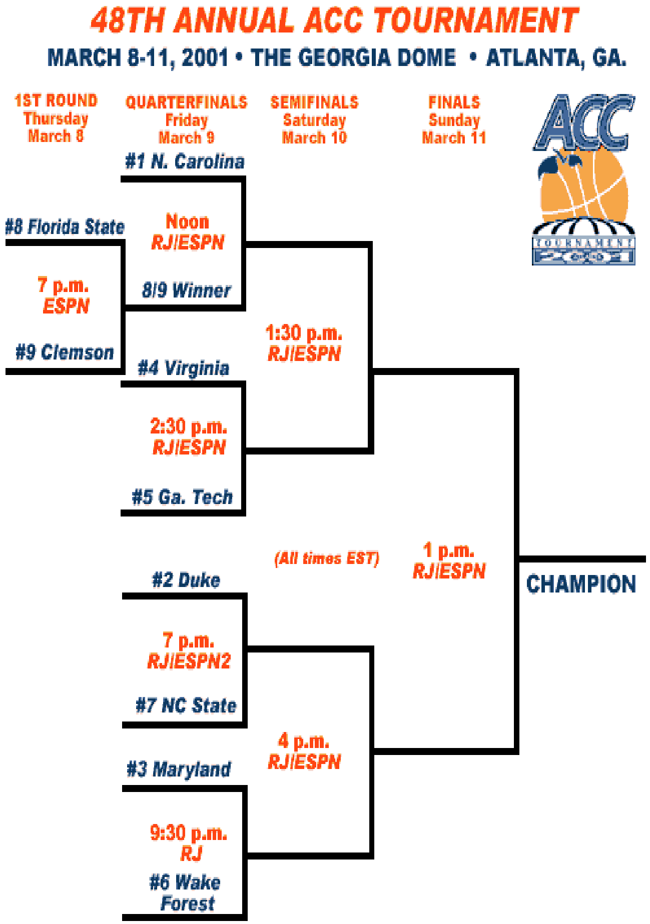
```
void breadth_first(TreeType node)
{
   QueueType queue; // queue of pointers
   if (node!=NULL) {
       enq(node,queue);
       while (!empty(queue)) {
          node=deq(queue);
          printf(node->key);
          if (node->left !=NULL)
             enq(node->left,queue);
          if (node->right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

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.