Data Structures (Not UML)

Pseudo-code Syntax, Trees

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M1 TAL/SC 2023–2024

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Class Organisation

Second Lab :

- Reminder : optional exercise TD2 (due October 27th) ;
- hand back on a sheet of paper (October 27th), send it by e-mail, or hand back on Arche.
- Correction of the second lab (except bonus exercise) will be uploaded today (October 20th)
- Points and feedback on the optional exercise of TD1 before Wednesday.

How to find the Arche repository :

- on your Arche top bar (blue-ish), click on "Home" ("Accueil") ;
- then "LORRAINE MANAGEMENT" (purple) ;
- and search for "Data Structure" ;
- Full name of the course is "Data Structures - Beginners", password is "Nox".

Syntax

Variable

Variable

A variable is an object, or a buffer. You can create it, initialise it, modify it. It is used to store data, like a result for example.

- Create and initialise a variable : $new\_var \leftarrow init\_value$
- Modify a variable : $var \leftarrow new\_value$
  - Create and initialise empty structures like last week :

    1: $S \leftarrow S_0$ *-- creates an empty stack*
  - But it can work with any type of data :

    1: $c \leftarrow 5$ *-- creates a variable c of value 5*

    2: $c \leftarrow 0$ *-- modifies the variable c, it is now of value 0*

    3: $c \leftarrow c + 3$ *-- modifies the variable c, it is now of value 3 (0 + 3)*

Variable

- There exists variables of any type ;
- When you create a variable, you can assign it to a value of any type :
  - Integer :

    1: $var \leftarrow 5$
  - Boolean :

    1: $var \leftarrow true$

    2: $var \leftarrow false$

    3: $iable \leftarrow var$

    4: $iable \leftarrow true$
  - String :

    1: $var \leftarrow$ "*tadaaaaa*"
  - List :

    1: $var \leftarrow [5, 8, 6, 9, 2]$
  - Dictionary :

    1: $var \leftarrow \{(6, [12, 24]), (7, [7, 14]), (2, [6])\}$
  - Queue :

    1: $var \leftarrow Q_0$
  - Stack :

    1: $var \leftarrow S_0$

If Block

If/Then/Else block

If the condition is satisfied, instructions 1, 2, etc. are executed. If the condition is not satisfied, instructions A, B, etc. are executed.

Note : It is not mandatory to have the "else" part ; in that case, when the condition is not satisfied, no instructions are executed.

```
if condition then
    instruction 1
    instruction 2
    etc.
else    -- optional part
    instruction A
    instruction B
    etc.
end if    -- but this one is mandatory
```

Loops (1)

For loop

In a *for loop*, we create a variable that will take several values one after the other, *i.e.*, we will iterate over some elements and the variable will take one value at a time. The loop is thus executed a known definite number of times. The instructions 1, 2, etc. will be executed as many times as there are elements.

Note : The loop variable (here X) can be used in the loop.

```
for X in elements do
    instruction 1
    instruction 2
    etc.
end for
```

Loops (2)

While loop

The *loop condition* is a condition that is true or false, it may use some variable used elsewhere in the algorithm. The instructions 1, 2, etc. will be executed as long as the *loop condition* remains satisfied (i.e., true).

```
while loop condition do
    instruction 1
    instruction 2
    etc.
end while
```

Return instruction

This instruction returns *result*, and ends the algorithm.
(Note : If you encounter a ***return*** *in the middle of an algorithm,* ***THE FOLLOWING INSTRUCTIONS WILL NOT BE EXECUTED !****)*

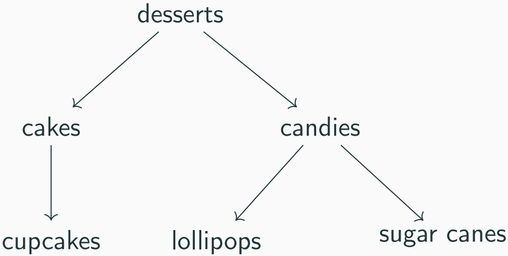
```
return result
```

Note : If you want to return more than one thing, use comas !

```
return result1, result2, result3
```

Trees

Trees : Idea



“I want to organise my desserts !”

- Nox wants to organise its favourite desserts ;
- In a kind of diagram, he draws each subtype of dessert below surtype.
- We have a tree of desserts !

Trees : Definition

Tree

A Tree is a data structure composed of nodes and branches.

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- The unique top node is the root ;

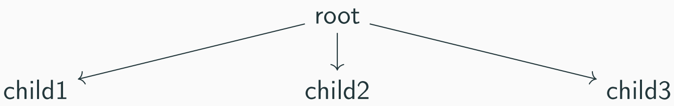
root

Trees : Definition

Tree

A Tree is a data structure composed of nodes and branches.

- The unique top node is the root ;
- Each node may have children (or descendants) nodes ;
- The parent node and its children are linked by branches (arrows from the parent to the child) ;

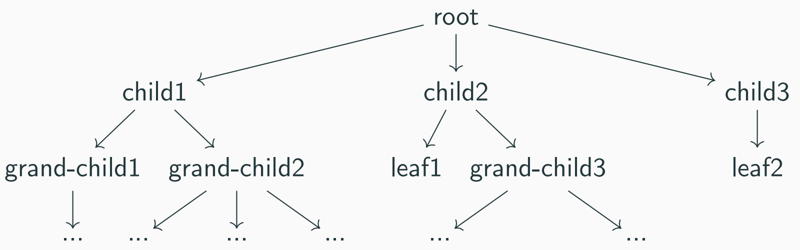


Trees : Definition

Tree

A Tree is a data structure composed of nodes and branches.

- The unique top node is the root ;
- Each node may have children (or descendants) nodes ;
- The parent node and its children are linked by branches (arrows from the parent to the child) ;
- A node that has no child (or descendant) is called a leaf.



Trees : Definition

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- The unique top node is the root ;
- Each node may have children (or descendants) nodes ;
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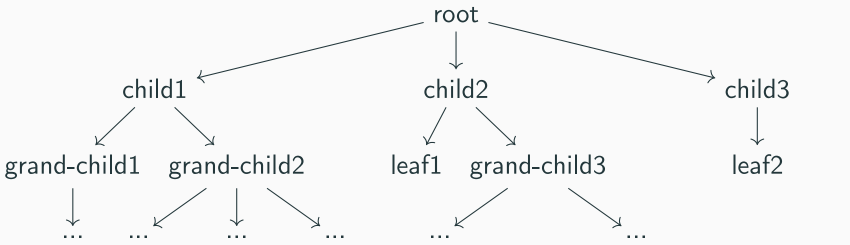
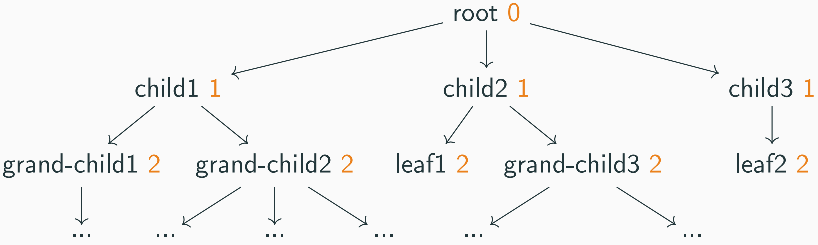
→ *Like a family tree in human life for example*



Trees : Definition

Properties

- The root of a tree is its unique top node ;
- The depth of a node is the number of ancestor it has (the depth of the root is 0) *(cf. the tree below, in orange)* ;
- The height of a tree is the depth of the deepest leaf ;
- If each node of a tree has 0 to 2 children, the tree is said binary.



Trees : Some Formalism

If we consider a set of elements E, we can write $Trees(E)$ the set of all the trees containing elements of E. The empty tree $\{\ \}$ is in $Trees(E)$.

We will consider only binary trees in this class. A tree (or a sub-tree) is characterised by its root, its left sub-tree and its right sub-tree. We represent each tree or sub-tree by a dictionary that has 3 pairs :

$$\{(`root', value), (`left\ child', left\ sub{-}tree), (`right\ child', right\ sub{-}tree)\}$$

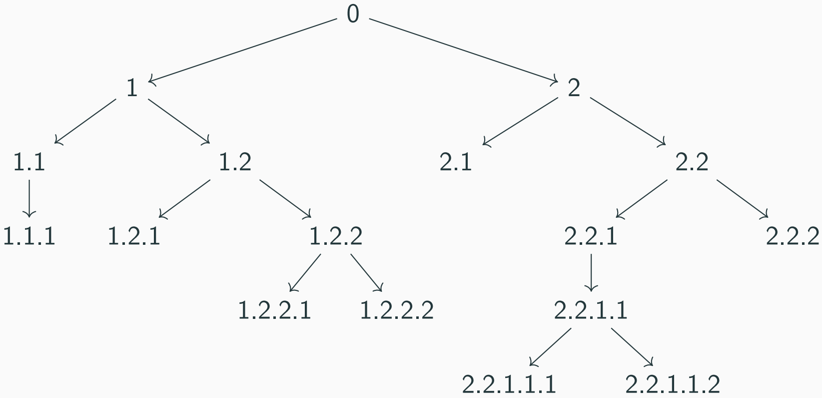
If $e \in E$, and $T \in Trees(E)$, the following operations exist :

Operations

- $isEmpty(T)$ returns *true* if the tree is empty, false otherwise ;
- $T[`root']$ returns the value of root of the tree ;
- $T[`left\ child']$ return the left sub-tree of T (it is a tree) ;
- $T[`right\ child']$ return the right sub-tree of T (it is a tree).

Trees : Some Formalism

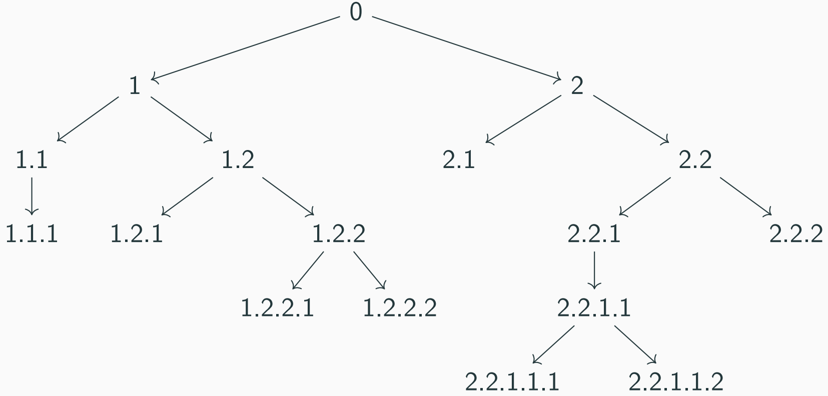
Let T be the following tree.



Trees : Some Formalism

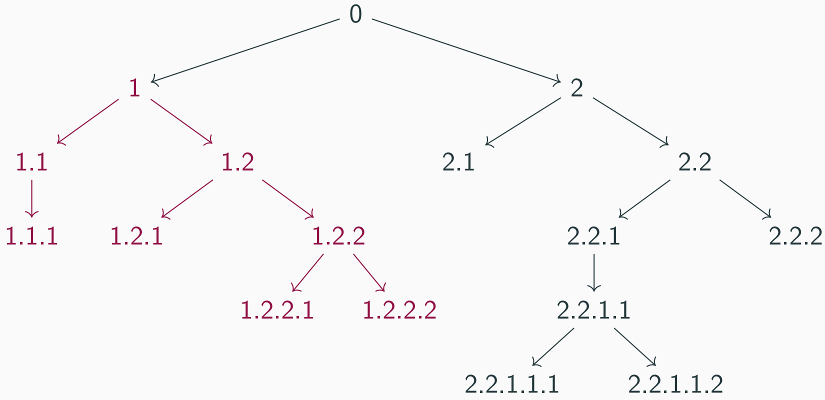
Let T be the following tree. Then :

- $T[\text{‘}root\text{'}] = 0$;
- The height of T is 5.



Let T be the following tree. Then :

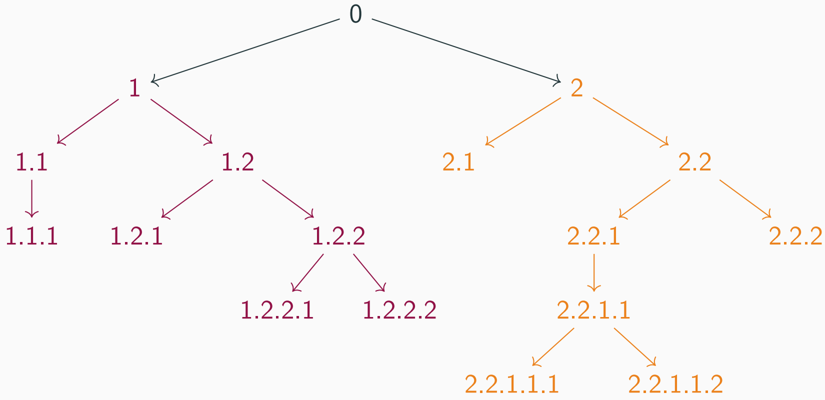
- $T[\text{'}\textit{left child}\text{'}]$ will return the purple tree



Trees : Some Formalism

Let T be the following tree. Then :

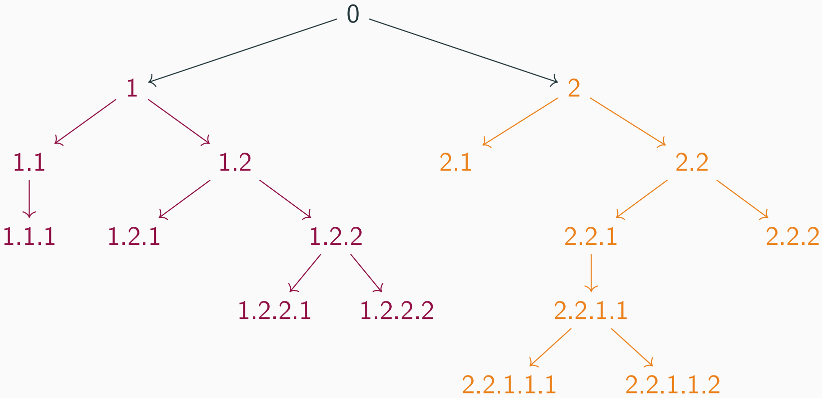
- $T[\text{'}\textit{right child}']$ will return the orange tree



Trees : Some Formalism

Let T be the following tree. Then :

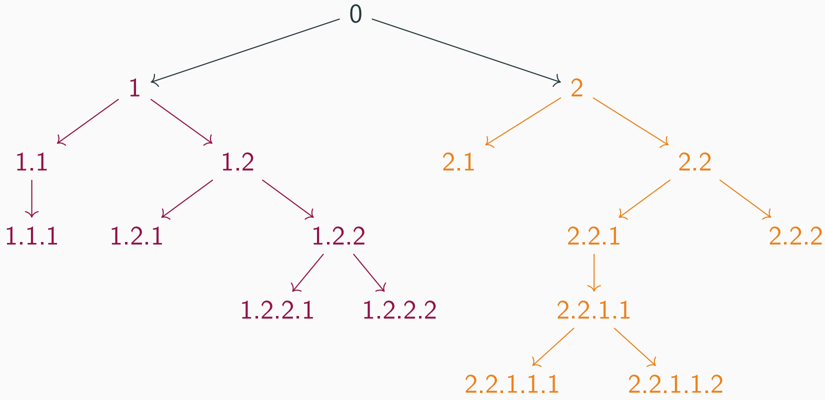
- $T[\text{'}left\ child'][\text{'}right\ child'][\text{'}right\ child'][\text{'}root'] = 1.2.2$



Trees : Some Formalism

Let T be the following tree. Then :

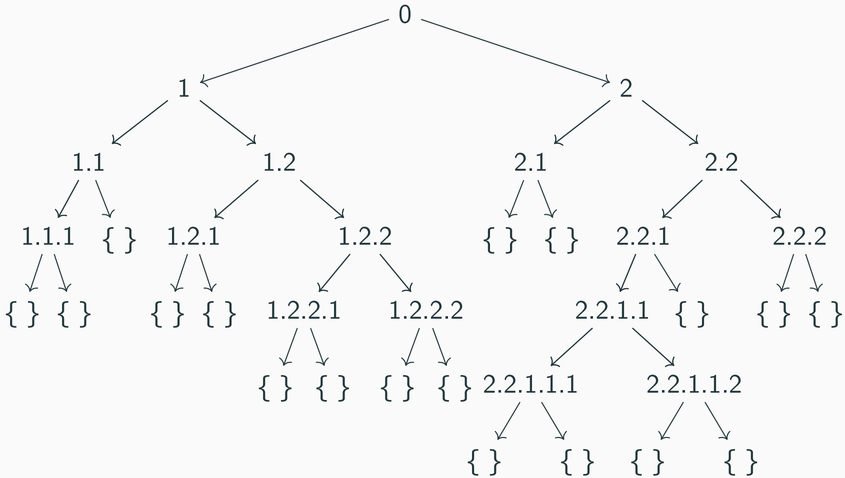
- $isEmpty(T[\text{'}right\ child\text{'}][\text{'}right\ child\text{'}][\text{'}left\ child\text{'}][\text{'}right\ child\text{'}])$
  $= true$



Trees : Some Formalism

Let T be the following tree. Then :

- $isEmpty(T[\text{`}right\ child'][\text{`}right\ child'][\text{`}left\ child'][\text{`}right\ child'])$ $= true$. Indeed, you actually encode this :



Trees : Don't panic

Regarding trees, we expect from you :

- to be able to represent a tree, either in its "drawing" form, or in its dictionary form ;
- to be able to *apply* a given algorithm on a given tree ;
- to understand a given algorithm on trees (and be able to say what it does) ;
- to be able to write a single basic instruction or a basic algorithm ("how do I get the value of *this* node in *this* tree" for instance, for a given tree and node) ;
- to give the *principle* (not the algorithm itself) of an algorithm to answer a question ;

We do not expect from you :

- to write a whole algorithm on trees.

Trees : Example

```
Require: T, value
S ← S_0
add(T, S)
while !isEmpty(S) do
    tree ← get(S)
    remove(S)
    if !isEmpty(tree) then
        if tree['root'] == value then
            return true
        end if
        if !isEmpty(tree['right child']) then
            add(tree['right child'], S)
        end if
        if !isEmpty(tree['left child']) then
            add(tree['left child'], S)
        end if
    end if
end while
return false
```

Question

What does this algorithm do ?

Trees : Example

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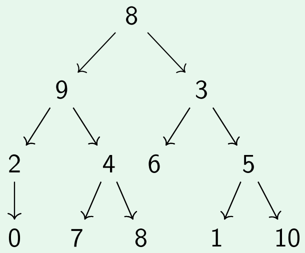
        end if
        if !isEmpty(tree['right child']) then
            add(tree['right child'], S)
        end if
        if !isEmpty(tree['left child']) then
            add(tree['left child'], S)
        end if
    end if
end while
return false
```

Question

What does this algorithm do ?

Try with the following tree and value 5 :



Trees : Example

```
Require: T, value
S ← S_0
add(T, S)
while !isEmpty(S) do
    tree ← get(S)
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    if !isEmpty(tree) then
        if tree['root'] == value then
            return true
        end if
        if !isEmpty(tree['right child']) then
            add(tree['right child'], S)
        end if
        if !isEmpty(tree['left child']) then
            add(tree['left child'], S)
        end if
    end if
end while
return false
```

Question

What does this algorithm do ?

It takes a tree and a value as input, and returns *true* if the input value is the value of one of the node of the input tree, and *false* otherwise.

TD1 Optional Exercise

TD1 Optional Exercise : General Feedback

- Several solutions were possible, we put one of them on Arche ;
- Almost all of you had the right idea/principle concerning your algorithm ;
- Read the question, and follow the given constraint ! If we say "this algo should use at most 2 structures" do not use more than 2 structures ;
- Use the operations and instructions given during the class (no queue.pop(), no unqueue, etc.) ;
- In general, **ALWAYS** comment your algorithm, and **ALWAYS** add a few lines explaining the principle of your algorithm ;

TD1 Optional Exercise : General Feedback

- Several algorithms had syntax problems :
  - A **break** instruction will make you go out of the current loop without taking into the consideration the loop instruction (for loop) or the loop condition (while loop). *If you put a **break** just before a **return**, you will not return for instance. Tip : do not use **break**, but define your loop instruction/condition more precisely* ;
  - If you encounter the instruction **return** while executing (or applying) your algorithm, the execution will stop. All the following instructions will not be executed. *So if you use two **return** one after the other, the second one will never be read* ;
  - If you forgot the **end if**, **end for** or **end while**, make sure you respected the indentation. If you forgot both (the **end** – and the indentation) your algorithm becomes unreadable or false ;

TD1 Optional Exercise : General Feedback

- Several algorithms had queues and stacks related problems :
  - Do not forget that a queue is FIFO, and a stack is LIFO ;
  - If Q is a queue, get(Q) will read the first element of the queue. It will NOT remove it. If you want to remove the element you have to use the instruction remove(Q) (Caution, remove(Q) does NOT read the element.) ;
  - If S is a stack, get(S) will read the last element of the stack. It will NOT remove it. If you want to remove the element you have to use the instruction remove(S) (Caution, remove(S) does NOT read the element.) ;
  - You can't iterate over a queue or a stack. You have to (get the element, and then) remove the element.

Summary

Summary

- Trees are a complex data structure ;
- They are made of nodes and branches ;
- We will consider only binary trees (trees such that each of their nodes has 0 to 2 children) ;
- The unique top node of a tree is the root and a node without any child is a leaf ;
- Each node has a depth and a tree has a height ;
- We have chosen to represent trees with dictionaries ;
- Their root, left child, and right child are accessible via the keys of the dictionary representing them ;
- Do not forget that a sub-tree is also a tree, and thus represented by a dictionary too.