Ministry of Higher Education and Scientific Research
Djilali BOUNAAMA University - Khemis Miliana(UDBKM)
Faculty of Science and Technology
Department of Mathematics and Computer Science

Chapter 2

Subprograms:
Functions and Procedures

MI-L1-UEF121 : Algorithms and Data Structures II

Noureddine AZZOUZA

n.azzouza@univ-dbkm.dz

Course Topics

1. **Modularity**
2. **Passing parameters**
3. **Local variables and global variables**
4. **Functions**
5. **Procedures**

Modularity


source_fuel
fuel_source
air_source
General
Fuel Properties
simulate_aero
aero_volume
aero_points
sources
colliders
influence_fields
settings
adaptivity
collider
collider
geometry
General
Common Properties
Volume Collider Prop...
assign_material
out_geometry
geometry
set_surface
surface_material
set_displacement
displacement_material
set_volume
volume_material
material_reference
aero_solver_settings
solver_settings
combustion_settings
simulation_bounds
General
Aero Solver Globals
Accuracy
Diffusion Handling
"assign_material" Type: Rendering::Materials/assign_material

Modularity

Problem

Combination Calculation

Find the number of combinations of p objects among n such that

$$C_n^p = \frac{n!}{p!*(n-p)!}$$

```
Algorithm Calcul_ Combinaison ;
Var n,p,c : integer ;
      fact_ n, fact_ p, fact_ np: integer;
Begin
   //les entrées
   Read (n,p);

    //manipulation des données
    fact_ n = 1;
   For i := 1 to n Do
        fact_ n := fact_ n * i;

    fact_ p = 1;
   For i := 1 à p Do
        fact_ p := fact_ p * i;

    fact_ np = 1;
    For i := 1 à (n-p) Do
        fact_ np := fact_ np * i;

    c := fact_ n/(fact_ p*fact_ np);

    //les sorties
    Write ('le nombre de combinaisons=',c);
End.
```

Modularity

Problem

Repeating the factorial calculation

$fact\_n = 1;$
For $i := 1$ to n **Do**
    $fact\_n := fact\_n * i;$

$fact\_p = 1;$
For $i := 1$ to p **Do**
    $fact\_p := fact\_p * i;$

$fact\_np = 1;$
For $i := 1$ to $n\text{-}p$ **Do**
    $fact\_np := fact\_np * i;$

How to write the solution only once? Organize the code?

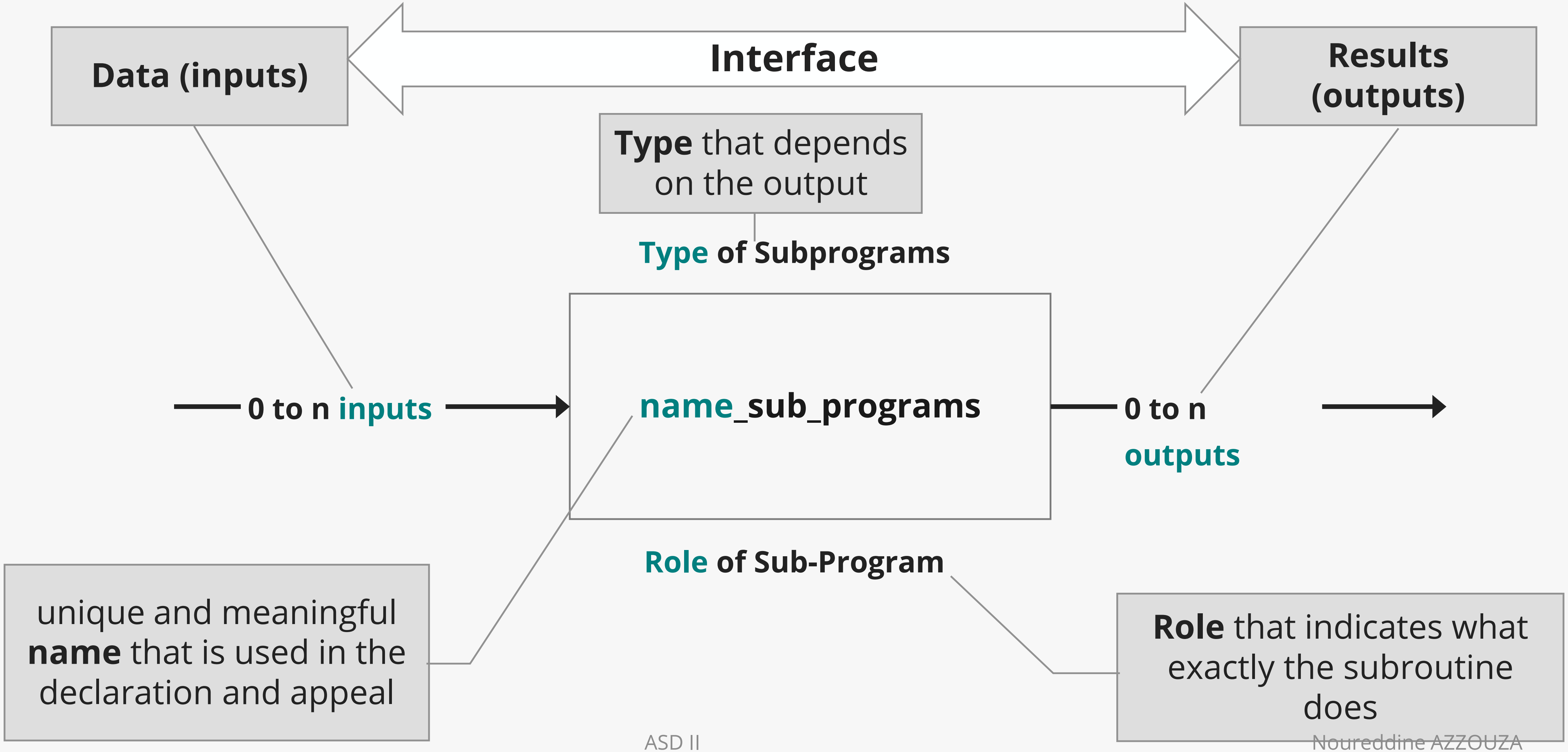
Modules / Subprograms

Modularity

Definition

- ✓ A **subprogram** or module is a set of instructions with a well-defined interface that performs a specific task.
- ✓ The purpose of a subroutine is:
    1. Receive input data
    2. Carry out processing/transformation of this data
    3. Return one or more results
- ✓ The **interface** consists of the inputs/outputs of the module. It makes it possible to establish the link between the module and its environment (main algorithm, other modules).

Structure



Modularity

Types

✓ Depending on the number and type of outputs, there are two (02) types of Subprograms (modules):

1. **Function** : When the module returns a single (1) result and this result is elementary (basic) type data, example:
   - ➢ Function that calculates the sum of an array of integers (return ***an integer***)
   - ➢ Function that checks if a number is prime (return ***a boolean***)
2. **Procedure** : When the module returns 0 to n results or the result is of structured type, examples:
   - ➢ Procedure that displays a matrix (return ***0 result***)
   - ➢ Procedure solves a 2nd degree equation (return ***2 results***)
   - ➢ Procedure that reverses the content of an array(return ***an array***)

Qualities

✓ In order to decide whether a sequence of instructions deserves to be designed in the form of a subroutine or module, the following qualities must be checked:

1. **Reuse**: a module is designed so that it can be reused in several solutions. It must be generalized as much as possible.
2. **Independence**: avoid using global variables in a module so that it is independent of the main algorithm. Same thing for reads and writes.
3. **Simplicity**: keep your code readable and design a module that meets a specific task.

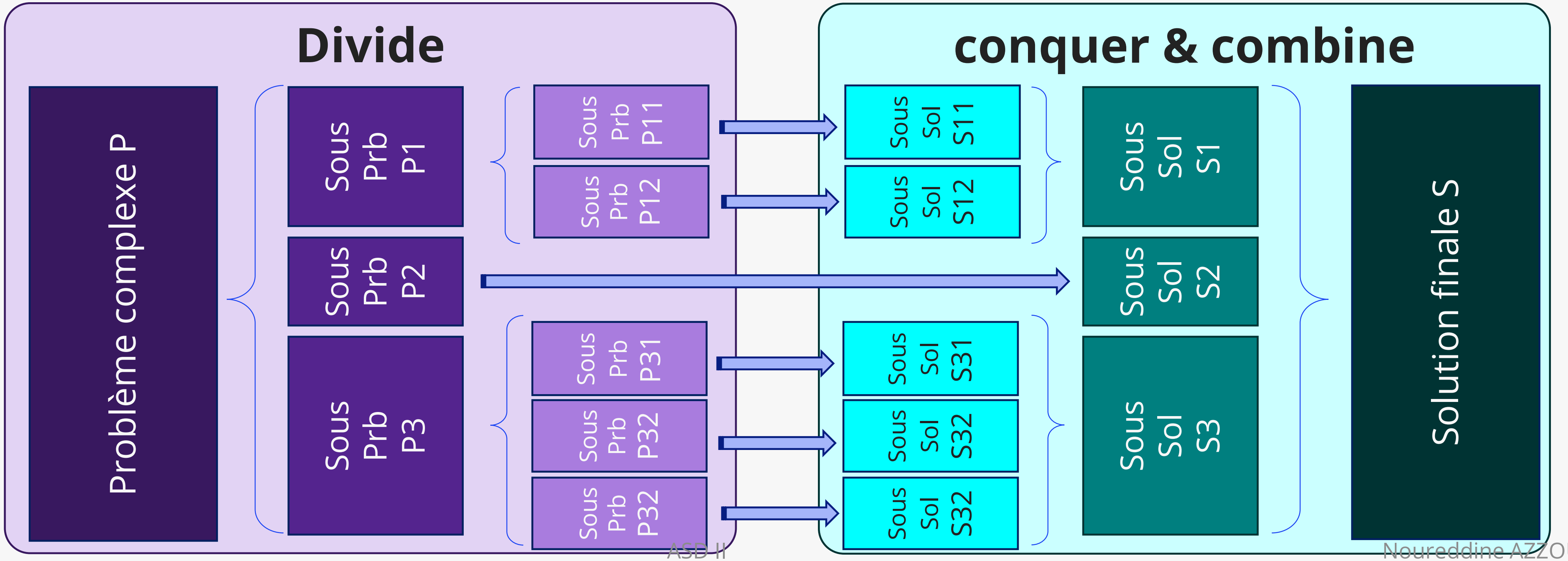
Definitions

- ✓ **Modularity**: "It is a way of thinking aimed at building algorithms starting from a very general level and gradually detailing each treatment, until arriving at the lowest level of description."
- ✓ **Modularity**: is a **Top-down Analysis** which **divides** (cuts) a problem into sub-problems to **conquer** them then **combine** the sub-solutions and obtain an overall result.
- ✓ **Modularity**: the basis of **structured programming** consists of solving a problem by building simple, readable and reusable **modules**.

Modularity

Objectifs / Goals

- ✓ Cut (divide) a complex problem into simple sub-problems which will be solved separately.
- ✓ Propose a solution to a (sub)problem once and only once



Modularity

Modular Approach Stages

1st STEP: Understanding the problem

2nd STEP: Analysis and Design

- Modular Cutting/Split
- Construction of Modules

3rd STEP: Realization

Modular Breaking/Splitting

- ✓ Break the problem into coherent modules:
  - ❑ Start extracting obvious modules that are easy to detect.
  - ❑ Improve and enrich the breakdown as you progress in solving the problem

Build Modules

✓ To build a module, we start with its description:

- ❑ Draw the Module
- ❑ Give it a name
- ❑ Define your interface
- ❑ Specify its nature (function or procedure)
- ❑ Indicate its role

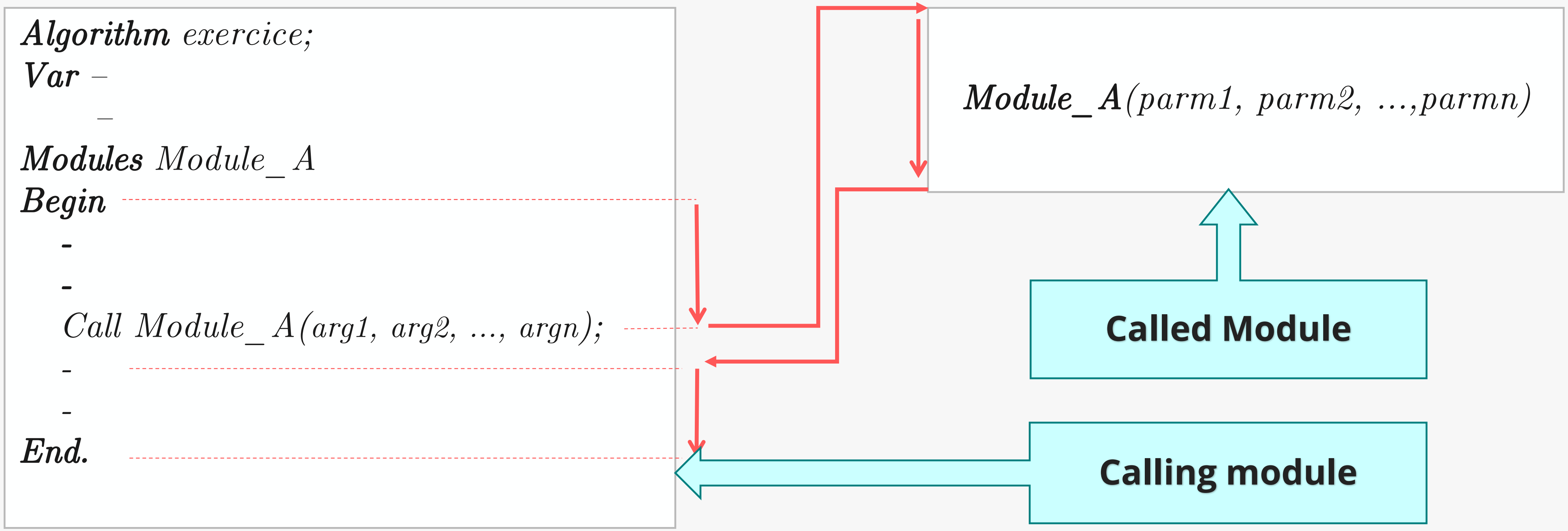
✓ If the module already exists, we do not build it. Its description is given only

Modularity

Avantages / Benefits

- ✓ Cutting into coherent modules is done using a Top-Down Approach
- ✓ Simplifies design
- ✓ Independent and separate construction of modules
- ✓ Readability and ease of understanding of algorithms
- ✓ Ease of maintenance and code updating
- ✓ Reuse of modules (Subprograms) already designed

Communication between Modules



✓ When a **call** to a module is encountered,

- ❑ Suspend the execution of the ***calling module*** (For example: Main algorithm)
- ❑ Start and run the ***called module*** (For example: Module_A)
- ❑ Resume execution of the calling module just after the calling instruction

Communication

Parameters and Arguments

- ✓ The variables used during the construction of the module (subroutine header) are called ***Parameters*** or ***formal parameters***
  - ❑ **Example** : les paramètres (ou paramètre formels) du module « **Module_A** » sont : $parm1,\ parm2,\ \ldots,parmn$
- ✓ The variables used when calling (using) a module are called ***Effective parameters*** or ***arguments***. They replace the formal parameters during the call.
  - ❑ **Example** : les arguments (ou paramètre effectifs) du module « **Module_A** » utilisés dans son appel à l'algorithme principale sont : $arg1,\ arg2,\ \ldots,\ argn$
- ✓ The ***number*** of arguments must match the number of parameters.
- ✓ The ***order*** of arguments must match the order of parameters.
- ✓ The ***type*** of the k_{th} argument must match the type of the k_{th} parameter.
- ✓ The correspondence between arguments and parameters is done using the ***order***.

Params Passing Modes

Parameters Passing Modes

- ✓ It is the ***substitution*** of ***formal*** parameters by an ***effective*** parameters when calling a subprogram.
- ✓ On distingue deux mode de passage :
  - ❑ ***Passing by Value***: Any modification of the content of the parameter in the called program has no effect on the value of the effective parameter in the calling program.
  - ❑ ***Passing by Variable (by Reference)***: any modification of the content of the formal parameter automatically results in the modification of the effective parameter.
- ✓ formal parameters passed by variable are preceded by the keyword ***VAR*** in the header of the

type_module nom_fonction (Formal input parameters; ***VAR*** *Formal output parameters);*

Passing by Value

- ✓ Copy the argument values to the start of the subprogram.
- ✓ This is in fact an assignment of the values of the arguments in the associated formal parameters.
- ✓ Can receive any expression (constant, variable, expression, function call, etc.)
- ✓ Peut recevoir n'importe qu'elle expression (constant, variable, expression, appel de fonct …)

❑ **Example** subroutine (function) which calculate the area of a rectangle.

Call:

```
surf := Surface (x, y);
```

Module:

```
Function Surface(long, larg:real):real;
Var       S: integer;
Begin
    S := long * larg;
    Surface := S;
End;
```

equivalent to

```
Function Surface(long, larg:real): real;
Var       S: integer;
Begin
    long := x; larg := y;
    S := long * larg;
    Surface := S;
End;
```

Passing by Variable

- ✓ In passing by variable (or reference) the parameter itself becomes the argument,
- ✓ that is, the parameter becomes an alias of the argument.
- ✓ Can only be linked to variables..
  - ❑ **Example** : subroutine (procedure) which swaps (exchanges) the values of two variables..

Call

```
Echange (a, b);
```

équivalent à

Module

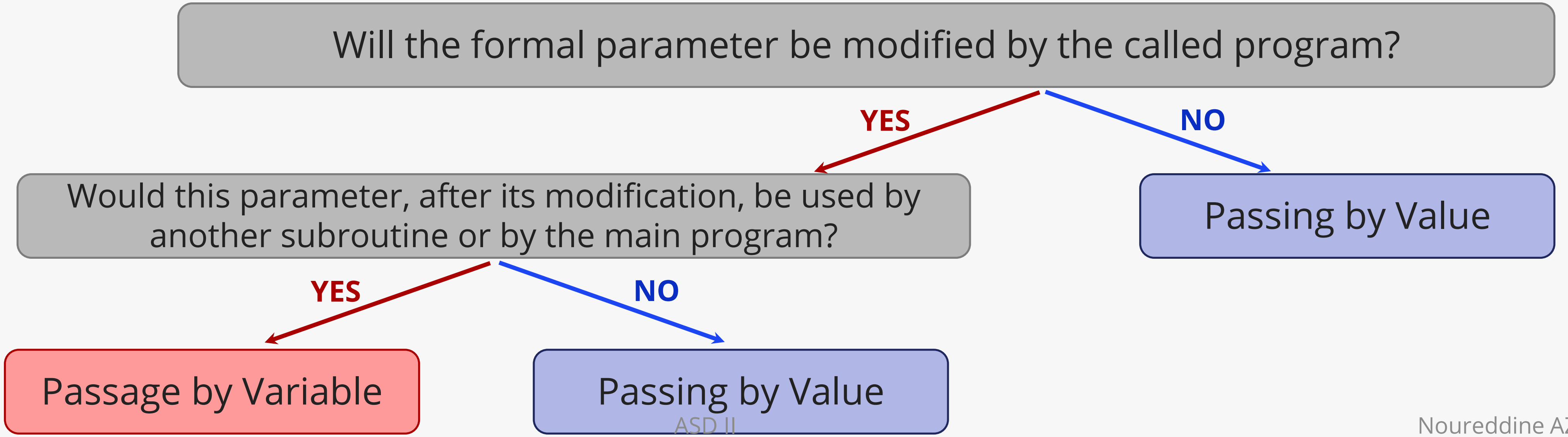
```
Procedure Echange(VAR x, y:integer);
Var      z: integer;
Begin
   z := x;
   x := y;
   y := z;
End;
```

```
Procedure Echange(VAR x, y: integer);
Var      z: integer;
Begin
   z := a;
   a := b;
   b := z;
End;
```

Params Passing Modes

- ***Passing by Value***: is adopted when we want the module to return the **same value** that the parameter had at the input, or the parameter **is not used** in other modules (useless to find the final result).

- ***Passage by Variable (by Reference)***: is adopted when the input parameter **is modified** during the execution of a subroutine and it is the **modified content** of the parameter that we want.



Notes

- It is recommended to use:

- A **passing by values** for the **input** parameters of a **function**.

- A **passing per variable** for all the **output** parameters of a **procedure**.

Local Variables and Global Variables

There are two categories of variables:

- ➢ ***Local Variables***: which are defined in a module and which can only be manipulated in this module.
- ➢ ***Global Variables***: which are defined in a calling module and can be manipulated in this module and in all modules called by this module.

- ❑ **The scope**: of a variable is the set of modules where this variable is accessible (or defined).

Local Variables and Global Variables

```
Module_Appelant
Var     A, B, X: real;
    Module_1
    Var     X: integer;
            T: booléen;
        Module_2
        Var     C: integer;
    Module_3
    Var     X, Y, Z: integer;
Begin
    -
    -
End;
```

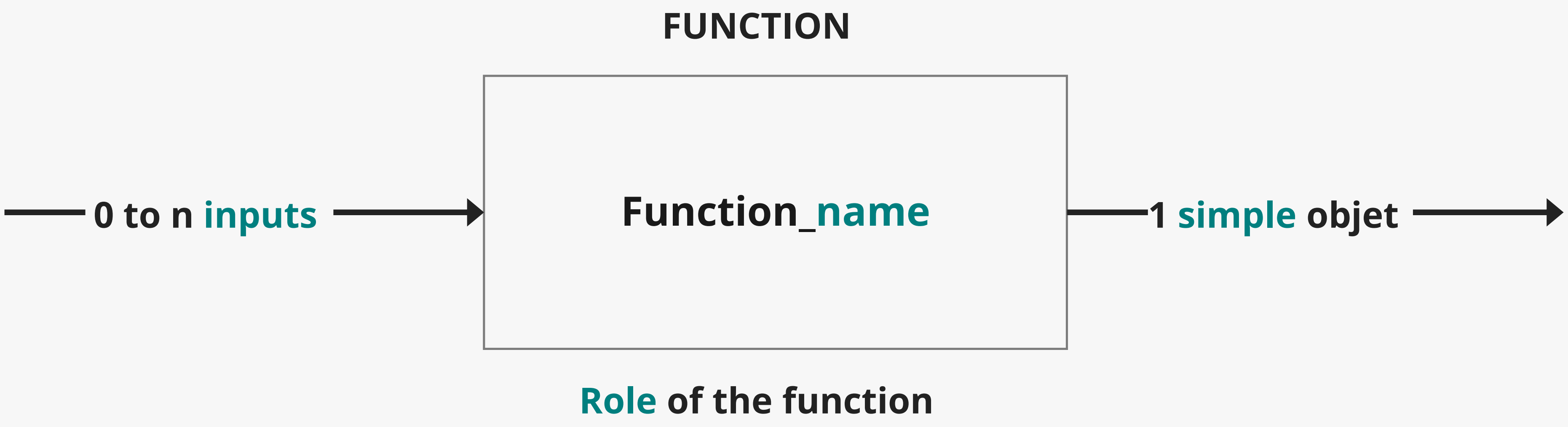
Variable	Scope (Portée)
A,B	Module_Appelant , Module_1, Module_2, Module_3
T	Module_1, Module_2
C	Module_2
X:déclaré au Module_Appelant	Module_Appelant
X:déclaré au Module_1	Module_1, Module_2
X:déclaré au Module_3	Module_3
Y, Z	Module_3

Functions


$host;
$username;
$password;
$database;
$charset;
= null;
connect()
mysql_connect(self::
throw new MysqlException(

Definition and Description

- ✓ A function is a sub-programme (subroutine or module) which returns a single result (single output) of simple (elementary) type: integer, real, boolean, character. It can receive 0 to n input parameters.



Description of a fuonction

Structure and Syntax

Header

Function fonction_ name (List of formal input parameters :Type): Return Type;

Body

Type –
Const –
Var –

{ **Déclaration des données (objets) locales** }

Begin
-
-
-
-
-

{ **Traitements** }

- *fonction_ name := Result;*

End;

Properties & Notes

- ✓ The body of a function can contain all **declarations** (Type, Const, Var, etc.) and algorithmic **structures** (Assignment, Repetition, Conditional, etc.).
- ✓ The calculated result (return value) must be **passed in the function name**. This assignment is located – in most cases – at the end of the function.
- ✓ **Formal parameters** describe the input parameters used in the function as well as their **type** and their passing **mode**.
- ✓ In Functions, formal parameters are used in **passing-by-value** mode.

Calls

- ✓ Calling a function can be used as:
  - ❑ ***Expression*** in an **assignment,**
  - ❑ ***Operand*** in a **condition**
  - ❑ ***Argument*** in a **procedure** or **function call**
- ✓ **Examples:**
  - ❑ X $:=$ Prime (a)
  - ❑ if Prime (a) = True then write (a, ‘is prime’)
  - ❑ Res $:=$ Prime (Fact(n))

1st Step : Split Modules

Function : Fact

Fact (n) = n!
= n*(n-1)*….*3*2*1

FUNCTION

n: integer → **Fact** → integer

Role : Retour the factoriel of **n** (n!)

Function : Comb

Comb (n,p) = $C_n^p = \frac{n!}{p! * (n-p)!}$

= Fact(n)/Fact(p)*Fact(n-p)

FUNCTION

n: integer →
p: integer → **Comb** → integer

Role : return the num of combinaison of **p** objets from **n**

Example: Calcul of Combinaisons

2nd Step: Construction of modules

```
Function Fact (n: integer): integer;
Var       F, i: integer;
Begin
    F := 1;
    for i := 1 to n Do
            F := F * i;

     Fact := F;
End;
```

```
Function Comb (n , p: integer): integer;
Functions :   Fact;
Begin
    Comb := Fact(n)/ Fact(p)* Fact(n-p);
End;
```

3rd Step: Main Algorithm

```
Algorithm Calcul_comb;
Var        x,y,c: integer;
Functions : Comb;
Begin
    Read(x,y);
    c := Comb(x,y);
    Write ('Le nombre de combinaison = ', c);
End;
```

Function declaration

PASCAL

FUNCTION nom_fonction (Input parameters): type_retour;
var { *Déclaration des données locales* }
begin
- { *Instructions* }
-
-

nom_fonction := valeur_retour;
fin;

```pascal
function Fact(n: integer) : integer;
 var F,i : integer;
 begin
   F := 1;
   for i := 2 to n do
       F := F*i;

   Fact := F;
 end;
```

C

type_retour nom_fonction (Input parameters)
{ { *Déclaration des données locales* }
- { *Instructions* }
-
-
-

return valeur_retour;
}

```c
int Fact (int n)
{
    int F , i;
    F = 1;
    for (i=2; i<=n; i++){
        F = F*i;
    }

    return F;
}
```

PASCAL

- ✓ In PASCAL, Functions and procedures must be declared **before** the main program.
- ✓ In general, each called module must be constructed **before** the calling module for it to be **recognized**.
- ✓ In this example:
  - ❑ A ***Call*** to a Fact function (line **17**)
  - ❑ **n**: ***parameter*** (***formal*** parameter) (line **5**)
  - ❑ **x**: ***argument*** (***effective*** parameter)(line **17**)

```
1  program factoriel;
2   uses Crt;
3   var x : integer;
4
5   function Fact(n: integer) : integer;
6    var F,i : integer;
7    begin
8      F := 1;
9      for i := 2 to n do
10         F := F*i;
11
12     Fact := F;
13   end;
14
15 begin
16   Readln(x);
17   Writeln(x,'! =', Fact(x));
18 end.
```

Function declaration

Programmation C / PASCAL

C

- ✓ In C language, Functions and procedures can be declared **before** and **after** the *main* function.
- ✓ If the function is placed **before** the *main* , the compiler checks the parameters and executes the function.
- ✓ If the function is placed **after** the *main* , we need to define a **prototype** of the function for it to be recognized.

```c
#include <stdio.h>

int Fact (int n)
{
    int F , i;
    F = 1;
    for (i=2; i<=n; i++){
        F = F*i;
    }

    return F;
}

int main()
{
    int x;
    scanf("%d", &x);
    printf("%d! = %d", x, Fact(x));

    return 0;
}
```

Function declaration

C

- ✓ **A prototype** is a function declaration so that it can be used (called) even before it is coded.
- ✓ The prototype is placed at the **beginning of the program** (just after the libraries declaration).
- ✓ A prototype is declared as a function

type_retour nom_fonction (Input parameters)

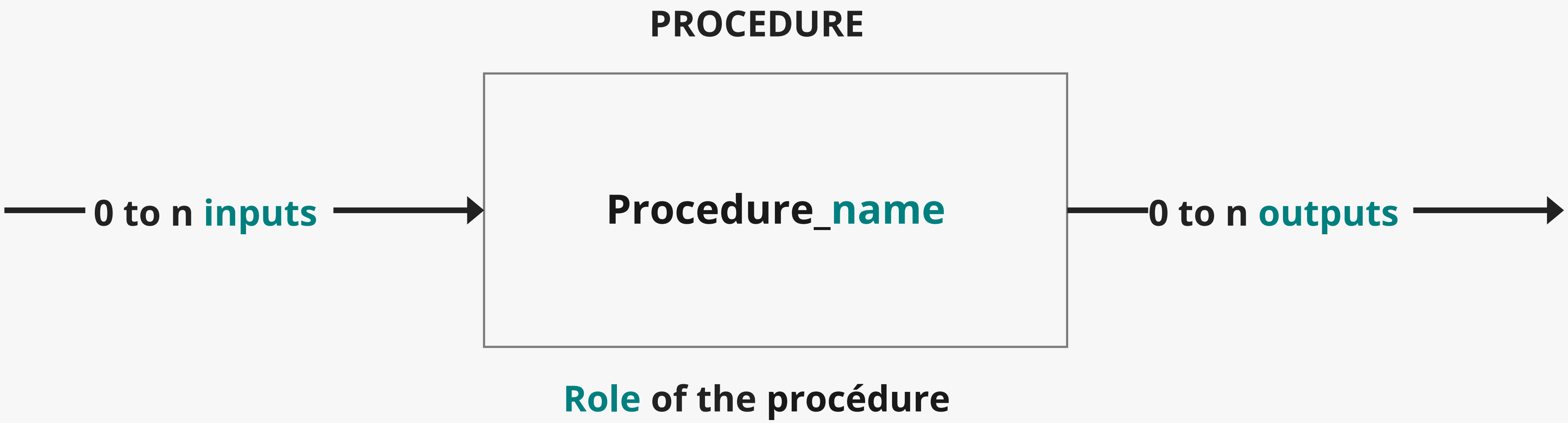
```c
#include <stdio.h>

int Fact (int n);

int main()
{
    int x;
    scanf("%d", &x);
    printf("%d! = %d", x, Fact(x));

    return 0;
}

int Fact (int n)
{
    int F , i;
    F = 1;
    for (i=2; i<=n; i++){
        F = F*i;
    }

    return F;
}
```

Procedures


string sInput;
int iLength, iN;
double dblTemp;
bool again = true;
while (again) {
iN = -1;
again = false;
getline(cin, sInput);
system("cls");
again = true;
continue;
} else if (sInput[iLength - 3] !=
again = true;
continue;
} while (++iN < iLength) {
if (isdigit(sInput[iN])) {
continue;
} else if (iN == (iLength -

Definition and Description

✓ A procedure is a sous-programme (subroutine or module) which returns 0 to n results (multiple output) of simple or compound type. It can receive 0 to n input parameters.



Description of a procedure

Structure & Syntax

Header

Procedure procedure_ name (List of formels input and output parameters :Type);

Body

Type –
Const –
Var –

{ **Déclaration des données (objets) locales** }

Begin
-
-
-
-
-
End;

{ **Traitements** }

Procedures

Properties & Notes

- ✓ The body of a procedure can contain all **declarations** (Type, Const, Var, etc.) and algorithmic **structures** (Assignment, Repetition, Conditional, etc.).
- ✓ The **formal parameters** describe the **input** and **output** parameters used in the procedure as well as their **type** and their **passing mode**.
- ✓ In Procedures, formal **output** parameters must always be described in a **passing-by-variable** mode.

Calls

- ✓ Calling a procedure is a **primitive action**. It is composed of the name of the procedure followed in parentheses by the list of effec tive input and output parameters separated by commas.
- ✓ As for functions, the **number**, **order**, and **type** of the effective paramete rs must be identical to those of the formal parameters.
- ✓ **Examples:**
  - ❑ remplir_tab (n, T)
  - ❑ echange (x, y)

Example: Convert a time T (in seconds) to hours, minutes and seconds

1st Step : Split Modules

Procedure: convert_temps

convert_temps (T, h, m, s)

1. On divise T sur 360 : le quotient est h
2. Le reste de cette division est divisé sur 60
    a. Le quotient est m
    b. Le reste est s

PROCEDURE

Role : Converts a time T (in seconds) into h hours, m minutes and s seconds

Functions

2nd Step: Construction of modules

```
Procedure convert_temps (T: integer; VAR h, m, s : integer);
Var      R: integer;
Begin
    h := T DIV 3600;
    R := T MOD 3600;
    m := R DIV 60;
    s := R MOD 60;
End;
```

Example: Convert a time T (in seconds) to hours, minutes and seconds

3rd Step: Main Algorithm

```
Algorithm Convert;
Var        A, x, y, z: integer;
Procedures : convert_temps;
Begin
    Read(A);
    convert_temps(A, x, y, z);
    Write (A,'=',x,'heures et ',y,' minutes et ',z,'secondes');
End;
```

Exemple: Convertir un temps T (en secondes) en heures, minutes et secondes

PASCAL

PROCEDURE nom_procedure (Input/output parameters);
var {Déclaration des données locales}
begin
\-
\- {Instructions}
\-
\-
fin;

```
procedure convert_temps(T: integer; VAR h,m,s: integer);
 var R : integer;
 begin
   h := T DIV 3600;
   R := T MOD 3600;
   m := R DIV 60;
   s := R MOD 60;
 end;
```

C

void nom_fonction (Input/output parameters)
{ {Déclaration des données locales}
\-
\- {Instructions}
\-
\-
\-
}

```
void convert_temps (int T, int *h, int *m, int *s)
{
     int R;

     *h = T / 3600;
     R = T % 3600;
     *m = R / 60;
     *s = R % 60;
}
```

Declaration of a Procedure

PASCAL

✓ Dans cet exemple:

- ❑ Un ***Appel*** d'une procédure convert_temps (ligne **5**)
- ❑ **T** : ***paramètre*** (paramètre ***formel*** d'entrée) (ligne **5**)
- ❑ **h,m,s** : ***paramètre*** (paramètre ***formel*** de sortie) (ligne **5**)
- ❑ **A** : ***argument*** (paramètre ***effectif***) d'entrée (ligne **17**)
- ❑ **x,y,z** : ***argument*** (paramètre ***effectif***) de sortie (ligne **17**)

```
1  program Convert;
2   uses Crt;
3   var A,x,y,z : integer;
4
5   procedure convert_temps(T: integer; VAR h,m,s: integer);
6    var R : integer;
7    begin
8      h := T DIV 3600;
9      R := T MOD 3600;
10     m := R DIV 60;
11     s := R MOD 60;
12   end;
13
14 begin
15   Readln(A);
16   convert_temps(A, x, y, z);
17   Writeln(A,'=',x,'heures et ',y,' minutes et ',z,'secondes');
18 end.
```

Declaration of a Procedure

C

- ✓ In C language, the return type of procedures is specified as *void*.
- ✓ When declaring the procedure, formal output parameters are preceded by *****.
- ✓ When calling this procedure, the effective output parameters are preceded by **&**.

```c
#include <stdio.h>

void convert_temps (int T, int *h, int *m, int *s);

int main()
{
    int A, x, y, z;
    scanf("%d", &A);
    convert_temps(A, &x, &y, &z);
    printf("%d = %d heures et %d minutes et %d secondes", A, x, y, z);

    return 0;
}

void convert_temps (int T, int *h, int *m, int *s)
{
    int R;

    *h = T / 3600;
    R = T % 3600;
    *m = R / 60;
    *s = R % 60;
}
```