Chapter 5: Arrays and Strings

1. Some notions:(reminder)

1.1. Identifier:

- An identifier designates the name of a variable, constant, data type, procedure or function…

1.2. Variable:

- A variable has a name, a type, and a value.

1.3. Kind :

- The data can be simple or structured types, in addition there is the possibility of defining new data types.
  - ✓ Simple types:

  Example : integer, real, character, boolean
  - ✓ Structured Types:

Example: Arrays, String, Record…

2. Arrays

- An array is a data structure grouping together a fixed number of variables of the same type.

2.1. Vectors: (one-dimensional array)

Statement : To declare a vector, we use the following syntax:

Nom_vect **[**size**]**: **array of** type

1) **We can specify the size by a positive integer:**

V [20]: array of integers;

2) **Or using positive integer constant:**

CONST n←10;

V [n]: array of integers;

Representation of a Vector:

12.5	3.9	0.8	1.13	2.0	0.0	5.0	1.2	0.1	0.5
i=1	i=2	i=3	i= 4	i=5	i=6	i=7	i=8	i=9	i=10

V[5] = 2.0

The index can be:

- A Value: V [5]
- An integer variable : V [i]

- An expression of integer type : V [i*2+1]

Example :

Write an algorithm that reads the averages of 25 students, then calculates the difference between the average of each student and that of the group average?

ALGORITHM Exp_Vect

CONST n ← 25;

VMOY [n]: array of real;
i: integer;
SMOY, MOYG: real;
Begin
// Load (read) the array

For i = 1 to n **Do**
  Write ("give the average of the student N°", i)
  Read (VMOY [i])
End For

// Calculate the group average

SMOY ← 0;
For i = 1 to n Do
  SMOY ← SMOY+VMOY[i] ;
End for
MOYG ← SMOY/N;
Write ("the average of the group is ", **MOYG**)

/*Calculate the difference between the average of the group and that of the student*/

For i = 1 to n **Do**
Write ("the difference of the average of the group and that of the student", i, "is=", MOYG - VMOY[i]);
End for
END.
We can write the first two loops in one; to simplify this algorithm.

Noticed :

- The size of an array is fixed and therefore cannot be changed in a program: this results in two faults:
  - ✓ If you limit the size of an array too much, you risk overflowing.
  - ✓ The reserved memory space is insufficient to receive all the data

2.2. Search methods in a vector:

a) Finding the maximum of a vector:

- It consists in defining the largest element of a vector
- For that, we must traverse the vector by preserving with each iteration the largest element obtained,
- At the end, we obtain the maximum of all the elements.

Algorithm Search_max

Const sizeM ←100; // the maximum size of the array

Vect [sizeM]: real arrays;

Max: real;

i,n: integer; // n represents the actual number of elements

Begin

//after reading n which represents the number of elements that we are going to read

//It is assumed that the **n** elements of the vector have already been read.

Max ← vector[1]; //we assume that the first element is the maximum

For i =**2** to **n** do // we start from the 2nd element

If vector[i] > max **then**

Max ← vector[i];

End if

End for;

Write ('the maximum is ', **Max**);

END.

b) Sequential search:

- One of the first operations on the arrays is the search for an element, its number of appearance, its or their positions.
- To do this, we must traverse the entire vector element by element and compare it with the value of the element to be sought.

<u>Example:</u>

1. Find the position of the first occurrence of the element 5 in vector V containing n integer elements.

Algorithm search1

Const n←10;

V[n]: Array of integer;

i: integer;

```
Begin
// assume that the elements of the vector have already been read.
// Find the position of the first occurrence of element 5
i←1;
While (i<= n and V[i] ≠5) do
  i←i+1;
end while
 If (i>n) then
  Write ("Element not found");
 else
  Write ("The position of the element is:", i);
 End if
END.
```

2. Find the number of occurrences of element **5** in a vector V containing **n** elements, as well as the **positions** of the occurrences of this element?

```
Algorithm search2
Const n←10;
V[n]: Array of integer;
i, nba: integer;
Begin
//read the elements of the array
For i = 1 to n Do
 Write ("give the element N°", i);
 Read (V [i]);
End for
// End of loading
i←1; count←0;
While (i<=n) do
  If ( V[i] = 5 ) then
     count ←count+1;
     write ("the position of occurrence 5 is", i);
  end if
  i←i+1;
end while
```

Write ("the number of occurrences of 5 is:”, **count**);

END.

c) Dichotomous search:

- This type of search is performed in an **ordered** array:

  1) The array is **divided** into **two** roughly equal parts,
  2) We compare the value to look for with the element in the **middle**,
  3) If they are not equal, we are interested only in the part containing the desired elements and we abandon the other part.
  4) We repeat these 3 steps until we obtain the value or we have only one element to compare.

Application :

We assume that we have a vector V of n elements. We want to find the value **Val**?

```
Algorithm rech_dich
Const n←100;
V[n]: Array of integer;
Iinf, Isup, Imil, Val: integer;
Found: Boolean;
Begin
Iinf ← 1; Isup ← n;
Found ← false;
While ((Iinf <= Isup) and (Found = false )) Do
   Imil ← (Iinf+Isup) div 2;
  If (V[Imil] = Val) Then
     Found ← true;
  Else
   If (V [Imil] < Val) Then
     Iinf ← Imil + 1;
   Else
     Isup ← Imil -1;
   End if
 End if
end while
If (Found = true) Then
  Write (Val, "exists at position", Imil);
```

Else

Write (Val, "does not exist in V");

End if

END.

2.3. Sorting methods in a vector:

- Sorting a vector consists of ordering it according to one direction, from the smallest to the largest or the opposite direction.

Example :

7	5	8	3	2	9

- Sort ascending order:

2	3	5	7	8	9

- Sort descending order:

9	8	7	5	3	2

a) Sorting by bubbles:(by exchange)

- It consists in carrying out a certain number of traversals of the vector to be sorted.
- A traversal consists of going from one end of the vector to the other by comparing two successive elements and by permuting them if they are not ordered.
- This comparison goes up in the vector like a bubble by dragging the extremum (maximum or minimum).

Example:

- **1st step**

7	5	1	9	2	3

5	7	1	9	2	3

5	1	7	9	2	3

5	1	7	2	9	3

5	1	7	2	3	9

- **2nd step**

5	1	7	2	3	9

1	5	7	2	3	9

1	5	7	2	3	9

1	5	2	7	3	9

1	5	2	3	7	9

➢ **3rd step**

1	5	2	3	7	9

1	5	2	3	7	9

1	2	5	3	7	9

1	2	3	5	7	9

1	2	3	5	7	9

1	2	3	5	7	9

➢ **4th step**

We do the same, we find that we have nothing to sort, so the vector is sorted.

Algorithm TriBubble
const n← 6;
V[n]: integer array;
i: integer;
Sort: boolean;
Begin
//we assume that the array is already read
Repeat
 Sort ← True;
 For i = 1 **to** n - 1 **do**
  If (V[i] > V[i+1]) **then**
   X ← V[i];
   T[i] ← V[i+1];
   V[i+1] ← x;
   Sort ← False;
  End if
 End for
Until (Sort=True);

END.

b) Sort by selection:

➢ This method consists of finding the minimum and placing it in the first position.

➢ Iterate through the rest of the values to find the next smallest element and place it in the next position and so on.

Remarks :

-For convenience, we consider all values to be distinct in the following algorithm.

-We can find the maximum and place it at the end, and so on.

Example

7	5	8	9	2	3

First we are looking for the maximum for the 6 elements which is 9, so we will put it in the last box of the table

~~7~~	~~5~~	~~8~~	~~3~~	~~2~~	9

We performed n-1 operation to find the max with n=6.
Now we only talk about the 5 elements
Second we seek the max in the remaining (6-1) elements which is 8 and we place it in the 5th position and we obtain the new array

~~7~~	~~5~~	~~2~~	~~3~~	8	9

We performed n-2 operations to find the max with n=6.
Then we go to (6-2)=4 elements of the array

3rd we do the same thing for the 4 remaining elements so 7 is the maximum, we place it in position 4 and we obtain the following table:

~~3~~	~~5~~	~~2~~	7	8	9

We performed n-3 operations to find the max with n=6.

4th we iterate the same thing, so the max is 5 for the (6-3)=3, we place 5 at position 3.

~~3~~	~~2~~	5	7	8	9

We performed n-4 operations to find the max with n=6.

5th same thing as before, we seek the max in the (6-4)=2 remaining elements and we obtain 3, we place it at position 2.

~~2~~	3	5	7	8	9

We performed n-5 operations to find the max with n=6.

6th we seek the max with the last remaining element of the array which remains the same.

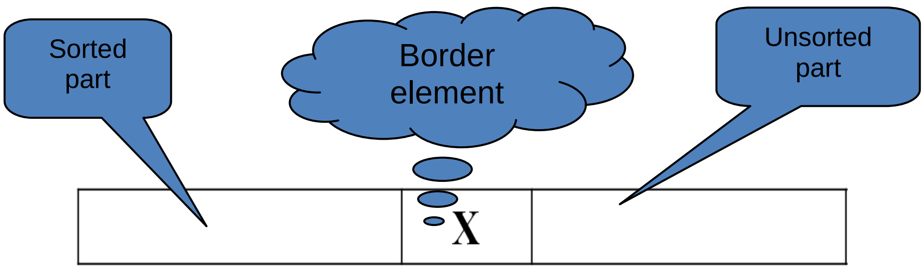
2	3	5	7	8	9

Finally we get the sorted array.
So the number of operations is 1+2+3+4+5 which is a numerical sequence whose sum is:
(n-1) n/2.

Algorithm TriSelection
const n← 6;
V[n]: integer array;
i, j, Min, Pos: integer;
Begin
//we assume that the array is already read
For i =1 to n do
Min←T[i];
Pos ← i;
For j= i+1 to n do
 If T[j] < Min then
  Min ← T[d];
  Pos←j;
 End if;
 endfor;
T[pos] ← T[i] ;
T[i] ← Min;
endfor;
END.

c) Insertion sort:

- It's the sort that everyone naturally uses when they have files (or anything else) to classify.
- We take a file and put it in its place among the already sorted files. Then we start again with the next file.



- As long as the unsorted part is not empty,
- We take the border element with the unsorted part
- And we insert it in its place in the sorted part and then we move on to the next element.

For i = 2 to n do

/* Store i-value */

x←t[i];

/* Search for the largest index p */

/* less than i such that t[p]<=t[i] */

p←i-1;

While (t[p] > x AND p > 0) **do**

p←p-1;

EndWhile

/* We must insert t[i] just after this box */

p←p+1;

/* Shift values between p and i */

For j = i-1 to p step =-1 do

t[d+1]←t[j];

EndFor

y[p]←x;

End For

2.4. Matrices :(two-dimensional array)

declaration: we have three ways to declare a matrix:

1)

M [5, 10]: array of **real**;

2)

CONST n←5, m←10;

M [n, m]: array of **integer**;

3)

n, m: real;

Mat [n, m]: array of integer;

Representation of a Matrix:

	D=1	D=2	D=3	D=4	D=5	D=6	D=7	D=8	D=9	D=10
I=1	-4	3	14	6	67	4	2	0	7	2
I=2	1	2	3	4	5	6	7	8	9	10
I=3	9	9	3	87	76	5	2	2	2	1
I=4	1	3	2	4	- 5	6	7	8	9	4
I=5	9	9	7	8	9	-7	-1	3	5	17

The element of index [i,j] is that of the intersection of row i with column j

M[4,5] is -5

Example :

Let Mat(n,m) be a matrix of **n** x **m** real elements. Write an algorithm that calculates the largest (max) and smallest (min) elements of the matrix?

Algorithm maxmin

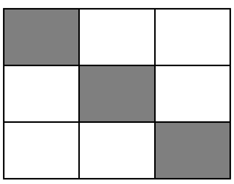
Const n←10, m←12;

Mat [n, m]: real array;

```
max, min: real;
i, j: integer;
Begin
//Read the elements of the matrix
For i = 1 to n do
  For j = 1 to m do
    Read (mat[i,j]);
 End for
End for
// calculate from largest (max) and smallest (min)
max← mat[1, 1]; min←mat[1.1];
For i = 1 to n do
 For j = 1 to m do
    If (mat[i, j] >max) then
      max ← mat[i, j];
    end if
    If (mat[i][j] <min) then
      min ← mat[i, j];
    end if
  End For
End For
Write ("the largest value of the matrix", max);
Write ("the smallest value of the matrix", min);
END.
```

<u>Noticed :</u>

- ***square matrix***: a matrix whose number of rows is equal to the number of columns.
- Such a matrix has a ***main diagonal*** (all elements for which i=j).
- Elements above the diagonal have their indices i<j and those below the diagonal have their indices i>j.



3. Strings:

- A String is a sequence of characters, that is to say a set of symbols belonging to the character set, defined by the ASCII code, UTF8 etc.
- Some languages (Pascal, Java, Basic...) have a real string type (String).
- In the C++ language, there is no type of variable for strings as there is for integers (int) or for characters (char).
- The strings are in fact stored in an array of char whose end is marked by a Null character, with value 0 and represented by the character '\0'.

Example :

- In memory, the string "GOOD MORNING" is represented as follows:

G	O	O	D	M	O	R	N	I	N	G	\0

- Everything after the character '\0' will be ignored

3.1. string declarations:

- The declaration of a string is as follows:
  <*Identifier*>: String**;**

Example :

S: String; // S is of type string with a maximum size of 255 characters.

3.2. Reading and writing strings:

- In our course, we will use the following notation for reading (resp.) displaying strings:
  - **Reading :**Read (S);
  - **Display :**Write (S)
- You can display several adjoining strings using the +.

Example :

Algorithm Exp_string

S, R, T: chain;

Begin

S← ' Hello ' ;

R←'ladies';

T←'and gentlemen';

To write(S+R+T); // Will print 'Hello ladies and gentlemen'

END.

Noticed : The + operator represents the concatenation and not the sum.