Arrays

CS10001: Programming & Data Structures

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Array

- Many applications require multiple data items that have common characteristics.
  - In mathematics, we often express such groups of data items in indexed form:
    - $x_1, x_2, x_3, \ldots, x_n$

- Array is a data structure which can represent a collection of data items which have the same data type (float/int/char)

Example: Finding Minima of Numbers

3 numbers

```
if   ((a <= b) && (a <= c))
    min = a;
else
    if   (b <= c)
          min = b;
    else
          min = c;
```

4 numbers

```
if   ((a <= b) && (a <= c) && (a <= d))
    min = a;
else
    if   ((b <= c) && (b <= d))
          min = b;
    else
         if  (c <= d)
              min = c;
        else
             min = d;
```

The Problem

- Suppose we have 10 numbers to handle.
- Or 20.
- Or 100.
- Where do we store the numbers ? Use 100 variables ??
- How to tackle this problem?

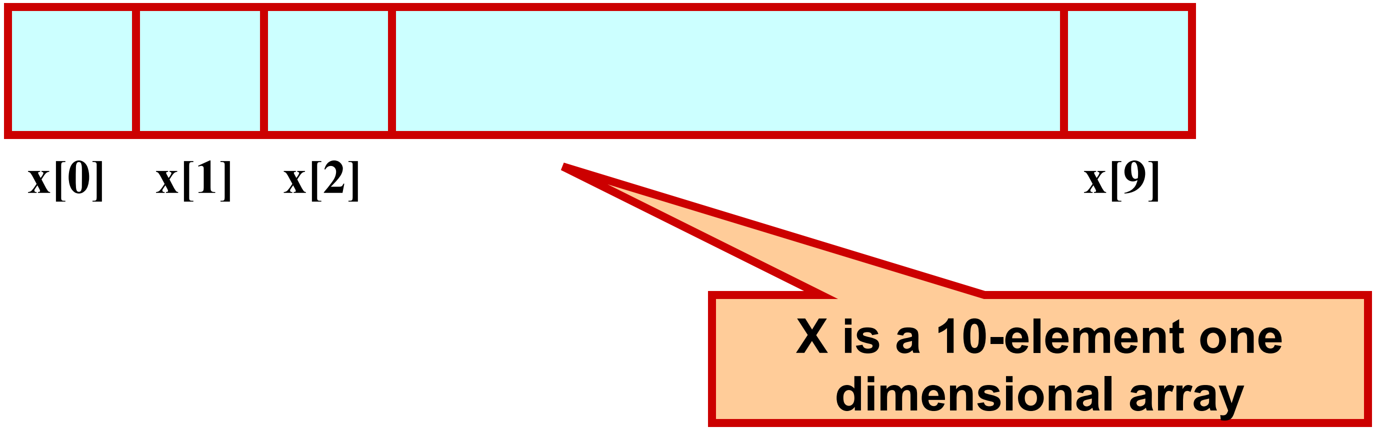
- Solution:
  - Use arrays.

Using Arrays

- All the data items constituting the group share the same name.

```
int  x[10];
```

- Individual elements are accessed by specifying the index.



Declaring Arrays

- Like variables, the arrays that are used in a program must be declared before they are used.
- General syntax:

```
type   array-name [size];
```

  - type specifies the type of element that will be contained in the array (int, float, char, etc.)
  - size is an integer constant which indicates the maximum number of elements that can be stored inside the array.

```
int   marks[5];
```

  - marks is an array containing a maximum of 5 integers.

- **Examples:**

```
int  x[10];
char  line[80];
float  points[150];
char  name[35];
```

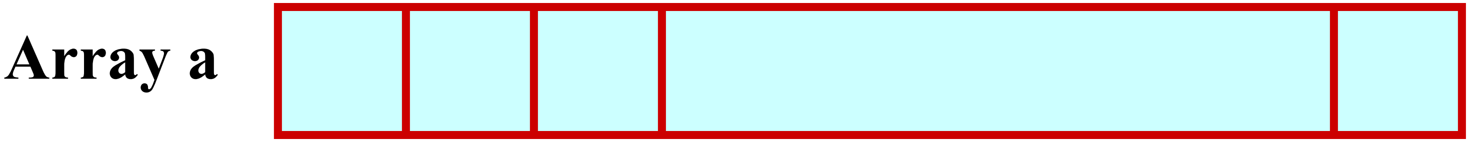
- **If we are not sure of the exact size of the array, we can define an array of a large size.**

```
int   marks[50];
```

though in a particular run we may only be using, say, 10 elements.

How an array is stored in memory?

- Starting from a given memory location, the successive array elements are allocated space in consecutive memory locations.



  - x: starting address of the array in memory
  - k: number of bytes allocated per array element

– a[i] → is allocated memory location at address x + i*k

Accessing Array Elements

- A particular element of the array can be accessed by specifying two things:
  - Name of the array.
  - Index (relative position) of the element in the array.
- In C, the index of an array starts from zero.
- Example:
  - An array is defined as `int x[10];`
  - The first element of the array x can be accessed as x[0], fourth element as x[3], tenth element as x[9], etc.

Contd.

- The array index must evaluate to an integer between 0 and n-1 where n is the number of elements in the array.

```
a[x+2] = 25;
b[3*x-y] = a[10-x] + 5;
```

A Warning

- In C, while accessing array elements, array bounds are not checked.

- Example:

```
int   marks[5];
:
:
marks[8] = 75;
```

  - The above assignment would not necessarily cause an error.
  - Rather, it may result in unpredictable program results.

Initialization of Arrays

- General form:

```
type   array_name[size]  =  { list of values };
```

- Examples:

```
int  marks[5] = {72, 83, 65, 80, 76};
char  name[4] = {‘A’, ‘m’, ‘i’, ‘t’};
```

- Some special cases:
  - If the number of values in the list is less than the number of elements, the remaining elements are automatically set to zero.

```
float  total[5] = {24.2, -12.5, 35.1};
```

➔ total[0]=24.2, total[1]=-12.5, total[2]=35.1, total[3]=0, total[4]=0

Contd.

- The size may be omitted. In such cases the compiler automatically allocates enough space for all initialized elements.

```
int   flag[ ] = {1, 1, 1, 0};
char  name[ ] = {‘A’, ‘m’, ‘i’, ‘t’};
```

Character Arrays and Strings

```
char C[8] = { 'a', 'b', 'h', 'i', 'j', 'i', 't', '\0' };
```

- C[0] gets the value 'a', C[1] the value 'b', and so on. The last (7th) location receives the null character ‘\0’.
- Null-terminated character arrays are also called strings.
- Strings can be initialized in an alternative way. The last declaration is equivalent to:

```
char C[8] = "abhijit";
```

- The trailing null character is missing here. C automatically puts it at the end.
- Note also that for individual characters, C uses single quotes, whereas for strings, it uses double quotes.

Example 1: Find the minimum of a set of 10 numbers

```
#include  <stdio.h>
main()
{
    int  a[10], i, min;

    for  (i=0; i<10; i++)
        scanf (“%d”, &a[i]);

    min = 99999;
    for  (i=0; i<10; i++)
    {
        if  (a[i] < min)
            min = a[i];
    }
    printf (“\n Minimum is %d”, min);
}
```

Alternate Version 1

Change only one line to change the problem size

```
#include  <stdio.h>
#define   size   10

main()
{
    int  a[size], i, min;

    for  (i=0; i<size; i++)
        scanf (“%d”, &a[i]);

    min = 99999;
    for  (i=0; i<size; i++)
    {
        if  (a[i] < min)
            min = a[i];
    }
    printf (“\n Minimum is %d”, min);
}
```

Alternate Version 2

Define an array of large size and use only the required number of elements

```
#include  <stdio.h>

main()
{
   int  a[100], i, min, n;

   scanf (“%d”, &n);  /* Number of elements */
   for  (i=0; i<n; i++)
      scanf (“%d”, &a[i]);

   min = 99999;
   for  (i=0; i<n; i++)
   {
      if  (a[i] < min)
         min = a[i];
   }
   printf (“\n Minimum is %d”, min);
}
```

Example 2: Computing gpa

```
#include  <stdio.h>
#define  nsub  6

main()
{
   int  grade_pt[nsub], cred[nsub], i,
          gp_sum=0, cred_sum=0, gpa;

   for  (i=0; i<nsub; i++)
      scanf (“%d %d”, &grade_pt[i], &cred[i]);

   for  (i=0; i<nsub; i++)
   {
      gp_sum += grade_pt[i] * cred[i];
      cred_sum += cred[i];
   }
   gpa = gp_sum / cred_sum;
   printf (“\n Grade point average:  is %d”, gpa);
}
```

Handling two arrays at the same time

Things you can⑦⑧t do

- You cannot
  - use = to assign one array variable to another

    ```
    a = b;   /* a and b are arrays */
    ```

  - use == to directly compare array variables

    ```
    if  (a = = b)  ………..
    ```

  - directly scanf or printf arrays

    ```
    printf (“……”, a);
    ```

How to copy the elements of one array to another?

- By copying individual elements

```
for  (j=0; j<25; j++)
   a[j] = b[j];
```

How to read the elements of an array?

- By reading them one element at a time

```
    for  (j=0; j<25; j++)
        scanf  (“%f”, &a[j]);
```

- The ampersand (&) is necessary.
- The elements can be entered all in one line or in different lines.

How to print the elements of an array?

- By printing them one element at a time.

```
for  (j=0; j<25; j++)
    printf  (“\n %f”, a[j]);
```

  - The elements are printed one per line.

```
printf  (“\n”);
for  (j=0; j<25; j++)
    printf (“ %f”, a[j]);
```

  - The elements are printed all in one line (starting with a new line).

Two Dimensional Arrays

- We have seen that an array variable can store a list of values.
- Many applications require us to store a **table** of values.

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Student 1	75	82	90	65	76
Student 2	68	75	80	70	72
Student 3	88	74	85	76	80
Student 4	50	65	68	40	70

Contd.

- The table contains a total of 20 values, five in each line.
  - The table can be regarded as a matrix consisting of four rows and five columns.
- C allows us to define such tables of items by using two-dimensional arrays.

Declaring 2-D Arrays

- General form:

```
type   array_name [row_size][column_size];
```

- Examples:

```
int  marks[4][5];
float  sales[12][25];
double  matrix[100][100];
```

Accessing Elements of a 2-D Array

- Similar to that for 1-D array, but use two indices.
  - First indicates row, second indicates column.
  - Both the indices should be expressions which evaluate to integer values.
- Examples:

```
x[m][n] = 0;
c[i][k] += a[i][j] * b[j][k];
a = sqrt (a[j*3][k]);
```

How is a 2-D array is stored in memory?

- Starting from a given memory location, the elements are stored **row-wise** in consecutive memory locations.
  - x: starting address of the array in memory
  - c: number of columns
  - k: number of bytes allocated per array element
  - a[i][j] ➔ is allocated memory location at address $x + (i * c + j) * k$

a[0]0] a[0][1] a[0]2] a[0][3] a[1][0] a[1][1] a[1][2] a[1][3] a[2][0] a[2][1] a[2][2] a[2][3]

Row 0 Row 1 Row 2

How to read the elements of a 2-D array?

- By reading them one element at a time

```
for  (i=0; i<nrow; i++)
   for  (j=0; j<ncol; j++)
      scanf  (“%f”, &a[i][j]);
```

- The ampersand (&) is necessary.
- The elements can be entered all in one line or in different lines.

How to print the elements of a 2-D array?

- By printing them one element at a time.

```
for  (i=0; i<nrow; i++)
    for  (j=0; j<ncol; j++)
        printf  (“\n %f”, a[i][j]);
```

  - The elements are printed one per line.

```
for  (i=0; i<nrow; i++)
               for  (j=0; j<ncol; j++)
                   printf  (“%f”, a[i][j]);
```

  - The elements are all printed on the same line.

Contd.

```
for  (i=0; i<nrow; i++)
{
   printf  (“\n”);
   for  (j=0; j<ncol; j++)
      printf (“%f   ”, a[i][j]);
 }
```

- The elements are printed nicely in matrix form.

Example: Matrix Addition

```
#include  <stdio.h>

main()
{
   int  a[100][100], b[100][100],
            c[100][100], p, q, m, n;

   scanf (“%d %d”, &m, &n);

   for  (p=0; p<m; p++)
      for  (q=0; q<n; q++)
         scanf (“%d”, &a[p][q]);

   for  (p=0; p<m; p++)
      for  (q=0; q<n; q++)
         scanf (“%d”, &b[p][q]);
```

```
   for  (p=0; p<m; p++)
      for  (q=0; q<n; q++)
         c[p]q] = a[p][q] + b[p][q];

   for  (p=0; p<m; p++)
   {
      printf  (“\n”);
      for  (q=0; q<n; q++)
         printf (“%f   ”, a[p][q]);
   }
}
```

Some Exercise Problems to Try Out

- Find the mean and standard deviation of a set of n numbers.
- A shop stores n different types of items. Given the number of items of each type sold during a given month, and the corresponding unit prices, compute the total monthly sales.
- Multiple two matrices of orders mxn and nxp respectively.

Passing Arrays to Function

- Array element can be passed to functions as ordinary arguments.
    - IsFactor (x[i], x[0])
    - sin (x[5])

Passing Entire Array to a Function

- **An array name can be used as an argument to a function.**
  - **Permits the entire array to be passed to the function.**
  - **The way it is passed differs from that for ordinary variables.**
- **Rules:**
  - **The array name must appear by itself as argument, without brackets or subscripts.**
  - **The corresponding formal argument is written in the same manner.**
    - **Declared by writing the array name with a pair of empty brackets.**

Whole array as Parameters

```
#define ASIZE 5
float average (int a[])          {
    int i, total=0;
    for (i=0; i<ASIZE; i++)
          total = total + a[i];
    return ((float) total / (float) ASIZE);
}

main ( )   {
    int x[ASIZE] ; float x_avg;
    x = {10, 20, 30, 40, 50}
    x_avg = average (x) ;
}
```

Contd.

We don’t need to write the array size. It works with arrays of any size.

```
main()
{
    int  n;
    float   list[100], avg;
    :
    avg  =  average (n, list);
    :
}

float  average  (a, x)
int  a;
float  x[];
{
    :
    sum = sum + x[i];
}
```

Arrays as Output Parameters

```
void VectorSum (int a[], int b[], int vsum[], int length)       {
      int i;
      for (i=0; i<length; i=i+1)
                vsum[i] = a[i] + b[i] ;
}
int main (void)       {
      int x[3] = {1,2,3}, y[3] = {4,5,6}, z[3];
      VectorSum (x, y, z, 3) ;
      PrintVector (z, 3) ;
}
void PrintVector (int a[], int length)      {
      int i;
      for (i=0; i<length; i++) printf (“%d “, a[i]);
}
```

The Actual Mechanism

- When an array is passed to a function, the values of the array elements are not passed to the function.
  - The array name is interpreted as the address of the first array element.
  - The formal argument therefore becomes a pointer to the first array element.
  - When an array element is accessed inside the function, the address is calculated using the formula stated before.
  - Changes made inside the function are thus also reflected in the calling program.

Contd.

- Passing parameters in this way is called
  call-by-reference.
- Normally parameters are passed in C using
  call-by-value.
- Basically what it means?
  - If a function changes the values of array elements, then these changes will be made to the original array that is passed to the function.
  - This does not apply when an individual element is passed on as argument.

Passing 2-D Arrays

- Similar to that for 1-D arrays.
  - The array contents are not copied into the function.
  - Rather, the address of the first element is passed.
- For calculating the address of an element in a 2-D array, we need:
  - The starting address of the array in memory.
  - Number of bytes per element.
  - Number of columns in the array.
- The above three pieces of information must be known to the function.

Example Usage

```
#include  <stdio.h>

main()
{
   int  a[15][25],  b[15]25];
   :
   :
   add (a, b, 15, 25);
   :
}
```

```
void  add (x, y, rows, cols)
int  x[][25], y[][25];
int  rows, cols;
{
   :
}
```

We can also write

```
int  x[15][25], y[15][25];
```