Arrays

Basic Concept

- **Many applications require multiple data items that have common characteristics.**
  - **In mathematics, we often express such groups of data items in indexed form:**
    - $x_1, x_2, x_3, \ldots, x_n$
- **Why are arrays essential for some applications?**
  - **Take an example.**
  - **Finding the minimum of a set 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.**

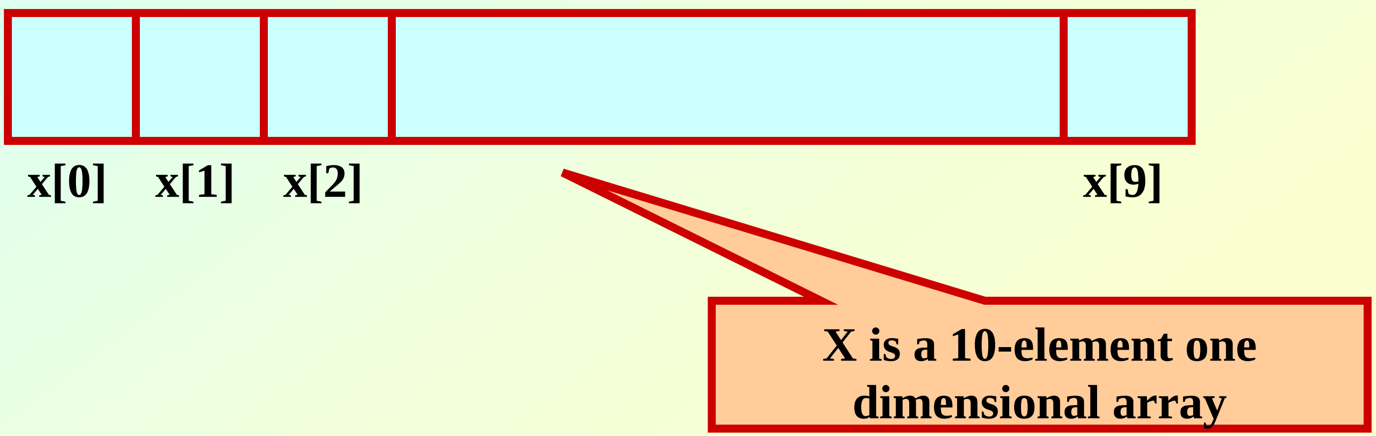
- **How to tackle this problem?**
- **Solution:**
  - **Use arrays.**

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];
```

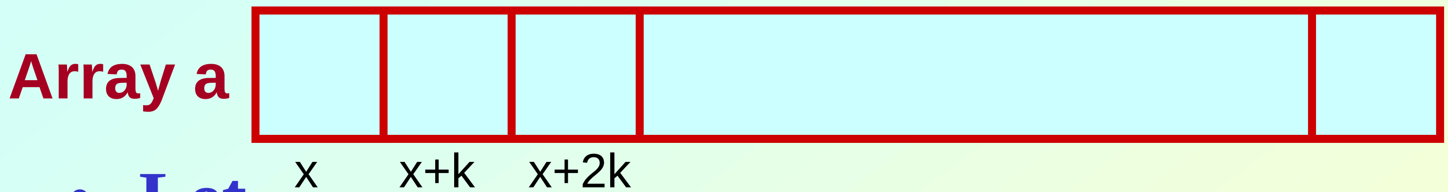
- **If we are not sure of the exact size of the array, we can define an array of a large size.**

```
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.



- Let

  x: starting address of the array in memory

  k: number of bytes allocated per array element

  – Element a[i] :: allocated memory location at address x + i*k

    - First array index assumed to start at zero.

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'};
```

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

```
#include  <stdio.h>
main()
{
    int  a[10], i, min;
   printf("Give 10 values \n");
    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);
}
```

Array declaration

Reading Array Element

Accessing Array Element

Alternate Version 1

Change only one line to change the problem size

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

main()
{
   int  a[size], i, min;
   printf("Give 10 values \n");
   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

```
#include  <stdio.h>

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

    printf(“Give number of elements (n) \n”);
    scanf (“%d”, &n);  /* Number of elements */

   printf(“Input all n integers \n”);
    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);
}
```

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

Example 2: Computing gpa

Handling two arrays at the same time

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

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

printf(“Input gr. points and credits for six subjects \n”);
   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);
}
```

Things you cannot 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**

```
int a[25],b[25];
 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**

```
int a[25];
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).**

Character String

Introduction

- **A string is an array of characters.**
  - **Individual characters are stored in memory in ASCII code.**
  - **A string is represented as a sequence of characters terminated by the null (‘\0’) character.**

“Hello” ➔

H	**e**	**l**	**l**	**o**	**‘\0’**

Declaring String Variables

- **A string is declared like any other array:**

  char string-name [size];

  - **size determines the number of characters in string_name.**
- **When a character string is assigned to a character array, it automatically appends the null character (‘\0’) at the end of the string.**
  - **size should be equal to the number of characters in the string plus one.**

Examples

```
char   name[30];
char   city[15];
char   dob[11];
```

- **A string may be initialized at the time of declaration.**

Equivalent

```
char   city[15] = “Calcutta”;
char   city[15] = {‘C’, ‘a’, ‘l’, ‘c’, ‘u’, ‘t’, ‘t’, ‘a’};

char   dob[] = “12-10-1975”;
```

Reading Strings from the Keyboard

- **Two different cases will be considered:**
  - **Reading words**
  - **Reading an entire line**

Reading "words"

- **scanf can be used with the "%s" format specification.**

```
char   name[30];
:
:
scanf ("%s", name);
```

  - **The ampersand (&) is not required before the variable name with "%s".**
  - **The problem here is that the string is taken to be upto the first white space (blank, tab, carriage return, etc.)**
    - **If we type "Rupak Biswas"**
    - **name will be assigned the string "Rupak"**

Reading a “line of text”

- **In many applications, we need to read in an entire line of text (including blank spaces).**
- **We can use the getchar() function for the purpose.**

```
char   line[81], ch;
int  c=0;
:
:
do
  {
      ch = getchar();
      line[c] = ch;
      c++;
  }
while  (ch != ‘\n’);

c = c – 1;
line[c] = ‘\0’;
```

Read characters until CR (‘\n’) is encountered

Make it a valid string

Reading a line :: Alternate Approach

```
char   line[81];
:
:
scanf  (“%[ ABCDEFGHIJKLMNOPQRSTUVWXYZ]”, line);
```

➔ **Reads a string containing uppercase characters and blank spaces**

```
char   line[81];
:
:
scanf  (“%[^\n]”, line);
```

➔ **Reads a string containing any characters**

Writing Strings to the Screen

- We can use **printf** with the "%s" format specification.

```
char name[50];
:
:
printf ("\n %s", name);
```

Processing Character Strings

- There exists a set of C library functions for character string manipulation.
  - strcpy :: string copy
  - strlen :: string length
  - strcmp :: string comparison
  - strtcat :: string concatenation
- It is required to include the following

```
#include <string.h>
```

strcpy()

- **Works very much like a string assignment operator.**

  strcpy (string1, string2);

  - **Assigns the contents of string2 to string1.**
- **Examples:**

  strcpy (city, “Calcutta”);

  strcpy (city, mycity);
- **Warning:**
  - **Assignment operator do not work for strings.**

city = “Calcutta”; → INVALID

strlen()

- **Counts and returns the number of characters in a string.**

```
len = strlen (string);   /* Returns an integer */
```

  - **The null character ('\0') at the end is not counted.**
  - **Counting ends at the first null character.**

```
char  city[15];
int  n;
:
:
strcpy (city, “Calcutta”);
n = strlen (city);
```

n is assigned 8

strcmp()

- **Compares two character strings.**

  int strcmp (string1, string2);

  – **Compares the two strings and returns 0 if they are identical; non-zero otherwise.**

- **Examples:**

```
if   (strcmp (city, "Delhi") = = 0)
  {  …….  }

if  (strcmp (city1, city2) ! = 0)
   { ……. }
```

strcat()

- **Joins or concatenates two strings together.**

  strcat (string1, string2);

  - **string2 is appended to the end of string1.**
  - **The null character at the end of string1 is removed, and string2 is joined at that point.**

- **Example:**

  strcpy (name1, “Amit “);

  strcpy (name2, “Roy“);

  strcat (name1, name2);

A	m	i	t		‘\0’

R	o	y	‘\0’

A	m	i	t		R	o	y	‘\0’

Example

```
/* Read a line of text and count the number of uppercase letters */
#include  <stdio.h>
#include  <string.h>
main()
{
   char  line[81];
   int  i, n, count=0;
   printf(“Input the line \n”);
   scanf (“%[^\n]”, line);
   n = strlen (line);
   for  (i=0; i<n; i++)
     {
        if  (isupper (line[i]))
               count++;
     }
   printf (“\n The number of uppercase letters in the string %s is %d”,
                        line, count);
}
```

Include header for string processing

Character Array for String

Reading a line of text

Computing string length

Checking whether a character is Uppercase

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.
- How to print two matrices side by side?

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]);
    }
}
```

Passing Arrays 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.**
  - **Array name is passed as the parameter, which is effectively the address of the first element.**
- **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.**
    - **Dimension or required number of elements to be passed as a separate parameter.**

Example: Average of numbers

```c
#include <stdio.h>

float avg(float [], int );

main()
{
  float a[]={4.0, 5.0, 6.0, 7.0};

  printf("%f \n", avg(a,4) );
}
```

prototype

Array name passed

Array as parameter

```c
float  avg (float x[], int n)
{
 float sum=0;
 int i;

 for(i=0; i<n; i++)
   sum+=x[i];
 return(sum/(float) n);
}
```

Number of Elements used

5.5000

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.**

Example: Minimum of a set of numbers

```
#include  <stdio.h>

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

   scanf ("%d", &n);
   for  (i=0; i<n; i++)
      scanf ("%d", &a[i]);

   printf ("\n Minimum is %d",
                              minimum (a, n));
}
```

```
int  minimum (x, size)
int  x[], size;
{
   int  i, min = 99999;

   for  (i=0; i<size; i++)
      if  (min < a[i])
         min = a[i];

   return (min);
}
```

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];

Number of columns

Example: Transpose of a matrix

```
void  transpose (int x[][100], int n)
{
   int  p, q;

   for  (p=0; p<n; p++)
      for  (q=0; q<n; q++)
        {
            t = x[p][q];
            x[p][q] = x[q][p];
            x[q][p] = t;
        }
}
```

10	20	30
40	50	60
70	80	90

a[100][100]

transpose(a,3)

10	20	30
40	50	60
70	80	90

The Correct Version

```
void  transpose (int x[][100], n)
{
   int  p, q;

   for  (p=0; p<n; p++)
      for  (q=p; q<n; q++)
         {
             t = x[p][q];
             x[p][q] = x[q][p];
             x[q][p] = t;
         }
}
```

10	20	30
40	50	60
70	80	90

10	40	70
20	50	80
30	60	90

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.**
- **Multiply two matrices of orders mxn and nxp respectively.**