One-Dimensional Arrays

Random access lists of elements

CS10003 PROGRAMMING AND DATA STRUCTURES

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: Printing Numbers in Reverse

3 numbers

```
int a, b, c;
scanf("%d", &a);
scanf("%d", &b);
scanf("%d", &c);
printf("%d  ", c);
printf("%d  ", b);
printf("%d  \n", a);
```

4 numbers

```
int a, b, c, d;
scanf("%d", &a);
scanf("%d", &b);
scanf("%d", &c);
scanf("%d", &d);
printf("%d  ", d);
printf("%d  ", c);
printf("%d  ", b);
printf("%d  \n", a);
```

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:

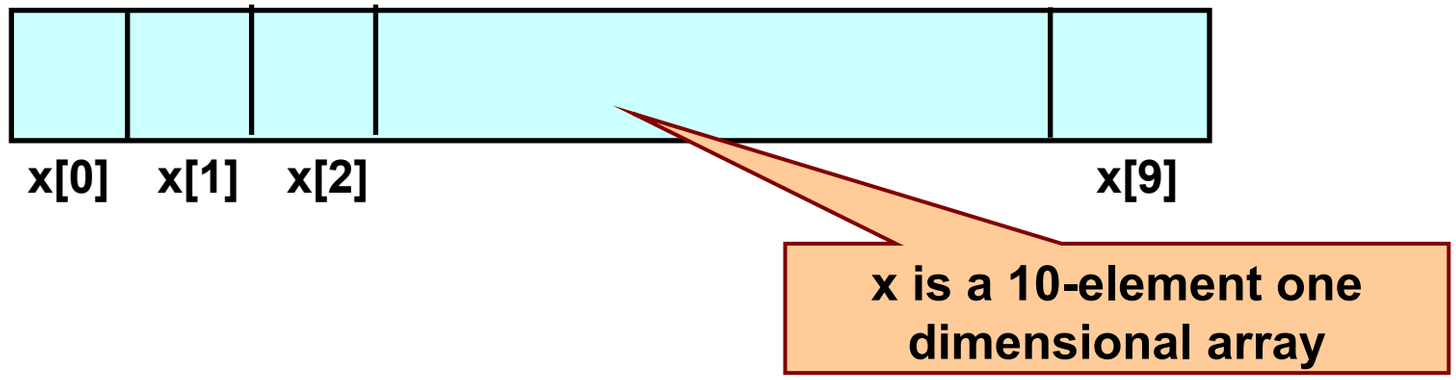
- Use arrays

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 used in a program must be declared before they are used

General syntax:

type array-name [size];

- type specifies the type of elements 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

- Example: marks is an array that can store a maximum of 5 integers:

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

Array Declarations: examples

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 that we will need, we can define an array of a large enough size:

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

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

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

Important to remember: In C, the index of an array starts from 0, not 1

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.

A First Example

Array size should be a constant

```
int main()
{
  int i;
  int data[10];
  for (i=0; i<10; i++)
      data[i]= i;
  i=0;
  while (i<10)
  {
     printf("Data[%d] = %d\n", i, data[i]);
     i++;
  }
  return 0;
}
```

"data" is a block of 10 integer variables:
data[0], data[1], …, data[9]

```
Data[0] = 0
Data[1] = 1
Data[2] = 2
Data[3] = 3
Data[4] = 4
Data[5] = 5
Data[6] = 6
Data[7] = 7
Data[8] = 8
Data[9] = 9
```

Output

How is an array stored in memory?

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

Array A

- Let x: starting address of the array in memory

  k: number of bytes allocated per array element (e.g., 4 for each int, 1 for each char)

- The array element `A[i]` is allocated memory location at address `x + i * k`

A Special Operator: AddressOf (&)

Remember that each variable is stored at a memory location with a unique address.

Putting **&** before a variable name gives the starting address of the variable in the memory (where it is stored, not the value).

Can be put before any variable (with no blank in between)

```
int a =10;
printf ("Value of a is %d, and address of a is %d\n", a, &a);
```

Similarly, if we have an array, say, `int Data[10];`

Memory address of the first array element is `&Data[0]`

Memory address of the second array element is `&Data[1]`

Memory address of the third array element is `&Data[2]`

Example

```
int main()
{
  int i;
  int data[10];
  for(i=0; i<10; i++)
  printf("&Data[%d] = %u\n", i, &data[i]);
  return 0;
}
```

Output

```
&Data[0] = 322122480
&Data[1] = 322122484
&Data[2] = 322122488
&Data[3] = 322122492
&Data[4] = 322122496
&Data[5] = 322122500
&Data[6] = 322122504
&Data[7] = 322122508
&Data[8] = 322122512
&Data[9] = 322122516
```

Note: memory addresses are being printed as unsigned integers using %u in printf

Typically, variables are allocated memory locations whose addresses are multiple of 4.

How to read the elements of an array?

By reading them one element at a time.

Suppose we have declared an array: `float a[25];`

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

Note the ampersand (&) in scanf.

The elements can be entered all in one line or in different lines.

Reading into an array: example

```
int main()  {
    const int MAX_SIZE = 100;
    int i, size;
    float marks[MAX_SIZE];
    float total;
    scanf("%d", &size);
    for (i=0, total=0; i<size; i++)
    {
        scanf("%f", &marks[i]);
        total = total + marks[i];
     }
    printf("Total = %f \n Avg = %f\n",
                        total, total/size);
    return 0;
}
```

Input a list of marks from the user and compute their total and average

Output

```
4
2.5
3.5
4.5
5
Total = 15.500000
 Avg = 3.875000
```

Printing in Reverse Using Arrays

```
int main()
{
   int n, A[100], i;
   printf ("How many numbers to read? ");
   scanf ("%d", &n);
   for (i=0; i < n; ++i)
   scanf ("%d", &A[i]); // input the i-th array element
   for (i=n-1; i >= 0; --i)// note - loop counts downward
   printf ("%d  ", A[i]);  // output the i-th array element
   printf("\n");
   return 0;
}
```

Indexes into Arrays

The array index can be any expression that evaluates to an integer between 0 and n-1 where n is the maximum number of elements possible in the array.

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

Remember that each array element is a variable in itself, and can be used anywhere a variable can be used (in expressions, assignments, conditions,…)

Initialization of Arrays

General form:

type array_name[size] = { comma-separated list of values };

Examples:

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

The size may be omitted if all initializers are specified. 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'};
```

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, which are very hard to debug.

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];
```

The element assignments will follow the rules of assignment expressions.

Destination array must have sufficient size.

Things you cannot do

You cannot:

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

- use = to assign one array variable to another

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

Indeed, a or b cannot be an l-value in any assignment.

- use == to compare arrays element by element

```
if (a == b)  ……
```

This is valid C syntax, but does not make element-by-element comparison

- directly scanf or printf arrays
(works, but not recommended unless purposefully made)

```
printf ("……", a);
scanf  ("……", a);
```

Example: Find the minimum of a set of 10 numbers

```
int main()
{
    int  a[10], i, min;

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

    min = a[0];
    for  (i=1; i<10; i++)
    {
        if  (a[i] < min)
            min = a[i];
    }
    printf ("\n Minimum is %d", min);
    return 0;
}
```

Alternate Version 1

Change only one line to change the problem size

```
#define size 10

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

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

    min = a[0];
    for  (i=1; i<size; i++)
    {
        if  (a[i] < min)
            min = a[i];
    }
    printf (“\n Minimum is %d”, min);
    return 0;
}
```

Alternate Version 2

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

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

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

    min = a[0];
    for  (i=1; i<n; i++)
    {
        if  (a[i] < min)
            min = a[i];
    }
    printf (“\n Minimum is %d”, min);
    return 0;
}
```

Example: Computing Grade Point Average

Handling two arrays at the same time

cred[j] stores credit of subject j

grade_pt[j] stores grade point obtained by a student in subject j

```
const int nsub = 6;
int main()
{
    int  grade_pt[nsub], cred[nsub], i, gp_sum=0, cred_sum=0;
    double 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 = ((float) gp_sum) / cred_sum;
    printf ("\n Grade point average:  is %f", gpa);
    return 0;
}
```

Example: Find largest contiguous sequence of equal numbers

```
#include<stdio.h>
int main()
{
  int i, n, A[20], k, maxbegin, maxcount, ssbegin, count;
  scanf ("%d", &n);
  for (i=0; i<n; i++)  scanf ("%d", &A[i]);
  printf ("A = ");
  for (i=0; i<n; i++)  printf ("%d, ", A[i]); printf("\n");
  maxbegin = 0; maxcount = 1;
  ssbegin = 0; count = 1; k = 1;
  while (k < n) {
    if (A[k] == A[k-1]) {
       count++;
       if (count > maxcount) {
          maxbegin = ssbegin;
          maxcount = count;
       }
    } else {
       ssbegin = k; count = 1;
    }
    k++;
  }
  printf ("Sequence starting from A[%d] of Length = %d, Value = %d \n",
           maxbegin, maxcount, A[maxbegin]);
}
```

```
10
1 2 2 2 3 2 2 2 2 7
A = 1, 2, 2, 2, 3, 2, 2, 2, 2, 7,
Sequence starting from A[5] of Length = 4, Value = 2
```

Character array

Reading characters into a character array

```
#include <stdio.h>

int main() {
    char str[20];
    int i;
    printf("Enter 20 characters:\n");

    for (i = 0; i < 20; i++) {
        scanf(" %c", &str[i]);
    }
    printf("Characters entered:\n");
    for (i = 0; i < 20; i++) {
        printf("%c", str[i]);
    }
    return 0;
}
```

Practice Problems

1. Read in an integer n (n < 25). Read n integers in an array A. Then do the following (write separate programs for each, only the reading part is common).
   a) Find the sum of the absolute values of the integers.
   b) Copy the positive and negative integers in the array into two additional arrays B and C respectively. Print A, B, and C.
   c) Exchange the values of every pair of values from the start (so exchange A[0] and A[1], A[2] and A[3] and so on). If the number of elements is odd, the last value should stay the same.

2. Read in two integers n and m (n, m < 50). Read n integers in an array A. Read m integers in an array B. Then do the following (write separate programs for each part, only the reading part is common).
   a) Find if there are any two elements x, y in A and an element z in B, such that x + y = z
   b) Copy in another array C all elements that are in both A and B (intersection)
   c) Copy in another array C all elements that are in either A and B (union)
   d) Copy in another array C all elements that are in A but not in B (difference)