One Dimension Arrays

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

Printing in Reverse Using Arrays

```
void 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]);
    for (i = n -1; i >= 0; --i)
        printf("%d  ", A[i]);
    printf("\n");
}
```

Using Arrays

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

  int x[10];

- Individual elements are accessed by specifying the index

x[0] x[1] x[2] x[9]

X is a 10-element one dimensional array

A first example

```
void 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++;
  }
}
```

data refers to a block of 10 integer variables, data[0], data[1], …, data[9]

The result

Array size should be a constant

```
void 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++;
  }
}
```

Output

```
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
```

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 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 that can store 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

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.

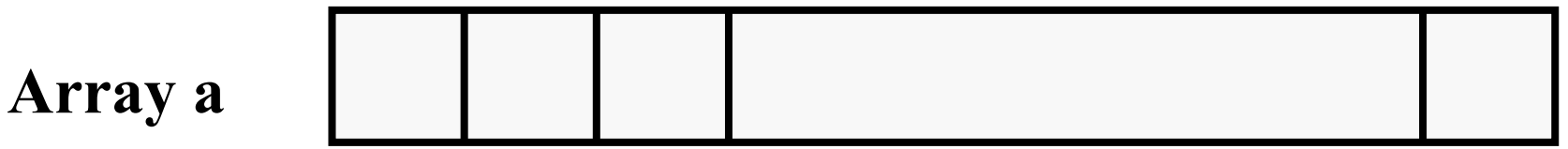
- The array index must evaluate to an integer between 0 and n-1 where n is the maximum number of elements possible in the array

```
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,…)

How is an array 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

Storage

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

Output

```
&Data[0] = 322122480
&Data[1] = 322122484
&Data[2] = 322122488
&Data[3] = 322122492
&Data[4] = 3221224496
&Data[5] = 3221224500
&Data[6] = 3221224504
&Data[7] = 3221224508
&Data[8] = 3221224512
&Data[9] = 3221224516
```

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’};

- 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’};

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

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

Reading into an array

```
void 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);
}
```

Output

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

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)

How to copy the elements of one array to another?

- By copying individual elements

```
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

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

```
void 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);
}
```

Alternate Version 1

Change only one line to change the problem size

```
const int size = 10;

void 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);
}
```

Alternate Version 2

Change only one line to change the problem size

Used #define macro

```
#define size 10

void 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);
}
```

#define macro

- #define X Y
- Preprocessor directive
- Compiler will first replace all occurrences of string X with string Y in the program, then compile the program
- Similar effect as read-only variables (const), but no storage allocated
- We prefer you use const instead of #define

Alternate Version 3

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

```
void 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);
}
```

Example 2: Computing cgpa

Handling two arrays at the same time

```
const int  nsub = 6;

void 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 %.2lf", gpa);
}
```

Example: Binary Search

- Searching for an element k in a sorted array A with n elements
- Idea:
  - Choose the middle element A[n/2]
  - If k == A[n/2], we are done
  - If k < A[n/2], search for k between A[0] and A[n/2 -1]
  - If k > A[n/2], search for k between A[n/2 + 1] and A[n-1]
  - Repeat until either k is found, or no more elements to search
- Requires less number of comparisons than linear search in the worst case ($\log_2 n$ instead of n)

```
void main() {
    int A[100], n, k, i, mid, low, high;
    scanf("%d %d", &n, &k);
    for (i=0; i<n; ++i) scanf("%d", &A[i]);
    low = 0; high = n – 1; mid = low + (high – low)/2;
    while (high >= low) {
        printf("low = %d, high = %d, mid = %d, A[%d] = %d\n",
     low, high, mid, mid, A[mid]);
        if (A[mid] == k) {
            printf("%d is found\n", k);
            break;
        }
        if (k < A[mid]) high = mid – 1;
        else low = mid + 1;
        mid = low + (high – low)/2;
    }
   If (high < low) printf("%d is not found\n", k);
}
```

Output

```
8  21
9  11  14  17  19  20  23  27
low = 0, high = 7, mid = 3, A[3] = 17
low = 4, high = 7, mid = 5, A[5] = 20
low = 6, high = 7, mid = 6, A[6] = 23
21 is not found
```

```
8 14
9 11 14 17 19 20 23 27
low = 0, high = 7, mid = 3, A[3] = 17
low = 0, high = 2, mid = 1, A[1] = 11
low = 2, high = 2, mid = 2, A[2] = 14
14 is found
```

Example: Selection Sort

- Sort the elements of an array A with n elements in ascending order
- Basic Idea:
  - Find the min of the n elements, swap it with A[0] (so min is at A[0] now)
  - Now find the min of the remaining n-1 elements, swap it with A[1] (so 2^{nd} min is at A[1] now)
  - Continue until no more elements left

```
void main() {
    int A[100], n, i, j, k, min, pos, temp;
    scanf("%d", &n);
    for (i=0; i<n; ++i) scanf("%d", &A[i]);
    for (i = 0; i < n - 1; ++i) {
            min = A[i]; pos = i;
            for (j = i + 1; j < n; ++j) {
                if (A[j] < min) {
                    min = A[j];
                    pos = j;
                }
            }
            temp = A[i];
            A[i] = A[pos];
            A[pos] = temp;
            for (k=0; k<n; ++k) printf("%d  ", A[k]);
            printf("\n");
    }
}
```

Output

```
6
7 12 5 15 17 9
5  12  7  15  17  9
5  7  12  15  17  9
5  7  9  15  17  12
5  7  9  12  17  15
5  7  9  12  15  17
```

```
8
9 8 7 6 5 4 3 2
2  8  7  6  5  4  3  9
2  3  7  6  5  4  8  9
2  3  4  6  5  7  8  9
2  3  4  5  6  7  8  9
2  3  4  5  6  7  8  9
2  3  4  5  6  7  8  9
2  3  4  5  6  7  8  9
```

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);

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 (last character is '\0') 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 if you define it like this
- Note also that for individual characters, C uses single quotes, whereas for strings, it uses double quotes

Reading strings: %s format

```
void main()
{
    char name[25];
    scanf("%s", name);
    printf("Name = %s \n", name);
}
```

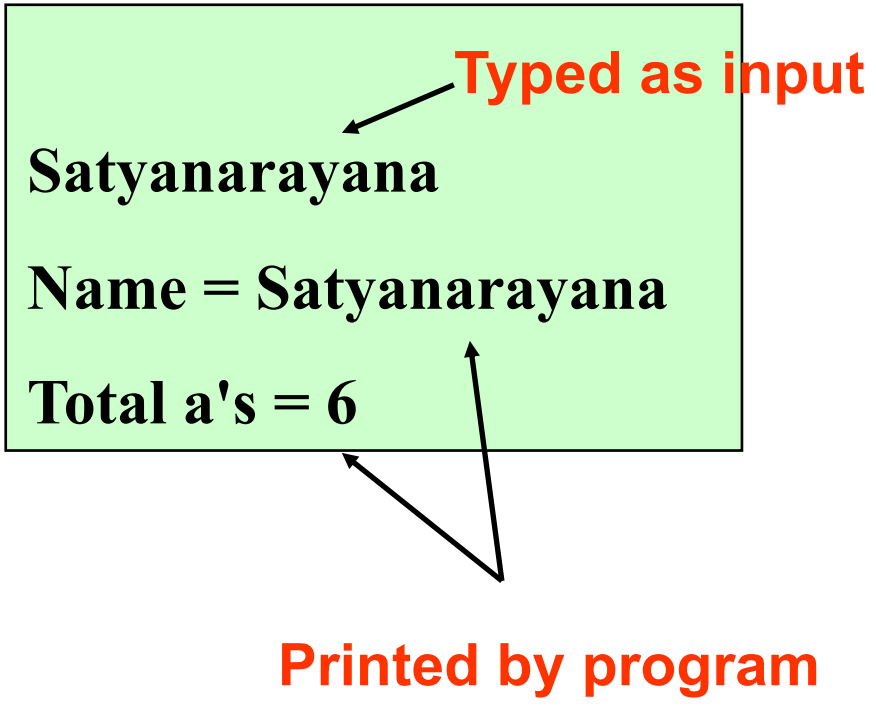
%s reads a string into a character array given the array name or start address.

It ends the string with '\0'

An example

```
void main()
{
  #define SIZE 25
  int i, count=0;
  char name[SIZE];
  scanf("%s", name);
  printf("Name = %s \n", name);
  for (i=0; name[i]!='\0'; i++)
    if (name[i] == 'a') count++;
  printf("Total a's = %d\n", count);
}
```

Seen on screen



Note that character strings read in %s format end with '\0'

Palindrome Checking

```
void main()
{
   const int SIZE = 25;
   int i, flag, count=0;
   char name[SIZE];
   scanf("%s", name);     /* Read Name */
   for (i=0; name[i]!='\0'; i++);    /* Find Length of String */
   printf("Total length = %d\n",i);
   count=i;  flag = 0;
   /* Loop below checks for palindrome  by comparison*/
   for(i=0; i<count; i++) if (name[i]!=name[count-i-1]) flag = 1;
   if (flag ==0) printf ("%s is a Palindrome\n", name);
   else printf("%s is NOT a Palindrome\n", name);
}
```

Some Exercises

1. **Write a C program that reads an integer n and stores the first n Fibonacci numbers in an array.**
2. **Write a C program that reads an integer n and uses an array to efficiently find out the first n prime numbers.**
3. **Read in an integer n, read in n integers and print the integer with the highest frequency.**
4. **Read in an integer n, read in n numbers and find out the mean, median and mode.**
5. **Read in two names and compare them and print them in lexicographic (dictionary) order.**
6. **Read in an integer n, read in n names and print the last name when compared in lexicographic order.**