CS1101: Foundations of Programming

1D Arrays

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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: Printing number 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

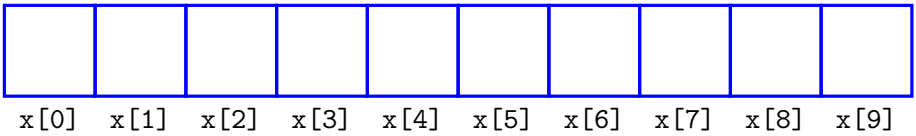
- Suppose we have 10 numbers to handle
  - Or 20
  - Or 100
- Where do we store the numbers? Use 100 variables?
- How to tackle this problem?
- Solution: Use arrays

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 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**

Array declaration

- **Examples:**

```
int x[10];
char line[100];
float points[90];
char names[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

- **Array size should be constant**

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.
- 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;
```

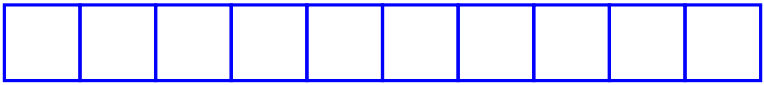
- Remember that each array element is a variable in itself, and can be used anywhere a variable can be used (in expressions, assignments, conditions,...)

Simple example

```
int main(){
  int data[10],i;
  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;
}
```

Storage for array 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
- `x[i]` — is allocated memory location at address `x + i * k`

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: %d, address of a: %u\n", a, &a);
```

Storage

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

```
&data[0]=22781894 8
&data[1]=22781895 2
&data[3]=22781895 6
...
```

Note: Memory addresses are being printed as unsigned integers using %u in printf. Address values can be negative if printed using %d.

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

Reading the elements into an array?

- By reading them one element at a time

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

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

Example

```
int main(){
  const int MAX_SZ=100;
  int a[MAX_SZ], i, sum=0, size;
  scanf("%d",&size);
  for(i=0; i < size; i++){
    scanf("%d",&a[i]);
    sum += a[i];
  }
  printf("Sum: %d, Avg: %f", sum, ((float) sum)/size);
  return 0;
}
```

Array index

- **The array index needs to be an integer and lies between 0 and $n-1$ where n is the declared size of the array**

```
a[x+2] = 54; // x int
a[3*x-2] = a[x+2] * a[x+1] ;
a[x] = a[a[x+2]];
```

- **Each element of an array is a variable and can be used in expressions, assignments, conditions, etc.**

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' };
```

Warning

- In C, while accessing array elements, array bounds are not checked
- **Example:**

```
int marks[10];
⋮
marks[14] = -3;
```

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

How to print the elements of an array?

- **By printing them one element at a time, one per line**

```
for(j=0; j<25; j++)
  printf("\n %d",a[j]);
```

- **The elements are printed all in one line**

```
for(j=0; j<25; j++)
  printf(" %d",a[j]);
```

How to copy the elements of an array to another?

- **By copying individual elements**

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

- **The elements assignments will follow the rules of assignments expressions**
- **Destination array must have sufficient size**

Note

- **Let** `int a[10], b[10];`
- **You cannot use = to assign one array to another**
  - `a = b; // not a valid one`
  - **Also,** `a, b` **cannot be an** `l-value` **in any assignment**
- **You cannot use == to compare two arrays**
  - `a == b; // valid syntax`
  - **Though valid syntax but does not compare element by element**
- **You cannot directly scanf or printf:** `printf("...",a);`

Example: Find the minimum of 10 numbers

Example: Find the minimum of 10 numbers

```
int main(){
  int i, min, a[10];
  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("Min=%d\n",min);
  return 0;
}
```

Alternate version - 1

```
const int size=10;
int main(){
  int i, min, a[size];
  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("Min=%d\n",min);
  return 0;
}
```

Change only one line to change the problem size

Alternate version - 2

```
#define size 10
int main(){
  int i, min, a[size];
  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("Min=%d\n",min);
  return 0;
}
```

Change only one line to change the problem size

Used `define` macro

`#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

```
int main(){
  int i, min, a[100], n;
  scanf("%d",&n); /* no 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("Min=%d\n",min);
  return 0;
}
```

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

Computing CPI

```
const int nsub=6;
int main(){
  int grade[nsub],credit[nsub],i,gpsum=0,creditsum=0;
  double cpi;
  scanf("%d",&n); /* no of elements */
  for(i=0; i<n; i++)
    scanf("%d%d",&grade[i],&credit[i]);
  for(i=0; i<n; i++){
    gpsum += grade[i]*credit[i];
    creditsum += credit[i];
  }
  cpi=((double)gpsum)/creditsum;
  printf("CPI=%lf\n",cpi);
  return 0;
}
```

$$cpi = \frac{\sum_{i=1}^{N} c_i \times g_i}{\sum_{i=1}^{N} c_i}$$

Handling two arrays

Practice problems

- **Write a C program that reads an integer n and stores the first n Fibonacci numbers in an array.**

  $F_n = F_{n-1} + F_{n-2}, F_0 = 0, F_1 = 1$

- **Write a C program that reads an integer n and uses an array to efficiently find out the first n prime numbers.**
- **Read in an integer n, read in n integers and print the integer with the highest frequency.**
- **Read in an integer n, read in n numbers and find out the mean, median and mode.**
- **Read in two integers, m and n. Read m integers in array X and n integers in B. Find out the common elements in arrays X & Y and store it those another array Z.**
- **Read in two integers, m and n. Read m integers in array X and n integers in B. Find out the elements that are either in X or Y and store those in another array Z.**