Arrays:
Part 1 of 2

CMSC 104, Spring 2014

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(thanks to John Park for slides)

Arrays, Part 1 of 2

Topics

- Definition of a Data Structure
- Definition of an Array
- Array Declaration, Initialization, and Access
- Program Example Using Arrays

Reading

- Sections 6.1 - 6.5

Data Types

- So far, we have seen only **simple data types**, such as int, float, and char.
- Simple variables can hold only one value at any time during program execution, although that value may change.
- A **data structure** is a data type that can hold multiple values, in a structured form, at the same time. (Synonyms: **complex data type**, **composite data type**)
- The **array** is one kind of data structure.

A Motivating Example

- We want to write a program that will accept a collection of numerical grades, and then print out the mean grade

A Motivating Example

```
#include <stdio.h>

int main() {
    int counter = 0;
    float total = 0.0;

    do {
        scanf(“%d”, &grade);
        if (grade >= 0) {
            total += grade;
            counter++;
        }
    } while (grade >= 0);
    printf(“Mean for %d grades is %f”, counter, total / counter);
    return(0);
}
```

A Motivating Example

Now, the user wants us to print out the *median* grade:

- We don't know in advance exactly how many grades we will be getting
  - (We can, however, enforce an upper limit on how many we can handle)
- Can we do it "in place", as with calculating the mean?
  - Unfortunately, NO.
- Can we do it with a collection of simple variables?
  - Again, NO.
- So, we need a special place to save *all* the input values

Arrays

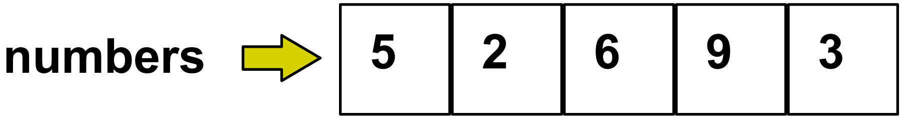
- An array is a group of related data items that all have the same data type, and share a common name
- Arrays can be of any data type we choose.
- Arrays are **static** in that they remain the same size throughout program execution.
- An array's data items are stored contiguously in memory.
- Each of the data items is known as an **element** of the array. Each element can be accessed individually.

Array Declaration and Initialization

```
int numbers[5] ;
```

- The name of this example array is “numbers”.
- This declaration sets aside a chunk of memory that is big enough to hold 5 integers.
- It does not initialize those memory locations to 0 or any other value. They contain garbage.
- Initializing an array may be done with an **array initializer**, as in :

```
int numbers[5] = { 5, 2, 6, 9, 3 } ;
```



numbers ⇨

5	**2**	**6**	**9**	**3**

Array Declaration and Initialization

- A special case is an “array of chars”:

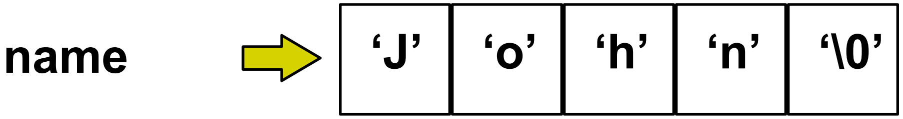
  char name[5] ;

- A string is in fact an array of chars, usually ending in a 0
  - The 0-valued char at the end is called a “null terminator”
  - Strings do not necessarily have to be null-terminated.
- Initializing a char array may be done the usual way, as in:

  char name[5] = { ‘J’, ‘o’, ‘h’, ‘n’, 0 } ;

  …or with a string constant:

  char name[5] = “John” ;

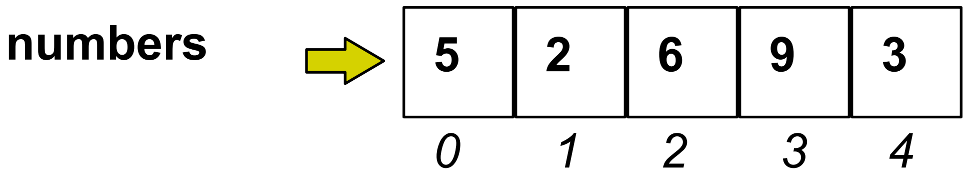


name

‘J’	‘o’	‘h’	‘n’	‘\0’

Accessing Array Elements

- Each element in an array has a **subscript** (**index**) associated with it.



numbers

5	2	6	9	3
0	*1*	*2*	*3*	*4*

- Subscripts are integers and always begin at zero.
- Values of individual elements can be accessed by **indexing** into the array. For example,

```
printf(“The third element = %d.\n”, numbers[2]);
```

would give the output

```
The third element = 6.
```

Accessing Array Elements (con’t)

- A subscript can also be any expression that evaluates to an integer.

```
numbers[(a + b) * 2] ;
```

- Caution! It is a logical error when a subscript evaluates to a value that is out of range for the particular array. Some systems will handle an **out-of-range error** gracefully and some will not (including ours).

Modifying Elements

- Individual elements of an array can also be modified using subscripts.

```
numbers[4] = 20 ;  /*changes the value of the element found at
                     subscript 4 to 20 */
```

- Initial values may be stored in an array using indexing, rather than using an array initializer.

```
numbers[0] = 5 ;
numbers[1] = 2 ;
numbers[2] = 6 ;
numbers[3] = 9 ;
numbers[4] = 3 ;
```

Filling Large Arrays

- Since many arrays are quite large, using an array initializer can be impractical.
- Large arrays are often filled using a for loop.

  ```
  for ( i = 0; i < 100; i++ )
  {
      values [ i ] = 0 ;
  }
  ```

  would set every element of the 100 element array “values” to 0.

More Declarations

```
int  score [39] , gradeCount [5];
```

- Declares two arrays of type int.
- Neither array has been initialized.
- “score” contains 39 elements (one for each student in a class).
- “gradeCount” contains 5 elements (one for each possible grade, A - F).

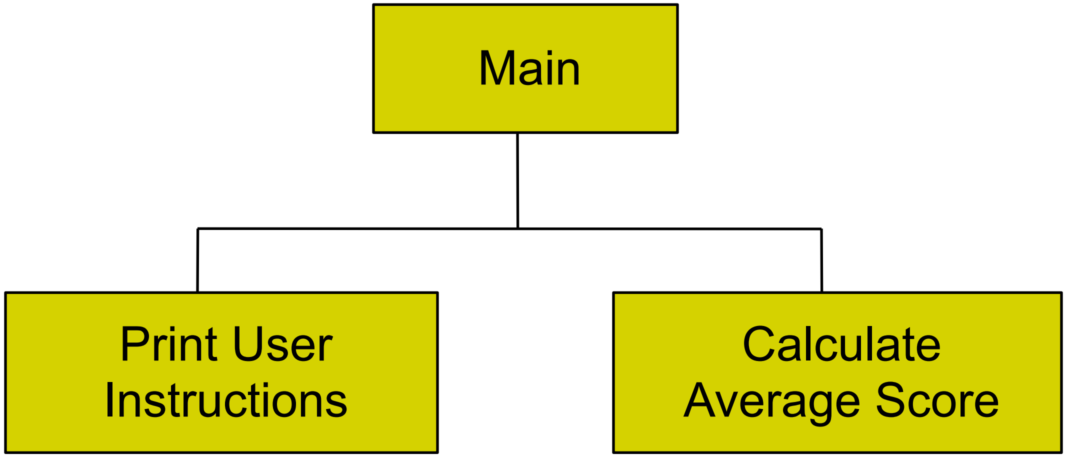
Using #define for Array Sizes

```
#define SIZE 39
#define GRADES 5
int main ( )
{
    int score [SIZE] ;
    int gradeCount [GRADES] ;
      .
      .
      .
}
```

Example Using Arrays

Problem: Find the average test score and the number of A's, B's, C's, D's, and F's for a particular class.

Design:



"Clean" Example Using Arrays (con't)

```
#include <stdio.h>
#define  SIZE 39          /* number of tests                                  */
#define  GRADES 5      /* number of different grades: A, B, C, D, F */
void PrintInstructions ( ) ;
double FindAverage (double sum, int quantity) ;
int main ( )
{
    int i ;                                       /* loop counter                          */
    int total ;                                   /* total of all scores                   */
    int score [SIZE] ;                            /* student scores                        */
    int gradeCount [GRADES] ;    /* count of A's, B's, C's, D's, F's */
    double average ;                              /* average score                         */

    /* Print the instructions for the user */
    PrintInstructions ( ) ;
```

“Clean” Example Using Arrays (con’t)

```
/* Initialize grade counts to zero */

for ( i = 0; i < GRADES; i++ )
{
    gradeCount [ i ] = 0 ;
}

/* Fill score array with scores */

for ( i = 0; i < SIZE; i++ )
{
    printf (“Enter next score: ”) ;
    scanf (“%d “, &score [ i ] ) ;
}
```

“Clean” Example Using Arrays (con’t)

```
/* Calculate score total and count number of each grade */

for ( i = 0; i < SIZE; i++ )
{
    total += score [ i ] ;
    switch ( score [ i ] / 10 )
    {
        case 10 :
        case   9 :  gradeCount [4]++  ;
                    break ;
        case   8 :  gradeCount [3]++ ;
                    break ;
        case   7 :  gradeCount [2]++  ;
                    break ;
        case   6 :  gradeCount [1]++ ;
                    break ;
        default    :  gradeCount [0]++ ;
    }
}
```

“Clean” Example Using Arrays (con’t)

```
     /* Calculate the average score */

     average = FindAverage (total, SIZE) ;

     /* Print the results */

    printf (“The class average is %.2f\n”, average ) ;
    printf (“There were %2d As\n”, gradeCount [4] ) ;
    printf (“                    %2d Bs\n”, gradeCount [3] ) ;
    printf (“                    %2d Cs\n”, gradeCount [2] ) ;
    printf (“                    %2d Ds\n”, gradeCount [1] ) ;
    printf (“                    %2d Fs\n”, gradeCount [0] ) ;

    return 0 ;

 } /* end main */
```

“Clean” Example Using Arrays (con’t)

```
/**************************************************************
** PrintInstructions - prints the user instructions
** Inputs:  None
** Outputs:  None
/**************************************************************
void PrintInstructions ( )
{
    printf (“This program calculates the average score\n”) ;
    printf (“for a class of 39 students.  It also reports the\n”) ;
    printf (“number of A’s, B’s, C’s, D’s, and F’s.  You will\n”) ;
    printf (“be asked to enter the individual scores.\n”) ;
}
```

“Clean” Example Using Arrays (con’t)

```
/******************************************************************************
** FindAverage - calculates an average
** Inputs:  sum - the sum of all values
**              num - the number of values
** Outputs:  the computed average
******************************************************************************/
double FindAverage (double sum, int num)
{
   double average ;   /* computed average */

    if ( num != 0 ) {
        average = sum / num ;
    }
    else {
        average = 0 ;
   }

   return average ;
}
```

Improvements ?

- We’re trusting the user to enter valid grades. Let’s add input error checking.
- If we aren’t handling our array correctly, it’s possible that we may be evaluating garbage rather than valid scores. We’ll handle this by adding all the cases for F’s (0 - 59) to our switch structure and using the default case for reporting errors.
- We still have the “magic numbers” 4, 3, 2, 1, and 0 that are the quality points associated with grades. Let’s use symbolic constants for these values.

Improved Program

```
#include <stdio.h>
#define  SIZE 39          /* number of scores                            */
#define GRADES 5        /* number of different grades: A, B, C, D, F  */
#define A 4             /* A's position in grade count array          */
#define B 3             /* B's position in grade count array          */
#define C 2             /* C's position in grade count array          */
#define D 1             /* D's position in grade count array          */
#define F 0             /* F's position in grade count array          */
#define MAX 100         /* maximum valid score                         */
#define MIN 0           /* minimum valid score                         */

void PrintInstructions ( ) ;
double FindAverage (double sum, int quantity) ;

int main ( )
{
    int i ;                        /* loop counter                  */
    int total ;                    /* total of all scores           */
    int score [SIZE] ;             /* student scores                */
    int gradeCount [GRADES] ;    /* count of A's, B's, C's, D's, F's */
    double average ;               /* average score                 */
```

Improved Program (con’t)

```
/* Print the instructions for the user */

PrintInstructions ( ) ;

/* Initialize grade counts to zero */

for ( i = 0; i < GRADES; i++ )
{
    gradeCount [ i ] = 0 ;
}
```

Improved Program (con’t)

```
/* Fill array with valid scores */

for ( i = 0; i < SIZE; i++ )
{
    printf (“Enter next score : ”) ;
    scanf (“%d “, &score [ i ] ) ;
    while ( (score [ i ] < MIN)  ||  (score [ i ] > MAX) )
    {
        printf (“Scores must be between”) ;
        printf (“ %d and %d\n”, MIN, MAX) ;
        printf (“Enter next score : ”) ;
        scanf (“%d “, &score [ i ] ) ;
    }
}
```

Improved Program (con’t)

```
/* Calculate score total and count number of each grade */
for ( i = 0 ; i < SIZE ; i++ )
{
    total += score [ i ] ;
    switch ( score [ i ] / 10 )
    {
        case 10 :
        case   9 :  gradeCount [A]++  ;
                    break ;
        case   8 :  gradeCount [B]++ ;
                    break ;
        case   7 :  gradeCount [C]++  ;
                    break ;
        case   6 :  gradeCount [D]++ ;
                    break ;
        case   5 :  case 4 :  case 3 :  case 2 :  case 1 :  case 0 :
                    gradeCount [F]++ ;
                    break;;
        default  :  printf(“Error in score.\n”) ;
    }
}
```

Improved Program (con’t)

```
    /* Calculate the average score */

    average = FindAverage (total, SIZE) ;

    /* Print the results */

   printf (“The class average is %.2f\n”, average ) ;
   printf (“There were %2d As\n”, gradeCount [A] ) ;
   printf (“           %2d Bs\n”, gradeCount [B] ) ;
   printf (“           %2d Cs\n”, gradeCount [C] ) ;
   printf (“           %2d Ds\n”, gradeCount [D] ) ;
   printf (“           %2d Fs\n”, gradeCount [F] )  ;

   return 0 ;

} /* end main */
```

Other Improvements?

- Why is main so large?
- Couldn't we write functions to:
  - Initialize an array to hold all 0s?
  - Fill an array with values entered by the user?
  - Count the grades and find the class average?
  - Print the results?
- Yes, we can as soon as we learn about passing arrays as parameters to functions in the next lecture.