CSE / ENGR 142 Programming I

Arrays

Chapter 8

8.1 Declaration and Referencing

8.2 Subscripts

8.3 Loop through arrays

8.4 & 8.5 Arrays arguments and parameters

8.6 Example

8.7 Multi-Dimensional Arrays

Motivation: Sorting

Input: 10 15 4 25 17 3 12 36 48 32 9 21

Desired output:
3 4 9 10 12 15 17 21 25 32 36 48

How can this be done?

If we had lots of variables we could store each input in a variable.

But think about what the program would be like.

Is there a better way?

Another Motivation - Averaging Grades

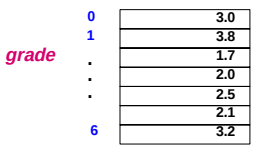
```
double grade1, grade2, grade3, grade4, grade5,
       grade6, grade7, total ;

/* initialize grades somehow...*/

total = grade1 + grade2 + grade3 + grade4
       + grade5 + grade6 + grade7 ;

printf( "average =  %f \n", total /  7.0) ;
```


Data Structures

- Functions give us a way to organize programs.
- Data structures are needed to organize data, especially:
  - large amounts of data
  - variable amounts of data
  - sets of data where the individual pieces are related to one another
- In this course, we will structure data using
  - arrays
  - *structs*
  - combinations of arrays and *structs*

Arrays

- Definition: *A named, ordered collection of values of identical type*
- Name the collection; number the elements
- Example: grades for 7 students



C expressions:

grade[0] is 3.0

grade[6] is 3.2

*2.0*grade[3]* is 4.0

...

Averaging Grades II

```
double grade[7], total ;
int i;
... /* initialize grades somehow... then:
total = grade[0]+grade[1]+grade[2]+grade[4]+grade[5]+grade[6];
or here's how we really would do it: */
total = 0;
for( i=0; i<7; i = i+1) {
    total = total + grade[i];
}
printf( "average =  %f \n", total /  7.0) ;
```


Array Terminology

`type name[size];`

- array declaration
- size must be an int constant

double grade[7]

grade is of type array of double with size 7.

grade[0], grade[1], ... , grade[6] are the elements of the array grade. Each is of type double.

0,1, ... , 6 are the indices of the array. Also called subscripts.

The bounds are the lowest and highest values of the subscripts (here: 0 and 6).

Array names are identifiers

- Therefore:
  - They follow the all usual rules for C identifiers (start with a letter, etc.)
  - They must be declared before they are used
- If you see ***x[y]*** in a program, then you know that
  - ***x*** should be the name of an array
  - ***y*** should have an integer value

Index Rule

Rule: ***An array index must evaluate to an int between 0 and n-1, where n is the number of elements in the array.*** **No exceptions!**

Example:

```
grade[i+3+k]      /* OK as long as 0 ≤ i+3+k ≤ 6 */
```

The index may be very simple

```
grade[0]
```

or incredibly complex

```
grade[(int) (3.1 * fabs(sin (2.0*PI*sqrt(29.067))))]
```


C Array Bounds are Not Checked

```
#define CLASS_SIZE 7

double grade[CLASS_SIZE] ;
int i ;
i = 9 ;
...
grade[i] = 3.5 ;              /* Is i out of range?? */

if ( 0 <= i  &&  i < CLASS_SIZE )
    grade[i] = 3.5 ;
else
    printf("Array index %d out of range. \n", i) ;
```


Element Rule

Rule: ***An array element can be used wherever a simple variable of the same type can be used.*** **No exceptions!**

- **Examples:**

```
scanf ( "%lf", &grade[i] ) ;
grade[i] = sin (2.0*PI*sqrt(29.067))
```

Using Array Elements

```
double grade[7];     int i=3;  /*declarations*/

printf( "Last two are %f, %f", grade[5], grade[6]);

grade[5] = 0.0 ;

grade[i] = 2.0 * grade[i+1] ;

scanf( "%lf",  &grade[0] );

swap( &grade[i], &grade[i+1] );
```


Things You Can and Can't Do

- You can't
  use = to assign one array variable to another.
- You can't
  use == to directly compare array variables
- You can't
  directly *scanf* or *printf* arrays

But you can do these things on array elements!

And you can write functions to do them

Averaging Grades III

```
#define CLASS_SIZE 7

double grade[CLASS_SIZE];
double total;
int i ;

printf ( "Enter %d grades \n", CLASS_SIZE ) ;
for ( i = 0 ;  i < CLASS_SIZE ;  i = i + 1 )
     scanf ( "%lf", &grade[i] ) ;

/* print and total grades */
total = 0.0;
for ( i = 0;  i  < CLASS_SIZE ;  i = i + 1)  {
     printf ( "The %d-th grade is %f \n", i, grade[i] ) ;
     total = total + grade[i] ;
}
printf ( "average =  %f \n",  total / (double) CLASS_SIZE ) ;
```


Are Arrays Necessary?

```
#define CLASS_SIZE 7

double next_grade, total ;
int i ;

/* read,  print, and total grades */
printf ( "Enter %d grades \n", CLASS_SIZE ) ;
total = 0.0 ;
for ( i = 0 ;  i < CLASS_SIZE ;  i = i + 1)  {
     scanf ( "%lf", &next_grade ) ;
     printf ( "The %d-th grade is %f \n", i, next_grade ) ;
     total = total + next_grade ;
}
printf ( "average =  %f \n",  total / (double) CLASS_SIZE ) ;
```

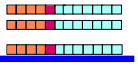

Average Grades IV

```
/* read grades, print ones above average only*/
double grade[CLASS_SIZE], average, total ;
int i ;
total = 0.0 ;
for ( i = 0 ;  i < CLASS_SIZE ;  i = i + 1 )  {
    scanf ( "%lf", &grade[i] ) ;
    total = total + grade[i] ;
}
average = total / (double) CLASS_SIZE ;
for ( i = 0 ;  i < CLASS_SIZE ;  i = i + 1 )
    if ( grade[i] > average )
       printf("Grade %d is high:%f \n", i, grade[i]);
```


Parallel Arrays

```
#define MT_WEIGHT        0.30
#define FINAL_WEIGHT     0.70
#define MAX_STUDENTS     200

int num_student,
    midterm[MAX_STUDENTS],
    final[MAX_STUDENTS] ;
double score[MAX_STUDENTS] ;
```

Parallel Arrays



/* Suppose we have input the value of *num_students*, read student *i*'s grades for midterm and final, and stored them in *midterm[i]* and *final[i]*. Now:

Store a weighted average of exams in the array *score*.

*/

```
if (num_student <= MAX_STUDENTS)
    for ( i = 0 ;   i < num_student ;   i = i + 1 )  {
        score[i] = MT_WEIGHT * (double) midterm[i] +
                   FINAL_WEIGHT * (double) final[i] ;
}
```


Reading Array Elements

/* Read in student midterm and final grades and store them in two arrays

*/

```
#define MAX_STUDENTS    200
int   midterm [MAX_STUDENTS] ;
int       final [MAX_STUDENTS] ;
int   num_student ;       /* actual number of students */
int   i, done, s_midterm, s_final ;
```


Reading Arrays

```
printf("Input number of students: ") ;
scanf("%d", &num_student) ;

if ( num_student > MAX_STUDENTS )
    printf("Too many students") ;
else
    for ( i = 0 ;  i < num_student ;  i = i+1 )
        scanf("%d %d", &midterm[i], &final[i]) ;
```


Reading Arrays II

```
done = FALSE ;  num_student = 0 ;
while (! done)  {
    scanf("%d %d", &s_midterm, &s_final) ;
    if (s_midterm == -1 || num_student >= MAX_STUDENTS ) {
        done = TRUE ;
    } else {
        midterm[num_student] = s_midterm ;
        final[num_student] = s_final ;
        num_student =  num_student + 1 ;
    }
}
```

Terminate input with "sentinel" -1, -1

Shifting Array Elements

/* Shift *x[0], x[1], ..., x[n-1]* one position upwards to make space for a new element at *x[0]*.

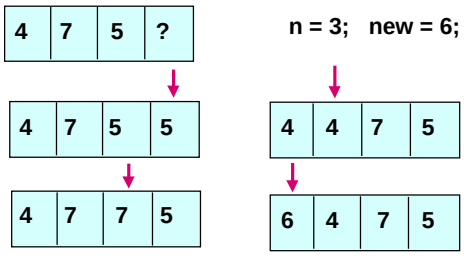
Insert the value *new* at *x[0]*.

Update the value of *n*.

*/

```
for ( k = n ;   k >= 1 ;   k = k - 1 )
    x[k] = x[k-1] ;
x[0] = new ;
n = n+1 ;
```


Shifting Array Elements



Review: initializing variables

- "Initialization" means giving something a value for the first time.
  - General rule: variables have to be initialized before their value is used.
- *Various ways of initializing*
  - *initializer when declaring*
  - *assignment statement*
  - *scanf (or other function call using &)*
  - *parameters are initialized with actual values*

Initialization Quiz

```
void init_example (int a) { /*line 1*/
   int b, c, d=10, e[5];      /*line 2*/
   b=5;                       /*line 3*/
   d=6;                       /*line 4*/
   scanf("%d %d", &b, &c);    /*line 5*/
   }
```

Q: Where is each of a, b, c, d, and e initialized?

Array Initializers

```
int w[4] = {1, 2, 30, -4};
        /*w has size 4, all 4 are initialized */

char vowels[6]    = {'a', 'e', 'i', 'o', 'u'},
   /*vowels has size 6, only 5 have initializers */
   /* vowels[5] is uninitialized */
```

Cannot use this notation in assignment statement:

```
w = {1, 2, 30, -4}; /*SYNTAX ERROR */
```


Incomplete Array Size

```
double x[ ] = {1.0, 3.0, -15.0, 7.0, 9.0};
   /*x has size 5, all 5 are initialized */

But:
double x[ ];  /* ILLEGAL */
```


Review: Array Elements as Parameters

```
printf( "Last two are %f, %f", grade[5], grade[6] ) ;
draw_house( color[i], x[i], y[i], windows[i] ) ;
scanf( "%lf",  &grade[0] ) ;
swap( &grade[i], &grade[i+1] ) ;
```

Just apply the element rule: *An array element can be used wherever a simple variable of the same type can be used.*

Whole Array as Parameters

```
#define ARRAY_SIZE  200
double average ( int a[ARRAY_SIZE] ) {
   int i, total = 0 ;
   for ( i = 0 ;  i < ARRAY_SIZE ;  i = i + 1 )
      total = total + a[i]  ;
   return ((double) total /  (double) ARRAY_SIZE) ;
}

int x[ARRAY_SIZE] ;
...
x_avg = average ( x ) ;
```

Arrays as Output Parameters

```
/* Sets vsum to sum of  vectors a and b. */
void vector_sum( int a[3], int b[3], int vsum[3])  {
    int i ;
    for ( i = 0 ;  i < 3 ;  i = i + 1 )
        vsum[i] = a[i] + b[i] ;
}

int main(void)  {
    int x[3] = {1,2,3},  y[3] = {4,5,6},  z[3] ;
    vector_sum( x , y , z );
    printf( "%d %d %d", z[0], z[1], z[2] ) ;
}
```

note:
no *
no &

General Vector Sum

```
void vector_sum( int a[ ] , int b[ ] ,
                 int vsum[ ] , int length)  {
   int i ;
   for ( i = 0 ;  i < length ;  i = i + 1 )
     vsum[i] = a[i] + b[i] ;
}
```

```
int x[3] = {1,2,3},  y[3] = {4,5,6},  z[3] ;
vector_sum( x , y , z , 3 );
```


Array Parameter Summary

Array **elements**:

Just like simple variables of that type, both input & output parameters

Whole arrays:

Arrays are **not** passed by value, i.e. **not** copied

Formal parameter: *type array_name [SIZE]*
Or : *type array_name [ ]*
no *

Actual parameter: *array_name*
no [ ] , no &

An Array as a Pointer

int A[100];