CSE 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) ;
```

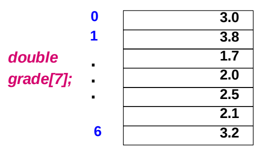
What if we had 500 grades to add up instead of 7?

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 *(grade)*; number the elements *(0 to 6)***
- **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

```
#define MAXGRADES 7
double grade[MAXGRADES], total ;
int index;
... /* initialize grades somehow... then:
total = grade[0] + grade[1] + grade[2] + grade[3]
        + grade[4] + grade[5] + grade[6];
  or here's how we really would do it: */
total = 0;
for( index=0; index<MAXGRADES; index++) {
     total = total + grade[index];
}
printf( "average =  %f \n", total /  MAXGRADES) ;
```

5/7/00 K-7

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 a variable 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).

5/7/00 K-8

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**

5/7/00 K-9

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 $0 \le i+3+k \le 6$ */**

The index may be very simple

grade[0]

or incredibly complex

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

5/7/00 K-10

C Array Bounds are Not Checked

```
#define CLASS_SIZE 7

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

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

5/7/00 K-11

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))

5/7/00 K-12

Samples of 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 entire array to another.
- You can’t
  use == to directly compare entire arrays
- You can’t
  directly *scanf* or *printf* entire 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      student ;

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

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

Are Arrays Really Necessary?

```
/*Solve the grade average problem without arrays:*/
#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 ) ;
```

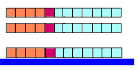
Do we ever really need to store all of the grades?

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



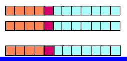
A set of arrays may be used in parallel when more than one piece of information must be stored for each item.

Example: each student has a midterm grade, final exam grade, and average score: 3 pieces of information for each item (student).

```
#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 array *score*.

***/**

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

Reading Array Elements

/* Read in student midterm and final grades and store them in two (parallel) 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

Terminate input with "sentinel" -1, -1

```
scanf("%d %d", &s_midterm, &s_final) ;
num_student = 0 ;
while (s_midterm != -1 && num_student < MAX_STUDENTS){
        midterm[num_student] = s_midterm ;
        final[num_student] = s_final ;
        scanf("%d %d", &s_midterm, &s_final) ;
        num_student++;
}
```

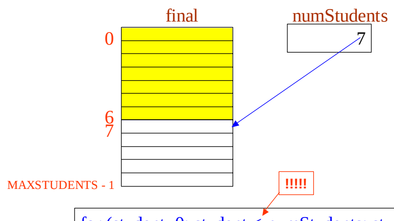
Keeping Track of the Elements In-Use

- Since the array has to be declared a fixed size, you often declare it bigger than you think you'll really need

```
#define MAXSTUDENTS 750
int       final[MAXSTUDENTS];
```

- How do you know which elements in the array actually hold data, and which are unused extras?
    1. Keep the valid entries together at the front
    2. Record number of valid entries in a separate variable

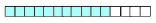
Keep the valid entries together

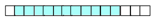


```
for (student=0; student < numStudents; student++) {
        …
}
```

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]*. 

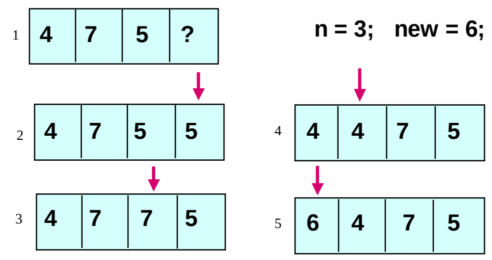
Update the value of *n*. 

**/*

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

Shifting Array Elements

n = 3;   new = 6;



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

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

```
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] ) ;
```

Whole Arrays 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 VectorSum( int a[3], int b[3], int vsum[3])  {
              int i ;
note:         for ( i = 0 ;  i < 3 ;  i = i + 1 )
no *              vsum[i] = a[i] + b[i] ;
no &      }

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

General Vector Sum

```
void VectorSum( 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] ;
VectorSum( x , y , z , 3 );
```

Array Parameter Summary

Array elements:

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

Whole arrays:

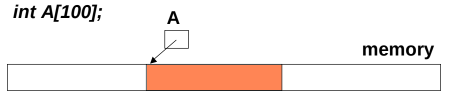
Arrays are not passed by value, i.e. not copied

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];



A[0]	equivalent to	*A
A[i]	equivalent to	*(A + i)

pointer addition