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Programação – Aula Teórica 6
Vetores

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Vetores em C++

Outline

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Objectives

- **In this lesson, you will learn:**
  - To introduce the array data structure
  - To understand the use of arrays to store, sort and search lists and tables of values
  - To understand how to define an array, initialize an array and refer to individual elements of an array
  - To be able to pass arrays to functions
  - To understand basic sorting techniques
  - To be able to define and manipulate multiple subscript arrays

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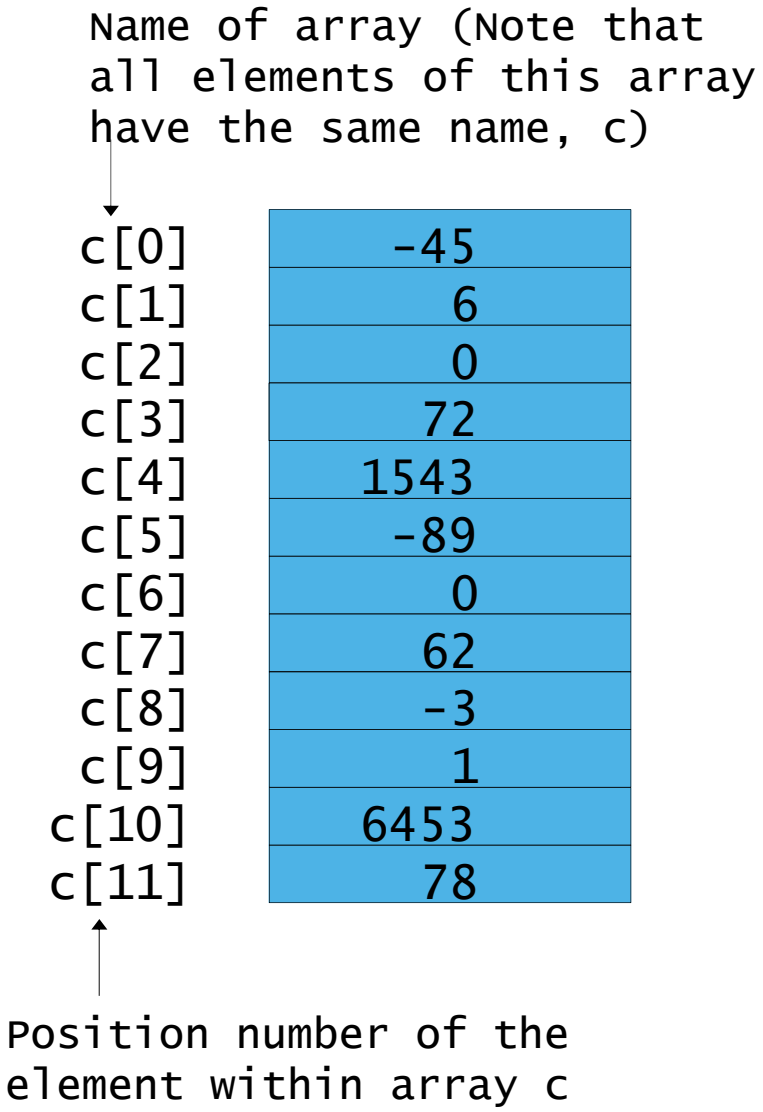
6.1 Introduction

- **Arrays**
  - Structures of related data items
  - For now: Static entity – same size throughout program
  - Dynamic data structures are not discussed in this lesson

6.2 Arrays

- **Array**
  - Group of consecutive memory locations
  - Same name and type
- **To refer to an element, specify**
  - Array name
  - Position number
- **Format:**

  arrayname [*position number*]
  - First element at position 0
  - n element array named `c`:
    - `c[0],c[1]...c[n-1]`



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6.2 Arrays

- **Array elements are like normal variables**

```
c[ 0 ] =  3;
printf( "%d", c[ 0 ] );
```

  - Perform operations in subscript. If x equals 3

```
c[ 5 - 2 ] == c[ 3 ] == c[ x ]
```

Operators						Associativity	Type
[]	()					left to right	highest
++	--	!	(*type*)			right to left	unary
*	/	%				left to right	multiplicative
+	-					left to right	additive
<	<=	>	>=			left to right	relational
==	!=					left to right	equality
&&						left to right	logical and
||						left to right	logical or
?:						right to left	conditional
=	+=	-=	*=	/=	%=	right to left	assignment
,						left to right	comma

Fig. 6.2 Operator precedence.

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6.3 Defining Arrays

- **When defining arrays, specify**
  - Name
  - Type of array
  - Number of elements

```
arrayType arrayName[ numberOfElements ];
```

  - Examples:

```
int c[ 10 ];
float myArray[ 3284 ];
```

- **Defining multiple arrays of same type**
  - Format similar to regular variables
  - Example:

```
int b[ 100 ], x[ 27 ];
```

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6.4 Examples Using Arrays

- **Initializers**

```
int n[ 5 ] = { 1, 2, 3, 4, 5 };
```

  - If not enough initializers, rightmost elements become 0

```
int n[ 5 ] = { 0 }
```

    - All elements 0
  - If too many a syntax error is produced syntax error
  - C arrays have no bounds checking
- **If size omitted, initializers determine it**

```
int n[ ] = { 1, 2, 3, 4, 5 };
```

  - 5 initializers, therefore 5 element array

```c
/* Fig. 6.3: fig06_03.c
   initializing an array */
#include <stdio.h>

/* function main begins program execution */
int main()
{
   int n[ 10 ]; /* n is an array of 10 integers */
   int i;       /* counter */

   /* initialize elements of array n to 0 */
   for ( i = 0; i < 10; i++ ) {
      n[ i ] = 0; /* set element at location i to 0 */
   } /* end for */

   printf( "%s%13s\n", "Element", "Value" );

   /* output contents of array n in tabular format */
   for ( i = 0; i < 10; i++ ) {
      printf( "%7d%13d\n", i, n[ i ] );
   } /* end for */

   return 0; /* indicates successful termination */

} /* end main */
```

Element	Value
0	0
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0

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6.4 Examples Using Arrays

- **Character arrays**
  - String "`first`" is really a static array of characters
  - Character arrays can be initialized using string literals

```
char string1[] = "first";
```

    - Null character `'\0'` terminates strings
    - `string1` actually has 6 elements
      - It is equivalent to

```
char string1[] = { 'f', 'i', 'r', 's', 't', '\0' };
```

  - Can access individual characters

```
string1[ 3 ] is character 's'
```

  - Array name is address of array, so & not needed for scanf

```
scanf( "%s", string2 );
```

    - Reads characters until whitespace encountered
    - Can write beyond end of array, be careful

```c
/* Fig. 6.4: fig06_04.c
   Initializing an array with an initializer list */
#include <stdio.h>

/* function main begins program execution */
int main()
{
   /* use initializer list to initialize array n */
   int n[ 10 ] = { 32, 27, 64, 18, 95, 14, 90, 70, 60, 37 };
   int i; /* counter */

   printf( "%s%13s\n", "Element", "Value" );

   /* output contents of array in tabular format */
   for ( i = 0; i < 10; i++ ) {
      printf( "%7d%13d\n", i, n[ i ] );
   } /* end for */

   return 0; /* indicates successful termination */

} /* end main */
```

Element	Value
0	32
1	27
2	64
3	18
4	95
5	14
6	90
7	70
8	60
9	37

```c
/* Fig. 6.5: fig06_05.c
   Initialize the elements of array s to the even integers from 2 to 20 */
#include <stdio.h>
#define SIZE 10

/* function main begins program execution */
int main()
{
   /* symbolic constant SIZE can be used to specify array size */
   int s[ SIZE ]; /* array s has 10 elements */
   int j;         /* counter */

   for ( j = 0; j < SIZE; j++ ) { /* set the values */
      s[ j ] = 2 + 2 * j;
   } /* end for */

   printf( "%s%13s\n", "Element", "Value" );

   /* output contents of array s in tabular format */
   for ( j = 0; j < SIZE; j++ ) {
      printf( "%7d%13d\n", j, s[ j ] );
   } /* end for */

   return 0; /* indicates successful termination */

} /* end main */
```

Element	Value
0	2
1	4
2	6
3	8
4	10
5	12
6	14
7	16
8	18
9	20

fig06_06.c

```c
/* Fig. 6.6: fig06_06.c
   Compute the sum of the elements of the array */
#include <stdio.h>
#define SIZE 12

/* function main begins program execution */
int main()
{
   /* use initializer list to initialize array */
   int a[ SIZE ] = { 1, 3, 5, 4, 7, 2, 99, 16, 45, 67, 89, 45 };
   int i;         /* counter */
   int total = 0; /* sum of array */

   /* sum contents of array a */
   for ( i = 0; i < SIZE; i++ ) {
      total += a[ i ];
   } /* end for */

   printf( "Total of array element values is %d\n", total );

   return 0; /* indicates successful termination */

} /* end main */
```

```
Total of array element values is 383
```

```c
/* Fig. 6.7: fig06_07.c
   Student poll program */
#include <stdio.h>
#define RESPONSE_SIZE 40 /* define array sizes */
#define FREQUENCY_SIZE 11

/* function main begins program execution */
int main()
{
   int answer; /* counter */
   int rating; /* counter */

   /* initialize frequency counters to 0 */
   int frequency[ FREQUENCY_SIZE ] = { 0 };

   /* place survey responses in array responses */
   int responses[ RESPONSE_SIZE ] = { 1, 2, 6, 4, 8, 5, 9, 7, 8, 10,
        1, 6, 3, 8, 6, 10, 3, 8, 2, 7, 6, 5, 7, 6, 8, 6, 7, 5, 6, 6,
        5, 6, 7, 5, 6, 4, 8, 6, 8, 10 };

```

```
21    /* for each answer, select value of an element of array responses
22       and use that value as subscript in array frequency to
23       determine element to increment */
24    for ( answer = 0; answer < RESPONSE_SIZE; answer++ ) {
25       ++frequency[ responses [ answer ] ];
26    } /* end for */
27
28    /* display results */
29    printf( "%s%17s\n", "Rating", "Frequency" );
30
31    /* output frequencies in tabular format */
32    for ( rating = 1; rating < FREQUENCY_SIZE; rating++ ) {
33       printf( "%6d%17d\n", rating, frequency[ rating ] );
34    } /* end for */
35
36    return 0; /* indicates successful termination */
37
38 } /* end main */
```

Rating	Frequency
1	2
2	2
3	2
4	2
5	5
6	11
7	5
8	7
9	1
10	3

```c
/* Fig. 6.8: fig06_08.c
   Histogram printing program */
#include <stdio.h>
#define SIZE 10

/* function main begins program execution */
int main()
{
   /* use initializer list to initialize array n */
   int n[ SIZE ] = { 19, 3, 15, 7, 11, 9, 13, 5, 17, 1 };
   int i; /* outer counter */
   int j; /* inner counter */

   printf( "%s%13s%17s\n", "Element", "Value", "Histogram" );

   /* for each element of array n, output a bar in histogram */
   for ( i = 0; i < SIZE; i++ ) {
      printf( "%7d%13d          ", i, n[ i ]) ;

      for ( j = 1; j <= n[ i ]; j++ ) { /* print one bar */
         printf( "%c", '*' );
       } /* end inner for */

```

```
24          printf( "\n" ); /* start next line of output */
25       } /* end outer for */
26
27       return 0; /* indicates successful termination */
28
29    } /* end main */
```

```
Element         Value      Histogram
      0            19      ********************
      1             3      ***
      2            15      ***************
      3             7      *******
      4            11      ***********
      5             9      *********
      6            13      *************
      7             5      *****
      8            17      *****************
      9             1      *
```

```c
/* Fig. 6.9: fig06_09.c
   Roll a six-sided die 6000 times */
#include <stdio.h>
#include <stdlib.h>
#include <time.h>
#define SIZE 7

/* function main begins program execution */
int main()
{
   int face;                      /* random number with value 1 - 6 */
   int roll;                      /* roll counter */
   int frequency[ SIZE ] = { 0 }; /* initialize array to 0 */

   srand( time( NULL ) ); /* seed random-number generator */

   /* roll die 6000 times */
   for ( roll = 1; roll <= 6000; roll++ ) {
      face = rand() % 6 + 1;
      ++frequency[ face ]; /* replaces 26-line switch of Fig. 5.8 */
   } /* end for */

   printf( "%s%17s\n", "Face", "Frequency" );

```

```
25    /* output frequency elements 1-6 in tabular format */
26    for ( face = 1; face < SIZE; face++ ) {
27       printf( "%4d%17d\n", face, frequency[ face ] );
28    } /* end for */
29
30    return 0; /* indicates successful termination */
31
32 } /* end main */
```

```
Face        Frequency
   1             1029
   2              951
   3              987
   4             1033
   5             1010
   6              990
```

```c
/* Fig. 6.10: fig06_10.c
   Treating character arrays as strings */
#include <stdio.h>

/* function main begins program execution */
int main()
{
   char string1[ 20 ];                 /* reserves 20 characters */
   char string2[] = "string literal"; /* reserves 15 characters */
   int i;                              /* counter */

   /* read string from user into array string2 */
   printf("Enter a string: ");
   scanf( "%s", string1 );

   /* output strings */
   printf( "string1 is: %s\nstring2 is: %s\n"
           "string1 with spaces between characters is:\n",
           string1, string2 );

   /* output characters until null character is reached */
   for ( i = 0; string1[ i ] != '\0'; i++ ) {
      printf( "%c ", string1[ i ] );
   } /* end for */

```

```
26    printf( "\n" );
27
28    return 0; /* indicates successful termination */
29
30 } /* end main */
```

```
Enter a string: Hello there
string1 is: Hello
string2 is: string literal
string1 with spaces between characters is:
H e l l o
```

```c
/* Fig. 6.11: fig06_11.c
   Static arrays are initialized to zero */
#include <stdio.h>

void staticArrayInit( void );    /* function prototype */
void automaticArrayInit( void ); /* function prototype */

/* function main begins program execution */
int main()
{
   printf( "First call to each function:\n" );
   staticArrayInit();
   automaticArrayInit();

   printf( "\n\nSecond call to each function:\n" );
   staticArrayInit();
   automaticArrayInit();

   return 0; /* indicates successful termination */

} /* end main */

```

```c
/* function to demonstrate a static local array */
void staticArrayInit( void )
{
   /* initializes elements to 0 first time function is called */
   static int array1[ 3 ];
   int i; /* counter */

   printf( "\nValues on entering staticArrayInit:\n" );

   /* output contents of array1 */
   for ( i = 0; i <= 2; i++ ) {
      printf( "array1[ %d ] = %d  ", i, array1[ i ] );
   } /* end for */

   printf( "\nValues on exiting staticArrayInit:\n" );

   /* modify and output contents of array1 */
   for ( i = 0; i <= 2; i++ ) {
      printf( "array1[ %d ] = %d  ", i, array1[ i ] += 5 );
   } /* end for */

} /* end function staticArrayInit */

```

```
46 /* function to demonstrate an automatic local array */
47 void automaticArrayInit( void )
48 {
49    /* initializes elements each time function is called */
50    int array2[ 3 ] = { 1, 2, 3 };
51    int i; /* counter */
52
53    printf( "\n\nValues on entering automaticArrayInit:\n" );
54
55    /* output contents of array2 */
56    for ( i = 0; i <= 2; i++ ) {
57       printf("array2[ %d ] = %d  ", i, array2[ i ] );
58    } /* end for */
59
60    printf( "\nValues on exiting automaticArrayInit:\n" );
61
62    /* modify and output contents of array2 */
63    for ( i = 0; i <= 2; i++ ) {
64       printf( "array2[ %d ] = %d  ", i, array2[ i ] += 5 );
65    } /* end for */
66
67 } /* end function automaticArrayInit */
```

First call to each function:

Values on entering staticArrayInit:
array1[0] = 0 array1[1] = 0 array1[2] = 0
Values on exiting staticArrayInit:
array1[0] = 5 array1[1] = 5 array1[2] = 5

Values on entering automaticArrayInit:
array2[0] = 1 array2[1] = 2 array2[2] = 3
Values on exiting automaticArrayInit:
array2[0] = 6 array2[1] = 7 array2[2] = 8

Second call to each function:

Values on entering staticArrayInit:
array1[0] = 5 array1[1] = 5 array1[2] = 5
Values on exiting staticArrayInit:
array1[0] = 10 array1[1] = 10 array1[2] = 10

Values on entering automaticArrayInit:
array2[0] = 1 array2[1] = 2 array2[2] = 3
Values on exiting automaticArrayInit:
array2[0] = 6 array2[1] = 7 array2[2] = 8

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6.5 Passing Arrays to Functions

- **Passing arrays**
  - To pass an array argument to a function, specify the name of the array without any brackets

```
int myArray[ 24 ];
myFunction( myArray, 24 );
```

    - Array size usually passed to function
  - Arrays passed call-by-reference
  - Name of array is address of first element
  - Function knows where the array is stored
    - Modifies original memory locations
- **Passing array elements**
  - Passed by call-by-value
  - Pass subscripted name (i.e., `myArray[ 3 ]`) to function

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6.5 Passing Arrays to Functions

- **Function prototype**

```
void modifyArray( int b[], int arraySize );
```

  - Parameter names optional in prototype
    - `int b[]` could be written `int []`
    - `int arraySize` could be simply `int`

```c
/* Fig. 6.12: fig06_12.c
   The name of an array is the same as &array[ 0 ] */
#include <stdio.h>

/* function main begins program execution */
int main()
{
   char array[ 5 ]; /* define an array of size 5 */

   printf( "    array = %p\n&array[0] = %p\n"
      "   &array = %p\n",
      array, &array[ 0 ], &array );

   return 0; /* indicates successful termination */

} /* end main */
```

```
    array = 0012FF78
&array[0] = 0012FF78
   &array = 0012FF78
```

```c
/* Fig. 6.13: fig06_13.c
   Passing arrays and individual array elements to functions */
#include <stdio.h>
#define SIZE 5

/* function prototypes */
void modifyArray( int b[], int size );
void modifyElement( int e );

/* function main begins program execution */
int main()
{
   int a[ SIZE ] = { 0, 1, 2, 3, 4 }; /* initialize a */
   int i; /* counter */

   printf( "Effects of passing entire array by reference:\n\nThe "
           "values of the original array are:\n" );

   /* output original array */
   for ( i = 0; i < SIZE; i++ ) {
      printf( "%3d", a[ i ] );
   } /* end for */

   printf( "\n" );

```

```
26    /* pass array a to modifyArray by reference */
27    modifyArray( a, SIZE );
28
29    printf( "The values of the modified array are:\n" );
30
31    /* output modified array */
32    for ( i = 0; i < SIZE; i++ ) {
33       printf( "%3d", a[ i ] );
34    } /* end for */
35
36    /* output value of a[ 3 ] */
37    printf( "\n\n\nEffects of passing array element "
38            "by value:\n\nThe value of a[3] is %d\n", a[ 3 ] );
39
40    modifyElement( a[ 3 ] ); /* pass array element a[ 3 ] by value */
41
42    /* output value of a[ 3 ] */
43    printf( "The value of a[ 3 ] is %d\n", a[ 3 ] );
44
45    return 0; /* indicates successful termination */
46
47 } /* end main */
48
```

```
49 /* in function modifyArray, "b" points to the original array "a"
50    in memory */
51 void modifyArray( int b[], int size )
52 {
53    int j; /* counter */
54
55    /* multiply each array element by 2 */
56    for ( j = 0; j < size; j++ ) {
57       b[ j ] *= 2;
58    } /* end for */
59
60 } /* end function modifyArray */
61
62 /* in function modifyElement, "e" is
     a local copy of array element
63    a[ 3 ] passed from main */
64 void modifyElement( int e )
65 {
66    /* multiply parameter by 2 */
67    printf( "Value in modifyElement is %d\n", e *= 2 );
68 } /* end function modifyElement */
```

Effects of passing entire array by reference:

The values of the original array are:

0 1 2 3 4

The values of the modified array are:

0 2 4 6 8

Effects of passing array element by value:

The value of a[3] is 6

Value in modifyElement is 12

The value of a[3] is 6

```c
/* Fig. 6.14: fig06_14.c
   Demonstrating the const type qualifier with arrays */
#include <stdio.h>

void tryToModifyArray( const int b[] ); /* function prototype */

/* function main begins program execution */
int main()
{
   int a[] = { 10, 20, 30 }; /* initialize a */

   tryToModifyArray( a );

   printf("%d %d %d\n", a[ 0 ], a[ 1 ], a[ 2 ] );

   return 0; /* indicates successful termination */

} /* end main */

```

```
20 /* in function tryToModifyArray, array b is const, so it cannot be
21    used to modify the original array a in main. */
22 void tryToModifyArray( const int b[] )
23 {
24    b[ 0 ] /= 2;    /* error */
25    b[ 1 ] /= 2;    /* error */
26    b[ 2 ] /= 2;    /* error */
27 } /* end function tryToModifyArray */
```

```
Compiling...
FIG06_14.C
fig06_14.c(24) : error C2166: l-value specifies const
object
fig06_14.c(25) : error C2166: l-value specifies const
object
fig06_14.c(26) : error C2166: l-value specifies const
object
```

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6.6 Sorting Arrays

- **Sorting data**
  - Important computing application
  - Virtually every organization must sort some data
- **Bubble sort (sinking sort)**
  - Several passes through the array
  - Successive pairs of elements are compared
    - If increasing order (or identical), no change
    - If decreasing order, elements exchanged
  - Repeat
- **Example:**
  - original: 3 4 2 6 7
  - pass 1: 3 2 4 6 7
  - pass 2: 2 3 4 6 7
  - Small elements "bubble" to the top

```c
/* Fig. 6.15: fig06_15.c
   This program sorts an array's values into ascending order */
#include <stdio.h>
#define SIZE 10

/* function main begins program execution */
int main()
{
   /* initialize a */
   int a[ SIZE ] = { 2, 6, 4, 8, 10, 12, 89, 68, 45, 37 };
   int i;    /* inner counter */
   int pass; /* outer counter */
   int hold; /* temporary location used to swap array elements */

   printf( "Data items in original order\n" );

   /* output original array */
   for ( i = 0; i < SIZE; i++ ) {
      printf( "%4d", a[ i ] );
   } /* end for */

```

```
22    /* bubble sort */
23    /* loop to control number of passes */
24    for ( pass = 1; pass < SIZE; pass++ ) {
25
26       /* loop to control number of comparisons per pass */
27       for ( i = 0; i < SIZE - 1; i++ ) {
28
29          /* compare adjacent elements and swap them if first
30          element is greater than second element */
31          if ( a[ i ] > a[ i + 1 ] ) {
32             hold = a[ i ];
33             a[ i ] = a[ i + 1 ];
34             a[ i + 1 ] = hold;
35          } /* end if */
36
37       } /* end inner for */
38
39    } /* end outer for */
40
41    printf( "\nData items in ascending order\n" );
42
```

```
43    /* output sorted array */
44    for ( i = 0; i < SIZE; i++ ) {
45       printf( "%4d", a[ i ] );
46    } /* end for */
47
48    printf( "\n" );
49
50    return 0; /* indicates successful termination */
51
```

```
Data items in original order
   2   6   4   8  10  12  89  68  45  37
Data items in ascending order
   2   4   6   8  10  12  37  45  68  89
```

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6.7 Case Study: Computing Mean, Median and Mode Using Arrays

- **Mean – average**
- **Median – number in middle of sorted list**
  - 1, 2, 3, 4, 5
  - 3 is the median
- **Mode – number that occurs most often**
  - 1, 1, 1, 2, 3, 3, 4, 5
  - 1 is the mode

```c
/* Fig. 6.16: fig06_16.c
   This program introduces the topic of survey data analysis.
   It computes the mean, median, and  mode of the data */
#include <stdio.h>
#define SIZE 99

/* function prototypes */
void mean( const int answer[] );
void median( int answer[] );
void mode( int freq[], const int answer[] ) ;
void bubbleSort( int a[] );
void printArray( const int a[] );

/* function main begins program execution */
int main()
{
   int frequency[ 10 ] = { 0 }; /* initialize array frequency */

```

```
19    /* initialize array response */
20    int response[ SIZE ] =
21       { 6, 7, 8, 9, 8, 7, 8, 9, 8, 9,
22         7, 8, 9, 5, 9, 8, 7, 8, 7, 8,
23         6, 7, 8, 9, 3, 9, 8, 7, 8, 7,
24         7, 8, 9, 8, 9, 8, 9, 7, 8, 9,
25         6, 7, 8, 7, 8, 7, 9, 8, 9, 2,
26         7, 8, 9, 8, 9, 8, 9, 7, 5, 3,
27         5, 6, 7, 2, 5, 3, 9, 4, 6, 4,
28         7, 8, 9, 6, 8, 7, 8, 9, 7, 8,
29         7, 4, 4, 2, 5, 3, 8, 7, 5, 6,
30         4, 5, 6, 1, 6, 5, 7, 8, 7 };
31
32    /* process responses */
33    mean( response );
34    median( response );
35    mode( frequency, response );
36
37    return 0; /* indicates successful termination */
38
39 } /* end main */
40
```

```c
/* calculate average of all response values */
void mean( const int answer[] )
{
   int j;          /* counter */
   int total = 0; /* variable to hold sum of array elements */

   printf( "%s\n%s\n%s\n", "********", "  Mean", "********" );

   /* total response values */
   for ( j = 0; j < SIZE; j++ ) {
      total += answer[  j  ];
   } /* end for */

   printf( "The mean is the average value of the data\n"
           "items. The mean is equal to the total of\n"
           "all the data items divided by the number\n"
           "of data items ( %d ). The mean value for\n"
           "this run is: %d / %d = %.4f\n\n",
           SIZE, total, SIZE, (  double  ) total / SIZE );
} /* end function mean */
```

```
62 /* sort array and determine median element's value */
63 void median( int answer[] )
64 {
65    printf( "\n%s\n%s\n%s\n%s",
66            "********", " Median", "********",
67            "The unsorted array of responses is" );
68
69    printArray( answer ); /* output unsorted array */
70
71    bubbleSort( answer ); /* sort array */
72
73    printf( "\n\nThe sorted array is" );
74    printArray( answer ); /* output sorted array */
75
76    /* display median element */
77    printf( "\n\nThe median is element %d of\n"
78            "the sorted %d element array.\n"
79            "For this run the median is %d\n\n",
80            SIZE / 2, SIZE, answer[ SIZE / 2 ] );
81 } /* end function median */
82
```

```
83 /* determine most frequent response */
84 void mode( int freq[], const int answer[] )
85 {
86    int rating;        /* counter */
87    int j;             /* counter */
88    int h;             /* counter */
89    int largest = 0;   /* represents largest frequency */
90    int modeValue = 0; /* respesents most frequent response */
91
92    printf( "\n%s\n%s\n%s\n",
93            "********", "  Mode", "******** );
94
95    /* initialize frequencies to 0 */
96    for ( rating = 1; rating <= 9; rating++ ) {
97       freq[ rating ] = 0;
98    } /* end for */
99
100    /* summarize frequencies */
101   for ( j = 0; j < SIZE; j++ ) {
102      ++freq[ answer[ j ] ];
103   } /* end for */
104
```

```
105   /* output headers for result columns */
106   printf( "%s%11s%19s\n\n%54s\n%54s\n\n",
107           "Response", "Frequency", "Histogram",
108           "1    1    2    2", "5    0    5    0    5" );
109
110   /* output results */
111   for ( rating = 1; rating <= 9; rating++ ) {
112      printf( "%8d%11d          ", rating, freq[ rating ] );
113
114      /* keep track of mode value and largest frequency value */
115      if ( freq[ rating ] > largest ) {
116         largest = freq[ rating ];
117         modeValue = rating;
118      } /* end if */
119
120      /* output histogram bar representing frequency value */
121      for ( h = 1; h <= freq[ rating ]; h++ ) {
122         printf( "*" );
123      } /* end inner for */
124
125      printf( "\n" ); /* being new line of output */
126   } /* end outer for */
127
```

```
128   /* display the mode value */
129   printf( "The mode is the most frequent value.\n"
130           "For this run the mode is %d which occurred"
131           " %d times.\n", modeValue, largest );
132} /* end function mode */
133
134/* function that sorts an array with bubble sort algorithm */
135void bubbleSort( int a[] )
136{
137   int pass; /* counter */
138   int j;    /* counter */
139   int hold; /* temporary location used to swap elements */
140
141   /* loop to control number of passes */
142   for ( pass = 1; pass < SIZE; pass++ ) {
143
144      /* loop to control number of comparisons per pass */
145      for ( j = 0; j < SIZE - 1; j++ ) {
146
147         /* swap elements if out of order */
148         if ( a[ j ] > a[ j + 1 ] ) {
149            hold = a[ j ];
150            a[ j ] = a[ j + 1 ];
151            a[ j + 1 ] = hold;
152         } /* end if */
153
```

```
154       } /* end inner for */
155
156    } /* end outer for */
157
158 } /* end function bubbleSort */
159
160 /* output array contents (20 values per row) */
161 void printArray( const int a[] )
162 {
163    int j; /* counter */
164
165    /* output array contents */
166    for ( j = 0; j < SIZE; j++ ) {
167
168       if ( j % 20 == 0 ) { /* begin new line every 20 values */
169          printf( "\n" );
170       } /* end if */
171
172       printf( "%2d", a[ j ] );
173    } /* end for */
174
175 } /* end function printArray */
```

****
 Mean
****

The mean is the average value of the data items. The mean is equal to the total of all the data items divided by the number of data items (99). The mean value for this run is: 681 / 99 = 6.8788

****
 Median
****

The unsorted array of responses is

```
6 7 8 9 8 7 8 9 8 9 7 8 9 5 9 8 7 8 7 8
6 7 8 9 3 9 8 7 8 7 7 8 9 8 9 8 9 7 8 9
6 7 8 7 8 7 9 8 9 2 7 8 9 8 9 8 9 7 5 3
5 6 7 2 5 3 9 4 6 4 7 8 9 6 8 7 8 9 7 8
7 4 4 2 5 3 8 7 5 6 4 5 6 1 6 5 7 8 7
```

The sorted array is

```
1 2 2 2 3 3 3 3 4 4 4 4 4 5 5 5 5 5 5
5 6 6 6 6 6 6 6 6 6 7 7 7 7 7 7 7 7 7
7 7 7 7 7 7 7 7 7 7 7 7 7 8 8 8 8 8 8
8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
```

The median is element 49 of the sorted 99 element array.
For this run the median is 7

****
 Mode
****

```
Response  Frequency       Histogram

                      1   1   2   2
                  5   0   5   0   5

    1         1       *
    2         3       ***
    3         4       ****
    4         5       *****
    5         8       ********
    6         9       *********
    7        23       ***********************
    8        27       ***************************
    9        19       *******************
```

The mode is the most frequent value.
For this run the mode is 8 which occurred 27 times.

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6.8 Searching Arrays: Linear Search and Binary Search

- **Search an array for a *key value***
- **Linear search**
  - Simple
  - Compare each element of array with key value
  - Useful for small and unsorted arrays

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6.8 Searching Arrays: Linear Search and Binary Search

- **Binary search**
  - For sorted arrays
  - Compares `middle` element with `key`
    - If equal, match found
    - If `key < middle`, looks in first half of array
    - If `key > middle`, looks in last half
    - Repeat
  - Very fast; at most n steps, where 2^n > number of elements
    - 30 element array takes at most 5 steps
      - $2^5 > 30$ so at most 5 steps

```c
/* Fig. 6.18: fig06_18.c
   Linear search of an array */
#include <stdio.h>
#define SIZE 100

/* function prototype */
int linearSearch( const int array[], int key, int size );

/* function main begins program execution */
int main()
{
   int a[ SIZE ]; /* create array a */
   int x;         /* counter */
   int searchKey; /* value to locate in a */
   int element;   /* variable to hold location of searchKey or -1 */

   /* create data */
   for ( x = 0; x < SIZE; x++ ) {
      a[ x ] = 2 * x;
   } /* end for */

   printf( "Enter integer search key:\n" );
   scanf( "%d", &searchKey );

```

```
25    /* attempt to locate searchKey in array a */
26    element = linearSearch( a, searchKey, SIZE );
27
28    /* display results */
29    if ( element != -1 ) {
30       printf( "Found value in element %d\n", element );
31    } /* end if */
32    else {
33       printf( "Value not found\n" );
34    } /* end else */
35
36    return 0; /* indicates successful termination */
37
38 } /* end main */
39
40 /* compare key to every element of array until the location is found
41    or until the end of array is reached; return subscript of element
42    if key or -1 if key is not found */
43 int linearSearch( const int array[], int key, int size )
44 {
45    int n; /* counter */
46
47    /* loop through array */
48    for ( n = 0; n < size; ++n ) {
49
```

```
50          if ( array[ n ] == key ) {
51             return n; /* return location of key */
52          } /* end if */
53
54       } /* end for */
55
56       return -1; /* key not found */
57
58    } /* end function linearSearch */
```

```
Enter integer search key:
36
Found value in element 18


Enter integer search key:
37
Value not found1
```

```c
/* Fig. 6.19: fig06_19.c
   Binary search of an array */
#include <stdio.h>
#define SIZE 15

/* function prototypes */
int binarySearch( const int b[], int searchKey, int low, int high );
void printHeader( void );
void printRow( const int b[], int low, int mid, int high );

/* function main begins program execution */
int main()
{
   int a[ SIZE ]; /* create array a */
   int i;         /* counter */
   int key;       /* value to locate in array a */
   int result;    /* variable to hold location of key or -1 */

   /* create data */
   for ( i = 0; i < SIZE; i++ ) {
      a[ i ] = 2 * i;
   } /* end for */

   printf( "Enter a number between 0 and 28: " );
   scanf( "%d", &key );

```

```
27    printHeader();
28
29    /* search for key in array a */
30    result = binarySearch( a, key, 0, SIZE - 1 );
31
32    /* display results */
33    if ( result != -1 ) {
34       printf( "\n%d found in array element %d\n", key, result );
35    } /* end if */
36    else {
37       printf( "\n%d not found\n", key );
38    } /* end else */
39
40    return 0; /* indicates successful termination */
41
42 } /* end main */
43
44 /* function to perform binary search of an array */
45 int binarySearch( const int b[], int searchKey, int low, int high )
46 {
47    int middle; /* variable to hold middle element of array */
48
```

```
49    /* loop until low subscript is greater than high subscript */
50    while ( low <= high ) {
51
52       /* determine middle element of subarray being searched */
53       middle = ( low + high ) / 2;
54
55       /* display subarray used in this loop iteration */
56       printRow( b, low, middle, high );
57
58       /* if searchKey matched middle element, return middle */
59       if ( searchKey == b[ middle ] ) {
60          return middle;
61       } /* end if */
62
63       /* if searchKey less than middle element, set new high */
64       else if ( searchKey < b[ middle ] ) {
65          high = middle - 1; /* search low end of array */
66       } /* end else if */
67
68       /* if searchKey greater than middle element, set new low */
69       else {
70          low = middle + 1; /* search high end of array */
71       } /* end else */
72
73    } /* end while */
74
```

```
75    return -1;   /* searchKey not found */
76
77 } /* end function binarySearch */
78
79 /* Print a header for the output */
80 void printHeader( void )
81 {
82    int i; /* counter */
83
84    printf( "\nSubscripts:\n" );
85
86    /* output column head */
87    for ( i = 0; i < SIZE; i++ ) {
88       printf( "%3d ", i );
89    } /* end for */
90
91    printf( "\n" ); /* start new line of output */
92
93    /* output line of - characters */
94    for ( i = 1; i <= 4 * SIZE; i++ ) {
95       printf( "-" );
96    } /* end for */
97
98    printf( "\n" ); /* start new line of output */
99 } /* end function printHeader */
100
```

```
/* Print one row of output showing the current
   part of the array being processed. */
void printRow( const int b[], int low, int mid, int high )
{
   int i; /* counter */

   /* loop through entire array */
   for ( i = 0; i < SIZE; i++ ) {

      /* display spaces if outside current subarray range */
      if ( i < low || i > high ) {
         printf( "    " );
      } /* end if */
      else if ( i == mid ) { /* display middle element */
         printf( "%3d*", b[ i ] ); /* mark middle value */
      } /* end else if */
      else { /* display other elements in subarray */
         printf( "%3d ", b[ i ] );
      } /* end else */

   } /* end for */

   printf( "\n" ); /* start new line of output */
} /* end function printRow */
```

```
Enter a number between 0 and 28: 25

Subscripts:
 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14
---------------------------------------------------------
 0  2  4  6  8 10 12 14* 16 18 20 22 24 26 28
                   16 18 20 22* 24 26 28
                               24 26* 28
                               24*

25 not found

Enter a number between 0 and 28: 8

Subscripts:
 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14
---------------------------------------------------------
 0  2  4  6  8 10 12 14* 16 18 20 22 24 26 28
 0  2  4  6* 8 10 12
            8 10* 12
            8*

8 found in array element 4
```

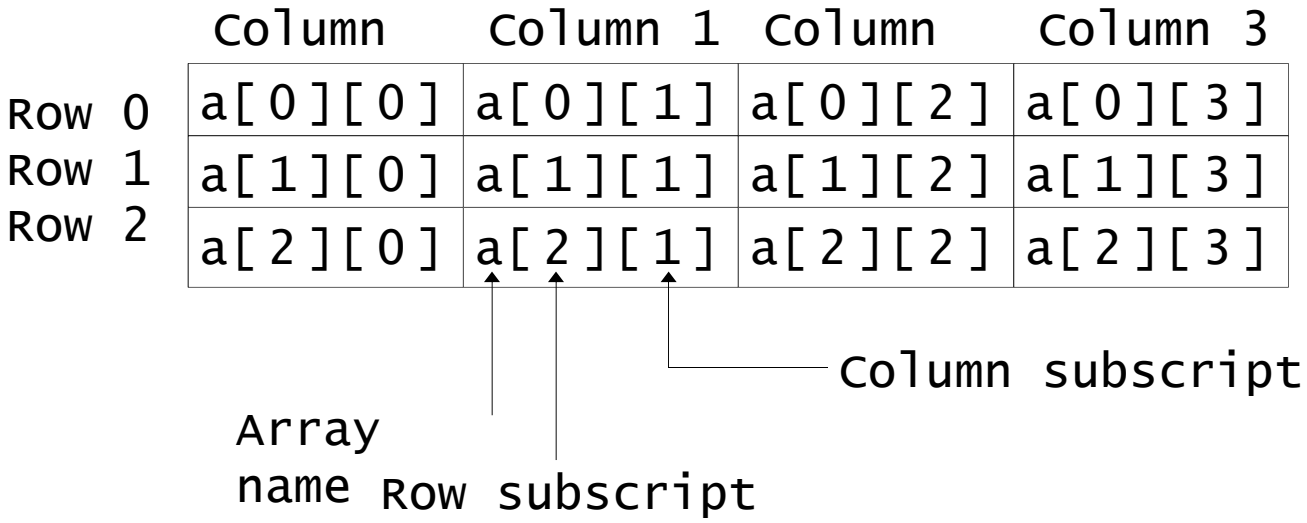
```
Enter a number between 0 and 28: 6

Subscripts:
 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14
---------------------------------------------------------
 0  2  4  6  8 10 12 14* 16 18 20 22 24 26
28
 0  2  4  6* 8 10 12

6 found in array element 3
```

6.9 Multiple-Subscripted Arrays

- **Multiple subscripted arrays (Matrix)**
  - Tables with rows and columns (m by n array)
  - Like matrices: specify row, then column



6.9 Multiple-Subscripted Arrays

- **Initialization**
  - `int b[2][2]={{1,2},{3,4}};`
  - Initializers grouped by row in braces
  - If not enough, unspecified elements set to zero

    `int b[2][2]={{1},{3,4}};`

1	2
3	4

- **Referencing elements**
  - Specify row, then column

    `printf("%d",b[0][1]);`

1	0
3	4

```c
/* Fig. 6.21: fig06_21.c
   Initializing multidimensional arrays */
#include <stdio.h>

void printArray( const int a[][ 3 ] ); /* function prototype */

/* function main begins program execution */
int main()
{
   /* initialize array1, array2, array3 */
   int array1[ 2 ][ 3 ] = { { 1, 2, 3 }, { 4, 5, 6 } };
   int array2[ 2 ][ 3 ] = { 1, 2, 3, 4, 5 };
   int array3[ 2 ][ 3 ] = { { 1, 2 }, { 4 } };

   printf( "Values in array1 by row are:\n" );
   printArray( array1 );

   printf( "Values in array2 by row are:\n" );
   printArray( array2 );

   printf( "Values in array3 by row are:\n" );
   printArray( array3 );

   return 0; /* indicates successful termination */

} /* end main */
```

```
28 /* function to output array with two rows and three columns */
29 void printArray( const int a[][ 3 ] )
30 {
31    int i; /* counter */
32    int j; /* counter */
33
34    /* loop through rows */
35    for ( i = 0; i <= 1; i++ ) {
36
37       /* output column values */
38       for ( j = 0; j <= 2; j++ ) {
39          printf( "%d ", a[ i ][ j ] );
40       } /* end inner for */
41
42       printf( "\n" ); /* start new line of output */
43    } /* end outer for */
44
45 } /* end function printArray */
```

```
Values in array1 by row are:
1 2 3
4 5 6
Values in array2 by row are:
1 2 3
4 5 0
Values in array3 by row are:
1 2 0
4 0 0
```

```c
/* Fig. 6.22: fig06_22.c
   Double-subscripted array example */
#include <stdio.h>
#define STUDENTS 3
#define EXAMS 4

/* function prototypes */
int minimum( const int grades[][ EXAMS ], int pupils, int tests );
int maximum( const int grades[][ EXAMS ], int pupils, int tests );
double average( const int setOfGrades[], int tests );
void printArray( const int grades[][ EXAMS ], int pupils, int tests );

/* function main begins program execution */
int main()
{
   int student; /* counter */

   /* initialize student grades for three students (rows) */
   const int studentGrades[ STUDENTS ][ EXAMS ] =
      { { 77, 68, 86, 73 },
        { 96, 87, 89, 78 },
        { 70, 90, 86, 81 } };

```

```
24    /* output array studentGrades */
25    printf( "The array is:\n" );
26    printArray( studentGrades, STUDENTS, EXAMS );
27
28    /* determine smallest and largest grade values */
29    printf( "\n\nLowest grade: %d\nHighest grade: %d\n",
30       minimum( studentGrades, STUDENTS, EXAMS ),
31       maximum( studentGrades, STUDENTS, EXAMS ) );
32
33    /* calculate average grade for each student */
34    for ( student = 0; student <= STUDENTS - 1; student++ ) {
35       printf( "The average grade for student %d is %.2f\n",
36          student, average( studentGrades[ student ], EXAMS ) );
37    } /* end for */
38
39    return 0; /* indicates successful termination */
40
41 } /* end main */
42
43 /* Find the minimum grade */
44 int minimum( const int grades[][ EXAMS ], int pupils, int tests )
45 {
46    int i;              /* counter */
47    int j;              /* counter */
48    int lowGrade = 100; /* initialize to highest possible grade */
49
```

```
50    /* loop through rows of grades */
51    for ( i = 0; i < pupils; i++ ) {
52
53       /* loop through columns of grades */
54       for ( j = 0; j < tests; j++ ) {
55
56          if ( grades[ i ][ j ] < lowGrade ) {
57             lowGrade = grades[ i ][ j ];
58          } /* end if */
59
60       } /* end inner for */
61
62    } /* end outer for */
63
64    return lowGrade; /* return minimum grade */
65
66 } /* end function minimum */
67
68 /* Find the maximum grade */
69 int maximum( const int grades[][ EXAMS ], int pupils, int tests )
70 {
71    int i;              /* counter */
72    int j;              /* counter */
73    int highGrade = 0; /* initialize to lowest possible grade */
74
```

```
75    /* loop through rows of grades */
76    for ( i = 0; i < pupils; i++ ) {
77
78       /* loop through columns of grades */
79       for ( j = 0; j < tests; j++ ) {
80
81          if ( grades[ i ][ j ] > highGrade ) {
82             highGrade = grades[ i ][ j ];
83          } /* end if */
84
85       } /* end inner for */
86
87    } /* end outer for */
88
89    return highGrade; /* return maximum grade */
90
91 } /* end function maximum */
92
93 /* Determine the average grade for a particular student */
94 double average( const int setOfGrades[], int tests )
95 {
96    int i;          /* counter */
97    int total = 0; /* sum of test grades */
98
```

```
99     /* total all grades for one student */
100    for ( i = 0; i < tests; i++ ) {
101       total += setOfGrades[ i ];
102    } /* end for */
103
104    return ( double ) total / tests; /* average */
105
106 } /* end function average */
107
108 /* Print the array */
109 void printArray( const int grades[][ EXAMS ], int pupils, int tests )
110 {
111    int i; /* counter */
112    int j; /* counter */
113
114    /* output column heads */
115    printf( "                [0]  [1]  [2]  [3]" );
116
117    /* output grades in tabular format */
118    for ( i = 0; i < pupils; i++ ) {
119
120       /* output label for row */
121       printf( "\nstudentGrades[%d] ", i );
122
```

```
123       /* output grades for one student */
124       for ( j = 0; j < tests; j++ ) {
125          printf( "%-5d", grades[ i ][ j ] );
126       } /* end inner for */
127
128    } /* end outer for */
129
130} /* end function printArray */
```

```
The array is:
                  [0]  [1]  [2]  [3]
studentGrades[0] 77   68   86   73
studentGrades[1] 96   87   89   78
studentGrades[2] 70   90   86   81

Lowest grade: 68
Highest grade: 96
The average grade for student 0 is 76.00
The average grade for student 1 is 87.50
The average grade for student 2 is 81.75
```

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Questões?

Programação – Aula Teórica 6

Vetores

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(Slides Baseados em Deitel e Deitel 2010 e L.P.Reis et al., 2006)