Arrays & Vectors

Week 5

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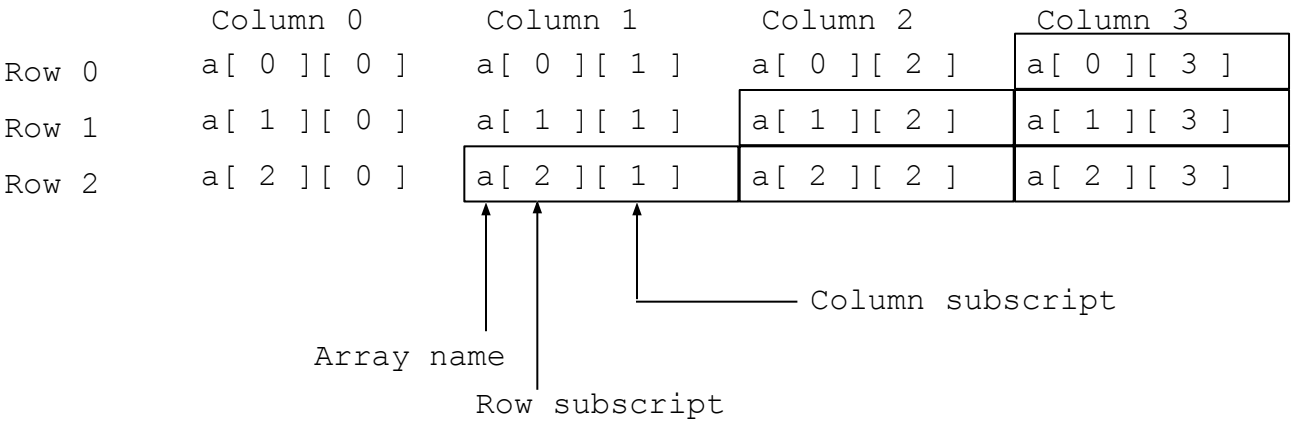
Multiple-Subscripted Arrays

- Multiple subscripts
  - **`a[ i ][ j ]`**
  - Tables with rows and columns
  - Specify row, then column
  - "Array of arrays"
    - **`a[0]`** is an array of 4 elements
    - **`a[0][0]`** is the first element of that array



Multiple-Subscripted Arrays

- To initialize
  - Default of **0**
  - Initializers grouped by row in braces

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

1	2
3	4

Row 0 Row 1

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

1	0
3	4

Multiple-Subscripted Arrays

- Referenced like normal

```
cout << b[ 0 ][ 1 ];
```

  - Outputs **0**
  - Cannot reference using commas

```
cout << b[ 0, 1 ];
```

    - Syntax error

1	0
3	5

```
1  // Fig. 3.22: fig04_22.cpp
2  // Initializing multidimensional arrays.
3  #include <iostream>
4
5  using std::cout;
6  using std::endl;
7
8  void printArray( int [][ 3 ] );
9
10 int main()
11 {
12    int array1[ 2 ][ 3 ] = { { 1, 2, 3 }, { 4, 5, 6 } };
13    int array2[ 2 ][ 3 ] = { 1, 2, 3, 4, 5 };
14    int array3[ 2 ][ 3 ] = { { 1, 2 }, { 4 } };
15
16    cout << "Values in array1 by row are:" << endl;
17    printArray( array1 );
18
19    cout << "Values in array2 by row are:" << endl;
20    printArray( array2 );
21
22    cout << "Values in array3 by row are:" << endl;
23    printArray( array3 );
24
25    return 0;  // indicates successful termination
26
27 } // end main
```

Note the format of the prototype.

Note the various initialization styles. The elements in `array2` are assigned to the first row and then the second.

```
28
29  // function to output array with two rows and three columns
30  void printArray( int a[][ 3 ] )
31  {
32    for ( int i = 0; i < 2; i++ ) {    // for each row
33
34      for ( int j = 0; j < 3; j++ )   // output column values
35        cout << a[ i ][ j ] << ' ';
36
37      cout << endl;  // start new line of output
38
39    } // end outer for structure
40
41  } // end function printArray
```

For loops are often used to iterate through arrays. Nested loops are helpful with multiple-subscripted arrays.

```
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
```

Multiple-Subscripted Arrays

- Next: program showing initialization
  - After, program to keep track of students grades
  - Multiple-subscripted array (table)
  - Rows are students
  - Columns are grades

	Quiz1	Quiz2
Student0	1	85
Student1	89	80

```
1  // Fig. 3.23: fig04_23.cpp
2  // Double-subscripted array example.
3  #include <iostream>
4
5  using std::cout;
6  using std::endl;
7  using std::fixed;
8  using std::left;
9
10 #include <iomanip>
11
12 using std::setw;
13 using std::setprecision;
14
15 const int students = 3;   // number of students
16 const int exams = 4;      // number of exams
17
18 // function prototypes
19 int minimum( int [][ exams ], int, int );
20 int maximum( int [][ exams ], int, int );
21 double average( int [], int );
22 void printArray( int [][ exams ], int, int );
23
```

```
24 int main()
25 {
26    // initialize student grades for three students (rows)
27    int studentGrades[ students ][ exams ] =
28       { { 77, 68, 86, 73 },
29         { 96, 87, 89, 78 },
30         { 70, 90, 86, 81 } };
31
32    // output array studentGrades
33    cout << "The array is:\n";
34    printArray( studentGrades, students, exams );
35
36    // determine smallest and largest grade values
37    cout << "\n\nLowest grade: "
38         << minimum( studentGrades, students, exams )
39         << "\nHighest grade: "
40         << maximum( studentGrades, students, exams ) << '\n';
41
42    cout << fixed << setprecision( 2 );
43
```

```
44    // calculate average grade for each student
45    for ( int person = 0; person < students; person++ )
46       cout << "The average grade for student " << person
47            << " is "
48            << average( studentGrades[ person ], exams )
49            << endl;
50
51    return 0;  // indicates successful termination
52
53 } // end main
54
55 // find minimum grade
56 int minimum( int grades[][ exams ], int pupils, int tests )
57 {
58    int lowGrade = 100; // initialize to highest possible grade
59
60    for ( int i = 0; i < pupils; i++ )
61
62       for ( int j = 0; j < tests; j++ )
63
64          if ( grades[ i ][ j ] < lowGrade )
65             lowGrade = grades[ i ][ j ];
66
67    return lowGrade;
68
69 } // end function minimum
```

Determines the average for one student. We pass the array/row containing the student's grades. Note that `studentGrades[0]` is itself an array.

```
70
71  // find maximum grade
72  int maximum( int grades[][ exams ], int pupils, int tests )
73  {
74    int highGrade = 0;  // initialize to lowest possible grade
75
76    for ( int i = 0; i < pupils; i++ )
77
78      for ( int j = 0; j < tests; j++ )
79
80        if ( grades[ i ][ j ] > highGrade )
81          highGrade = grades[ i ][ j ];
82
83    return highGrade;
84
85  } // end function maximum
86
```

```
87 // determine average grade for particular student
88 double average( int setOfGrades[], int tests )
89 {
90    int total = 0;
91
92    // total all grades for one student
93    for ( int i = 0; i < tests; i++ )
94       total += setOfGrades[ i ];
95
96    return static_cast< double >( total ) / tests;  // average
97
98 } // end function maximum
```

```
99
100 // Print the array
101 void printArray( int grades[][ exams ], int pupils, int tests )
102 {
103   // set left justification and output column heads
104   cout << left << "               [0]  [1]  [2]  [3]";
105
106   // output grades in tabular format
107   for ( int i = 0; i < pupils; i++ ) {
108
109     // output label for row
110     cout << "\nstudentGrades[" << i << "] ";
111
112     // output one grades for one student
113     for ( int j = 0; j < tests; j++ )
114       cout << setw( 5 ) << grades[ i ][ j ];
115
116   } // end outer for
117
118 } // 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

"Well, I'll eat it," said Alice, "and if it makes me grow larger, I can reach the key; and if it makes me grow smaller, I can creep under the door; so either way I'll get into the garden."

Lewis Carroll, Alice's Adventures in Wonderland

VECTORS

Array

- cannot change the length

Vector

- the same purpose as arrays
  - ✔ except can change length while the program is running

Like an array, a vector has a base type, and like an array, a vector stores a collection of values of its base type.

Vectors

Library:

#include <vector>

Declaration:

vector <base_type> name;

Example:

vector <int> v;

vector <int> v(10);

Vectors

- To add an element to a vector for the first time, you normally use the member function ***push_back***.

Example:

```
int main() {

    vector<double> sample;
    sample[0]=1;
    sample.push_back(0.0);
    sample.push_back(1.1);
    sample.push_back(2.2);

}
```

Vectors

- The number of elements in a vector is called the **size of the vector.**
- The member function **size** can be used to determine how many elements are in a vector.

Example:

```
for (int i = 0; i < sample.size( ); i++){
    cout << sample[i] << endl;
}
```

// Demonstrating C++ Standard Library class template vector.

```cpp
#include <iostream>
using std::cout;
using std::cin;
using std::endl;

#include <iomanip>
using std::setw;

#include <vector>
using std::vector;

void outputVector( const vector< int > & ); // display the vector
void inputVector( vector< int > & ); // input values into the vector

int main()
{
   vector< int > integers1( 7 ); // 7-element vector< int >
   vector< int > integers2( 10 ); // 10-element vector< int >
```

```
// print integers1 size and contents
cout << "Size of vector integers1 is " << integers1.size()
     << "\nvector after initialization:" << endl;
outputVector( integers1 );

// print integers2 size and contents
cout << "\nSize of vector integers2 is " << integers2.size()
     << "\nvector after initialization:" << endl;
outputVector( integers2 );

// input and print integers1 and integers2
cout << "\nEnter 17 integers:" << endl;
inputVector( integers1 );
inputVector( integers2 );

cout << "\nAfter input, the vectors contain:\n"
     << "integers1:" << endl;
outputVector( integers1 );
cout << "integers2:" << endl;
outputVector( integers2 );
```

```
// use inequality (!=) operator with vector objects
cout << "\nEvaluating: integers1 != integers2" << endl;

if ( integers1 != integers2 )
   cout << "integers1 and integers2 are not equal" << endl;

// create vector integers3 using integers1 as an
// initializer; print size and contents
vector< int > integers3( integers1 ); // copy constructor

cout << "\nSize of vector integers3 is " << integers3.size()
     << "\nvector after initialization:" << endl;
outputVector( integers3 );

// use overloaded assignment (=) operator
cout << "\nAssigning integers2 to integers1:" << endl;
integers1 = integers2; // integers1 is larger than integers2

cout << "integers1:" << endl;
outputVector( integers1 );
cout << "integers2:" << endl;
outputVector( integers2 );
```

```
   // use equality (==) operator with vector objects
   cout << "\nEvaluating: integers1 == integers2" << endl;

   if ( integers1 == integers2 )
      cout << "integers1 and integers2 are equal" << endl;
   // use square brackets to create rvalue
   cout << "\nintegers1[5] is " << integers1[ 5 ];

   // use square brackets to create lvalue
   cout << "\n\nAssigning 1000 to integers1[5]" << endl;
   integers1[ 5 ] = 1000;
   cout << "integers1:" << endl;
   outputVector( integers1 );

   // attempt to use out-of-range subscript
   cout << "\nAttempt to assign 1000 to integers1.at( 15 )" << endl;
   integers1.at( 15 ) = 1000; // ERROR: out of range
   return 0;
} // end main
```

```cpp
// output vector contents
void outputVector( const vector< int > &array )
{
   size_t i; // declare control variable
   for ( i = 0; i < array.size(); i++ )
   {
      cout << setw( 12 ) << array[ i ];
      if ( ( i + 1 ) % 4 == 0 ) // 4 numbers per row of output
         cout << endl;
   } // end for

   if ( i % 4 != 0 )
      cout << endl;
} // end function outputVector

// input vector contents
void inputVector( vector< int > &array )
{
   for ( size_t i = 0; i < array.size(); i++ )
      cin >> array[ i ];
} // end function inputVector
```

Two / Three / Multi Dimensioned arrays using vector

- A two dimensional array is a vector of vectors.
- The vector contructor can initialize the length of the array and set the initial value.
- Example of a vector of vectors to represent a two dimensional array:
  - vector< vector<int> > vI2Matrix(3, vector<int>(2,0));

```cpp
#include <iostream>
#include <vector>
using namespace std;
int main() {
    // Declare size of two dimensional array and initialize.
    vector< vector<int> > vI2Matrix(3, vector<int>(2,0));
    vI2Matrix[0][0] = 0;
    vI2Matrix[0][1] = 1;
    vI2Matrix[1][0] = 10;
    vI2Matrix[1][1] = 11;
    vI2Matrix[2][0] = 20;
    vI2Matrix[2][1] = 21;
    cout << "Loop by index:" << endl;
    int ii, jj;
    for(ii=0; ii < 3; ii++) {
        for(jj=0; jj < 2; jj++) {
            cout << vI2Matrix[ii][jj] << endl;
        }
    }
    return 0;
}
```

Loop by index:
0
1
10
11
20
21

Two / Three / Multi Dimensioned arrays using vector

- A three dimensional vector would be declared as:

```
#include <iostream>
#include <vector>
using namespace std;
void main() {
    // Vector length of 3 initialized to 0
    vector<int> vI1Matrix(3,0);
    // Vector length of 4 initialized to hold another
    // vector vI1Matrix which has been initialized to 0
    vector< vector<int> > vI2Matrix(4, vI1Matrix);
```

```cpp
#include <iostream>
#include <vector>
using namespace std;
int main() {
    vector<vector<vector<int>>> vI3Matrix(2, vector<vector<int>>(3, vector<int>(4,0)));
    for(int kk=0; kk<4; kk++) {
        for(int jj=0; jj<3; jj++) {
            for(int ii=0; ii<2; ii++) {
                cout << vI3Matrix[ii][jj][kk] << endl;
            }
        }
    }
    return 0;
}
```

Quiz

- 1. What is vector?
  - Benefits of vector over array.
  - Difference between array and vector.
  - Which one is better for what purpose?
- 2. Write a program that create a 2-dimensional vector *vec1.*
  - initialize all elements of a vector to 1.
  - then output content of the vector *vec1.*

Readings:

- **C++ How to Program,** By H. M. Deitel
  - Chapter 7. Arrays and Vectors