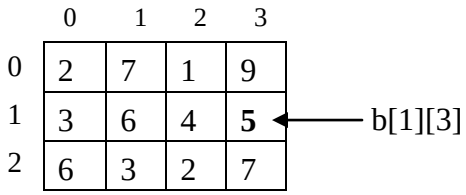
16 Multidimensional Arrays

1 Multidimensional arrays

The arrays we have seen so far are "1-dimensional", by which is meant that a single index suffices to identify any component of the array. A 2-dimensional array can be visualised as a grid; for example, a 2-dimensional integer array b with 4 columns and 3 rows can be pictured as



Each row and column is indexed from 0, and each component cell is identified by supplying two indices as indicated. We say that an array with m rows and n columns is an "m×n" array; for example, the array above is 3×4. A 2-dimensional array is also called a matrix. Arrays may have more than two dimensions.

In Java, a 3×4 integer array b is created by the following declaration:

```
int[][] b = new int[3][4];
```

Initialisation of the array can be included in the definition, as typified by

```
int[][] b = {{3,4,6,2}, {6,1,2,1}, {9,2,4,3}};
```

2 Example: magic squares

We write a program to generate a magic square, i.e. a square grid of distinct numbers whose rows, columns, and diagonals all have the same sum. The following is a magic square of order 3, i.e. a 3×3 magic square using the numbers 1 to 9, incl. (verify that each row, column, and diagonal adds up to 15):

8	1	6
3	5	7
4	9	2

When the numbers in the magic square are 1, 2, 3, ... we call it a *normal* magic square. We confine our attention to normal magic squares. The following is an algorithm to generate a (normal) magic square of order n, provided n is odd. Deposit 1, 2, 3, ..., n^2 in the cells of an n×n grid proceeding as follows. The first cell to receive a value is the middle of the top row. The successor cell in each case will be the cell immediately to the north-east (see how 6 follows 5 above). However, if the north-east cell does not exist, we wrap around the borders (see how 2 follows 1, and how 3 follows 2). After each group of n numbers have been deposited, the successor cell is immediately to the south rather than the north-east (see how 4 is to the south of 3 above). Test your understanding of this on the magic square above. For a further check, generate a magic square of order 5. You should get the following:

17	24	1	8	15
23	5	7	14	16
4	6	13	20	22
10	12	19	21	3
11	18	25	2	9

The program should print the number in each cell "right-justified", i.e. each column of numbers is aligned on the right-hand side. The magic squares program is given below. The command

```
java MagicSquare 5
```

will generate a magic square of order 5 (note that the size of the square is supplied as a command line argument).

```
class MagicSquare {
   public static void main(String[] args) {
```

```
   // Generate a magic square of order args[0], which
   // must be an odd positive integer
      int n = Integer.parseInt(args[0]);
      int[][] ms = new int[n][n]; // for the magic square
      int num = 1; // next number to be deposited
      int j = 0; int k = n/2; // next cell to be filled is ms[j][k]
      while (num<=n*n) {
         ms[j][k] = num; // fill in cell
         if (num%n==0) { // after each n steps go south
            j++;
         }
         else { // otherwise go north-east, with wrap around if necc.
            j--; if (j<0) j = n-1;
            k++; if (k==n) k = 0;
         }
         num++;
      }
      // print magic square
      for (j=0; j<n; j++) {
         for (k=0; k<n; k++) {
            // print  ms[j,k] right-justified in field of width 5
            System.out.printf("%5d", ms[j][k]);
         }
         System.out.println();
      }
   }
}
```

3 Arrays of arrays

We usually envisage a 2-dimensional array as a grid, as we have done above, and that picture will is sufficiently accurate to program with. The true picture is slightly more complex, however. A 2-dimensional array is actually implemented as an array of arrays: each row is a 1-dimsensional array. For example, given

```
int[][] b = new int[3][4]
```

b[1] is a 1-dimensional array of integers with four elements b[1][0], b[1][1], b[1][2], and b[1][3]. It is not a requirement that each row array have the same number of elements, e.g.

```
int[][] b = {{3,4,6,2}, {6,1}, {9,4,3}};
```

It is possible to supply b[1], say, whenever a 1-dimensional array is expected, as in:

```
int[][] b = {{3,4,6,2}, {6,1}, {9,4,3}};
int[] c = b[1];
```

We don't often use these additional possibilities.