Arrays (Chap 5)

• Array – an ordered collection of similar items
  – Student test scores
  – Mail boxes at your college
  – A collection of books on a shelf
• An array can be thought of as a type of container.

Array operations

• Create an array (build a book case to hold 20 books).
• Give a name to the array (the white book case in the hallway).
• Place items into certain positions in the array (put the books on the shelf in some particular order).
• Get the value of an item stored at a certain position in the array (get me the 5th book).

Array operations

• Create an array
  ```java
  new int[50]
  ```
• Use a variable to refer to the newly created array
  ```java
  int[] ourFirstArray = new int[50];
  ```
• Place items into certain positions in the array
  ```java
  ourFirstArray[i] = Console.in.readInt();
  ```
• Get the value of an item stored at a certain position in the array
  ```java
  System.out.println(ourFirstArray[i]);
  ```
// ReverseArray.java: One-dimensional array
import tiio.*;

class ReverseArray {
    public static void main(String[] args) {
        int[] simpleArray = new int[5];
        System.out.println("Enter 5 integers.");
        for(int i = 0; i < 5; i++)
            simpleArray[i] = Console.in.readInt();
        System.out.println("In reverse they are:");
        for(int i = 0; i < 5; i++)
            System.out.println(simpleArray[4-i]);
    }
}

// ArraySum.java - sum the elements in an array and
// compute their average

class ArraySum {
    public static void main(String[] args) {
        int[] data = {11, 12, 13, 14, 15, 16, 17};
        int sum = 0;
        double average;
        for (int i = 0; i < 7; i++) {
            sum = sum + data[i];
            System.out.print(data[i] + ", ");
        }
        average = sum / 7.0;
        System.out.println("\n\n sum = " + sum + " average = " + average);
    }
}

Common Error

IndexOutOfBoundsException

for(int i = 1; i <= data.length; i++)
    System.out.println(data[i]);
Another Common Error

- Forgot to create the array:
  ```java
  int[] x;
  ...
  for(int i = 0; i < x.length; i++)
  x[i] = ...;
  ```
- For local variables, the Java compiler will catch this (x is used before being assigned a value).
- If x is an instance variable, then it defaults to null and you get a NullPointerException.

```java
// sum the elements in an array using a method
class ArraySum2 {
    public static void main(String[] args) {
        int[] data1 = {1, 2, 3, 4, 5, 6, 7};
        int[] data2 = {16, 18, 77};

        System.out.println("data1:" + sum(data1));
        System.out.println("data2:" + sum(data2));
    }

    // sum the elements in an array
    static int sum (int[] a) {
        int sum = 0;
        for (int i = 0; i < a.length; i++)
            sum = sum + a[i];
        return sum;
    }
}
```

```java
// demonstrate that array parameters can be modified
class TestCopy {
    public static void main(String[] args) {
        int[] data1 = {1, 2, 3, 4, 5, 6, 7};
        int[] data2 = {8, 9, 10, 11, 12, 13, 14};
        copy(data1, data2);
        System.out.println("data1:");
        for (int i = 0; i < data1.length; i++)
            System.out.println(data1[i]);
        System.out.println("data2:");
        for (int i = 0; i < data2.length; i++)
            System.out.println(data2[i]);
    }

    static void copy(int[] from, int[] to) {
        for (int i = 0; i < from.length; i++)
            to[i] = from[i];
    }
}
```
static void copy(int[] from, int[] to){
    to = from;
}
Duplicating/Coping an array

```java
static int[] duplicate(int[] a) {
    int[] theCopy = new int[a.length];
    for (int i = 0; i < a.length; i++)
        theCopy[i] = a[i];
    return theCopy;
}

a1 = (int[])a2.clone(); // built in copy
```

// ArrayTest.java - minimum and maximum of an array
import tio.*;

class ArrayTest {
    public static void main(String[] args) {
        int[] data;
        int n;
        System.out.println("Enter size of data[]:");
        n = Console.in.readInt();
        data = new int[n];
        System.out.println("Enter " + n + " integers:");
        readArray(data);
        printArray(data, "My Data");
        System.out.println("minimum is " + minimum(data) + " maximum is " + maximum(data));
    }
}
// fill an array by reading values from the console
static void readArray(int[] a) {
  for (int i = 0; i < a.length; i++) {
    a[i] = Console.in.readInt();
  }
}

// find the maximum value in an array
static int maximum(int[] a) {
  int max = a[0]; // initial max value
  for (int i = 1; i < a.length; i++)
    if (a[i] > max)
      max = a[i];
  return max;
}

// find the minimum value in an array
static int minimum(int[] a) {
  int min = a[0]; // initial max value
  for (int i = 1; i < a.length; i++)
    if (a[i] < min)
      min = a[i];
  return min;
}

// print the elements of an array to the console
static void printArray(int[] a, String arrayName) {
  System.out.println(arrayName);
  for (int i = 0; i < a.length; i++)
    System.out.print(a[i] + "  ");
  System.out.println();
}

---

Sorting

- Sorting is a common task for computers.
- There are many different algorithms for sorting. Just a few are:
  - insertion sort - add elements one at a time
  - bubble sort - move item up until in right place
  - selection sort - pick 1st, then 2nd, etc.
  - quick sort - divide and conquer
- They differ in the number of comparisons required to sort N items.
// SelectionSort.java - sort an array of integers
import tio.*;

class SelectionSort {
    public static void main(String[] args) {
        int[] a = {7, 3, 66, 3, -5, 22, -77, 2};
        sort(a);
        for (int i = 0; i < a.length; i++){
            System.out.println(a[i]);
        }
    }
}

// sort using the selection sort algorithm
static void sort(int[] data) {
    int next, indexOfNext;
    for (next = 0; next < data.length - 1; next++) {
        indexOfNext = min(data, next, data.length - 1);
        swap(data, indexOfNext, next);
    }
}

// find the index of the smallest element in
// a specified range of indices in an array
static int min(int[] data, int start, int end) {
    int indexOfMin = start; // initial guess
    for (int i = start+1; i <= end; i++)
        if (data[i] < data[indexOfMin])
            indexOfMin = i; // found a smaller value
    return indexOfMin;
}

// swap to entries in an array
static void swap(int[] data, int first, int second){
    int temp;
    temp = data[first];
    data[first] = data[second];
    data[second] = temp;
}
original 7  3  66  3  -5  22  -77  2
First  -77  3  66  3  -5  22  7  2
Second  -77  -5  2  3  3  22  7  66
Third  -77  -5  2  3  3  22  7  66
Fourth  -77  -5  2  3  3  22  7  66
Fifth   -77  -5  2  3  3  22  7  66
Sixth   -77  -5  2  3  3  22  7  66
Seventh -77  -5  2  3  3  22  7  66

Searching an ordered array

• Like sorting, searching for an item in an ordered list is another common operation for computers.
• We can just search the list from the start.
• Starting in the middle is better - binary search.

// BinarySearch.java - use bisection search to find
// a selected value in an ordered array
class BinarySearch {
    public static void main(String[] args) {
        int[] data = {100, 110, 120, 130, 140, 150};
        int index = binarySearch(data, 120);
        System.out.println(index);
    }
}
```java
// find the index of element v in array keys
// return -1 if it is not found
static int binarySearch(int[] keys, int v) {
    int position, begin = 0, end = keys.length - 1;
    while (begin <= end) {
        position = (begin + end) / 2;
        if (keys[position] == v)
            return position; // just right
        else if (keys[position] < v)
            begin = position + 1; // too small
        else
            end = position - 1; // too big
    }
    return -1;
}
```

An array of something other than integers

```java
//Sieve of Eratosthenes for Primes up to 100.
class Primes {
    public static void main(String[] args) {
        boolean[] sieve = new boolean[100];
        int i;
        System.out.println(" Table of primes to 100.");
        for (i = 0; i < 100; i++)
            sieve[i] = true;
        for (int j = 2; j < Math.sqrt(100); j++)
            if (sieve[j])
                crossOut(sieve, j, j + j);
        for (i = 0; i < 100; i++) //print primes
            if (sieve[i])
                System.out.print(" " + i);
    }
}
```

```java
public static void crossOut(boolean[] s, int interval, int start) {
    for (int i = start; i < s.length; i += interval)
        s[i] = false;
}
```
//CountWord.java
import tio.*;
public class CountWord {
    public static void main(String[] args) {
        String input;
        char[] buffer;
        System.out.println("type in line ");
        input = Console.in.readLine();
        System.out.println(input);
        buffer = input.toCharArray();
        System.out.println("word count is 
              wordCount(buffer));
    }
}

//word are separated by nonalphabetic characters
public static int wordCount(char[] buf) {
    int position = 0, wc = 0;
    while (position < buf.length) {
        while (position < buf.length &&
            !isAlpha(buf[position]))
            position+=;
        if (position < buf.length)
            wc+=;
        while (position<buf.length &&
            isAlpha(buf[position]))
            position+=;
    } return wc;
}

public static boolean isAlpha(char c) {
    return (c >= 'a' && c <= 'z') ||
            (c >= 'A' && c <= 'Z');
}

There is actually a predefined function to do this:

public static boolean Character.isLetter(char c)
Arrays of non-primitive types

- We can have arrays of any type.

Arrays of Strings

// StringArray.java - uses a string array initializer
class StringArray {
    public static void main(String[] args) {
        String[] myStringArray = { "zero", "one", "two", "three", "four", "five", "six", "seven", "eight", "nine"};
        for (int i = 0; i < myStringArray.length; i++)
            System.out.println(myStringArray[i]);
    }
}

Command Line Arguments

// CommandLine.java - print command line arguments
class CommandLine {
    public static void main(String[] args) {
        for (int i = 0; i < args.length; i++)
            System.out.println(args[i]);
    }
}

os-prompt>java CommandLine this "is another" test
this
is another
test
```java
// PointArray.java - example array nonprimitive values
import java.awt.Point; // Point is a standard Java class

class PointArray {
    public static void main(String[] args) {
        Point[] triangle;
        triangle = new Point[3];
        triangle[0] = new Point(10, 20);
        triangle[1] = new Point(35, 90);
        triangle[2] = new Point(20, 85);
        for (int i = 0; i < triangle.length; i++)
            System.out.println(triangle[i]);
        translate(triangle, 100, 200);
        for (int i = 0; i < triangle.length; i++)
            System.out.println(triangle[i]);
    }
}

class PointArray {
    public static void translate(Point[] points, int deltaX, int deltaY) {
        for (int i = 0; i < points.length; i++)
            points[i].translate(deltaX, deltaY);
    }
}

java.awt.Point[x=10,y=20]
java.awt.Point[x=35,y=90]
java.awt.Point[x=20,y=85]
java.awt.Point[x=110,y=220]
java.awt.Point[x=135,y=290]
java.awt.Point[x=120,y=285]
```

Multi-Dimensional Arrays

- 2-D arrays can be used to represent tables of data with columns and rows.
- Three dimensional arrays can represent volume data with three coordinates, x-y-z.

String[] one;
double[][] two;
char[][][] three;
// TwoD.java - simple example of two-dimensional array
class TwoD {
    public static void main(String[] args) {
        int[][] data = new int[3][5];
        for (int i = 0; i < data.length; i++) {
            System.out.print("Row "+i+":   ");
            for (int j = 0; j < data[i].length; j++) {
                data[i][j] = i * j;
                System.out.print(data[i][j] + ", ");
            }
            System.out.println();
        }
    }
}

2D Initializers

int[][] a = {{1, 2}, {3, 4}, {5, 6}};
int[][] b = {{1, 2, 3}, {4, 5, 6}};
int[][] c = {{1, 2, 3, 4, 5, 6}}; // degenerate
int[][] ragged = {{1, 2}, {3, 4, 5}, {6}};
Conway’s Game of Life

• A cell is either empty (blank), or alive (X).
• Each cell is the center of a 3 x 3 square grid of cells, which contain the cell's 8 neighbors.
• Simple rules control which cells become alive or die in each step of the simulation.
• The simulation is conducted in principle on an infinite two-dimensional grid.

The "Rules" of Life

• An empty cell at time $t$ becomes alive at time $t+1$ if and only if exactly 3 neighboring cells are alive at time $t$.
• An alive cell at time $t$ remains alive at time $t+1$ if and only if either 2 or 3 neighboring cells are alive at time $t$. Otherwise it dies for lack of company ($< 2$) or overcrowding ($> 3$).

The "Blinker"

```
X X X
X X X
X X X
X X X
```

```
X X X
X X X
X X X

X X X
X X X
X X X
```

```
X X X
X X X
X X X
X X X
```
Game of Life: Requirements

- Used finite grid instead of infinite grid.
- Treat borders as lifeless zones.
- Set initial state by reading X's and dots from the console.
- The user will specify the size of the grid, which will always be square.
- The user specifies the number of steps to simulate.
- The program should echo the initial configuration and then print each new generation.

Top-Level Pseudocode

read in the size of the grid
read in the initial generation
read in the number of generations to simulate
print the current generation
for the specified number of generations
  advance one generation
  print the generation
end for loop

Advance one generation

for each cell
  compute the number of neighbors
  apply the game rules to decide if the cell should be alive or dead in the next gen
end for loop
Compute the number of neighbors

visit each cell in the 3x3 subarray around the cell
keep a count of how many of those are alive
if the center cell is alive
    then return one less than the count found
else return the count found

Top-Level Refined

read in the size of the grid

create two arrays, currentGen and nextGen

read in the initial generation into currentGen

read in the number of generations to simulate

print the current generation

for the specified number of generations

    update nextGen using currentGen

    swap currentGen and nextGen

    print currentGen

end for loop

Advance one generation: Refined

input: currentGen and nextGen

output: updated nextGen

for each cell in currentGen

    compute the number of neighbors

    apply the game rules to decide if the cell
    should be alive or dead in the next gen

    store the result, alive or dead, in the
    corresponding cell in nextGen

end for loop
// GameOfLife.java - Conway's Game of Life
import tio.*;

class GameOfLife {
    public static void main(String[] args) {
        // read in the size of the grid and create arrays
        int size = 10; // fix at 10 for testing
        boolean[][] currentGeneration, nextGeneration;
        currentGeneration = new boolean[size][size];
        nextGeneration = new boolean[size][size];
        readInitialGeneration(currentGeneration);

        // read in the number of generations to simulate
        int cycles = 4; // fix at 4 for testing
        printState(currentGeneration);
        for (int i = 0; i < cycles; i++) {
            System.out.println("Cycle = " + i + 
            advanceOneGen(currentGeneration,
            nextGeneration);
            printState(nextGeneration);
            // swap current and next generations
            boolean[][] temp = nextGeneration;
            nextGeneration = currentGeneration;
            currentGeneration = temp;
        }
    }
}

// read the initial generation from the input
// a dot means empty and an "*" means alive
// any other characters are ignored
// the border cells are all set to empty
// the method assumes the array is square
static void readInitialGeneration(boolean[][] w) {
    for (int i = 0; i < w.length; i++) {
        for (int j = 0; j < w[i].length; j++) {
            char c = (char)Console.in.readChar();
            // skip illegal characters
            while (c != '.' && c != '*')
                c = (char)Console.in.readChar();
            if (c == '.
                w[i][j] = EMPTY;
            else
                w[i][j] = ALIVE;
        }
    }
}
// set border cells to be empty
int border = w.length - 1;
for (int i = 0; i < w.length; i++) {
    w[i][0] = w[0][i] = EMPTY;
    w[i][border] = w[border][i] = EMPTY;
}
}

// print a generation to the console
static void printState(boolean[][] w) {
    for (int i = 0; i < w.length; i++) {
        System.out.println();
        for (int j = 0; j < w[i].length; j++)
            if (w[i][j] == ALIVE)
                System.out.print('X');
            else
                System.out.print('.');
        System.out.println();
    }
}

// compute the number of alive neighbors of a cell
static int neighbors(int row, int column,
            boolean[][] w) {
    int neighborCount = 0;
    for (int i = -1; i <= 1; i++)
        for (int j = -1; j <= 1; j++)
            if (w[row + i][column + j] == ALIVE)
                neighborCount = neighborCount + 1;
    return neighborCount;
}
static void advanceOneGen(boolean[][] wOld, boolean[][] wNew) {
    int neighborCount;
    for (int i = 1; i < wOld.length - 1; i++)
        for (int j = 1; j < wOld[i].length - 1; j++) {
            neighborCount = neighbors(i, j, wOld);
            if (neighborCount == 3)
                wNew[i][j] = ALIVE;
            else if (wOld[i][j] == ALIVE &&
                     neighborCount == 2)
                wNew[i][j] = ALIVE;
            else
                wNew[i][j] = EMPTY;
        }
    static final boolean ALIVE = true;
    static final boolean EMPTY = false;
}

A sample input file

..........
....*....
.....*....
..*...*....
..****....
..........
..........
..........
..........
..........

Sample Output

..........
....X....
.....X....
..X...X....
..XXXX....
..........
..........
..........
..........
..........

Cycle = 0
Skipping some intermediate output
Cycle = 3