



# INPUT AND OUTPUT

Spec

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The purpose of this assignment is to give you practice writing programs with input and output, including standard output, standard input, and standard drawing.

- Shannon entropy.** Write a program `ShannonEntropy.java` that takes a command-line integer  $m$ ; reads a sequence of integers between 1 and  $m$  from standard input; and prints the Shannon entropy to standard output, with 4 digits after the decimal point. The *Shannon entropy* of a sequence of integers is given by the formula:

$$H = - (p_1 \log_2 p_1 + p_2 \log_2 p_2 + \dots + p_m \log_2 p_m)$$

where  $p_i$  denotes the proportion of integers whose value is  $i$ . If  $p_i = 0$ , then treat  $p_i \log_2 p_i$  as 0.

```
~/Desktop/io> javac-introcs ShannonEntropy.java

~/Desktop/io> cat fair-coin.txt
1 1 1 1 2 1 2 1 1 2
2 2 2 2 1 2 1 2 2 1

~/Desktop/io> java-introcs ShannonEntropy 2 < fair-coin.txt
1.0000

~/Desktop/io> cat loaded-die.txt
3 2 6 2 4 3 2 1 2 2 1 3 2 3 2 2

~/Desktop/io> java-introcs ShannonEntropy 6 < loaded-die.txt
1.8750

~/Desktop/io> java-introcs DiscreteDistribution 1000000 80 20 | java-introcs ShannonEntropy 2
0.7221

~/Desktop/io> java-introcs DiscreteDistribution 1000000 80 20 | java-introcs ShannonEntropy 2
0.7217
```

*Step-by-step calculation.* Consider the following sequence of 16 integers generated from a loaded die.

3 2 6 2 4 3 2 1 2 2 1 3 2 3 2 2

This table shows the frequencies  $x_i$ , the proportions  $p_i$ , and the  $-p_i \log_2 p_i$  terms:

$i$	$x_i$	$p_i$	$-p_i \log_2 p_i$
1	2	1/8	3/8
2	8	1/2	1/2
3	4	1/4	1/2
4	1	1/16	1/4
5	0	0	0
6	1	1/16	1/4
	16	1	15/8

The Shannon entropy is  $1.875 = 15/8$ .

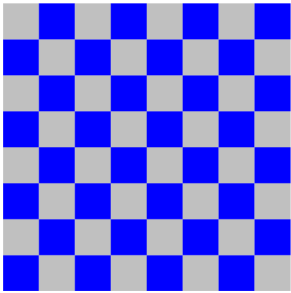
*The Shannon entropy is a measure of the rate of information produced by a random source, such as the outcomes of flipping a fair coin or rolling a loaded die. It is a fundamental concept in information theory and data compression.*

2. **Checkerboard.** Write a program `Checkerboard.java` that takes a command-line integer  $n$  and plots an  $n$ -by- $n$  checkerboard pattern to standard drawing. Color the squares blue and light gray, with the bottom-left square blue. To draw,

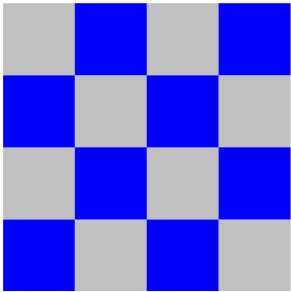
- Call `StdDraw.setScale(0, n)` so that  $x$ - and  $y$ -coordinates of the canvas range from 0 and  $n$ .
- Call either `StdDraw.filledSquare()` OR `StdDraw.filledPolygon()` to draw each of the  $n^2$  squares.
- Make sure that the squares fit snugly in the standard drawing window.
- Do not change the canvas size.

```
~/Desktop/io> javac-introcs Checkerboard.java

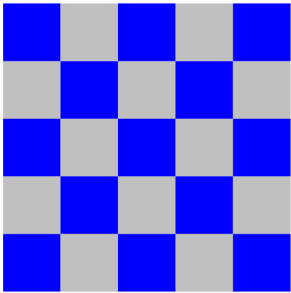
~/Desktop/io> java-introcs Checkerboard 8
```



```
~/Desktop/io> java-introcs Checkerboard 4
```



```
~/Desktop/io> java-introcs Checkerboard 5
```



3. **World maps.** Write a program `WorldMap.java` that reads boundary information of a country (or other geographic entity) from standard input and plots the results to standard drawing. A country consists of a set of regions (e.g., states, provinces, or other administrative divisions), each of which is described by a polygon.

*Input format.* The first line contains two integers: *width* and *height*. The remaining part of the input is divided into regions.

- The first entry in each region is the name of the region. For simplicity, names will not contain spaces.
- The next entry is an integer specifying the number of vertices in the polygon describing the region.
- Finally, the region contains the *x*- and *y*-coordinates of the vertices of the polygon.

```

% more usa.txt
1000 618 ← bounding box

Colorado
4
396.2799 283.6657
401.3928 373.6813
283.1565 386.8658
270.4205 295.1670
      ← polygon
      (4 vertices)

New_York ← region name
103       (no spaces)
865.8805 421.5374
864.7005 422.5489
862.0034 422.7174
      :
878.5235 417.4917 ← y-coordinate
873.8034 418.5031
869.7577 419.6831
      :

```

Diagram annotations:

- number of vertices**: points to the value 4.
- bounding box**: points to the values 1000 and 618.
- region name (no spaces)**: points to the value New\_York.
- x-coordinate**: points to the value 864.7005.
- y-coordinate**: points to the value 417.4917.

For simplicity, if a region requires more than one polygon to describe its boundary, we treat it as multiple regions, with one polygon per region.

*Output format.* Draw the polygons to standard drawing, using the following guidelines:

- Call `StdDraw.setCanvasSize()` to set the size of the canvas to be *width-by-height* pixels.
- Call `StdDraw.setXscale()` and `StdDraw.setYscale()` so that *x*-coordinates of the canvas range from 0 to *width* and the *y*-coordinates range from 0 to *height*.
- Call `StdDraw.polygon()` to draw each polygon.

Here are some sample executions for the input files [usa.txt](#), [russia.txt](#), and [world.txt](#). Additional input files are available for [100+ countries](#) and [all 50 U.S. states](#).

```
~/Desktop/io> javac-introcs WorldMap.java
```

```
~/Desktop/io> java-introcs WorldMap < usa.txt
```



```
~/Desktop/io> java-introcs WorldMap < russia.txt
```



```
~/Desktop/io> java-introcs WorldMap < world.txt
```



**Submission.** Submit a .zip file containing `ShannonEntropy.java`, `Checkerboard.java`, and `WorldMap.java`. You may not call library functions except those in the `java.lang` (such as `Integer.parseInt()` and `Math.sqrt()`) and `stdlib.jar` (such as `StdIn.readInt()` and `StdDraw.polygon()`). Use only Java features that have already been introduced in this course (e.g., loops and arrays, but not functions).

*This assignment was developed by Kevin Wayne.  
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