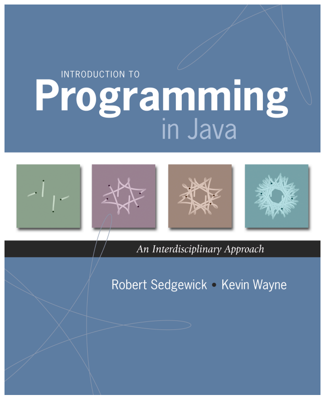
1.5 Input and Output



Input and Output

Input devices.

Output devices.

Goal. Java programs that interact with the outside world.

Input and Output

Input devices.

Output devices.

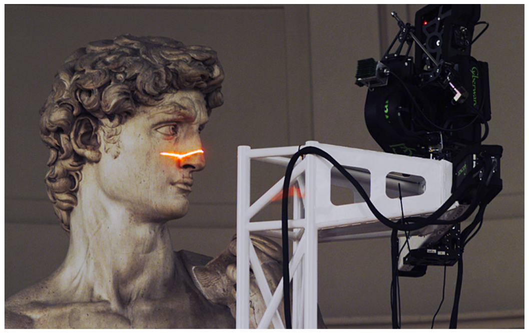
Our approach.

- Define Java libraries of functions for input and output.
- Use operating system (OS) to connect Java programs to: file system, each other, keyboard, mouse, display, speakers.

Digital Michelangelo Project

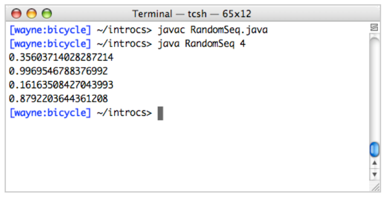
Goal. Precise 3D description of the David.

- Laser rangefinder.
- 5,000 hours of scanning, 32 Gigabytes !



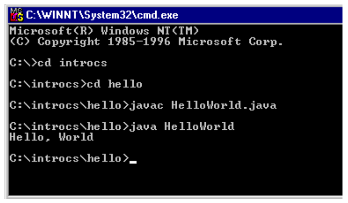
Terminal

Terminal. Application where you can type commands to control the operating system.



```
Terminal — tcsh — 65x12
[wayne:bicycle] ~/introcs> javac RandomSeq.java
[wayne:bicycle] ~/introcs> java RandomSeq 4
0.35603714028287214
0.9969546788376992
0.16163508427043993
0.8792203644361208
[wayne:bicycle] ~/introcs>
```

Mac OS X



```
C:\WINNT\System32\cmd.exe
Microsoft(R) Windows NT(TM)
(C) Copyright 1985-1996 Microsoft Corp.

C:\>cd introcs

C:\introcs>cd hello

C:\introcs\hello>javac HelloWorld.java

C:\introcs\hello>java HelloWorld
Hello, World

C:\introcs\hello>_
```

Microsoft Windows

Command-Line Input and Standard Output

Command-line input. Read an integer `N` as command-line argument.

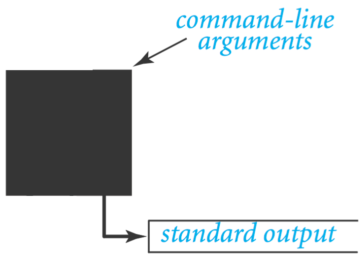
Standard output.

- Flexible OS abstraction for output.
- In Java, output from `System.out.println()` goes to `stdout`.
- By default, `stdout` is sent to Terminal.

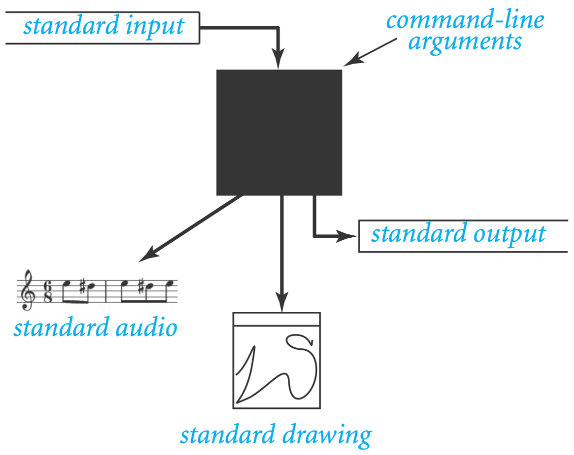
```
public class RandomSeq {
   public static void main(String[] args) {
      int N = Integer.parseInt(args[0]);
      for (int i = 0; i < N; i++) {
         System.out.println(Math.random());
      }
   }
}
```

```
% java RandomSeq 4
0.9320744627218469
0.4279508713950715
0.08994615071160994
0.6579792663546435
```

Old Bird's Eye View



New Bird's Eye View



Standard Input and Output

Command-line Input vs. Standard Input

Command line inputs.

- Use command line inputs to read in a few user values.
- Not practical for many user inputs.
- Input entered before program begins execution.

Standard input.

- Flexible OS abstraction for input.
- By default, `stdin` is received from Terminal window.
- Input entered while program is executing.

Standard Input and Output

Standard input. We provide library `StdIn` to read text input.
Standard output. We provide library `StdOut` to write text output.

public class StdIn

boolean	isEmpty()	*true if no more values, false otherwise*
int	readInt()	*read a value of type int*
double	readDouble()	*read a value of type double*
long	readLong()	*read a value of type long*
boolean	readBoolean()	*read a value of type boolean*
char	readChar()	*read a value of type char*
String	readString()	*read a value of type String*
String	readLine()	*read the rest of the line*
String	readAll()	*read the rest of the text*

public class StdOut

void	print(String s)	*print s*
void	println(String s)	*print s, followed by newline*
void	println()	*print a new line*
void	printf(String f, ...)	*formatted print*

Standard Input and Output

To use. Download `StdIn.java` and `StdOut.java` from booksite, and put in working directory (or use classpath).

see booksite

```
public class Add {
   public static void main(String[] args) {
      StdOut.print("Type the first integer: ");
      int x = StdIn.readInt();
      StdOut.print("Type the second integer: ");
      int y = StdIn.readInt();
      int sum = x + y;
      StdOut.println("Their sum is " + sum);
   }
}
```

```
% java Add
Type the first integer: 1
Type the second integer: 2
Their sum is 3
```

Averaging A Stream of Numbers

Average. Read in a stream of numbers, and print their average.

```
public class Average {
   public static void main(String[] args) {
      double sum = 0.0;  // cumulative total
      int n = 0;         // number of values
      while (!StdIn.isEmpty()) {
         double x = StdIn.readDouble();
         sum = sum + x;
         n++;
      }
      StdOut.println(sum / n);
   }
}
```

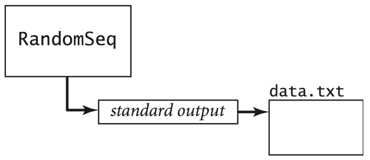
```
% java Average
10.0 5.0  6.0
 3.0 7.0 32.0
<Ctrl-d>
10.5
```

<Ctrl-d> is OS X/Linux/Unix EOF
<Ctrl-z> is Windows analog
currently no DrJava analog

Redirection and Piping

Redirecting Standard Output

Redirecting standard output. Use OS directive to send standard output to a file for permanent storage (instead of terminal window).

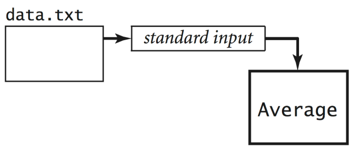


```
% java RandomSeq 1000 > data.txt
```

redirect stdout

Redirecting Standard Input

Redirecting standard input. Use OS directive to read standard input from a file (instead of terminal window).

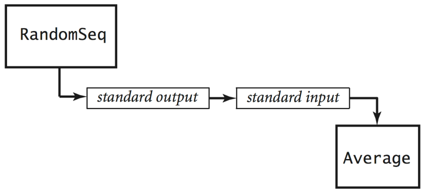


```
% more < data.txt
0.5475375782884312
0.4971087292684019
0.23123808041753813
…
% java Average < data.txt
0.4947655567740991
```

redirect stdin

Connecting Programs

Piping. Use OS directive to make the standard output of one program become the standard input of another.



```
% java RandomSeq 1000000 | java Average
0.4997970473016028
```

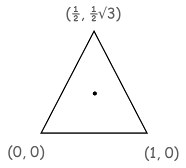
Standard Drawing

Standard Draw

Standard drawing. We provide library `StdDraw` to plot graphics.
To use. Download `StdDraw.java` and put in working directory.

```
public class Triangle {
   public static void main(String[] args) {
      double t = Math.sqrt(3.0) / 2.0;
      StdDraw.line(0.0, 0.0, 1.0, 0.0);
      StdDraw.line(1.0, 0.0, 0.5,   t);
      StdDraw.line(0.5,   t, 0.0, 0.0);
      StdDraw.point(0.5, t/3.0);
   }
}
```

```
% java Triangle
```



Data Visualization

Plot filter. Read in a sequence of (x, y) coordinates from standard input, and plot using standard drawing.

```
public class PlotFilter {
   public static void main(String[] args) {
      double xmin = StdIn.readDouble();
      double ymin = StdIn.readDouble();
      double xmax = StdIn.readDouble();
      double ymax = StdIn.readDouble();
      StdDraw.setXscale(xmin, xmax);
      StdDraw.setYscale(ymin, ymax);

      while (!StdIn.isEmpty()) {
         double x = StdIn.readDouble();
         double y = StdIn.readDouble();
         StdDraw.point(x, y);
      }
   }
}
```

← rescale coordinate system

← read in points, and plot them

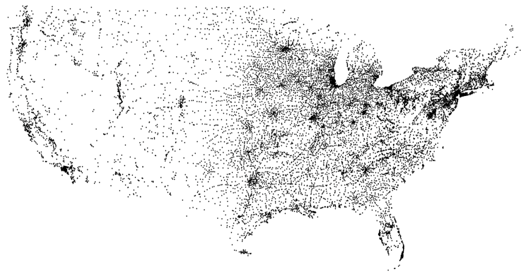
Data Visualization

```
% more < USA.txt
669905.0 247205.0 1244962.0 490000.0
 1097038.8890  245552.7780
 1103961.1110  247133.3330
 1104677.7780  247205.5560
 ...

% java PlotFilter < USA.txt
```

bounding box

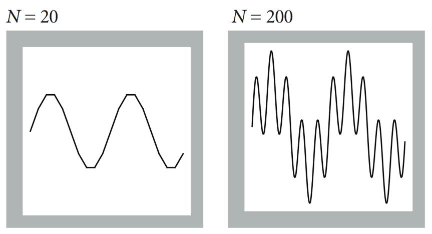
coordinates of 13,509 US cities



Plotting a Function

```
double[] a = new double[N+1];
for (int i = 0; i <= N; i++)
   a[i] = Math.sin(4*Math.PI*i/N) + Math.sin(20*Math.PI*i/N);

StdDraw.setXscale(0, N);
StdDraw.setYscale(-2.0, +2.0);
for (int i = 0; i < N; i++)
   StdDraw.line(i, a[i], i+1, a[i+1]);
```



$y = \sin 4x + \sin 20x$

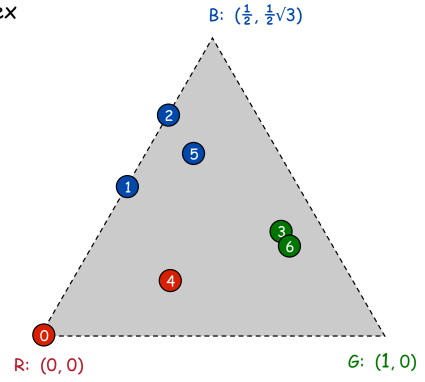
Chaos Game

Chaos game. Play on equilateral triangle, with vertices R, G, B.

- Start at R.
- Repeat the following N times:
  - pick a random vertex
  - move halfway between current point and vertex
  - draw a point in color of vertex

Q. What picture emerges?

B B G R B G …



Chaos Game

```
public class Chaos {
   public static void main(String[] args) {
      int T = Integer.parseInt(args[0]);
      double[] cx = { 0.000, 1.000, 0.500 };
      double[] cy = { 0.000, 0.000, 0.866 };

      double x = 0.0, y = 0.0;
      for (int t = 0; t < T; t++) {
         int r = (int) (Math.random() * 3);
         x = (x + cx[r]) / 2.0;
         y = (y + cy[r]) / 2.0;
         StdDraw.point(x, y);
      }
   }
}
```

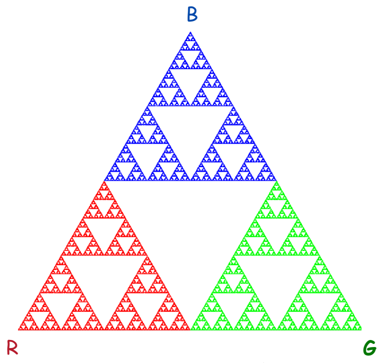
$\frac{1}{2}\sqrt{3}$ (avoid hardwired constants like this)

between 0 and 2

Chaos Game

Easy modification. Color point according to random vertex chosen using `StdDraw.setPenColor(StdDraw.RED)` to change the pen color.

```
% java Chaos 10000
```

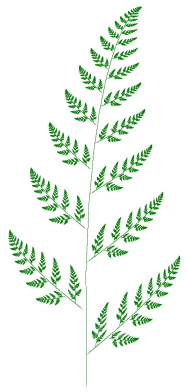


Sierpinski triangle

Barnsley Fern

Barnsley fern. Play chaos game with different rules.

probability	new x	new y
2%	.50	.27y
15%	-.14x + .26y + .57	.25x + .22y - .04
13%	.17x - .21y + .41	.22x + .18y + .09
70%	.78x + .03y + .11	-.03x + .74y + .27



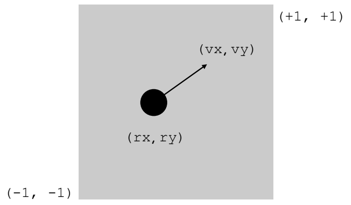
Q. What does computation tell us about nature?
Q. What does nature tell us about computation?

20th century sciences. Formulas.
21st century sciences. Algorithms?

Animation

Animation loop. Repeat the following:
- Clear the screen.
- Move the object.
- Draw the object.
- Display and pause for a short while.

Ex. Bouncing ball.
- Ball has position `(rx, ry)` and constant velocity `(vx, vy)`.
- Detect collision with wall and reverse velocity.



Bouncing Ball

```
public class BouncingBall {
   public static void main(String[] args) {
      double rx = .480, ry = .860;               position
      double vx = .015, vy = .023;               constant velocity
      double radius = .05;                       radius

      StdDraw.setXscale(-1.0, +1.0);             rescale coordinates
      StdDraw.setYscale(-1.0, +1.0);

      while(true) {
         if (Math.abs(rx + vx) > 1.0) vx = -vx;
         if (Math.abs(ry + vy) > 1.0) vy = -vy;        bounce

         rx = rx + vx;
         ry = ry + vy;          update position

         StdDraw.clear(StdDraw.GRAY);                  clear background
         StdDraw.setPenColor(StdDraw.BLACK);
         StdDraw.filledCircle(rx, ry, radius);         draw the ball
         StdDraw.show(50);
      }
   }
}
                  turn on animation mode:
                  display and pause for 50ms
```

Special Effects

Images. Put `.gif`, `.png`, or `.jpg` file in the working directory and use `StdDraw.picture()` to draw it.

Sound effects. Put `.wav`, `.mid`, or `.au` file in the working directory and use `StdAudio.play()` to play it.

Ex. Modify `BouncingBall` to display image and play sound upon collision.

- Replace `StdDraw.filledCircle()` with:

```
StdDraw.picture(rx, ry, "earth.gif");
```

- Add following code upon collision with wall:

```
StdAudio.play("boing.wav");
```

The Nbody Assignment