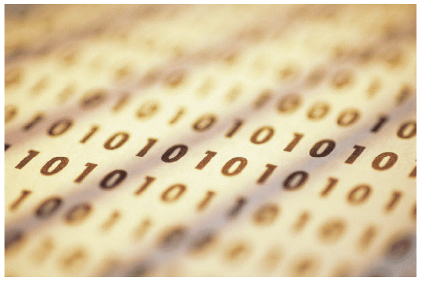
2.2 Input and Output



Today's goal. Java programs that interact with outside world.

Input and Output

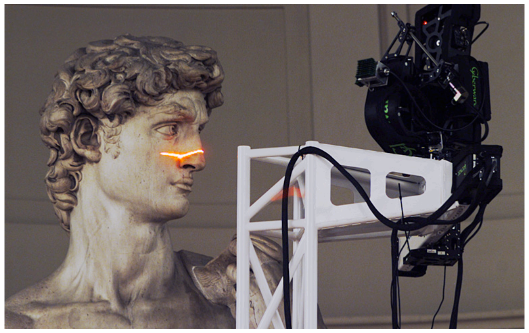
Input devices.

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, display.

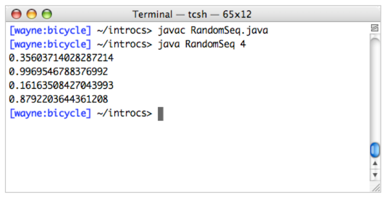
Digital Michelangelo Project

Goal. Precise 3D description of the David.
- Laser rangefinder.
- Stanford group, late 1990s.
- 5000 hours of scanning, 32 Gigabytes !



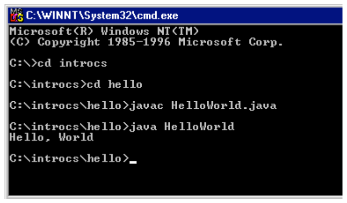
Terminal

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

Bird's Eye View

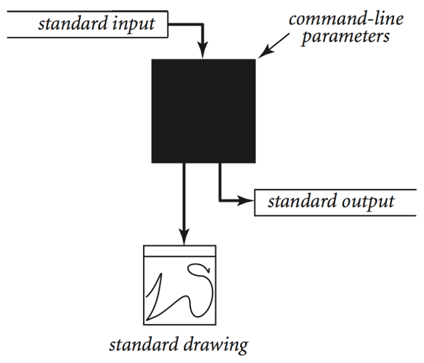
Command line input. Read an integer N from command line.

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
```

New Bird's Eye View



Standard Input Abstraction

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

Standard input. We provide library `StdIn` to read text input.
To use. Download `StdIn.java` from booksite and put in working directory.

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

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

Twenty Questions

Twenty questions. User thinks of an integer between one and 1 million. Computer tries to guess it.

```
public class TwentyQuestions {
   public static void main(String[] args) {
      int lo = 1, hi = 1000000;
      while (lo < hi) {
         int mid = (lo + hi) / 2;
         System.out.println("Is your number <= " + mid + "?");
         boolean response = StdIn.readBoolean();
         if (response) hi = mid;
         else          lo = mid + 1;
      }
      System.out.println("Your number is " + lo);
   }
}
```

Binary search. Each question removes half of possible remaining values.
Consequence. Always succeeds after 20 questions.

$2^{20} \approx 1$ million

Invariant: user's number always between lo and hi

Averaging A Stream of Numbers

Average. Read in real numbers, and print their average.

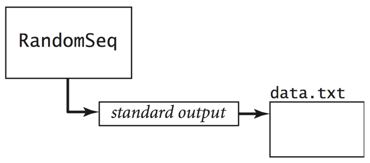
```
public class Average {
   public static void main(String[] args) {
      double sum = 0.0;
      int N = 0;
      while (!StdIn.isEmpty()) {
         double x = StdIn.readDouble();
         sum = sum + x;
         N++;
      }
      System.out.println(sum / N);
   }
}
```

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

<Ctrl-d> is Mac/Linux/Unix EOF
<Ctrl-z> is Windows analog

Redirecting Standard Output

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

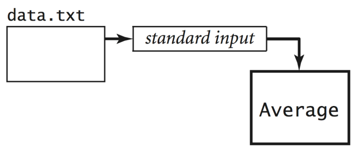


```
% java RandomSeq 1000 > data.txt
```

redirect stdout

Redirecting Standard Input

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



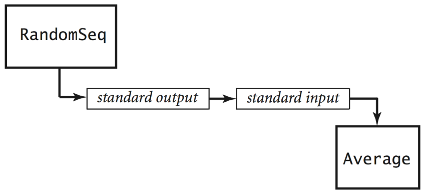
```
% more < data.txt
0.5475375782884312
0.4971087292684019
0.23123808041753813
…

% 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.



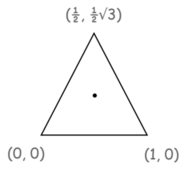
```
% java RandomSeq 1000000 | java Average
0.4997970473016028
```

Standard Draw

Standard draw. 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 xy-coordinates from standard input, and plot using standard draw.

```
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

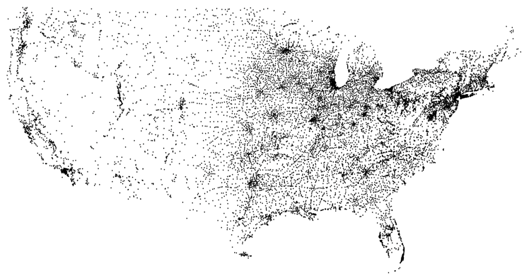
Data Visualization

```
% 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

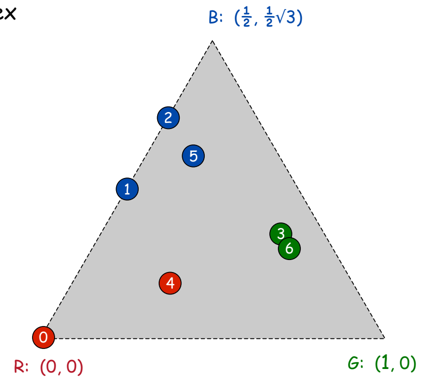


Chaos Game

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?



Chaos Game

```
public class Chaos {
   public static void main(String args[]) {
      int N = 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 i = 0; i < N; i++) {
         int r = StdRandom.uniform(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)

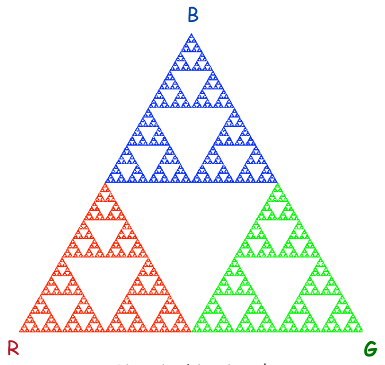
equally likely to be 0, 1, or 2

Chaos Game

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

see text for list of available colors
(see Section 3.1 for creating your own colors)

```
% java Chaos 10000
```

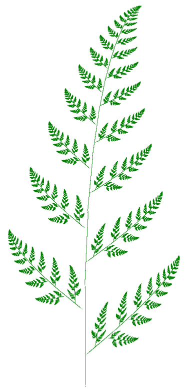


Sierpinski triangle

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(s).
- Draw the object(s).
- 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);
      }
   }                                        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 when collision detected:

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

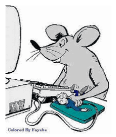
User Interfaces

Command line interface.

- User types commands at terminal.
- Easily customizable.
- Extends to complex command sequences.

Point and click.

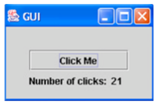
- User launches applications by clicking.
  - File → Open → HelloWorld.java
- Restricted to pre-packaged menu options.

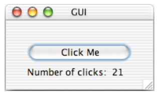


Swing Graphical User Interface

"Swing" is Java's GUI.

- Buttons.
- Menus.
- Scrollbars.
- Toolbars.
- File choosers.





```
import javax.swing.*;
import java.awt.*;
import java.awt.event.*;

public class GUI implements ActionListener {
   private int clicks = 0;
   private JFrame frame = new JFrame();
   private JLabel label = new JLabel("Number of clicks:  0     ");
   public GUI() {
      JButton button = new JButton("Click Me");
      button.addActionListener(this);
      JPanel  panel  = new JPanel();
      panel.setBorder(BorderFactory.createEmptyBorder(30, 30, 10, 30));
      panel.setLayout(new GridLayout(0, 1));
      panel.add(button);
      panel.add(label);
      frame.add(panel, BorderLayout.CENTER);
      frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
      frame.setTitle("GUI");
      frame.pack();
      frame.show();
   }

   public void actionPerformed(ActionEvent e) {
      clicks++;
      label.setText("Number of clicks:  " + clicks);
   };

   public static void main(String[] args) {
      GUI gui = new GUI();
   }
}
```

a sample Swing application

Ignore details.