6.005 Elements of Software Construction

Fall 2008

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Introduction

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Today's Topics

getting up to speed with Java

- note that programming experience is a prerequisite for 6.005
- we assume you've used Python
- these initial lectures will show the Java way to do things you should already be able to do in Python (or some other language)

what makes software "good"

- whether it works isn't the only consideration

Why We Use Java in 6.005

safety

- static typing catches errors before you even run (unlike Python)
- strong typing and memory safety catch errors at run time (unlike C/C++)

ubiquity

- Java is widely used in industry and education

libraries

- Java has libraries and frameworks for many things

tools

- excellent, free tools exist for Java development (like Eclipse)

it's good to be multilingual

- knowing two languages paves the way to learning more (which you should)

why we regret using Java...

- wordy, inconsistent, freighted with legacy baggage from older languages, no interpreter, no lambda expressions, no continuations, no tail recursion, ...

Hailstone Sequences

start with some positive integer n

- if n is even, then next number is n/2
- if n is odd, then next number is 3n+1
- repeat these moves until you reach 1

examples

2, 1	7, 22, 11, 34, 17, 52, 26, 13, 40, ...?
3, 10, 5, 16, 8, 4, 2, 1	2^n, 2^{n-1}, ... , 4, 2, 1
4, 2, 1	
5, 16, 8, 4, 2, 1	

- why "hailstone"? because hailstones in clouds also bounce up and down chaotically before finally falling to the ground

let's explore this sequence

- open question: does every positive integer *n* eventually reach 1?

Computing a Hailstone Sequence

Java

```
// hailstone sequence from n
while (n != 1) {
  if (n % 2 == 0) {
      n = n / 2;
  } else {
      n = 3 * n + 1;
  }
}
```

Python

```
# hailstone sequence from n
while n != 1:
  if n % 2 == 0:
      n = n / 2
  else:
      n = 3 * n + 1
```

Java Syntax

statement grouping

- curly braces surround groups of statements
- semicolons terminate statements
- indentation is technically optional but essential for human readers

comments

- // introduce comment lines
- /* … */ surround comment blocks

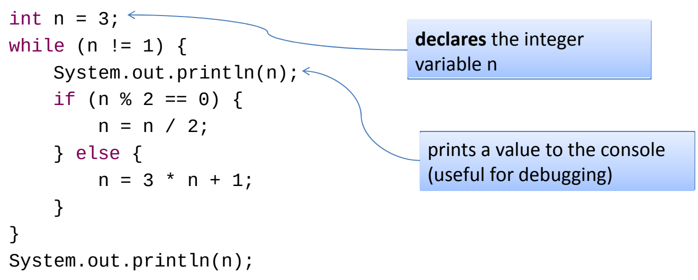
control statements

- **while** and **if** require parentheses around their conditions

operators

- mostly common with Python (+, -, *, /, <, >, <=, >=, ==)
- != means "not equal to"
- ! means "not" , so n!=1 is the same as !(n == 1)
- the % operator computes remainder after division

Computing a Hailstone Sequence



```
int n = 3;
while (n != 1) {
    System.out.println(n);
    if (n % 2 == 0) {
        n = n / 2;
    } else {
        n = 3 * n + 1;
    }
}
System.out.println(n);
```

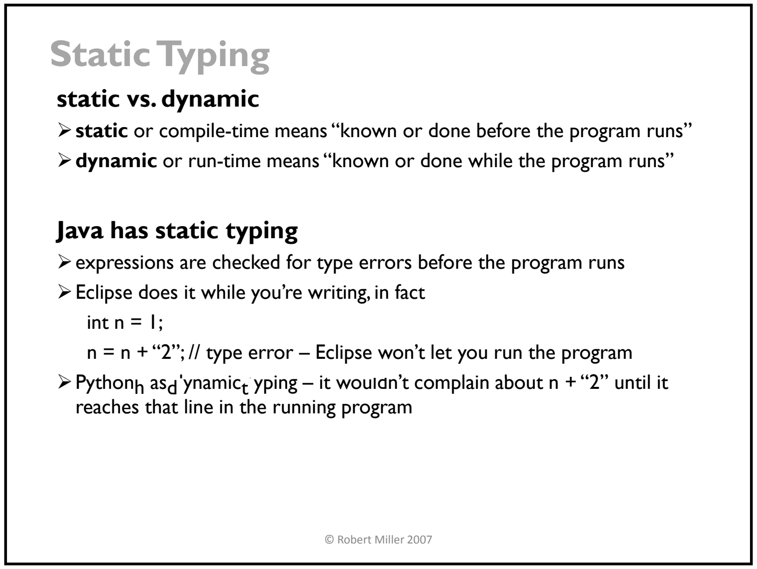
declares the integer variable n

prints a value to the console (useful for debugging)

Declarations and Types

variables must be declared before being used

- a declaration includes the **type** of the variable
- two kinds of types, primitive and object
- primitive types include
  - **int** (integers up to +/- 2 billion)
  - **long** (integers up to +/- 2^{63})
  - **boolean** (true or false)
  - **double** (floating-point numbers)
  - **char** (characters)
- object types include
  - **String** (a sequence of characters, i.e. text)
- you can define new object types (using classes), but you can't define new primitive types



Static Typing

static vs. dynamic

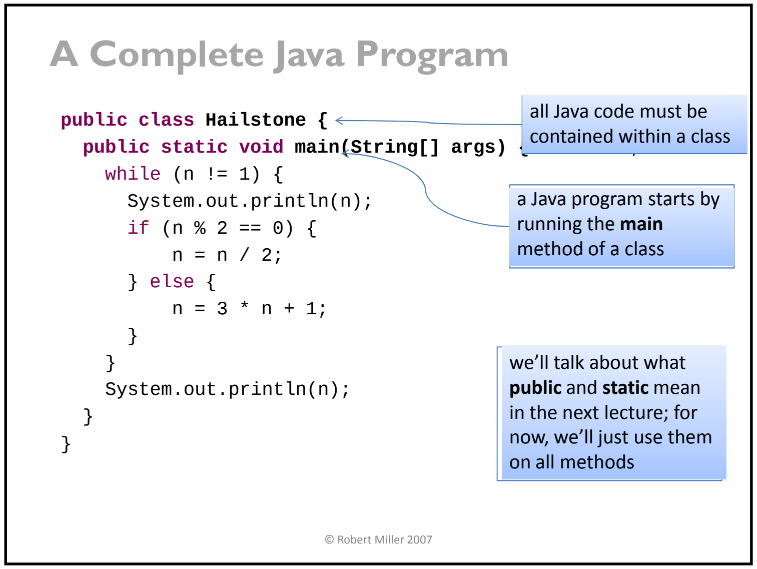
- **static** or compile-time means "known or done before the program runs"
- **dynamic** or run-time means "known or done while the program runs"

Java has static typing

- expressions are checked for type errors before the program runs
- Eclipse does it while you're writing, in fact

  int n = 1;

  n = n + "2"; // type error – Eclipse won't let you run the program
- Pythonh asd'ynamict yping – it wouldn't complain about n + "2" until it reaches that line in the running program



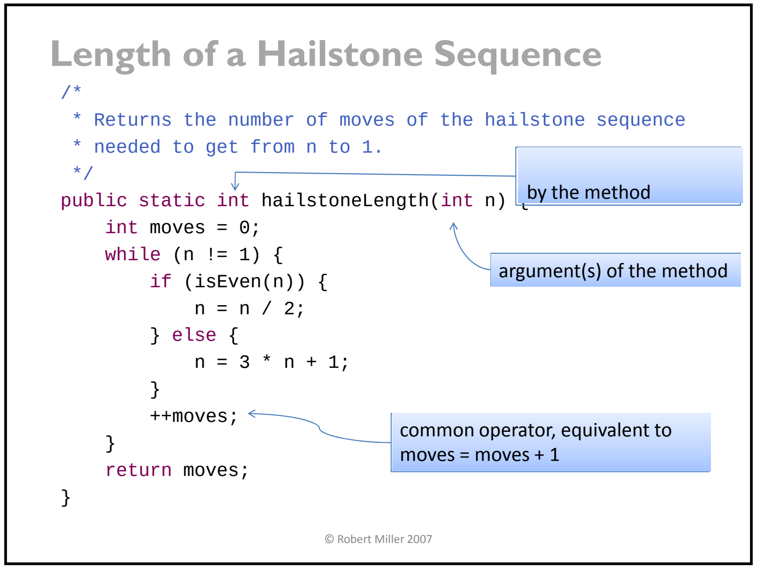
A Complete Java Program

```
public class Hailstone {
  public static void main(String[] args) {
    while (n != 1) {
      System.out.println(n);
      if (n % 2 == 0) {
          n = n / 2;
      } else {
          n = 3 * n + 1;
      }
    }
    System.out.println(n);
  }
}
```

all Java code must be contained within a class

a Java program starts by running the **main** method of a class

we'll talk about what **public** and **static** mean in the next lecture; for now, we'll just use them on all methods



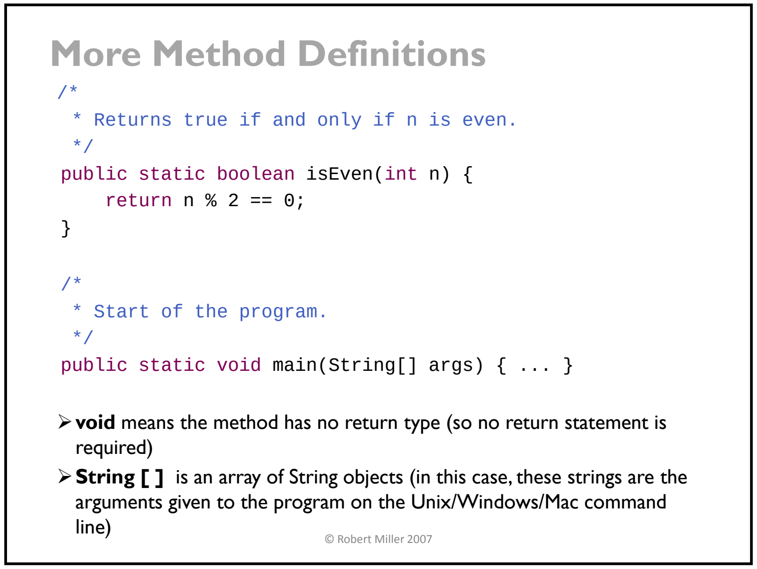
Length of a Hailstone Sequence

```
/*
 * Returns the number of moves of the hailstone sequence
 * needed to get from n to 1.
 */
public static int hailstoneLength(int n) {
    int moves = 0;
    while (n != 1) {
        if (isEven(n)) {
            n = n / 2;
        } else {
            n = 3 * n + 1;
        }
        ++moves;
    }
    return moves;
}
```

by the method

argument(s) of the method

common operator, equivalent to moves = moves + 1

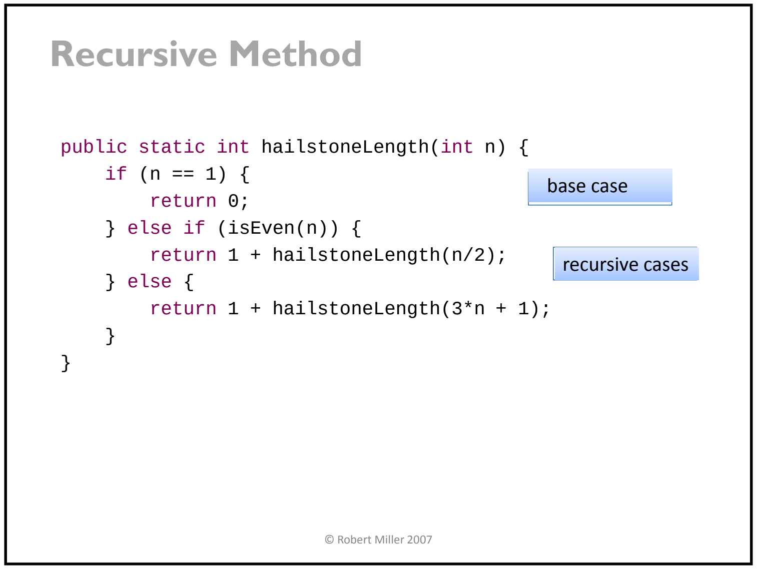


More Method Definitions

```
/*
 * Returns true if and only if n is even.
 */
public static boolean isEven(int n) {
    return n % 2 == 0;
}

/*
 * Start of the program.
 */
public static void main(String[] args) { ... }
```

- **void** means the method has no return type (so no return statement is required)
- **String [ ]** is an array of String objects (in this case, these strings are the arguments given to the program on the Unix/Windows/Mac command line)

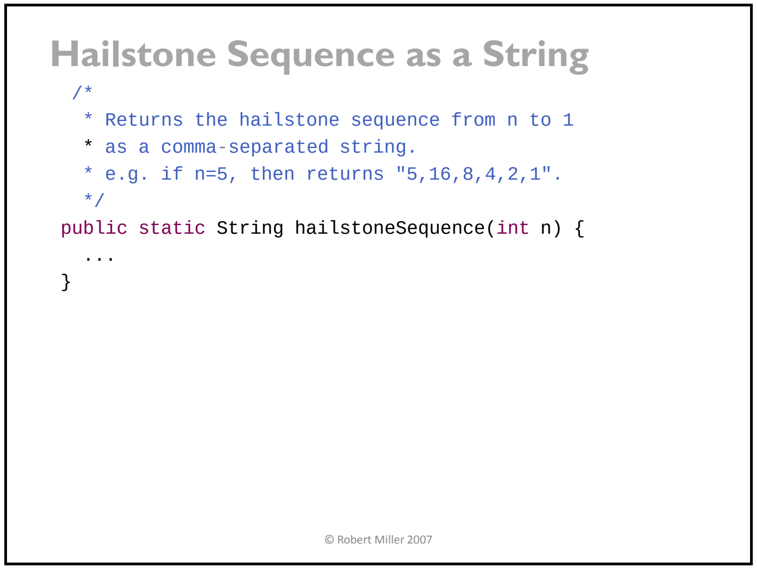


Recursive Method

```
public static int hailstoneLength(int n) {
    if (n == 1) {
        return 0;
    } else if (isEven(n)) {
        return 1 + hailstoneLength(n/2);
    } else {
        return 1 + hailstoneLength(3*n + 1);
    }
}
```

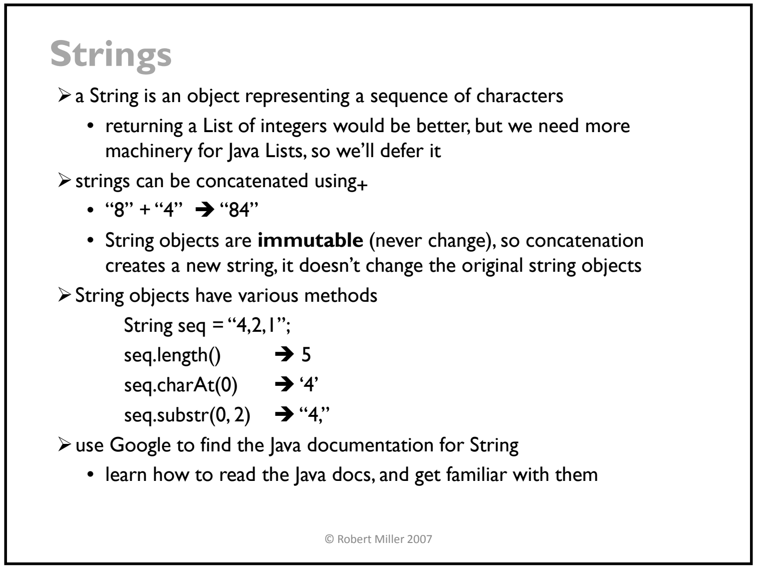
base case

recursive cases



Hailstone Sequence as a String

```
 /*
  * Returns the hailstone sequence from n to 1
  * as a comma-separated string.
  * e.g. if n=5, then returns "5,16,8,4,2,1".
  */
public static String hailstoneSequence(int n) {
  ...
}
```

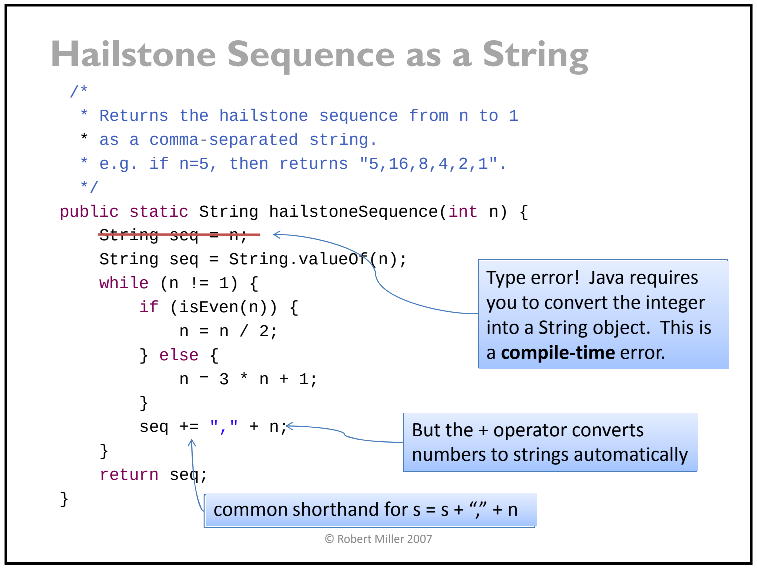


Strings

- a String is an object representing a sequence of characters
  - returning a List of integers would be better, but we need more machinery for Java Lists, so we'll defer it
- strings can be concatenated using +
  - "8" + "4" ➔ "84"
  - String objects are **immutable** (never change), so concatenation creates a new string, it doesn't change the original string objects
- String objects have various methods

String seq = "4,2,1";
seq.length() ➔ 5
seq.charAt(0) ➔ '4'
seq.substr(0, 2) ➔ "4,"

- use Google to find the Java documentation for String
  - learn how to read the Java docs, and get familiar with them



Hailstone Sequence as a String

```
 /*
  * Returns the hailstone sequence from n to 1
  * as a comma-separated string.
  * e.g. if n=5, then returns "5,16,8,4,2,1".
  */
public static String hailstoneSequence(int n) {
    ~~String seq = n;~~
    String seq = String.valueOf(n);
    while (n != 1) {
        if (isEven(n)) {
            n = n / 2;
        } else {
            n - 3 * n + 1;
        }
        seq += "," + n;
    }
    return seq;
}
```

Type error! Java requires you to convert the integer into a String object. This is a **compile-time** error.

But the + operator converts numbers to strings automatically

common shorthand for s = s + "," + n

Hailstone Sequence as an Array

```
/**
 * Returns the hailstone sequence starting from n as an
 * array of integers, e.g. hailstoneArray(8) returns
 * the length-4 array [8,4,2,1].
 */
public static int[] hailstoneArray(int n) {
  ...
}
```

Arrays

array is a fixed-length sequence of values

- base type of an array can be any type (primitive, object, another array type)
  - int[] intArray;
  - char[] charArray;
  - String[] stringArray;
  - double[][] matrix; // array of arrays of floating-point numbers
- fresh arrays are created with **new** keyword
  - intArray = new int[5]; // makes array of 5 integers
- operations on an array
  - intArray[0] = 200; // sets a value
  - intArray[0] ➔ 200 // gets a value
  - intArray.length ➔ 5 // gets array's length
- unlike a String, an array's elements can be changed
- but once created, an array's length cannot be changed
  - so it's not like a Python list – a Java array can't grow or shrink

Hailstone Sequence as an Array

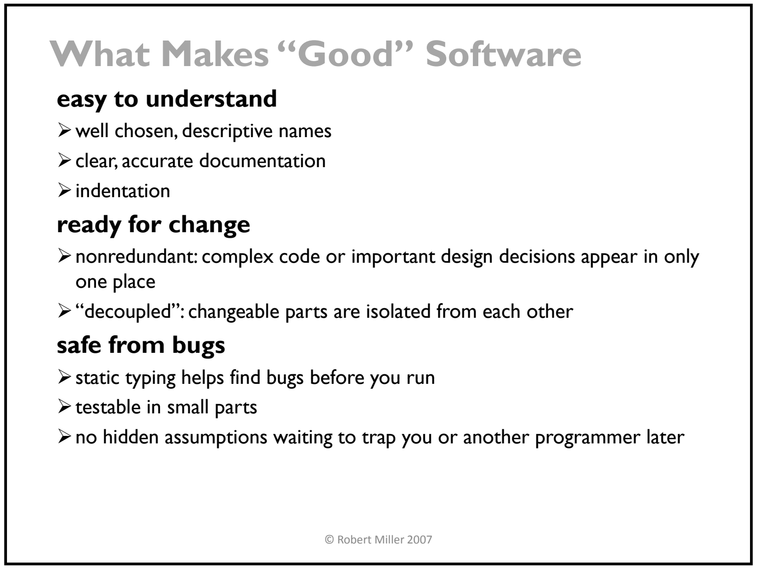
```
/**
 * Returns the hailstone sequence starting from n as an
 * array of integers, e.g. hailstoneArray(8) returns
 * the length-4 array [8,4,2,1].
 */
public static int[] hailstoneArray(int n) {
    int[] array = new int[hailstoneLength(n)+1];
    int i = 0;
    while (n != 1) {
        array[i] = n;
        ++i;
        if (isEven(n)) {
            n = n / 2;
        } else {
            n = 3 * n + 1;
        }
    }
    array[i] = n;
    return array;
}
```

What happens if you omit this "+1"? The array is too short, and Java produces a **runtime error** when you try to write the last number.

Maximum Value of an Array

```
/**
 * Returns the maximum value of an array of
 * positive integers.
 * Returns 0 if the array is empty.
 */
public static int maxValue(int[] array) {
    int max = 0;
    for (int i = 0; i < array.length; ++i) {
        if (array[i] > max) max = array[i];
    }
    return max;
}
```

The **for** loop is commonly used for iterating through a collection.
for (*init*; *test*; *update*) {... }
is roughly equivalent to
init; while (*test*) { ... ; *update* }



What Makes "Good" Software

easy to understand

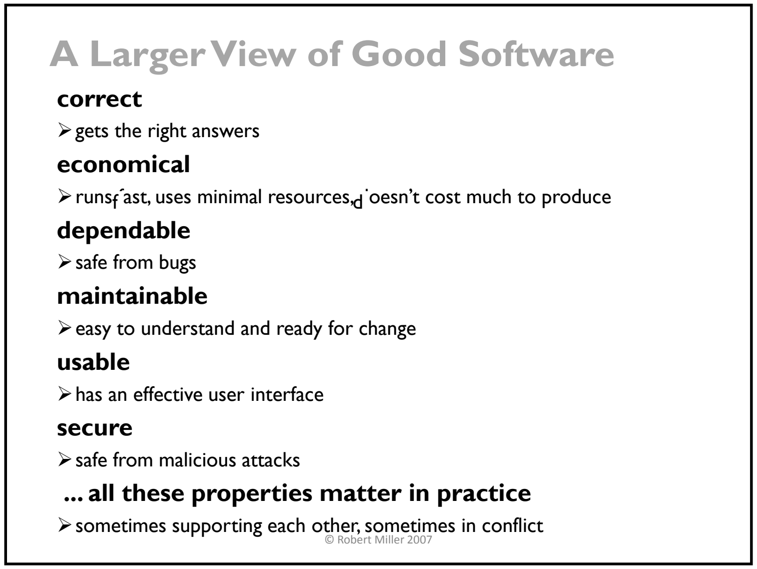
- well chosen, descriptive names
- clear, accurate documentation
- indentation

ready for change

- nonredundant: complex code or important design decisions appear in only one place
- "decoupled": changeable parts are isolated from each other

safe from bugs

- static typing helps find bugs before you run
- testable in small parts
- no hidden assumptions waiting to trap you or another programmer later



A Larger View of Good Software

correct

- gets the right answers

economical

- runs fast, uses minimal resources, doesn't cost much to produce

dependable

- safe from bugs

maintainable

- easy to understand and ready for change

usable

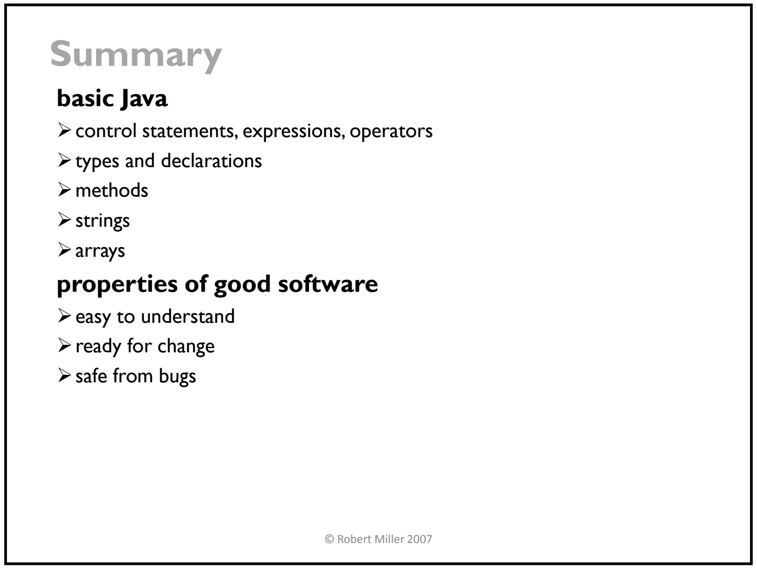
- has an effective user interface

secure

- safe from malicious attacks

... all these properties matter in practice

- sometimes supporting each other, sometimes in conflict



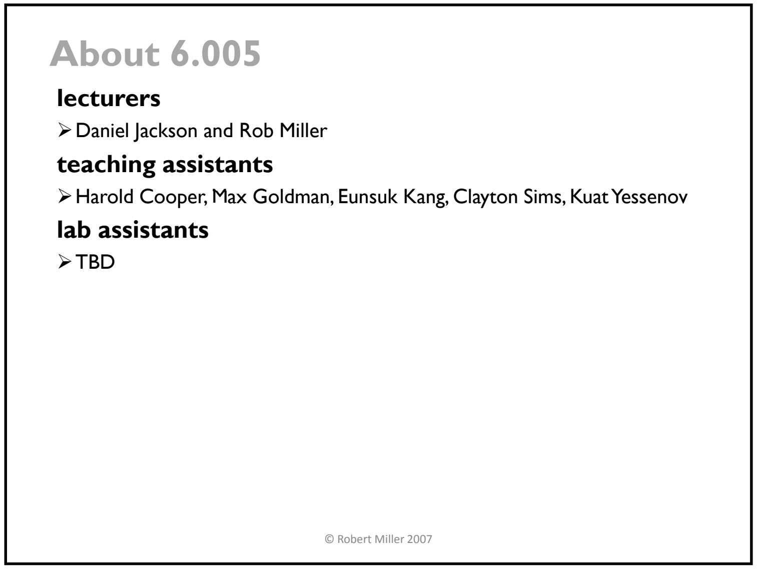
Summary

basic Java

- control statements, expressions, operators
- types and declarations
- methods
- strings
- arrays

properties of good software

- easy to understand
- ready for change
- safe from bugs



About 6.005

lecturers

- Daniel Jackson and Rob Miller

teaching assistants

- Harold Cooper, Max Goldman, Eunsuk Kang, Clayton Sims, Kuat Yessenov

lab assistants

- TBD

Objectives

what you should expect to get out of this course

fundamental programming skills

- how to specify, design, implement and test a program
- proficiency in Java and use of Java APIs
- use of standard development tools (Eclipse, SVN, JUnit)

engineering sensibilities

- capturing the essence of a problem
- inventing powerful abstractions
- appreciating the value of simplicity
- awareness of risks and fallibilities

cultural literacy

- familiarity with a variety of technologies (http, postscript, sockets, etc)

Intellectual Structure

three paradigms

- state machine programming
- symbolic programming
- object-based programming

pervasive themes

- models and abstractions
- interfaces and decoupling
- analysis with invariants

incremental approach

- concepts introduced as needed
- deepening sophistication as ideas are revisited

Your Responsibilities

assignments

- three 1-week **explorations**
  - writing a program we'll use as a lecture example
- three 2-week **problem sets**
  - both written and programming components
- three 2-week **projects**
  - in rotating teams of 3 people
- three 3-hour **project labs**, one for each project
  - project labs prepare you to get started on the project

meetings

- two **lectures** each week (Mon, Wed, sometimes Fri)
- one **recitation** each week
- **project meetings** with your team members and teaching staff
  - lecture time will often be made available for these meetings

Grading Policy

collaboration

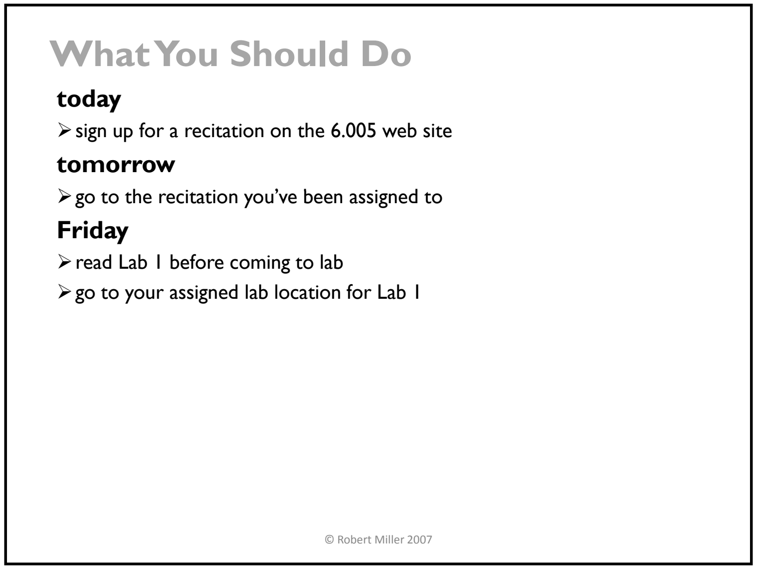
- projects in teams of 3: must have different teams for each project
- problem sets and explorations are done individually
  - discussion permitted but writing or code may not be shared

use of available resources

- can use publicly available code, designs, specs
- cannot reuse work done in 6.005 by another student (in this or past term)
- cannot make your work available to other 6.005 students

grade breakdown

- projects 40%
- problem sets 30%
- explorations 20%
- participation 10%



What You Should Do

today

- ➢ sign up for a recitation on the 6.005 web site

tomorrow

- ➢ go to the recitation you've been assigned to

Friday

- ➢ read Lab 1 before coming to lab
- ➢ go to your assigned lab location for Lab 1