Objects Analysis Threads Design 15-214

toad

Fall 2012

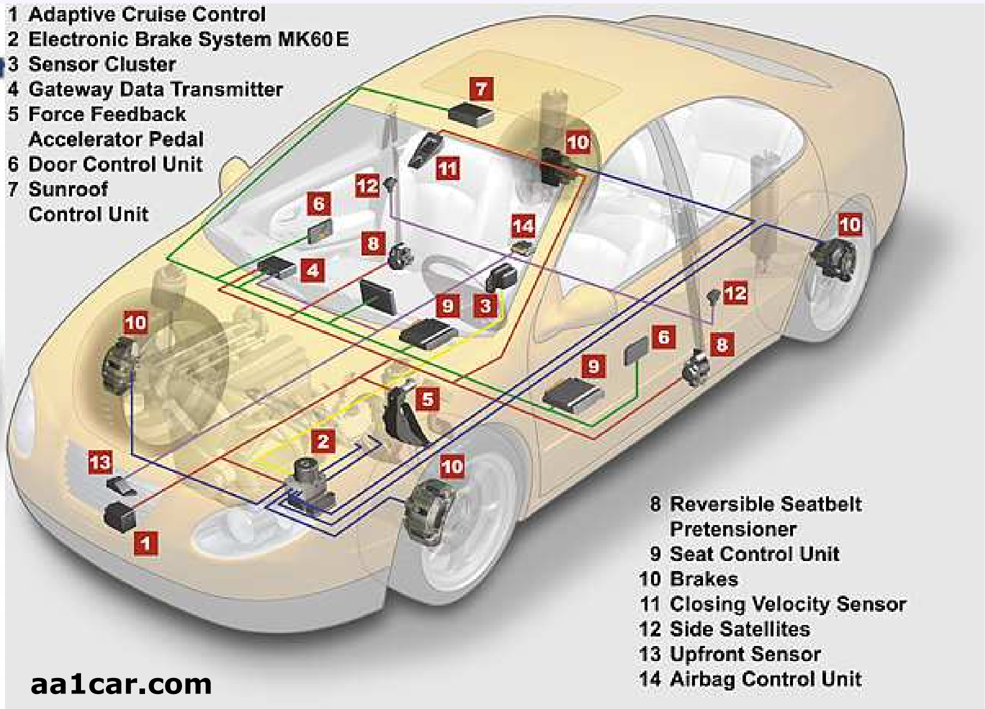
Principles of Software Construction: Objects, Design, and Concurrency

Course Introduction

Jonathan Aldrich Charlie Garrod

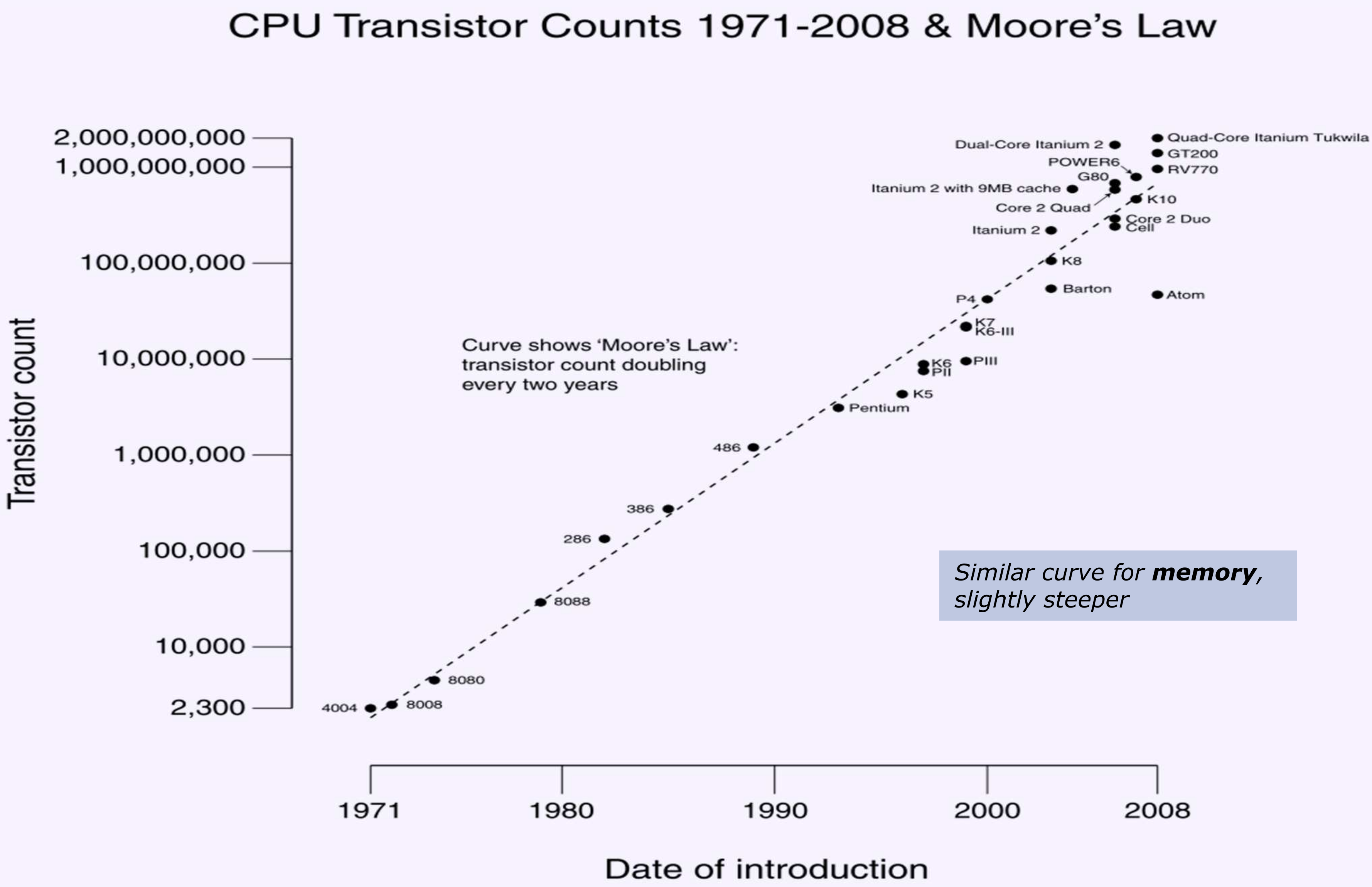
School of Computer Science
institute for SOFTWARE RESEARCH

Software and automobiles



Air-bag system	Antilock brakes	Automatic transmission
Alarm system	Climate control	Collision-avoidance system
Cruise control	Communication system	Dashboard instrumentation
Electronic stability control	Engine ignition	Engine control
Electronic-seat control	Entertainment system	Navigation system
Power steering	Tire-pressure monitoring	Windshield-wiper control

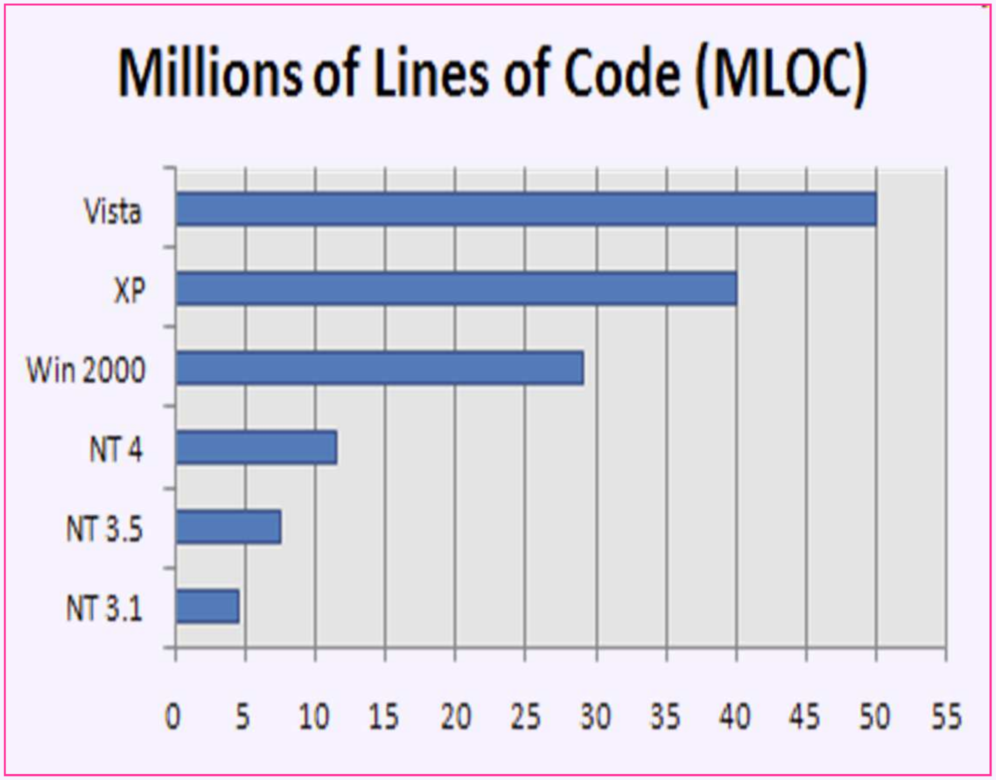
Moore's Law: transistors per chip



*Similar curve for **memory**, slightly steeper*

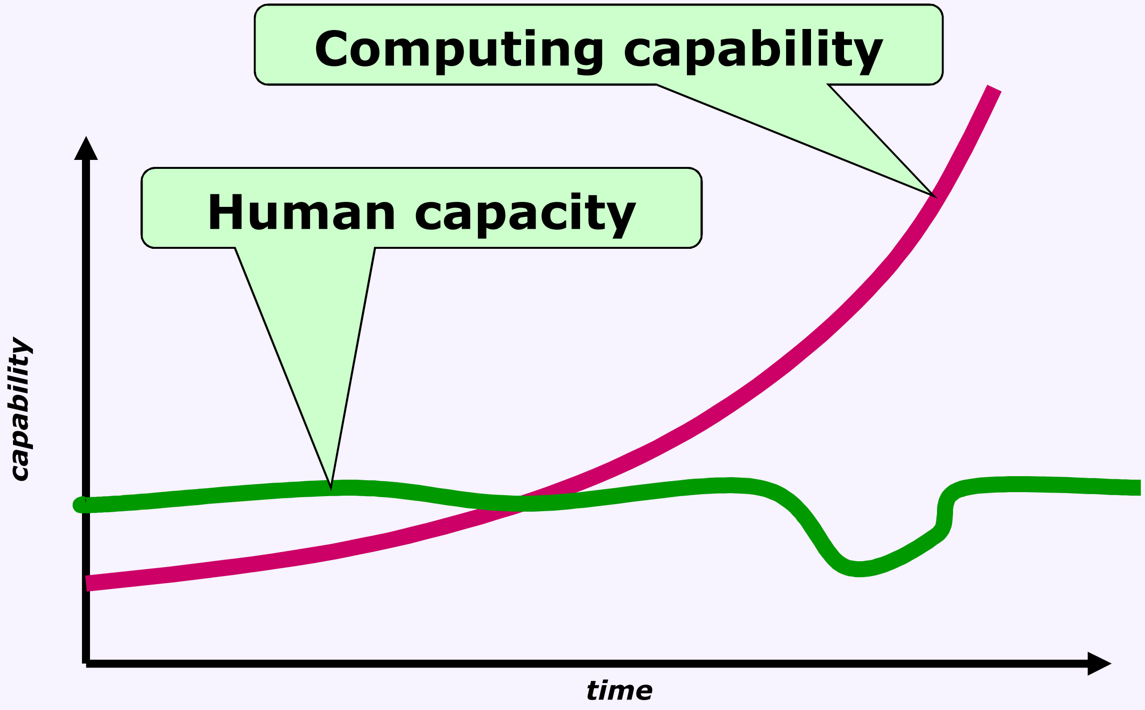
How much software?

System	Year	% of Functions Performed in Software
F-4	1960	8
A-7	1964	10
F-111	1970	20
F-15	1975	35
F-16	1982	45
B-2	1990	65
F-22	2000	80



(informal reports)

The limits of exponentials



Scaling Up: From Programs to Systems

- You’ve written small- to medium-size programs in 15-122

- This course is about managing software complexity
  - **Scale** of code: KLOC -> MLOC
  - Worldly **environment**: external I/O, network, asynchrony
  - Software **infrastructure**: libraries, frameworks, components
  - Software **evolution**: change over time

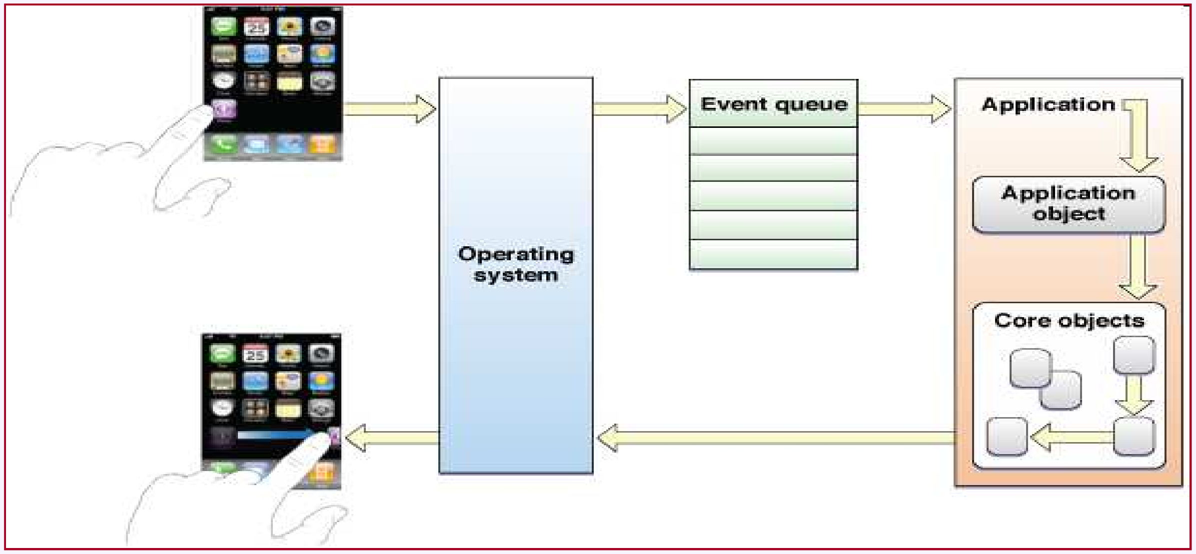
  - Contrast: algorithmic complexity
    - Not an emphasis in this course

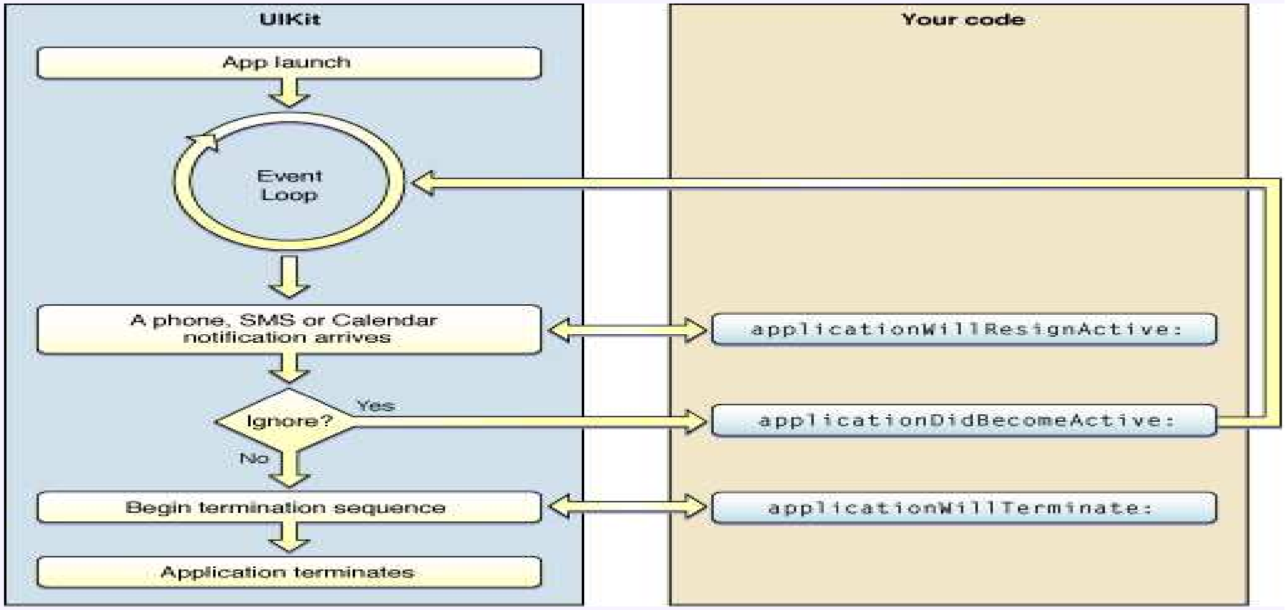
From Programs to Systems

Writing algorithms, data structures from scratch	→	Reuse of libraries, frameworks
Functions with inputs and outputs	→	Asynchronous and reactive designs
Sequential and local computation	→	Parallel and distributed computation
Full functional specifications	→	Partial, composable, targeted models

Our goal: understanding both the **building blocks** and also the **principles** for construction of software systems at scale

A framework for mobile app software (IOS)





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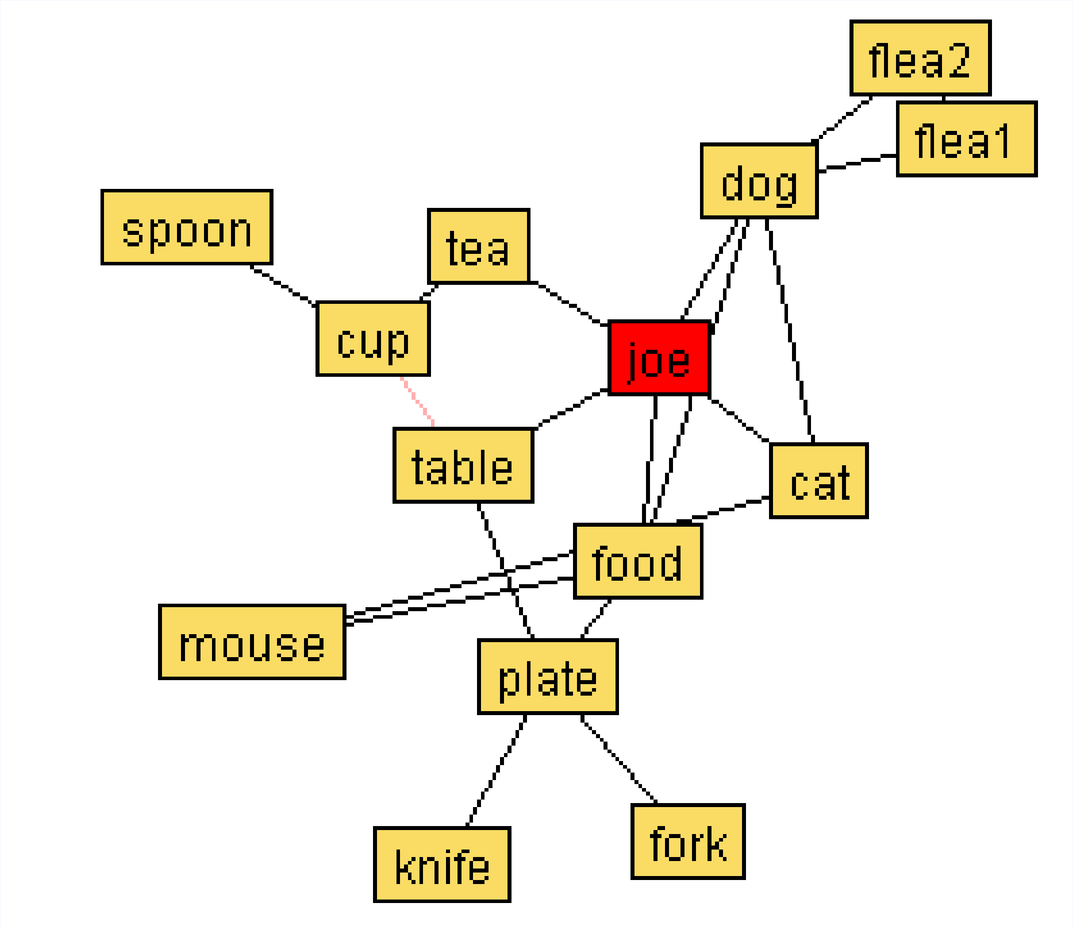
The four course themes

- **T**hreads and Concurrency
  - Concurrency is a crucial system abstraction
    - E.g., background computing while responding to users
  - Concurrency is necessary for performance
    - Multicore processors and distributed computing
  - *Our focus*: application-level concurrency
    - Cf. functional parallelism (150, 210) and systems concurrency (213)
- **O**bject-oriented programming
  - Excels for flexible designs and reusable code
  - A primary paradigm in industry – basis for modern frameworks
  - Focus on Java – used in industry, some upper-division courses
- **A**nalysis and Modeling
  - *Practical* specification techniques and verification tools
  - Address challenges of threading, correct library usage, etc.
- **D**esign
  - Proposing and evaluating alternatives
  - Modularity, information hiding, and planning for change
  - Patterns: well-known solutions to design problems

Motivating example #1: GraphLayout



Source code: http://java.sun.com/applets/jdk/1.4/demo/applets/GraphLayout/example1.html

Screenshot from http://stackoverflow.com/questions/1318770/impressive-examples-in-java

Discussion: GraphLayout

- What does the design of GraphLayout look like, conceptually?
- What is most important about the design?
- How should the GUI be organized? Why?

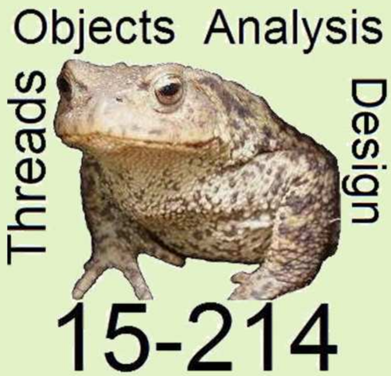
Motivating example #2: Virtual Worlds

Discussion: Virtual Worlds

- How can the virtual world to scale to thousands of users?
- How can we organize the system to easily add new things?
- How can we support different kinds of things, while taking advantage of their similarities? (can you think of an example?)

Considering the examples

- **T**hreads and Concurrency
  - In the GUI-based app
  - On game clients
  - On the game servers
- **O**bject-oriented programming
  - Organizing by object types, then actions
- **A**nalysis and Modeling
  - How to gain confidence regarding *all* possible executions
- **D**esign
  - How to organize systems that grow and evolve
  - How to define the interfaces between infrastructure and our code



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Course Mechanics

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Course Preconditions

- Preconditions
  - 15-122 or equivalent
    - 2 semesters of programming, knowledge of C-like languages
  - That is:
    - Basic programming skills
    - Basic reasoning about programs
    - Basic algorithms and data structures

Course Post-conditions

- Post-conditions
  - OO understanding
    - Objects, classes, types
    - Java development skills
  - Understanding larger-scale software
    - Design patterns
    - Design and use of libraries and frameworks
  - Modeling and analysis
    - Use of development, testing, and analysis tools
  - Concurrent and distributed systems
    - Scaling and performance
    - Safe programming practices for explicit concurrency

Important features of this course

- The team
  - Instructors
    - Jonathan **Aldrich** jonathan.aldrich@cs.cmu.edu
    - Charlie **Garrod** charlie@cs.cmu.edu
  - TAs
    - Patrick **Woody** pwoody@andrew.cmu.edu [Section A]
    - YoungSeok **Yoon** youngseok@cs.cmu.edu [Section B]
    - Alex **Duda** aduda@andrew.cmu.edu [Section C]
    - Saagar **Sethi** saagars@andrew.cmu.edu [Section D]
    - Ivan **Ruchkin** iruchkin@cs.cmu.edu [Cross-Section TA]

- The schedule
  - Lectures
    - Tues, Thurs 3:00 – 4:20pm HBH 1000
  - Recitations
    - A: Weds 9:30-10:20am WEH 5310
    - B: Weds 10:30-11:20am WEH 5310
    - C: Weds 11:30-12:20pm WEH 5310
    - D: Weds 12:30-1:20pm WEH 5310
  - Labs
    - Monday 9:30-1:30 in GHC 5201
  - Office hours
    - *To be announced – see course web page*

Recitations are required

Important features of this course

- Course website
  - Schedule, assignments, lecture slides, policy documents
    http://www.cs.cmu.edu/~aldrich/214
- Tools
  - Subversion
    - Assignment distribution, handin, and grades
  - Piazza
    - Discussion site – link from course page
  - Eclipse
    - Recommended for developing code
- Assignments
  - The first is easy, but important
    - Ensure all tools are working together
    - Subversion, Java, Eclipse
- First recitation, tomorrow
  - Introduction to Java and the tools in the course
  - ***Bring your laptop, if you have one!***
    - Install Subversion, Java, Eclipse beforehand – instructions on Piazza

Policies

- Late days for assignments
  - Five total for the semester
  - Use a maximum of 2 late days per assignment
  - No other late work accepted, except under extreme circumstances
- Recitations
  - Fleshing out lecture with new material
  - Practice of lecture material
  - Discussion, presentations, etc.
  - Attendance is required
- Labs
  - Mini-lecture at the beginning
  - Task that will help you on the homework
  - Doing the task is required, attendance at lab is not required
  - Not included every week
- No official lab on Labor Day
  - But Pat and Alex will be in GHC 5201 at 9:30 to help with HW0
  - This is in addition to regular office hours this week

Policies

- Grading (*subject to adjustment*)
  - 60% assignments
  - 35% midterm and final exam
  - 5% participation
    - Worksheets periodically used in class and recitation
- Cheating
  - Collaboration policy is on the course website
    - Read it—you are responsible for knowing what it says!
  - Ask if you have any questions
  - If you are feeling desperate, please reach out to us
- Texts
  - Alan Shalloway and James Trott. *Design Patterns Explained: A New Perspective on Object-Oriented Design* (2nd Ed).
  - Several free online texts (Java, etc.)

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Objects

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Object orientation (OO)

- History
  - Simulation – Simula 67, first OO language
  - Interactive graphics – SmallTalk-76 (inspired by Simula)

- Object-oriented programming (OOP)
  - Organize code bottom-up rather than top-down
  - Focus on **concepts** rather than **operations**
  - Concepts include both **conventional data types** (e.g. List), and **other abstractions** (e.g. Window, Command, State)

- Some benefits, informally stated
  - Easier to reuse concepts in new programs
    - Concepts map to ideas in the target domain
  - Easier to extend the program with new concepts
    - E.g. variations on old concepts
  - Easier to modify the program if a concept changes
    - **Easier** means the changes can be **localized** in the code base

Objects

- **Object**
  - A package of state (data) and behavior (actions)
- Data and actions
  - **Fields** in the object hold data values
    - Like the fields of a struct in C
    - Access to fields can be restricted
  - **Methods** describe operations or actions on that data
    - Like functions associated with an abstract data type
    - They have access to the all fields
    - Method calls can be thought of as "**messages**" to the object
- Thus…
  - **Methods** can control access to the fields
    - Best practice: Don't allow fields to be seen from outside
  - The **object** can be thought of as a *service* that is accessed through a managed interface. The **class** described a family of similar services.
    - E.g., a particular button (object) vs. buttons in general (class)

Example: Concept of a Rectangle

- What do you need to **know** about a rectangle?

- What might you want to **do** with a rectangle?

Example: Points and Rectangles

```
class Point {
    int x, y;
    int getX() { return x; } // a method; getY() is similar
    Point(int px, int py) { x = px; y = py; }  // constructor for creating the object
}
class Rectangle {
    Point origin;
    int width, height;
    Point getOrigin() { return origin; }
    int getWidth() { return width; }
    void draw() {
            drawLine(origin.getX(), origin.getY(),        // first line
                    origin.getX()+width, origin.getY());
            … // more lines here
    }
    Rectangle(Point o, int w, int h) {
            origin = o; width = w; height = h;
    }
}
```

Example: Points and Rectangles

```
class Po
    int x,
    int ge
    Point(
}
class Re
    Point
    int width, height;
    Point getOrigin() { return origin; }
    int getWidth() { return width; }
    void draw() {
            drawLine(origin.getX(), origin.getY(),        // first line
                    origin.getX()+width, origin.getY());
            … // more lines here
    }
    Rectangle(Point o, int w, int h) {
            origin = o; width = w; height = h;
    }
}
```

Some Client Code

```
Point o = new Point(0, 10); // allocates memory, calls ctor
Rectangle r = new Rectangle(o, 5, 10);
r.draw();
int rightEnd = r.getOrigin.getX() + r.getWidth(); // 15
```

Controlling access by client code

```
class Point {
    private int x, y;
    public int getX() { return x; } // a method; getY() is similar
    public Point(int px, int py) { x = px; y = py; }  // constructor for creating the object
}
class Rectangle {
    private Point origin;
    private int width, height;
    public Point getOrigin() { return origin; }
    public int getWidth() { return width; }
    public void draw() {
            drawLine(origin.getX(), origin.getY(),          // first line
                    origin.getX()+width, origin.getY());
            … // more lines here
    }
    public Rectangle(Point o, int w, int h) {
            origin = o; width = w; height = h;
    }
}
```

Hiding interior state

```
class Point
    private i
    public in
    public Po
}
class Recta
    private I
    private int width, height;
    public Point getOrigin() { return origin; }
    public in
    public v
            c

            .
    }
    public R
            c
    }
}
```

Some Client Code

```
Point o = new Point(0, 10); // allocates memory, calls ctor
Rectangle r = new Rectangle(o, 5, 10);
r.draw();
int rightEnd = r.getOrigin.getX() + r.getWidth(); // 15
```

Client Code that will *not* work in this version

```
Point o = new Point(0, 10); // allocates memory, calls ctor
Rectangle r = new Rectangle(o, 5, 10);
r.draw();
int rightEnd = r.origin.x + r.width; //  trying to "look inside"
```

Hiding interior state

```
class Point
    private i
    public in
    public Po
}
class Recta
    private P
    private int width, height;
    public Point getOrigin() { return origin; }
    public int getWidth() { return width; }
    public void draw() {
            drawLine(origin.getX(), origin.getY(),        // first line
                    origin.getX()+width, origin.getY());
            … // more lines here
    }
    public Rectangle(Point o, int w, int h) {
            origin = o; width = w; height = h;
    }
}
```

Discussion:

- ***What are the benefits of* private *fields?***
- ***Methods can also be private – why is this useful?***

The keyword **this** refers to the "receiver"

```
class Point {
  private int x, y;
  public int getX() { return x; }
  public Point(int px, int py) { x = px; y = py; }
}
```

can also be written in this way:

```
class Point {
  private int x, y;
  public int getX() { return x; }
  public Point(int x, int y) { this.x = x; this.y = y; }
}
```

Toad's Take-Home Messages

- 214: managing complexity, from programs to systems
  - Threads and concurrency
  - Object-oriented programming
  - Analysis and modeling
  - Design
- GraphLayout and virtual worlds illustrate some challenges
- Object-oriented programming organizes code around **concepts**
  - Methods capture behavior, fields capture state
  - As we will see, this organization allows
    - Greater reuse of concepts
    - Better support for change when concepts vary