Course Introduction

Principles of Software System Construction

Prof. Jonathan Aldrich

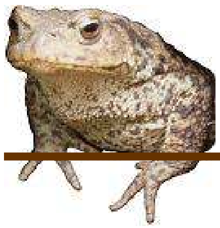
Fall 2011

Scaling Up: From Programs to Systems

- You’ve written small- to medium-size programs in 15-211
- This course is about managing **software complexity**
  - What does that mean?

- Some aspects of software complexity
  - Scale of code: KLOC -> MLOC
  - Software infrastructure: libraries, frameworks, components
  - Worldly environment: external I/O, network, asynchrony
  - Software evolution: change over time

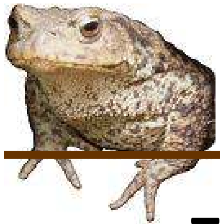
  - Contrast: algorithmic complexity
    - Not an emphasis in this course



From Programs to Systems

Algorithms and data structures written from scratch	→	Reuse of libraries, frameworks
Functions with inputs and outputs	→	Asynchronous and reactive
Sequential, local computation	→	Parallel and distributed computation
Formal functional specifications	→	Composable, scalable, targeted models

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



The Four Course Themes

- **T**hreads and Concurrency
  - Multicore processors → performance requires parallelism
  - Concurrency is also a crucial system abstraction
    - Compute in the background while maintaining responsiveness to users
  - Focus: application-level concurrency
    - Contrast functional parallelism (150, 210) and low-level concurrency (213)
- **O**bject-oriented programming
  - Excels at creating flexible designs and reusable code
  - A primary paradigm in industry
  - Focus: Java
    - Used in industry, 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

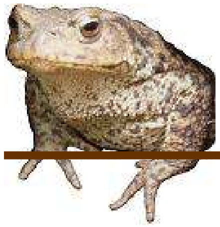
Course Preconditions and Postconditions

Preconditions

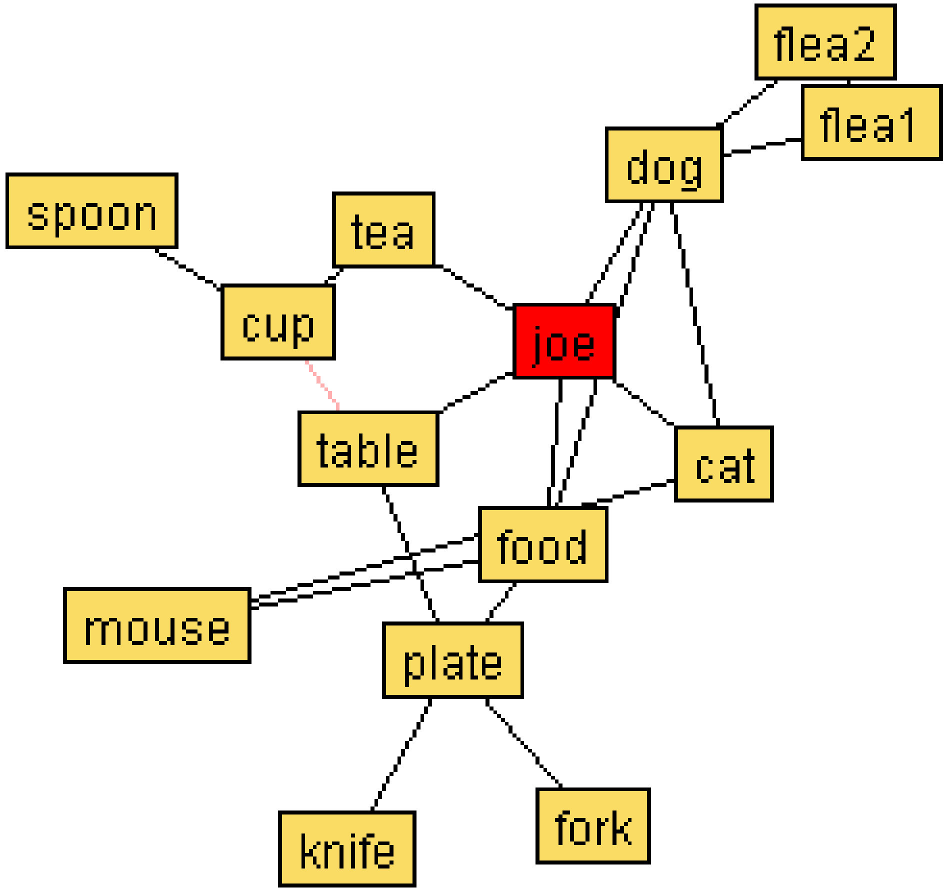
- 15-122 or equivalent
  - 2 semesters of programming, knowledge of C-like languages
  - Basic reasoning about programs; basic algorithms and data structures

Postconditions

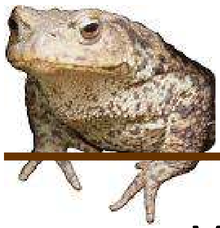
- Java and OO development skills
  - Use of development, testing, and analysis tools
  - Use of frameworks and libraries
- Understanding large-scale software
  - Frameworks, ecosystems, libraries, components
  - Design patterns and practices
- Concurrent and distributed systems
  - Scaling and performance
  - Safe programming practices



Motivating Example: 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



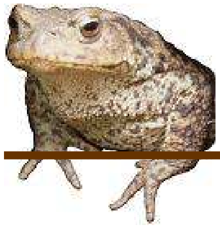
Discussion Points from Class

- What does the design of GraphLayout look like, conceptually?
  - Graph representation
  - Layout algorithm
  - GUI for displaying, responding to user input
- What is most important about the design?
  - Encapsulation
    - To enhance reuse
    - To protect data structures from undesired interference
    - To make the system more robust to change
- How should the GUI be organized
  - Events: need to react to external input, update on regular clock ticks
- How to avoid a “freezing display”
  - Compute, display in different threads → raises coordination challenges

Motivating Example: Virtual Worlds

Discussion Points from Class

- How can we get a virtual world to scale to thousands of users?
  - Offload graphics to the client
  - Take advantage of threads on multicore processors
  - Use a farm of servers, each hosting part of the world
- How can we organize the system to easily add new kinds of virtual objects
  - Need some way of associating each object with its behavior, e.g. using function pointers (or objects as we will see)
- How can we take advantage of similarities in the behavior of similar objects (e.g. different kinds of swords in WOW)
  - A: inheritance (to be discussed…)



Object Background

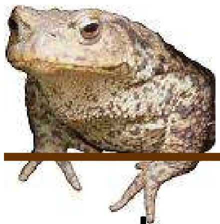
- Background: simulation → Simula 67, first OO language
- Object-oriented programming: A way of organizing code around data structures rather than operations
- Bottom-up rather than top-down design has benefits:
  - Easier to reuse concepts in new programs
  - Easier to extend the program with new concepts
    - E.g. variations on old concepts
  - Easier to modify the program if a concept changes
    - code changes localized to code implementing the concept

Objects

- An object is a package of state and behavior
  - Fields hold data values (this part is like a struct value)
  - Methods perform operations on that data
    - Functions embedded within the object, which have access to its fields
  - Methods also control access to the fields
    - Usually don't want to read the fields from outside—make them **private**

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

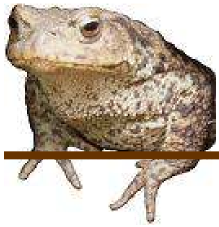
```
class Point {
    int x, y;
    int getX() { return x; } // a r
    Point(int px, int py) { x = px
}
class Rectangle {
    Point origin;
    int width, height;
    Point getOrigin() { return origin; }
    int getWidth() { return width; }
    void draw() {
        drawLine(origin.getX(), origin.getY(),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

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
```

Bureaucracy

- TA: Andrew Chang
- Section: bring your laptop tomorrow
- Textbooks (see web)
- Assignments and Evaluation (see web)
  - First assignment out tomorrow: Java warm-up
- Course Schedule (see web)
- Policies and Expectations (see web)



Toad’s Take-home Messages

- 214’s focus: 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