toad

Fall 2012

Principles of Software Construction: Objects, Design, and Concurrency

Course Introduction

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institute for SOFTWARE RESEARCH

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Construction of

Software Systems

at Scale

Libraries
Reuse
Design
Analysis
Concurrency

primes

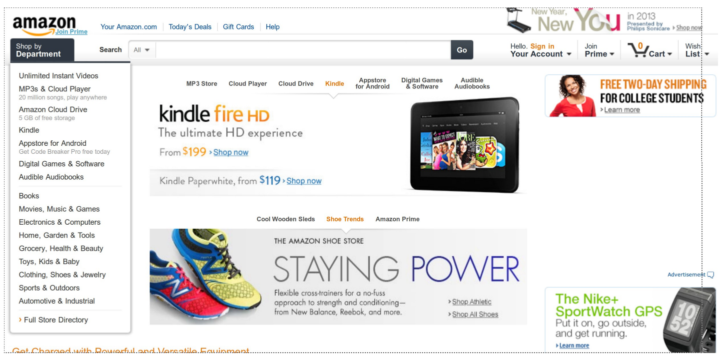
graph search

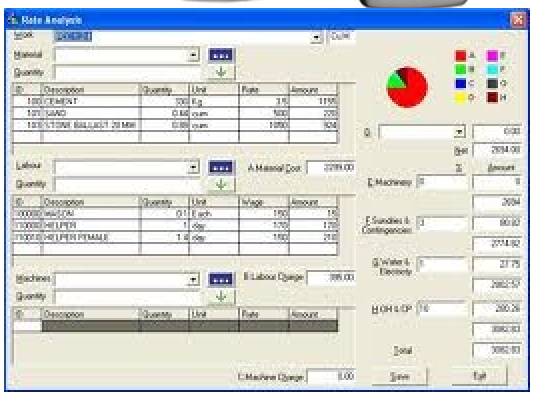
binary tree

GCD

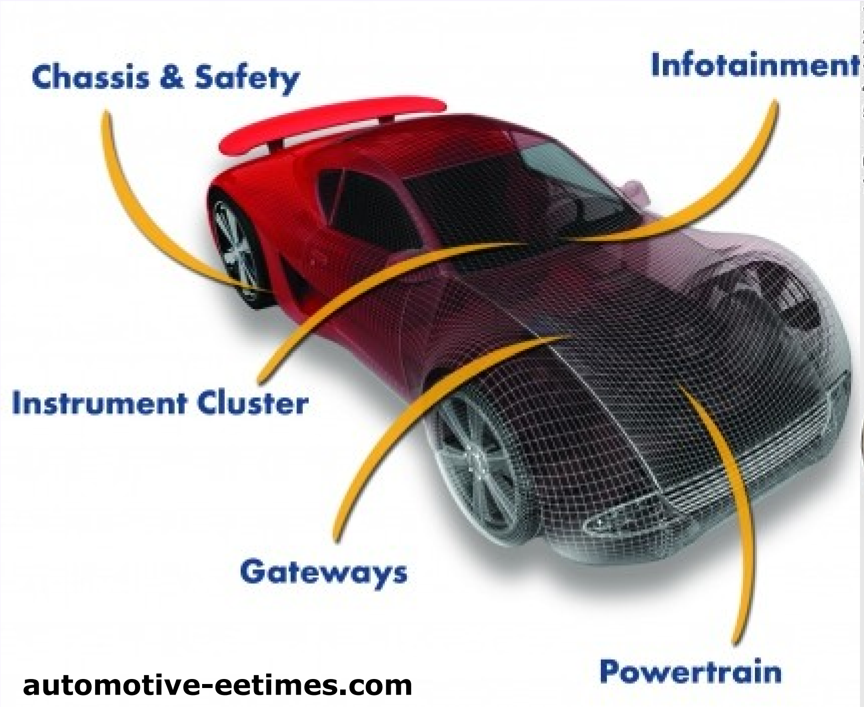
sorting

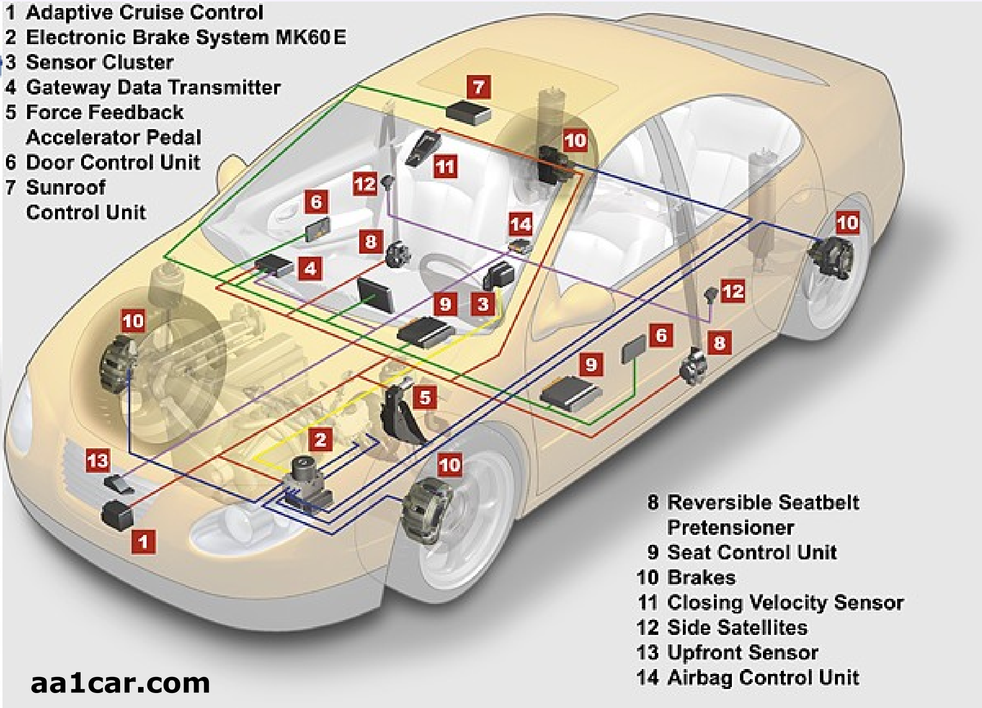
BDDs





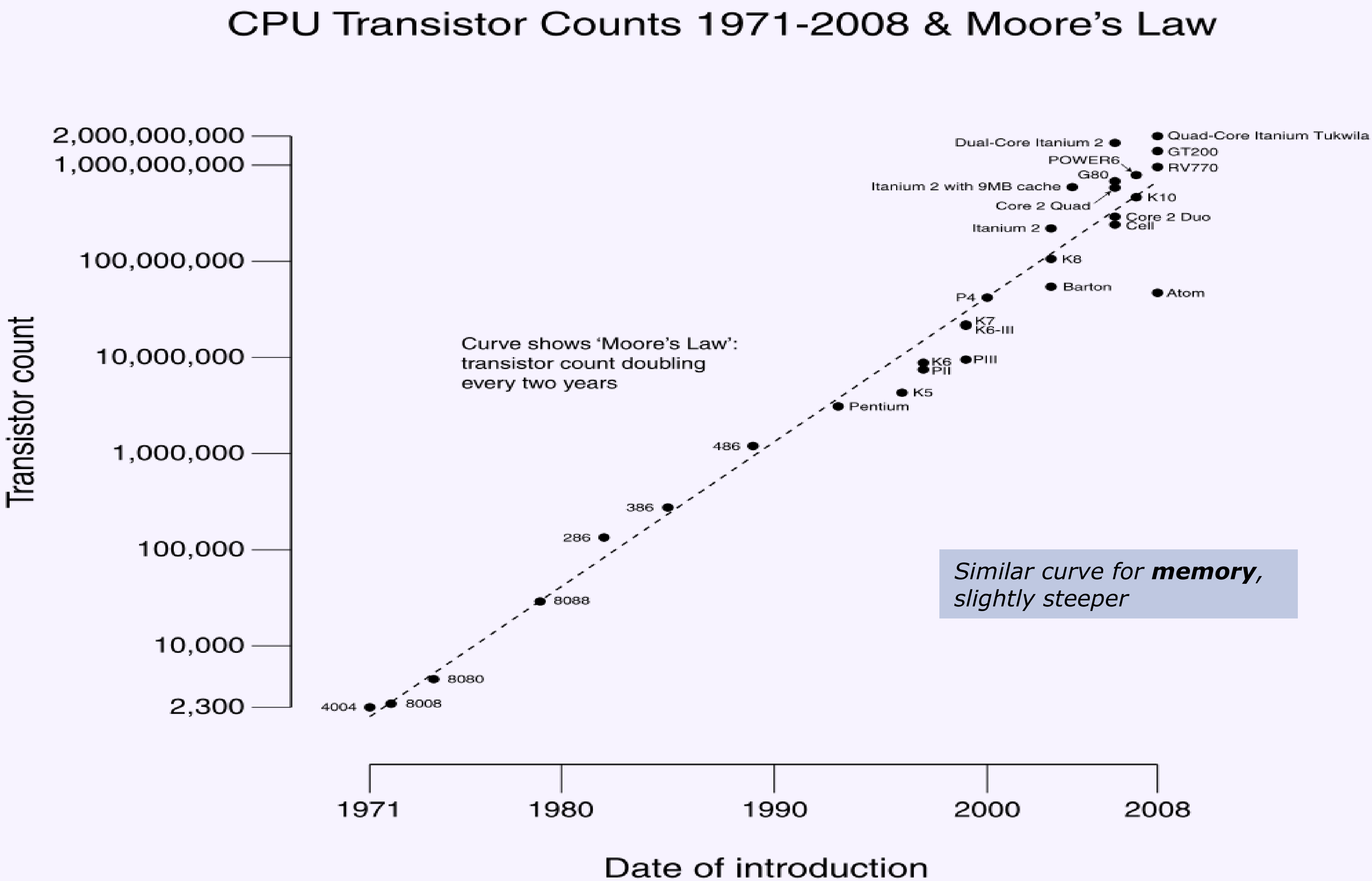
Software and automobiles





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



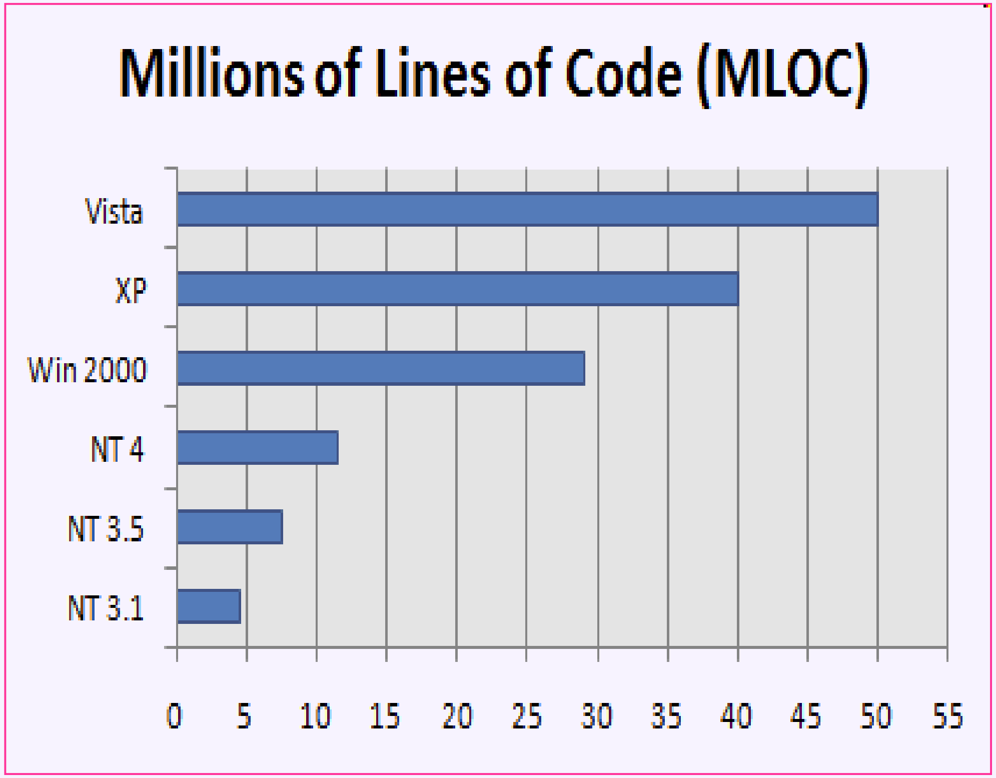
*Similar curve for **memory**, slightly steeper*

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

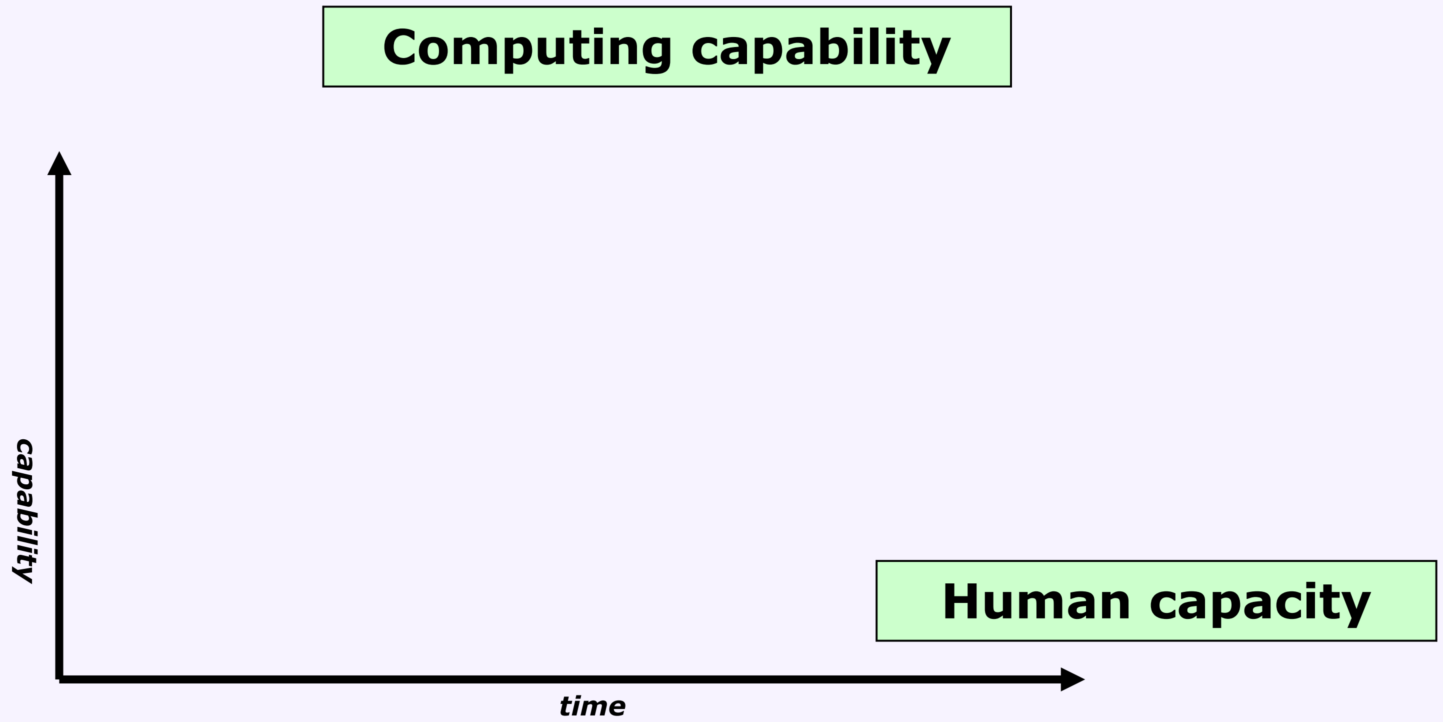
Source: PM Magazine

Table 3.3a – System functionality requiring software



(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

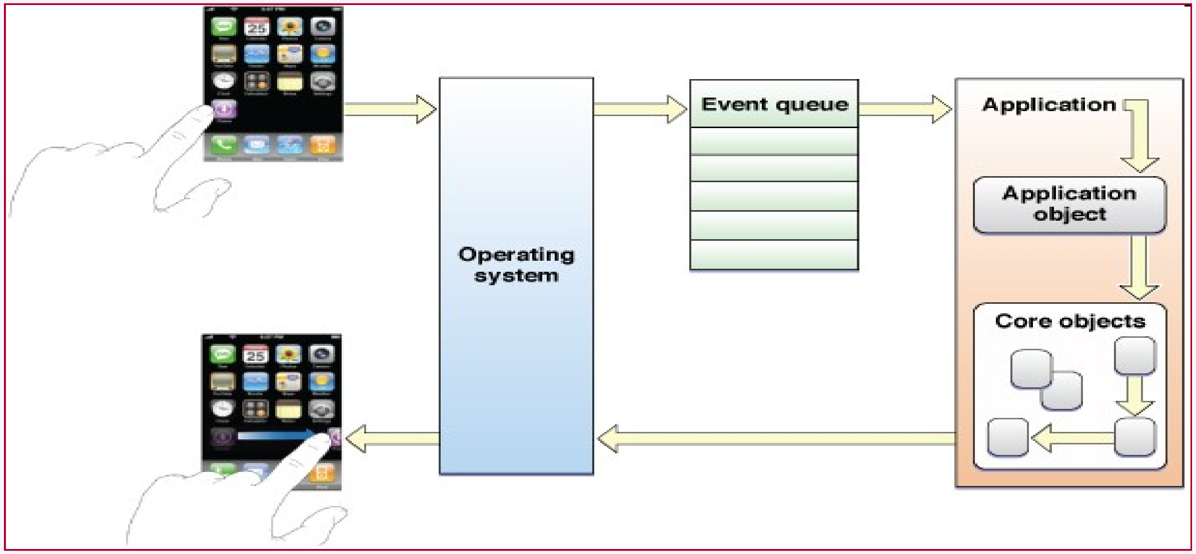
  - Contrast: algorithmic complexity
  - Not an emphasis in this course

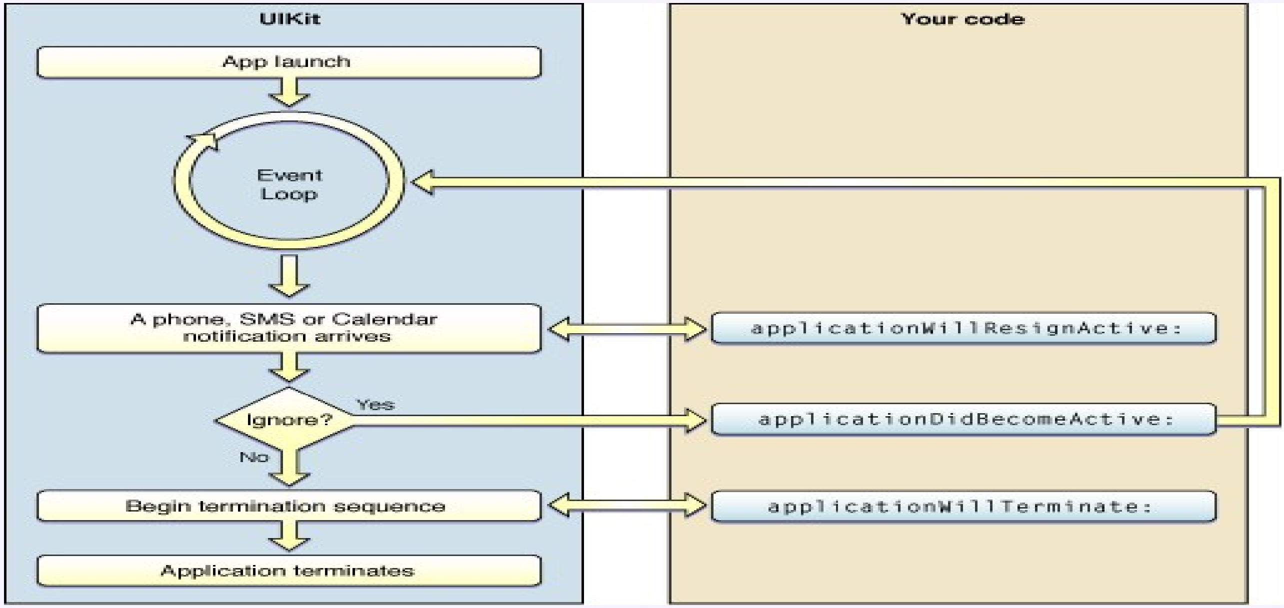
From Programs to Systems

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)

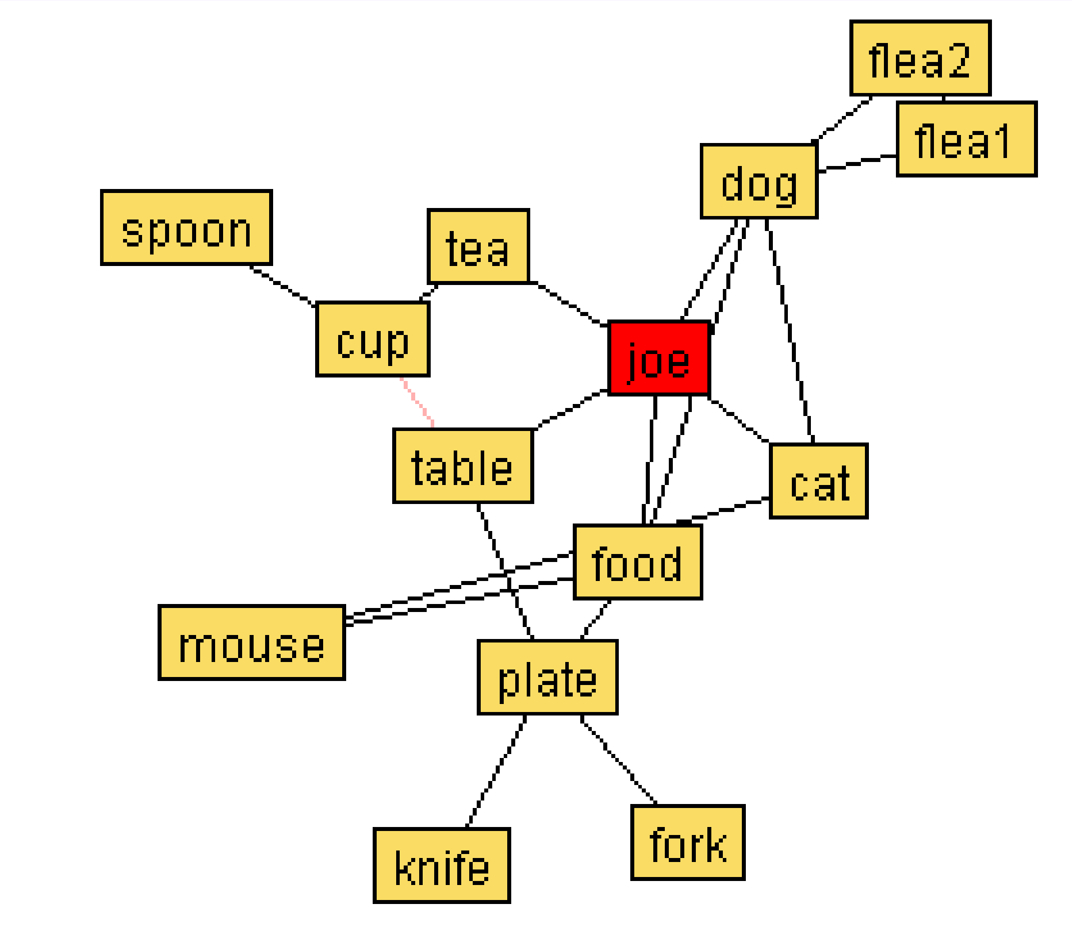




The four course themes

- Threads 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)
- Object-oriented programming
  - 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
- Analysis and Modeling
  - *Practical* specification techniques and verification tools
  - Address challenges of threading, correct library usage, etc.
- Design
  - 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

Objects Analysis

Threads Design

15-214

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Course Organization

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Course preconditions

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

Course postconditions

- 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
    - Christian Kästner kaestner@cs.cmu.edu
    - Charlie Garrod charlie@cs.cmu.edu
  - TAs
    - Daniel Lu dylu@andrew.cmu.edu [Section A]
    - Alex Lockwood alockwoo@andrew.cmu.edu [Section B]
    - Shannon Lee sjl1@andrew.cmu.edu [Section C]
    - Michael Maass mmaass@cs.cmu.edu [Section D]
- The schedule
  - Lectures
    - Tues, Thurs 3:00 – 4:20pm PH 100
  - 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
  - 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/~charlie/courses/15-214
- Tools
  - Subversion
    - Assignment distribution, handin, and grades
  - Piazza
    - Discussion site – link from course page
  - Eclipse
    - Recommended for developing code
- Assignments
  - Homework 0 available tonight
    - Ensure all tools are working together
    - Subversion, Java, Eclipse
- First recitation is 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

Course policies

- Grading (*subject to adjustment*)
  - 60% assignments
  - 15% midterm
  - 20% final exam
  - 5% participation
- Collaboration policy is on the course website
  - We expect your work to be your own
  - Ask if you have any questions
  - If you are feeling desperate, please reach out to us
    - Always turn in any work you've completed *before* the deadline
- Texts
  - Alan Shalloway and James Trott. *Design Patterns Explained: A New Perspective on Object-Oriented Design* (2nd Ed).
  - Several free online texts (Java, etc.)

Course policies

- Late days for homework assignments
  - 5 total late days for the semester
  - May use a maximum of 2 late days per assignment
  - No other late work accepted, except under extreme circumstances
- Recitations
  - Practice of lecture material
  - Discussion, presentations, etc.
  - Attendance is required
  - In general, bring a laptop if you can

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Objects

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Spring 2013

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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

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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?

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Example: Points and Rectangles

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

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