Principles of Software Construction: Objects, Design, and Concurrency

Part 1: Introduction

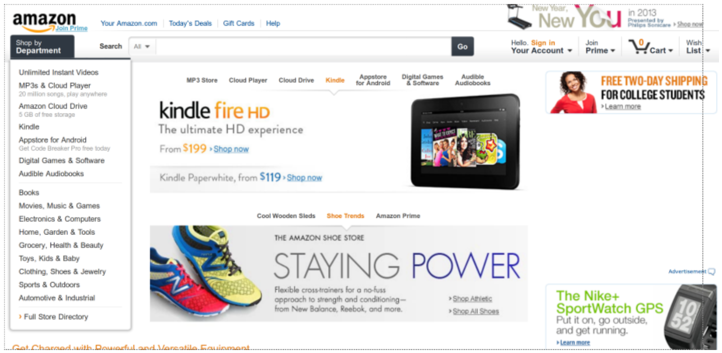
Course overview and introduction to software design

Charlie Garrod Chris Timperley

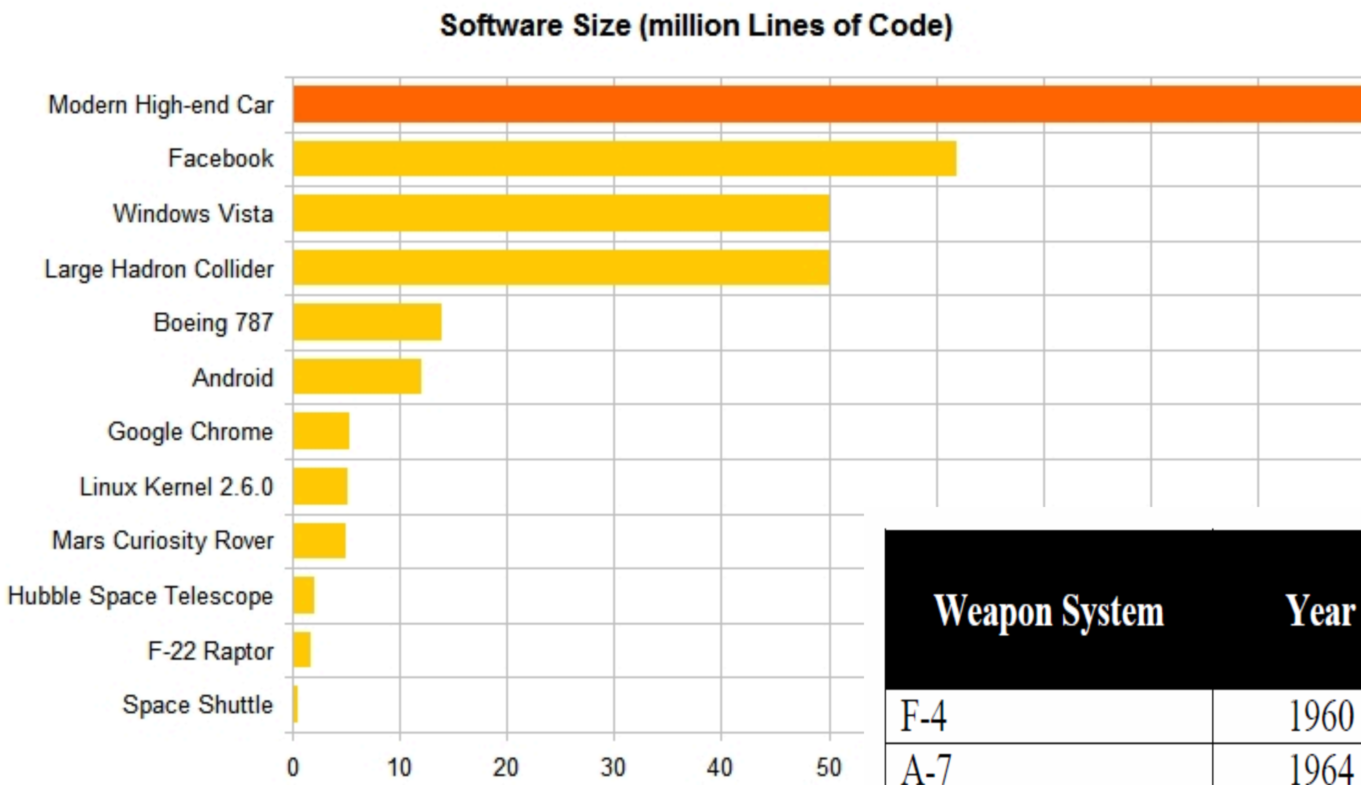
Carnegie Mellon University
School of Computer Science

institute for SOFTWARE RESEARCH

Software is everywhere



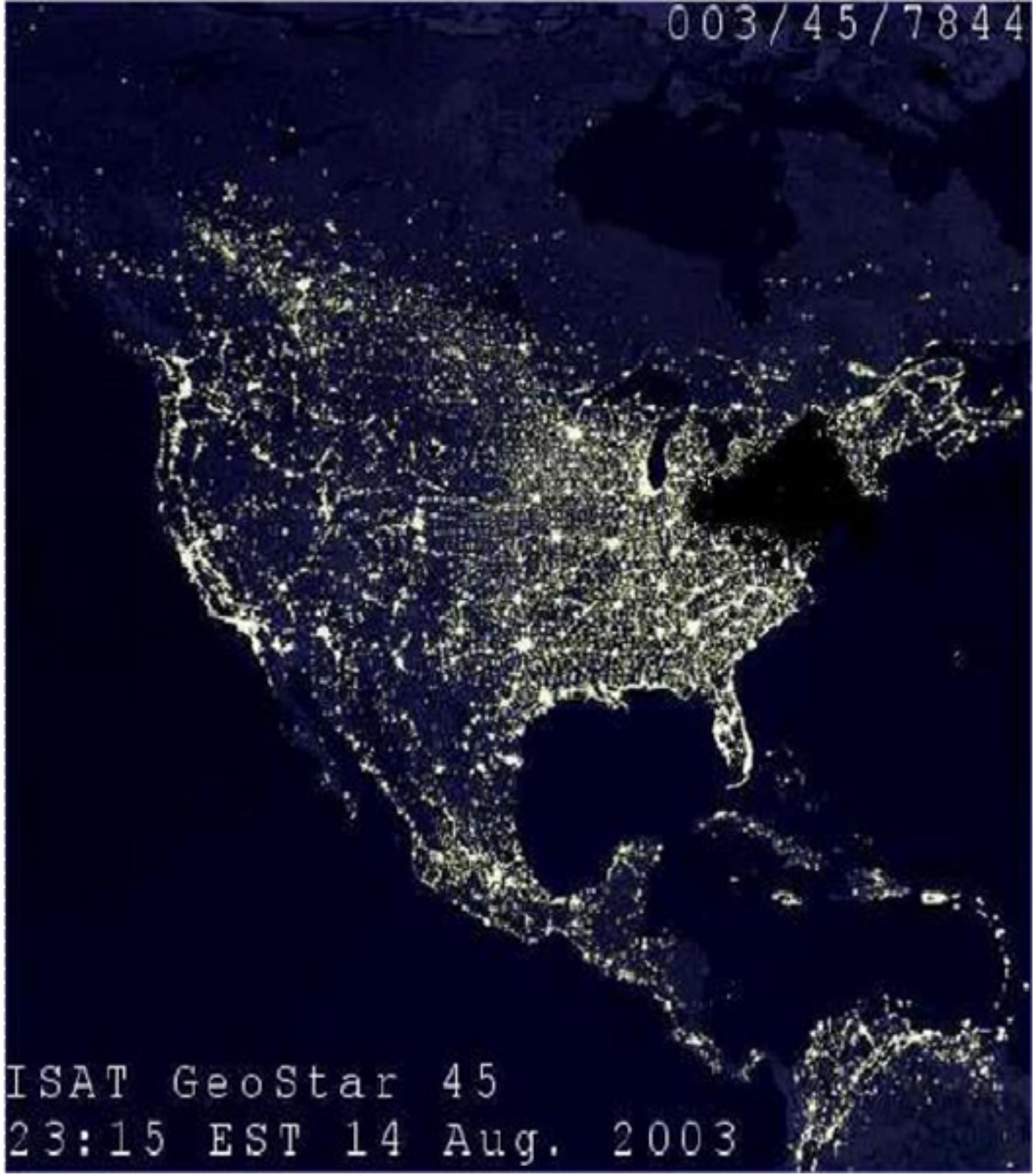
Growth of code and complexity over time



Weapon 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

Normal night-time image

Blackout of 2003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ISAT GeoStar 45
23:15 EST 14 Aug. 2003

COMMENTARY

Chris Murphy
Editor, InformationWeek

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Why Ford Just Became A Software Company

Ford is upgrading its in-vehicle software on a huge scale, embracing all the customer expectations and headaches that come with the development lifecycle.

6 Comments | Chris Murphy | November 14, 2011 09:31 AM

Sometime early next year, Ford will mail USB sticks to about 250,000 owners of vehicles with its advanced touchscreen control panel. The stick will contain a major upgrade to the software for that screen. With it, Ford is breaking from a history as old as the auto industry, one in which the technology in a car essentially stayed unchanged from assembly line to junk yard.

Ford is significantly changing what a driver or passenger experiences in its cars years after they're built. And with it, Ford becomes a software company--with all the associated high customer expectations and headaches.

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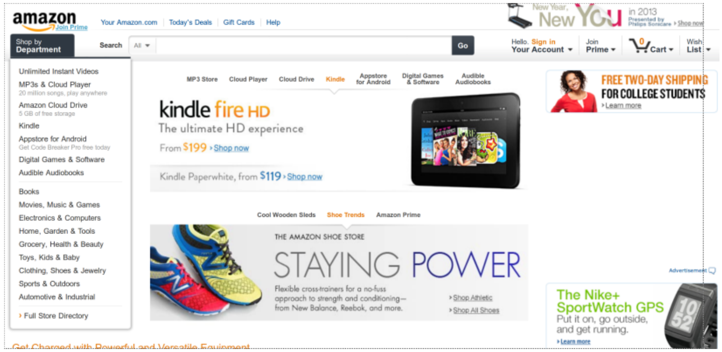
primes

graph search

binary tree

GCD

sorting



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 the **design principles** for construction of software systems

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Objects in the real world

Object-oriented programming

- Programming based on structures that contain both data and methods

```
public class Bicycle {
  private final Wheel frontWheel, rearWheel;
  private final Seat seat;
  private int speed;
  …

  public Bicycle(…) { … }

  public void accelerate() {
    speed++;
  }

  public int speed() { return speed; }
}
```

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Semester overview

- Introduction to Java and O-O
- Introduction to **design**
  - **Design** goals, principles, patterns
- **Designing** classes
  - **Design** for change
  - **Design** for reuse
- **Designing** (sub)systems
  - **Design** for robustness
  - **Design** for change (cont.)
- **Design** case studies
- **Design** for large-scale reuse
- Explicit concurrency

- Crosscutting topics:
  - Modern development tools: IDEs, version control, build automation, continuous integration, static analysis
  - Modeling and specification, formal and informal
  - Functional correctness: Testing, static analysis, verification

Sorting with a configurable order, version A

```
static void sort(int[] list, boolean ascending) {
   …
   boolean mustSwap;
   if (ascending) {
      mustSwap = list[i] > list[j];
   } else {
      mustSwap = list[i] < list[j];
   }
   …
}
```

Sorting with a configurable order, version B

```
interface Order {
  boolean lessThan(int i, int j);
}

class AscendingOrder implements Order {
  public boolean lessThan(int i, int j) { return i < j; }
}
class DescendingOrder implements Order {
  public boolean lessThan(int i, int j) { return i > j; }
}

static void sort(int[] list, Order order) {
  …
  boolean mustSwap =
    order.lessThan(list[j], list[i]);
  …
}
```

Sorting with a configurable order, version B'

```
interface Order {
  boolean lessThan(int i, int j);
}

final Order ASCENDING  = (i, j) -> i < j;
final Order DESCENDING = (i, j) -> i > j;

static void sort(int[] list, Order order) {
  …
  boolean mustSwap =
    order.lessThan(list[j], list[i]);
  …
}
```

Which version is better?

Version A:

```
static void sort(int[] list, boolean ascending) {
   …
   boolean mustSwap;
   if (ascending) {
      mustSwap = list[i] > list[j];
   } else {
      mustSwap = list[i] < list[j];
   }
   …
}
```

Version B':

```
interface Order {
  boolean lessThan(int i, int j);
}
final Order ASCENDING =  (i, j) -> i < j;
final Order DESCENDING = (i, j) -> i > j;

static void sort(int[] list, Order order) {
  …
  boolean mustSwap =
    order.lessThan(list[j], list[i]);
  …
}
```

It depends?

Software engineering is the branch of computer science that creates **practical, cost-effective solutions** to computing and information processing problems, preferably by applying scientific knowledge, developing software systems in the service of mankind.

Software Engineering for the 21st Century: A basis for rethinking the curriculum
Manifesto, CMU-ISRI-05-108

Software engineering is the branch of computer science that creates **practical, cost-effective solutions** to computing and information processing problems, preferably by applying scientific knowledge, developing software systems in the service of mankind.

Software engineering entails making **decisions under constraints** of limited time, knowledge, and resources…

- Engineering quality resides in engineering **judgment**…
- Quality of the software product depends on the engineer's **faithfulness to the engineered artifact**…
- Engineering requires reconciling **conflicting constraints**…
- Engineering skills improve as a result of careful systematic **reflection** on experience…
- Costs and time constraints matter, **not just capability**…

Software Engineering for the 21st Century: A basis for rethinking the curriculum
Manifesto, CMU-ISRI-05-108

Goal of software design

- For each desired program behavior there are infinitely many programs
  - What are the differences between the variants?
  - Which variant should we choose?
  - How can we create a variant with desired properties?

Metrics of software quality, i.e., *design goals*

Functional correctness	Adherence of implementation to the specifications
Robustness	Ability to handle anomalous events
Flexibility	Ability to accommodate changes in specifications
Reusability	Ability to be reused in another application
Efficiency	Satisfaction of speed and storage requirements
Scalability	Ability to serve as the basis of a larger version of the application
Security	Level of consideration of application security

Source: Braude, Bernstein, Software Engineering. Wiley 2011

A typical Intro CS design process

1. Discuss software that needs to be written
2. Write some code
3. Test the code to identify the defects
4. Debug to find causes of defects
5. Fix the defects
6. If not done, return to step 1

Better software design

- Think before coding: broadly consider quality attributes
  - Maintainability, extensibility, performance, …
- Propose, consider design alternatives
  - Make explicit design decisions

Using a design process

- A design process organizes your work
- A design process structures your understanding
- A design process facilitates communication

Preview: Design goals, principles, and patterns

- ***Design goals*** enable evaluation of designs
  - e.g. maintainability, reusability, scalability
- ***Design principles*** are heuristics that describe best practices
  - e.g. high correspondence to real-world concepts
- ***Design patterns*** codify repeated experiences, common solutions
  - e.g. template method pattern

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Concurrency

- Roughly: doing more than one thing at a time

Summary: Course themes

- Object-oriented programming
- Code-level design
- Analysis and modeling
- Concurrency

Software Engineering (SE) at CMU

- 17-214: Code-level design
  - Extensibility, reuse, concurrency, functional correctness
- 17-313: Human aspects of software development
  - Requirements, teamwork, scalability, security, scheduling, costs, risks, business models
- 17-413 Practicum, 17-415 Seminar, Internship
- Various courses on requirements, architecture, software analysis, SE for startups, etc.
- SE Minor: http://isri.cmu.edu/education/undergrad

COURSE ORGANIZATION

Preconditions

- 15-122 or equivalent
  - Two semesters of programming
  - Knowledge of C-like languages
- 21-127 or equivalent
  - Familiarity with basic discrete math concepts
- Specifically:
  - Basic programming skills
  - Basic (formal) reasoning about programs
    - Pre/post conditions, invariants, formal verification
  - Basic algorithms and data structures
    - Lists, graphs, sorting, binary search, etc.

Learning goals

- Ability to **design** and implement medium-scale programs
- Understanding **OO programming** concepts & design decisions
- Proficiency with basic **quality assurance** techniques for functional correctness
- Fundamentals of **concurrency**
- Practical skills

Course staff

- Charlie Garrod
  charlie@cs.cmu.edu
  Wean 5120

- Chris Timperley
  ctimperley@cmu.edu
  Wean 4206

- Teaching assistants: Alex, Alice, Emily, Jun, Michelle, Shruti, Tianyang, Tiffany, and Yang

Course meetings

Smoking Section

- Lectures: Tuesday and Thursday, noon – 1:20pm, HoA 160
  - Electronic devices discouraged
- Recitations: Wednesdays 9:30 - … - 3:20pm
  - Supplementary material, hands-on practice, feedback
  - Bring your laptop
- Office hours: see course web page
  - https://www.cs.cmu.edu/~charlie/courses/17-214/

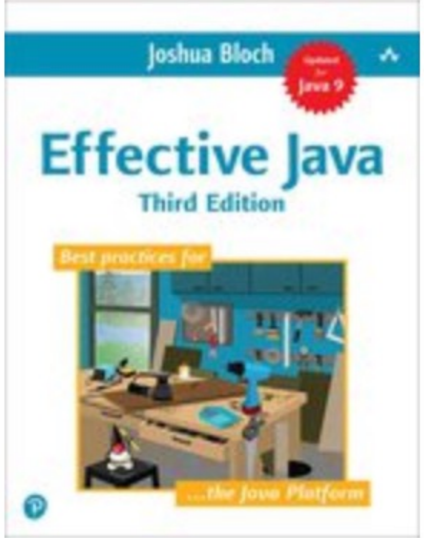
Recitation attendance is required

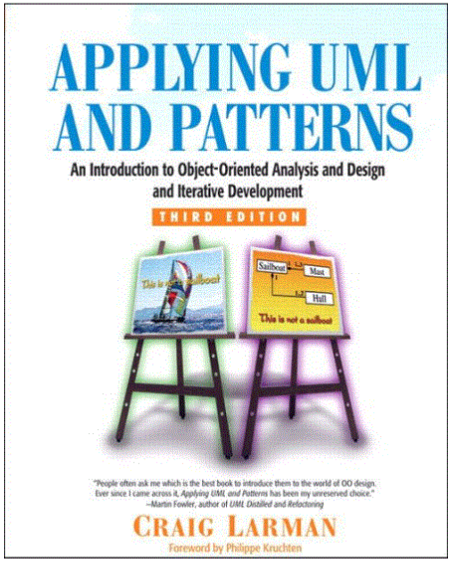
Infrastructure

- Course website: http://www.cs.cmu.edu/~charlie/courses/17-214
  - Schedule, office hours calendar, lecture slides, policy documents
- Tools
  - Git, Github: Assignment distribution, hand-in, and grades
  - Piazza: Discussion board
  - IntelliJ or Eclipse: Recommended for code development (other IDEs are fine)
  - Gradle, Travis-CI, Checkstyle, Findbugs: Practical development tools
- Assignments
  - Homework 1 available tomorrow
- First recitation is tomorrow
  - Introduction to Java and the tools in the course
  - Install Git, Java, some IDE, Gradle beforehand

Textbooks

- Required course textbooks (electronically available through CMU library):
  - Joshua Bloch. Effective Java, Third Edition. Addison-Wesley, ISBN 978-0-13-468599-1.
  - Craig Larman. Applying UML and Patterns. 3rd Edition. Prentice Hall, ISBN 978-0321356680.
- Additional readings on design, Java, and concurrency on the course web page





Approximate grading policy

- 50% assignments
- 20% midterms (2 x 10% each)
- 20% final exam
- 10% quizzes and participation

This course does not have a fixed letter grade policy; i.e., the final letter grades will not be A=90-100%, B=80-90%, etc.

Collaboration policy (also see the course syllabus)

- *We expect your work to be your own*
  - You must clearly cite external resources so that we can evaluate your own personal contributions.
- Do not release your solutions (not even after end of semester)
- Ask if you have any questions
- If you are feeling desperate, please mail/call/talk to us
  - Always turn in any work you've completed *before* the deadline
- We use cheating detection tools
- You must sign and return a copy of the collaboration policy before we will grade your work: https://goo.gl/CBXKQK

Late day policy

- You may turn in each* homework up to 2 days late
- You have five free late days per semester
  - 10% penalty per day after free late days are used
- We don't accept work 3 days late
- See the syllabus for additional details
- Got extreme circumstances? Talk to us

10% quizzes and participation

- Recitation participation counts toward your participation grade
- Lecture has in-class quizzes

Summary

- Software engineering requires decisions, judgment
- Good design follows a process
- You will get lots of practice in 17-214!