CSE 331
Software Design & Implementation

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Lecture 1 – Introduction & Overview

(Based on slides by Mike Ernst, Dan Grossman, Kevin Zatloukal, me, and many others)

What is CSE 331 about?

- It's about 10 weeks…
- It's lots of Java programming…
- It's weird Java language stuff like generic type bounds…
- It's git and gradle and Intellij and junit (and I already know all that stuff from my internship)…
- It's JavaScript and TypeScript and React, but I'm already a Full-Stack®™℠ Developer!...

- Yes, we'll do those things, but it's not (primarily) those things
  - It's the "why" behind the "what"
  - It's the rest of the course that goes with the lab (think chemistry, physics, mechanical/civil engineering, etc.)

What is the goal of CSE 331?

How to build harder-to-build software

- Move from CSE 143 problems toward what you'll see in upper-level CSE courses and in industry
- Move beyond coding to software design and development (and coding is actually a fairly small part of that)

Specifically, how to write programs of

- Higher **quality**
- Increased **complexity**

We will discuss *tools* and *techniques* to help with this and the *concepts* and *ideas* behind them

  - There are *timeless principles* to both
  - Widely used across industry

What is high quality?

Code is high quality when it is

1. **Correct**
   - Everything else is of secondary importance

2. Easy to **change**
   - Most work is making changes to existing systems

3. Easy to **understand**
   - Needed for 1 & 2 above

How do we ensure correctness...

... when **people** are involved?

People have been known to

- walk into windows
- drive away with a coffee cup on the roof
- drive away still tied to gas pump
- lecture wearing one brown shoe and one black shoe

What is increased complexity?

Analogy to building physical objects:

- 100 well-tested LOC = a nice cabinet
- 2,500 LOC = a room with furniture
- 2,500,000 LOC = 1000 rooms ≈

North Carolina class WW2 battleship

≈

the entire British Naval fleet in WW2

Actually, software is more complex…

- Every bit of code is unique, individually designed
  - US built 10 identical Essex carriers

  - Software equivalent would be one carrier 10 times as large:

- Defects can be even more destructive
  - A defect in one room can sink the ship
  - But a defective OS could sink the *whole fleet*

How do we cope with complexity?

We tackle complexity with **modularity**

- Split code into pieces that can be built independently
- Each must be documented so others can use it
- Also helps understandability and changeability

Scale makes everything harder

Modularity makes scale **possible** but it's still **hard**…

- Time to write N-line program grows faster than linear
  - Good estimate is $O(N^{1.05})$ [Boehm, '81]
- Bugs grow like $\Theta(N \log N)$ [Jones, '12]
  - 10% of errors are between modules [Seaman, '08]
- Communication costs dominate schedules [Brooks, '75]
- Small probability cases become high probability cases
  - Corner cases are more important with more users

Corollary: quality must be even higher, per line, in order to achieve overall quality in a *large* program

People Do Build Great Software

Full scope of the challenge:

- software is built by people, who make mistakes all the time
- surprisingly difficult to get even a small program to work
- needed to write hundreds of millions of lines of code
- each line gets harder to write as the program scale

Despite those challenges, we have lots of software that works

- hundreds of millions of lines of working programs
- products rarely fail because the software is too buggy

How do we do it?

How do we ensure correctness...

... when **people** are involved?

People have been known to

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Key insights:

- Can't stop people from making mistakes
- Can stop mistakes from getting to users

How do we ensure correctness?

Best practice: use three techniques (we'll study each)

1. **Tools**
   - Type checkers, test runners, etc.
2. **Inspection**
   - Think through your code carefully
   - Have another person review your code
3. **Testing**
   - Usually >50% of the work in building software

Each removes ~2/3 of bugs. Together >97%

What is high quality code?

In summary, we want our code to be:

1. Correct
2. Easy to change
3. Easy to understand
4. Easy to scale (modular)

These qualities also allow for increased complexity

What we will cover in CSE 331

- Everything we cover relates to the 4 goals
- We'll use Java but the principles apply in any setting

Correctness

1. Tools
   - Git, IntelliJ, JUnit, Javadoc, …
   - Java libraries: equality & hashing
   - Adv. Java: generics, assertions, …
   - debugging
2. Inspection
   - reasoning about code
   - specifications
3. Testing
   - test design
   - coverage

Changeability

- specifications, ADTs
- listeners & callbacks

Understandability

- specifications, ADTs
- Adv. Java: exceptions
- subtypes

Modularity

- module design & design patterns
- event-driven programming, MVC, GUIs

Administrivia

See course syllabus for full details

Who: Course staff

- Instructor:
  - Hal Perkins (long-time CSE 331 veteran)
- TAs:
  - ~20 great TAs, lots of veterans and some new folks

- Office hours posted soon
  - (Hope to start tomorrow)

Get to know us!

  - We're here to help you succeed

Who: Students

- Assuming you have mastered CSE142 and CSE 143
  - Will review things quickly, but not re-teach them

- Helpful if you've taken CSE 311
  - But not required – we cover everything we need
  - But will try to connect to CSE 311 when it arises

- Assuming you are fairly new to the Allen School
  - Good course to take *before* that internship
  - May be more redundant if you're about to graduate, but you ~~probably~~ definitely will see new connections between things – "ah, that's why they do that…"

Prerequisites

- Knowing Java is a prerequisite

Examples:

- Difference between `int` and `Integer`
- Distinction between `==` and `equals()`
- Aliasing: multiple references to the same object, what does assignment (`x=y;`) really mean?
- Subtyping via `extends` (classes) and `implements` (interfaces)
- Method calls: inheritance and overriding; dynamic dispatch
- Difference between compile-time and run-time type

Staying in touch

- "ed" Message Board for general discussion and announcements
  - You should have already received an invitation
  - Join in! Staff will read/contribute too
  - Help each other out and stay in touch outside of class

- "ed" Message Board for debugging/assignment help
  - Use private ed messages

- Course staff: **`cse331-staff@cs.washington.edu`**
  - For things that don't make sense to post on message board
    - Personal situations, grading questions, etc.
  - Please do *not* send messages to individual staff if possible – easier to route and follow up if it goes to the list

Lecture and section

- Both required – zoom week 1, then in-person (UW current plan)

- All materials posted, but they are visual aids
  - Attend regularly and pay attention (& take notes!)
  - If doing so doesn't save you time, one of us is messing up (!)
  - Lectures recorded for review, but not a substitute for attending

- Section will often be more tools and homework-details focused
  - Held the day most HW is released – should help you get started
  - Demos/tutorials will be recorded or we'll have videos
  - Group work and discussions not recorded

Homework Assignments

- Biggest misconception (?) about CSE331

  "Homework was programming projects that seemed disconnected from lecture"

  - If you think so, you are making them harder!
    - Reconsider
    - Seek out the connections by thinking-before-typing
    - Approaching them as CSE143 homework won't work well
    - Don't keep cutting with a dull blade

- First few assignments are on paper "like math problems", followed by software development and related problems that are increasingly substantial

- Deadlines: 11 pm or 11:59 pm? Does it make a difference?

Late Policy

- Assignments must be submitted by deadline. Full stop.
- But, stuff happens (bugs, computer crashes, …)
- So:
  - Up to **4** times this quarter you can turn in a homework assignment **one** (**1**) day late **=>*max*<=**
  - Late days are 24-hour chunks
  - That's it. Not accepted for credit after that.
    - Requests for "extensions" later in the quarter because of bad time management earlier are not looked on with favor
    - Do not plan to use late days – save for unexpected things
- Why?
  - Keep you on schedule (most important)
  - Allow staff to get feedback to you before next deadline
- This is almost certainly different from what you're used to. No excuses for not knowing what the policy is.

But: Unusual Situations

- Especially in these unsettled times, different people have unusual challenges

- We will do our best to work with you, but please contact course staff or the instructor in advance if you can (unless you can't because of a true emergency)
  - Please reach out early – don't let things fester until it's late and much harder to fix
  - We have a lot of flexibility to make things work

- And a reminder: if you're sick, *stay home*! *get well*!!
  - And get in touch so we can help you keep up

Resubmission: Coding Assignments

- You can re-submit coding assignments
- Aim of the policy is to limit the deductions for minor mistakes that end up causing a disproportionate number of test failures
- We will re-calculate the correctness score up to a maximum score of 80%
  - other scores (design, code quality, etc.) are not changed

Academic Integrity

- "The code you submit must be your own"
  - no copying from other students, web pages, etc.
- Read the full course policy carefully
  - ask questions if you are unsure
- Always explain in your HW any unconventional action
  - worst result then is some points lost
- Violations are unfair to other students and yourself

Exams

- We will have a regular midterm and final exam assuming we're back in person after not too long
  - Midterm: late afternoon, Tuesday, Feb. 8
    - One hour sometime between 4:30 and 6:30
  - Final exam: finals week, day/time will change
  - Everyone in all sections will take exams together at same time/location (to be announced)
  - Will try to pin down exact dates/times soon
- May supplement this with some lightweight quizzes, especially on readings (still to be determined)

Grading

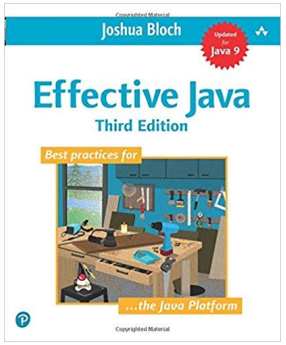
Approximate weighting (subject to change):

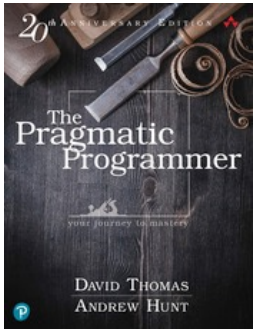
65%	Homework, projects
10%	Midterm
15%	Final
5%	Quizzes, other

Books

Required textbooks

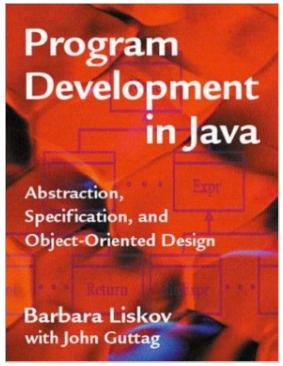
- *Effective Java* 3rd ed, Bloch (EJ)
- *Pragmatic Programmer*, 20th anniversary (2nd) edition, Hunt & Thomas (PP)

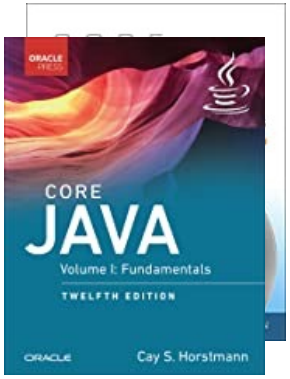




Other useful books:

- *Program Development in Java*, Liskov & Guttag
  - would be the textbook if not from 2001
- *Core Java* Vol I, Horstmann
  - good reference on language & libraries





Readings (and quizzes)

- These are “real” books about software, approachable in 331
  - Occasionally slight reach: accept the challenge
- Overlap only partial with lectures
- Important to “do it”
  - Reading and thinking about software design is essential
    - Books may seem expensive given your budget, but very cheap as a time-constrained professional
    - But: you can access them free!! online (see syllabus)
  - Quizzes & exams ☺

Books? In the 21st century?

- Why not just use Google, Stack Overflow, Reddit, Quora, …?
- Web-search good for:
  - Quick reference (What is the name of the function that does … in Java? What are its parameters?)
- (can be) Bad for
  - Why does it work this way?
  - What is the intended use?
  - How does my issue fit into the bigger picture?
- Beware:
  - Answers on the web are often **quickly** out of date (especially software configuration information)
    - aim is to answer the question at the time when asked
  - "This inscrutable incantation solved my problem on an unknown version for no known reason"

CSE 331 can be challenging

- Past experience tells us CSE 331 is **hard**
  - not our intention to make it difficult!
- Big change to move
  - **from** programming by trial & error
    - technique that does not work for building large scale software
  - **to** programming by careful design, reasoning, and testing
- Programming itself can be hard
  - surprisingly difficult to specify, design, implement, test, debug, and maintain even a simple program

CSE 331 can be challenging

- We strive to create assignments that are reasonable if you apply the techniques taught in class…
  - … but likely hard to do in a trial & error manner
    - … and almost certainly impossible to finish if you put them off until a few days before they're due

- Assignments will take more time than you think (**start early**)
  - even professionals *routinely* underestimate by 3x
  - these assignments will be a step up in difficulty
  - aim to finish a day early and leave yourself 24 hrs. to review and fix any last-minute problems

- If you are having trouble, *think* before you act
  - then, look for help

Other Advice

- Don't be afraid to make mistakes
  - accepting that you will make mistakes is perhaps the most important lesson of this course
  - we often learn best from our mistakes
  - if you're not making mistakes, you're not challenging yourself
    - "Never promote someone who hasn't made some bad mistakes because, if you do, you are promoting someone who has never done anything" — Dr. Herbert Dow (founder of the Dow Chemical Company)

- Don't expect everything to be spelled out for you
  - real-world problems don't come that way
    - if there are detailed instructions for solving a problem, then there should already be a program that does it
  - world needs you for your intuition, creativity, & intelligence

You have homework!

- Homework 0, due online by **10AM Wednesday** (no late days)
  - Write (don't run!) an algorithm to rearrange (swap) the elements in an array
  - in O(*n*) time (and preferably in a single pass)
  - And argue (prove) in concise, convincing English that your solution is correct!
  - (Pretend that you are presenting this on a whiteboard to someone – you cannot run the code!)

- Purpose:
  - Great practice
  - Surprisingly difficult (and useful calibration on what's easy!)
  - Help us start thinking about how we can reason about code and build code that works as intended

Concise to-do list

Before next class:

1. Familiarize yourself with website, do readings
   - Lecture slides will be posted on web evening before class
2. Read syllabus and academic-integrity policy
3. Do Homework 0 (see web calendar), due by **10AM Wednesday**! (no late days on this time)
   - Use gradescope to submit pdf copy (scan or use your phone)
   - Gradescope accounts will be created for everyone later today
   - (send mail to cse331-staff with name, ID #, and UW Email address if not registered so we can add you to the gradescope course roster to turn in the assignment)