CSE 331
Software Design & Implementation

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Spring 2020

Lecture 1 – Introduction & Administrivia

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

Motivation

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 courses and in industry

Specifically, how to write code 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 the 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*

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%

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

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

Who: Course staff

- **Instructor**: Kevin Zatloukal (kevinz at cs)
  - 15 years in industry, 5th year teaching

- ≈15 great **TA**s
  - mix of veterans and new

- Office hours posted soon
  - (starting later this week)

Get to know us!

  - We're here to help you succeed

Who: Students

- Assuming you have mastered CSE142 and CSE143
- Hoping (but not assuming) have you taken 311
  - will connect to 311 material where it arises
- Assuming you are in your second year of CS courses
  - seniors may be bored

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

Unique Situation (for all of us)

- Much of the rest of this is **subject to change**
  - but we are learning as we go

- Personal issues may arise
  - let me know
  - we will make accommodations as much as possible

Staying in touch

- Ed message board (link on course web page)
  - should have received an invitation already
  - best place to ask questions

- Course staff: **`cse331-staff@cs.washington.edu`**
  - For things that don't make sense to post on message board

- Course email list: **`cse331a_sp20@u.washington.edu`**
  - Students already subscribed (your UW email address)
  - You must get announcements sent there
  - Fairly low traffic – one way (from staff to everyone)

Lectures

- Includes a pre-recorded video and a live session

- Each pre-recording posted 2 days before
  - please watch that portion **beforehand**

- Each live session will each be a little different
  - some lecture, Q&A, problems, work in small groups, etc.
  - link to recording in Canvas
  - slides posted on web site

Section

- Will be focused on **helping with homework**
  - held on day HW is released
  - get you get you started with the work to be done
  - they should be very useful

- Live via Zoom video
  - links on Canvas (see Zoom app)

- Aiming to have 10 sections with 16 students each
  - will split time schedule sections into two parts
  - details coming soon

Homework Assignments

- Roughly 1 assignment per week

- First 3 are paper assignments
  - submit these in Gradescope
  - should get an invite email before Tuesday
    - let me know if you don't

- Remaining 7 are coding assignments
  - generally due on Wednesday by 11pm
  - submit and tag your code in Gitlab
    - TAs will grade and get feedback to you

Homework Assignments

- Biggest misconception (?) about CSE331

  "Homework was programming projects that seemed disconnected from lecture"

- If you think so, you are making them harder!
  - approaching them as CSE143 homework won't work well
  - each HW designed to teach topics from prior lectures
  - seek out the connections by before typing

- (Tip: this is also true of exams / quizzes)

Late Policy: Written Assignments

- Allowed only in special situations
  - let us know 36 hours beforehand
  - will also make exceptions for emergencies

Late Policy: Coding Assignments

- Same special situations as written assignments

- And also:
  - Up to **4** times this quarter you can turn in a homework assignment **one** day late
  - Not accepted for credit after that.
  - Late days are 24-hour chunks

- Why?
  - keep you on schedule (real world has deadlines)
  - get feedback to you before next deadline

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
  - worst result otherwise is expulsion
- Violations are unfair to other students and yourself

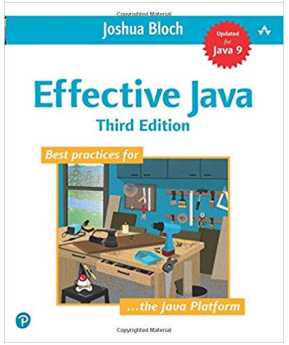
Quizzes

- Will have ≈5 quizzes during the quarter
  - 20-30 minutes each
  - probably multiple choice / short answer questions
  - may take place during the lecture period
    - make sure that time slot is available
  - details still TBD...

Books

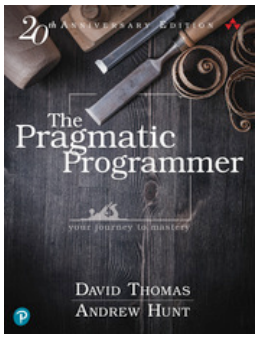
Required book

- *Effective Java* 3rd ed, Bloch (EJ)



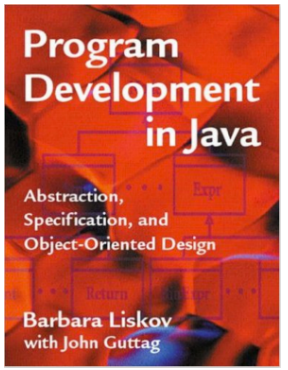
Optional book

- *Pragmatic Programmer*, new 20th anniversary (2nd) edition, Hunt & Thomas (PP)



Other 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



Books? In the 21st century?

- Why not just use Google, Stack Overflow, Reddit, Quora, …?
- Web-search good for
  - Finding the parameters of a Java API function
- (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
    - aim is to answer the question at the time when asked
  - "This incantation solved my problem"
    - give that to users without knowing how it works?

Readings

- Calendar will include book sections for you to read
  - EJ = required, PP = optional
- These are “real” books about software, approachable in 331
  - occasionally slight reach: accept the challenge
- Overlap only partially with lectures
  - books include lots of other useful information
- Readings are fair game for quizzes
  - want to make sure you do it

Exams

- No real exams

- Our final "exam"
  - demo your final HW solution to a TA
  - answer some questions about your experiences writing it

Grading

Approximate weighting (subject to change):

65%	Homework
25%	Quizzes
10%	Final “exam”

CSE 331 can be challenging

- Past experience tells us CSE 331 is **hard**
  - not my 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

- 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

- 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

Problems

A Problem

"Complete this method such that it returns the location of the largest value in the first **`n`** elements of the array **`arr`**."

```
int maxLoc(int[] arr, int n) {
    ...
}
```

Solution 1

```
int maxLoc(int[] arr, int n) {
  int maxIndex = 0;
  int maxValue = arr[0];
  for (int i = 1; i < n; i++) {
    if (arr[i] > maxValue) {
      maxIndex = i;
      maxValue = arr[i];
    }
  }
  return maxIndex;
}
```

Solution 2

```
int maxLoc(int[] arr, int n) {
  int maxIndex = -1;
  int maxValue = Integer.MIN_VALUE;
  for (int i = 0; i < n; i++) {
    if (arr[i] > maxValue) {
      maxIndex = i;
      maxValue = arr[i];
    }
  }
  return maxIndex;
}
```

A Problem

"Complete this method such that it returns the location of the largest value in the first **`n`** elements of the array **`arr`**."

```
int maxLoc(int[] arr, int n) {
    ...
}
```

What questions do you have about the *specification*?

- what if n = 0?
- what if n < 0?
- what if n > arr.length?
- what if there are two maximum elements?

A Problem

"Complete this method such that it returns the location of the largest value in the first **`n`** elements of the array **`arr`**."

```
int maxLoc(int[] arr, int n) {
    ...
}
```

Could we write a specification with only **one correct** solution?

- throw `IllegalArgumentException` if n <= 0
- throw `ArrayOutOfBoundsException` if n > arr.length
- return smallest index achieving maximum

Morals

- You can all write the code

- Writing the specification was harder than the code
  - multiple choices for the "right" specification
    - have to carefully think through corner cases
  - once the specification is chosen, code is straightforward
  - (both of those will be recurrent themes)

- Some math (e.g. "if n <= 0") often shows up in specifications
  - English ("if n is less or equal to than 0") is often worse

An exercise before next class

- Do HW0 (90 minutes max) before lecture on Wednesday
  - **write** an algorithm to rearrange array elements as described
  - **argue** in concise, convincing English that it is correct
    - don't just explain *what the code does!*
  - should run in O(n) time
    - (optional challenge: can you do it in a single pass?)
  - do not actually run your code!

- Start trying to **reason** about the code you write
  - this may be difficult... if so, remember that!
  - next, we will learn to use a set of tools that will make this easy

Before next class...

1. Familiarize yourself with website:

   http://courses.cs.washington.edu/courses/cse331/20sp/

   - read the syllabus
   - read the academic integrity policy
   - find the homework list
   - find the link to Canvas

2. Do HW0 before lecture on Wednesday!
   - limit this to 90 minutes
   - submit a PDF on Gradescope (invite coming today)
   - not graded