CSE 331
Software Design & Implementation

James Wilcox

Autumn 2021

Module Design & Style

The limits of scaling

Can't built arbitrarily large physical structures that work perfectly and indefinitely

- friction, gravity, wear-and-tear

Software has no such problems!

So what prevents arbitrarily large software?

… it's the difficulty of *understanding* it!

The force of friction is replaced by a force in software that creates **interdependence** ("coupling") between different parts of the code

- in particular, this force makes it hard to understand one part of the code without understanding many other parts

The limits of scaling

Can't built arbitrarily large physical structures that work perfectly and indefinitely

- friction, gravity, wear-and-tear

Software has no such problems!

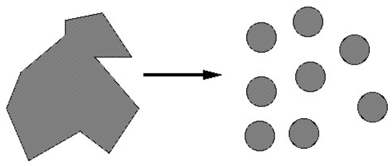
So what prevents arbitrarily large software?

… it's the difficulty of *understanding* it!

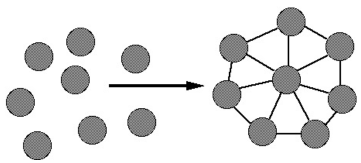
We make software easier to understand by breaking it into pieces that can be understood (and built) separately — using **modularity**

Many goals of modular software...

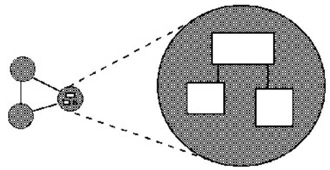
Decomposable – can be broken down into modules to reduce complexity and allow teamwork



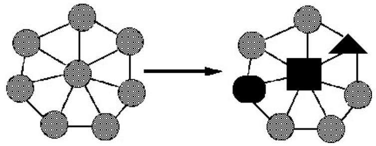
Composable – "Having divided to conquer, we must reunite to rule [M. Jackson]."



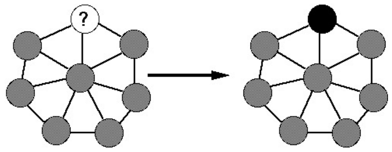
Understandable – one module can be examined, reasoned about, & developed in isolation



Continuity – a small change in the requirements should affect a small number of modules



Isolation – an error in one module should be as contained as possible



Most important design issues

Coupling – how much dependency there is between components

- want to understand each component without (much) understanding of the others

Cohesion – how well parts of a component fit and work together

- form something that is self-contained, independent, and with a single, well-defined purpose

Goals: *decrease* coupling, *increase* cohesion

Applies to modules and smaller units

– each method should do one thing well
– each module should provide a single abstraction

Cohesion

The common design objective, *separation of concerns*, suggests a module should represent a single concept

- a common kind of “concept” is an ADT

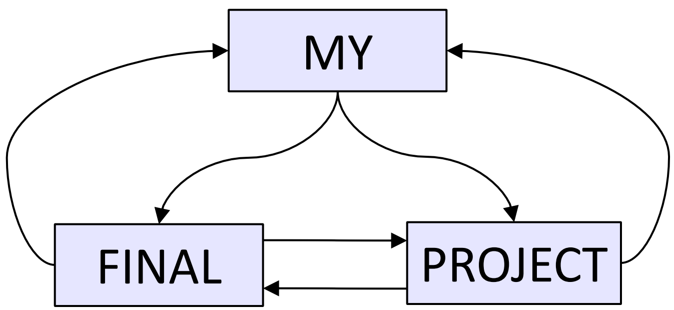
If a module implements more than one abstraction, consider breaking it into separate modules for each one

Coupling

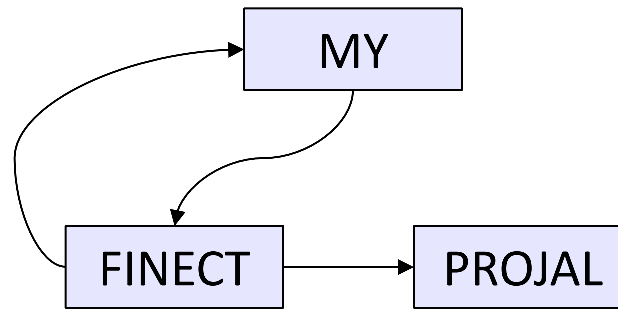
How are modules dependent on one another?

- statically (in the code)? dynamically (at run-time)? for us:
  - do we need to **understand** one to understand the other?
- ideally, split design into parts with little interdependency

An application



A poor decomposition (parts strongly coupled)



A better decomposition (parts weakly coupled)

The more coupled modules are, the more they need to be thought about all at the **same time** in order to be understood

Coupling leads to Spaghetti Code

- Coupling induces more and more coupling eventually turning into ”spaghetti code”

- Lacks all the properties of high quality code
  – hard to understand
  – hard to change
  – hard to make correct

- Can be necessary to **throw away** the code and start over

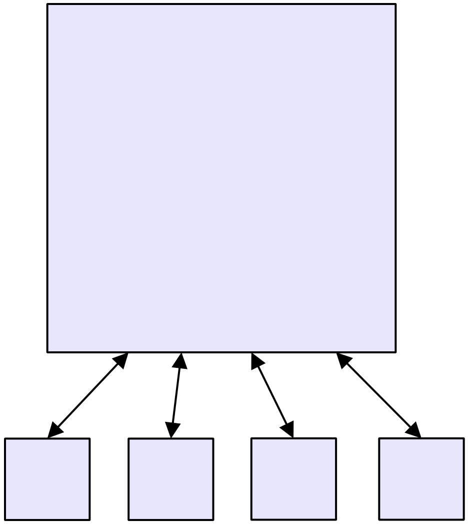
"God" classes

god class: hoards most of the data or functionality of a system

- depends on and is depended on by every other module
- poor cohesion – little thought about why all the elements are placed together
- reduces coupling but only by collapsing multiple modules into one (which replaces dependences between modules with dependences within a module)

A god class is an example of an *anti-pattern*

- a known **bad** way of doing things



DESIGN IN JAVA

Class design ideals

Cohesion and coupling, already discussed

Completeness: should every class present a complete interface?

- good advice for **public libraries**
- for other code, better to ***avoid unnecessary work***
  - can leave TODOs for what you want to add later
  - or have methods that
    throw RuntimeException("not yet implemented")

Consistency: in names, param/returns, ordering, and behavior

- (more later...)

But…

Don't include everything you can possibly think of

- if you include it, you're stuck with it forever
  (even if almost nobody ever uses it)

Tricky balancing act: include what's useful, but don't make things overly complicated

- you can always add it later if you really need it
- except for public libraries, better to wait if you can
  - less code is thrown away when you realize it's all wrong

Example: separate UI from rest

- Confine user interaction to a core set of “view” classes and isolate these from the classes that maintain the key system data
  - see Model-View-Controller (and HW9)
- Do not put print statements in your core classes
  - this locks your code into a text representation
  - makes it less useful if the client wants a GUI, a web app, etc.
- Instead, have your core classes return data that can be displayed by the view classes
  - which of the following is better?

```
public void printMyself()
public String toString()
```

Documenting a class

Keep internal and external documentation separate

External: `/** ... */` Javadoc for classes, interfaces, methods

- describes things that **clients** need to know about the class
- should be specific enough to exclude unacceptable implementations, but general enough to allow for all correct implementations
- includes all pre/postconditons, etc.

Internal: `//` comments inside method bodies

- describes details of how the code is implemented
- information for fellow developer working on this class
  - tricky parts of the code
  - loop and representation invariants
  - important decisions you made

Cohesion again…

Methods should do one thing well:

- compute a value but let client decide what to do with it
- don't print as a side effect of some other operation
- observe or mutate, don't do both

Having a method do multiple, not-necessarily-related things *limits future possible uses*

"Flag" variables are often a symptom of poor method cohesion

- often mean the method is doing multiple things

Method design

Effective Java (EJ) Tip: Design method signatures carefully

- avoid long parameter lists
- especially error-prone if parameters are all the same type
- avoid methods that take lots of Boolean “flag” parameters

Which of these has a bug?

- **`memset(ptr, size, 0);`**
- **`memset(ptr, 0, size);`**

EJ Tip: Use overloading judiciously

Can be useful, but avoid overloading with same number of parameters, and think about whether methods really are related

Consistency

A class or interface should have consistent names, parameters/returns, ordering, and behavior

Use similar naming; accept parameters in the same order

Counterexamples:

```
setFirst(int index, String value)
setLast(String value, int index)
```

`Date/GregorianCalendar` use 0-based months

`String` methods: **`equalsIgnoreCase`**, **`compareToIgnoreCase`**;
but **`regionMatches(boolean ignoreCase)`**

`String.length()`, `array.length`, `collection.size()`

Constructor design

Constructors should have all the arguments necessary to initialize the object's state – no more, no less

Object should be completely initialized after constructor is done
(i.e., the rep invariant should hold)

Shouldn't need to call other methods to “finish” initialization
- sometimes tempting but an easy way to cause bugs
- complex initialization can be done using a “builder” pattern
  - (more on this in later in the course)

Field design

A variable should be made into a field if and only if:

- it has a value that retains meaning throughout the object's life
- its state must persist past the end of any one public method

All other variables can and should be local to the methods

- fields should not be used to avoid parameter passing
- not every constructor parameter needs to be a field

Exception to the rule: when we don’t control the interface

- example: **`Thread.run`**

Choosing types – some hints

Numbers: favor **`int`** and **`long`** for most numeric computations

EJ Tip: avoid **`float`** / **`double`** if exact answers are required

Classic example: money (round-off is bad here)

Strings are often used since much data is read as text,
but keeping numbers as strings is a bad idea.

Enums make code more readable

Consider use of **`enums`**, even with only two values – which of the following is better?

```
oven.setTemp(97, true);

oven.setTemp(97, Temperature.CELSIUS);
```

Last thoughts (for now)

- Always remember your reader
  - Who are they?
    - Clients of your code
    - Other programmers working with the code
      - (including yourself in 6 weeks/months/years)
  - What do they need to know?
    - How to use it (clients)
    - How it works, but more important, *why* it was done this way (implementers)

- Think about mistakes that might be made (by you or others)
  - if you have enough clients, someone *will* make that mistake
  - design to prevent or at least catch those mistakes
  - pay special attention to bugs that will be hard to detect

READABILITY

Naming

- Choosing good names is important for **readability**

- With well chosen names, code can be “self-documenting”
  - no need to include comments with explanation
  - code explains itself

Bad names

`flag`, `status`, `compute`, `check`, `pointer`, names starting with **`my`**…

- convey very little useful information!
- (**`count`** is okay if meaning is *very* clear from context)

Describe what is being counted, what the "flag" indicates, etc.

`numStudents`, **`courseIsFull`**, … (fields)
`calculatePayroll`, **`validateWebForm`**, … (methods)

But short names in local contexts are good:

Good:
```
for (i = 0; i < size; i++) items[i]=0;
```

Bad:
```
for (theLoopCounter =  0;
     theLoopCounter < theCollectionSize;
     theLoopCounter++)
  theCollectionItems[theLoopCounter]=0;
```

Good names

EJ Tip: Adhere to generally accepted naming conventions

- Class names: generally nouns
  - start with a capital letter (unlike fields & variables)
  - use CamelCaps not Underscore_Name
- Interface names often –able/-ible adjectives:

  `Iterable`, **`Comparable`**, …
- Method names: noun or verb phrases
  - verbs+noun for observers: **`getX`**, **`isX`**, **`hasX`**
  - verbs for mutators: **`move`**, **`append`**
  - verbs+noun for mutators: **`setX`**
  - choose affirmative, positive names over negative ones

    `isSafe` not **`isUnsafe`**

    `isEmpty` not **`hasNoElements`**

Method Bodies

- Write method bodies to make them **easy to read**
  - make life easier for your code reviewer
  - (make life easier for yourself when you come back later)
- Break code into nicely sized “paragraphs”
  - i.e., consecutive lines of code with no blank lines
- Put a comment at the top of the paragraph
  - (unless the code is just as readable as the comment)
  - use full sentences and correct English

Method Bodies Example 1

This code computes “edit distance” (see CSE 421)

Even if you know what it does, it’s hard to follow.

```
for (int i = 0; i < m; i++)
  A[i][0] = i;
for (int j = 0; j < n; j++)
  A[0][j] = j;
for (int i = 1; i < m; i++)
  for (int j = 1; j < n; j++)
    A[i][j] = min(A[i-1][j] + 1, A[i][j-1] + 1,
           (s[i-1] == t[j-1]) ? A[i-1][j-1] : infinity);
return A[m-1][n-1];
```

Method Bodies Example 1

Break into smaller paragraphs and explain what each does.

```
// Fill in match costs for empty prefixes.
for (int i = 0; i < m; i++)
  A[i][0] = i;
for (int j = 0; j < n; j++)
  A[0][j] = j;

// Find the match costs between every pair of prefixes.
for (int i = 1; i < m; i++)
  for (int j = 1; j < n; j++)
    A[i][j] = min(A[i-1][j] + 1, A[i][j-1] + 1,
        (s[i-1] == t[j-1]) ? A[i-1][j-1] : infinity);

// Return the least cost to match the whole strings.
return A[m-1][n-1];
```

Method Bodies Example 1

Break into smaller paragraphs and comment each one.

```
// Fill in match costs for empty prefixes.
for (int i = 0; i < m; i++)
  A[i][0] = i;
for (int j = 0; j < n; j++)
  A[0][j] = j;

// Find the match costs between every pair of prefixes.
for (int i = 1; i < m; i++) {
  for (int j = 1; j < n; j++) {
    // Least cost way to match s[0:i] to t[0:j] is lowest
    // of three options: (1) ...
    A[i][j] = min(A[i-1][j] + 1, A[i][j-1] + 1,
        (s[i-1] == t[j-1]) ? A[i-1][j-1] : infinity);
```

Method Bodies Example 2

This comment is unnecessary (even insulting):

```
// close the reader
reader.close()
```

😑

A comment should add something. This adds a little:

```
// clean up
reader.close()
```

But really, the code is fine by itself:

```
reader.close()
```

Method Bodies Example 3

Don't necessarily need to comment each loop.

This has one comment that describes two `for` loops.

```
// Create directed edges between each pair of nodes.
for (Node start : nodes) {
  for (Node end : nodes) {
    if (!start.equals(end)) {
      graph.addEdge(start, end);
    }
  }
}
```

This is a case where writing the invariant in detail makes it *harder* to understand. (Generally true for "do X for each Y" loops.)