Principles of Software Construction: Objects, Design, and Concurrency

Refactoring & Anti-patterns

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Administrivia

Submit the correct link on Canvas.

- If you notice you submitted the wrong link, send us a DM and then resubmit the right link. We won't take late days if you submitted the wrong link on time.

HW4 will be released today, due either Tuesday or Wednesday depending on what the TAs need for grading.

- …but promise me you'll start HW5 early, it's much longer.

Midterm Review

- Thoughts/Opinions?

Some reflections:

- Is OO *required* for encapsulation?
- CI can run tests, but tests can only show incorrect code.
- Drawing control-flow diagrams for coverage helps
- Interaction diagrams: think about the actual code.
  - E.g., you can't skip a class when returning a value.

Today: Patterns, anti-patterns, and refactoring

- Patterns: using and choosing between them.
- Antipatterns and refactoring
  - Sidequest on equals, toString, typecasting
- Several other useful patterns

Refactoring: Any functionality-preserving rewrite or restructure.

Refactoring

- Any functionality-preserving restructuring
  - That is, the semantics of the program do not change, but the syntax does
  - Why might this be useful?

Refactoring

- Any functionality-preserving restructuring
  - That is, the semantics of the program do not change, but the syntax does
  - Why might this be useful?
    - What was the problem again? How would you fix it?

```
class Player {
    Board board;
    /* in code somewhere… */ this.getSquare(n);
    Square getSquare(String name) { // named monopoly squares
        for (Square s: board.getSquares())
            if (s.getName().equals(name))
                return s;
        return null;
}}
```


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Refactoring and Anti-Patterns

- Often, all the functionality is correct, but the organization is bad
  - High coupling, high redundancy, poor cohesion, god classes, …
- Refactoring is the principal tool to improve structure
  - Automated refactorings even guarantee correctness
  - A series of refactorings is usually enough to introduce design patterns

Refactoring and Anti-Patterns

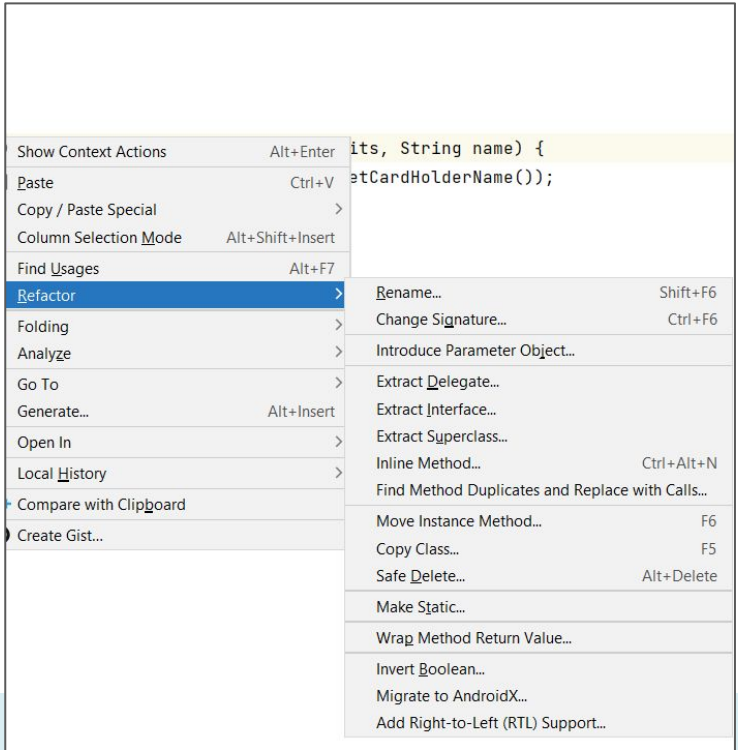
- Often, all the functionality is correct, but the organization is bad
  - High coupling, high redundancy, poor cohesion, god classes, …
- Refactoring is the principal tool to improve structure
  - Automated refactorings even guarantee correctness
  - A series of refactorings is usually enough to introduce design patterns
- HW4 involves analyzing such a system and making primarily refactoring changes
  - “primarily”, because sometimes you do need to alter things slightly.

Refactoring: IDE Support

- Many IDEs offer *automated* refactoring
  - Have you used any?

Refactoring: IDE Support

- Many IDEs offer *automated* refactoring
  - Rename class, method, variable
  - Extract method/inline method
  - Extract interface
  - Move method (up, down, laterally)
  - Replace duplicates



Anti-patterns

Anti-patterns are *common* forms of bad/no-design

- Can you think of examples?

Anti-patterns

- We have talked a fair bit about bad design heuristics
  - High coupling, low cohesion, law of demeter, …
- You will see a much larger vocabulary of related issues
  - Commonly called code/design “smells”
  - Worthwhile reads:
    - **A short overview: https://refactoring.guru/refactoring/smells**
    - Wikipedia: https://en.wikipedia.org/wiki/Anti-pattern#Software_engineering
    - Book on the topic (no required reading): Refactoring for Software Design Smells: Managing Technical Debt, Suryanarayana, Samarthyam and Sharma
      - S.O. summary: https://stackoverflow.com/a/27567960

Anti-patterns

Anti-patterns are *common* forms of bad/no-design

- Where do they come from?

Anti-patterns

Anti-patterns are *common* forms of bad/no-design

- Where do they come from?
- Two common causes:
  - Design issues that manifest as bad/unmaintainable code
  - Poorly written/evolved code that leads to bad design

Let’s See a Few Examples (in VSCode)

- Frogger
  - As a system grows, refactoring can help preserve cohesion
  - Refactoring: move method
- PersonalRecords
  - Introducing new constructs in the face of growing complexity
  - Refactorings: extract methods, create class, rename

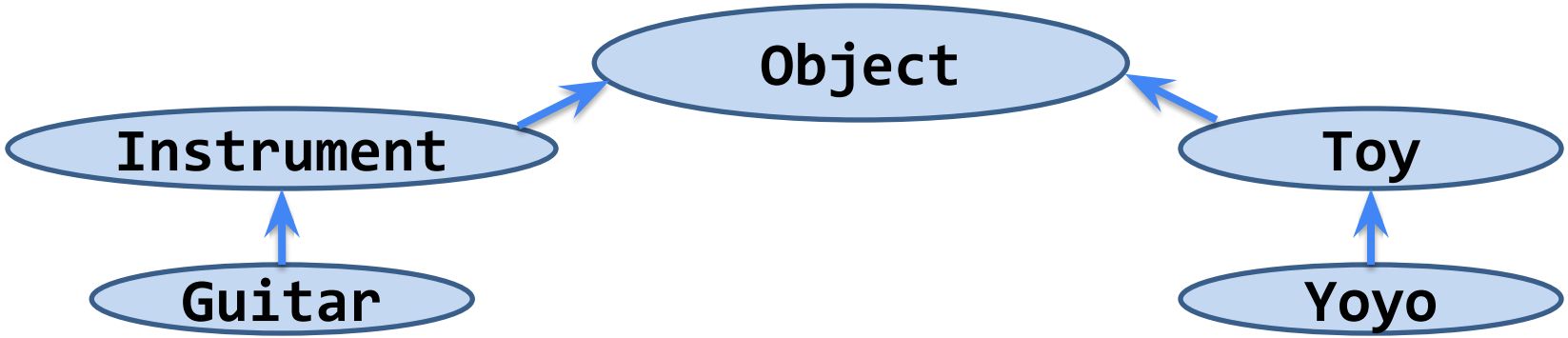
While we’re on the subject of objects and equality.

The Java class hierarchy

- The root is Object (all non-primitives are objects)
- All classes except Object have one parent class
  - Specified with an `extends` clause

    ```
    class Guitar extends Instrument { ... }
    ```

  - If `extends` clause omitted, defaults to `Object`
- A class is an instance of all its superclasses



Methods common to all objects

- How do collections know how to test objects for **equality**?
  - Why did this work:

```
for(Person p: this.records) {
   if(p.equals(newP)) {
    …
```

- How do they know how to **hash** and **print** them?
- The relevant methods are all present on `Object`
  - `equals` - returns true if the two objects are “equal”
  - `hashCode` - returns an `int` that must be equal for equal objects, and is likely to differ on unequal objects
  - `toString` - returns a printable string representation (default is gross: Type and hashcode

Comparing values

`x == y` compares x and y "directly":

primitive values: returns true if x and y **have the same value**

objects references: returns true if x and y **refer to same object**

`x.equals(y)` typically compares the ***values*** *of the objects referred to* by x and y*

* Assuming it makes sense to do so for the objects in question

True or false?

```
int i = 5;
int j = 5;
System.out.println(i == j);
---------------------------
```

True or false?

```
int i = 5;
int j = 5;
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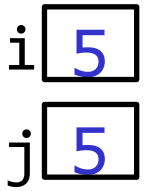
----------------------------
```

true



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True or false?

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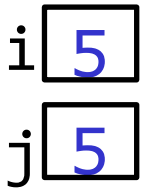


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String s = "foo";
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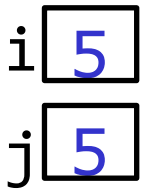


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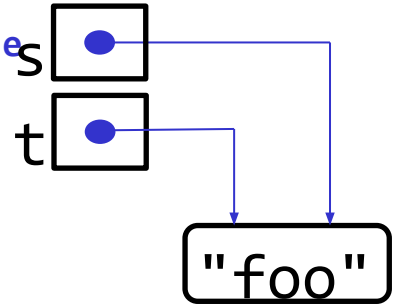

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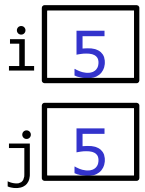


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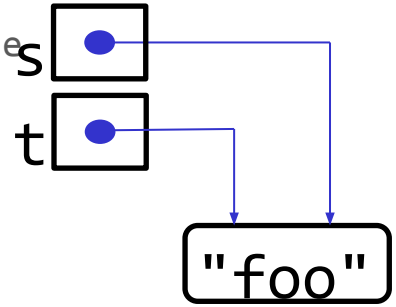


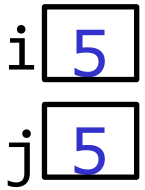

```
String u = "iPhone";
String v = u.toLowerCase();
String w = "iphone";
System.out.println(v == w);
---------------------------
```

True or false?

```
int i = 5;
int j = 5;
System.out.println(i == j);
```

---

true

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```

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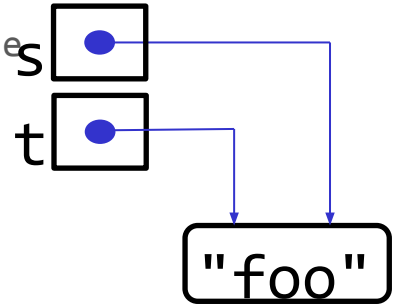
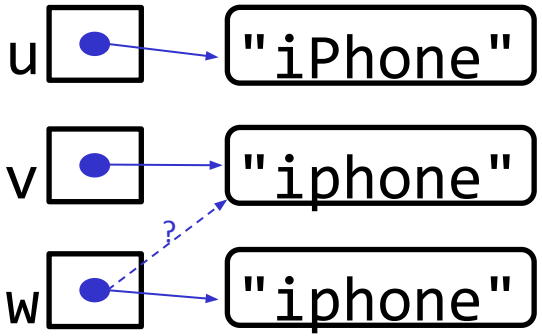



```
String u = "iPhone";
String v = u.toLowerCase();
String w = "iphone";
System.out.println(v == w);
```

---

false (in practice)



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The moral

- **Always use `.equals` to compare object refs!**
  - (Except for enums, which are special)
  - **The == operator can fail silently and unpredictably when applied to object references**
  - Same goes for the `!=` operator

Overriding `Object` implementations

- No need to override `equals` and `hashCode` if you want identity semantics
  - When in doubt, don't override them
  - It's easy to get it wrong
  - ‘record’ in Java gives you equals for free, neato!
- Nearly always override `toString`
  - `println` invokes it automatically
  - Why settle for ugly?

Overriding `toString` is easy and beneficial

```
final class PhoneNumber {
    private final short areaCode;
    private final short prefix;
    private final short lineNumber;
      ...
    @Override public String toString() {
        return String.format("(%03d) %03d-%04d",
            areaCode, prefix, lineNumber);
    }
}

Number jenny = ...;
System.out.println(jenny);
```

Prints: `(707) 867-5309`

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Typescript notes.

There is also a `toString`.

Equality is a funny thing: == (equality) vs === (strict equality)

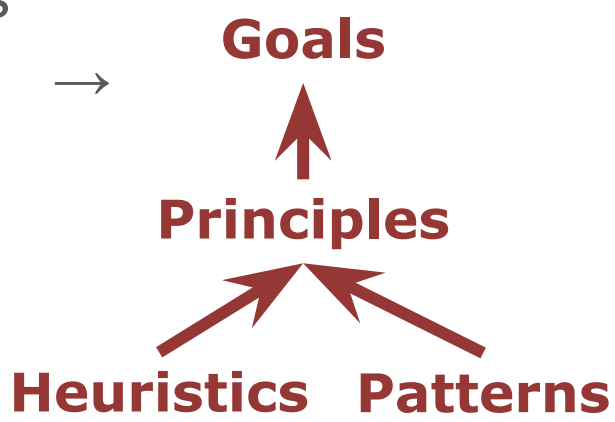
- Typescript requires that you compare things that are the same type, so this distinction is SLIGHTLY less important.
- Javascript lets you do `10 == '10' // true`

Equivalent behavior for, say, presence of an object in a Collection, is a bit trickier (no off-the-shelf equivalent of `equals`, but many ways to get it).

Back to anti-patterns/refactoring

Anti-patterns

- Kind of like the evil twins of design patterns
- Similar to the design hierarchy on the right → we want to think of both:
  - The design principles they run against
  - The low-level “heuristics” to detect them in code
    - Including many “code smells”
- As before, a pattern language helps
  - Many of these can be (re)paired with a correct pattern



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Anti-patterns

What defeats good principles?

- Bad encapsulation violates _____
- Bad modularization violates _____
- Bad abstraction violates _____
- Bad inheritance/hierarchy violates _____

Anti-patterns

What defeats good principles?

- Bad encapsulation violates information hiding
- Bad modularization violates coupling
- Bad abstraction violates cohesion
- Bad inheritance/hierarchy violates representational gap

Anti-patterns

What heuristics give it away?

- Bad encapsulation, violates information hiding
  - public fields should be private; interface leaks implementation details; lack of interface
- Bad modularization, violates coupling
  - related methods in different places, or vice versa; very large interface; “god” class
- Bad abstraction, violates cohesion
  - Not exposing relevant functionality; near-identical classes; too many responsibilities
- Bad inheritance/hierarchy
  - Violating behavioral subtyping; unnecessary inheritance; very large hierarchies (too wide or too deep)

Code Smells

Not necessarily bad, but worthwhile indicators to check. If problematic, these often point to design problems

- Long methods, large classes. Suggests bad abstraction
  - Tend to evolve over time; requires restructuring
- Inheritance despite low coupling (“refused bequest”)
  - Replace with delegation, or rebalance hierarchy
- ‘instanceof’ (or ‘switch’) instead of polymorphism
- Overly similar classes, hierarchies
- Any change requires lots of edits
  - High coupling across classes (“shotgun surgery”), or heavily entangled implementation (intra-class)

Code Smells

More code smells:

- Excessive, unused hierarchies
- Operations posing as classes
- Data classes
  - Tricky: not always bad, but ideally distinguish from regular classes (e.g., ‘record’), and assign responsibilities if any exist (think: FlashCard did equality checking)
- Heavy usage of one class’ data from another (“feature envy”, “inappropriate intimacy”; poor coupling)
- Long chains of calls needed to do anything (law of demeter)
- A class that only delegates work

Anti-patterns

- You can detect them from either side
  - Pick a design principle, look for violations
  - Identify “weird” code and figure out the design flaw

Anti-patterns

- You can detect them from either side
  - Pick a design principle, look for violations
  - Identify “weird” code and figure out the design flaw
- All fairly easy to spot on their own
  - But in HW4, there are multiple, tangled up
    - We actually provide way more guidance than you’ll get in the wild!
  - How do you approach that?

Refactoring and Anti-patterns

Identifying multiple design problems

- Make a list
  - Read the code, record anything that stands out
    - Pay attention to class names and their (apparent) interfaces
    - Make note of repetitive code (esp. across methods)
  - Draw a diagram, using a tool or by hand
    - Spot duplication, (lack of) interfaces, strange inheritance
  - This takes **practice**
- Don't solve every problem
  - Many issues are orthogonal
    - Or, at least, you can improve things somewhat
  - When issues intersect, prioritize fixing **interfaces**

Refactoring

So where is “refactoring” in all this?

- It’s what comes next.
- Most design issues can be resolved with one or more functionality-preserving transformation(s)
  - Too many parameters? Merge relevant ones into object and/or replace with method calls.
  - Two near-identical classes? Find the common interface
    - Then merge their signatures using renamings, parameterization
    - Then, delete one if useless, or extract a shared super-class, or compose both with shared object

More useful patterns! Remember that long parameter list?

Fluent APIs / Cascade Pattern

Setting up Complex Objects

Long constructors, lots of optional parameters, long lists of statements

```
Option find = OptionBuilder
    .withArgName("file")
    .hasArg()
    .withDescription("search..." )
    .create("find");
```

```
client.getItem('user-table')
    .setHashKey('userId', 'userA')
    .setRangeKey('column', '@')
    .execute()
    .then(function(data) {
        ...
     })
```

Liquid APIs

Each method changes state,
then returns `this`

(Immutable version:
Return modified copy)

```
class OptBuilder {
    private String argName = "";
    private boolean hasArg = false;
    ...
    OptBuilder withArgName(String n) {
        this.argName = n;
        return this;
    }
    OptBuilder hasArg() {
        this.hasArg = true;
        return this;
    }
    ...
    Option create() {
        return new Option(argName,
            hasArgs, ...)
    }
}
```

Python: Named parameters

```
parser = argparse.ArgumentParser(description='Process some integers.')
parser.add_argument('integers', metavar='N', type=int, nargs='+',
                    help='an integer for the accumulator')
parser.add_argument('--sum', dest='accumulate', action='store_const',
                    const=sum, default=max,
                     help='sum the integers (default: find the max)')
```

JavaScript: JSON Objects

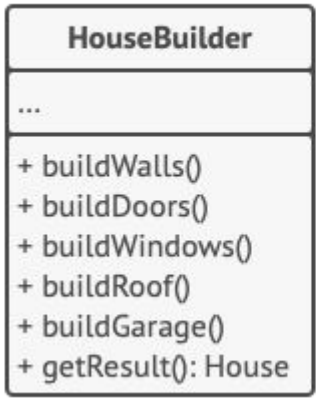
```
var argv = require('yargs/yargs')(process.argv.slice(2))
  .option('size', {
    alias: 's',
    describe: 'choose a size',
    choices: ['xs', 's', 'm', 'l', 'xl']
  })
   .argv
```

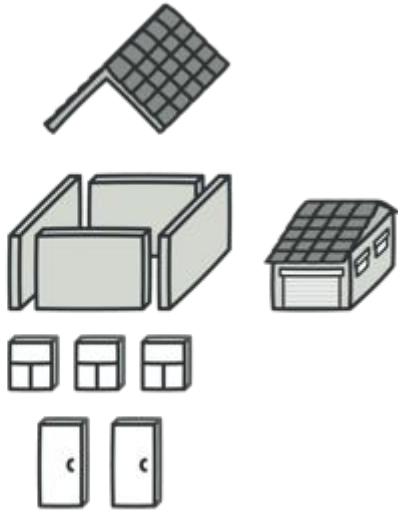
Notice the combination of cascading and complex JSON parameters

Under the Hood: Builder Pattern

When creating many variations of a complex object:

- Assign assembling work to a Builder object
  - When cascading, the builder returns itself, modified on every update
  - Offers a method that generates the resulting object
- Direct clients to *only* use the Builder
  - E.g., hide the constructor





https://refactoring.guru/design-patterns/builder

Fluent APIs: Discussion and Tradeoffs

Problem: Complex initialization and configuration

Advantages:

- Fairly readable code
- Can check individual arguments
- Avoid untyped complex arguments

Disadvantages:

- Runtime error checking of constraints and mandatory arguments
- Extra complexity in implementation
- Not always obvious how to terminate
- Possibly harder to debug

Iterator Pattern & Streams

(what's up with `for(Person p : this.records)`?)

Traversing a collection

- Since Java 1.0:

```
Vector arguments = …;
for (int i = 0; i < arguments.size(); ++i) {
  System.out.println(arguments.get(i));
}
```

- Java 1.5: enhanced for loop

```
List<String> arguments = …;
for (String s : arguments) {
  System.out.println(s);
}
```

- Works for every implementation of `Iterable`

```
public interface Iterable<E> {
  public Iterator<E> iterator();
}
public interface Iterator<E> {
  boolean hasNext();
  E next();
  void remove();
```

- In JavaScript (ES6)

```
let arguments = …
for (const s of arguments) {
  console.log(s)
}
```

- Works for every implementation with a “magic” function `[Symbol.iterator]` providing an iterator

```
interface Iterator<T> {
  next(value?: any): IteratorResult<T>;
  return?(value?: any): IteratorResult<T>;
  throw?(e?: any): IteratorResult<T>;
}
interface IteratorReturnResult<TReturn> {
  done: true;
  value: TReturn;
}
```

The Iterator Idea

Iterate over elements in arbitrary data structures (lists, sets, trees) without having to know internals

Typical interface:

```
interface Iterator<E> {
  boolean hasNext();
  E next();
}
```

(in Java also remove)

Using an iterator

Can be used explicitly

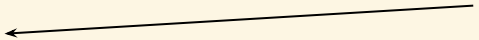
```
List<String> arguments = …;
for (Iterator<String> it = arguments.iterator(); it.hasNext();  ) {
  String s = it.next();
  System.out.println(s);
}
```

Often used with magic syntax:

```
for (String s : arguments)
for (const s of arguments)
```

Java: Getting an Iterator

```
public interface Collection<E> extends Iterable<E> {
  boolean     add(E e);
  boolean     addAll(Collection<? extends E> c);
  boolean     remove(Object e);
  boolean     removeAll(Collection<?> c);
  boolean     retainAll(Collection<?> c);
  boolean     contains(Object e);
  boolean     containsAll(Collection<?> c);
  void        clear();
  int         size();
  boolean     isEmpty();
  Iterator<E> iterator();
  Object[]    toArray()
  <T> T[]     toArray(T[] a);
  …
}
```



Defines an interface for creating an Iterator,
but allows Collection implementation to decide which Iterator to create.

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Iterators for everything

```
public class Pair<E> {
  private final E first, second;
  public Pair(E f, E s) { first = f; second = s; }









}
```

```
Pair<String> pair = new Pair<String>("foo", "bar");
for (String s : pair) { … }
```

An Iterator implementation for Pairs

```
public class Pair<E> implements Iterable<E> {
  private final E first, second;
  public Pair(E f, E s) { first = f; second = s; }
  public Iterator<E> iterator() {
    return new PairIterator();
  }
  private class PairIterator implements Iterator<E> {
    private boolean seenFirst = false, seenSecond = false;
    public  boolean hasNext() { return !seenSecond; }
    public  E next() {
      if (!seenFirst)  { seenFirst  = true; return first;  }
      if (!seenSecond) { seenSecond = true; return second; }
      throw new NoSuchElementException();
    }
    public void remove() {
      throw new UnsupportedOperationException();
    }
  }
}
```

```
Pair<String> pair = new Pair<String>("foo", "bar");
for (String s : pair) { … }
```

Iterator design pattern

- Problem: Clients need uniform strategy to access all elements in a container, independent of the container type
  - Order is unspecified, but access every element once
- Solution: A strategy pattern for iteration
- Consequences:
  - Hides internal implementation of underlying container
  - Easy to change container type
  - Facilitates communication between parts of the program

Streams

Stream ~ Iterator – a sequence of objects

- Typically provide operations to produce new stream from old stream (map, flatMap, filter) and operations on all elements (fold, sum) – using higher-order functions/strategy
  - Often provide efficient/parallel implementations (subtype polymorphism)
- Built-in in Java since Java 8; basics in Node libraries in JavaScript

```java
List<String>results = stream.map(Object::toString)
                .filter(s -> pattern.matcher(s).matches())
                .collect(Collectors.toList());
```

```java
int sum = numbers.parallelStream().reduce(0, Integer::sum);
```

```javascript
for (let [odd, even] in numbers.split(n => n % 2, n => !(n % 2)).zip()) {
    console.log(`odd = ${odd}, even = ${even}`);  // [1, 2], [3, 4], ...
 }
```

```javascript
Stream(people).filter({age: 23}).flatMap("children").map("firstName")
   .distinct().filter(/a.*/i).join(", ");
```

Summary

- Practice applying design patterns, recognizing anti-patterns
  - Create scenarios and try to write code
  - Find examples in public projects
  - Use this time to gain experience
  - Read lots of code, think about alternatives, like in HW4
  - Learn a vocabulary of anti-patterns