Principles of Software Construction: Objects, Design, and Concurrency

API Design, Part I: Process and Naming

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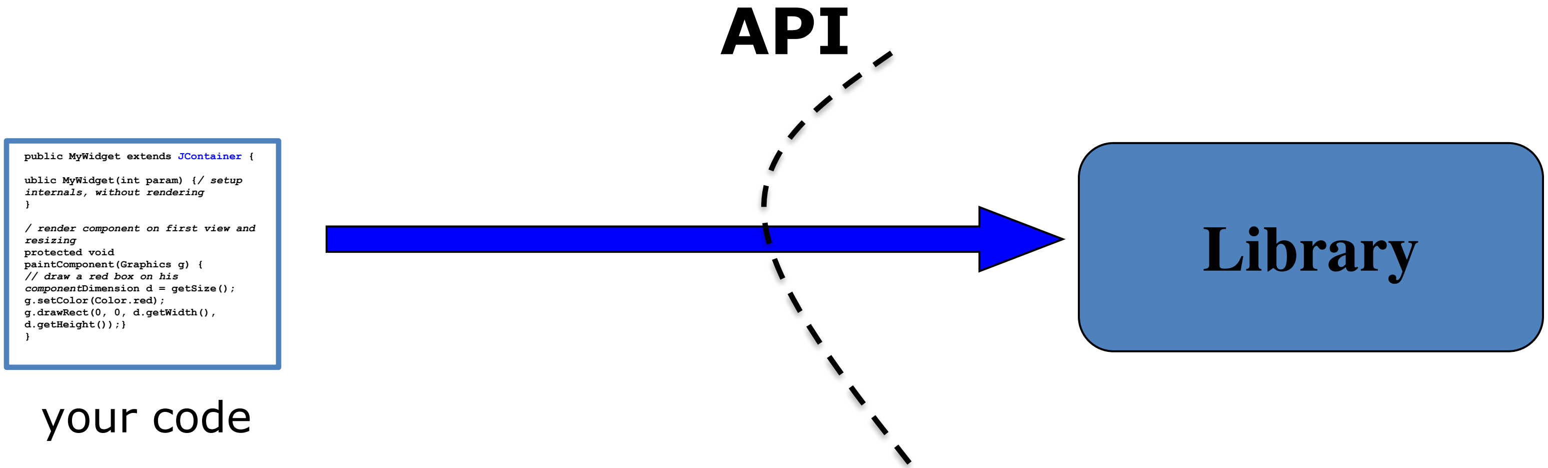
Administrivia

- Homework 4c due next Thursday
- Reading assignment due next Tuesday
  - Effective Java, Items 6, 7, and 63

Review: libraries, frameworks both define APIs

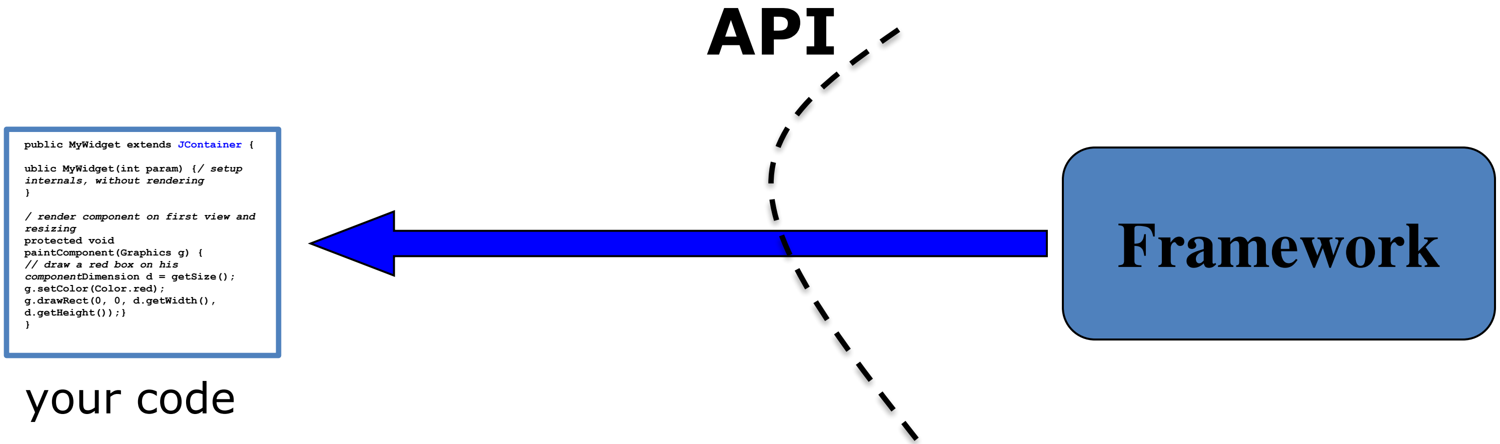


```
public MyWidget extends JContainer {

ublic MyWidget(int param) {/ setup
internals, without rendering
}

/ render component on first view and
resizing
protected void
paintComponent(Graphics g) {
// draw a red box on his
componentDimension d = getSize();
g.setColor(Color.red);
g.drawRect(0, 0, d.getWidth(),
d.getHeight());}
}
```

your code



```
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your code

The next two lectures: API design

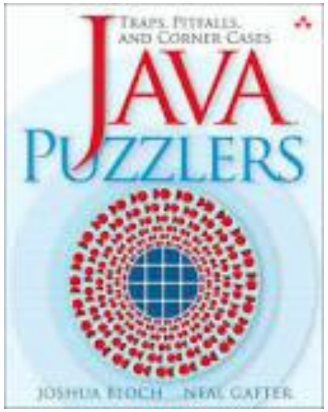
- An API design process
- The key design principle: information hiding
- Concrete advice for user-centered design

Based heavily on "How to Design a Good API and Why it Matters" by Josh Bloch.

“Time for Change” (2002)

If you pay $2.00 for a gasket that costs $1.10, how much change do you get?

```
public class Change {
    public static void main(String args[]) {
        System.out.println(2.00 - 1.10);
    }
}
```



What does it print?

```
public class Change {
    public static void main(String args[]) {
        System.out.println(2.00 - 1.10);
    }
}
```

(a) `0.9`
(b) `0.90`
(c) It varies
(d) None of the above

What does it print?

(a) `0.9`

(b) `0.90`

(c) It varies

(d) None of the above: `0.8999999999999999`

Decimal values can't be represented exactly by `float` or `double`

Another look

```
public class Change {
    public static void main(String args[]) {
        System.out.println(2.00 - 1.10);
    }
}
```

How do you fix it?

```
// You could fix it this way...
import java.math.BigDecimal;
public class Change {
    public static void main(String args[]) {
        System.out.println(
            new BigDecimal("2.00").subtract(
                new BigDecimal("1.10")));
    }
}
```

Prints 0.90

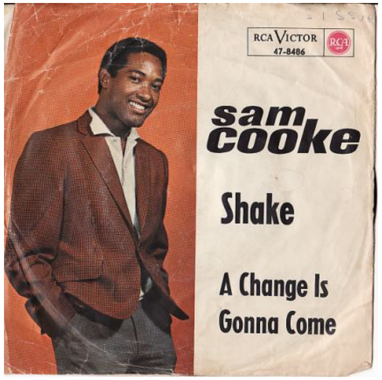
```
// ...or you could fix it this way
public class Change {
    public static void main(String args[]) {
        System.out.println(200 - 110);
    }
}
```

Prints 90

The moral

- Avoid `float` and `double` where exact answers are required
  - For example, when dealing with money
- Use `BigDecimal` or `long` instead

2. “A Change is Gonna Come”



If you pay $2.00 for a gasket that costs $1.10, how much change do you get?

```
import java.math.BigDecimal;

public class Change {
    public static void main(String args[]) {
        BigDecimal payment = new BigDecimal(2.00);
        BigDecimal cost = new BigDecimal(1.10);
        System.out.println(payment.subtract(cost));
    }
}
```

What does it print?

(a) `0.9`
(b) `0.90`
(c) `0.8999999999999999`
(d) None of the above

```
import java.math.BigDecimal;

public class Change {
    public static void main(String args[]) {
        BigDecimal payment = new BigDecimal(2.00);
        BigDecimal cost = new BigDecimal(1.10);
        System.out.println(payment.subtract(cost));
    }
}
```

What does it print?

(a) `0.9`

(b) `0.90`

(c) `0.8999999999999999`

(d) None of the above:

`0.899999999999999911182158029987476766109466552734375`

We used the wrong `BigDecimal` constructor

What’s going on here?

The spec says:

`public BigDecimal(double val)`

Translates a double into a BigDecimal which is the exact decimal representation of the double's binary floating-point value.

```
import java.math.BigDecimal;

public class Change {
    public static void main(String args[]) {
        BigDecimal payment = new BigDecimal(2.00);
        BigDecimal cost = new BigDecimal(1.10);
        System.out.println(payment.subtract(cost));
    }
}
```

How do you fix it?

Prints `0.90`

```
import java.math.BigDecimal;

public class Change {
    public static void main(String args[]) {
        BigDecimal payment = new BigDecimal("2.00");
        BigDecimal cost = new BigDecimal("1.10");
        System.out.println(payment.subtract(cost));
    }
}
```

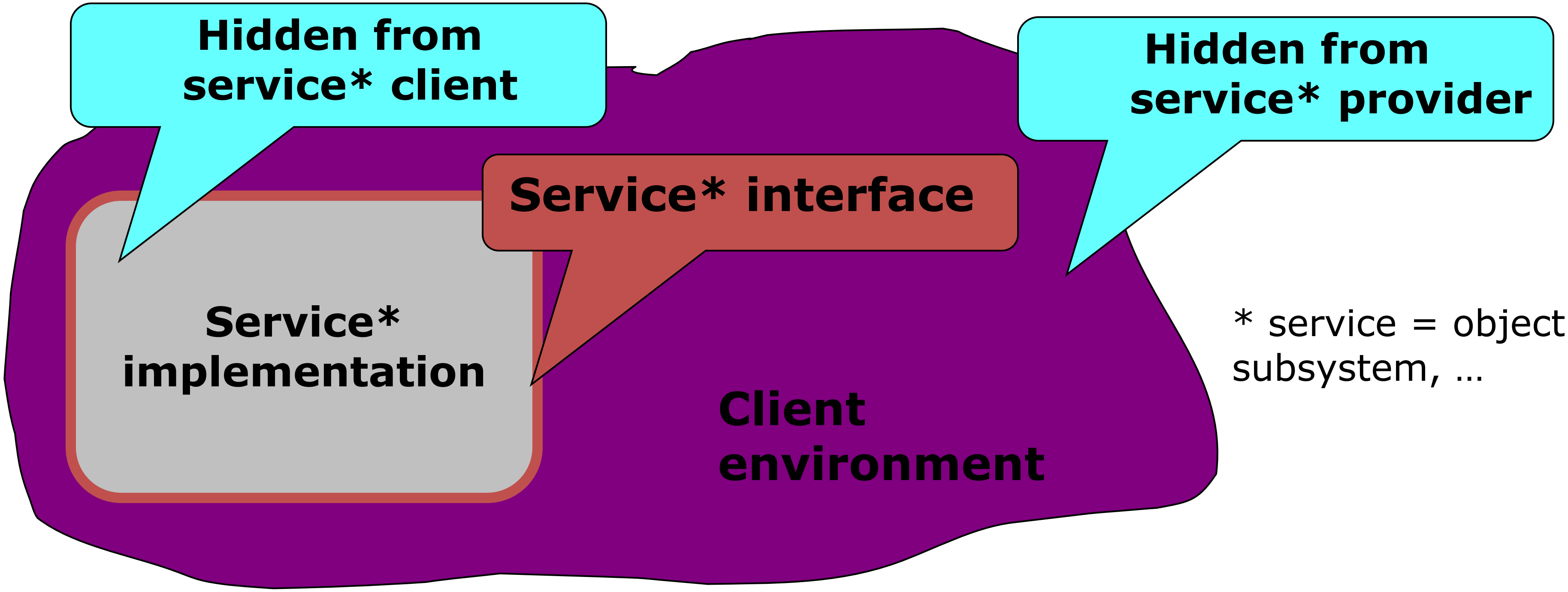
The moral

- Use `new BigDecimal(String)`,
  not `new BigDecimal(double)`
- `BigDecimal.valueOf(double)` is better, but not perfect
  - Use it for non-constant values.
  - Uses canonical string representation to construct decimal
- For API designers
  - Make it easy to do the commonly correct thing
  - Make it hard to misuse
  - Make it possible to do exotic things

Fundamental Design Principle for Change:

Information Hiding

- Expose as few implementation detail as necessary
- Allows implementation to be changed at a later date



* service = object, subsystem, …

Why create a public API?

Good APIs can be a great asset!

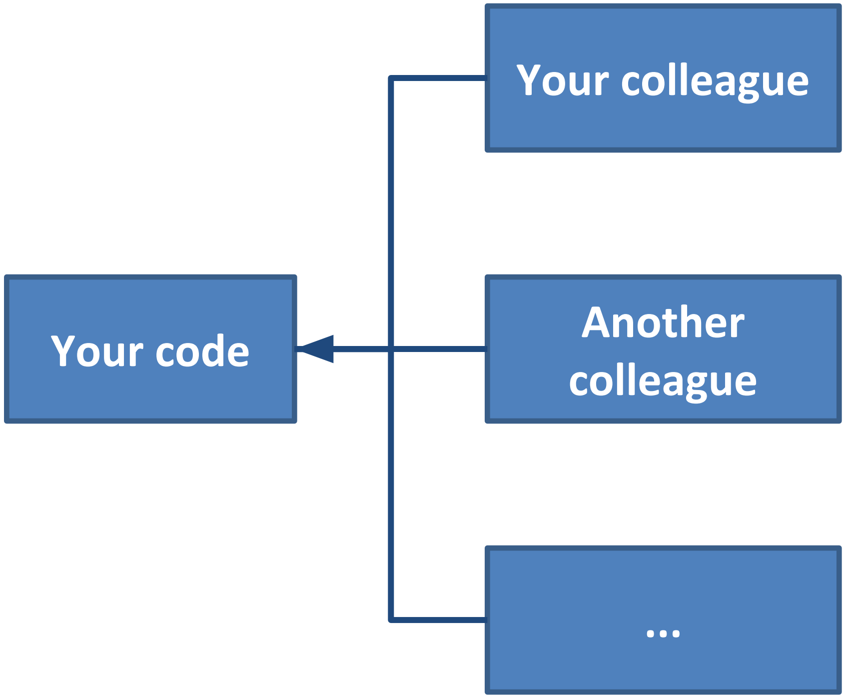
- Distributed development among many teams
  - Incremental, non-linear software development
  - Facilitates communication
- Long-term buy-in from clients & customers
  - Users invest heavily: acquiring, writing, learning
  - Cost to **stop** using an API can be prohibitive
  - Successful public APIs capture users

Poor APIs can be a great liability!

- Lost productivity from your software developers
- Wasted customer support resources
- Lack of buy-in from clients & customers

http://www.throughlinegroup.com/wp-content/uploads/2013/10/Paper-Buried-By.jpg

Public APIs are forever

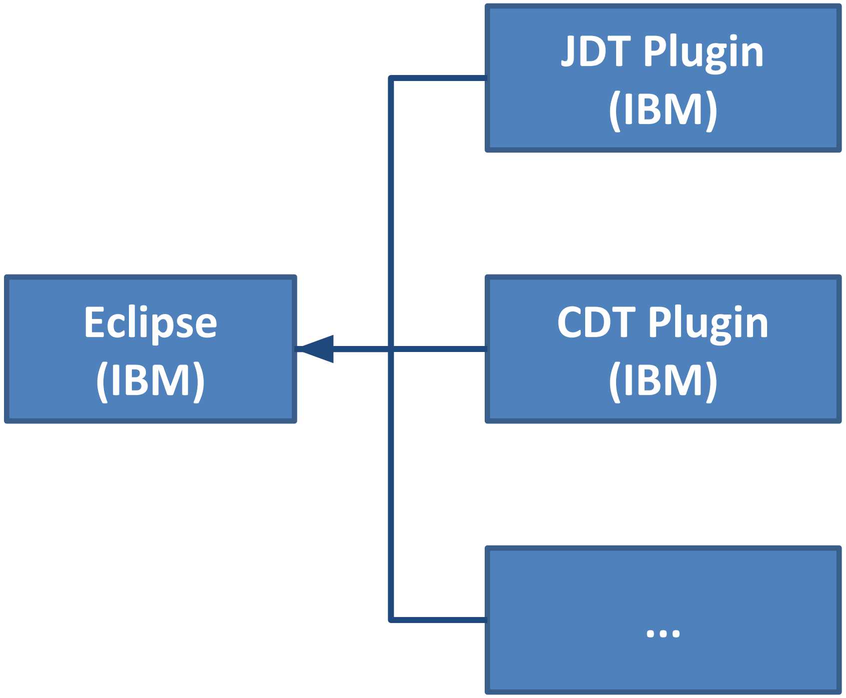

Your colleague

Your code

Another colleague

…

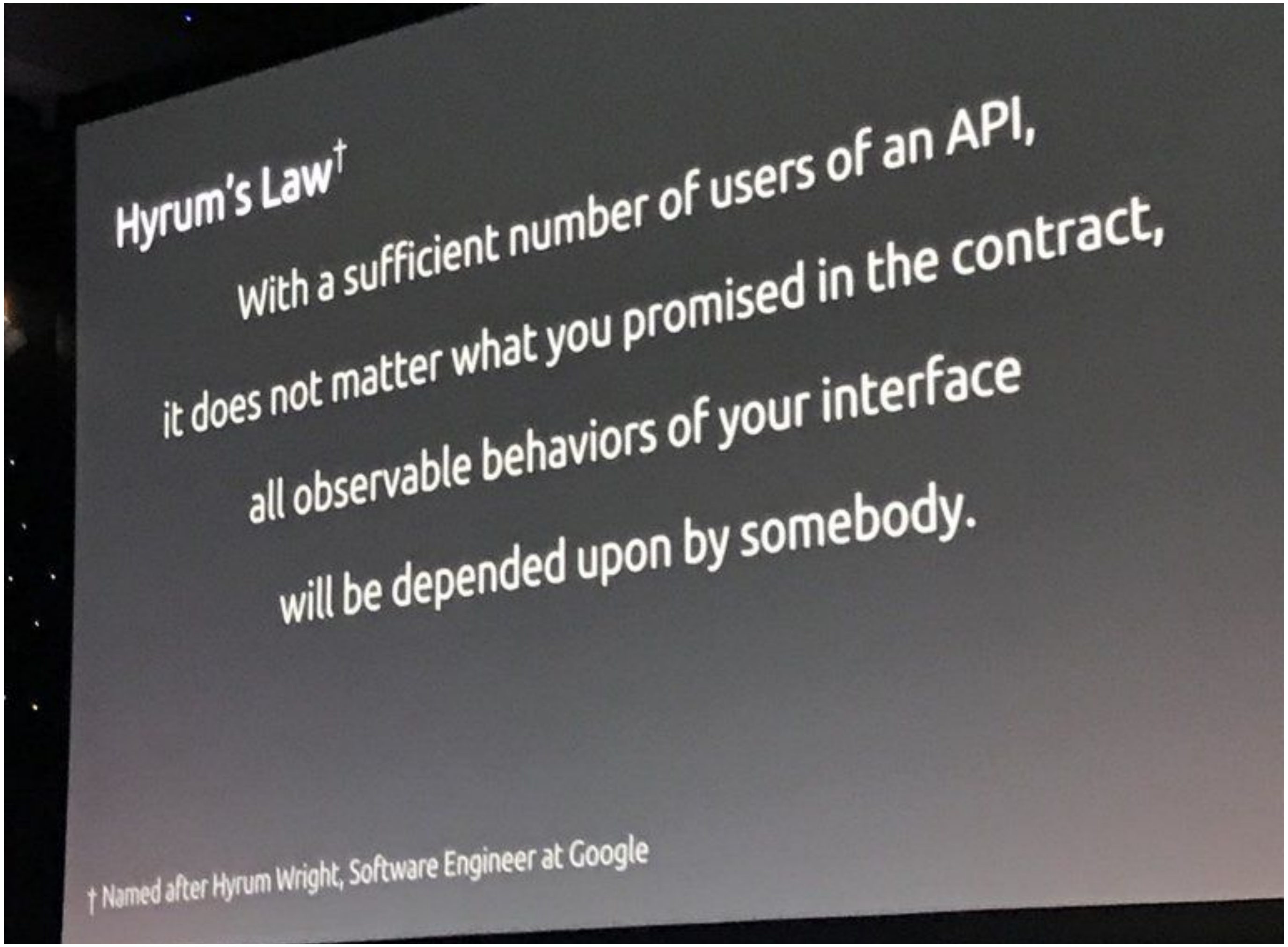
Public APIs are forever



Hyrum’s Law

Hyrum Wright
@hyrumwright

Infrastructure software engineer. Googler. Father. Occasional professor.



Hyrum’s Law†

With a sufficient number of users of an API,
it does not matter what you promised in the contract,
all observable behaviors of your interface
will be depended upon by somebody.

† Named after Hyrum Wright, Software Engineer at Google

Today's topic: API Design

Review: what is an API?

- Short for Application Programming Interface
- Component specification in terms of operations, inputs, & outputs
  - Defines a set of functionalities independent of implementation
- Allows implementation to vary without compromising clients
- Defines component boundaries in a programmatic system
- A *public* API is one designed for use by others

Exponential growth in the power of APIs

This list is approximate and incomplete, but it tells a story

’50s-’60s – Arithmetic. Entire library was 10-20 calls!

’70s – malloc, bsearch, qsort, rnd, I/O, system calls, formatting, early databases

’80s – GUIs, desktop publishing, relational databases

’90s – Networking, multithreading, 3D graphics

’00s – **Data structures(!)**, higher-level abstractions, Web APIs: social media, cloud infrastructure

’10s – Machine learning, IOT, robotics, pretty much everything

What the dramatic growth in APIs has done for us

- Enabled code reuse on a grand scale
- Increased the level of abstraction dramatically
- A single programmer can quickly do things that would have taken months for a team
- What was previously impossible is now routine
- APIs have given us super-powers

Why is API design important?

- A good API is a joy to use; a bad API is a nightmare
- APIs can be among your greatest assets
  - Users invest heavily: acquiring, writing, learning
  - Cost to **stop** using an API can be prohibitive
  - Successful public APIs capture users
- APIs can also be among your greatest liabilities
  - Bad API can cause unending stream of support calls
  - Can inhibit ability to move forward
- **Public APIs are forever – one chance to get it right**

Why is API design important to you?

- If you program, you are an API designer
  - Good code is modular – each module has an API
- Useful modules tend to get reused
  - Good reusable modules are an asset
  - Once module has users, can't change API at will
- Thinking in terms of APIs improves code quality

Characteristics of a good API

- Easy to learn
- Easy to use, even without documentation
- Hard to misuse
- Easy to read and maintain code that uses it
- Sufficiently powerful to satisfy requirements
- Easy to evolve
- Appropriate to audience

Outline

- The Process of API Design
- Naming
- Documentation

Gather requirements–skeptically

- Often you'll get proposed solutions instead
  - Better solutions may exist
- Your job is to extract true requirements
  - Should take the form of use-cases
- Can be easier & more rewarding to build more general API

What they say: "We need new data structures and RPCs with the Version 2 attributes"

What they mean: "We need a new data format that accommodates evolution of attributes"

An often overlooked part of requirements gathering

- Ask yourself if the API **should** be designed
- Here are several good reasons **not** to design it
  - It's superfluous
  - It's impossible
  - It's unethical
  - The requirements are too vague
- If any of these things are true, **now** is the time to raise red flag
- If the problem can't be fixed, fail fast!
  - The longer you wait, the more costly the failure

Start with short spec – 1 page is ideal

- At this stage, agility trumps completeness
- Bounce spec off as many people as possible
  - Listen to their input and take it seriously
- If you keep the spec short, it’s easy to modify
- Flesh it out as you gain confidence

Sample early API draft

```
// A collection of elements (root of the collection hierarchy)
public interface Collection<E> {
    // Ensures that collection contains o
    boolean add(E o);
    // Removes an instance of o from collection, if present
    boolean remove(Object o);
    // Returns true iff collection contains o
    boolean contains(Object o) ;
    // Returns number of elements in collection
    int size() ;
    // Returns true if collection is empty
    boolean isEmpty();
    ...  // Remainder omitted
}
```

Write to your API early and often

- Start *before* you’ve implemented the API
  - Saves you doing implementation you'll throw away
- Start *before* you’ve even specified it properly
  - Saves you from writing specs you'll throw away
- Continue writing to API as you flesh it out
  - Prevents nasty surprises right before you ship
- Code lives on as examples, unit tests
  - **Among the most important code you’ll ever write**
  - Forms the basis of *Design Fragments* [Fairbanks, Garlan, & Scherlis, OOPSLA ‘06, P. 75]

Try API on at least 3 use cases before release

- If you write one, it probably won’t support another
- If you write two, it will support more with difficulty
- If you write three, it will probably work fine
- Ideally, get different people to write the use cases
  - This will test documentation & give you different perspectives
- This is even more important for plug-in APIs
- Will Tracz calls this “The Rule of Threes”
  (Confessions of a Used Program Salesman, Addison-Wesley, 1995)

Maintain realistic expectations

- Most API designs are over-constrained
  - You won't be able to please everyone – don’t try!
  - Come up with a unified, coherent design that represents a compromise
  - It can be hard to decide which “requirements” are important
- Expect to make mistakes
  - Real-world use will flush them out
  - Expect to evolve API

Issue tracking

- Throughout process, maintain a list of design issues
  - Individual decisions such as what input format to accept
    - Write down all the options
    - Say which were ruled out and why
    - When you decide, say which was chosen and why
- Prevents wasting time on solved issues
- Provides rationale for the resulting API
  - Reminds its creators
  - Enlightens its users

Key design artifacts

1. **Requirements document**
2. **Issues list**
3. **Use-case code**

Maintain throughout design and retain when done

- They guide the design process
- When API is done, they're the basis of the **design rationale**
  - Public explanation for design
  - For an example, see https://docs.oracle.com/javase/8/docs/technotes/guides/collections/designfaq.html

Disclaimer – one size does not fit all

- This process has worked for me
- Others developed similar processes independently
- But I'm sure there are other ways to do it
- The smaller the API, the less process you need

Puzzler: “Big Trouble”

```
public static void main(String [] args) {
   BigInteger fiveThousand = new BigInteger("5000");
   BigInteger fiftyThousand = new BigInteger("50000");
   BigInteger fiveHundredThousand = new BigInteger("500000");

   BigInteger total = BigInteger.ZERO;
   total.add(fiveThousand);
   total.add(fiftyThousand);
   total.add(fiveHundredThousand);

   System.out.println(total);
}
```

What Does It Print?

```
public static void main(String [] args) {
   BigInteger fiveThousand = new BigInteger("5000");
   BigInteger fiftyThousand = new BigInteger("50000");
   BigInteger fiveHundredThousand = new BigInteger("500000");

   BigInteger total = BigInteger.ZERO;
   total.add(fiveThousand);
   total.add(fiftyThousand);
   total.add(fiveHundredThousand);

   System.out.println(total);
}
```

(a) 0
(b) 500000
(c) 555000
(d) Other

What Does It Print?

(a) `0`

(b) `500000`

(c) `555000`

(d) It varies

`BigInteger` is immutable!

Another Look

```
public static void main(String [] args) {
   BigInteger fiveThousand = new BigInteger("5000");
   BigInteger fiftyThousand = new BigInteger("50000");
   BigInteger fiveHundredThousand = new BigInteger("500000");

   BigInteger total = BigInteger.ZERO;
   total.add(fiveThousand);          // Ignores result
   total.add(fiftyThousand);         // Ignores result
   total.add(fiveHundredThousand);   // Ignores result

   System.out.println(total);
}
```

How do you fix it?

```
public static void main(String [] args) {
   BigInteger fiveThousand = new BigInteger("5000");
   BigInteger fiftyThousand = new BigInteger("50000");
   BigInteger fiveHundredThousand = new BigInteger("500000");

   BigInteger total = BigInteger.ZERO;
   total = total.add(fiveThousand);
   total = total.add(fiftyThousand);
   total = total.add(fiveHundredThousand);

   System.out.println(total);
}
```

Prints 555000

The moral

- Names like `add`, `subtract`, `negate` suggest mutation
- Better names: `plus`, `minus`, `negation`
- Generally (and loosely) speaking:
  - Action verbs for mutation
  - Prepositions, linking verbs, nouns, or adjectives for pure functions
- **Names are important!**

Outline

- The Process of API Design
- Naming
- Documentation

How to name things:

the hardest problem in programming

@PeterHilton

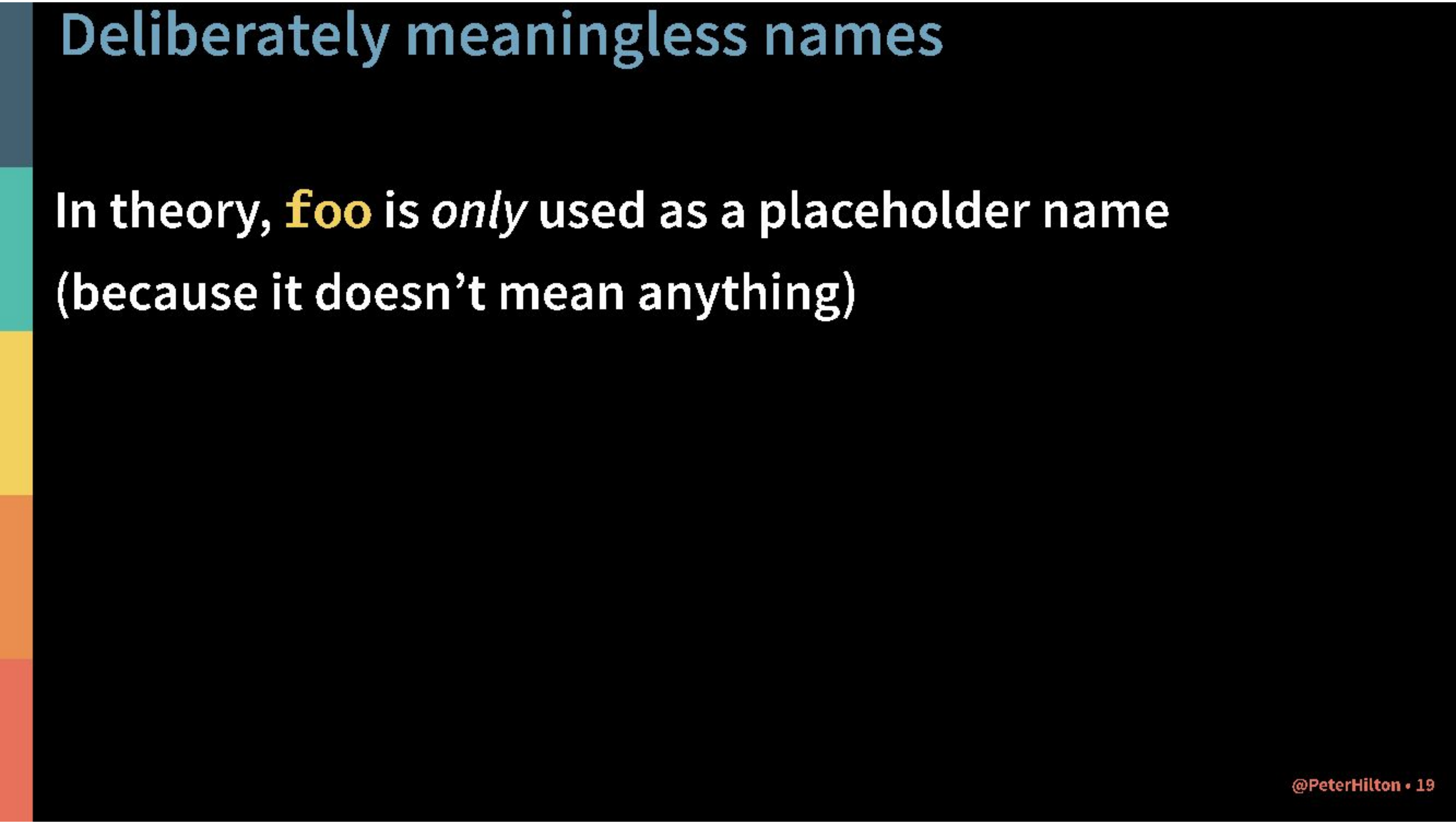
http://hilton.org.uk/

https://hilton.org.uk/presentations/naming

Names Matter – API is a little language

Naming is perhaps the single most important factor in API usability

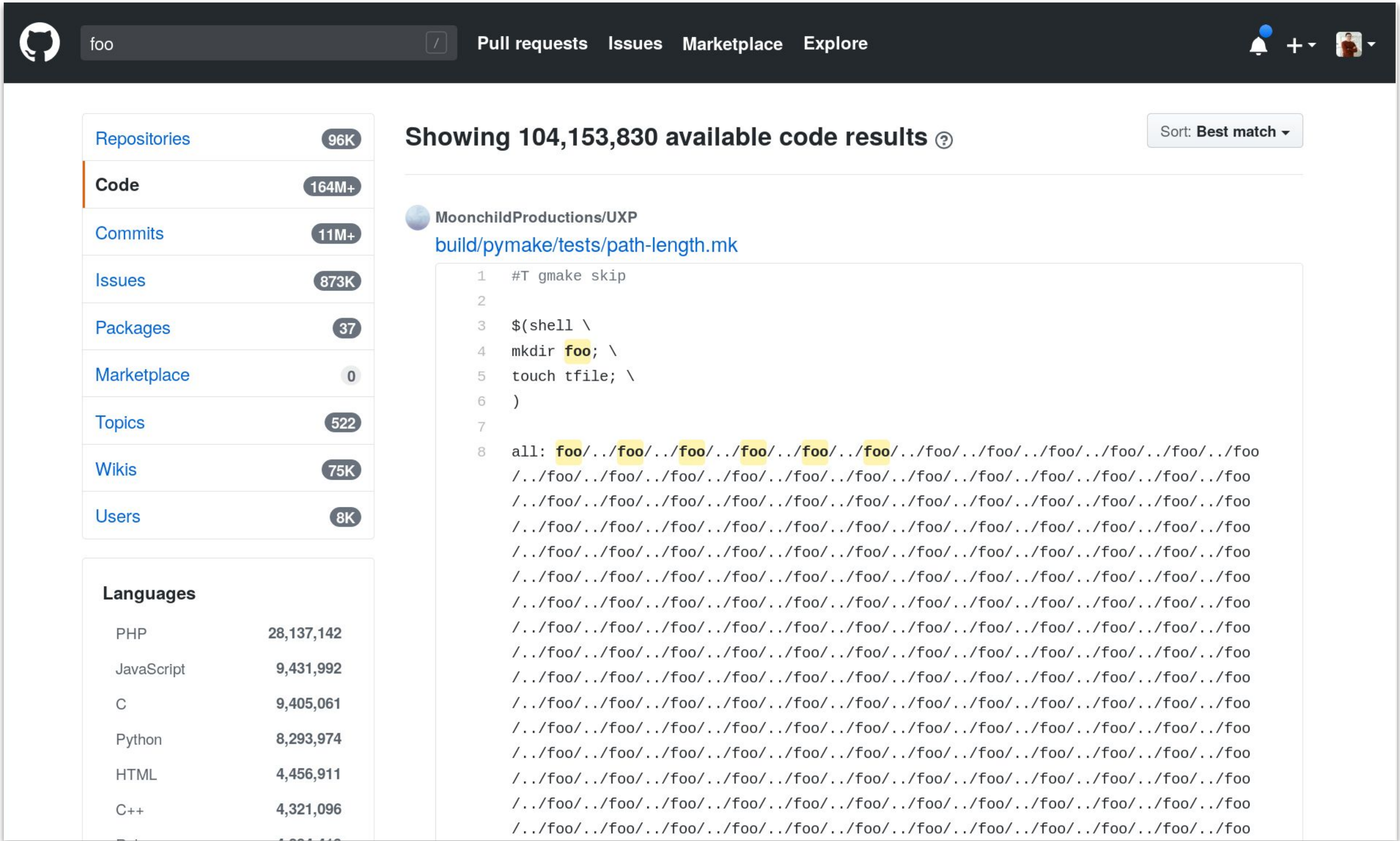
- Primary goals
  - **Client code should read like prose** (“easy to read”)
  - **Client code should mean what it says** (“hard to misread”)
  - **Client code should flow naturally** (“easy to write”)
- To that end, names should:
  - be largely self-explanatory
  - leverage existing knowledge
  - interact harmoniously with language and each other



Deliberately meaningless names

In theory, **foo** is *only* used as a placeholder name (because it doesn't mean anything)

@PeterHilton • 19



Repositories	96K
Code	164M+
Commits	11M+
Issues	873K
Packages	37
Marketplace	0
Topics	522
Wikis	75K
Users	8K

Languages

PHP	28,137,142
JavaScript	9,431,992
C	9,405,061
Python	8,293,974
HTML	4,456,911
C++	4,321,096

Showing 104,153,830 available code results

MoonchildProductions/UXP

build/pymake/tests/path-length.mk

```
#T gmake skip

$(shell \
mkdir foo; \
touch tfile; \
)

all: foo/../foo/../foo/../foo/../foo/../foo/../foo/../foo/../foo/../foo/../foo/../foo
/../foo/../foo/../foo/../foo/../foo/../foo/../foo/../foo/../foo/../foo/../foo/../foo
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```

The easy part: typographical naming conventions

*The **language specification** demands that you follow these*

- Package or module – `org.junit.jupiter.api`, `com.google.common.collect`
- Class or Interface – `Stream`, `FutureTask`, `LinkedHashMap`, `HttpClient`
- Method or Field – `remove`, `groupingBy`, `getCrc`
- Parameter – `numerator`, `modulus`
- Constant Field – `MIN_VALUE`, `NEGATIVE_INFINITY`
- Type Parameter – `T`, `E`, `K`, `V`, `X`, `R`, `U`, `V`, `T1`, `T2`

How to choose names that are easy to read & write

- Choose key nouns carefully!
  - Related to finding good abstractions, which can be hard
  - If you *can't* find a good name, it's generally a bad sign
- If you get the key nouns right, other nouns, verbs, and prepositions tend to choose themselves
- Names can be literal or metaphorical
  - Literal names have literal associations
    - e.g., **Matrix** → inverse, determinant, eigenvalue, etc.
  - Metaphorical names enable reasoning by analogy
    - e.g., **Publication**, **Subscriber** → publish, subscribe, cancel, issue, issueNumber, circulation, etc.

Another way names drive development

- Names may remind you of another API
- Consider **copying** its vocabulary and structure
- People who know other API will have an easy time learning yours
- You may be able to develop it more quickly
- You may be able to use types from the other API
- You may even be able to share implementation

Names drive development, for better or worse

- Good names drive good development
- Bad names inhibit good development
- Bad names result in bad APIs unless you take action
- **The API talks back to you. Listen!**

Vocabulary consistency

- Use words consistently throughout your API
  - Never use the same word for multiple meanings
  - Never use multiple words for the same meaning
  - i.e., words should be isomorphic to meanings

Vocabulary consistency as it relates to scope

APIs are actually little language ***extensions***

- The tighter the scope, the more important is consistency
  - **Within APIs, consistency is critical**
  - In related APIs on a platform, it’s highly desirable
  - Across the platform, it’s desirable
  - Between platforms, it’s nice-to-have
- **If forced to choose between local & platform consistency, choose local**
- But look to platform libraries for vocabulary
  - Ignoring obsolete and unpopular libraries
- Finally, look to similar APIs on other platforms for naming ideas

Avoid abbreviations except where customary

- Back in the day, storage was scarce & people abbreviated everything
  - Some continue to do this by force of habit or tradition
- Ideally, use complete words
- But sometimes, names just get too long
  - If you must abbreviate, do it tastefully
  - **No excuse for cryptic abbreviations**
- Of course you should use `gcd`, `Url`, `cos`, `mba`, etc.

Grammar is a part of naming too

- Nouns for classes
  - `BigInteger`, `PriorityQueue`
- Nouns or adjectives for interfaces
  - `Collection`, `Comparable`
- Nouns, linking verbs or prepositions for non-mutative methods
  - `size`, `isEmpty`, `plus`
- Action verbs for mutative methods
  - `put`, `add`, `clear`
- If you follow these, they quickly become second nature

Names should be regular – strive for symmetry

- If API has 2 verbs and 2 nouns, support all 4 combinations
  - Unless you have a very good reason not to
- Programmers will try to use all 4 combinations
  - They will get upset if the one they want is missing
- In other words, good APIs are generally *orthogonal*

Don’t mislead your user

- Names have implications
  - Learn them and uphold them in your APIs
- Don’t violate **the principle of least astonishment**
- Ignore this advice at your own peril
  - Can cause unending stream of subtle bugs

```
public static boolean interrupted()
```

Tests whether the current thread has been interrupted. The interrupted status of the thread is cleared by this method....

Don't lie to your user

- Name method for what it does, not what you wish it did
- If you can't bring yourself to do this, fix the method!
- Again, ignore this at your own peril

`public long` **`skip(long n)`** `throws IOException`

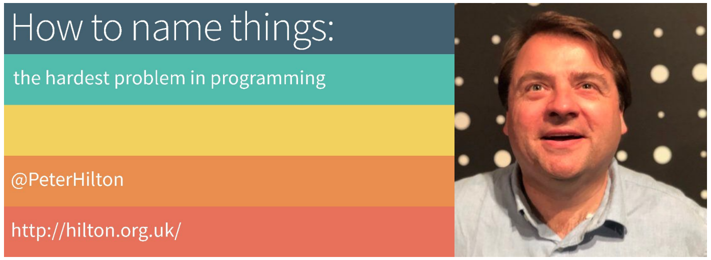
Skips over and discards n bytes of data from this input stream. The skip method may, for a variety of reasons, end up skipping over some smaller number of bytes, possibly 0. This may result from any of a number of conditions; reaching end of file before n bytes have been skipped is only one possibility. The actual number of bytes skipped is returned…

Good naming takes time, but it’s worth it

- Don’t be afraid to spend hours on it; I do.
  - And I still get the names wrong sometimes
- Discuss names with colleagues; it really helps.

Adopt better naming practices

- Start with *meaning* and *intention*.
- Use words with precise meanings.
- Prefer fewer words in names.
- No abbreviations in names (except id)
- Use code review to improve names.
- Read the code out loud to check that it *sounds* okay.
- Actually rename things.



How to name things:

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@PeterHilton

http://hilton.org.uk/

Lecture summary

- APIs took off in the past thirty years and gave us super-powers
- Good APIs are a blessing; bad ones, a curse
- Following an API design process greatly improves API quality
- Naming is critical to API usability