Principles of Software Construction: Objects, Design, and Concurrency (Part 5: Large-Scale Reuse)

Principles of API Design

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Closely based on *How To Design A Good API and Why It Matters* by Josh Bloch

Agenda

- Introduction to APIs: Application Programming Interfaces
- An API design process
- Key design principle: Information hiding
- Concrete advice for user-centered design

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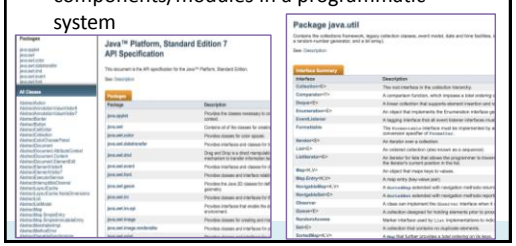
- Introduction to APIs: Application Programming Interfaces
- An API design process
- Key design principle: Information hiding
- Concrete advice for user-centered design
- Based heavily on "How to Design a Good API and Why it Matters by Josh Bloch"
  - If you have "Java" in your resume you should own *Effective Java*, our optional course textbook.

Learning goals

- Understand and be able to discuss the similarities and differences between API design and regular software design
  - Relationship between libraries, frameworks and API design
  - Information hiding as a key design principle
- Acknowledge, and plan for failures as a fundamental limitation on a design process
- Given a problem domain with use cases, be able to plan a coherent design process for an API for those use cases, e.g., "Rule of Threes"

API: Application Programming Interface

- An API defines the boundary between components/modules in a programmatic system



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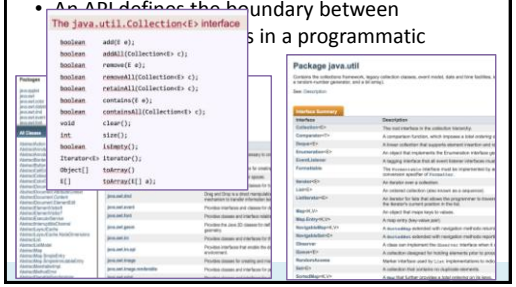

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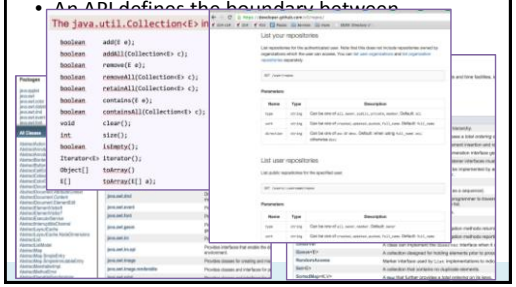

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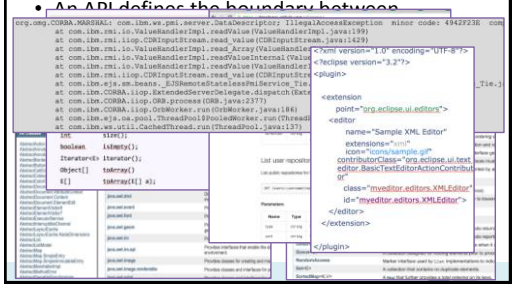
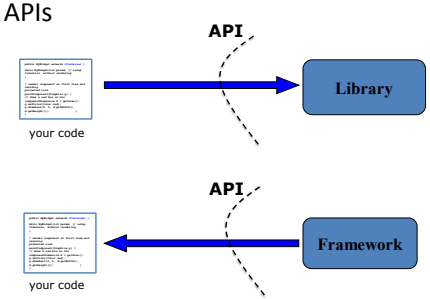


Libraries and frameworks both define APIs



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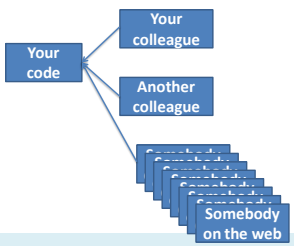
APIs are forever



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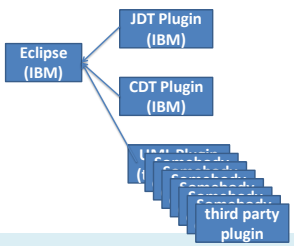

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Evolutionary problems: Public (used) APIs are forever

- "One chance to get it right"
- Can add features to library
- Cannot remove method from library
- Cannot change contract in library
- Cannot change plugin interface of framework
- Deprecation of APIs as weak workaround

awt.Component, deprecated since Java 1.1 still included in 7.0

APIs are everywhere

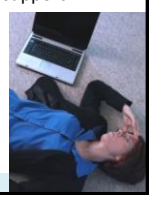
- Frameworks
- Libraries
- Any code that is reused really
  - …may turn slowly into a library

Motivation to create a public API

- Good APIs are a great asset
  - Distributed development among many teams
    - Incremental, non-linear software development
    - Facilitates communication
  - Long-term buy-in from clients & customers
- Poor APIs are a great liability
  - Lost productivity from your software developers
  - Lack of buy-in from clients & customers
  - Wasted customer support resources

Good and bad APIs

- Lots of reuse
  - including from yourself
- Lots of users/customers
- User buy-in and lock-in
- Lost productivity, inefficient reuse
- Maintenance and customer support liability



An API design process

- Define the scope of the API
  - Collect use-case stories, define requirements
  - Be skeptical
    - Distinguish true requirements from so-called solutions
    - "When in doubt, leave it out."
- Draft a specification, gather feedback, revise, and repeat
  - Keep it simple, short
- Code early, code often
  - Write *client code* before you implement the API

Case Study: Java Date and Calendars

Plan with Use Cases

- Think about how the API might be used?
  - e.g., get the current time, compute the difference between two times, get the current time in Tokyo, get next week's date using a Maya calendar, …
- What tasks should it accomplish?
- Should all the tasks be supported?
  - If in doubt, leave it out!
- How would you solve the tasks with the API?

Respect the rule of three

- Via Will Tracz (via Josh Bloch), *Confessions of a Used Program Salesman*:
  - "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 work fine."

Contracts and Documentation

- APIs should be self-documenting
  - Good names drive good design
- Document religiously anyway
  - All public classes
  - All public methods
  - All public fields
  - All method parameters
  - Explicitly write behavioral specifications
- Documentation is integral to the design and development process

Key design principle: Information hiding

- "When in doubt, leave it out."

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- Documentation is integral to the design and development process
- Do not document implementation details


```
public class Point {
    public double x;
    public double y;
}
```

vs.

```
public class Point {
    private double x;
    private double y;
    public double getX() { /* … */ }
    public double getY() { /* … */ }
}
```

Key design principle: Information hiding (2)

- Minimize the accessibility of classes, fields, and methods
  - "You can add features, but never remove or change the behavioral contract for an existing feature"

Applying Information Hiding: Fields vs Getter/Setter Functions

```
public class Point {
    public double x;
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vs.

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public class Point {
    private double x;
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```



```
public class Rectangle {
 public Rectangle(Point e, Point f) …
}
```

vs.

```
public class Rectangle {
 public Rectangle(PolarPoint e, PolarPoint f) …
}
```


Applying Information hiding: Interface vs. Class Types

```
public class Rectangle {
 public Rectangle(Point e, Point f) …
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vs.

```
public class Rectangle {
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```


Applying Information hiding: Factories

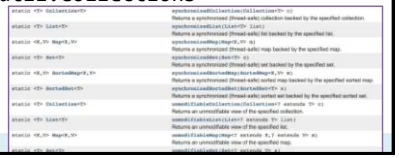
- Consider implementing a factory method instead of a constructor
- Factory methods provide additional flexibility
  - Can be overridden
  - Can return instance of any subtype; hides dynamic type of object
  - Can have a descriptive method name

Applying Information Hiding: Hide Information Details

- Subtle leaks of implementation details through
  - Documentation
  - Implementation-specific return types
  - Implementation-specific exceptions
  - Output formats
  - `implements Serializable`
- Lack of documentation -> Implementation becomes specification –> no hiding

Minimize conceptual weight

- Conceptual weight: How many concepts must a programmer learn to use your API?
  - APIs should have a "high power-to-weight ratio"
- See `java.util.*`, `java.util.Collections`



Apply principles of user-centered design

- Other programmers are your users
- e.g., "Principles of Universal Design"
  - Equitable use
  - Flexibility in use
  - Simple and intuitive use
  - Perceptible information
  - Tolerance for error
  - Low physical effort
  - Size and space for approach and use


```
public class Thread implements Runnable {
   // Tests whether current thread has been interrupted.
   // Clears the interrupted status of current thread.
   public static boolean interrupted();
 }
```


Good names drive good design

- Do what you say you do:
  - "Don't violate the Principle of Least Astonishment"

```
public class Thread implements Runnable {
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- get_x() vs getX()
- Timer vs timer
- isEnabled() vs. enabled()
- computeX() vs. generateX()?
- deleteX() vs. removeX()?

Good names drive good design (2)

- Follow language- and platform-dependent conventions
  - Typographical:
    - `get_x() vs. getX()`
    - `timer vs. Timer, HTTPServlet vs HttpServlet`
    - `edu.cmu.cs.cs214`
  - Grammatical:
    - Nouns for classes
    - Nouns or adjectives for interfaces

Good names drive good design (3)

- Use clear, specific naming conventions
  - `getX()` and `setX()` for simple accessors and mutators
  - `isX()` for simple boolean accessors
  - `computeX()` for methods that perform computation
  - `createX()` or `newInstance()` for factory methods
  - `toX()` for methods that convert the type of an object
  - `asX()` for wrapper of the underlying object

Good names drive good design (4)

- Be consistent
  - computeX() vs. generateX()?
  - deleteX() vs. removeX()?

Do not violate Liskov's behavioral subtyping rules

- Use inheritance only for true subtypes
- Favor composition over inheritance

```
// A Properties instance maps Strings to Strings
public class Properties extends HashTable {
    public Object put(Object key, Object value);
    …
}

public class Properties {
    private final HashTable data = new HashTable();
    public String put(String key, String value) {
        data.put(key, value);
    }
    …
}

class Stack extends Vector …
```


Minimize mutability

- Immutable objects are:
  - Inherently thread-safe
  - Freely shared without concern for side effects
  - Convenient building blocks for other objects
  - Can share internal implementation among instances
    - See `java.lang.String`

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  - Inherently thread-safe
  - Freely shared without concern for side effects
  - Convenient building blocks for other objects
  - Can share internal implementation among instances
    - See `java.lang.String`
- Mutable objects require careful management of visibility and side effects
  - e.g. `Component.getSize()` returns a mutable `Dimension`
- Document mutability
  - Carefully describe state space

Overload method names judiciously

- Avoid ambiguous overloads for subtypes
  - Recall the subtleties of method dispatch:

```
public class Point() {
    private int x;
    private int y;
    public boolean equals(Point p) {
        return this.x == p.x && this.y == p.y;
    }
}
```

- If you must be ambiguous, implement consistent behavior

```
public class TreeSet implements SortedSet {
  public TreeSet(Collection c);  // Ignores order.
  public TreeSet(SortedSet s);   // Respects order.
}
```

Use consistent parameter ordering

- An egregious example from C:
  - `char* strncpy(char* dest, char* src, size_t n);`
  - `void bcopy(void* src, void* dest, size_t n);`

Avoid long lists of parameters

- Especially avoid parameter lists with repeated parameters of the same type

```
HWND CreateWindow(LPCTSTR lpClassName, LPCTSTR lpWindowName,
  DWORD dwStyle, int x, int y, int nWidth, int nHeight,
  HWND hWndParent, HMENU hMenu, HINSTANCE hInstance,
  LPVOID lpParam);
```

- Break up the method or use a helper class to hold parameters instead


```
// A Properties instance maps Strings to Strings
public class Properties extends HashTable {
  public Object put(Object key, Object value);

  // Throws ClassCastException if this instance
  // contains any keys or values that are not Strings
  public void save(OutputStream out, String comments);
}
```


Fail fast

- Report errors as soon as they are detectable
  - Check preconditions at the beginning of each method
  - Avoid dynamic type casts, run-time type-checking

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Avoid behavior that demands special processing

- Do not return `null` to indicate an empty value
  - e.g., Use an empty `Collection` or array instead
- Do not return `null` to indicate an error
  - Use an exception instead
- Do not return a `String` if a better type exists
- Do not use exceptions for normal behavior
- Avoid checked exceptions if possible

```
try {
    Foo f = (Foo) g.clone();
} catch (CloneNotSupportedException e) {
    // Do nothing. This exception can't happen.
}
```


Don't let your output become your de facto API

- Document the fact that output formats may evolve in the future
- Provide programmatic access to all data available in string form

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```
public class Throwable {
  public void printStackTrace(PrintStream s);
  public StackTraceElement[] getStackTrace();
}

public final class StackTraceElement {
  public String  getFileName();
  public int     getLineNumber();
  public String  getClassName();
  public String  getMethodName();
  public boolean isNativeMethod();
}
```


Summary

- Accept the fact that you, and others, will make mistakes
  - Use your API as you design it
  - Get feedback from others
  - Think in terms of use cases (domain engineering)
  - Hide information to give yourself maximum flexibility later
  - Design for inattentive, hurried users
  - Document religiously