

# FOCUS ON QUALITY ATTRIBUTES

## AND CONFLICTS BETWEEN THEM

---

Barbora Bühnová  
buhnova@fi.muni.cz

LAB OF SOFTWARE ARCHITECTURES  
AND INFORMATION SYSTEMS

FACULTY OF INFORMATICS  
MASARYK UNIVERSITY, BRNO



# Where do we stand?

---

We already know many techniques for code-level quality:

- **Clean code principles**

- **SOLID** (Single responsibility, Open/closed, Liskov substitution, etc.)
- **GRASP** (High cohesion, Low coupling, Polymorphism, etc.)

- **Bad code smells**

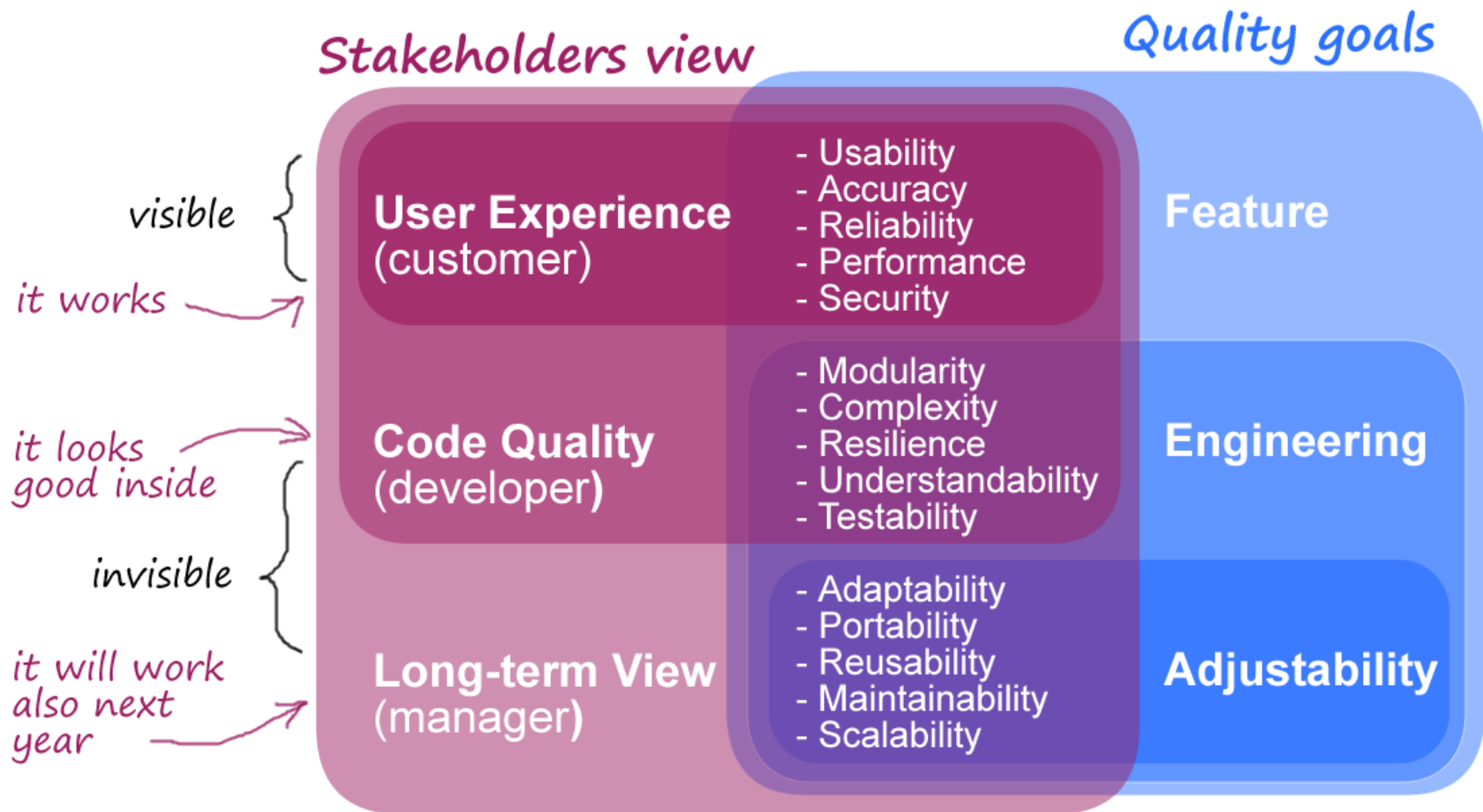
- Abstraction levels, dependencies, cohesion, naming conventions, etc.

- **Refactoring**

- When, where and how

Is this enough to ensure code-level quality?

# ... and your customer? What "quality" means to you? ... and your manager?



# Outline of the lecture

---

- Bad code smells for
  - Performance
  - Scalability
  - Reliability
  - Testability
  - Maintainability
- Tactics for
  - Discussed quality attributes
  - Conflicts between them

Our big five



# Outline of the lecture

---

- Bad code smells for
  - Performance
  - Scalability
  - Reliability
  - Testability
  - Maintainability
- Tactics for
  - Discussed quality attributes
  - Conflicts between them



# Bad code smells for Performance

---

- Let's assume our code is perfectly **CLEAN**
- **What about performance?**  
Are there any performance code smells we could check for?

Let's discuss four **performance smells**:

- Smell #1: Redundant Work
- Smell #2: One by One Processing
- Smell #3: Long Critical Section
- Smell #4: Busy Waiting

# Motivating example #1: Fibonacci Sequence

---

- 1, 1, 2, 3, 5, 8, 13, 21, ...
- $\text{Fib}(0) = \text{Fib}(1) = 1$   
 $\text{Fib}(n+2) = \text{Fib}(n+1) + \text{Fib}(n)$  where  $n \geq 0$

## In Java:

```
public int fibonacci(int n) {  
    if(n <= 1) return 1;  
    return fibonacci(n-1) + fibonacci(n-2);  
}
```

# Smell #1: Redundant Work

---

- **Description**

- A time-consuming method computes the same many times in a single execution path

- **Consequences**

- A slower execution time since the time-consuming operation is performed multiple times

- **Solution**

- Call the heavy method only once and store the result for further reuse

Note: Applies also in more complex scenarios, such as caching of database results in distributed systems.



# Example #1: Fibonacci refactored

---

```
Map<Integer,Integer> cache1 = new HashMap<Integer,Integer>();
```

```
long fibonacci(int n) {  
    if (cache1.containsKey(n))  
        return cache1.get(n);  
    if (n==0 || n==1) {  
        int var1 = 1;  
        cache1.put(n, var1);  
        return var1;  
    }  
    int var2 = fibonacci(n-1) + fibonacci(n-2);  
    cache1.put(n, var2);  
    return var2;  
}
```

# Motivating example #2: Search

---

```
private ArrayList<Item> list = new ArrayList<Item>();

List<Item> findGreaterThan(int value) {
    List<Item> ret = new ArrayList<Item>();

    for (Item item : list) {
        if (item.isGreaterThan(value)) {
            ret.add(item);
        }
    }
    return ret;
}
```

# Smell #2: One by One Processing

---

- **Description**
  - Overused linear search/processing
- **Consequences**
  - Slower performance
- **Solution**
  - Use smarter algorithms and/or data structures (binary search, sorted collections, map with precomputed search predicates)

Note: Become familiar with the performance of operations you execute on different types of **data structures**. And think about the complexity of your algorithms.

# Example #2: Search refactored

---

```
private List<Item> list = new ArrayList<Item>();  
private List<Item> var1 = new SortedList<Item>( ... );
```

...

```
List<Item> findGreaterThan(int value) {  
    return subList(var1, value);  
}
```

# Motivating example #3: Password Cracking

---

```
static List<String> passwordsToCheck;

// launch 100 threads and FOR each thread
void run() {
    while (!passwordsToCheck.isEmpty()) {
        synchronized(passwordsToCheck) {
            if (!passwordsToCheck.isEmpty()) {
                String pwd = passwordsToCheck.remove(0);
                checkPassword(pwd);
            }
        }
    }
}

void checkPassword() { ... }
```

# Smell #3: Long Critical Section

---

- **Description**
  - Unnecessary code performed in a critical section
- **Consequences**
  - More like single-threaded model
- **Solution**
  - Move the code outside the critical section

Note: Sometimes it is favorable to use multiple locks within a class to enable partial locking of an object. See an example below.

# Example #3: Password Cracking refactored

---

```
static List<String> passwordsToCheck;

// launch 100 threads and FOR each thread
void run() {
    while (!passwordsToCheck.isEmpty()) {
        synchronized(passwordsToCheck) {
            if (!passwordsToCheck.isEmpty()) {
                String pwd = passwordsToCheck.remove(0);
            }
        }
        checkPassword(pwd);
    }
}

void checkPassword() { ... }
```

## Example #3.b: Multiple locks within a class

---

```
public class MyUpdater {
    private long var1 = 0;
    private long var2 = 0;

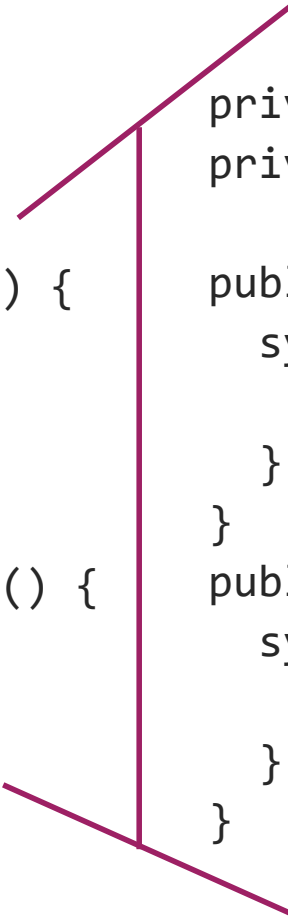
    private Object lock1 = new Object();
    private Object lock2 = new Object();

    public void updateVar1() {
        synchronized(this) {
            // update var1
        }
    }

    public void updateVar1() {
        synchronized(lock1) {
            // update var1
        }
    }

    public void updateVar2() {
        synchronized(this) {
            // update var2
        }
    }

    public void updateVar2() {
        synchronized(lock2) {
            // update var2
        }
    }
}
```





# Smell #4: Busy Waiting

- **Description**

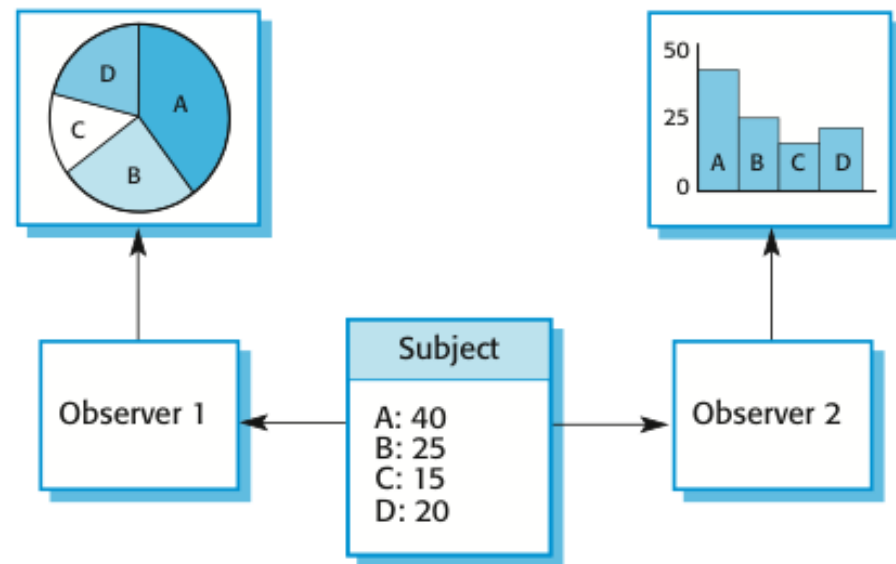
- Repeatedly checking if something interesting happened (e.g. value changed, user input arrived).

- **Consequences**

- A lot of work with mostly no value, slowing down the system

- **Solution**

- **Hollywood principle:**  
"Don't call us, we'll call you."
- Observer pattern  
(Gang of Four book)



# Outline of the lecture

---

- Bad code smells for
  - Performance
  - Scalability
  - Reliability
  - Testability
  - Maintainability
- Tactics for
  - Discussed quality attributes
  - Conflicts between them



# Bad smells (beliefs) for Scalability

---

- **Smell #1: Distribution improves performance**
  - Not always. Distributed systems must use network I/O, more CPU to maintain coherence, partitioning and replication.
- **Smell #2: Just performance**
  - If you want to get distributed, there are many lessons to learn in reliability, maintainability, security, testability, and many other domains.
- **Smell #3: My framework takes care of it**
- Distributed applications must address many new concerns:
  - State sharing
  - Data consistency
  - Caching
  - Load balancing
  - Failure management

**Fowler's First Law of Distributed Object Design: Don't distribute your objects.**

Advice: Better clean up your application and stay local, if you can.



# Outline of the lecture

---

- Bad code smells for
  - Performance
  - Scalability
  - Reliability
  - Testability
  - Maintainability
- Tactics for
  - Discussed quality attributes
  - Conflicts between them



# Bad code smells for Reliability

---

- **Smell #1: Input Kludge**
  - Check all **inputs for validity!** On all user interfaces and service interfaces.
- **Smell #2: Blind Faith**
  - Do **not trust others** (limit access to your code, check bug fixes), **nor yourself** (check the correctness of your results).
- **Smell #3: Poorly Handled Exceptions**
- **Smell #4: Unguarded Sequential Coupling**
  - Assumptions on the **right ordering of method calls** without control.
- **Smell #5: Fashionable Coding**
  - Usage of all the **new cool technologies** and constructs you do not really understand.

# Outline of the lecture

---

- **Bad code smells for**
  - Performance
  - Scalability
  - Reliability
  - **Testability**
  - Maintainability
- **Tactics for**
  - Discussed quality attributes
  - Conflicts between them



# Bad code smells for Testability

---

- Smell #1: **Global State**
  - Do not allow your objects to communicate secretly.
- Smell #2: Lack of **Dependency Injection**
  - Make your dependencies explicit.
- Smell #3: **Law of Demeter** violation
  - Only talk to your immediate friends.
- Smell #4: Misplaced and Hard Coded **new** Operator
  - Do not mix factory and service code.

Note: In over 90% of cases, Global State is the problem.

General advice: If your code is difficult to test, do not ask how to hack it, but what is wrong with that code!

# Motivating example #1: Secret Communication

---

```
class X {  
    ...  
    X() { ... }  
  
    public int doSomething() { ... }  
}
```

```
int a = new X().doSomething();  
int b = new X().doSomething();
```

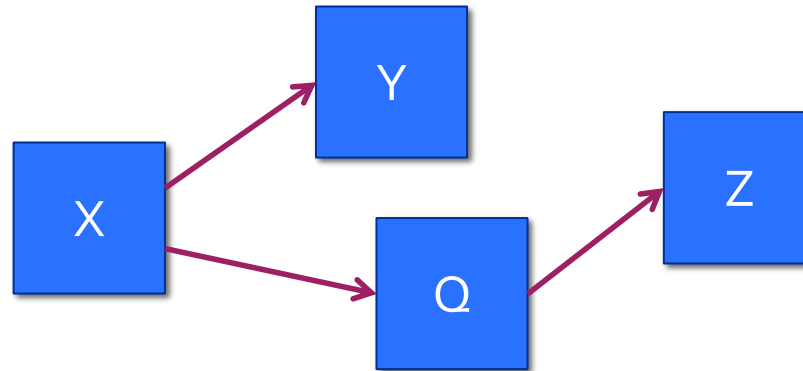
**Does a==b ??**



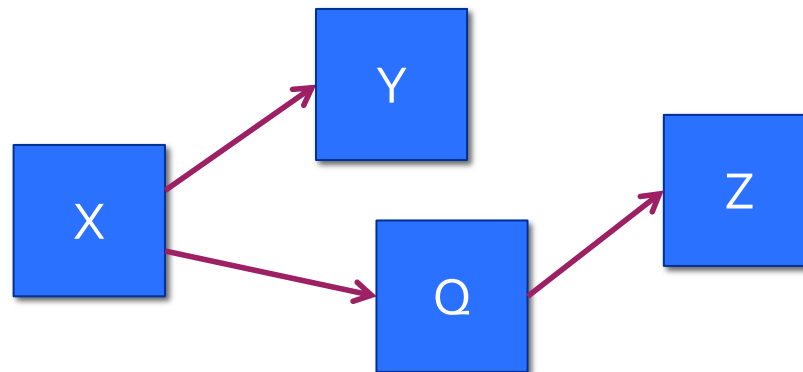
# Motivating example #1: Secret Communication

---

`a = new X()` →



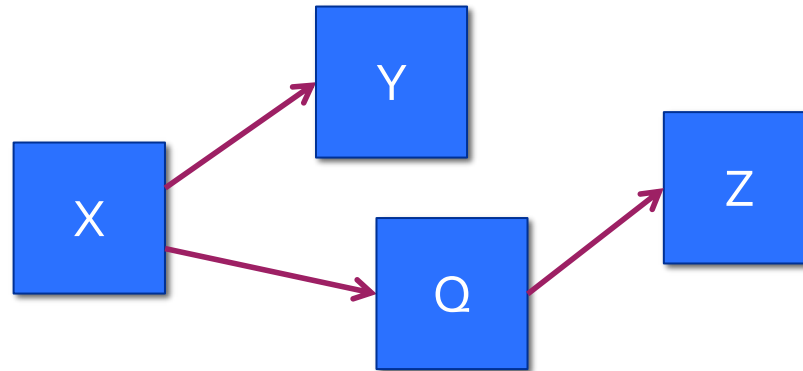
`b = new X()` →



# Motivating example #1: Secret Communication

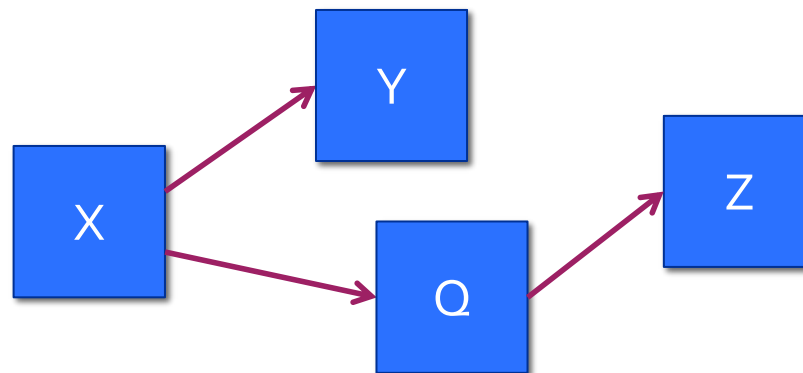
---

`a = new X() →`  
`a.doSomething()`



**`a==b` ✓**

`b = new X() →`  
`b.doSomething()`

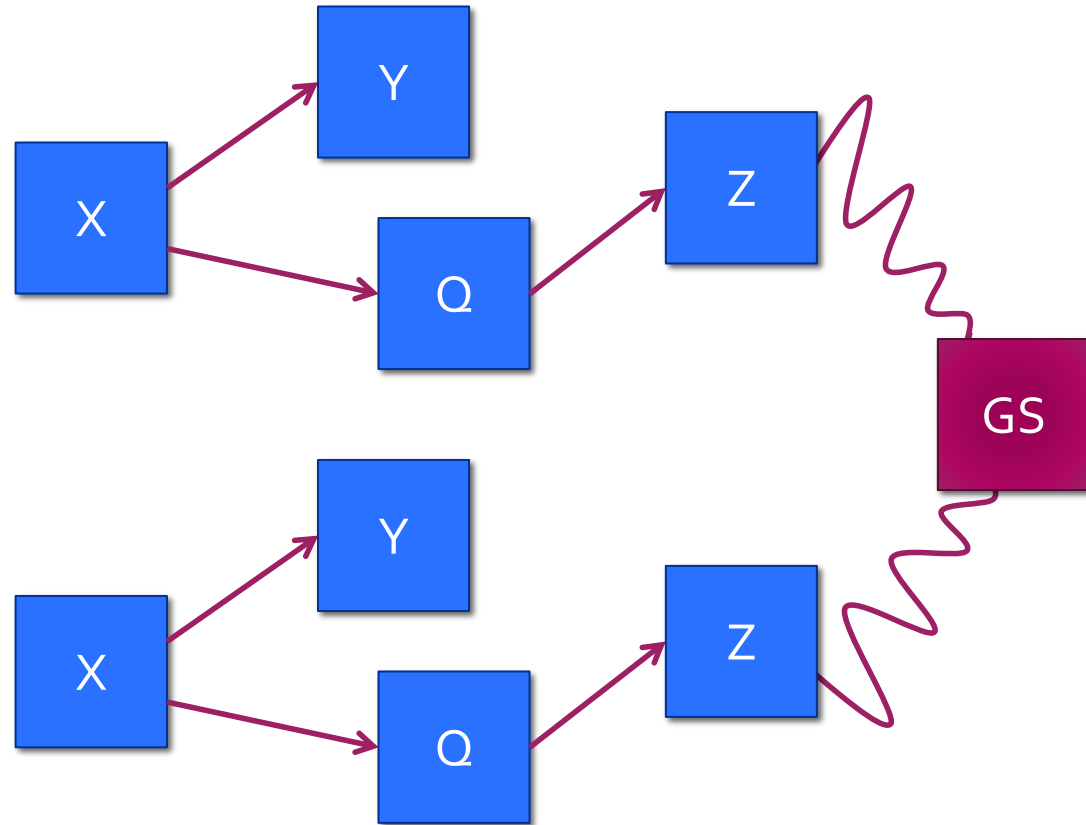


# Motivating example #1: Secret Communication

```
a = new X() →  
a.doSomething()
```

**a==b X**

```
b = new X() →  
b.doSomething()
```



# Smell #1: Global State

---

- Multiple executions can produce different results
    - Test flakiness
    - Order of tests matters
    - Cannot run tests in parallel
  - Unbounded location of state
    - Transitive dependencies
  - Hidden global states
    - `System.currentTimeMillis()`
    - Database
- What about Singletons?

# Motivating example #2: Deceptive API

---

```
testCharge() {  
    CreditCard cc;  
    cc = new CreditCard("1234567890121234");  
    cc.charge(100);  
}
```

# Motivating example #2: Deceptive API

---

```
testCharge() {  
    CreditCard cc;  
    cc = new CreditCard("1234567890121234");  
    cc.charge(100);  
}
```

[java.lang.NullPointerException](#)  
[at talk3.CreditCard.charge\(CredicCard.java:48\)](#)

# Motivating example #2: Deceptive API

---

```
testCharge() {  
    CreditCardProcessor.init();  
    CreditCard cc;  
    cc = new CreditCard("1234567890121234");  
    cc.charge(100);  
}
```

# Motivating example #2: Deceptive API

---

```
testCharge() {  
    CreditCardProcessor.init();  
    CreditCard cc;  
    cc = new CreditCard("1234567890121234");  
    cc.charge(100);  
}
```

[java.lang.NullPointerException](#)

[at talk3.CreditCardProcessor.init\(CreditCardProcessor.java:146\)](#)



# Motivating example #2: Deceptive API

---

```
testCharge() {  
    OfflineQueue.start();  
    CreditCardProcessor.init();  
    CreditCard cc;  
    cc = new CreditCard("1234567890121234");  
    cc.charge(100);  
}
```

# Motivating example #2: Deceptive API

---

```
testCharge() {  
    OfflineQueue.start();  
    CreditCardProcessor.init();  
    CreditCard cc;  
    cc = new CreditCard("1234567890121234");  
    cc.charge(100);  
}
```

[java.lang.NullPointerException](#)  
[at talk3.OfflineQueue.start\(OfflineQueue.java:16\)](#)

# Motivating example #2: Deceptive API

---

```
testCharge() {  
    Database.connect(...);  
    OfflineQueue.start();  
    CreditCardProcessor.init();  
    CreditCard cc;  
    cc = new CreditCard("1234567890121234");  
    cc.charge(100);  
}
```

# Motivating example #2: Deceptive API

---

```
testCharge() {  
    Database.connect(...);  
    OfflineQueue.start();  
    CreditCardProcessor.init();  
    CreditCard cc;  
    cc = new CreditCard("1234567890121234");  
    cc.charge(100);  
}
```

- **CreditCard API lies**

- It pretends to not need the CreditCardProcessor even though in reality it does.

# Motivating example #2: Better API

---

```
testCharge() {  
    ??  
    CreditCard cc;  
    cc = new CreditCard("1234567890121234", ccProc);  
    cc.charge(100);  
}
```

# Motivating example #2: Better API

---

```
testCharge() {  
    ??  
    ccProc = new CreditCardProcessor(queue);  
    CreditCard cc;  
    cc = new CreditCard("1234567890121234", ccProc);  
    cc.charge(100);  
}
```

# Motivating example #2: Better API

---

```
testCharge() {  
    ??  
    queue = new OfflineQueue(db);  
    ccProc = new CreditCardProcessor(queue);  
    CreditCard cc;  
    cc = new CreditCard("1234567890121234", ccProc);  
    cc.charge(100);  
}
```

# Motivating example #2: Better API

---

```
testCharge() {  
    db = new Database(...);  
    queue = new OfflineQueue(db);  
    ccProc = new CreditCardProcessor(queue);  
    CreditCard cc;  
    cc = new CreditCard("1234567890121234", ccProc);  
    cc.charge(100);  
}
```



# Motivating example #2: Better API

---

```
testCharge() {  
    db = new Database(...);  
    queue = new OfflineQueue(db);  
    ccProc = new CreditCardProcessor(queue);  
    CreditCard cc;  
    cc = new CreditCard("1234567890121234", ccProc);  
    cc.charge(100);  
}
```

 Dependency Injection

# Smell #2: Lack of Dependency Injection

---

- **Dependency injection** makes your **dependencies explicit**
  - It does not make the dependencies in your code **better** or **worse**
  - It only makes them **visible**
- If there are **too many dependencies**, **do not blame DI!**
  - The dependencies have always been there, DI only showed them to you
- **Dependency injection** enforces the **order of initialization at compile time**
  - Compiler helps to prevent illegal test setup

Won't my system get flooded with arguments passed around?

# Smell #2: Lack of Dependency Injection

---

- **Dependency injection** makes your **dependencies explicit**
  - It does not make the dependencies in your code **better** or **worse**
  - It only makes them **visible**
- If there are **too many dependencies**, **do not blame DI!**
  - The dependencies have always been there, DI only showed them to you
- **Dependency injection** enforces the **order of initialization at compile time**
  - Compiler helps to prevent illegal test setup

Won't my system get flooded with arguments passed around?

NO

```
testCharge() {  
    db = new Database(...);  
    queue = new OfflineQueue(db);  
    ccProc = new CreditCardProcessor(queue);  
    CreditCard cc;  
    cc = new CreditCard("1234567890121234", ccProc);  
    cc.charge(100);  
}
```

© Miško Hevery [4]

# Smell #3: Law of Demeter violation

---

## Law of Demeter: “Only talk to your immediate friends”

- If an object needs links to too many objects, there may be something wrong with the object
- Revealed by **Dependency Injection**
- “Our code often smells because we have a **few objects** doing **too much work**, which requires them to **know about too many other objects.**” [Brandon Keepers]
  - A nice rule of thumb is to check if we are able to **describe the purpose** of each class and method without using **AND** and **OR**.



Single Responsibility  
Principle

# Smell #4: Misplaced and Hard Coded new Operator

---

**To avoid misplace**, clearly separate:

- “Code with a whole bunch of **new** operators and no **if** statement”  
= code responsible for **starting and wiring things**, i.e. **Factories**.
- “Code with a whole bunch of **if** statements and no **new** operator”  
= code that is actually **doing something**, i.e. **Services**.

**To avoid hard coding**, make sure that:

- **Constructor only constructs** the object and its dependencies.
  - Doing any **other work** in the constructor can significantly **hinder testing**.
  - You can end up doing unrelated work (e.g. sending emails) every time you need the object in your test.

# Outline of the lecture

---

- Bad code smells for
  - Performance
  - Scalability
  - Reliability
  - Testability
  - Maintainability
- Tactics for
  - Discussed quality attributes
  - Conflicts between them



# Bad code smells for Maintainability

---

- Smell #1: Early Tuning
  - Never compromise code clarity for premature code optimization.
- Smell #2: Super-Flexibility
  - “Flexibility breeds complexity.”
  - Do not shoot for something that is flexible from the early beginning. Shoot for something that is simple and build flexibility upon that.
- Smell #3: Simple = Stupid, Complex = Smart
  - “Too complicated answers are always wrong, no matter what the question was.”
  - Even very smart systems can be based on simple structures. Look at **embedded systems** or **human brain!**

# Outline of the lecture

---

- Bad code smells for
  - Performance
  - Scalability
  - Reliability
  - Testability
  - Maintainability
- Tactics for
  - Discussed quality attributes
  - Conflicts between them





# Tactics for Performance

---

- **Tactic #1: Take a profiler into action**
  - **Do not guess** where the performance problem is. Start your profiler and find the bottlenecks objectively.
  - It helps you to understand what is **happening in the background**.
- **Tactic #2: Examine complexity and frequency of your computations**
  - **Complexity** – Maybe you can do the thing **more efficiently**.
  - **Frequency** – Maybe you can do the thing **less often**.
- **Tactic #3: Concurrency**
  - Only if you **understand all aspects and consequences** of parallel execution.
- **Tactic #4: Control the use of resources**
  - Balance the load, control access, cache, replicate, etc.

# Tactics for Reliability

---

- **Tactic #1: Monitor** what is going on
  - **Acceptance checking** for individual methods and code fragments, **events** collection, **processing** and **logging**.
- **Tactic #2: Handle exceptions** carefully
  - Think twice about exception handling strategy and **responsibilities** inside the system.
- **Tactic #3: Make your system fault tolerant**
  - **Redundancy** and **self-healing**, e.g. seamless rebinding to a new service provider.
- **Tactic #4: Implement restart/recovery** capabilities
  - Redirection to a **filled-in form** when the form submission fails.
  - System **diagnostics** and **clean-up** after major failure.

Note 1: We only care about SW reliability (because this is a Software Quality course), not HW, although HW fault tolerance is a very interesting topic.

Note 2: We assume that we do not deal with an ultra-reliable system. If so, other mechanisms would need to be in place (e.g. n-version programming).

# Tactics for Testability

---

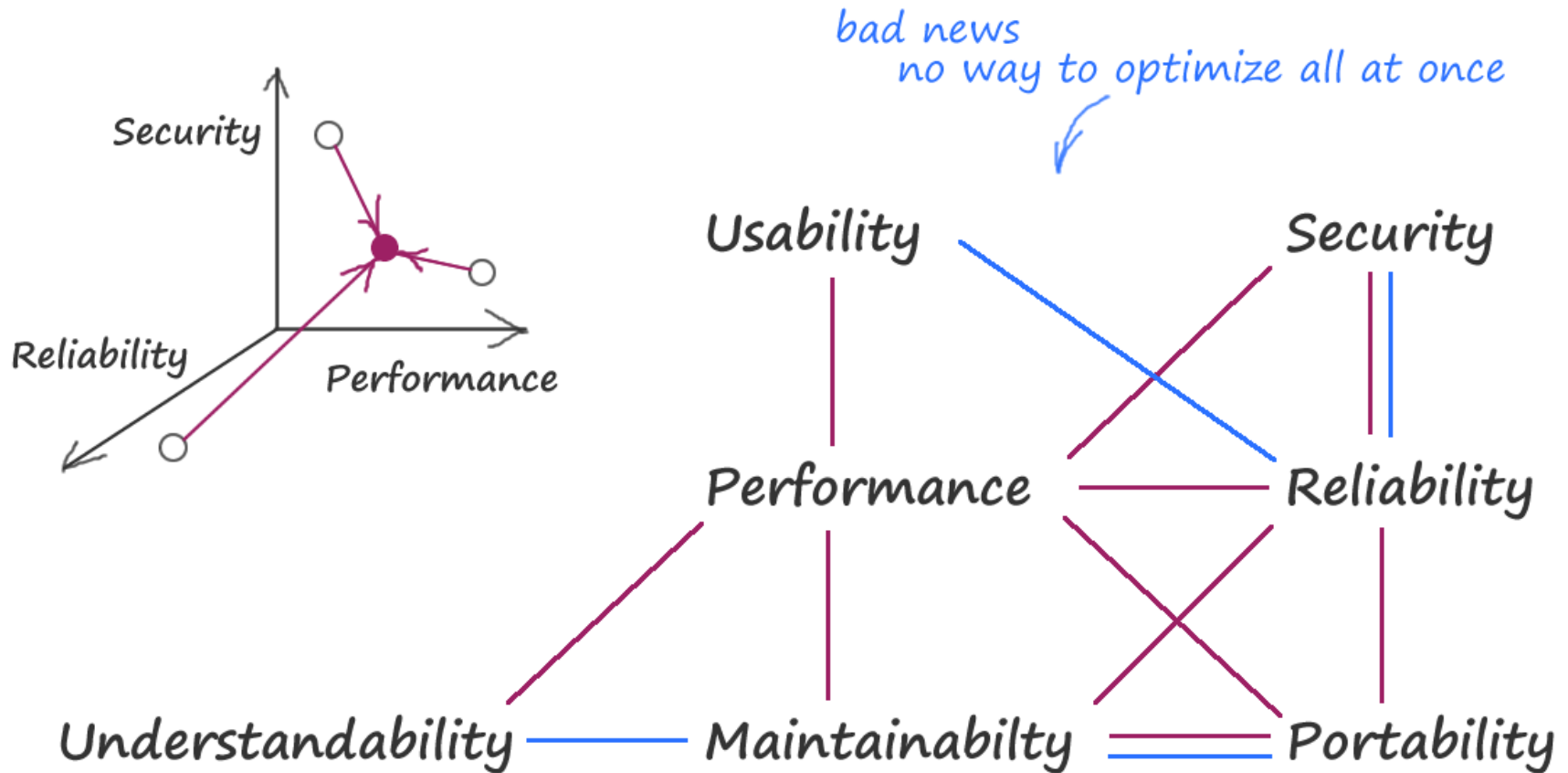
- **Tactic #1: Write CLEAN code**
  - Simplicity matters.
- **Tactic #2: Avoid global state**
  - Including its **hidden** forms.
- **Tactic #3: Separate interfaces from implementation**
  - Make it possible to **exchange implementations** during testing.
- **Tactic #4: Make your dependencies explicit**
  - It makes the life of developers/testers easier, and then even **compiler can help** to inspect it.
- **Tactic #5: Separate factories from business logic**
  - During testing it is important to have **access to each of these parts** without mixing it with the other.

# Tactics for Maintainability

---

- **Tactic #1: Write CLEAN code**
  - “Premature optimization is the root of all evil.”
  - Clean code is not only easier to change, but also easier to optimize (e.g. for performance, scalability).
- **Tactic #2: Get ready for change**
  - “Change is the only constant.”
  - Understand – Interfaces, Inheritance, Polymorphism, Design Patterns.
- **Tactic #3: Design your SW Architecture carefully**
  - Proper modularization of your system is one of the keys for maintainability.
- **Tactic #4: Watch all dependencies**
  - Check – Law of Demeter, High Cohesion, Low Coupling.

# Conflicts between quality attributes



# Takeaways

---

- **Bad Code Smells** apply also to **quality attributes**.
  - They are just **not that easy to Google**.
- **Tactics** in comparison to **Bad Code Smells** are usually defined on a higher level of abstraction.
- Each **tactic for a specific quality** attribute can act as an **anti-pattern** for a different quality attribute.
  - That is where **conflicts** between quality attributes emerge.

Barbora Bůhnová, FI MU Brno

[buhnova@fi.muni.cz](mailto:buhnova@fi.muni.cz)

[www.fi.muni.cz/~buhnova](http://www.fi.muni.cz/~buhnova)

contact me

thanks for listening



# References

---

- [1] Martin Fowler et al. Refactoring: Improving the Design of Existing Code, Addison-Wesley, Mar 2012. ISBN 978-0133065268.
- [2] Patrycja Wegrzynowicz. Automated Refactoring of Performance and Concurrency AntiPatterns. YouTube, Jan 2013. Available at <https://www.youtube.com/watch?v=XLCbb6dcsJQ>.
- [3] Brandon Keepers. Why Our Code Smells. YouTube, June 2012. Available at <https://www.youtube.com/watch?v=JxPKljUkFQw>.
- [4] Miško Hevery. The Clean Code Talks - Global State and Singletons. YouTube, Nov 2008. Available at <https://www.youtube.com/watch?v=-FRm3VPhsel>.
- [5] Miško Hevery. Guide: Writing Testable Code, Google, Nov 2008. Available in the int. syllabus in IS.
- [6] Slava Imeshev. Architecture for Scaling Java Applications to Multiple Servers. YouTube, Aug 2012. Available at <https://www.youtube.com/watch?v=DhKpqGDXRck>.
- [7] Lars Lundberg et al. (editors). Software quality attributes and trade-offs, Blekinge Institute of Technology, June 2005.
- [8] Mikael Svahnberg et al. A Method for Understanding Quality Attributes in Software Architecture Structures. In Proc. of SEKE'02, pages 819-826. ACM New York, 2002. ISBN:1-58113-556-4.
- [9] Michael Feathers. Escaping the Technical Debt Cycle. YouTube, Oct 2014. Available at <https://www.youtube.com/watch?v=7hL6g1aTGvo>.