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Quality Assurance
Coding Principles II

Part II - Lecture 13

Today's Outline

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- Modularity
- Information Hiding

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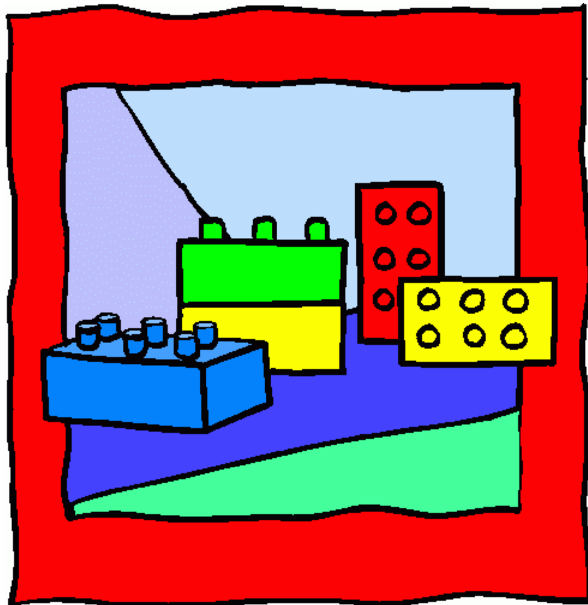
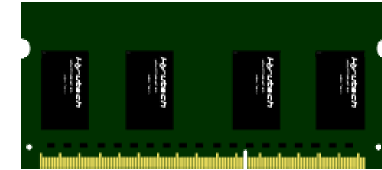
Modularity



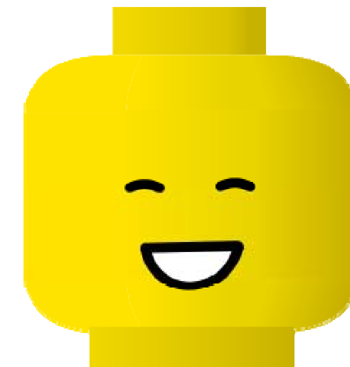
LEGO is not a toy.
It's a way of life.
(Mike Smith)

Modularity

- Complex systems can usually be **divided into simpler pieces** called modules
- **Module:** self-contained component of a system
  - Has a **well-defined interface** to other modules
  - **Separates its interface** from its implementation
  - Usually corresponds to a **set of data types and code**, similar to Java packages



- **Modular systems** (i.e. systems that are composed of modules) are easier to understand, develop and maintain
  - When dealing with a module the details of other modules can be ignored (**separation of concerns**)
  - Modules can be **developed independently**
  - Better **isolation** between modules can prevent failure in one module to cause failure in other modules
  - Modules can be **exchanged** by other modules
  - Modules can be **reused** in several systems



Component Frameworks

- **Component frameworks** support the development and connection of modules
  - Format for specifying module interfaces
  - Functionality for loading, connecting and running modules
- **Module interconnection languages** allow to specify the module interconnections in a system on a high level
  - **Programming-in-the-small**: coding a module
  - **Programming-in-the-large**: assembling a system with modules

Multimedia stream processing

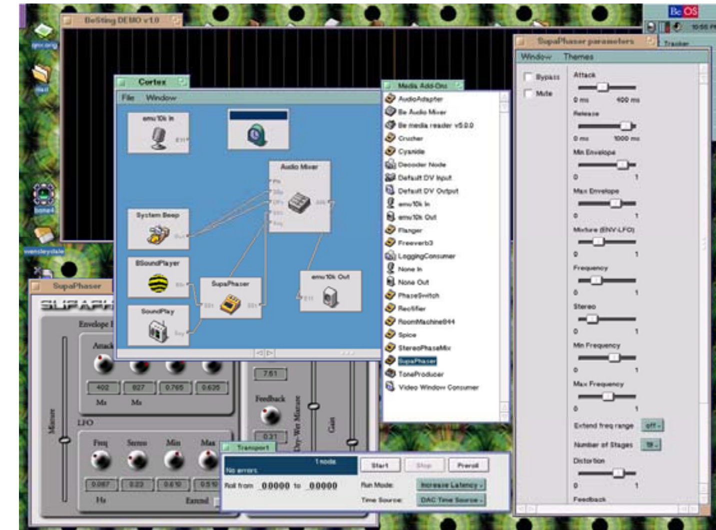
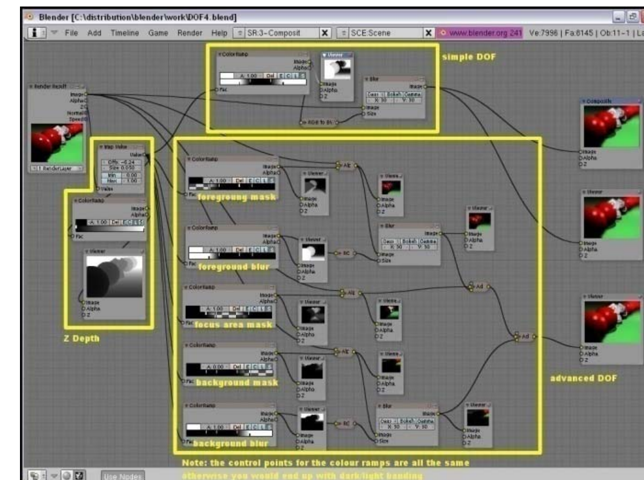


Image processing with Blender



Separation of Concerns

- How to deal with complexity in a system?
- **Separation of concerns** (SoC)
  - Separate issues (break down large problems into pieces) and concentrate on one at a time
  - Break a program into distinct features that overlap in functionality as little as possible
  - **Concern**: a piece of a program, usually a feature or a particular program behavior
- Can be achieved in various ways
  - Traditionally approached through modularity
  - In OO: separate concerns into classes and methods
  - In UIs: separate content from presentation and presentation from application logic
  - Service-Oriented Architecture (SOA): split up functionality into different (web-) services
  - Aspect-Oriented Programming (AOP): separate concerns into "aspects"

Cohesion and Coupling

- Rule for the design of modules: "low coupling, high cohesion"
- A module should be highly cohesive
  - It should form a meaningful, **self-contained unit**
  - The parts in the module **fit and work together** closely
- Between modules there should be low coupling
  - **Little dependencies** between modules
  - A module is independent from the internal implementation of another module
  - Changing the implementation of one module does not require changing other modules
  - The interaction between modules is restricted (through a stable interface)
  - Each module should be understandable without having to understand the details of other modules
- Cohesion and coupling are **usually related**:
  low coupling goes with high cohesion and vice versa
- In OO: less connections between classes (low coupling) if we group related methods of a class together (high cohesion)

Coupling in OO Programming

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Coupling is increased between two classes **A** and **B** if:

- **A** has an attribute that has type **B**
- **A** calls a method of **B**
- **A** has a method which uses **B** (return type, parameter or local var)
- **A** is a subclass of (or implements) **B**

```
class A extends B {
  B b1;
  B m1(B b2) {
    B b3 = b1.m2(b2);
    return b3;
  }
}
```

Disadvantages of high coupling include:

- **Hard to understand** a class in isolation
- Change of one class often **forces changes** in other classes
- **Hard to reuse** or test a class because dependent class must also be available

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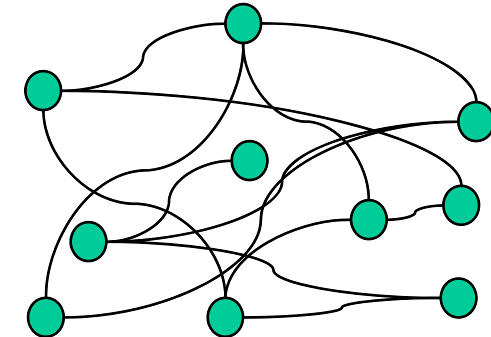
Spaghetti Code vs. Modular System

Spaghetti Code

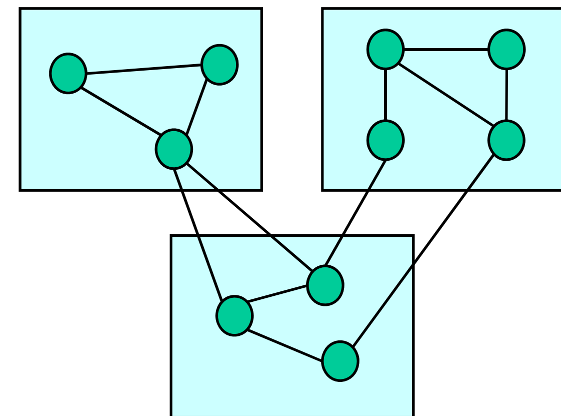
- Haphazard connections, probably grown over time
- No visible cohesive groups
- High coupling: high interaction between random parts
- Understand it all or nothing



10 parts, 13 connections

Modular System

- High cohesion within modules
- Low coupling between modules
- Modules can be understood separately
- Interaction between modules is well-understood and thoroughly specified



10 parts, 13 connections, 3 modules

Layered Architecture

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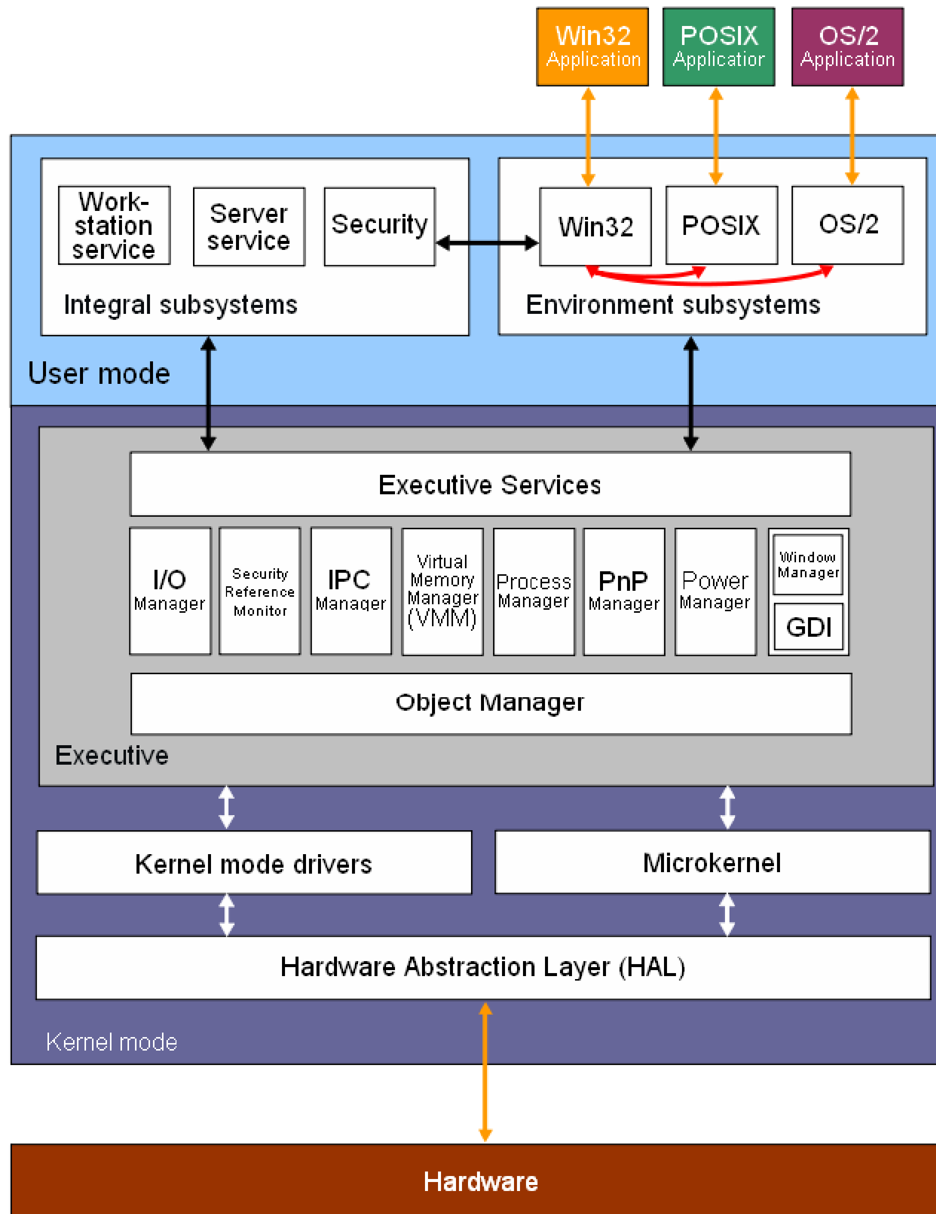

- Example: Windows OS
- Layered architecture:
  - Modules stacked onto each other
  - Often each level can only access the one below it
- Lowest level talks directly to hardware
- The higher, the more abstraction from concrete hardware

Separate Subsystems: Libraries and "Engines"

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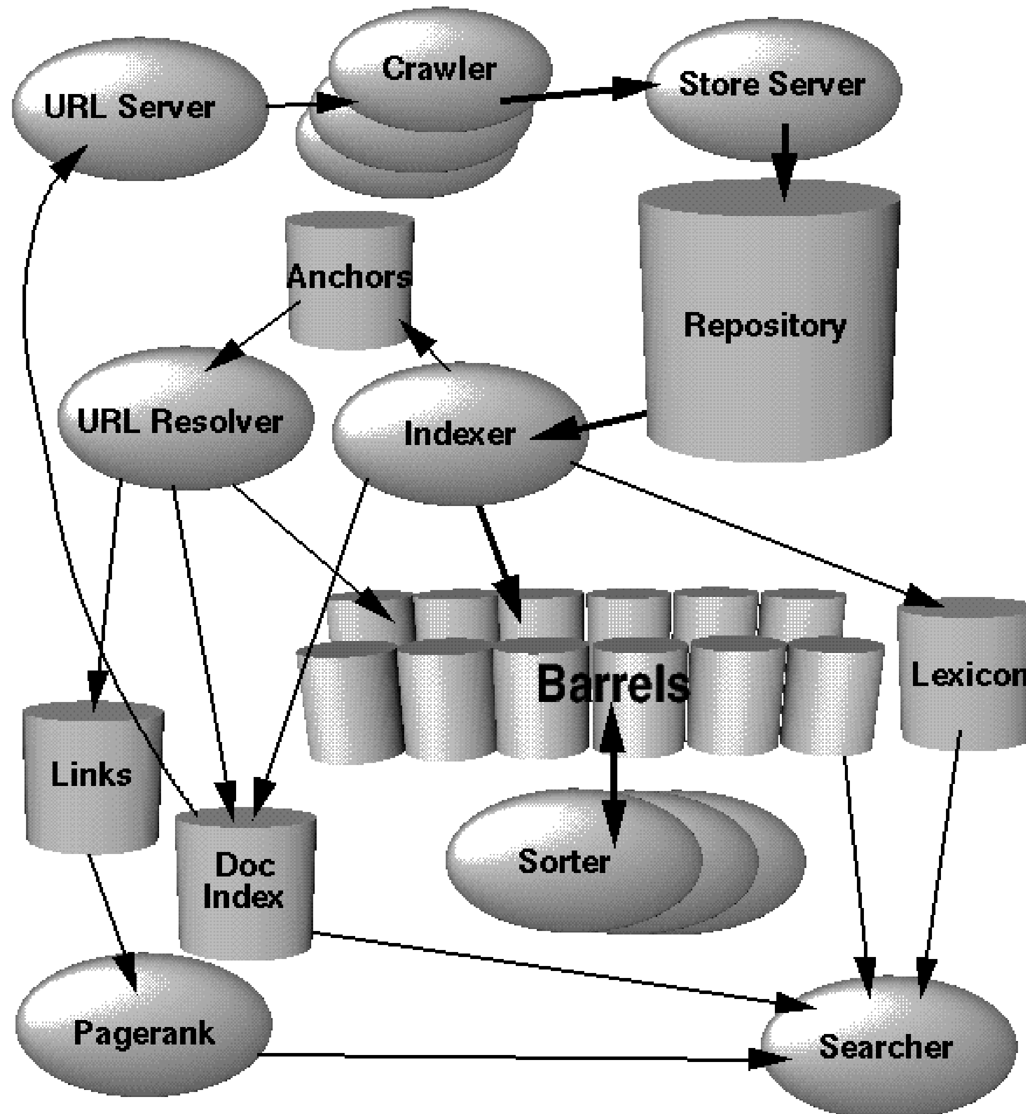
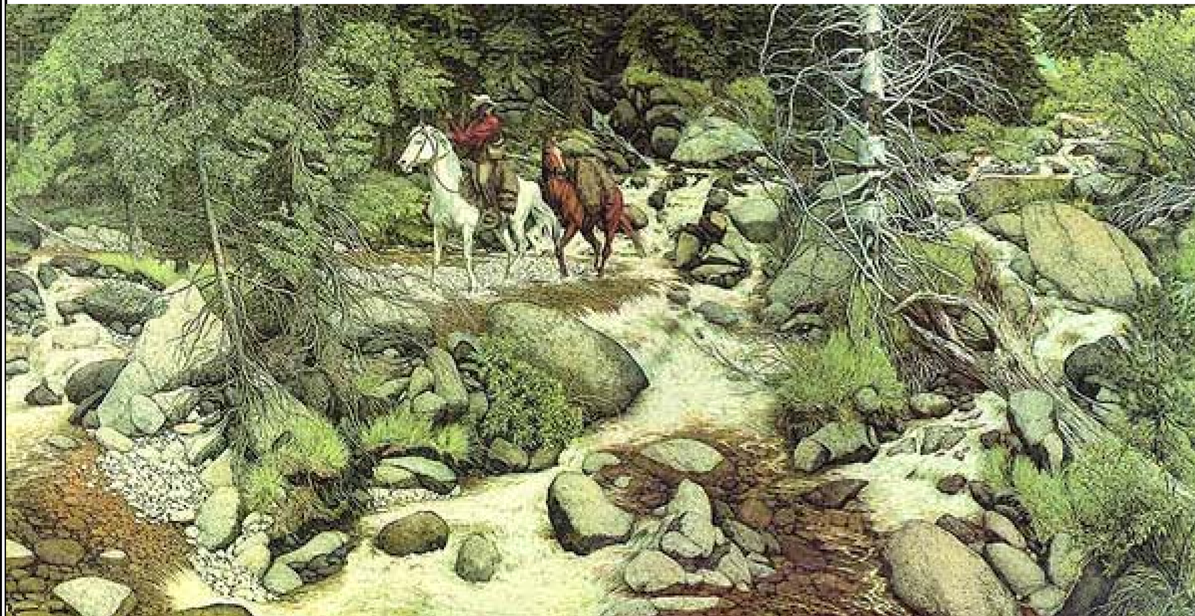
- Example: game
- Common problem: making them work together

Separate Subsystems: Parallel Processes



- Example: Google
- Massive data load requires massive **parallelism**
- Several modules working together concurrently and asynchronously
- Scalable architecture
- Modules can be optimized independently

Information Hiding



Out of sight,
out of mind.

Information Hiding

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- Hide information that does not need to be visible in order to use a class/module/program
- Too much information can be **confusing**: what is important for usage and what not?
- Too much information can lead to undesired **dependencies**
  - If internals are visible & accessible, someone might use/change them (e.g. create a "hack" to use something in an unintended manner)
  - If internals are changed then external code that relies on them might not work anymore
- Allowing only restricted access gives us more **flexibility**
  - Class/module/program can be (ex)changed without breaking other parts
  - Many design decisions can be hidden and the system design can evolve without collapsing

Scope

- Where we declare a variable determines where it can be accessed (i.e. its scope)
- Scope of instance variables > scope of local variables in methods > scope of local variables in statement blocks
- The scope of a variable should be **as small as possible**
- If a variable can be accessed where it should not be accessed: confusion and mistakes

```
class C {
  public int x;
  private int y;
  private int z;
  void m() {
    y = 0;
    for(z=0; z<10; z++)
      y += z;
    return y;
} }
```

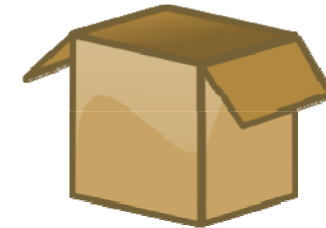
```
class C {
  public int x;


  void m() {
    int y = 0;
    for(int z=0; z<10; z++)
      y += z;
    return y;
} }
```

Access Modifiers

Can be used to control access to groups of parts

1. **`public:`**
   accessible everywhere



2. **`protected`** or no modifier (“default”):
   accessible in the same package

3. **`private`**:
   only accessible from within the class
   in which they are declared

General rule: expose parts only if necessary (same as for scope)

Limitations of access modifiers:

- Only for pre-defined groups
- Access rights only depend on **who** (what other class) wants access, not how they actually need to use it (e.g. only 1 method)

The Concept of Interfaces

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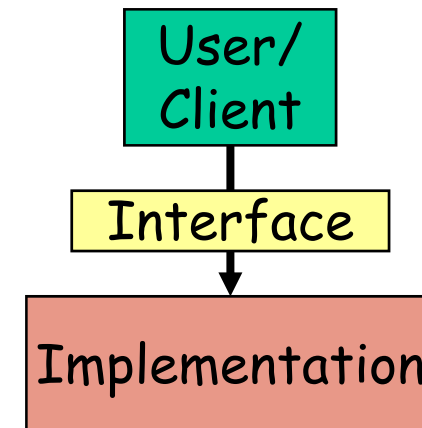
There are different kinds of interfaces

- **User Interfaces**
  - Not just for software: any kind of tool
  - Usually it may change, sometimes it must not change
- **APIs**: important for programs that use them
- **Java `interfaces`**: important for classes that use other classes through them

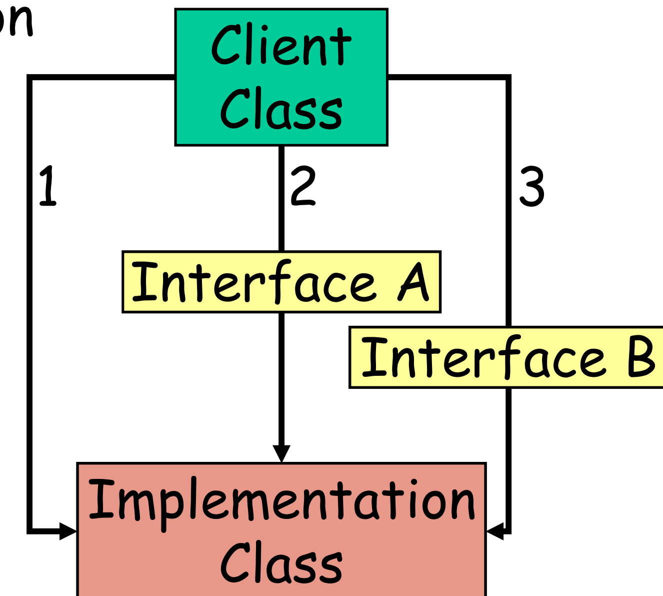
The intention is always the same:

- The interface defines and restricts **how** something can be used
- Users/clients perform operations only through the interface
- If the internal implementation changes, the users/clients do not have to change



Java Interfaces

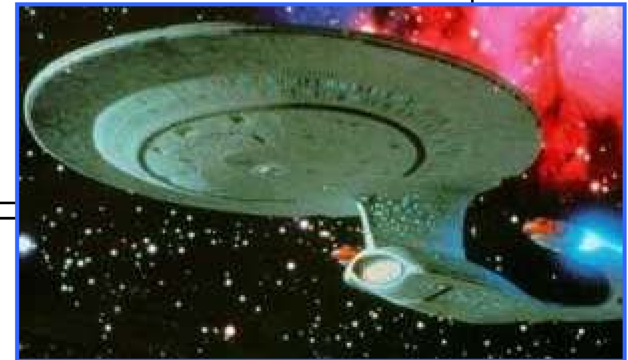
- Access modifiers can only control access depending on **who** uses a class/method/field
- With interfaces we can restrict access in a more flexible manner:
  - A class can implement several interfaces
  - Use a different interface depending on
    - **who** uses it (which other class)
    - **what** it is used for
- However: often using interfaces vs. accessing a class directly is a conscious decision
  - Programmers need to know that they should use interfaces
  - Programmers need to know which interfaces to use



1 or 2 or 3 ?

Interfaces Example

```
public class USSEnterprise
 implements Maintenance, SafeControl, FullControl {
   public void navigate(Point dest) { … }
   public void warpJump(Point dest) { … }
   public int checkSystems() { … }
   public void selfDestruct() { … }
}
```



```
interface Maintenance {
   public int checkSystems();
}
```

```
interface SafeControl extends Maintenance {
   public void navigate(Point dest);
   public void warpJump(Point dest);
}
```

```
interface FullControl extends SafeControl {
   public void selfDestruct();
}
```

Interfaces Example

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Scotty accessing the system:

```
Maintenance e = new USSEnterprise();
int status = e.checkSystems();
```

Spock accessing the system:

```
SafeControl e = new USSEnterprise();
e.warpJump(new Point(103, 789));
e.selfDestruct();
```

Borg accessing the system:

```
USSEnterprise e = new USSEnterprise();
e.selfDestruct();   // Boooom!
```

Access can be safely restricted by accessing through an appropriate interface.

- Choose an appropriate interface to access a class
- Accessing a class directly may lead to dependencies and other mistakes that could have been detected by the compiler

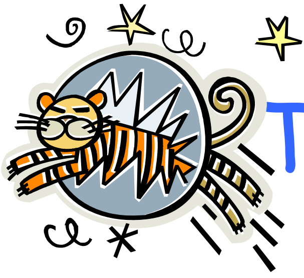
Enforcing Usage of Interfaces with Factories


```
protected class USSEnterprise
 implements Maintenance, SafeControl, FullControl {
   protected USSEnterprise() {}   ...    }
```

```
public class EnterpriseFactory {
   public static Maintenance getMaintenance() {
     return (Maintenance) new USSEnterprise();
   }
   public static FullControl getFullControl(String pw) {
     if(pw.equals("please"))
       return (FullControl) new USSEnterprise();
     else throw new RuntimeException("Alarm!!!");
   }
   // similar for SafeControl
}
```

Now access only possible through interfaces:

```
Maintenance e = EnterpriseFactory.getMaintenance();
int status = e.checkSystems();
```



Today's Summary

- **Modularity** means that a system is composed of self-contained parts (modules) with well-defined interfaces
  - Can be achieved by "**separation of concerns**"
  - Rule of thumb: "**low coupling, high cohesion**"
- **Information hiding** means that only the information is visible that is actually necessary to use something
  - Access is only possible through well-specified **interface**
  - Implementation **internals are hidden** and can be (ex)changed without breaking the system

Quiz

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1. What advantages do modular systems offer?
2. Why do we want modules to be lowly coupled?
3. What is the purpose of interfaces?