Originality is Overrated: OO Design Principles

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Lecture Goals

- Review material from Chapter 8 of the OO A&D textbook
  - Object-Oriented Design Principles
    - Open-Closed Principle
    - Don’t Repeat Yourself
    - Single Responsiblity Principle
    - Liskov Substitution Principle
    - Aggregation and Composition, Revisited
  - Discuss the examples in Chapter 8
  - Emphasize the OO concepts and techniques encountered in Chapter 8

Originality is Overrated

- Corollary: “Only Steal from the Best” — various sources
- OO A&D has been performed in various forms and in various contexts for nearly 40 years
  - Over that time, designers have developed a set of principles that ease the task of creating OO designs
  - If you apply these principles in your own code, you will be “stealing” from the best that the OO A&D community has to offer
    - The same is true of Design Patterns

OO Principles: What We've Seen So Far

- We've seen the following principles in action over the past eight lectures
  - **Classes are about behavior**
    - Emphasize the behavior of classes over the data of classes
      - Don't subclass, for instance, for data-related reasons
  - **Encapsulate what varies**
    - Provides info. hiding, limits impact of change, increases cohesion
  - **One reason to change**
    - Limits impact of change, increases cohesion
  - **Code to an Interface**
    - Promotes flexible AND extensible code
      - Code applies across broad set of classes, subclasses can be added in a straightforward fashion (including at run-time)

New Principles

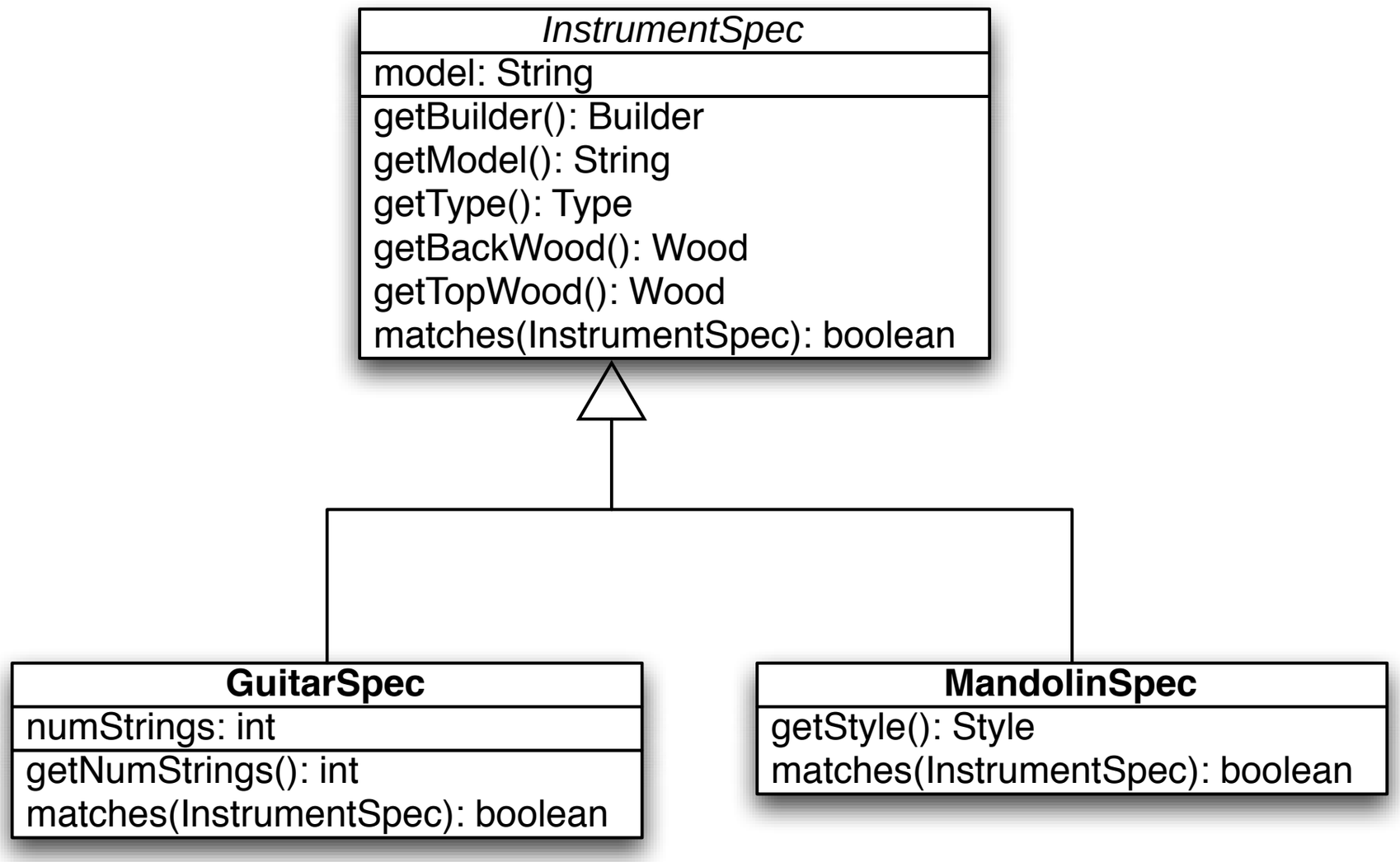
- Open-Closed Principle (OCP)
  - Classes should be open for extension and closed for modification
- Don’t Repeat Yourself (DRY)
  - Avoid duplicate code by abstracting out things that are common and placing those things in a single location
- Single Responsibility Principle (SRP)
  - Every object in your system should have a single responsibility, and all the object’s services should be focused on carrying it out
- Liskov Substitution Principle (LSP)
  - Subtypes must be substitutable for their base types

Open-Closed Principle

- Classes should be open for extension and closed for modification
- Basic Idea:
  - Prevent, or heavily discourage, changes to the behavior of existing classes
    - especially classes that exist near the root of an inheritance hierarchy
  - If a change is required, create a subclass and allow it to extend/override the original behavior
    - This means you must carefully design what methods are made public and protected in these classes; private methods cannot be extended
- Why is this important?
  - Limits impact on code that follows “Code to an Interface” principle
    - If you change the behavior of an existing class, a lot of client code may need to be updated

Example

- We've seen one example of the Open-Closed Principle in action
  - InstrumentSpec.matches() being extended by GuitarSpec and MandolinSpec

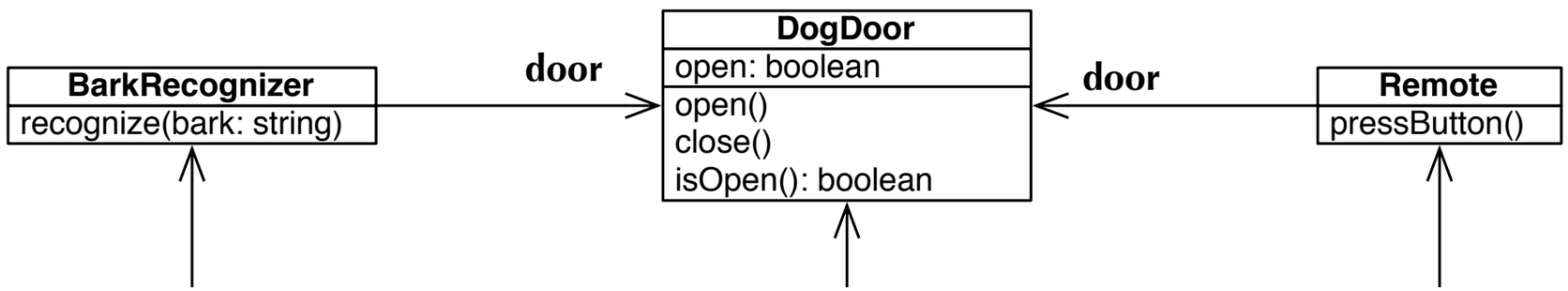


Don’t Repeat Yourself

- Avoid duplicate code by abstracting out things that are common and placing those things in a single location
- Basic Idea
  - Duplication is Bad!
  - At all levels of software engineering: Analysis, Design, Code, and Test
- We want to avoid duplication in our requirements, use cases, feature lists, etc.
- We want to avoid duplication of responsibilities in our code
- We want to avoid duplication of test coverage in our tests
- Why?
  - Incremental errors that can creep into a system, when one copy is changed but the others are not
  - Isolation of Change Requests: We want to go to ONE place when responding to a change request

Example (I)

- Duplication of Code: Closing the Door in Chapter 2



  - We had the responsibility for closing the door automatically in our “dog door” example originally living in the RemoteControl Class.
  - When we added a BarkRecognizer Class to the system, it opened the door automatically but failed to close the door
    - We could have placed a copy of the code to automatically close the door in BarkRecognizer but that would have violated the DRY principle
  - Instead, we moved the responsibility to the shared Door class

Example (II)

- DRY is really about ONE requirement in ONE place
  - We want each responsibility of the system to live in a single, sensible place
- New Requirements for the Dog Door System: Beware of Duplicates
  - The dog door should alert the owner when something inside the house gets too close to the dog door
  - The dog door will open only during certain hours of the day
  - The dog door will be integrated into the house's alarm system to make sure it doesn't activate when the dog door is open
  - The dog door should make a noise if the door cannot open because of a blockage outside
  - The dog door will track how many times the dog uses the door
  - When the door closes, the house alarm will re-arm if it was active before the door opened

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- Duplicates Removed!

Example (IV)

- Ruby on Rails makes use of DRY as a core part of its design
  - focused configuration files; no duplication of information
  - for each request, often single controller, single model update, single view
- But, prior to Ruby on Rails 1.2, there was duplication hiding in the URLs used by Rails applications
  - `POST /people/create  # create a new person`
  - `GET /people/show/1  # show person with id 1`
  - `POST /people/update/1  # edit person with id 1`
  - `POST /people/destroy/1 # delete person with id 1`

Example (V)

- The duplication exists between the HTTP method name and the operation name in the URL
  - `POST /people/create`
- Recently, there has been a movement to make use of the four major “verbs” of HTTP
  - POST == create information (create)
  - GET == retrieve information (read)
  - PUT == update information (update)
  - DELETE == destroy information (destroy)
- These verbs mirror the CRUD operations found in databases
  - Thus, saying “create” in the URL above is a duplication

Example (VI)

- In version 1.2, Rails eliminates this duplication for something called "resources"
- Now URLs look like this:
  - POST /people
  - GET /people/1
  - PUT /people/1
  - DELETE /people/1
- And the duplication is **logically** eliminated
  - Disclaimer: … but not actually eliminated… Web servers do not universally support PUT and DELETE "out of the box". As a result, Rails uses POST
    - POST /people/1
      Post-Semantics: Delete

Single Responsibility Principle

- Every object in your system should have a single responsibility, and all the object's services should be focused on carrying it out
  - This is obviously related to the "One Reason to Change" principle
  - If you have implemented SRP correctly, then each class will have only one reason to change
- The "single responsibility" doesn't have to be "small", it might be, for instance, "manage units" in Gary's Game System Framework
- We've encountered SRP before
  - SRP == high cohesion
  - "One Reason To Change" **promotes** SRP
  - DRY is often used to achieve SRP

Return to Textual Analysis

- One way of identifying high cohesion in a system is to do the following
  - For each class C
    - For each method M
      - Write “The C Ms itself”
  - Examples
    - The Automobile drives itself
    - The Automobile washes itself
    - The Automobile starts itself
- If any one of these sentences doesn’t make sense then investigate further. You may have discovered a service that belongs to a different responsibility of the system and should be moved to a different class
  - This may require first creating a new class before performing the move

SRP in Action

- We've seen SRP used in several places over the last eight lectures
  - Automatically closing the door in the dog door example
  - InstrumentSpec handling all instrument-related properties in Rick's Guitars
  - Instrument handling all inventory-related properties in Rick's Guitars
  - Board handling board-releated services in the Game System Framework
  - Unit handling all property-related functionality in the Game System Framework
- Essentially any time we've seen a highly cohesive class!

Liskov Substitution Principle

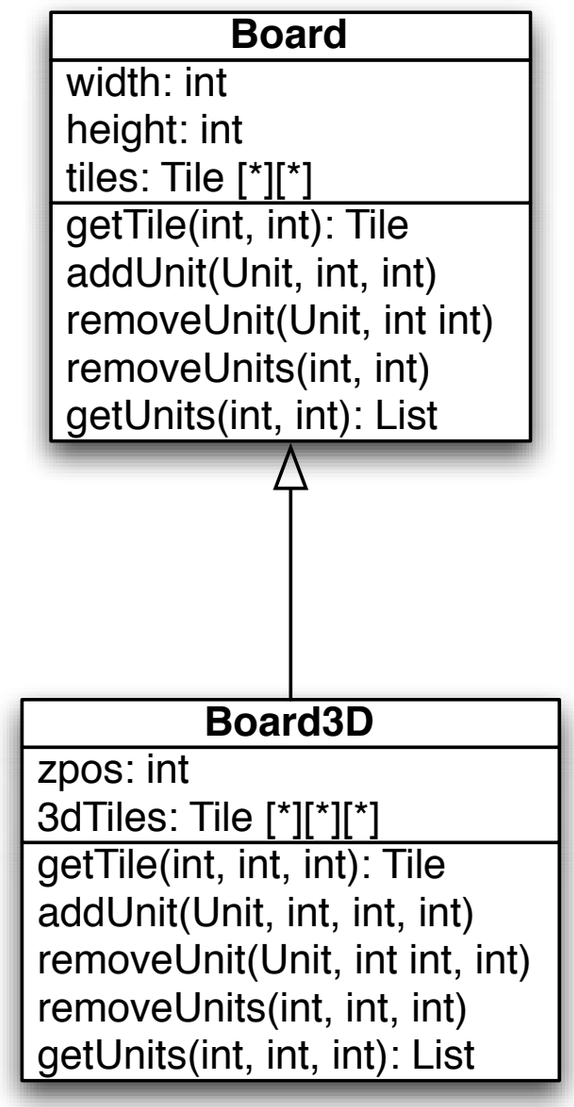
- Subtypes must be substitutable for their base types
- Basic Idea
  - Instances of subclasses do not violate the behaviors exhibited by instances of their superclasses
    - They may constrain that behavior but they do not **contradict** that behavior
- Named after Barbara Liskov who co-authored a paper with Jeannette Wing in 1993 entitled ***Family Values: A Behavioral Notion of Subtyping***
  - *Let q(x) be a property provable about objects x of type T. Then q(y) should be true for objects y of type S where S is a subtype of T.*
- Properties that hold on superclass objects, hold on subclass objects
  - **Return to Rectangle/Square**: *WidthAndHeightMayBeDifferent(Rectangle)* equals true for Rectangles and equals false for Square

Well-Designed Inheritance

- LSP is about well-designed inheritance
  - When I put an instance of a subclass in a place where I normally place an instance of its superclass
    - the functionality of the system must remain **correct**
    - (not necessarily the **same**, but correct)

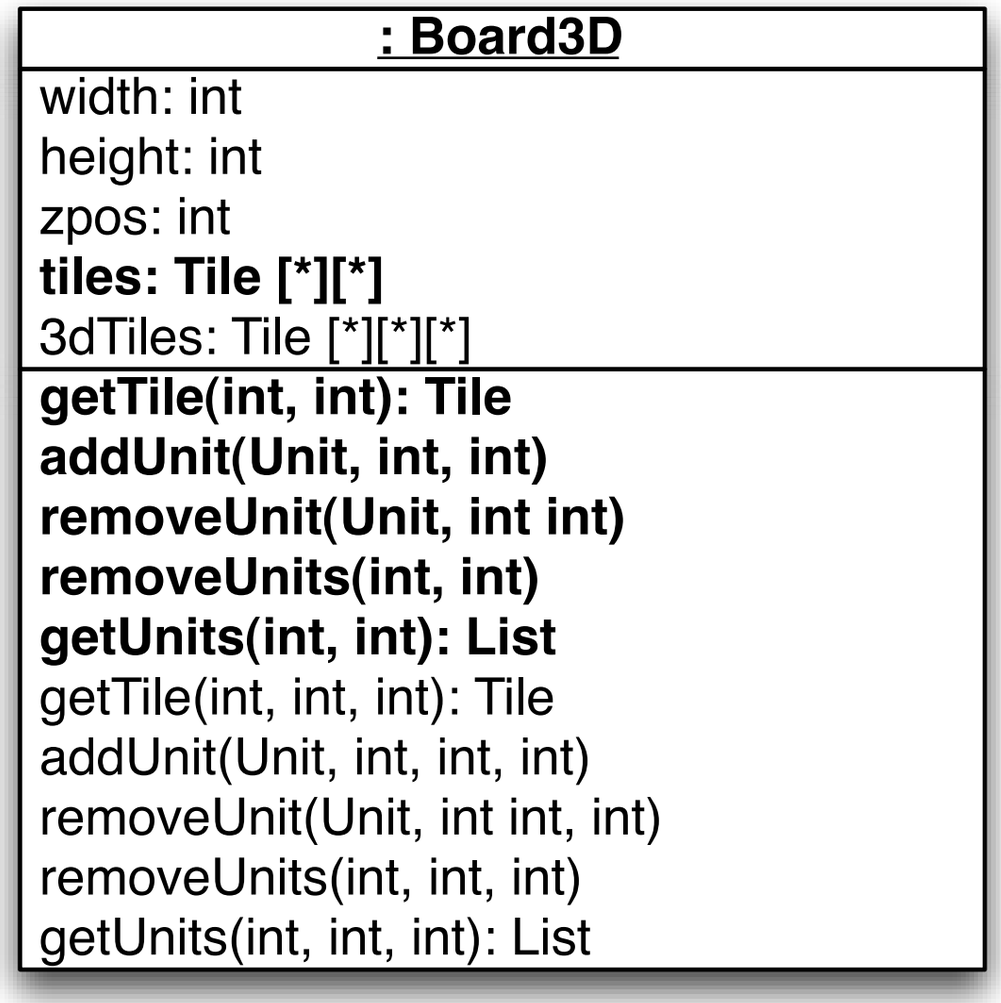
Bad Example (I)

- The book provides an example of misusing inheritance (and violating the LSP)
  - Extend Board to produce Board3D



Bad Example (II)

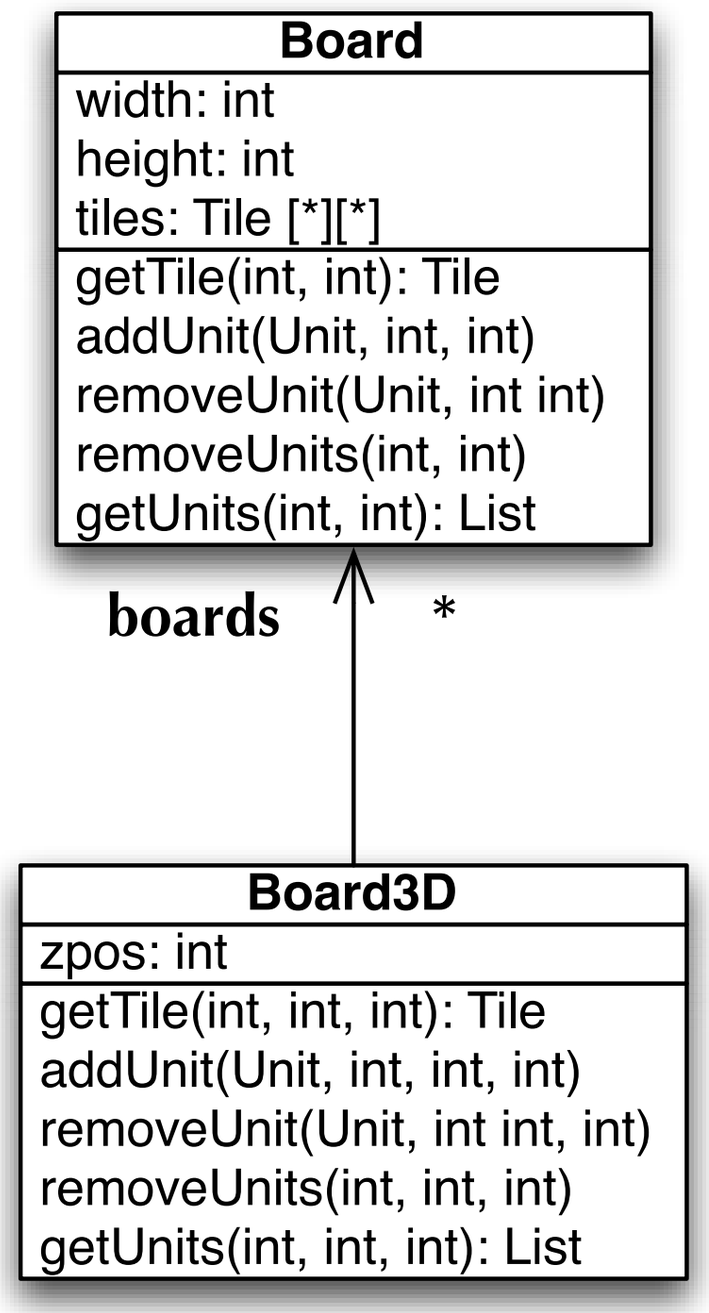
- But this means that an instance of Board3D looks like this:
  - Each attribute and method in bold is meaningless in this object
  - Board3D is getting nothing useful from Board except for width and height!!
  - We certainly could NOT create a Board3D object and hand it to code expecting a Board object!
  - As a result, this design violates the LSP principle
  - How to fix?



Delegation to the Rescue! (Again)

- You can understand why the Game System Framework thought they could extend Board when creating Board3D
  - Board has a lot of useful functionality and a Board3D should try to reuse that functionality as much as possible
  - However, the Board3D has no need to CHANGE that functionality and the Board3D doesn't really behave in the same way as a board
    - For instance, a unit on "level 10" may be able to attack a unit on "level 1"; such functionality doesn't make sense in the context of a 2D board
- Thus, if you need to use functionality in another class, but you don't want to change that functionality, consider using **delegation** instead of inheritance
  - Inheritance was simply the wrong way to gain access to the Board's functionality
  - Delegation is when you hand over the responsibility for a particular task to some other class or method

New Class Diagram



Board3D now maintains a list of Board objects for each legal value of “zpos”

It then delegates to the Board object to handle the requested service

```
public Tile getTile(int x, int y, int z) {
    Board b = boards.get(z);
    return b.getTile(x,y);
}
```

Note: book gets UML diagram wrong on page 405. The “3dTiles: Tile [*][*][*] attribute is eliminated with this new design

Another Take on Composition

- The book defines composition as
  - Composition allows you to use behavior from a family of classes, and to change that behavior at runtime
    - Their definition is essentially equivalent to the Strategy design pattern
- Delegation is useful when the behavior of the object you're delegating to never changes
  - Delegation is still used in composition, but the object that you are delegation to can change at run-time
- Example: Unit and Weapon
  - A unit can invoke the attack() method on its Weapon; as the game progresses, the unit may switch among different weapons at will
  - The unit is composing its "attack behavior" out of a number of Weapon instances; existence dependency applies; delete unit ⇒ delete weapons

Another Take on Aggregation

- In composition, the object composed of other behaviors owns those behaviors. When the object is destroyed, so are all of its behaviors
  - The behaviors in a composition do not exist outside of the composition itself
- If this is not what you want, then use aggregation: composition without the abrupt ending
  - Aggregation is when one class is used as part of another class, but still exists outside of that other class
  - The book uses an example of a Unit that can arrive at a building and leave its weapons there in storage, the relationship between Unit and Weapon is now an aggregation

Implication: Use Inheritance Sparingly

- Delegation, composition, and aggregation all offer alternatives to inheritance when you need to reuse the behavior of another class
  - Only use inheritance when
    - an IS-A relationship exists between the superclass and the subclass
    - AND the subclass behaves like a superclass (i.e. maintains the properties of the superclass in its behavior)
- If you favor delegation, composition, and aggregation **over** inheritance, your software will usually be more flexible and easier to maintain, extend, and reuse
  - This was the subject of a religious war during the 90s
    - Unlike “emacs vs. vi”, the war is over and delegation won!

Wrapping Up

- We've added four new OO principles to our toolkit
  - Apply these principles and you'll see a marked increase in the flexibility and extensibility of your OO designs
  - Indeed, one of the "secrets" of design patterns is that they invariably lead to code that exhibit these principles
- We've also seen that inheritance is a tool to be used sparingly
  - Favor delegation, composition, and aggregation to gain run-time flexibility
  - Use inheritance when the subclass's semantics and behavior fit neatly with its superclass

Coming Up Next

- Lecture 14: Testing And Iterating
  - Read Chapter 9 of the OO A&D book
- Lecture 15: Putting It All Together
  - Read Chapter 10 of the OO A&D book