MORE DESIGN TECHNIQUES
CSCI 4448/5448: OBJECT-ORIENTED ANALYSIS & DESIGN
LECTURE 23 — 04/05/2011
Goals of the Lecture

- Cover the material in Chapters 15 & 16 of our textbook
  - Commonality and Variability Analysis
  - The Analysis Matrix
- And, jump ahead and cover a design pattern
  - Decorator from Chapter 17
- But first, another quick example of the power of delegation and the Delegate pattern (UITableView)
Use the Lessons

- You may not always be able to use design patterns in your designs.
- You can however apply the lessons learned from studying design patterns in ALL of your designs.
- For instance, you can apply a technique known as commonality and variability analysis to identify variation in your problem domains.
- You can then use design pattern principles to encapsulate that variation and protect your software from potential changes.
Examine the Problem Domain (I)

- One key aspect of design is identifying what elements of the problem domain belong in your solution domain.

- You need to identify the right things to model (or track) in your software.

- You want to do this as accurately as possible because the next step is to identify the relationships between those concepts.

- Once you have the relationships defined, changes to the design become more difficult.
Examine the Problem Domain (II)

- Once you have concepts and relationships defined, inserting new concepts and relationships is less easy
  - You have to decide where the new concepts “fit” and how they will be integrated into the existing design
  - Existing relationships may change or be removed and new ones will be inserted
  - This is why maintenance is so hard, when you are asked to change existing functionality or add new functionality, you must deal with the web of concepts and relationships that already exist in the system
Use Commonality and Variability Analysis

- Commonality and Variability Analysis attempts to identify the commonalities (generic concepts) and variations (concrete implementations) in a problem domain.

- Such analysis will produce the abstract base classes that can be used to interface with the concrete implementations in a generic way that will enable abstraction, type encapsulation and polymorphism.

- Our authors demonstrate/explain the technique by example by applying it to the CAD/CAM problem.
Applying CVA to CAD/CAM

- The CAD/CAM problem consists of
  - Version 1 and Version 2 of the CAD/CAM System
  - Slots, holes, cutouts, etc.
  - Version 1 Models and Version 2 Models
- These are concrete variations of generic concepts
- CAD/CAM system, Feature, Model
- Generically: Commonality C has variations a, b, c
Another technique

- Take any 2 elements of the problem domain
  - And ask
    - Is one of these a variation of the other?
    - Are both of these a variation of something else?
  - Iterate until you start to converge on the commonalities
    - Each with their associated variations
      - which are just concrete elements of the domain
Potential Problem (I)

- Each commonality should be based on one issue
  - Beware collapsing two or more issues into a concept
- For the CAD/CAM domain, you might do something like
  - CAD/CAM Features
    - V1Slot, V2Slot, V1Cutout, V2Cutout
  - Here you have collapsed “feature” and “version” into a single concept
Potential Problem (II)

- What you need is
  - CAD/CAM System
    - V1 and V2 (versions)
  - Feature
    - Slots, cutouts, holes, etc.
- Now you have one issue per concept
- and this will lead to cohesive designs
Translating to Classes

Model
  V1Model
  V2Model

System
  V1System
  V2System

Feature
  Slot
  Special
    Cutout
    Hole
    Irregular
Identify Relationships

- If you are confident that you have identified the major concepts of the domain and their variations, you are then ready to identify the relationships that exist between them.

- Models are aggregations of Features.

- Models are generated from a CAD/CAM System.

- Features are generated from a CAD/CAM System.

- We’ll represent “is generated from” as a uses relationship, since it is conceivable that once these concepts are instantiated, they access the CAD system from time to time.
Translating to Class Diagram

Model

V1Model  V2Model

Feature

Slot  Special

Cutout  Hole  Irregular

System

V1System  V2System

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Tuesday, April 5, 2011
Reflect on the Variations

- We have a duplication in the current design
  - V1 Model and V2 Model
- AND
  - V1 System and V2 System

We can remove this duplication by deciding that a model produced by V1 will have features that are different than a model produced by V2 and so we can get by with just the variation in the CAD/CAM system.
Updated Class Diagram

Model

Feature

System

V1System

V2System

Slot

Special

Cutout

Hole

Irregular
Connect to the Actual Systems

- We must now connect this design to the actual CAD/CAM Systems
  - CAD/CAM Version 1 has the C API
  - CAD/CAM Version 2 has the OO API
Updated Class Diagram

- Model
- System
- Feature
  - Slot
  - Special
    - Cutout
    - Hole
    - Irregular
  - V1System
  - V2System
    - V1Modules
    - OOGFeature
    - OOGCutout

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Compare with Previous Design

- Model
- Feature
- FeatureImpl
- Slot
- Hole
- Special
- V1Impl
- V2Impl
- V1Facade
- OOGFeature
- V1 C API
Comparison with Design Pattern Approach (I)

- CVA produced a design that is similar to the design we created in Lecture 21 using an approach that was driven by design patterns.
  - Identify patterns that provide context for other patterns.
- The two approaches are synergistic and can be used in tandem.
  - Design Patterns establish relationships between entities in the problem domain.
  - CVA identifies entities in the problem domain and whether one entity is a variation of another.
Comparison with Design Pattern Approach (II)

- The difference is that CVA can be used in all design contexts
- whereas the design pattern approach requires that you know of design patterns that match the relationships found in the problem domain
Another Technique: Analysis Matrix

- Chapter 16 presents another design technique known as the Analysis Matrix to help designers deal with large amounts of variations in a problem domain.
- Uses an e-commerce system example in which packages must be shipped to customers in response to orders where different rules become active depending on the countries involved in the order.
Variations

- Real world domains have a lot of variations
  - Patients always check in to a hospital before they are admitted
    - UNLESS it is an emergency
      - IN WHICH CASE they go to the emergency room to get stabilized and
        - THEN get admitted to the hospital
          - (IF REQUIRED)
Just like in CVA, Find Concepts

- When dealing with lots of variations, you still ask the question
  - what concept is this “thing” a variation of

- To organize this work, you create a matrix
  - a concept becomes a “row header”
  - a variation is an entry in the matrix
  - related variations go into a column
    - and the column header groups the variations by a particular scenario relevant to the problem domain
Requirements are the Input

- The input to this process are the requirements gathered from the customer
- For the e-commerce system, we might have reqs like:
  - Calculate shipping based on the country
  - In the US, state and local taxes apply to the orders
  - In Canada, use GST and PST for tax
  - Use U.S. postal rules to verify addresses
  - ...

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## Organize by Matrix

<table>
<thead>
<tr>
<th></th>
<th>U.S. Orders</th>
<th>Canadian Orders</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Calculate Freight</strong></td>
<td><strong>Use U.S. Postal Rates</strong></td>
<td><strong>Use Canadian Rates</strong></td>
</tr>
<tr>
<td><strong>Verify Addresses</strong></td>
<td><strong>Use U.S. Postal Rules</strong></td>
<td><strong>Use Canadian Rules</strong></td>
</tr>
<tr>
<td><strong>Calculate Taxes</strong></td>
<td><strong>Use State and Local Tax Rates</strong></td>
<td><strong>Use GST and PST</strong></td>
</tr>
<tr>
<td><strong>Money</strong></td>
<td><strong>U.S. Dollars</strong></td>
<td><strong>Canadian Dollars</strong></td>
</tr>
</tbody>
</table>
## Organize by Matrix

<table>
<thead>
<tr>
<th></th>
<th><strong>U.S. Orders</strong></th>
<th><strong>Canadian Orders</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Calculate Freight</strong></td>
<td><img src="concrete.png" alt="Concrete Implementations of Shipping Rates" /></td>
<td><img src="concrete.png" alt="Concrete Implementations of Shipping Rates" /></td>
</tr>
<tr>
<td><strong>Verify Addresses</strong></td>
<td><img src="concrete.png" alt="Concrete Implementations of Postal Rules" /></td>
<td><img src="concrete.png" alt="Concrete Implementations of Postal Rules" /></td>
</tr>
<tr>
<td><strong>Calculate Taxes</strong></td>
<td><img src="concrete.png" alt="Concrete Implementations of Tax Rules" /></td>
<td><img src="concrete.png" alt="Concrete Implementations of Tax Rules" /></td>
</tr>
<tr>
<td><strong>Money</strong></td>
<td><img src="generic.png" alt="Generic Class that Handles Currencies" /></td>
<td><img src="generic.png" alt="Generic Class that Handles Currencies" /></td>
</tr>
</tbody>
</table>
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<th></th>
<th>U.S. Orders</th>
<th>Canadian Orders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculate Freight</td>
<td>STRATEGY PATTERN</td>
<td></td>
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<tr>
<td>Verify Addresses</td>
<td>STRATEGY PATTERN</td>
<td></td>
</tr>
<tr>
<td>Calculate Taxes</td>
<td>STRATEGY PATTERN</td>
<td></td>
</tr>
<tr>
<td>Money</td>
<td>GENERIC CLASS THAT HANDLES CURRENCIES</td>
<td></td>
</tr>
</tbody>
</table>

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Organize by Matrix

<table>
<thead>
<tr>
<th></th>
<th>U.S. Orders</th>
<th>Canadian Orders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculate Freight</td>
<td>THESE IMPLEMENTATIONS ARE USED WHEN WE HAVE A U.S. CUSTOMER</td>
<td>THESE IMPLEMENTATIONS ARE USED WHEN WE HAVE A CANADIAN CUSTOMER</td>
</tr>
<tr>
<td>Verify Addresses</td>
<td></td>
<td></td>
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<tr>
<td>Calculate Taxes</td>
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<td>Money</td>
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</table>
### Organize by Matrix

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<tr>
<th></th>
<th>U.S. Orders</th>
<th>Canadian Orders</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Calculate Freight</strong></td>
<td>ABSTRACT FACTORY</td>
<td>ABSTRACT FACTORY</td>
</tr>
<tr>
<td><strong>Verify Addresses</strong></td>
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<td></td>
</tr>
<tr>
<td><strong>Calculate Taxes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Money</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Discussion (I)

- This technique gets more useful as the matrix gets bigger
  - If you have requirements for a new scenario that adds an additional row (concept) that you have not previously considered
    - this indicates that your previous scenarios were incomplete
      - you can now go back and fill in the missing pieces
Discussion (II)

- Sometimes your special cases will have special cases
- In the U.S. different shippers may have different requirements and different fees
- You can capture this information in another analysis matrix that shares some of the columns and rows of the original but which add additional concepts just for those special situations
We've now seen four design techniques

- The OO A&D method of Homework 3
- Design Pattern-Driven Design
- Commonality and Variability Analysis
- Analysis Matrix

Which one should we use?

Whatever helps you make progress! You might use more than one and switch between them until they converge
The Decorator Pattern provides a powerful mechanism for adding new behaviors to an object at run-time. The mechanism is based on the notion of “wrapping” which is just a fancy way of saying “delegation” but with the added twist that the delegator and the delegate both implement the same interface.

- You start with object A that implements interface C.
- You then create object B that also implements interface C.
- You pass A into B’s constructor and then pass B to A’s client.
- The client thinks it’s talking to A but it’s actually talking to B.
- B’s methods augment A’s methods to provide new behavior.
Why? Open-Closed Principle

• The decorator pattern provides yet another way in which a class’s runtime behavior can be extended without requiring modification to the class.

• This supports the goal of the open-closed principle:
  • Classes should be open for extension but closed to modification.
    • Inheritance is one way to do this, but composition and delegation are more flexible (and Decorator takes advantage of delegation).
    • As the Gang of Four put it: “Decorator let you attach additional responsibilities to an object dynamically. Decorators provide a flexible alternative to subclassing for extending functionality.”

• Our “Starbuzz Coffee” example, taken from Head First Design Patterns, clearly demonstrates why inheritance can get you into trouble and why delegation/composition provides greater run-time flexibility.
Starbuzz Coffee

• Under pressure to update their “point of sale” system to keep up with their expanding set of beverage products

  • Started with a Beverage abstract base class and four implementations: HouseBlend, DarkRoast, Decaf, and Espresso

  • Each beverage can provide a description and compute its cost

• But they also offer a range of condiments including: steamed milk, soy, and mocha

  • These condiments alter a beverage’s description and cost

    • The use of the word “Alter” here is key since it provides a hint that we might be able to use the Decorator pattern
With inheritance on your brain, you may add condiments to this design in one of two ways

1. One subclass per combination of condiment (won't work in general but especially not in Boulder)
2. Add condiment handling to the Beverage superclass
Approach One: One Subclass per Combination

This is incomplete, but you can see the problem…
(see page 81 for a more complete picture)
Approach Two: Let Beverage Handle Condiments

1. This assumes that all concrete Beverage classes need these condiments
2. Condiments may vary (old ones go, new ones are added, price changes, etc.), shouldn’t they be encapsulated some how?
3. How do you handle “double soy” drinks with boolean variables?

Houston, we have a problem…
Decorator Pattern: Definition and Structure

Inheritance is used to make sure that components and decorators share the same interface: namely the public interface of Component which is either an abstract class or an interface.

At run-time, concrete decorators wrap concrete components and/or other concrete decorators.

The object to be wrapped is typically passed in via the constructor.

Each decorator is cohesive, focusing just on its added functionality.
In both situations, Client thinks it's talking to a Component. It shouldn't know about the concrete subclasses.
StarBuzz Using Decorators (Incomplete)
Demonstration

• Starbuzz Example

• Use of Decorator Pattern in java.io package
  • InputStream == Component
  • FilterInputStream == Decorator
  • FileInputStream, StringBufferInputStream, etc. == ConcreteComponent
  • BufferedInputStream, LineNumberInputStream, etc. == ConcreteDecorator
The Textbook’s Take (I)

- As we saw, Decorator offers another solution to the problem of rapidly multiplying combinations of subclasses.
  - We saw examples of other solutions back in Chapters 8 and 10 where we made use of the strategy pattern and the bridge pattern.

- The decorator pattern provides a means for creating different combinations of functionality by creating chains in which each member of the chain can augment or “decorate” the output of the previous member.
  - And, it separates the step of building these chains from the use of these chains.
The Decorator pattern comes into play when there are a variety of *optional* functions that can precede or follow another function that is *always* executed.

This is a very powerful idea that can be implemented in a variety of ways (see the end of Chapter 17 for a discussion of some of the variations).

The fact that all of the classes in the decorator pattern hide behind the abstraction of Component enables all of the good benefits of OO design discussed previously.
Wrapping Up

- **Commonality and Variability Analysis**
  - helps us identify generic concepts in our problem domains and their associated concrete implementations

- **Analysis Matrix**
  - helps us deal with variations in a problem domain and provide hints as to the concepts they are related to and how to implement them

- **Decorator Pattern**
  - Another technique for applying the open-closed principle
Coming Up Next

- Lecture 24: Decorator, Observer, Template Method
  - Chapters 17, 18 and 19
- Homework 7 Due on Friday
- Homework 8 Assigned on Friday (same as homework 7)
- Status report on your second iteration