Design Patterns

V22.0474-001 Software Engineering
Lecture 8

How Do We Design Software?

- We all understand
  - Algorithms
  - Data structures
  - Classes
- When describing a design, algorithms/data structures/classes form the vocabulary
- But there are higher levels of design

Design Patterns: History

- Christopher Alexander
  - An architect
  - A professor
  - The father of *design patterns*
    - As applied to architecture
    - "Pattern Languages" (1977)
- Design Patterns in Software
  - Erich Gamma, Richard Helm, Ralph Johnson, John Vlissides
  - Application of design patterns to object-oriented programming
  - Book: *Design Patterns: Elements of Reusable Object-Oriented Software*

What are Design Patterns?

"A pattern describes a problem that occurs often, along with a tried solution to the problem"
- Christopher Alexander, 1977

- Descriptions of <u>communicating objects</u> and classes that are <u>customized</u> to solve a general <u>design problem</u> in a particular context
  - Not individual classes or libraries
    - Such as lists, hash tables
  - Not full designs

Elements of a Design Pattern

1. Pattern name
   - Useful part of design vocabulary
2. Problem solved and applicability
   - When to apply the pattern
3. Solution
   - Participants and their relationships
4. Consequences
   - Costs of applying the pattern, space and time trade-offs

Improved Communication

One of the main benefits of design patterns is that they name common (and successful) ways of building software.

More Specifically

- Teaching and learning
  - It is much easier to learn architecture from descriptions of design patterns than from reading code
- Teamwork
  - Members of a team have a way to name and discuss the elements of their design

Example: A Text Editor

- Describe a text editor using patterns
  - A running example
- Introduces several important patterns
- Gives an overall flavor of pattern culture

Note: This example is from the "Design Patterns" book.

Text Editor Requirements

- A WYSIWYG editor
- Text and graphics can be freely mixed
- Graphical user interface
    - Toolbars, scrollbars, etc.
- Multiple windowing systems
- Traversal operations: spell-checking, hyphenation

The Game

- I describe a design problem for the editor
- I ask "What is your design?"
    - This is audience participation time
- I give you the wise and insightful pattern

Problem: Document Structure

A document is represented by its physical structure:

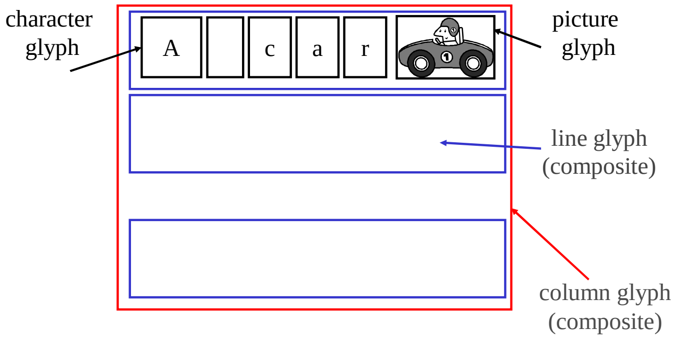
- Primitive *glyphs*
    - characters, rectangles, circles, pictures, . . .
- Lines
    - A sequence of glyphs
- Columns
    - A sequence of lines
- Pages
    - A sequence of columns
- Documents
    - A sequence of pages

What is your design?

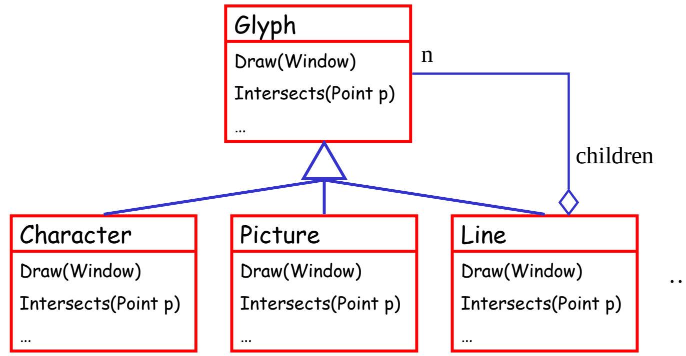
Alternative Designs

- Classes for Character, Circle, Line, Column, Page, …
    - Not so good
    - A lot of code duplication
- One (abstract) class of Glyph
    - Each element realized by a subclass of Glyph
    - All elements present the same interface
        - How to draw
        - Compute bounding rectangle
        - Mouse hit detection
        - …
    - Makes extending the class easy
    - Treats all elements uniformly

Example of Hierarchical Composition



Diagram



Notes

- Drawing
  - Each primitive element draws itself
    - At its assigned location
  - Each compound element recursively calls draw on its elements
    - But doesn't care what those elements are

```
Line::Draw(Window w) {
  for each c in children do
      c->Draw(w);
}
```


Composites

- This is the *composite* pattern
  - Goes by many other names
    - Recursive composition, structural induction, tree walk, …
    - Predates design patterns
- Applies to any hierarchical structure
  - Leaves and internal nodes have same functionality
  - Composite implements the same interface as the contained elements

Problem: Formatting

- A particular physical structure for a document
  - Decisions about layout
  - Must deal with e.g., line breaking
- Design issues
  - Layout is complicated
  - No best algorithm
    - Many alternatives, simple to complex

What is your design?

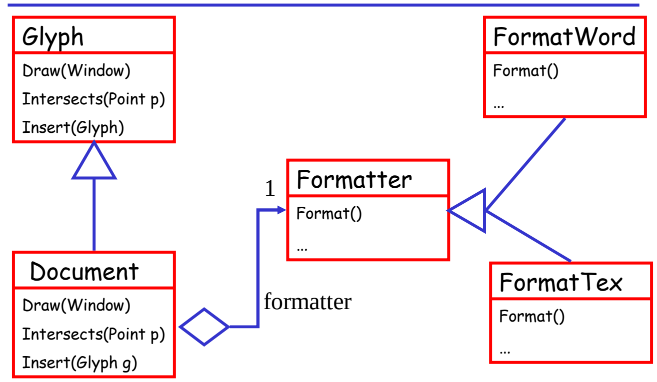
Not So Good

- Add a *format* method to each Glyph class
- Problems
  - Can't modify the algorithm without modifying Glyph
  - Can't easily add new formatting algorithms

The Core Issue

- Formatting is complex
  - We don't want that complexity to pollute Glyph
  - We may want to change the formatting method
- Encapsulate formatting behind an interface
  - Each formatting algorithm an instance
  - Glyph only deals with the interface

Diagram



Strategies

- This is the *strategy* pattern
  - Isolates variations in algorithms we might use
  - Formatter is the strategy, Compositor is context
- General principle

  encapsulate variation
- In OO languages, this means defining abstract classes for things that are likely to change

Problem: Enhancing the User Interface

- We will want to decorate elements of the UI
  - Add borders
  - Scrollbars
  - Etc.
- How do we incorporate this into the physical structure?

What is your design?

Not So Good

- Object behavior can be extended using inheritance
  - Major drawback: inheritance structure is static
- Subclass elements of Glyph
  - BorderedComposition
  - ScrolledComposition
  - BorderedAndScrolledComposition
  - ScrolledAndBorderedComposition
  - ...
- Leads to an explosion of classes

Decorators

- Want to have a number of decorations (e.g., Border, ScrollBar, Menu) that we can mix independently

  x = new ScrollBar(new Border(new Character))

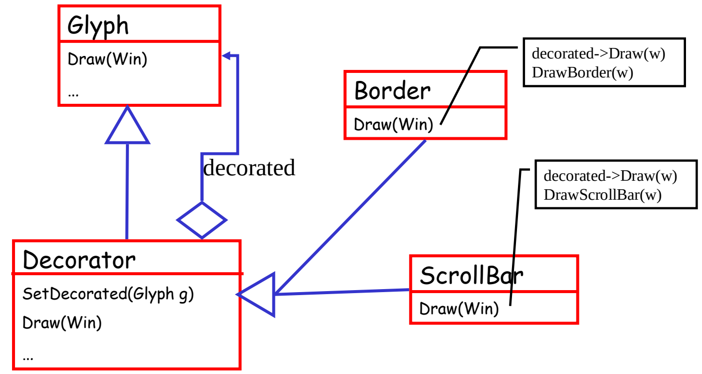
  - We have n decorators and 2^n combinations

Transparent Enclosure

- Define Decorator
  - Implements Glyph
  - Has one member Glyph decorated
  - Border, ScrollBar, Menu extend Decorator

```
Border::Draw(Window w) {
        decorated->draw(w);
        drawBorder(decorated->bounds());
}
```


Diagram



Decorators

- This is the *decorator* pattern
- A way of adding responsibilities to an object
- Commonly extending a composite
  - As in this example

Problem: Supporting Look-and-Feel Standards

- Different look-and-feel standards
  - Appearance of scrollbars, menus, etc.
- We want the editor to support them all
  - What do we write in code like

```
ScrollBar scr = new ?
```

What is your design?

The Not-so-Good Strawmen

- Terrible

  ScrollBar scr = new MotifScrollBar

- Little better

  ScrollBar scr;

  if (style == MOTIF) then scr = new MotifScrollBar
  else if (style == …) then …

  - will have similar conditionals for menus, borders, etc.

Abstract Object Creation

- Encapsulate what varies in a class
- Here object creation varies
  - Want to create different menu, scrollbar, etc
  - Depending on current look-and-feel
- Define a GUIFactory class
  - One method to create each look-and-feel dependent object
  - One GUIFactory object for each look-and-feel
  - Created itself using conditionals

Diagram

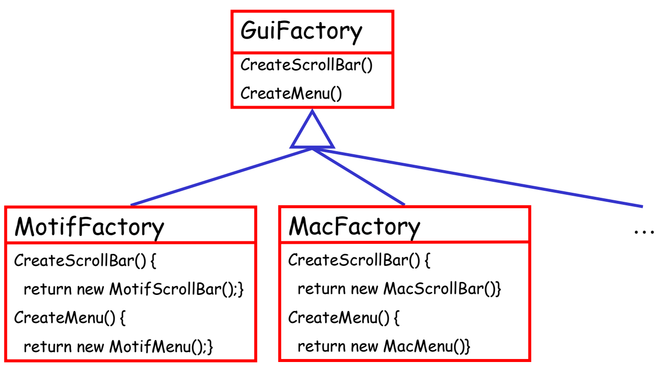
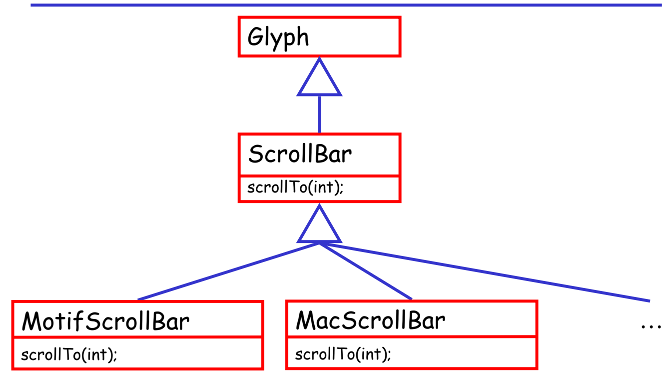


Diagram 2: Abstract Products



Factories

- This is the *abstract factory* pattern
- A class which
  - Abstracts the creation of a family of objects
  - Different instances provide alternative implementations of that family
- Note
  - The "current" factory is still a global variable
  - The factory can be changed even at runtime

Problem: Supporting Multiple Window Systems

- We want to run on multiple window systems
- Problem: Wide variation in standards
  - Big interfaces
    - Can't afford to implement our own windowing system
  - Different models of window operations
    - Resizing, drawing, raising, etc.
  - Different functionality

What is your design?

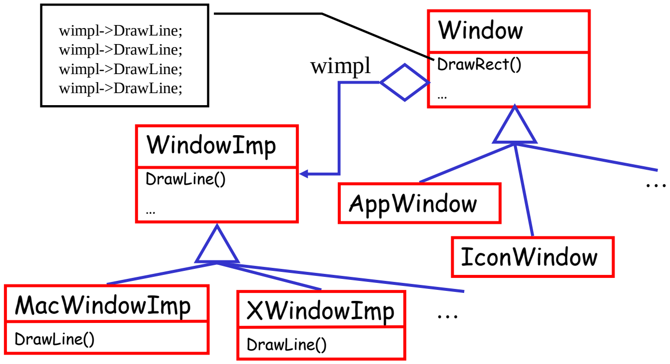
A First Cut

- Take the intersection of all functionality
  - A feature is in our window model if it is in every real-world windowing system we want to support
- Define an abstract factory to hide variation
  - Create windowing objects for current window system using the factory
- Problem: intersection of functionality may not be large enough

Second Cut

- Define our own abstract window hierarchy
  - All operations we need represented
  - Model is tuned to our application
- Define a parallel hierarchy
  - Abstracts concrete window systems
  - Has all functionality we need
    - I.e., could be more than the intersection of functions
    - Requires writing methods for systems missing functionality

Diagram



Bridges

- This is the *bridge* pattern
- Note we have two hierarchies
  - Logical
    - The view of our application, tuned to our needs
  - Implementation
    - The interface to the outside world
    - Abstract base class, with multiple implementations
- Logical, implementational views can evolve
  - independently,
  - So long as the "bridge" is maintained

User Commands

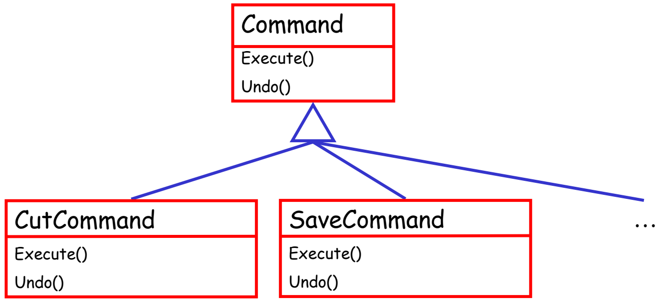
- User has a vocabulary of operations
  - E.g., jump to a particular page
  - Operations can be invoked multiple ways
    - By a menu
    - By clicking an icon
    - By keyboard shortcut
  - Want undo/redo/command line option/menu option
- How do we represent user commands?

What is your design?

A Good Design

- Define a class of user operations
  - Abstract class
  - Presents interface common to all operations
    - E.g., undo/redo
- Each operation is a subclass
  - Jump to a page, cut, paste, …

Diagram



Commands

- This is the *command* pattern
- Note the user has a small "programming language"
  - The abstraction makes this explicit
  - In this case the language is finite
    - Class structure can represent all possibilities explicitly
- Other patterns for richer languages
  - E.g., the Interpreter Pattern

Problem: Spell Checking

- Considerations
  - Spell-checking requires traversing the document
    - Need to see every glyph, in order
    - Information we need is scattered all over the document
  - There may be other analyses we want to perform
    - E.g., grammar analysis

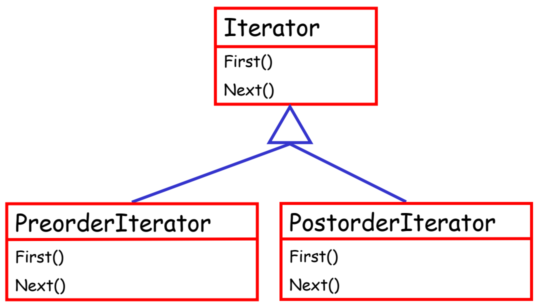
What is your design?

One Possibility

- Iterators
  - Hide the structure of a container from clients
  - A method for
    - pointing to the first element
    - advancing to the next element
    - getting the current element
    - testing for termination

```
iterator i = CreateIterator(composition);
for(i = i->first(); !(i->isdone()); i = i->next())
   { … do something with Glyph  i->current() …; }
```

Diagram



Notes

- Iterators work well if we don't need to know the type of the elements being iterated over
  - E.g., send kill message to all processes in a queue
- Not a good fit for spell-checking

```
for(i = i->first(); !(i->isdone()); i = i->next())
    { … do something with Glyph  i->current() …; }
```

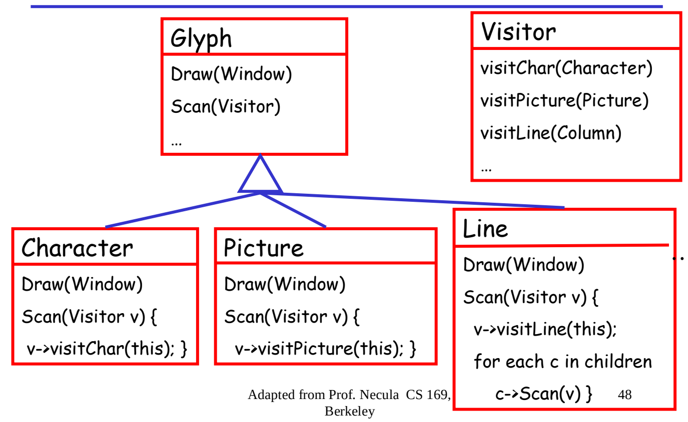
- Must cast i->current() to spell-check it . . .

```
if(i instanceof Char) { … } else { … }
```


Visitors

- The visitor pattern is more general
  - Iterators provide traversal of containers
  - Visitors allow
    - Traversal
    - <u>And type-specific actions</u>
- The idea
  - Separate traversal from the action
  - Have a "do it" method for each element type
    - Can be overridden in a particular traversal

Diagram



Visitor Comments

- The dynamic dispatch on Glyph::Scan achieves type-safe casting
  - dynamic dispatch to Char::Scan, Picture::Scan, …
- Each of the Glyph::Scan
  - calls the visitor-specific action (e.g., Visitor:visitChar)
  - implements the search (e.g., in Line::Scan)
- Have a visitor for each action (e.g., spell-check, search-and-replace)

Design Patterns

- A good idea
  - Simple
  - Describe useful "micro-architectures"
  - Capture common organizations of classes/objects
  - Give us a richer vocabulary of design
- Relatively few patterns of real generality
- Watch out for the hype . . .