Principles of Software Construction: Objects, Design and Concurrency

Design Patterns and Java I/O

15-214

toad

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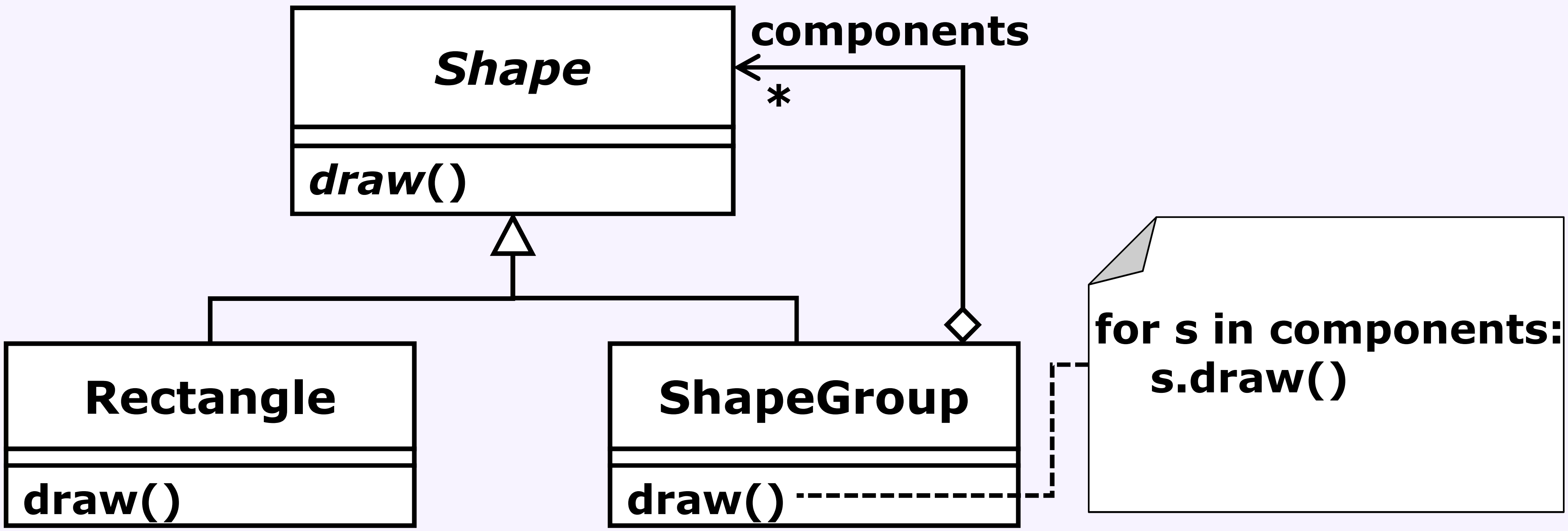
Design Patterns

- "Each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice”
  – Christopher Alexander

- Every Composite has its own domain-specific interface
  - But they share a common problem and solution

Example: Composite Windows

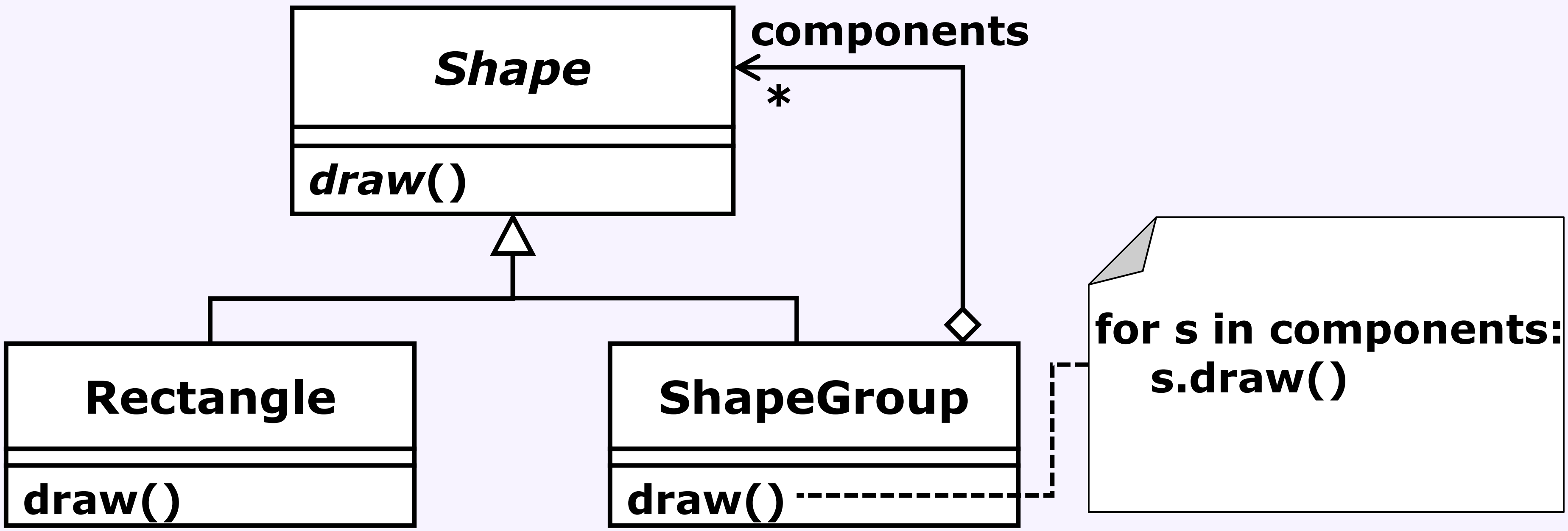


- Problem
  - Express a part-whole hierarchy of shapes
  - Allow treating a group of shapes just like shapes
- Consequences
  - Makes clients simple; they can ignore the difference
  - Easy to add new kinds of shapes

Elements of a Pattern

- Name
  - Important because it becomes part of a design vocabulary
  - Raises level of communication
- Problem
  - When the pattern is applicable
- Solution
  - Design elements and their relationships
  - Abstract: must be specialized
- Consequences
  - Tradeoffs of applying the pattern
    - Each pattern has costs as well as benefits
    - Issues include flexibility, extensibility, etc.
    - There may be variations in the pattern with different consequences

Example: Composite Windows



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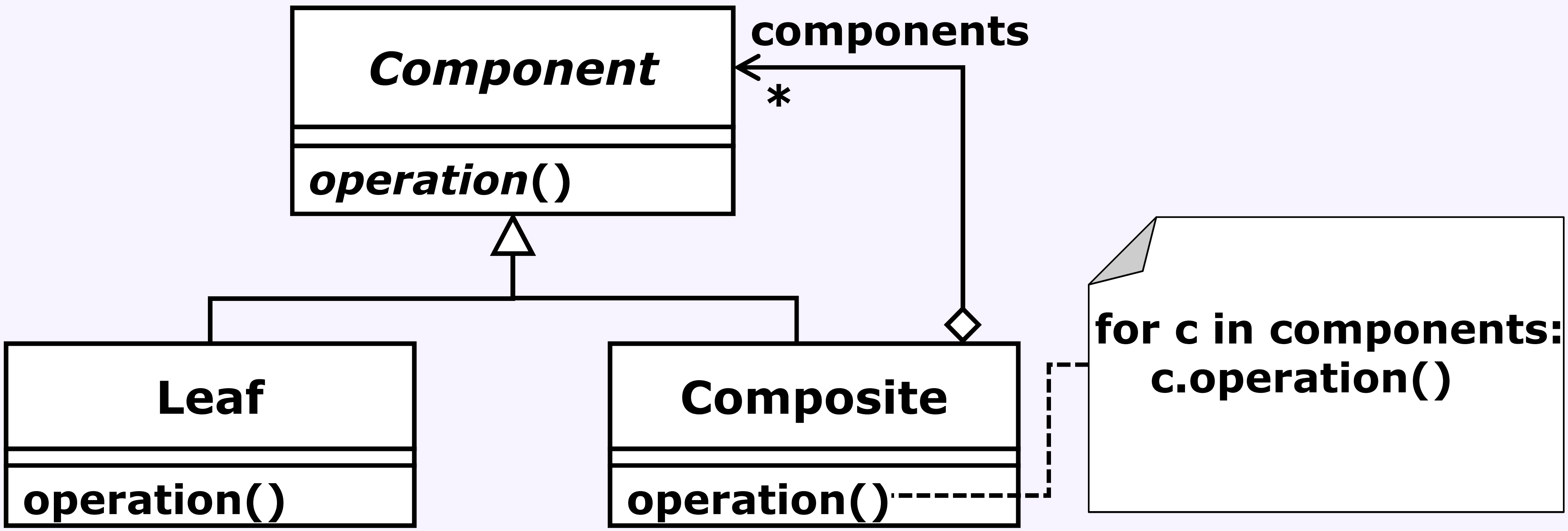
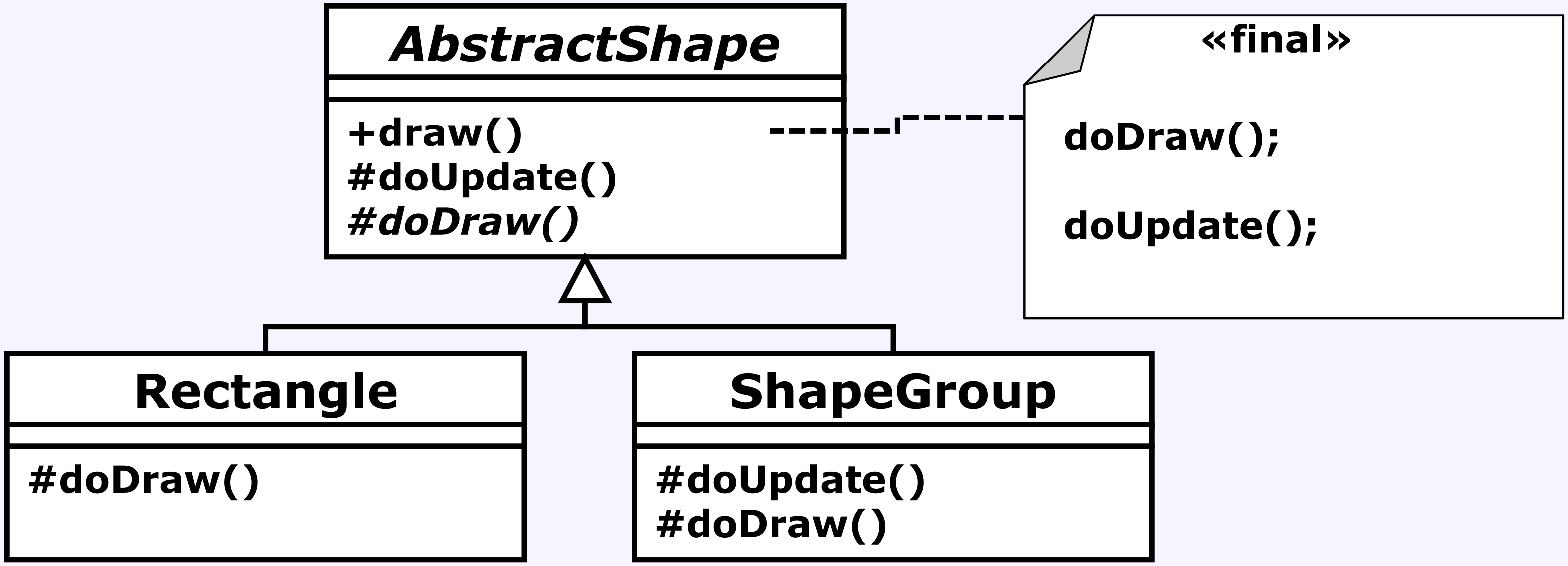
Composite Pattern



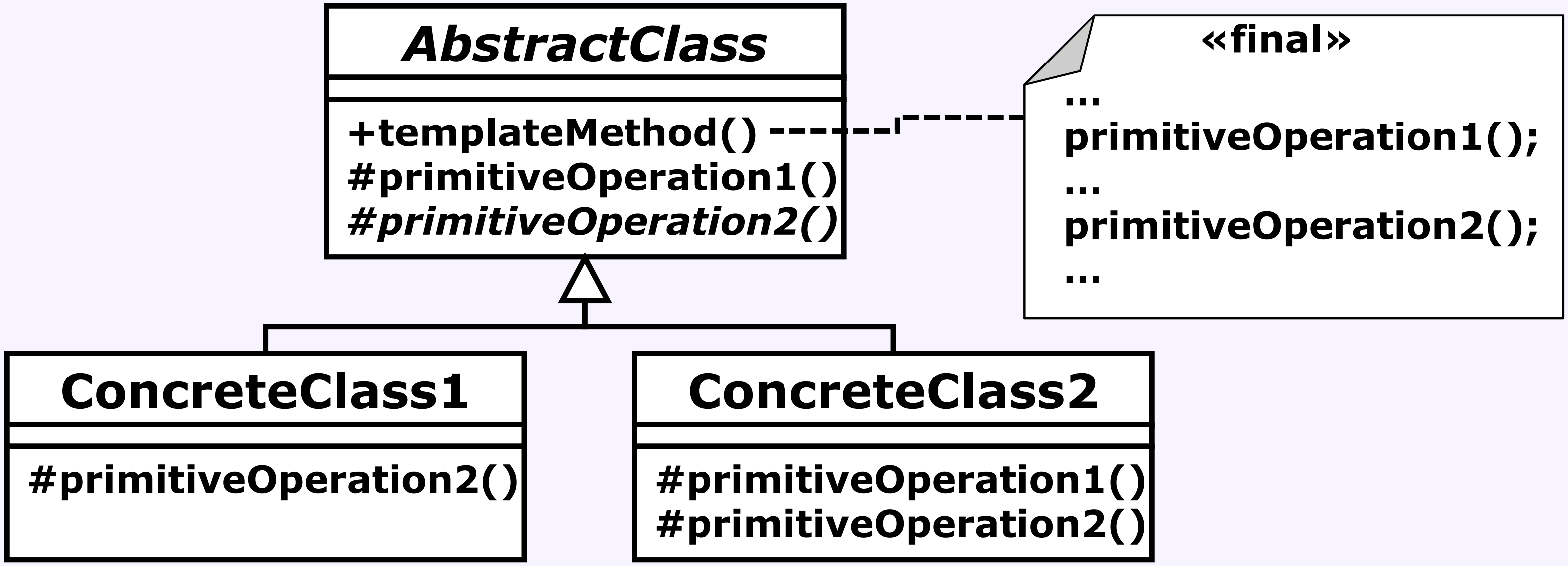
- Problem (generic)
  - Express a part-whole hierarchy of components
  - Allow treating a composite just like a component
- Consequences (generic)
  - Makes clients simple; they can ignore the difference
  - Easy to add new kinds of components
  - Can be overly general – uniformity is not always good

Example: Shape Change Notification



- Problem
  - Drawing changes from shape to shape, but updating doesn't - want to reuse updating code
  - Future shape implementations should not forget to update
- Consequences
  - Code reuse
  - Authors of subclasses will not unintentionally forget to do the update

Template Method Pattern



- Problem (generic)
  - Express an algorithm with varying and invariant parts
  - When common behavior should be factored and localized
  - When subclass extensions should be limited

- Consequences (generic)
  - Code reuse
  - Inverted "Hollywood" control: don't call us, we'll call you
  - Invariant algorithm parts are not changed by subclasses

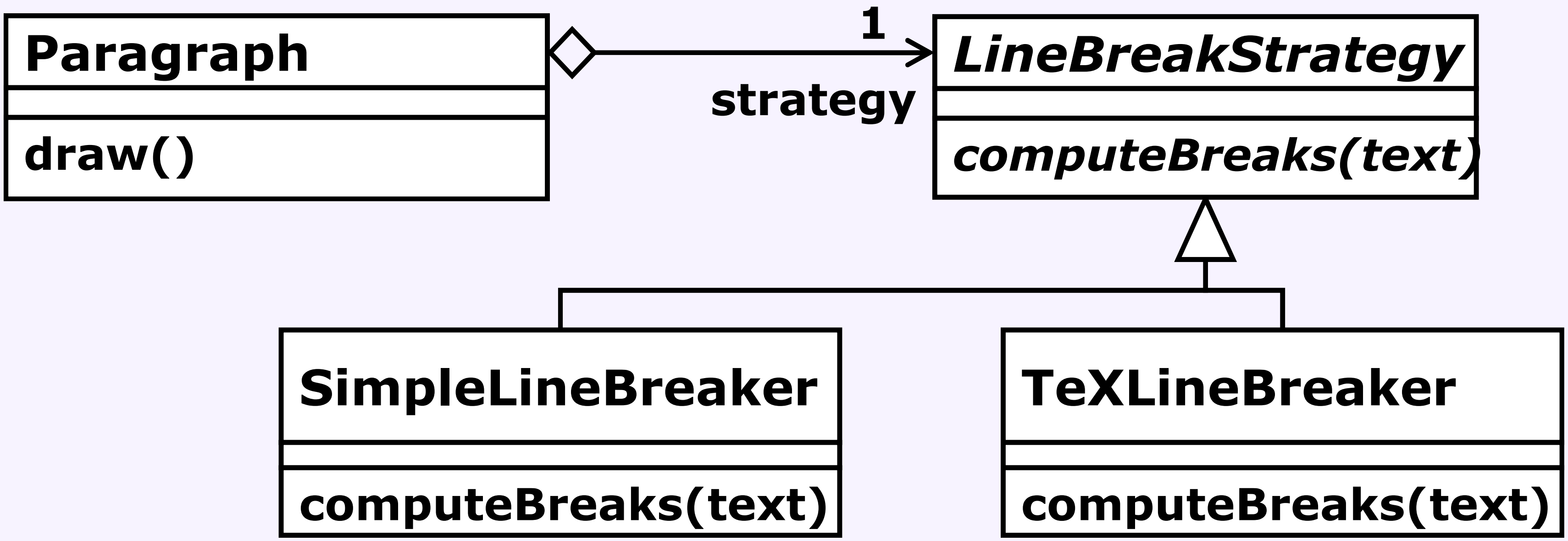
The Template Method Pattern in the Virtual World

- Did you use a template method in the Virtual World assignment? How and why?
- Let's look at the code…
- For more details, see the Piazza post "How to Reuse Code in hw2"

Problem: Line Breaking Implementations

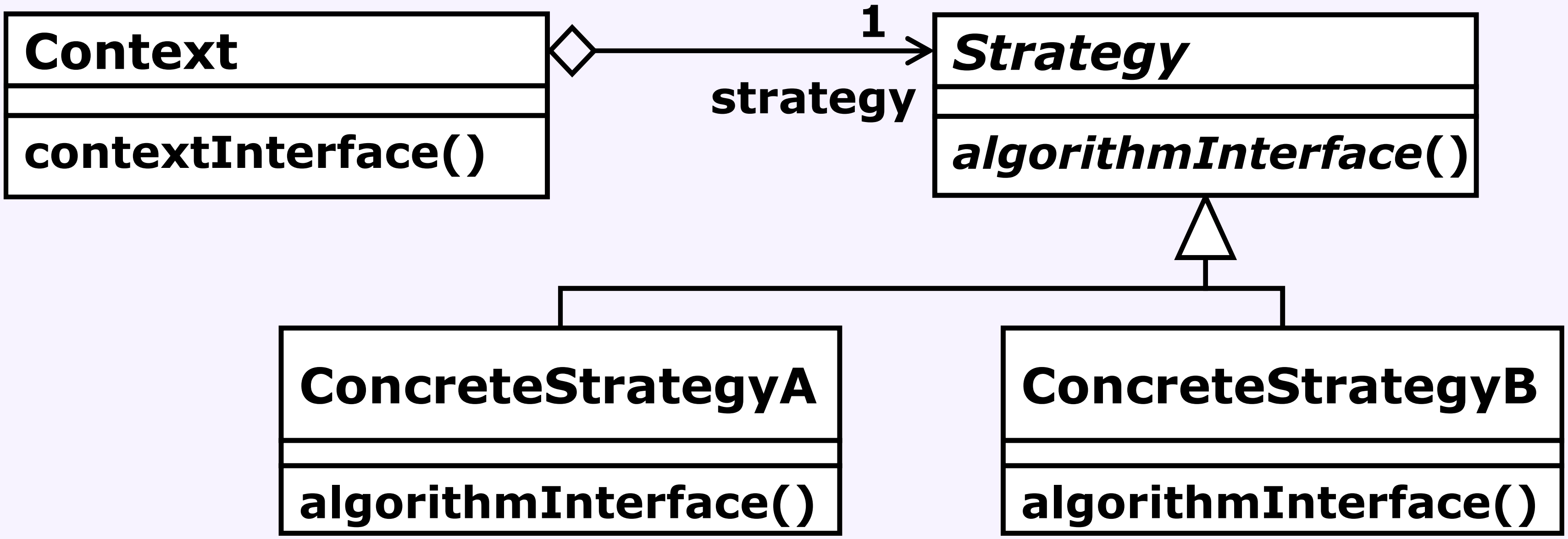
- Context: document editor
- Many ways to break a paragraph into lines
  - Blind: just cut off at 80 columns
  - Greedy: fit as many words in this line, then wrap
  - Global (e.g. TeX): minimize badness in entire paragraph
    - Might move a small word to next line if it reduces extra spaces there
- Option 1: We could put this in class Paragraph
  - But this is not Paragraph's main function
  - Putting many algorithms into Paragraph makes it too big
  - Other classes might need line breaking, too
  - Adding new line breaking algorithms is difficult
- Option 2?

Option 2: Encapsulate the Line Breaking Strategy



- Problem
  - Paragraphs needs to break lines in different ways
  - Want to easily change or extend line breaking algorithm
  - Want to reuse algorithm in new places
- Consequences
  - Easy to add new line breaking strategies
  - Separates strategy → vary strategy, paragraph independently
  - Adds objects and dynamism → code harder to understand

Strategy Pattern



- Problem (generic)
  - Behavior varies among instances of an abstraction
  - An abstraction needs different variants of an algorithm
- Consequences (generic)
  - Easy to add new strategies (e.g. compared to conditionals)
  - Separates algorithm → vary algorithm, context independently
  - Adds objects and dynamism → code harder to understand
  - Fixed strategy interface → high overhead for some impls.

The Strategy Pattern in the Virtual World

- Did you see the strategy pattern in the Virtual World assignment? How and why?

- Let's look at the code…

Tradeoffs

```
void sort(int[] list, String order) {
   …
  boolean mustswap;
  if (order.equals("up")) {
    mustswap = list[i] < list[j];
  } else if (order.equals("down")) {
    mustswap = list[i] > list[j];
  }
  …
}
```

```
void sort(int[] list, Comparator cmp) {
   …
  boolean mustswap;
  mustswap = cmp.compare(list[i], list[j]);
  …
}
interface Comparator {
  boolean compare(int i, int j);
}
class UpComparator implements Comparator {
  boolean compare(int I, int j) { return i<j; }}

class DownComparator implements Comparator {
  boolean compare(int I, int j) { return i>j; }}
```

Fundamental OO Design Principles

- Patterns emerge from fundamental principles applied to recurring problems
  - Design to interfaces
  - Favor composition over inheritance
  - Find what varies and encapsulate it
- Patterns are discovered, not invented
  - Best practice by experienced developers

Fundamental Principles underlying the Strategy Pattern

- Design to interfaces
  - Strategy: the algorithm interface
- Favor composition over inheritance
  - Strategy could be implemented with inheritance
    - Multiple subclasses of Context, each with an algorithm
    - Drawback: couples Context to algorithm, both become harder to change
    - Drawback: can’t change algorithm dynamically
- Find what varies and encapsulate it
  - Strategy: the algorithm used
- Side note: how do you implement the Strategy pattern in functional languages?

Kinds of Patterns

- Categories
  - Structural – vary object structure
  - Behavioral – vary the behavior you want
  - Creational – vary object creation

- Derived from scenarios

- UML diagram credit: Pekka Nikander
  - http://www.tml.tkk.fi/~pnr/GoF-models/html/

Patterns to Know

- Façade, Adapter, Composite, Strategy, Bridge, Abstract Factory, Factory Method, Decorator, Observer, Template Method, Singleton, Command, State, Proxy, and Model-View-Controller

- Know pattern name, problem, solution, and consequences

Java Streams – and their Patterns

- What is System.out? Let's look at the Javadoc

System.out is a java.io.PrintStream

- `java.io.PrintStream`: Allows you to conveniently print common types of data

```
void close();
void flush();
void print(String s);
void print(int i);
void print(boolean b);
void print(Object o);
…
void println(String s);
void println(int i);
void println(boolean b);
void println(Object o);
…
```

Let’s look at the stream design

The fundamental I/O abstraction: a stream of data

- `java.io.InputStream`

```
void            close();
abstract int    read();
int             read(byte[] b);
```

- `java.io.OutputStream`

```
void            close();
void            flush();
abstract void   write(int b);
void            write(byte[] b);
```

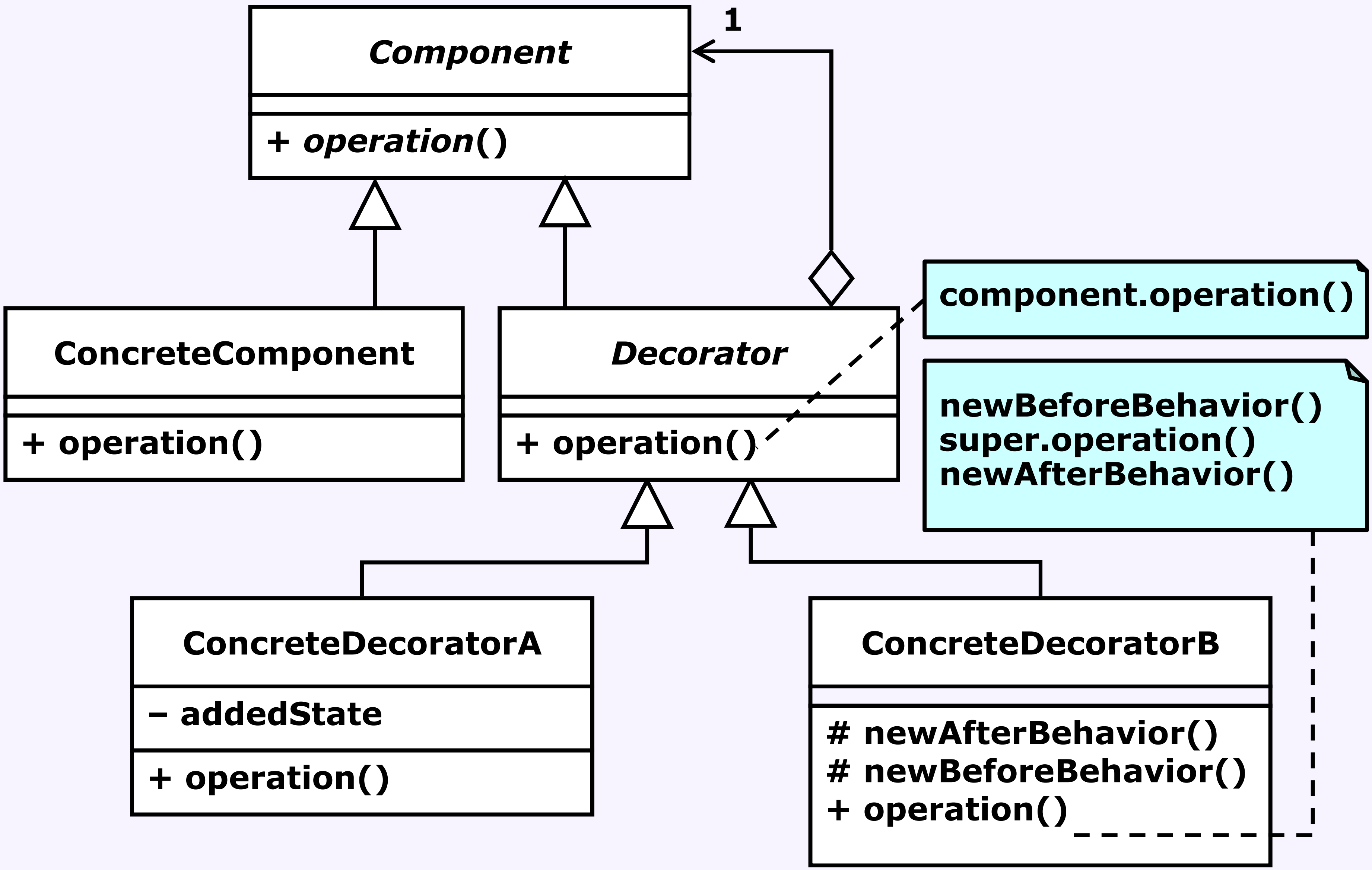
- Aside: If you have an `OutputStream` you can construct a `PrintStream`:

```
PrintStream(OutputStream out);
PrintStream(File file);
PrintStream(String filename);
…
```

Design Problem: how to add functionality to streams?

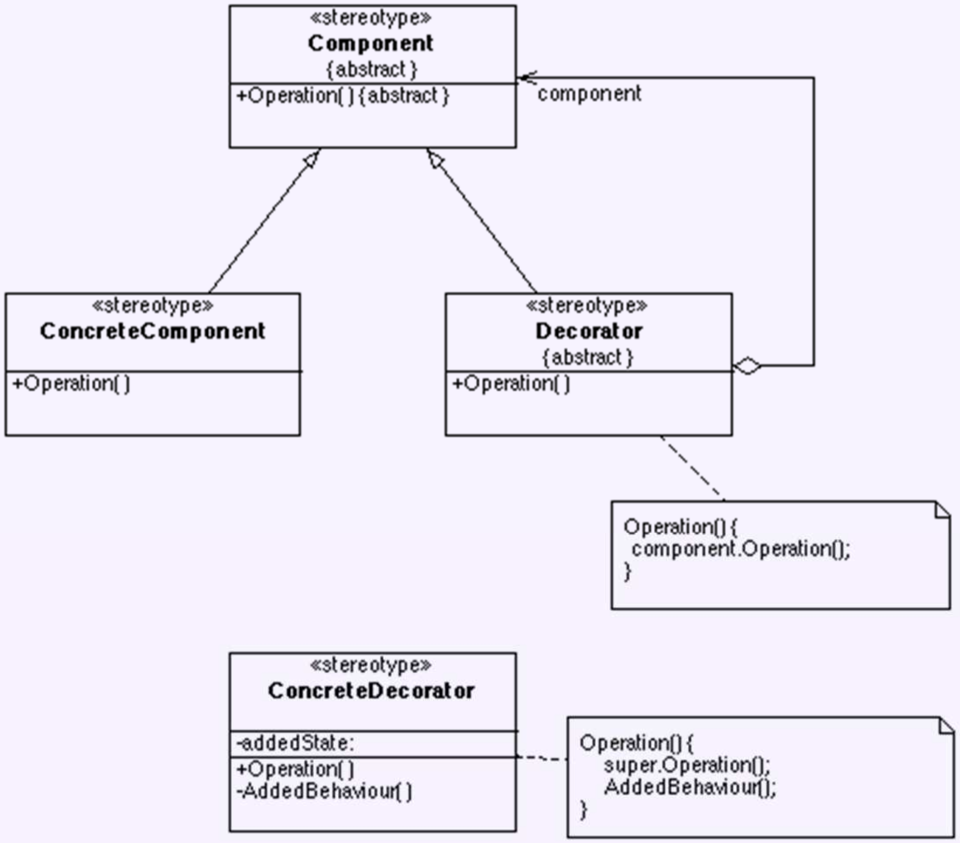
- We could do lots of things to a stream of data
  - Compress it
  - Encrypt it
  - Compute (or check) a checksum or digest
  - Translate it
  - (your idea here)
- It's unreasonable to add all this functionality explicitly to OutputStream
- What can we do instead?

The Decorator Pattern



Structural: Decorator

- Applicability
  - To add responsibilities to individual objects dynamically and transparently
  - For responsibilities that can be withdrawn
  - When extension by subclassing is impractical
- Consequences
  - More flexible than static inheritance
  - Avoids monolithic classes
  - Breaks object identity
  - Lots of little objects



FilterOutputStream as a Decorator

Why “Decorator?”

- Origins in GUIs
- Imagine you have a window that can display a lot of text on any size screen, but doesn’t scroll
- Scrolling can be added via a decorator that:
  - Overrides draw
  - Draws a scrollbar
  - Scales and moves the viewport according to the scrolling position
  - Calls draw() on the underlying window