Design Pattern Detection

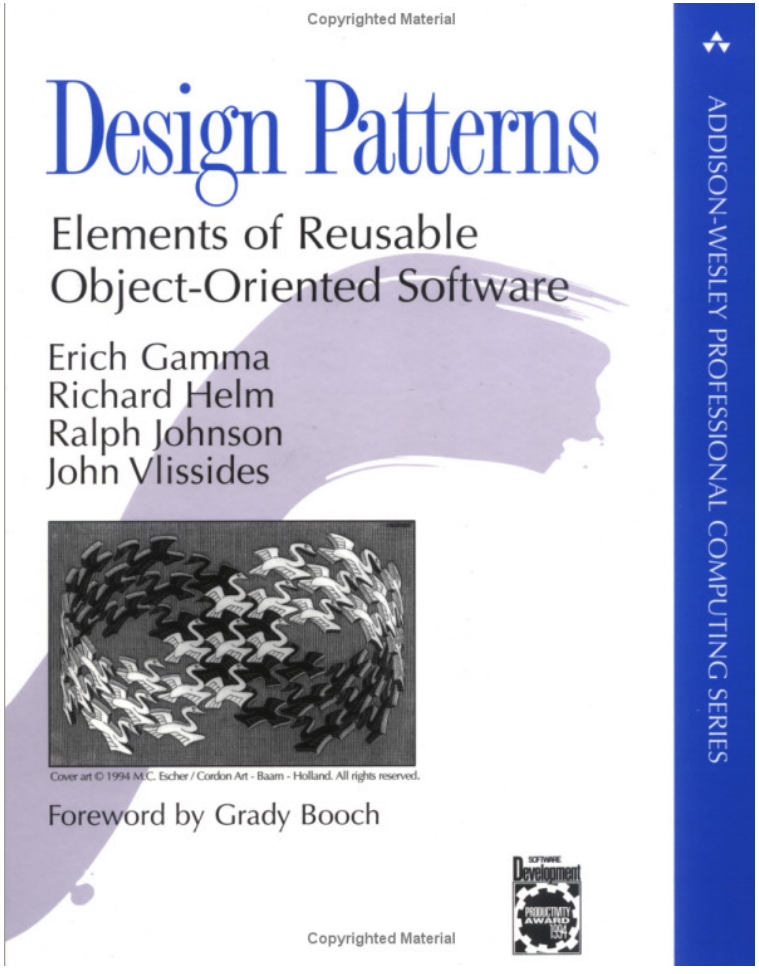
Design Patterns

- A design pattern systematically names, explains and evaluates an important and recurring design problem and its solution
- Good designers know not to solve every problem from first principles
  - They reuse solutions
- This is very different from code reuse

Design Patterns - Definition

From the Gang of Four textbook

Design patterns are descriptions of communicating objects and classes that are customized to solve a general design problem in a particular context



Essential Elements of a Design Pattern

- Name
  - Naming a pattern increases our design vocabulary
- Problem
  - When to apply the pattern
- Solution
  - Elements that make up the design, their relationships, responsibilities, and collaborations
- Consequences
  - Results and trade-offs of applying the pattern

How Design Patterns Solve Design Problems

- Finding appropriate objects
- Determining object granularity
- Specifying object interfaces
- Specifying object implementations
- Putting reuse mechanisms to work
  - Inheritance vs. Composition
  - Delegation
- Designing for change

Pattern Benefits

- Enable large scale reuse of software architectures
- Explicitly capture expert knowledge and design trade-offs
- Help improve developer communication
- Help ease the transition to OO methods

Pattern Drawbacks

- Patterns do not lead to direct code reuse
- Patterns are often deceptively simple
- You may suffer from pattern overload
- Patterns must be validated by experience and debate rather than automated testing
- Integrating patterns into a process is human intensive rather than a technical activity

Pattern Description Template

- Name
- Intent
  - What does the pattern do? What problems does it address?
- Motivation
  - A scenario of pattern applicability
- Applicability
  - In which situations can this pattern be applied
- Participants
  - Describe participating classes/objects

Pattern Description Template (cont.)

- Collaborations
  - How do the participants carry out their responsibilities?
- Diagram
  - Graphical representation of the pattern
- Consequences
  - How does the pattern support its objectives?
- Implementation
  - Pitfalls, language specific issues
- Examples

Classification

- Structural
  - Deal with decoupling interface and implementation of classes and objects
- Behavioural
  - Deal with dynamic interaction among collections of classes and objects
- Creational
  - Deal with initializing and configuring collections of classes and objects

Detecting design patterns

- A difficult task
- Patterns are primarily a literary form
- No rigorous mathematical definitions
- Automatic detection beyond the state of the art of Artificial Intelligence
- Instead, detect the artifacts of implementing the solution of the design pattern
- Purely structural patterns are easier to detect
- Purely behavioural patterns are much harder
- Most patterns are somewhere in the middle

Template solution

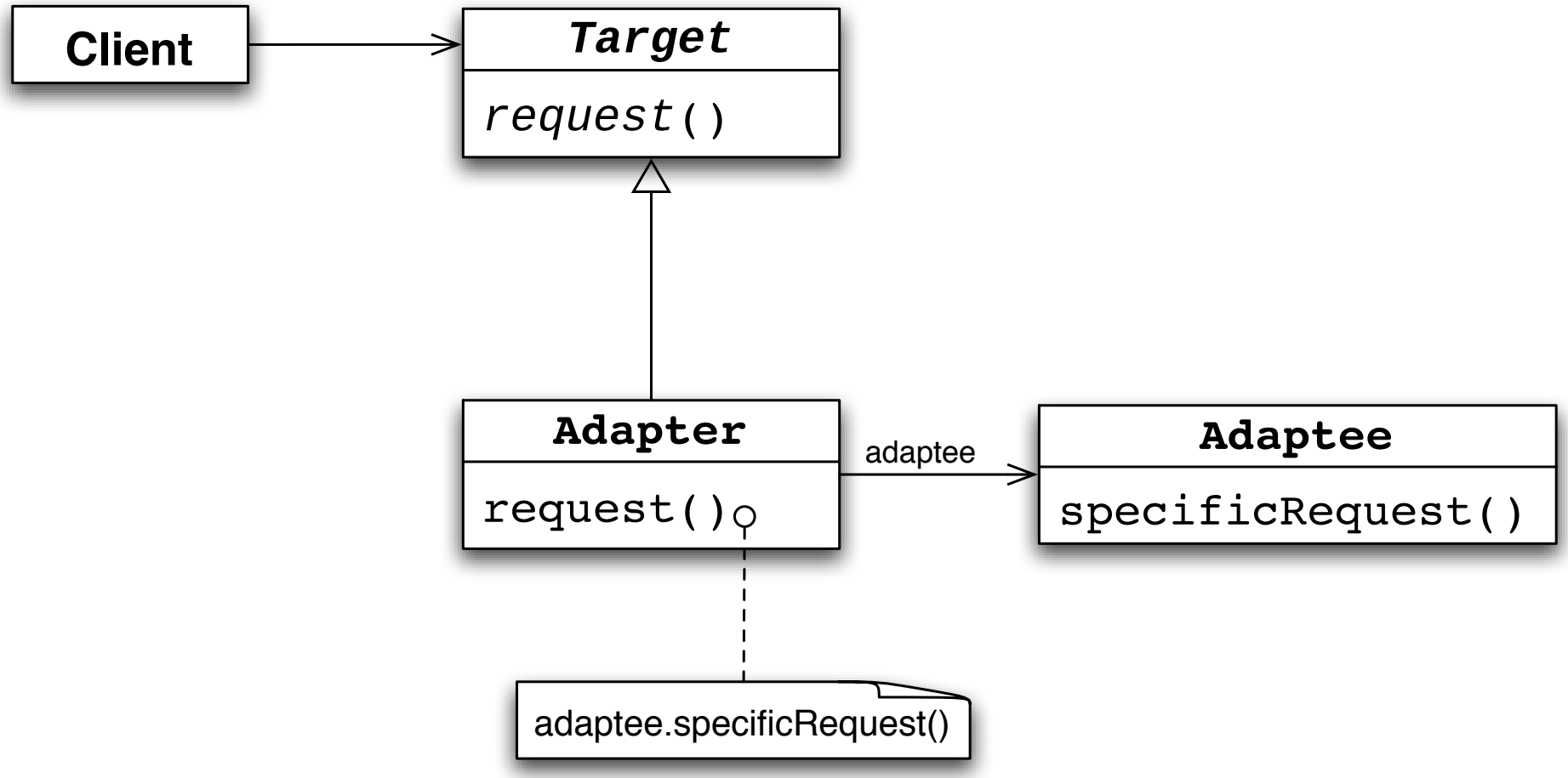
- A template solution needs to be both

  Distinctive
  - The static structure is not likely to be represented in a design that does not use the pattern

  Unambiguous
  - Can only be done in one way (or in a small number of variants)

- An object adapter is unambiguous but not distinctive

Object Adapter Static Structure



Composite vs. Decorator

- A Decorator is sometimes referred to as a degenerate Composite.
- The static structure of the two patterns is very similar
- The dynamic behaviour is also the same
- Static difference: A Composite contains a collection of Components, while a Decorator contains only one
- Intent difference: The Composite pattern groups components into a whole. The Decorator patterns enhances the responsibility of a component.

State vs. Strategy

- Both patterns allow flexible choice from a set of alternatives
- In their simple variants, the static structure and the dynamic behaviour are exactly the same
- The difference: Choosing a particular behaviour (State) vs. choosing a particular algorithm (Strategy)

Analysis synergy

- Both static and dynamic analysis are necessary in order to detect patterns
- Static analysis
  - The static structure of the pattern has to match a subgraph of the static structure of the software system
- Dynamic analysis
  - Message passing during run-time has to match the message flow that implements the behaviour of the pattern

Design Pattern Instances

- Each design pattern has a fixed set of roles, e.g. in the Adapter pattern, there is a Client, a Target, an Adapter, and an Adaptee
- Every detection technique attempts to discover instances of the design pattern in the software system being examined
- A design pattern *instance* is a set of classes that match the roles

Design Pattern Detection Research Issues

- False positive elimination
  - The precision of most published approaches is quite poor, often below 50%
- Dealing with Variants
  - Patterns are conceptual. Their implementation may vary considerably depending on the specific context
- Counting instances
  - Different detection approaches do it differently

Detecting Design Patterns in Java software with PDE

- PDE is a tool that collects static and dynamic facts from a system written in Java and detects design patterns in it
- A possible course project is to apply PDE (or another design pattern detection tool) to an open source system and evaluate the results

PDE - Static analysis

- Every pattern has a static definition, e.g.

```
uses client target
inherits adapter target
uses adapter adaptee
```

- Javex and grok are used to extract static facts such as

```
uses ClassA ClassB
inherits ClassC ClassB
uses ClassC ClassD
```

- QL matches the static definition to the static facts

PDE - Dynamic analysis

- Every pattern has a dynamic definition in XML

```
<entry className="adapter"
    calledByClass="client"
    thisObject="object1"
    nextCallInSubtree="yes">
  <entry className="adaptee"
    calledByClass="adapter"
    calledByObject="object1"
    thisObject="object2">
  </entry>
</entry>
```

PDE - Dynamic analysis

- Probekit is used to collect dynamic facts such as

```
<entry
   calledByClass="ContactAdapter"
   calledByMethod="setTitle"
   calledByObject="ContactAdapter@145"
   className="ChovnatlhImpl"
   methodName="cherPatlh"
   thisObject="ChovnatlhImpl@110">
```

- If the dynamic facts do not match the dynamic definition the candidate instance is deemed a false positive

Results with sample pattern implementations

- PDE detects 22/23 patterns
  - Except Facade, all patterns are detected
  - Facade is more an architectural design pattern
- PINOT detects 17/23
  - Pattern definitions are hard coded
- FUJABA detects 14/23
  - Behavioral patterns hard to detect

	PDE	PINOT	FUJABA
Creational			
Abstract Factory	√	√	√
Builder	√	-	-
Factory Method	√	√	√
Prototype	√	-	♯
Singleton	√	√	√
Structural			
Adapter	√	√	√
Bridge	√	√	√
Composite	√	♯	√
Decorator	√	√	√
Facade	-	√	-
Flyweight	√	√	√
Proxy	√	√	√
Behavioral			
Chain of Resp.	√	√	-
Command	√	-	-
Interpreter	√	-	-
Iterator	√	-	√
Mediator	√	√	-
Memento	√	√	-
Observer	√	√	√
State	√	√	♯
Strategy	√	√	√
Template Method	√	√	√
Visitor	√	√	√
Sum	**22/23**	**17/23**	**14/23**

PDE Full Results

Abstract Factory	4		8																			
Factory Method	2	1	1											2				2				
Adapter	1		1																			
Bridge			2	2																1		
Builder			1		3		3							11						1		
Chain of Responsibility						2																
Command	1		2				3							9				1	2	2		
Composite						2		4												4	1	
Decorator	2		2			3			4					3					1			
Flyweight	1									2	1		2	2						2		
Interpreter	3		3				6		6		2									8		
Iterator												1										
Mediator	1				4		12				3		3	4	8			1	2	4		
Memento														1				1				
Observer													2	13	2			1	2			
Prototype														1		1						
Proxy	2		3											1			1					
Singleton														2				2				
State	1		2			1	4			1	2		3	6			1	2	2	2		
Strategy			2				2				2			2				2		1		
Template Method			2			1								2					1		1	
Visitor	3				12		12			1	3		3						4	3		1