Software Construction and Design 2
SOFT3202 / COMP9202
Advanced Design Patterns (GoF & Enterprise)

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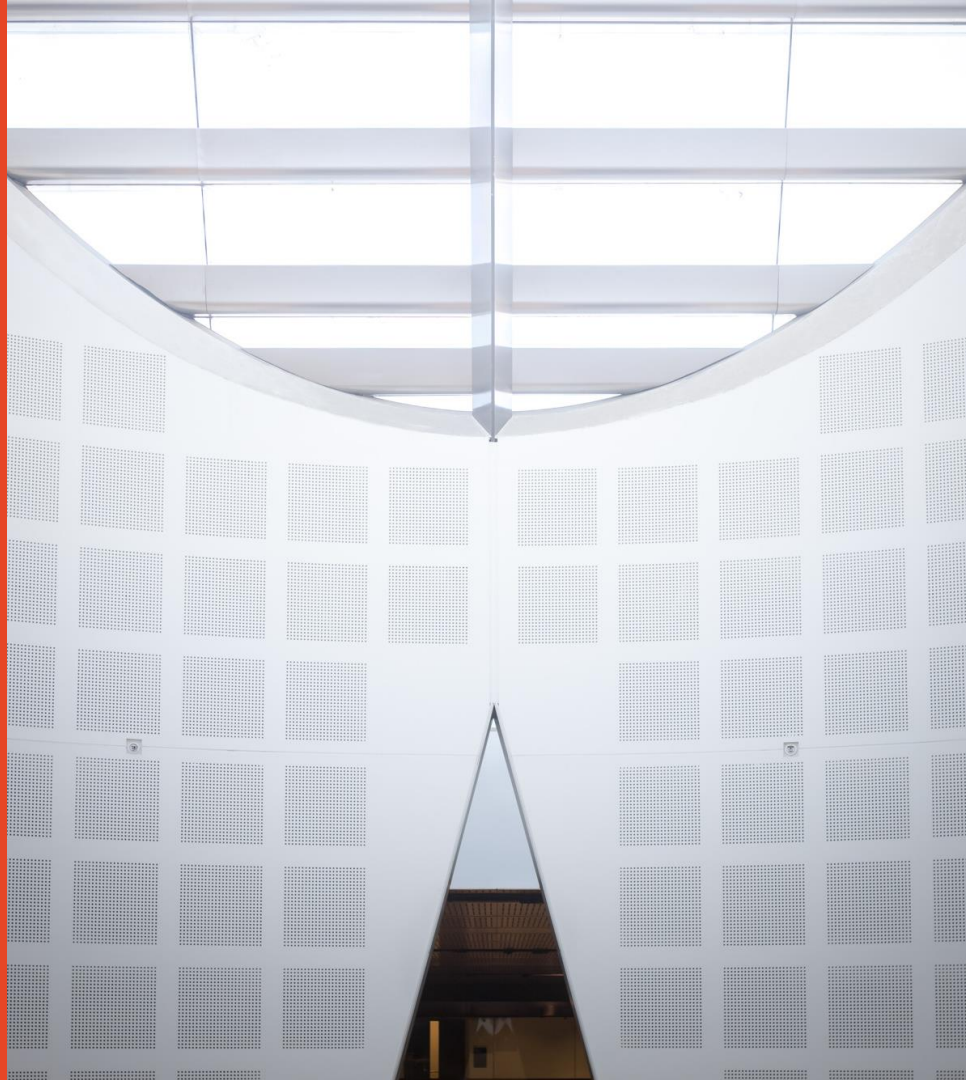

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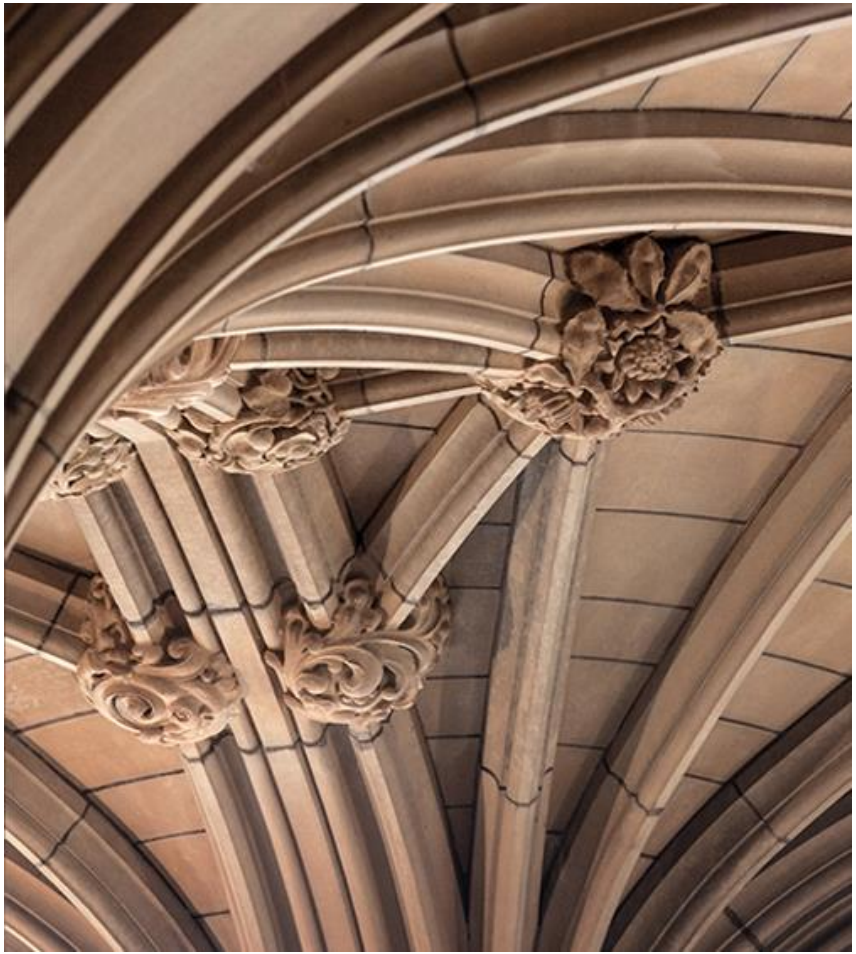
Agenda

- GoF Design Patterns
  - Visitor
  - Template Method
- Model-View-Controller
  - Page Controller
  - Template View

Visitor Design Pattern (GoF)

Object Behavioural



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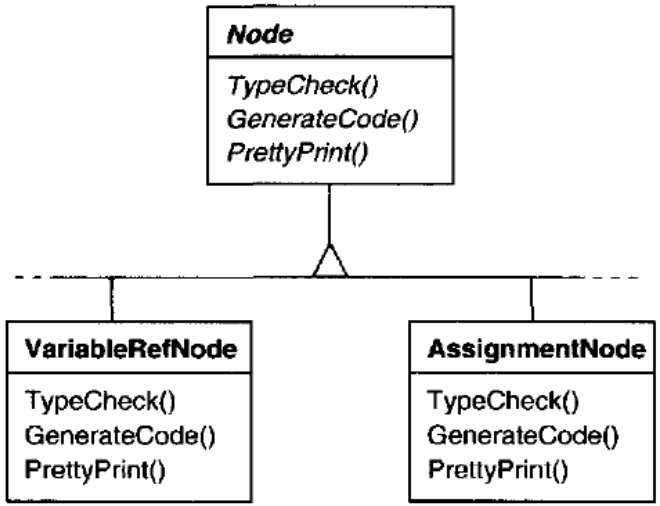
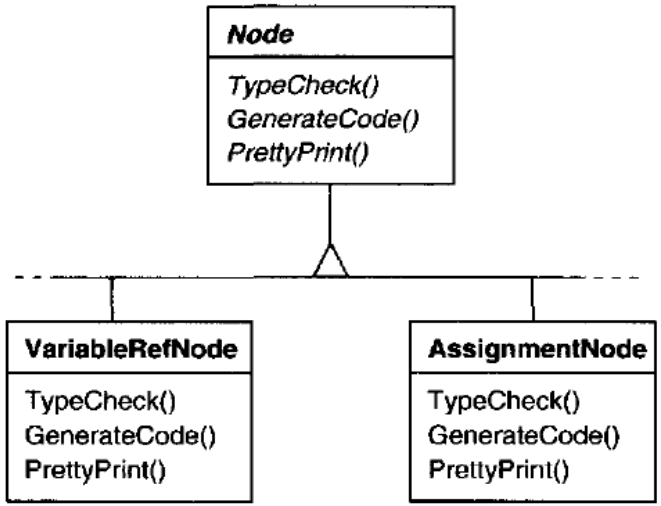
Motivation – A Compiler

- A compiler represents programs as abstract syntax trees
- Operations like type-checking, variable assignment and code generation
- Different classes (nodes) for different statements (e.g., assignment statement, arithmetic expressions
- *Discuss: is this a good design? Why/why not?*



Motivation – A Compiler

- Problems:
  - Operations are distributed across various node classes
    - Difficult to understand, maintain and change design
  - Add new operations will require recompiling all of the classes
    - Difficult to extend



A Compiler Application – Improved Design

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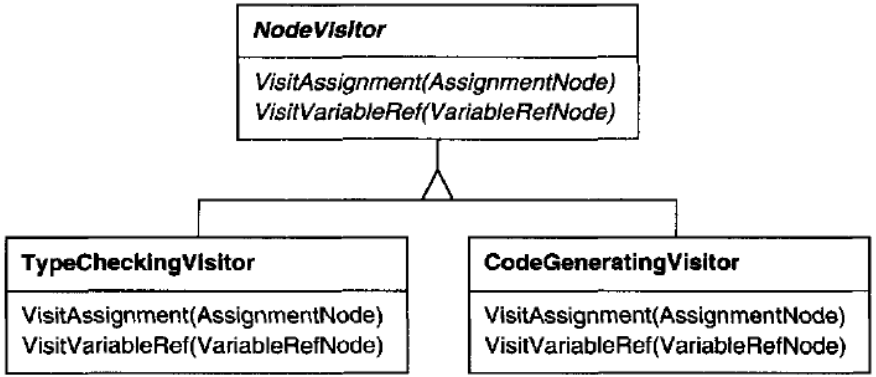
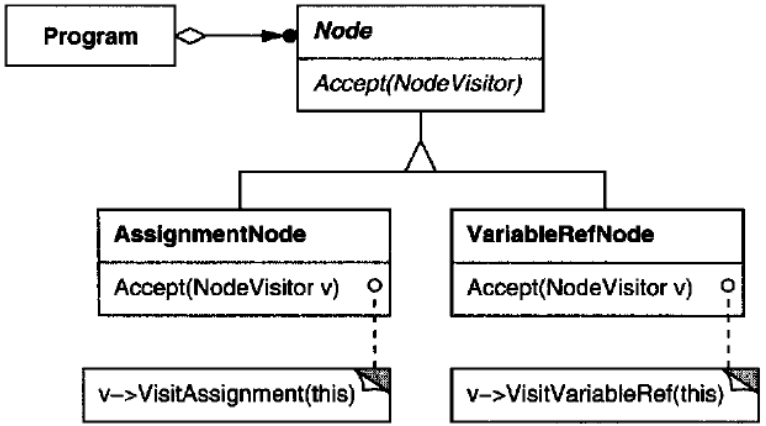


Node Visitor Hierarchy



Node Hierarchy

Visitor Pattern – Class Hierarchies

- Node Hierarchy
  - For the elements being operated on
- Node Visitor Hierarchy
  - For the visitors that define operations on the elements
- To create a new operation, add a new subclass to the visitor hierarchy

Visitor Pattern – How it Works

- Group set of related operations from each class in a separate object (visitor)
- Pass this object to elements of the syntax tree as it is traversed
- An element accepts the visitor to be able to send request to (element passed as an argument)
- The visitor will run the operation for that element

Visitor Pattern

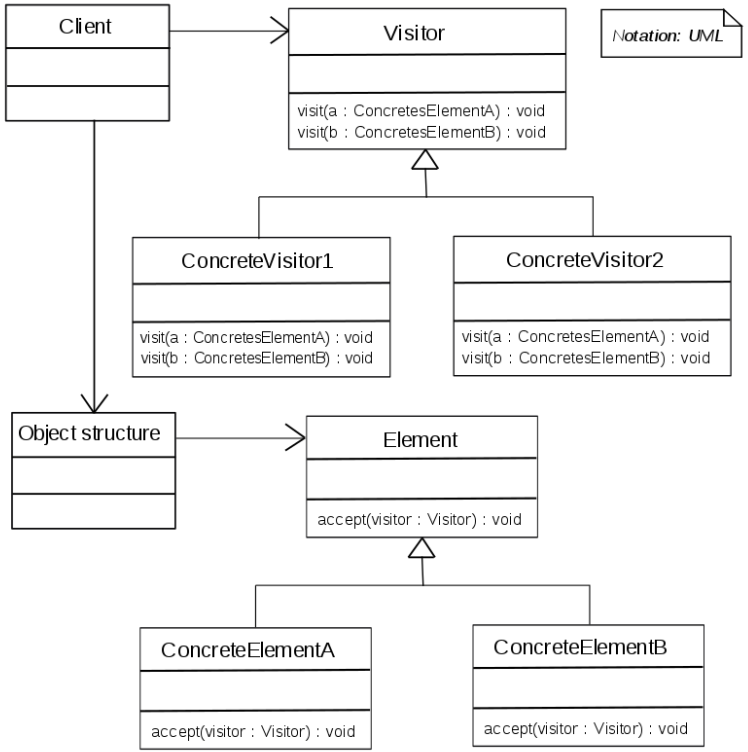
- Object behavioral

- Intent:
  - Modify a new operation without changing the classes of the elements on which it operates

- Applicability:
  - You want to perform operations on objects that depend on their concrete classes
  - You want to avoid mixing many distinct unrelated objects' operations in an object structure with their classes
  - The classes that define the object structure rarely change, but often it is needed to define new operations over the structure

Visitor Pattern – Structure

–



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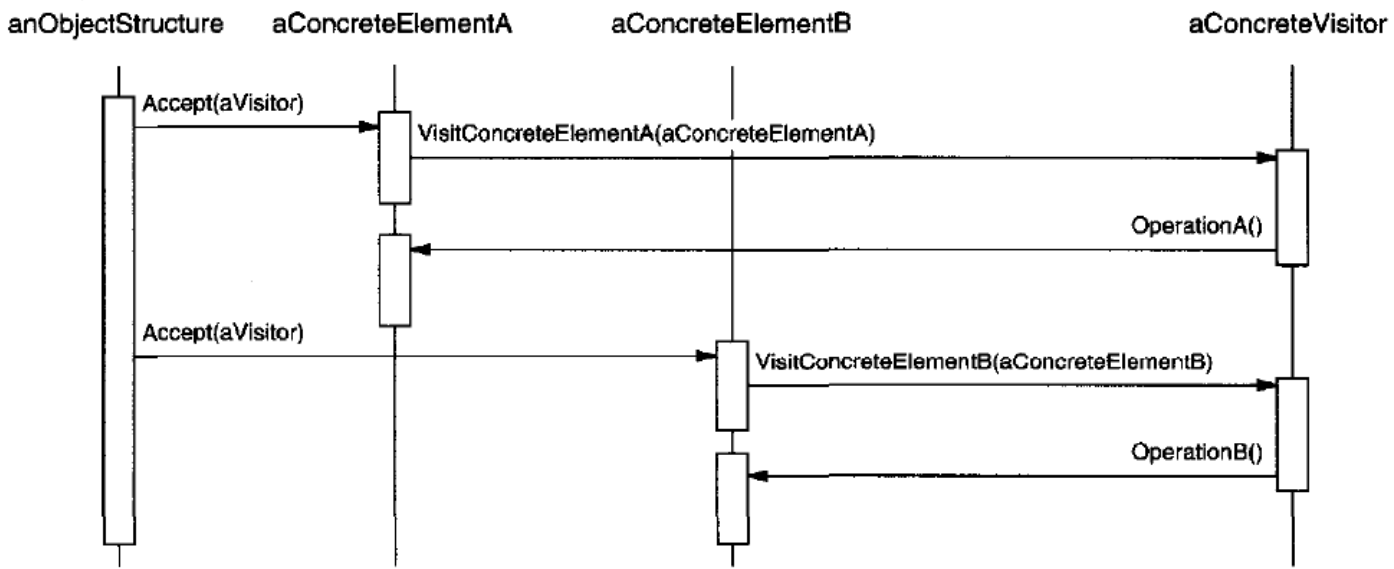
Visitor Pattern – Participants

- Visitor (NodeNisitor)
  - Declares a Visit operation for each class of ConcreteElement in the object structure
  - Classes identified by the operation's name and signature
- ConcreteVisitor (TypeCheckVistor)
  - Implement each operation declared by Visitor
  - Each operation implements a fragment of the algorithm defined for the corresponding class of object in the structure
- Element (Node)
  - Defines an "Accept" operation that takes a visitor as an argument

Visitor Pattern – Participants

- ConcereteElement (AssignmentNode,VariableRefNode)
  - Implements Accept operation (visitor as argument)
- ObjectStructure (Program)
  - Can enumerate its elements
  - May either be composite or a collection
  - May provide an interface to allow the visitor to visit its elements

Visitor Pattern – Collaboration



Visitor Pattern – Benefits

- Easy way to add new operations
  - Add a new Visitor
- Gather related behaviors (algorithms defined in the Visitors)
  - Specific data structure can be hidden in the visitor
- Visiting across class hierarchies
  - It can visit object structures with different types of elements (unlike iterator)
- State accumulation in the object structure
  - Otherwise, pass the state as an argument to the operations or declare it as global variables

Visitor Pattern – Drawbacks

- Violating encapsulation
  - It may enforce using public operations that access an element's internal state

- Difficult to add new concrete element classes
  - Adding new Concrete Element requires adding new abstract operation on Visitor and a corresponding implementation in every Concrete Visitor
    - Exception: default implementation to be provided or inherited by most Concrete Visitors

  - Consider the likelihood to change the algorithm applied over an object structure or classes of objects that make up the structure

Visitor Example – Element Implementation

```
1  interface Element {
2      void accept(Visitor v);
3  }
```

```
4  class ConcreteElementA implements Element {
5      public void accept(Visitor v) {
6          v.visit(this);
7      }
8      public String getElementA() {
9          return "Concrete Element A";
10     }
11 }
12 class ConcreteElementB implements Element {
13     public void   accept( Visitor v ) {
14         v.visit( this );
15     }
16     public String getElementB() {
17         return "Concrete Element B";
18     }
19 }
20 class ConcreteElementC implements Element {
21     public void accept(Visitor v) {
22         v.visit(this);
23     }
24     public String getElementC() {
25         return "Concrete Element C";
26     }
27 }
```

Visitor Example – Visitor Implementation

```
29 interface Visitor {
30     void visit(ConcreteElementA a);
31     void visit(ConcreteElementB b);
32     void visit(ConcreteElementC c);
33 }
```

```
34 class ConcreteVisitor1 implements Visitor {
35     public void visit(ConcreteElementA a) {
36         System.out.println("do visitor1 on " + a.getElementA());
37     }
38     public void visit(ConcreteElementB b) {
39         System.out.println("do visitor1 on " + b.getElementB());
40     }
41     public void visit(ConcreteElementC c) {
42         System.out.println( "do visitor1 on " + c.getElementC() );
43     }
44 }
45
46 class ConcreteVisitor2 implements Visitor {
47     public void visit(ConcreteElementA a) {
48         System.out.println("do visitor2 on " + a.getElementA());
49     }
50     public void visit(ConcreteElementb b) {
51         System.out.println("do visitor2 on " + b.getElementB());
52     }
53     public void visit(ConcreteElementC c ) {
54         System.out.println("do visitor1 on " + c.getElementC());
55     }
56 }
```

Visitor Example – Client Implementation

```
58 public class VisitorClient {
59     public static void main( String[] args ) {
60         Element[] list = {new ConcreteElementA(), new ConcreteElementB(), new ConcreteElementC()};
61         ConcreteVisistor1 v1 = new ConcreteVisistor1();
62         ConcreteVisistor2 v2 = new ConcreteVisistor2();
63         for (Element element : list) {
64             element.accept(v1);
65         }
66         for (Element element : list) {
67             element.accept(v2);
68         }
69     }
70 }
```

- What is the output of this code?

Visitor – Implementation (1)

- Each object structure will be associated with a Visitor (abstract class)
  - Declares *VisitConcreteElement* for each class of *ConcreteElements* defining the object structure
  - Visit operation declares a particular *ConcreteElemnt* as its argument to allow the visitor to access the interface of *ConcreteElement* directly
  - *ConcreteVistor* classes override each visit operation to implement visitor-specific behavior

- *ConcreteElement* classes implement their Accept operation that calls the matching Visit operation on the Visitor for that *ConcreteElement*

Visitor – Implementation (2)

- Double dispatch
  - The execution of an operation depends on the kind of request and the types of two receivers

- Visitor pattern allows adding operations to classes without changing them through the Accept method which is double dispatch
  - Accept method depends on Visitor and Element types which let visitors request different operations on each class of element

Visitor – Implementation (3)

- Traversing the object structure; a visitor must visit each element of the object structure – How?

- Can be a responsibility of
  - Object structure: a collection iterates over its elements calling the Accept operation on each (use *Composite*)

  - Separate iteration object: using an *Iterator* to visit the elements
    - Internal operator will call an operations on the visitor with an element as an argument (not using double dispatching)

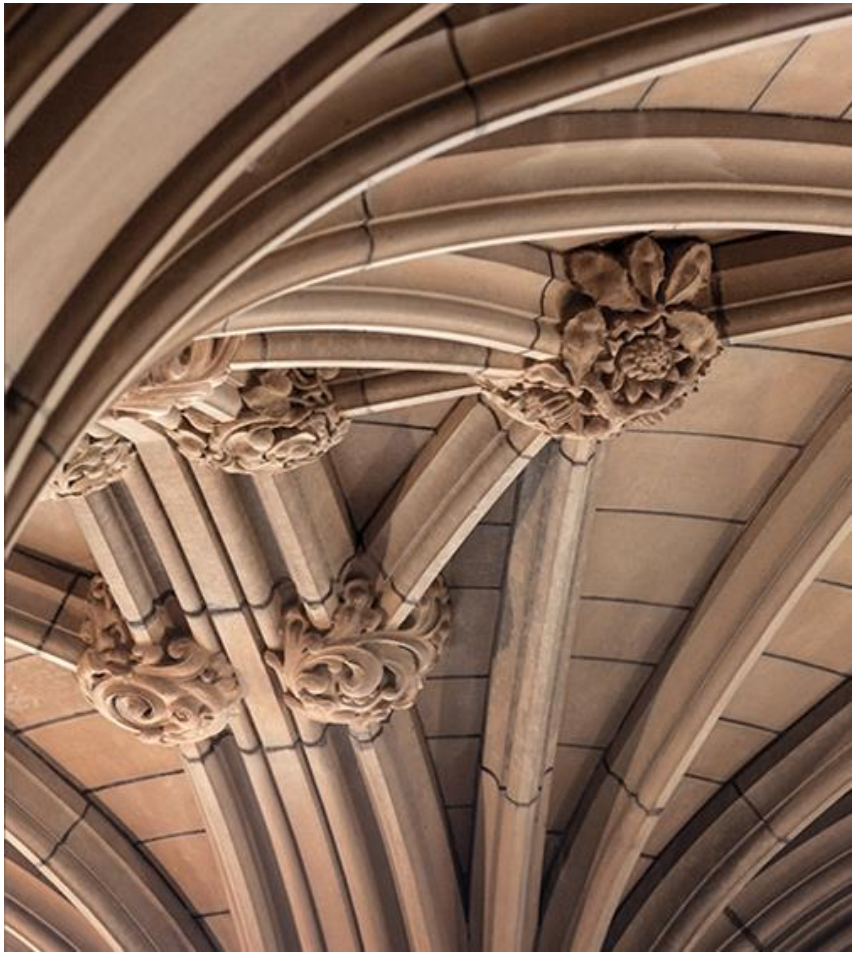
  - Visitor: implement the traversal logic in the Visitor
    - Allows to implement particularly complex traversal
    - Code duplication

Visitor – Related Patterns

- Composite
  - The composite pattern can be used to define an object structure over which a Visitor can iterate to apply an operation
- Interpreter
  - Visit or may be applied to do the interpretation

Template Method Pattern (GoF)

Class behavioural



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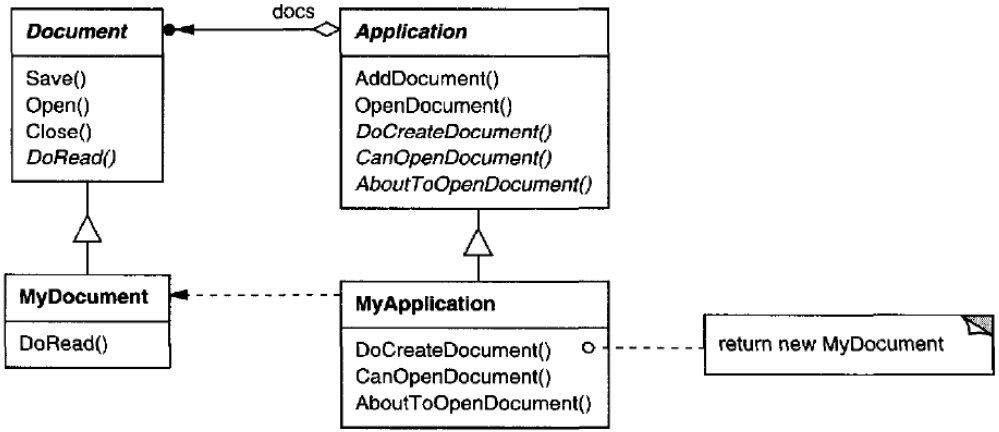
Motivating Scenario

- Application framework
- Application opens existing documents stored in external format
- Document represents the document's info once its read
- Sub-classing:
  - SpreadsheetDocument and SpreadsheetApplication are Spreadsheet Application
- *OpenDocument()* to define the algorithm for opening and reading a document (Template Method)



Motivating Scenario – Template Method

- A template method defines abstract operations (algorithm) to be concretely implemented by subclasses

- Application sub-classes
  - Some steps of the algorithm (e.g., for CanOpenDocument() and DoCreateDocument())

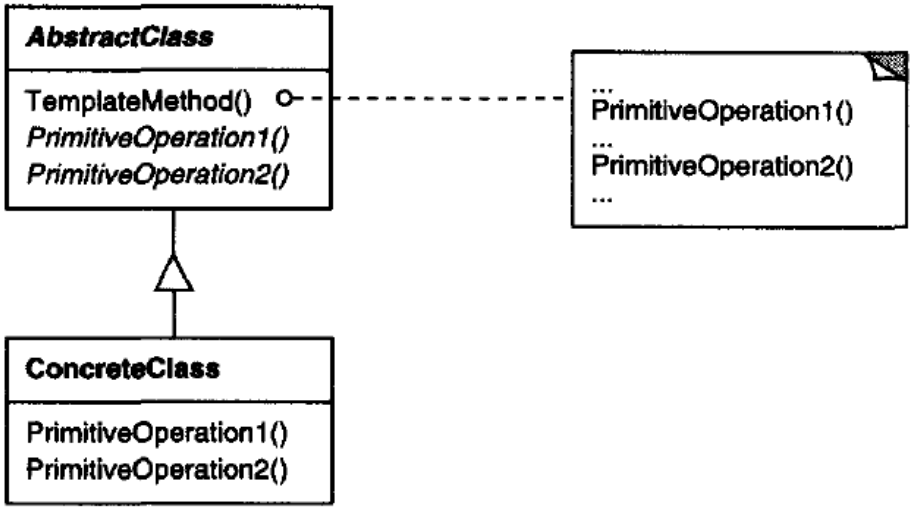
- Document sub-classes
  - Steps to carry on the operation (e.g., DoRead() to read the document)

- Let sub-classes know when something is about to happen in case they care
  - E.g., AboutToOpenDocument()

Template Method Pattern

- Class behavioral
- Intent
  - Let subclasses redefine certain steps of an algorithm without changing the algorithm's structure
- Applicability
  - Implement invariant parts of an algorithm once and let subclasses implement the varying behavior
  - Common behavior among subclasses to reduce code duplication ("*refactoring to generalize*")
  - Control subclasses extensions
    - Template method calls hook operations at specific points

Template Method Pattern – Structure



Template Method – Participants and Collaboration

- AbstractClass (Application)
  - Defines abstract primitive operations
  - Implement a template method defining an algorithm's skeleton
  - The template method calls primitive operations and AbstractClass' operations

- ConcreteClass (MyApplication)
  - Implements the primitive operations to perform sub-class specific steps of the algorithm
  - Relies on Abstract class to implement invariant algorithm's steps

Template Method – Consequences

- Code reuse (e.g., class libraries)
- Inverted control structure ("the Hollywood principle" – "Don't call us, we'll call you"
- Template methods can call:
  - Concrete operations (ConcreteClass or client classes)
  - Concrete AbstractClass operations
  - Primitive (abstract) operations (must be overridden)
  - Factory methods
  - Hook operations
    - Provides default behavior that subclass can extend if needed
    - Often does nothing by default, subclass override it to extend its behavior
  - Subclasses must know which operations are designed for overriding (hook or abstract/primitive)

Template Method Pattern – Implementation

- Minimize primitive operations a subclass must override
  - More primitive operations can increase client's tasks

- Naming conventions to identify operations that should be overridden
  - E.g., MacApp framework (Macintosh applications) prefixes template method names with "Do" (DoRead, DoCreateDocument)

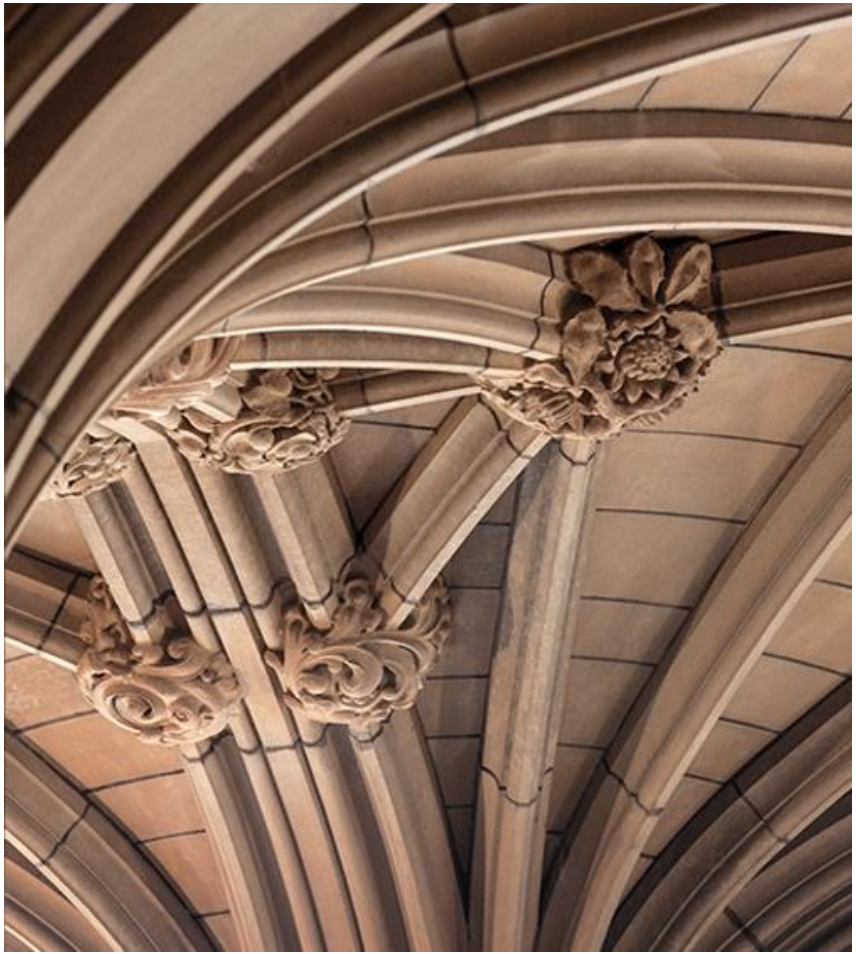
Template Method Pattern – Related Patterns

- Factory
  - Template Methods often call Factory Methods
  - e.g., DoCreateDocument called by OpenDocument

- Strategy
  - Strategy vary the entire algorithm using delegation
  - Template method vary part of an algorithm using inheritance

Model View Controller

Enterprise (Web) Application



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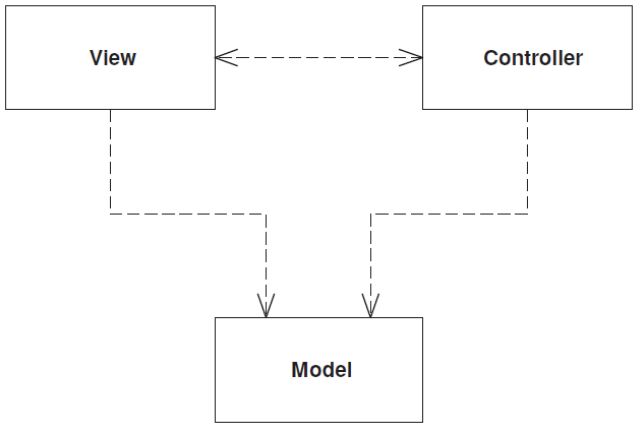
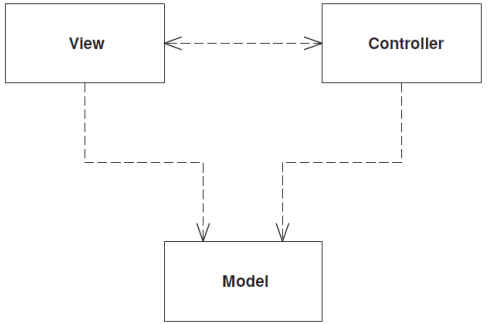
Model View Controller (MVC)

– *"Splits user interface interaction into three distinct roles"*



MVC – How it Works

- *Model*
  - An object represent information about the domain
  - E.g., customer object
- *View*
  - Representation of the model (data) in the UI
  - UI widget or HTML page rendered with info from the model
- *Controller*
  - Handle user interactions, manipulate the model and update the view accordingly



MVC – When to Use it

- MVC separate the presentation from the model and the controller from the view

- Benefits of separating the presentation from the model:
  - Separation of concerns (UI design vs. business policies/database interactions)
  - Multiple different views based on the same model
  - Easier to test the domain logic without irrespective to UI

MVC – View and Model

- Dependencies
  - The presentation depends on the model but not vice-versa
  - Maintain the presentation without changing the model

- Discuss:
  - What design consequences that might arise from the dependency of the presentation on the model? How to addressed it?

MVC – View and Model

- Dependencies
  - The presentation depends on the model but not vice-versa
  - Maintain the presentation without changing the model

- Discuss:
  - What design consequences that might arise from the dependency of the presentation on the model? How to addressed it?

- Several presentations of a model on multiple windows/UIs. If the user makes changes to the model through one of the presentations, this should be reflected in the other presentations
- Use the Observer pattern (GoF); presentation is observer of the model

MVC –View and Controller

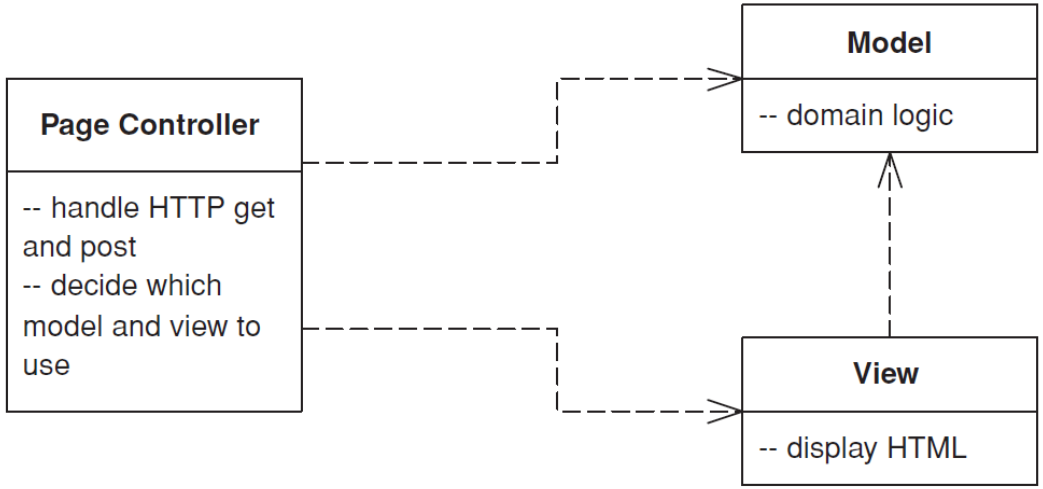
- Separation/dependency is less important

- Can be designed/implemented differently
  - One view and two controllers to support “editable” and “non-editable” behavior
    - Controllers as Strategies (GoF) for the view
  - In practice, one controller per view
  - Web interfaces help popularizing the separation

- Some GUI frameworks combine view and controller but led to confusion

MVC – Page Controller

"An object that handles a request for a specific page or action on a Web site"



Page Controller – How It works

- One module on the Web server act as the controller for each page on the Web site (ideally)
- With dynamic content different pages might be sent, controllers link to each action (e.g., click a link or button)
- Page controller can be structured as a script (e.g., servlet) or as a server page (e.g., PHP, JSP)

Page Controller – Responsibilities

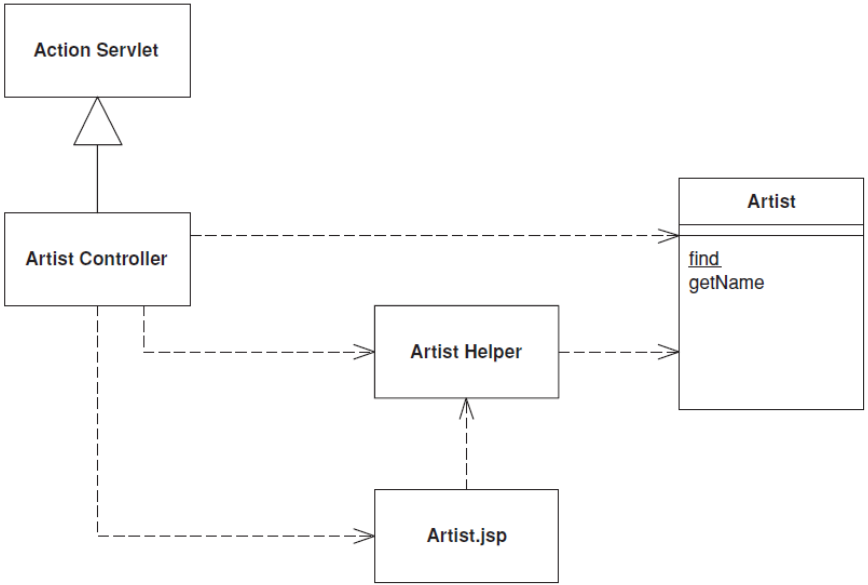
- Decode the URL and extract form data for the required request action
- Create and invoke any model objects to process the data
- Decide which view to display the result page and forward model information to it
- Invoke helper objects to help in handling a request
  - Handlers that do similar tasks can be grouped in one (reduce code duplication)

Page Controller – When to Use it

- Whether to use Page Controller or Front Controller?
- Page controller works particularly where most URLs can be handled with a server page or script, and more complex ones with helper objects

Page Controller – Example

- Simple display with a servlet Controller and a JSP view in Java
  - http://www.thingy.com/recordingApp/artist?name=danielaMercury



Page Controller – Example

- Mapping incoming requests (URLs) to corresponding controllers

```
<servlet>
    <servlet-name>artist</servlet-name>
    <servlet-class>actionController.ArtistController</servlet-class>
</servlet>
    <servlet-mapping>
    <servlet-name>artist</servlet-name>
    <url-pattern>/artist</url-pattern>
</servlet-mapping>
```

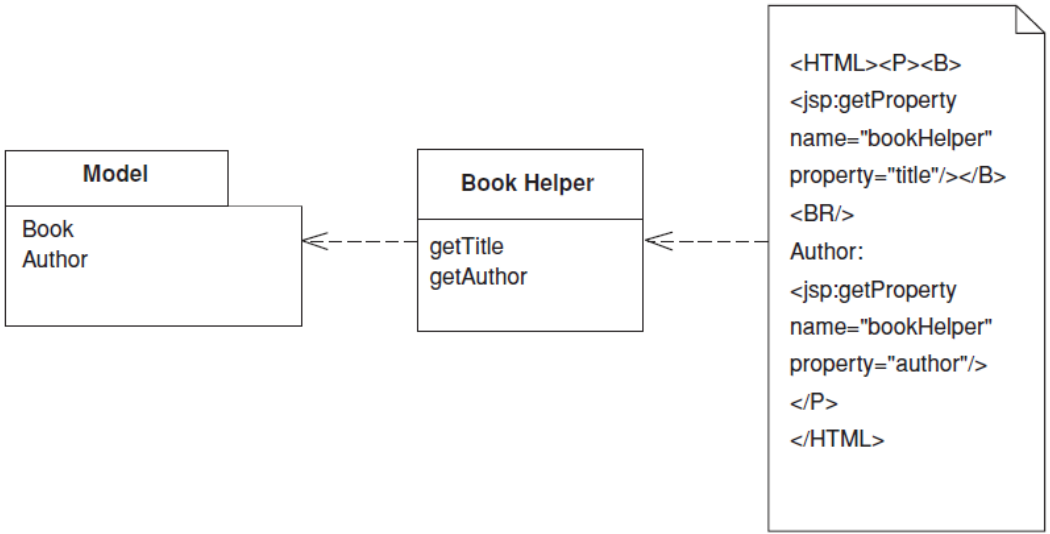
Page Controller – Example

- Class controller for handling /artist requests

```
1
2  class ArtistController {
3
4      //....
5      public void doGet(HttpServletRequest request, HttpServletResponse response)
6          throws IOException, ServletException {
7      Artist artist = Artist.findNamed(request.getParameter("name"));
8      if (artist == null)
9          forward("/MissingArtistError.jsp", request, response);
10     else {
11         request.setAttribute("helper", new ArtistHelper(artist));
12     forward("/artist.jsp", request, response);
13     }
14     }
15 }
```

MVC – Template View

– *"Renders information into HTML by embedding markers in an HTML page"*



Template View – Embedding the Markers

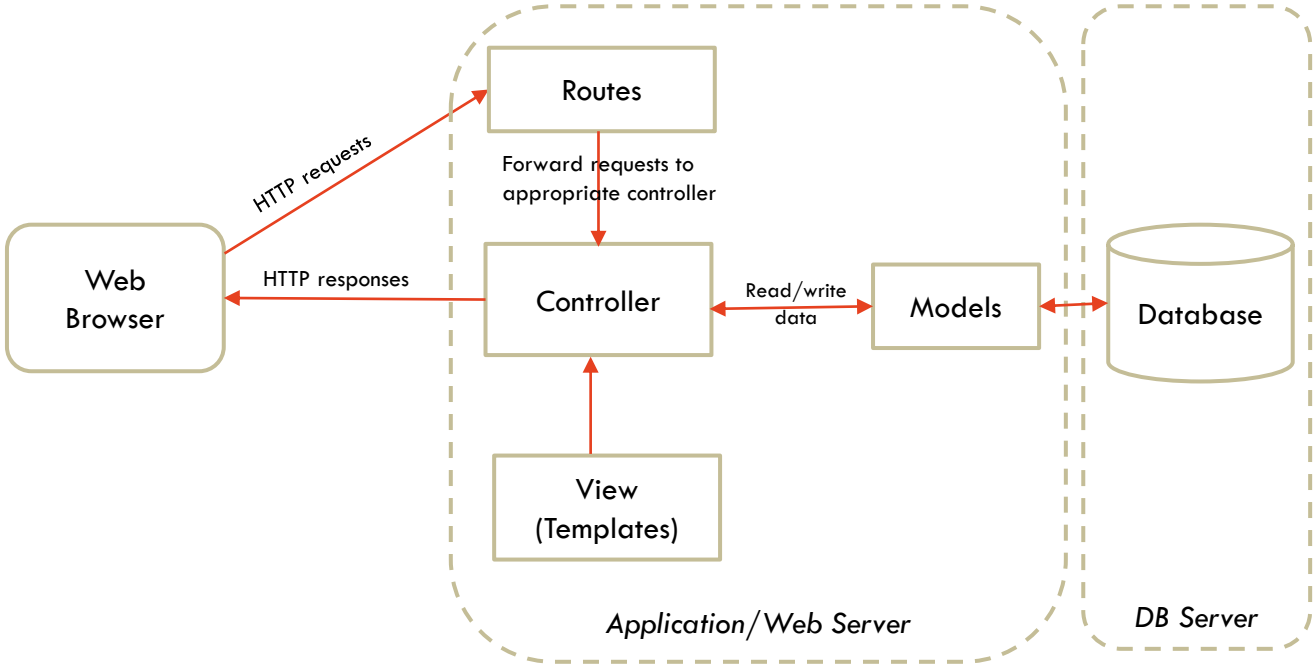
- HTML-like tags which will be treated differently (e.g., XML)
- Using special text markers not recognised by HTML editor but easier to understand and maintain
- Server pages (ASP, JSP, EJS) allows to embed programming logic (known as scriplets)
  - Not easy to understand when it becomes complex (programming logic + display)
  - E.g., conditional display, iteration

Template View – Helper Objects

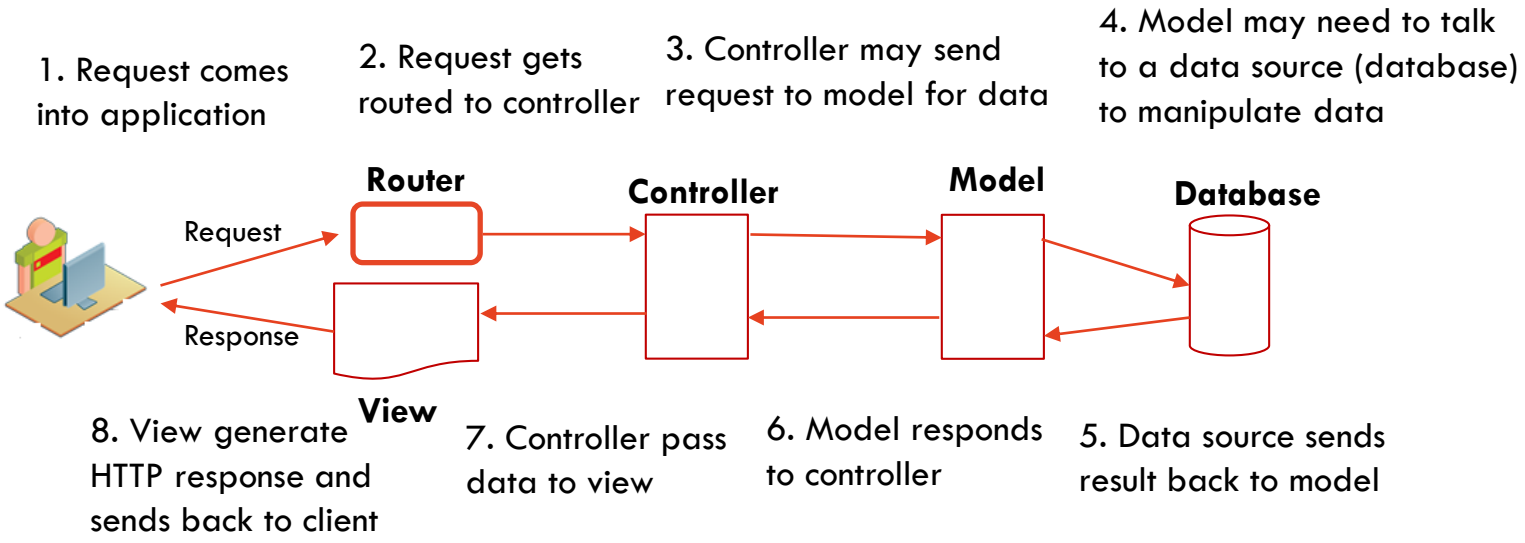
- Helper objects can be used to handle the programming logic where possible
- This can simplify the views by having those markers to be replaced with dynamic content
  - E.g., conditions and iterations logic in the helper object and called from the template view
- Developers can focus on the logic (helper objects) and designers on the views (template view)

MVC – Web Application

– Example of MVC design for Web application using Node.js/Express.js



MVC – Full Workflow (Example Node.js/Express.js)



- Data base related code should be put in model layer
- Controller should not have knowledge about the actual database
- Modularity allows easy switching between technologies
  - e.g. different view templates, different database management systems

References

- Erich Gamma, Richard Helm, Ralph Johnson, and John Vlissides. 1995. *Design Patterns: Elements of Reusable Object-Oriented Software*. Pearson.

- Martin Fowler (With contributions from David Rice, Matthew Foemmel, Edward Hieatt, Robert Mee, and Randy Stafford). 2003. *Patterns of Enterprise Applications Architecture*. Pearson.
- Alexander Shevts, Dive into Design Patterns. ebook
- Web Application Development (COMP5347) slides

W9 Tutorial: Practical Exercises/coding
W9 Lecture: Enterprise Design Patterns
Design Pattern Assignment

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