Chapter 6 – Architectural Design

Topics covered

- ✧ Architectural design decisions
- ✧ Architectural views
- ✧ Architectural patterns
- ✧ Application architectures

Architectural design

- Architectural design is concerned with understanding how a software system should be organized and designing the overall structure of that system.
- Architectural design is the critical link between design and requirements engineering, as it identifies the main structural components in a system and the relationships between them.
- The output of the architectural design process is an architectural model that describes how the system is organized as a set of communicating components.

Agility and architecture

- It is generally accepted that an early stage of agile processes is to design an overall systems architecture.
- Refactoring the system architecture is usually expensive because it affects so many components in the system

Architectural abstraction

- Architecture in the small is concerned with the architecture of individual programs. At this level, we are concerned with the way that an individual program is decomposed into components.
- Architecture in the large is concerned with the architecture of complex enterprise systems that include other systems, programs, and program components. These enterprise systems are distributed over different computers, which may be owned and managed by different companies.

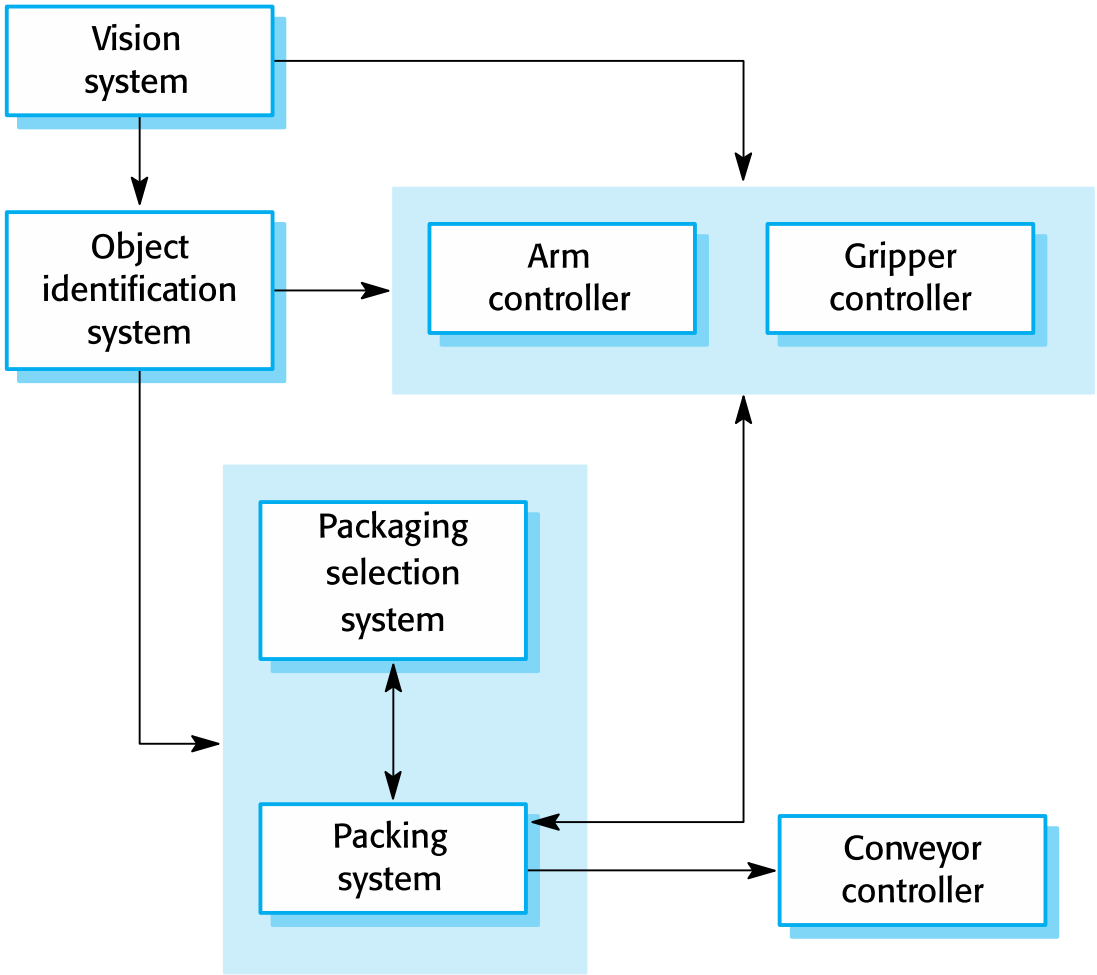
Advantages of explicit architecture

- ✧ Stakeholder communication
  - Architecture may be used as a focus of discussion by system stakeholders.
- ✧ System analysis
  - Means that analysis of whether the system can meet its non-functional requirements is possible.
- ✧ Large-scale reuse
  - The architecture may be reusable across a range of systems
  - Product-line architectures may be developed.

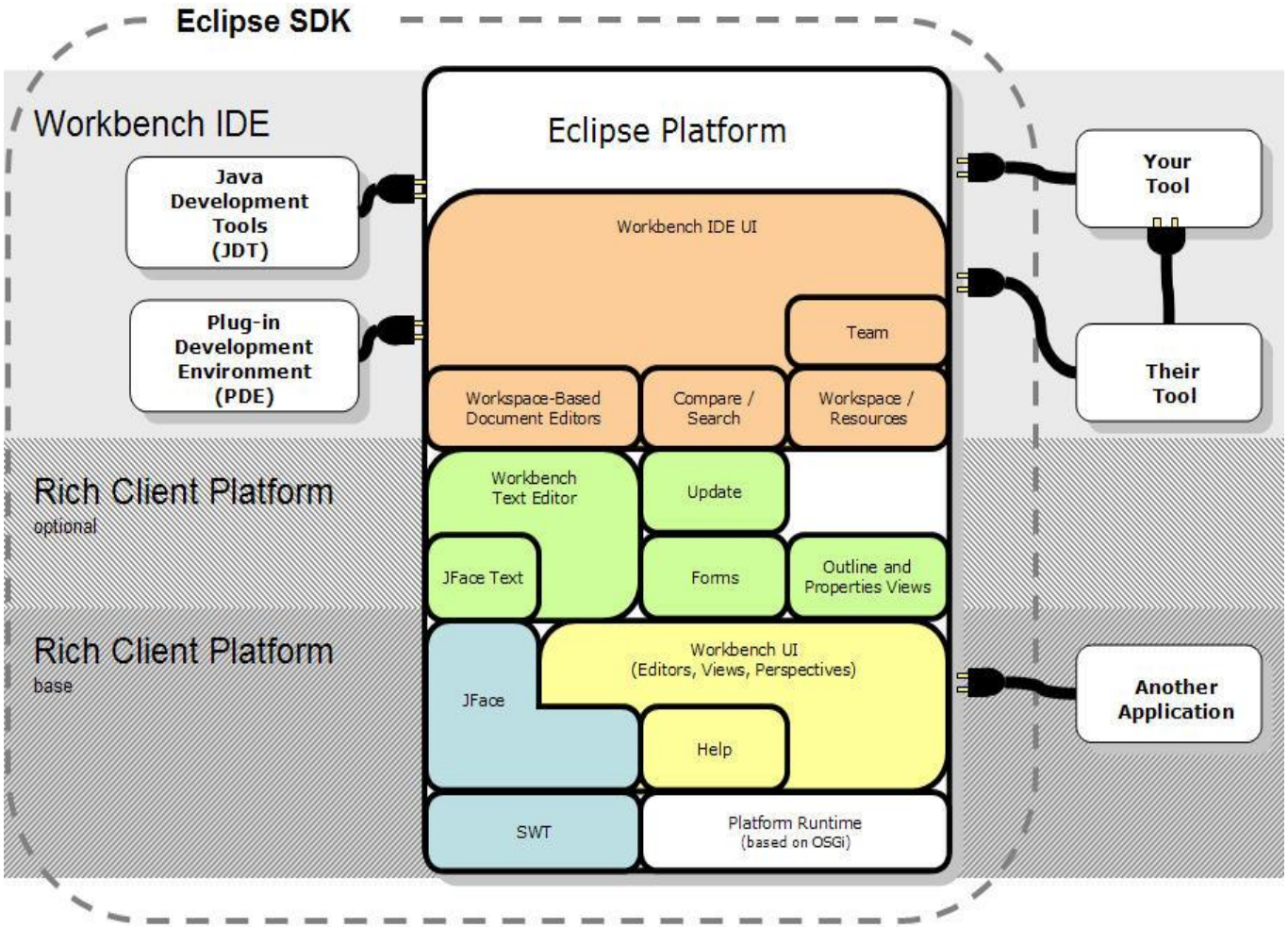
Architectural representations

- Simple, informal block diagrams showing entities and relationships are the most frequently used method for documenting software architectures.
- But these have been criticised because they lack semantics, do not show the types of relationships between entities nor the visible properties of entities in the architecture.
- Depends on the use of architectural models. The requirements for model semantics depends on how the models are used.

The architecture of a packing robot control system



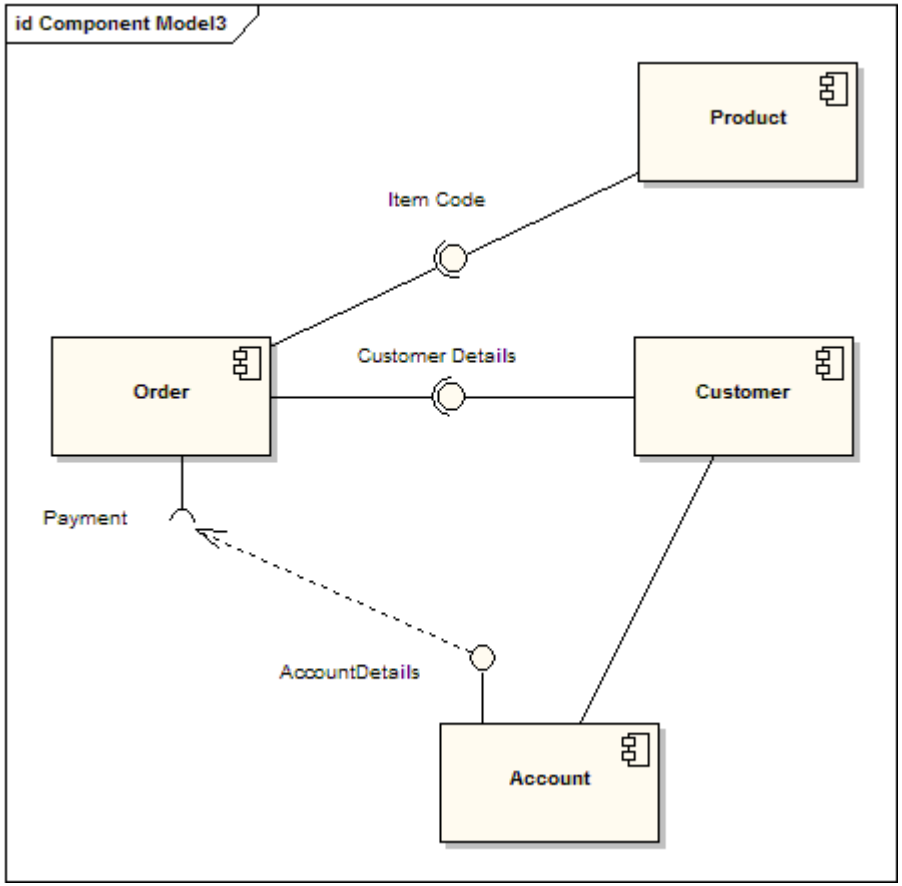
Eclipse architecture – informal model

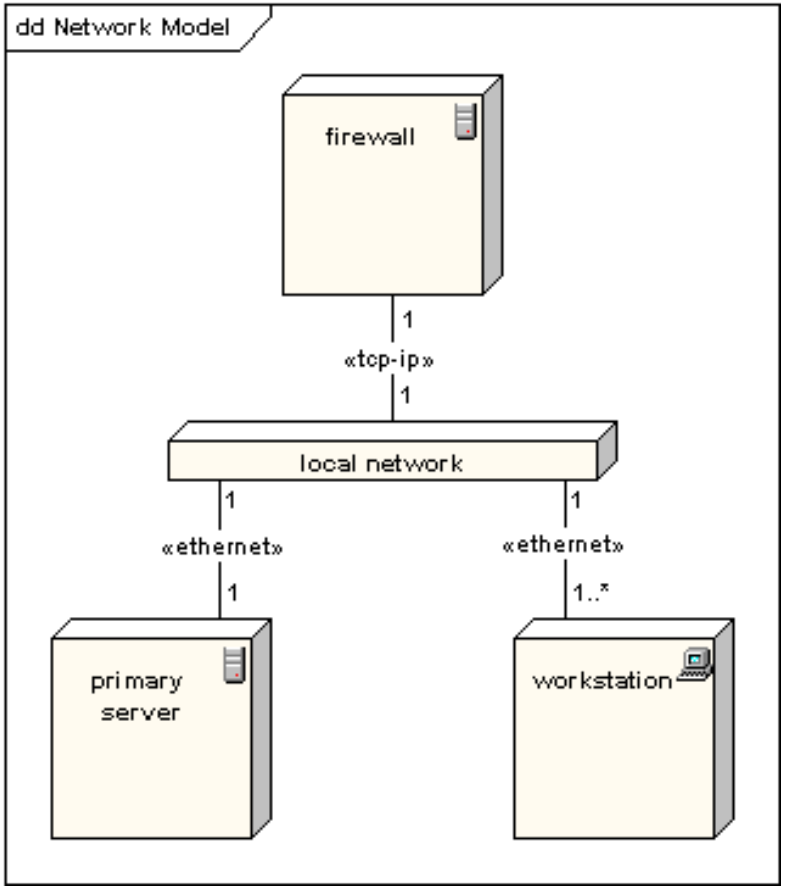


Box and line diagrams

- Very abstract - they do not show the nature of component relationships nor the externally visible properties of the sub-systems.
- However, useful for communication with stakeholders and for project planning.

…So we will use Components and Deployment diagrams





Use of architectural models

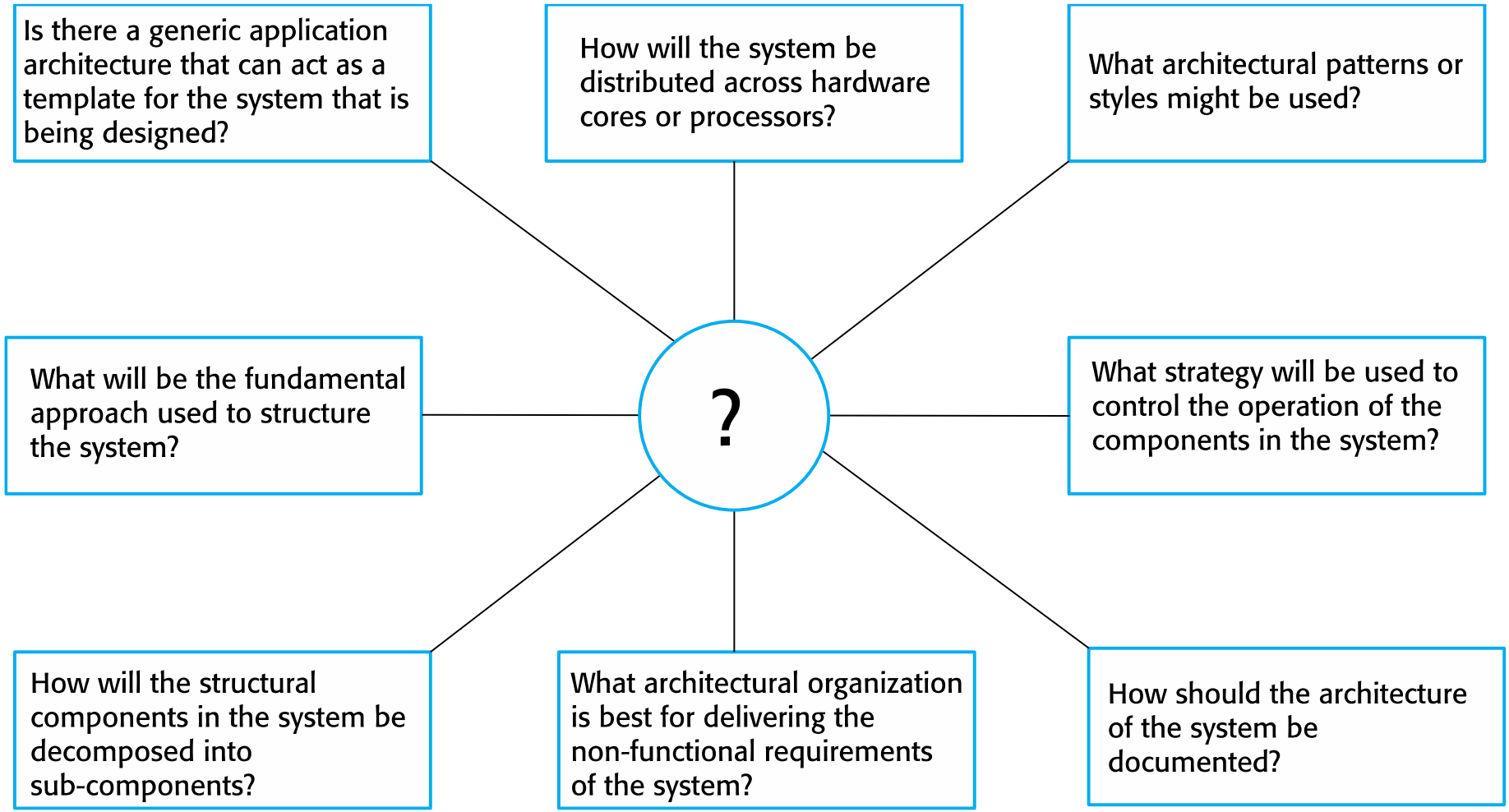
- As a way of facilitating discussion about the system design
  - A high-level architectural view of a system is useful for communication with system stakeholders and project planning because it is not cluttered with detail. Stakeholders can relate to it and understand an abstract view of the system. They can then discuss the system as a whole without being confused by detail.
- As a way of documenting an architecture that has been designed
  - The aim here is to produce a complete system model that shows the different components in a system, their interfaces and their connections.

Architectural design decisions

Architectural design decisions

- Architectural design is a creative process so the process differs depending on the type of system being developed.
- However, a number of common decisions span all design processes and these decisions affect the non-functional characteristics of the system.

Architectural design decisions



Architecture reuse

- Systems in the same domain often have similar architectures that reflect domain concepts.
- Application product lines are built around a core architecture with variants that satisfy particular customer requirements.
- The architecture of a system may be designed around one of more architectural patterns or ‘styles’.
  - These capture the essence of an architecture and can be instantiated in different ways.

Architecture and system characteristics

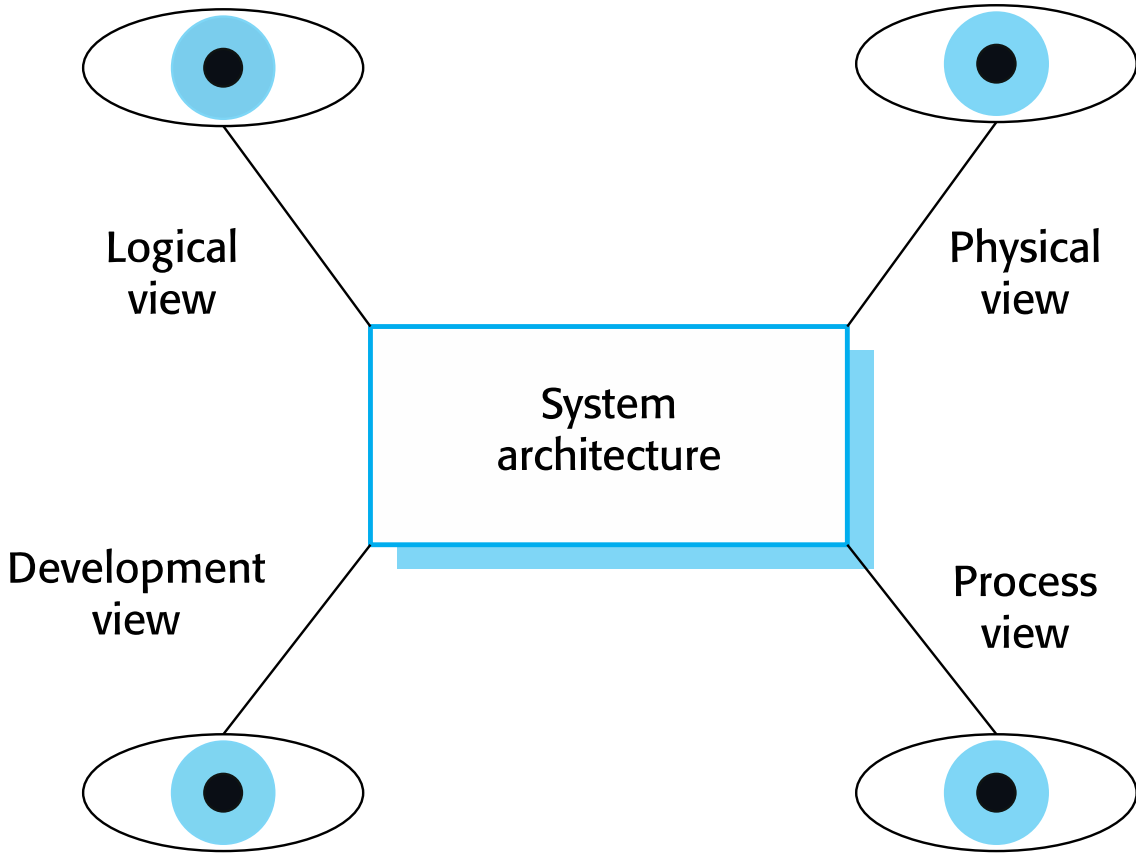
- ✧ Performance
  - Localise critical operations and minimise communications. Use large rather than fine-grain components.
- ✧ Security
  - Use a layered architecture with critical assets in the inner layers.
- ✧ Safety
  - Localise safety-critical features in a small number of sub-systems.
- ✧ Availability
  - Include redundant components and mechanisms for fault tolerance.
- ✧ Maintainability
  - Use fine-grain, replaceable components.

Architectural views

Architectural views

- What views or perspectives are useful when designing and documenting a system's architecture?
- What notations should be used for describing architectural models?
- Each architectural model only shows one view or perspective of the system.
  - It might show how a system is decomposed into modules, how the run-time processes interact or the different ways in which system components are distributed across a network.
  - For both design and documentation, you usually need to present multiple views of the software architecture.

Architectural views



Views and UML diagrams

4+1 View Model (Philippe Kruchten)

- **Logical View**
- **Process View**
- **Deployment View**
- **Development View**
- **Scenario View**
  Or Use Case View

UML (industry standard)

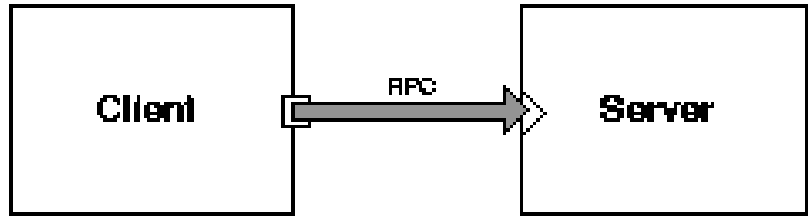
- Class Diagram
- Use Case Diagram
- Object diagram
- State-chart diagram
- Sequence diagram
- Collaboration diagram
- Activity diagram
- Component diagram
- Deployment diagram

4 + 1 view model of software architecture

- A logical view, which shows the key abstractions in the system as objects or object classes.
- A process view, which shows how, at run-time, the system is composed of interacting processes.
- A development view, which shows how the software is decomposed for development.
- A physical (deployment) view, which shows the system hardware and how software components are distributed across the processors in the system.
- Related using use cases or scenarios (+1)

Representing architectural views

- Some people argue that the Unified Modeling Language (UML) is an appropriate notation for describing and documenting system architectures
- Architectural description languages (ADLs) have been developed but are not widely used




```
System simple_cs = {
        Component client = { Port send-request; };
        Component server = { Port receive-request; };
        Connector rpc = { Roels { caller, callee}};
        Attachments {
            client.send-request to rpc.caller;
            server.receive-request to rpc.callee; }}
```

Architectural patterns

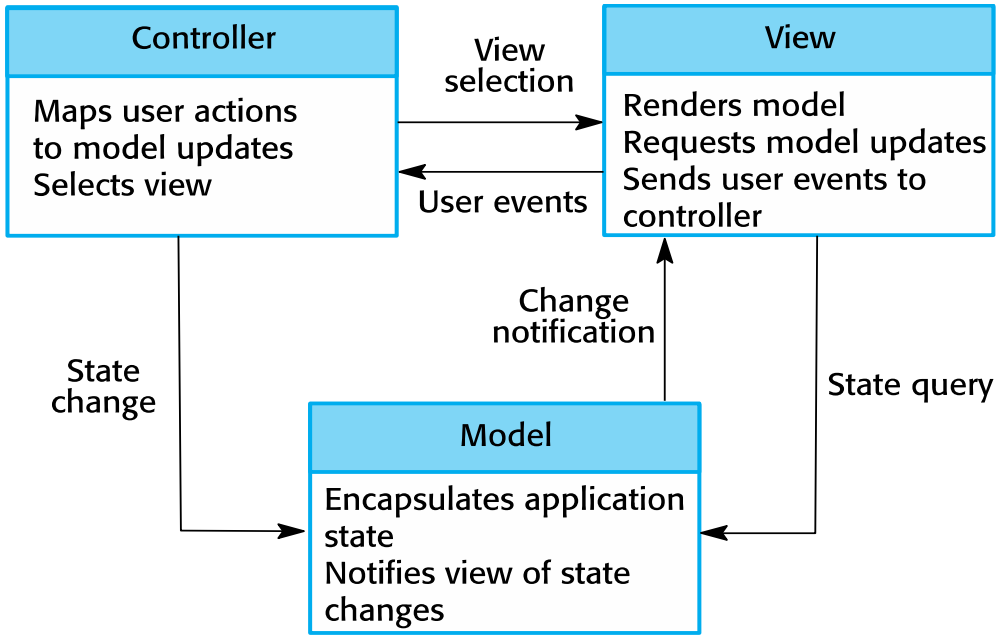
Architectural patterns

- Patterns are a means of representing, sharing and reusing knowledge.
- An architectural pattern is a stylized description of good design practice, which has been tried and tested in different environments.
- Patterns should include information about when they are and when the are not useful.
- Patterns may be represented using tabular and graphical descriptions.

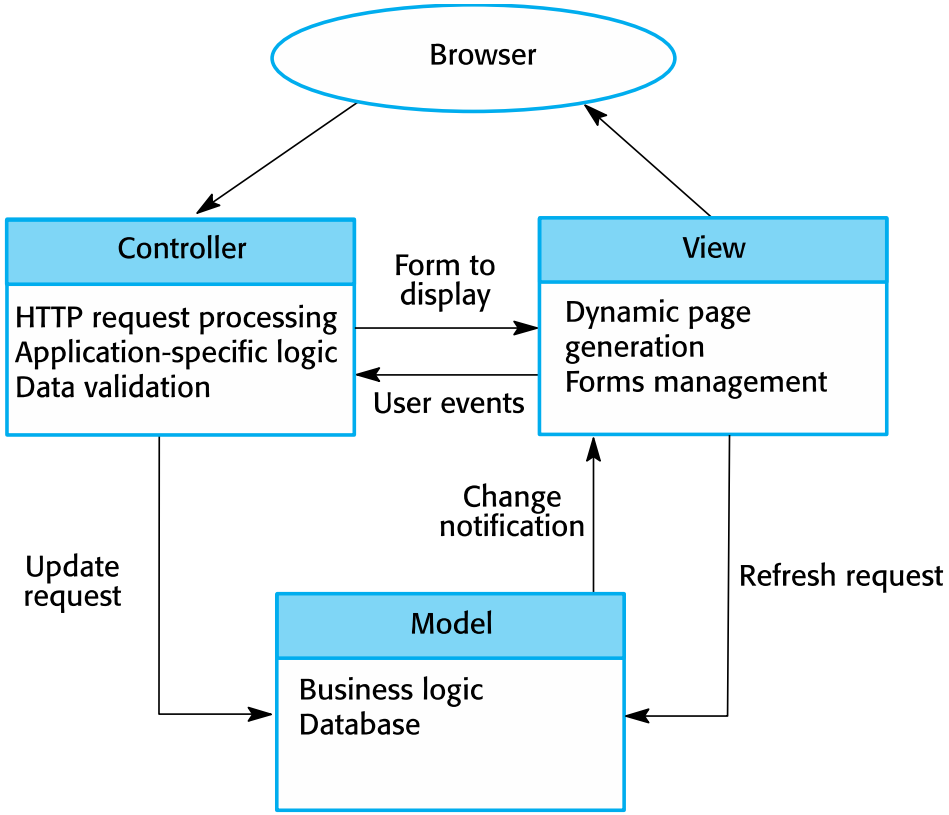
The Model-View-Controller (MVC) pattern

Name	MVC (Model-View-Controller)
Description	Separates presentation and interaction from the system data. The system is structured into three logical components that interact with each other. The Model component manages the system data and associated operations on that data. The View component defines and manages how the data is presented to the user. The Controller component manages user interaction (e.g., key presses, mouse clicks, etc.) and passes these interactions to the View and the Model. See Figure 6.3.
Example	Next Figure shows the architecture of a web-based application system organized using the MVC pattern.
When used	Used when there are multiple ways to view and interact with data. Also used when the future requirements for interaction and presentation of data are unknown.
Advantages	Allows the data to change independently of its representation and vice versa. Supports presentation of the same data in different ways with changes made in one representation shown in all of them.
Disadvantages	Can involve additional code and code complexity when the data model and interactions are simple.

The organization of the Model-View-Controller



Web application architecture using the MVC pattern



Layered architecture

- ✧ Used to model the interfacing of sub-systems.
- ✧ Organises the system into a set of layers (or abstract machines) each of which provide a set of services.
- ✧ Supports the incremental development of sub-systems in different layers. When a layer interface changes, only the adjacent layer is affected.
- ✧ However, often artificial to structure systems in this way.

The Layered architecture pattern

Name	Layered architecture
Description	Organizes the system into layers with related functionality associated with each layer. A layer provides services to the layer above it so the lowest-level layers represent core services that are likely to be used throughout the system. See Figure 6.6.
Example	A layered model of a system for sharing copyright documents held in different libraries.
When used	Used when building new facilities on top of existing systems; when the development is spread across several teams with each team responsibility for a layer of functionality; when there is a requirement for multi-level security.
Advantages	Allows replacement of entire layers so long as the interface is maintained. Redundant facilities (e.g., authentication) can be provided in each layer to increase the dependability of the system.
Disadvantages	In practice, providing a clean separation between layers is often difficult and a high-level layer may have to interact directly with lower-level layers rather than through the layer immediately below it. Performance can be a problem because of multiple levels of interpretation of a service request as it is processed at each layer.

A generic layered architecture

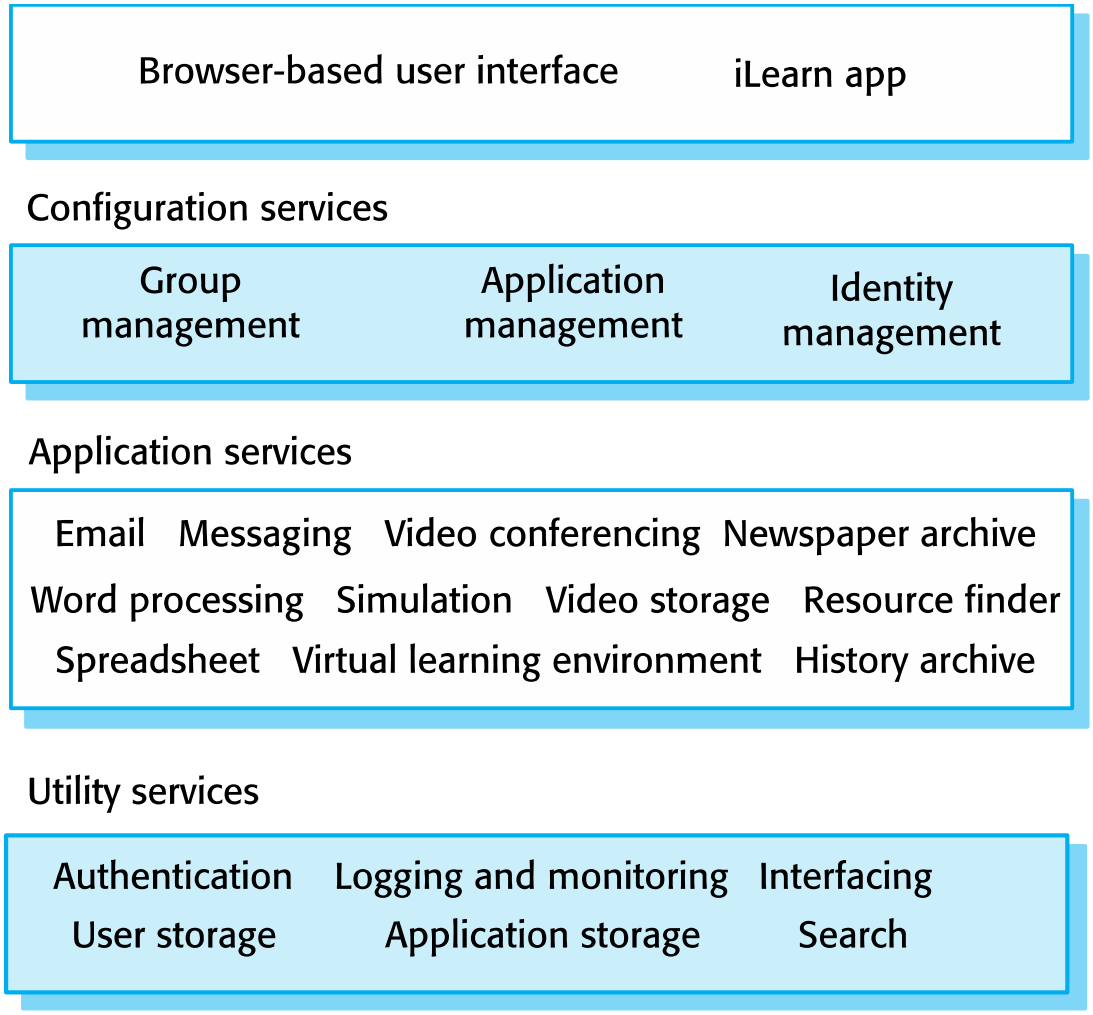
User interface

User interface management
Authentication and authorization

Core business logic/application functionality
System utilities

System support (OS, database etc.)

The architecture of the iLearn system



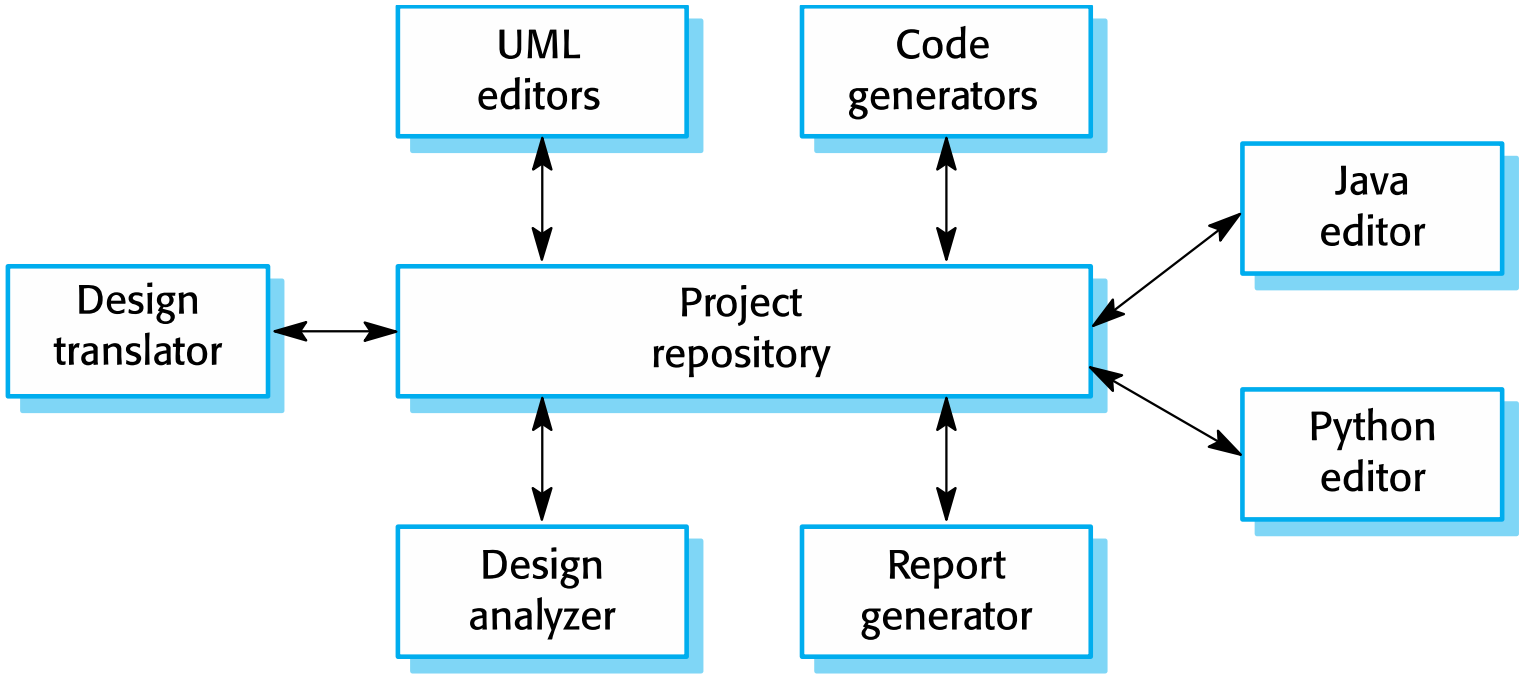
Repository architecture

- Sub-systems must exchange data. This may be done in two ways:
  - Shared data is held in a central database or repository and may be accessed by all sub-systems;
  - Each sub-system maintains its own database and passes data explicitly to other sub-systems.
- When large amounts of data are to be shared, the repository model of sharing is most commonly used as this is an efficient data sharing mechanism.

The Repository pattern

Name	Repository
Description	All data in a system is managed in a central repository that is accessible to all system components. Components do not interact directly, only through the repository.
Example	Next Figure is an example of an IDE where the components use a repository of system design information. Each software tool generates information which is then available for use by other tools.
When used	You should use this pattern when you have a system in which large volumes of information are generated that has to be stored for a long time. You may also use it in data-driven systems where the inclusion of data in the repository triggers an action or tool.
Advantages	Components can be independent—they do not need to know of the existence of other components. Changes made by one component can be propagated to all components. All data can be managed consistently (e.g., backups done at the same time) as it is all in one place.
Disadvantages	The repository is a single point of failure so problems in the repository affect the whole system. May be inefficiencies in organizing all communication through the repository. Distributing the repository across several computers may be difficult.

A repository architecture for an IDE



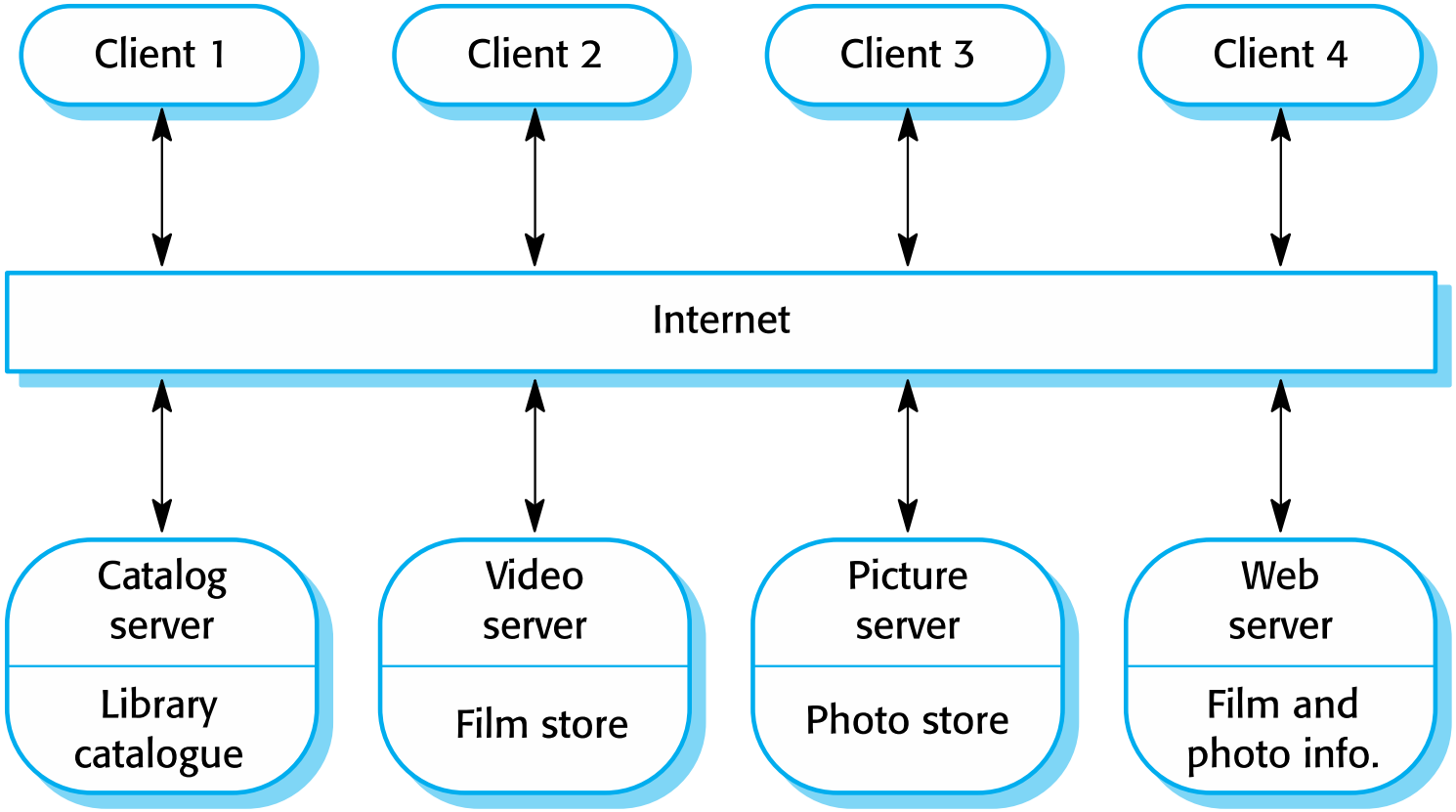
Client-server architecture

- Distributed system model which shows how data and processing is distributed across a range of components.
  - Can be implemented on a single computer.
- Set of stand-alone servers which provide specific services such as printing, data management, etc.
- Set of clients which call on these services.
- Network which allows clients to access servers.

The Client–server pattern

Name	Client-server
Description	In a client–server architecture, the functionality of the system is organized into services, with each service delivered from a separate server. Clients are users of these services and access servers to make use of them.
Example	Next Figure is an example of a film and video/DVD library organized as a client–server system.
When used	Used when data in a shared database has to be accessed from a range of locations. Because servers can be replicated, may also be used when the load on a system is variable.
Advantages	The principal advantage of this model is that servers can be distributed across a network. General functionality (e.g., a printing service) can be available to all clients and does not need to be implemented by all services.
Disadvantages	Each service is a single point of failure so susceptible to denial of service attacks or server failure. Performance may be unpredictable because it depends on the network as well as the system. May be management problems if servers are owned by different organizations.

A client–server architecture for a film library



Design patterns

Design patterns

- A design pattern is a way of reusing abstract knowledge about a problem and its solution.
- A pattern is a description of the problem and the essence of its solution.
- It should be sufficiently abstract to be reused in different settings.
- Pattern descriptions usually make use of object-oriented characteristics such as inheritance and polymorphism.

Patterns

- *Patterns and Pattern Languages are ways to describe best practices, good designs, and capture experience in a way that it is possible for others to reuse this experience.*

Pattern elements

- ✧ Name
  - A meaningful pattern identifier.
- ✧ Problem description.
- ✧ Solution description.
  - Not a concrete design but a template for a design solution that can be instantiated in different ways.
- ✧ Consequences
  - The results and trade-offs of applying the pattern.

The Observer pattern

- Name
  - Observer.
- Description
  - Separates the display of object state from the object itself.
- Problem description
  - Used when multiple displays of state are needed.
- Solution description
  - See slide with UML description.
- Consequences
  - Optimisations to enhance display performance are impractical.

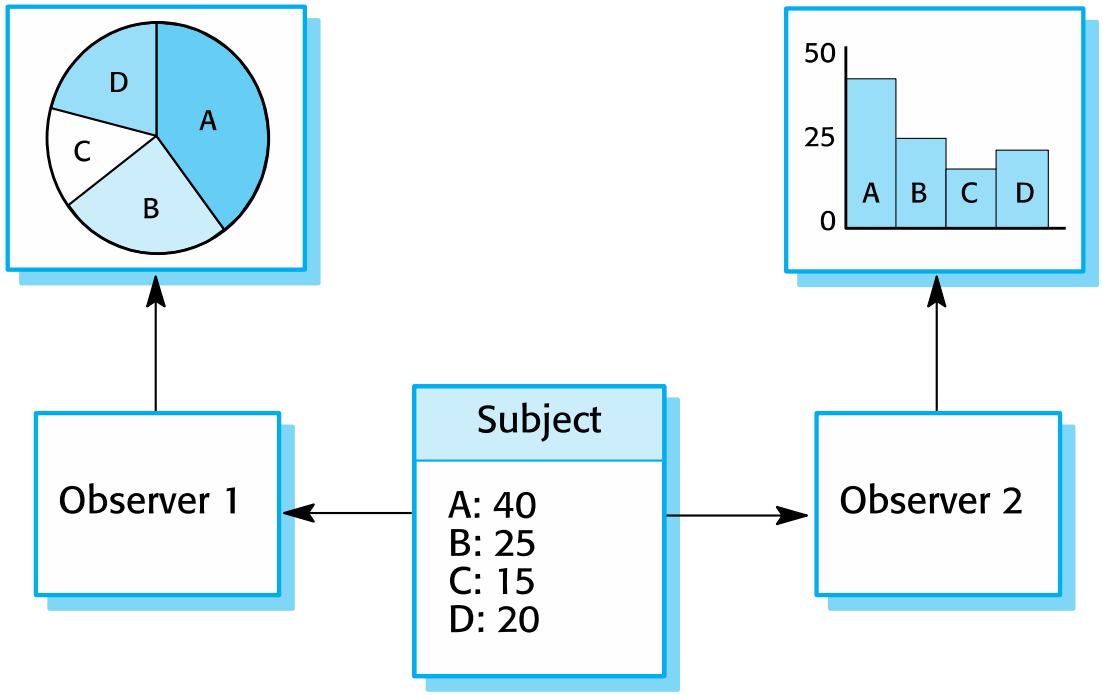
The Observer pattern (1)

Pattern name	Observer
Description	Separates the display of the state of an object from the object itself and allows alternative displays to be provided. When the object state changes, all displays are automatically notified and updated to reflect the change.
Problem description	In many situations, you have to provide multiple displays of state information, such as a graphical display and a tabular display. Not all of these may be known when the information is specified. All alternative presentations should support interaction and, when the state is changed, all displays must be updated. This pattern may be used in all situations where more than one display format for state information is required and where it is not necessary for the object that maintains the state information to know about the specific display formats used.

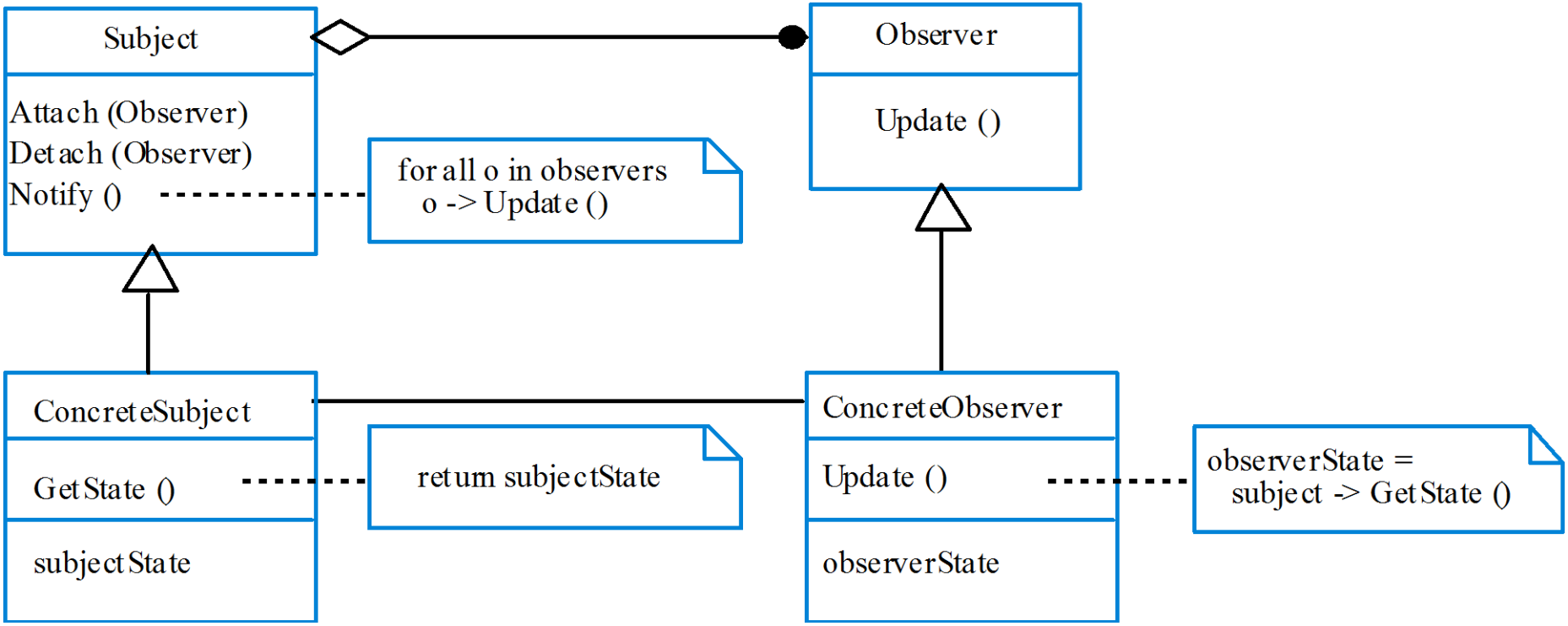
The Observer pattern (2)

Pattern name	Observer
Solution description	This involves two abstract objects, Subject and Observer, and two concrete objects, ConcreteSubject and ConcreteObject, which inherit the attributes of the related abstract objects. The abstract objects include general operations that are applicable in all situations. The state to be displayed is maintained in ConcreteSubject, which inherits operations from Subject allowing it to add and remove Observers (each observer corresponds to a display) and to issue a notification when the state has changed. The ConcreteObserver maintains a copy of the state of ConcreteSubject and implements the Update() interface of Observer that allows these copies to be kept in step. The ConcreteObserver automatically displays the state and reflects changes whenever the state is updated.
Consequences	The subject only knows the abstract Observer and does not know details of the concrete class. Therefore there is minimal coupling between these objects. Because of this lack of knowledge, optimizations that enhance display performance are impractical. Changes to the subject may cause a set of linked updates to observers to be generated, some of which may not be necessary.

Multiple displays using the Observer pattern



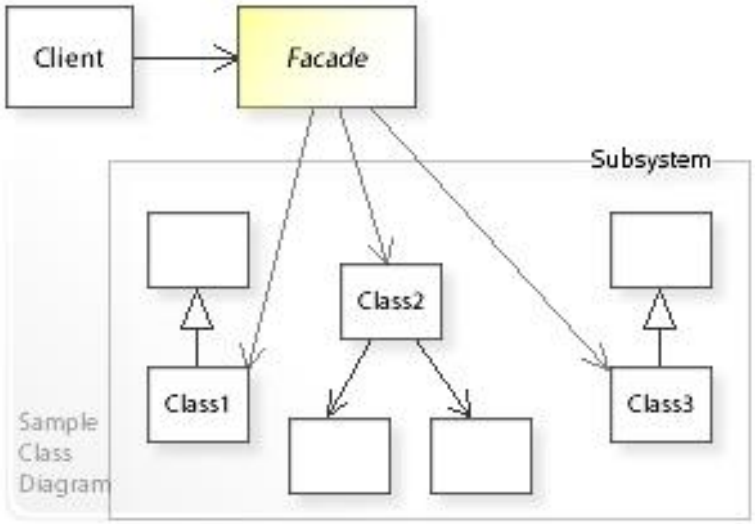
A UML model of the Observer pattern

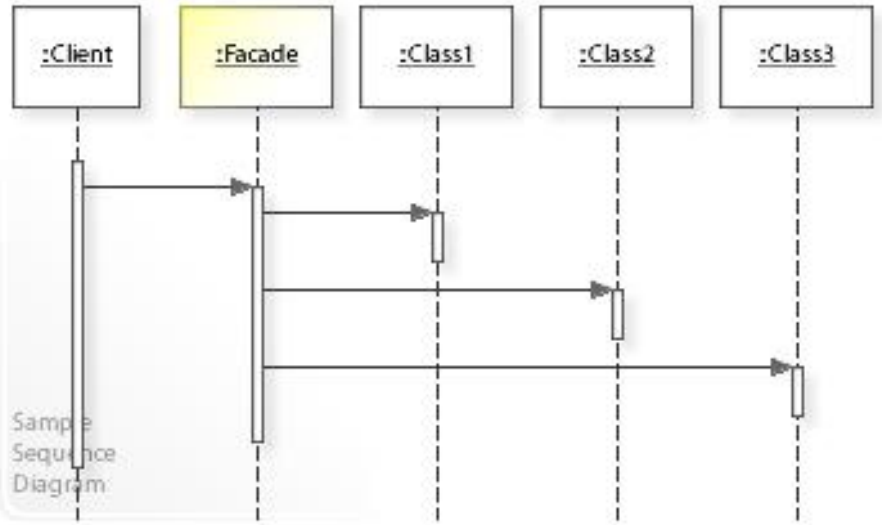


Façade pattern

✧ The facade pattern is typically used when

- a simple interface is required to access a complex system,
- a system is very complex or difficult to understand,
- an entry point is needed to each level of layered software, or
- the abstractions and implementations of a subsystem are tightly coupled.

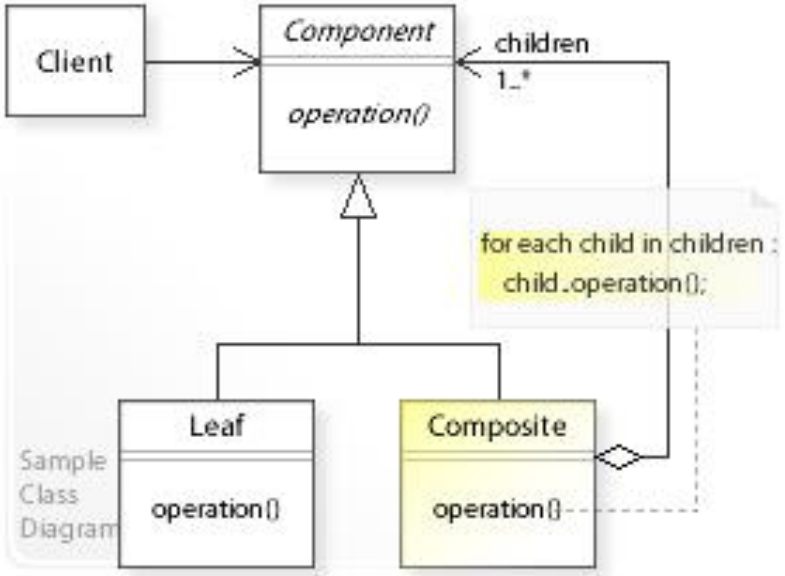


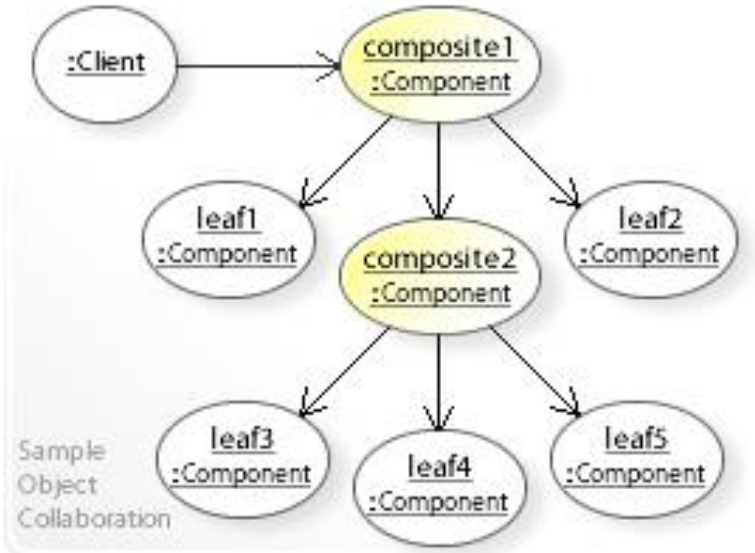


Composite pattern

✧ What problems can the Composite design pattern solve?

- A part-whole hierarchy should be represented so that clients can treat part and whole objects uniformly.
- A part-whole hierarchy should be represented as tree structure.





Key points

- A software architecture is a description of how a software system is organized.
- Architectural design decisions include decisions on the type of application, the distribution of the system, the architectural styles to be used.
- Architectures may be documented from several different perspectives or views such as a conceptual view, a logical view, a process view, and a development view.
- Architectural patterns are a means of reusing knowledge about generic system architectures. They describe the architecture, explain when it may be used and describe its advantages and disadvantages.