Inf2-SEPP
Lecture 7: Introduction to Design. Architectural Design

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Previous lectures

- Requirements engineering:
  - In general, with its concepts and sub-activities
  - Using use cases and use case diagrams
  - In different types of systems and software development processes
  - Use of personnas, scenarios and user stories in product engineering

This lecture

Design

- Concept
- Outputs of the design process
- Criteria for good design
- Levels of design
    - Architectural design
        - Concept and importance of an architecture
        - Considerations for architectural design: system decomposition, distribution, technologies
        - Some important architectures

What is design?

Design is the process of deciding how software will meet requirements.

Usually excludes detailed coding level.

Outputs of design process

Outputs include

- models.
  - E.g. using UML or Simulink
  - Often graphical
  - Can be executable

- written documents
  - Important that these record reasons for decisions

(Some) criteria for a good design

- It can meet the known requirements
  (functional and non-functional)
- It is maintainable:
  i.e. it can be adapted to meet future requirements
- It is straightforward to explain to implementors
- It makes appropriate use of existing technology,
  e.g. reusable components

Notice the human angle in most of these points, and the situation-dependency, e.g.

- whether an OO design or a functional design is best depends (partly) on whether it is to be implemented by OO programmers or functional programmers;
- different design choices will make different future changes easy – a good design makes the most likely ones easiest.

Levels of design

Design occurs at different levels, e.g. someone must decide:

- how is your system split up into subsystems?
  (high-level, or architectural, design)
- what are the classes in each subsystem?
  (low-level, or detailed, design)

What is an architecture?

"An architecture is the fundamental organisation of a software system embodied in its components, their relationships to each other and to the environment, and the principles guiding its design and evolution" (IEEE)

Pervasive, hence hard to change. An alternative definition is "what stays the same" as the system develops, and between related systems.

Other important definitions: component, service, module

A component is "a named software unit that offers one or more services to other software components or to end-users of the software". It "can be anything from a program (large scale) to an object (small scale)". (Sommerville ESP)

A service is a "coherent unit of functionality" (Sommerville ESP)

A module is a "named set of components" which "should have something in common. For example, they may provide a set of related services" (Sommerville ESP)

Why is architecture important?

- Because it has a *fundamental influence on non-functional (very important!) characteristics* of the system:
  Non-functional attributes may not all be optimizable
  E.g. two components sharing or not a database has different cost vs. maintainability and resilience effects
- Because it *affects the complexity of the software*: the more complex, the less maintainable, more error prone, less secure.
  Minimising complexity important goal for architectural design

Architectural design

Involves creating a description of the architecture showing components and their relationships.

Important architectural design issues to consider:

- Non-functional requirements
- Product lifetime: if long-lived, architecture should be able to evolve
- Software reuse: saves time, constrains architectural choices
- Number of users: if very variable, architecture should allow quickly scaling up and down
- Software compatibility: constrains architectural choices
- Planned schedule, team capabilities, budget etc.

Architectural design: trade-offs

- *Maintainability vs performance*: having fine-grained components with individual responsibilities and own data structures good for maintainability, but affects performance due to communication and data transfer overheads
- *Security vs usability*: layers of components can help with security, but affects usability as multiple authentication layers frustrate users.
- *Availability vs time to market and cost*: redundant components help with availability, but at increased cost, complexity, error proneness.

Architectural design: main questions

1. How should the system be decomposed into a set of components?
2. (web-bases systems) How should the components be distributed and communicate?
3. What technologies should be used in developing the system?

1. Decomposing the system into architectural components

Identifying large-scale components, then analysing and splitting them up into smaller components.

Concerns:

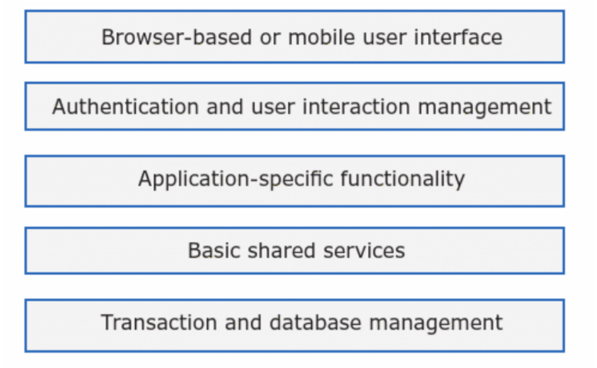
- Some non-functional requirements (e.g. security, performance, reliability) may be cross-cutting
- *Complexity* (major concern) due to the number of components and their relationships, the latter increasing exponentially.

1. Decomposing the system into architectural components

Design guidelines for controlling complexity:

- *Separation of concerns*: components doing only one thing; grouping components with related functionality.
- *Implement once*: not duplicating functionality
- *Stable interfaces*: hiding a component's implementation details behind a component interface (API) so that dependant components do not need to change when this component changes

Example: A generic layered architecture for a web-based application


Browser-based or mobile user interface
Authentication and user interaction management
Application-specific functionality
Basic shared services
Transaction and database management

Taken from: Sommerville, I., 2020. Engineering Software Products. Pearson.

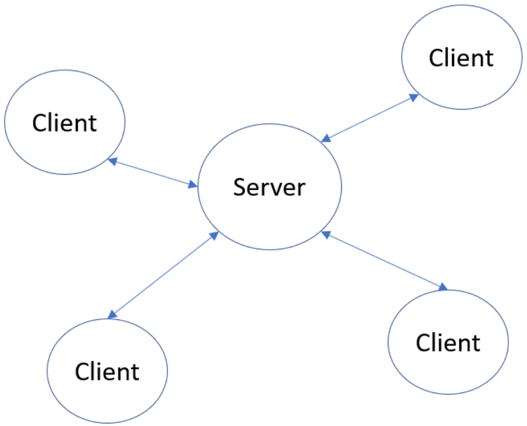
2. The distribution architecture (for web-based systems)

Defines how components are distributed online.

Some well-known architectures:

- Client-server architecture, with some variations:
    - Multi-tier client server architecture
    - Service-oriented architecture
- Peer to peer architecture
- Message bus architecture

Client-server architecture: high-level view with one server



Client-server architecture: logical view for web-based and mobile software systems

Clients send requests to servers, which process these requests and provide a response

Client responsible for user interaction, based on the data moving between it and the server

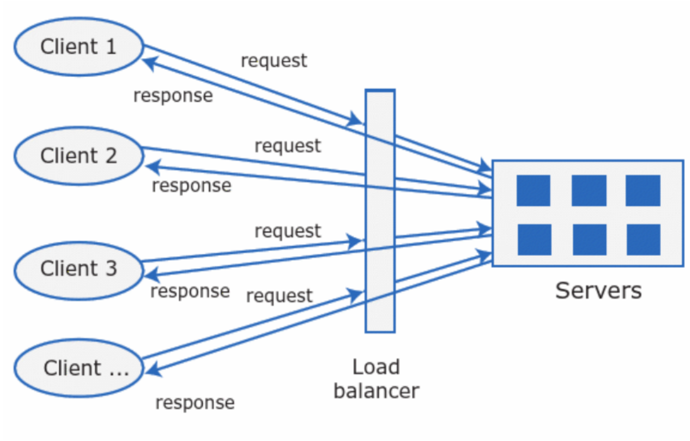
Servers initially conducted all processing, now clients are computers or mobile devices with large processing power so significant processing on clients

Several servers e.g. web and database

Load balancer distributes requests to servers, ensures even load

Organised frequently using the *Model-View-Controller (MVC)* pattern.

Client-server architecture: logical view for web-based and mobile software systems



Taken from: Sommerville, I., 2020. Engineering Software Products. Pearson.

Client-server architecture variation 1: The multi-tier client-server architecture

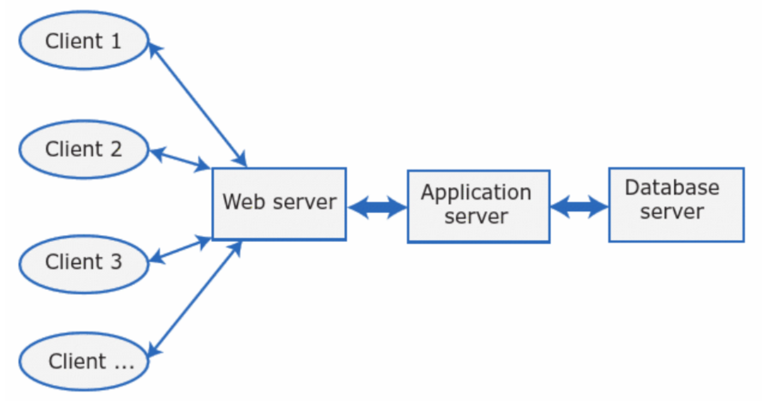
Use of an object-oriented approach (from the 1990s)

Single "monolithic" system with a shared database

Several communicating servers with different individual responsibilities and running large software components

Good if using structured data with concurrent updates, and for business systems running on local servers.

Client-server architecture variation 1: The multi-tier client-server architecture



Taken from: Sommerville, I., 2020. Engineering Software Products. Pearson.

Client-server architecture variation 2: The service-oriented architecture

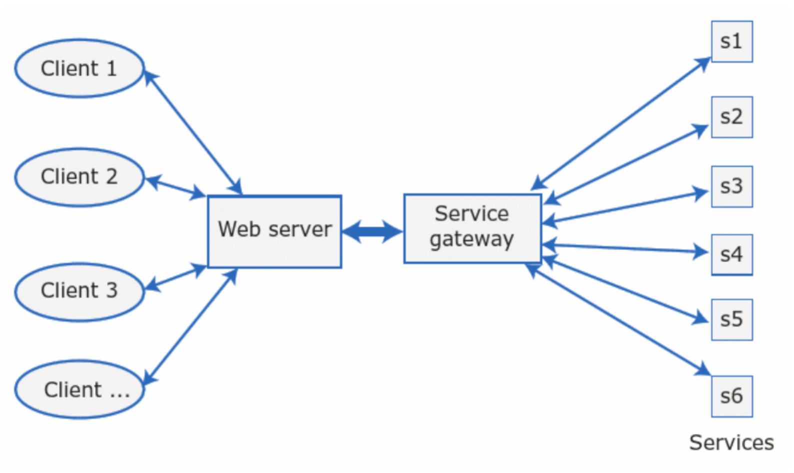
More modern, becoming the norm

Fine-grained services that may be provided by many servers

Services are stateless, so independent and can be replicated, distributed, migrated between servers

Good if system components need to be updated often, or there is a need for scalability (e.g. use on the cloud) and resilience to failure

Client-server architecture variation 2: The service-oriented architecture



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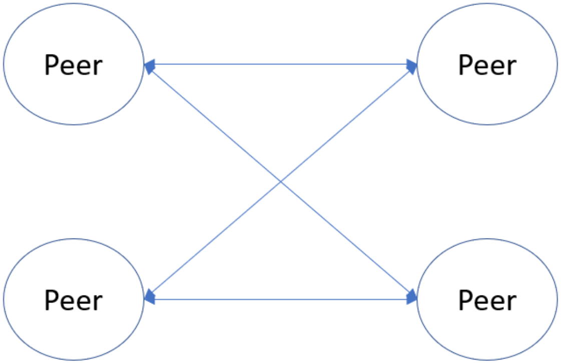
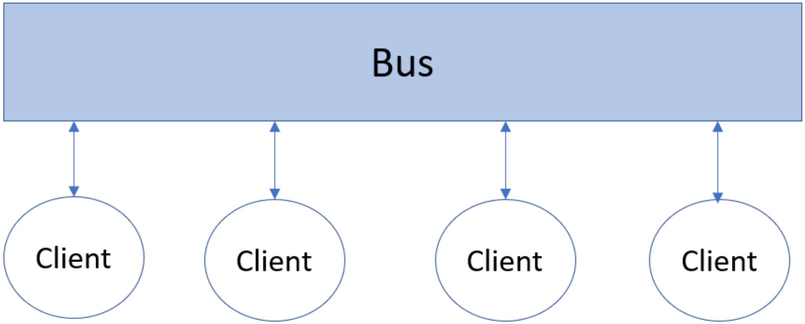
Peer to peer architecture



Message bus architecture



3. Technological considerations

Technologies need to be decided since architectural design, as changing them later is difficult and expensive

Technologies to consider:

- Database: relational or NoSQL?
- Delivery platform: browser-based or mobile?
- Server: using the cloud and, if so, what cloud provider?
- Use of open source souftware?
- Development technology: mobile development toolkits, web application frameworks advantageous?

Resources

Essential: Sommerville ESP Chapter 4

Essential: Sommerville SE 6.1, 6.3.3