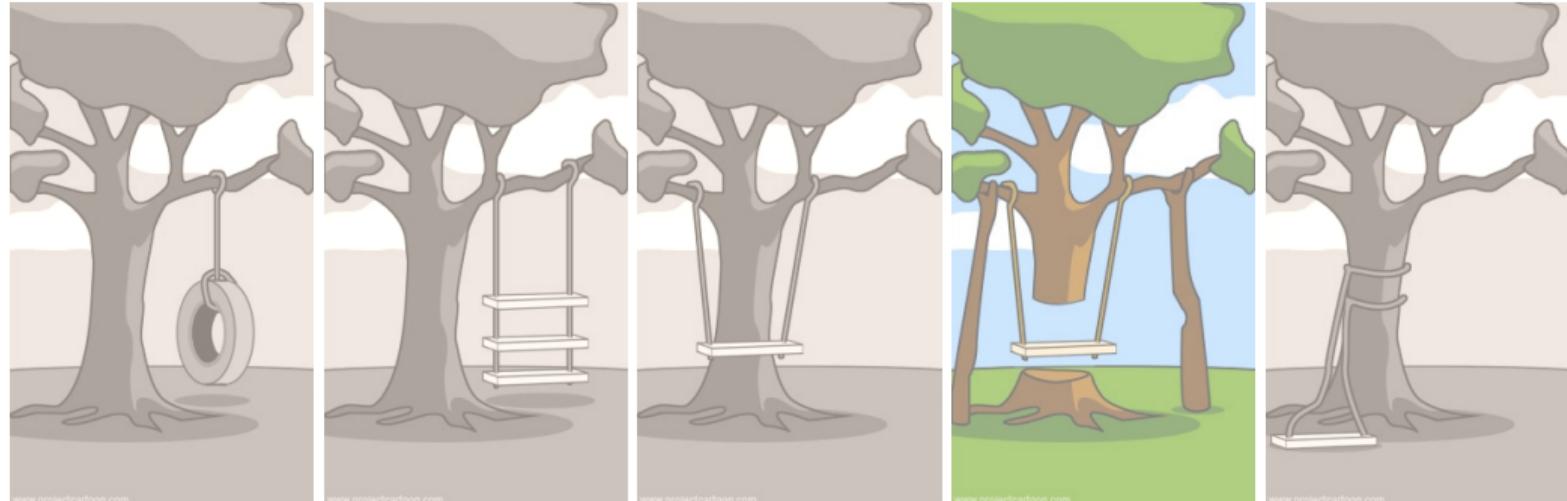




# Software Engineering

4. Software Architecture | Thomas Thüm | November 26, 2020

# Why Software Architecture?



what the customer  
really needed

how the customer  
explained it

how the project  
leader understood it

how the analyst  
designed it

how the programmer  
implemented it

# Lecture Overview

1. Introduction to Software Architecture
2. Modeling Structure with Component Diagrams
3. Common Architectural Patterns

# Introduction to Software Architecture

# On the Role of Architecture



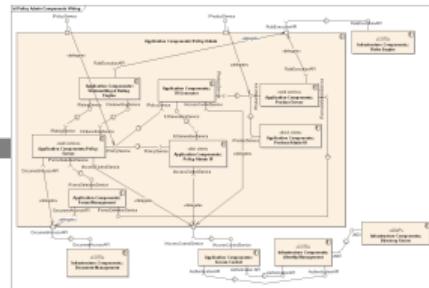
# Architecture Bridges the Gap

Large software systems ...

- have numerous requirements
- require many developers
- need separation of concerns  
*(Trennung von Belangen)*



Requirements



Software Architecture

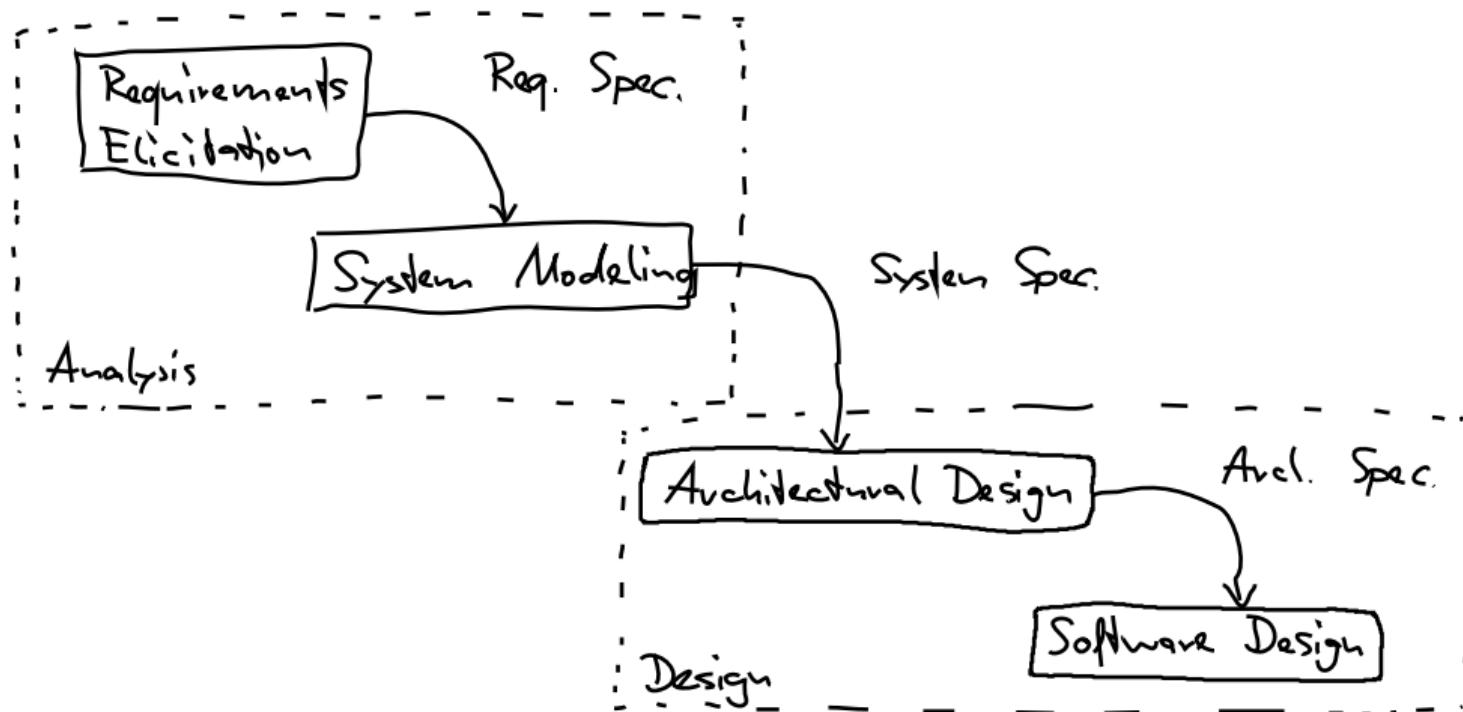
"Weeks of coding can save you hours of planning." [anon]



```
if (n > 100) {
    try {
        t.open("GET" + n, "send");
        xa.open();
        xa.type = 1;
        xa.write(xa.response);
        if (xa.size > 10000) {
            dn = 1;
            xa.position =
            xa.function =
            return;
        }
    } catch (Exception e) {
        e.printStackTrace();
    }
}
```

Implementation

# Analysis and Design



# Software Architecture

## Architectural Design (Architekturentwurf)

“**Architectural design** is a creative process in which you design a system organization that will satisfy the functional and non-functional requirements of a system.” [Sommerville]

## Software Architecture

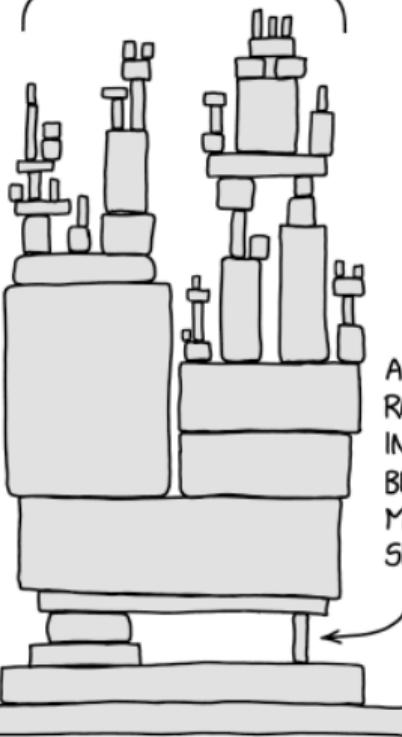
“A **software architecture** is a description of how a software system is organized. Properties of a system such as performance, security, and availability are influenced by the architecture used.” [Sommerville]

## In Practice:

[Sommerville]

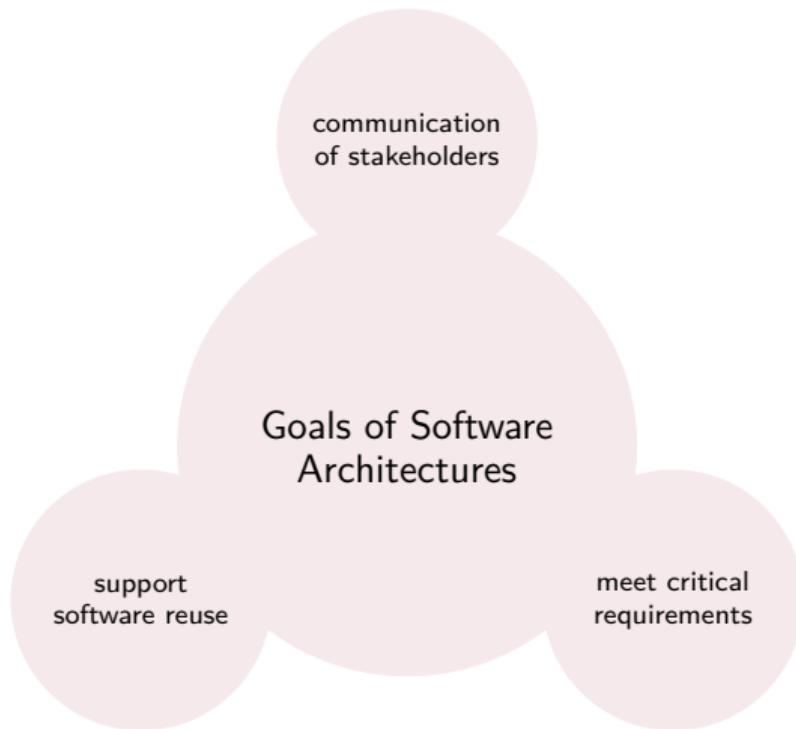
“You might propose an abstract system architecture where you associate groups of system functions or features with large-scale components or subsystems. You then use this decomposition to discuss the requirements and more detailed features of the system with stakeholders.”

ALL MODERN DIGITAL  
INFRASTRUCTURE

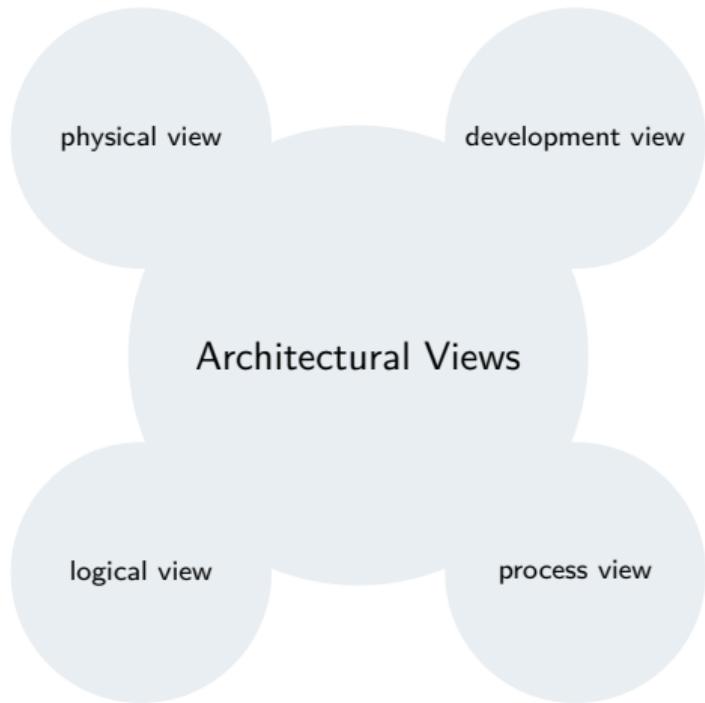


A PROJECT SOME  
RANDOM PERSON  
IN NEBRASKA HAS  
BEEN THANKLESSLY  
MAINTAINING  
SINCE 2003

# 3 Goals of Software Architecture [Sommerville]



# 4 Views in Software Architecture [Sommerville]



## Sommerville:

"A **logical view**, which shows the key abstractions in the system as objects or object classes. It should be possible to relate the system requirements to entities in this logical view.

A **process view**, which shows how, at runtime, the system is composed of interacting processes. This view is useful for making judgments about non-functional system characteristics such as performance and availability.

A **development view**, which shows how the software is decomposed for development; that is, it shows the breakdown of the software into components that are implemented by a single developer or development team. This view is useful for software managers and programmers.

A **physical view**, which shows the system hardware and how software components are distributed across the processors in the system. This view is useful for systems engineers planning a system deployment."



### Conway's Law

[Melvin E. Conway, 1968]

“Any organization that designs a system [...] will produce a design whose structure is a copy of the organization’s communication structure.”

# Introduction to Software Architecture

## Lessons Learned

- What is software architecture?
- Why is software architecture so important?
- Further Reading: Sommerville, Chapter 6.0–6.2 (p. 167–175)

## Practice

- Invest five minutes trying to understand the Corona-Warn-App by inspecting the source code of the Android client:  
<https://github.com/corona-warn-app/cwa-app-android/tree/main/Corona-Warn-App/src/main/java/de/rki/coronawarnapp>
- Summarize what you learned about the app by answering a questionnaire in Moodle:  
<https://moodle.uni-ulm.de/mod/choice/view.php?id=293405>

# Lecture Contents

## 1. Introduction to Software Architecture

On the Role of Architecture

Analysis and Design

Software Architecture

3 Goals of Software Architecture

4 Views in Software Architecture

Lessons Learned

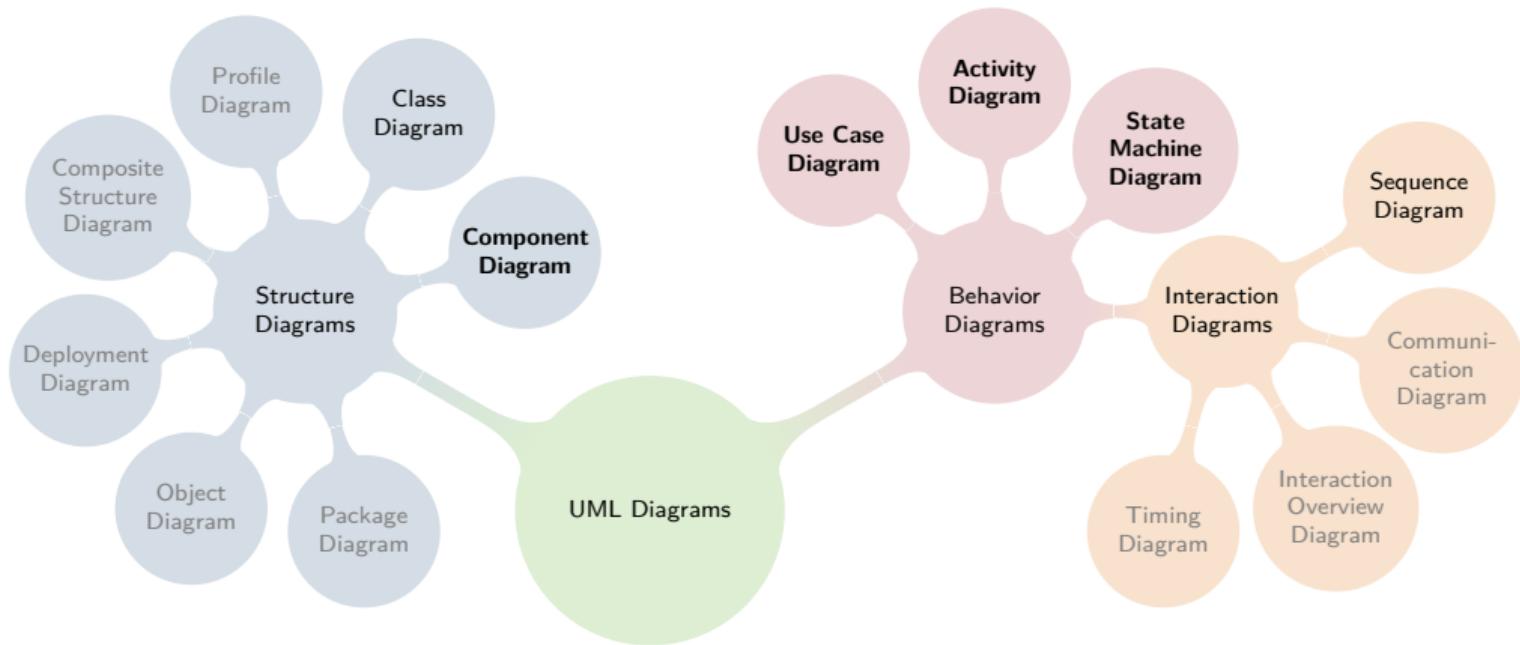
## 2. Modeling Structure with Component Diagrams

## 3. Common Architectural Patterns

## Modeling Structure with Component Diagrams

# Recap: 14 Types of UML Diagrams

[UML 2.5.1]

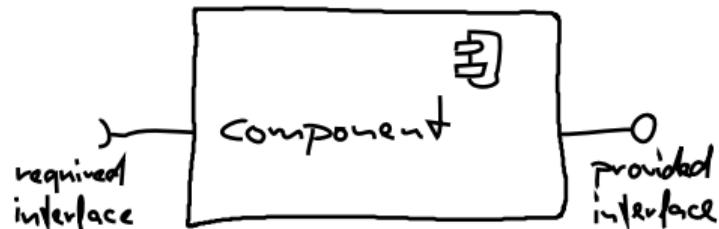


# Component Diagrams

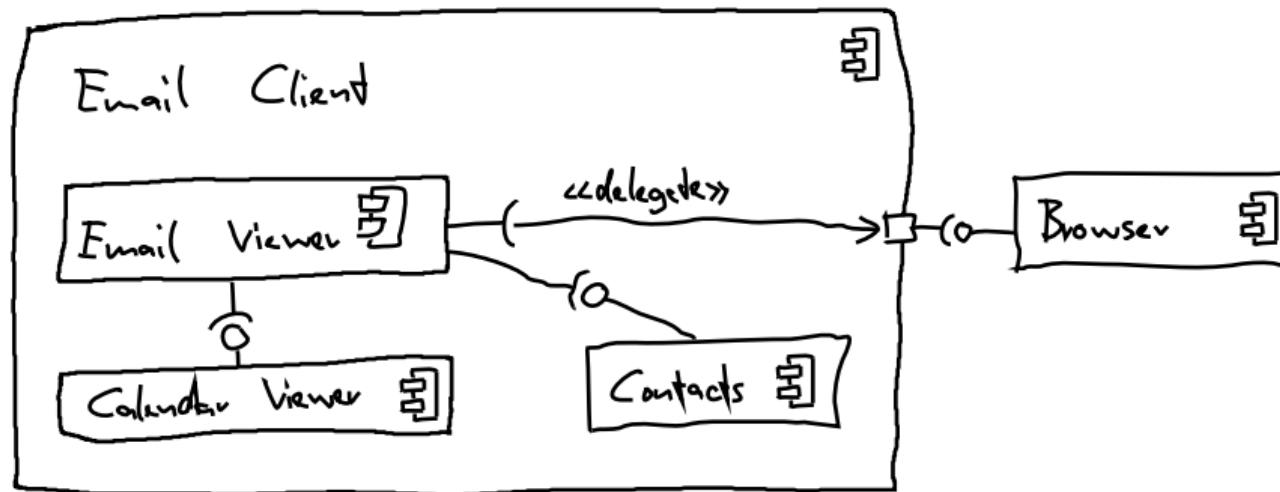
## Component Diagram (Komponentendiagramm)

A **component** is a replaceable part of a system that conforms to and provides the realization of a set of interfaces. An **interface** is a collection of operations that specify a service that is provided by or requested from a class or component. An interface that a component realizes is called a **provided interface**, meaning an interface that the component provides as a service to other components. The interface that a component uses is called a **required interface**, meaning an interface that the component conforms to when requesting services from other components.

(Komponente, angebotene/benötigte Schnittstelle) [adapted from UML User Guide]



# Example of a Component Diagram



# Hierarchical Component Diagrams

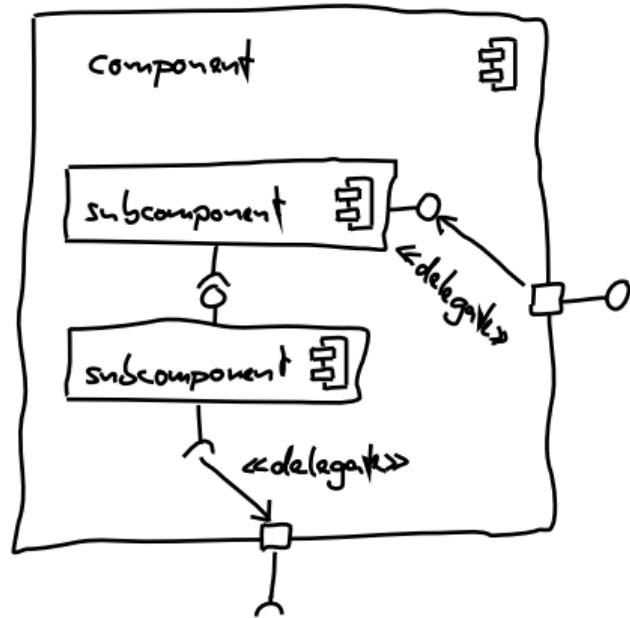
## Nesting of Components (Verschachtelung)

**Motivation:** decompose/structure large systems

**Nesting:** A component may contain any number of **subcomponents**. (Teilkomponenten)

**Ports and Delegates:** A **port** is an explicit window into an encapsulated component. A **delegate** connects provided or required interfaces with ports.

[adapted from UML User Guide]



# Rules for Component Diagrams

## Rules for Component Diagrams

- component names are unique
- a component may have any number of required or provided interfaces
- every required interface is connected to provided interface
- every component is directly or indirectly connected to every other component
- subcomponents may be nested to any level
- when subcomponents communicate to a higher-level component, they need to communicate via ports



**Gordon Bell:**

“The cheapest, fastest, and most reliable components are those that aren’t there.”

# Modeling Structure with Component Diagrams

## Lessons Learned

- How to describe architectures with UML component diagrams?
- How to decompose large systems with nesting?
- Further Reading: UML User Guide, Chapter 15

## Practice

- Design the architecture of a contract tracing app with a component diagram and submit it in Moodle:  
<https://moodle.uni-ulm.de/mod/moodleoverflow/discussion.php?d=1991>
- Give a positive vote for one other diagram and give feedback to others if you find any potential problems.

# Lecture Contents

1. Introduction to Software Architecture
2. Modeling Structure with Component Diagrams
  - Recap: 14 Types of UML Diagrams
  - Component Diagrams
  - Hierarchical Component Diagrams
  - Rules for Component Diagrams
  - Lessons Learned
3. Common Architectural Patterns

## Common Architectural Patterns

# Architectural Patterns

## Architectural Pattern (Architekturmuster)

“Architectural patterns capture the essence of an architecture that has been used in different software systems. [...] Architectural patterns are a means of reusing knowledge about generic system architectures.”  
[Sommerville]

## Goals



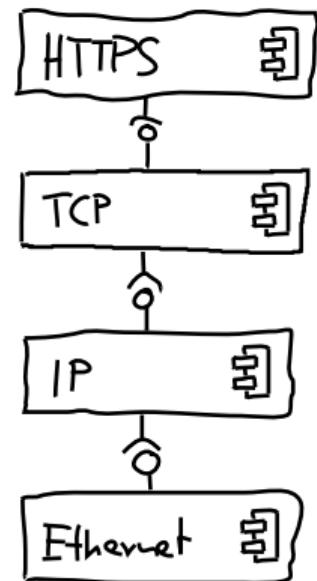
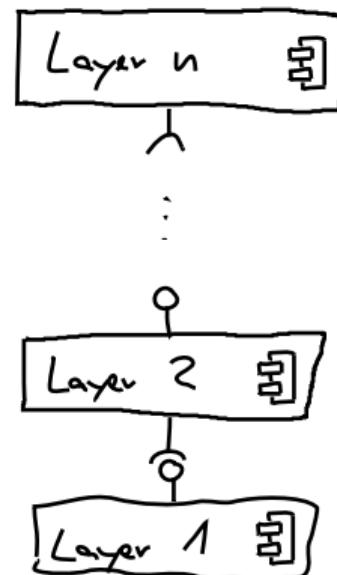
- preserve knowledge of software architects
- reuse of established architectures
- enable efficient communication

# Layered Architecture (Schichtenarchitektur)

## Layered Architecture

[Sommerville]

- **Problem:** subsystems are hard to adapt and replace
- **Idea:** decomposition into layers (**Schichten**)
- layer provides services to layers above
- layer delegates subtasks to layers below
- strict layers: every layer can only access the next layer
- relaxed layers: every layer can access all layers below
- information hiding: layers hide implementation details behind interface



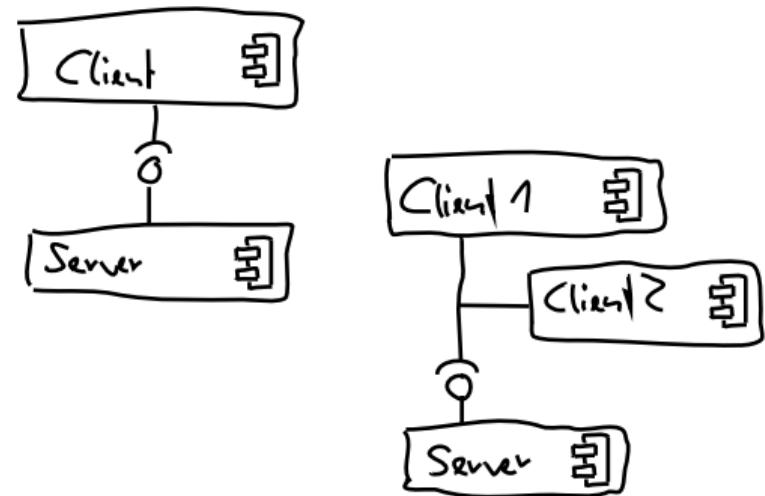
# Client-Server Architecture (2-Schichten-Architektur)

## Client-Server Architecture (aka. 2-Tier)

- **Problem:** several clients need to access the same data
- **Idea:** separation of application (client) and data management (server)
- clients initiate the communication with a server
- typical: multiple clients of the same kind
- optional: multiple clients of different kinds  
[Sommerville]

## Example

a browser uses a URL to connect to a server in the world wide web and receives an HTML page



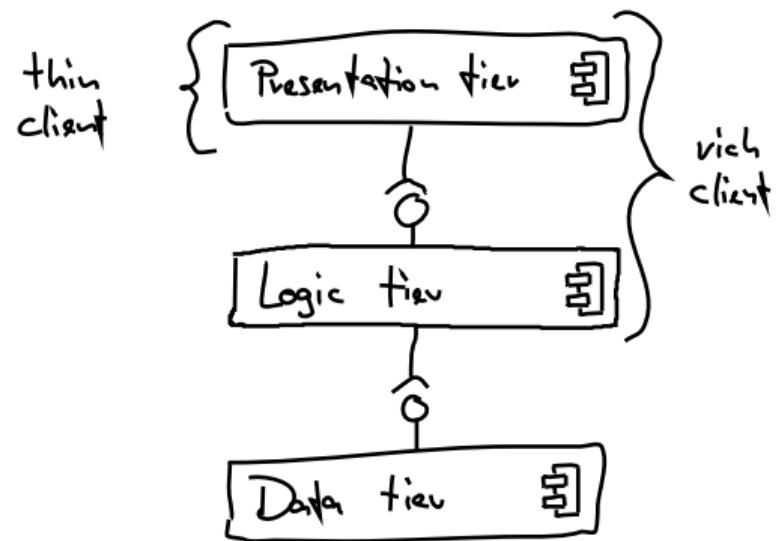
# 3-Tier Architecture (3-Schichten-Architektur)

## 3-Tier Architecture

- **Problem:** clients with same functionality but different presentation needed
- **Idea:** separation of data presentation, application logic, and data management
- thin-client application: application logic on the server
- rich-client application: application logic in the client

## Rule of Thumb

If you can use the application offline, then it is most likely a rich-client application.



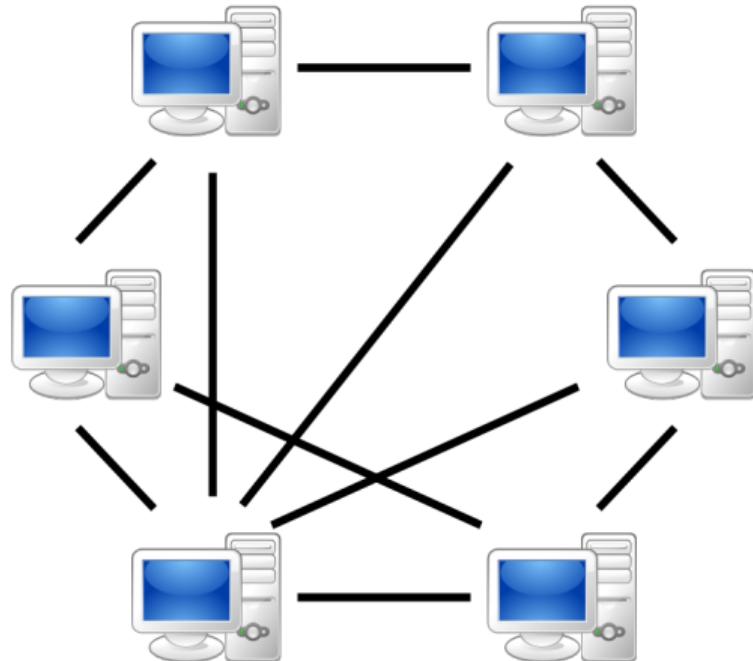
# Peer-to-Peer Architecture

## Peer-to-Peer Architecture

- **Problem:** high load on server and high risk of failure when transmitting all client data to the server
- **Idea:** decentralized transmission of data
- peers connect to each other and transfer data directly
- peers take over client or server roles
- arbitrary, dynamic topology

## In Practice

often combined with a client-server architecture



# Peer-to-Peer Architecture in Windows 10

## Delivery Optimization

Delivery Optimization provides you with Windows and Store app updates and other Microsoft products quickly and reliably.

### Allow downloads from other PCs

If you have an unreliable Internet connection or are updating multiple devices, allowing downloads from other PCs can help speed up the process.

If you turn this on, your PC may send parts of previously downloaded Windows updates and apps to PCs on your local network or on the Internet. Your PC won't upload content to other PCs on the Internet when you're on a metered network.

[Learn more](#)

#### Allow downloads from other PCs



On

PCs on my local network

PCs on my local network, and PCs on the Internet

### Advanced options

By default, we're dynamically optimizing the amount of bandwidth your device uses to both download and upload Windows and app updates, and other Microsoft products. But you can set a specific limit if you're worried about data usage.

#### Download settings

Limit how much bandwidth is used for downloading updates in the background



45%

Limit how much bandwidth is used for downloading updates in the foreground



90%

#### Upload settings

Limit how much bandwidth is used for uploading updates to other PCs on the Internet



50%

Monthly upload limit



500 GB

Note: when this limit is reached, your device will stop uploading to other PCs on the Internet.



Monthly upload to date  
N/A

Amount left  
500.0 GB

# Model-View-Controller Architecture

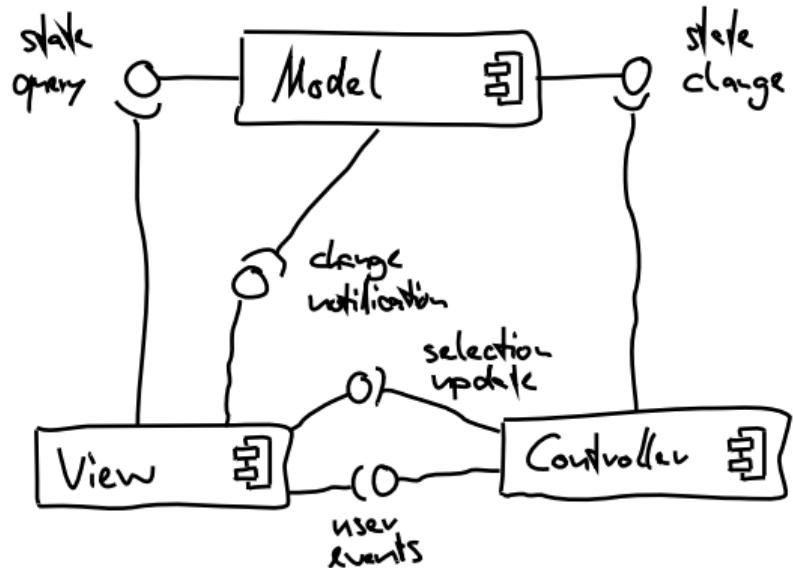
## Model-View-Controller Architecture

- **Context:** data is presented and manipulated over several views
- **Problem:** data inconsistent and new views hard to add
- **Idea:** separation into three components
- model: stores the relevant data independent of their presentation
- view: shows (a part of) the data independent of manipulations
- controller: user interface for the manipulation of data

[Sommerville]

## Example

In a spreadsheet, data is presented in tables and diagrams. Changing values in a table leads to an update of affected diagrams and tables.



# Pipe-and-Filter Architecture

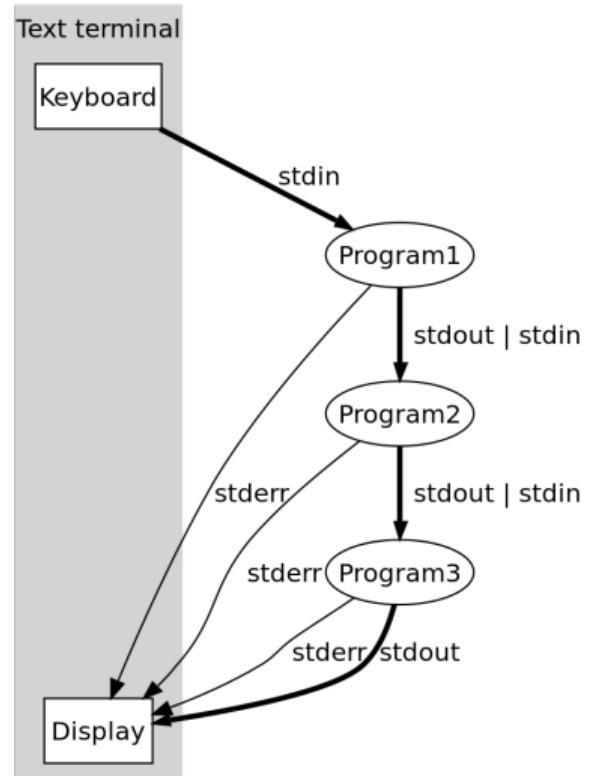
## Pipe-and-Filter Architecture

[Sommerville]

- **Problem:** data is processed in numerous processing steps, which are prone to change
- **Idea:** modularization of each processing step into a component
- filter components process a stream of data continuously
- pipes transfer data unchanged from filter output to filter input

## Pipe Operator in UNIX

"ls -al | grep '2020' | grep -v 'Nov' | more" searches files in a folder from the year 2020 except those from November and delivers the results in pages.



# Common Architectural Patterns

## Lessons Learned

- What are architectural patterns?
- What is the difference between common architectures? layered architecture, client-server, 3-tier, peer-to-peer, model-view-controller, pipe-and-filter
- Further Reading: Sommerville, Chapter 6.3 (p. 175–184)

## Practice

- Describe a further example for one of the discussed architectures (or a combination thereof) in Moodle:  
<https://moodle.uni-ulm.de/mod/moodleoverflow/discussion.php?d=1999>
- Vote for at least one other example.

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Architectural Patterns

Layered Architecture

Client-Server Architecture (2-Schichten-Architektur)

3-Tier Architecture (3-Schichten-Architektur)

Peer-to-Peer Architecture

Model-View-Controller Architecture

Pipe-and-Filter Architecture

Lessons Learned