Software Engineering for Business Applications
Lecture Notes

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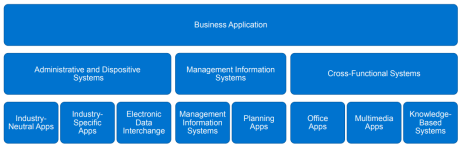
1 IT Support for Business Applications

1.1 Classification of Business Applications

- **Definition "Business Application":**
  - in narrower sense: totality of all programs, i.e. **application software**, and associated **data** for a concrete business use case
  - in broader sense: additionally **hardware**, **system software** and necessary **communication** facilities required for the use of application software
- **Two roles of Business Applications:**
  - **supporting**, **improving** or **automating** existing operational processes in bookeeping, accounting, etc. (size, speed, correctness...)
  - **enabling** new products and services (e.g. online shopping and banking)
- **Classification of Business Applications by Business Purpose:**



Examples of

  - **administrative systems:** financial accounting, payroll accounting, administration of stocks
  - **disposition systems:** calculation and cost accounting, material procurement, field service control
  - **management information systems (MIS):** use of internal company data, use of external data, combination of multiple data sources in a flexible form
  - **planning systems:** planning of individual functional areas, integrated planning of several functional areas, corporate planning
- **Cross-Cutting Applications:**
  - independent of company hierarchy and fuctional domains
  - used either directly via user interface or programmatically via administration and disposition systems
  - *Examples:* office suites, groupware, workflow management systems

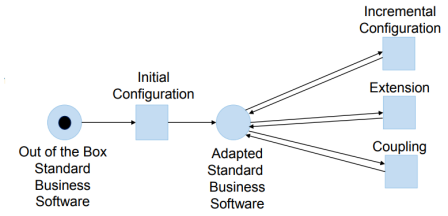
- **Enterprise Resource Planning (ERP): ERP system** is an integrated business application (suite, collection of programs), which supports all essential functions of administration, disposition and management with a common interface and a shared and integrated data management.
  - consists of platform and function-oriented application components that exchange info and events
  - is realized as (customizable) standard software
  - *Examples:* external accounting, controlling, procurement
  - Today's ERP systems support an **extended value chain**[1].

1.2 Standard and Custom Software

- **Standard Software vs. Custom Software:**
  - **Standard software** *(e.g. SAP)*
    - developed for specific **market**
    - distributed by a software house
    - can be used by **several companies**
    - implements "standard business processes" at its core
    - maintained by **manufacturer**, adapted to changes
    - must or can be **customized** to company (e.g. authorizations and roles, currencies)
  - **Custom software**
    - specifically developed for **one company**
    - tailored to specific business processes/requirements
    - result of a project for a known client
    - **individually** maintained and adapted to changes

[1] **Value chain** is a business model that describes the full range of activities needed to create a product or service.

- **Adaptation Techniques for Standard Business Software:**
  - Adaptation of operational standard software can be divided into **Configuration**, **Extension** and **Coupling** (= **Customizing**).



  - **Configuration** describes functionalities and techniques
    - that are obligatory on first deployment
    - that allow to define predefined settings
    - that lead to an individual variation of standard software
  - **Extension** describes functionalities and techniques
    - that are optional for productive use
    - that allow to map requirements not foreseen by manufacturer
    - implemented by manufacturer to expand the range of services
  - **Coupling** refers to functionalities and techniques
    - to connect external systems of other manufacturers
    - to connect external systems of the same type
    - that are predefined in the form of data file formats, APIs, or communication protocols
  - *Example:* mapping the structure of a company to SAP applications via organizational units (can be assigned to single or multiple apps)

- **Configuration: Challenges**
  - A **standard software** must
    - provide all relevant configuration options
    - support a wide range of different corporate structures and processes
    - check dependencies between these many variants
    - provide appropriate documentation about the effects of individual configurations
  - **Consequences:**
    - need for experts who are familiar with configuration options of each release and componant
    - scarcity of such experts

    - expensive training
    - expensive consultancy services

- **Examples for Extensions:**
  - automation of **multi-step business workflows**
  - integration of company-specific calculations/rules/checks
  - connecting customers

- **Coupling Options:**
  - different coupling options depending on the scenario
  - programming language used for coupling
  - available mechanisms to couple

- **Multi Tenancy:** Software multitenancy is a software architecture in which a single instance of software runs on a server and serves multiple tenants (e.g. companies).
  - several companies can be represented in one system
  - distinction between tenant-dependent and -independent data
  - supporting tenant-dependent authorization (e.g. A may only perform transactions in client 002)
  - individual adaptations of tenants (e.g. currency, couplings)

- **Multilingualism:**
  - **Multilingualism of a business information system** makes it possible to
    - store and display texts in different languages in the system
    - assigning graphics and symbols specific to different languages
  - Multilingualism requires
    - that one system can process all relevant character sets at once
    - storage and recognition of words, numbers etc.
    - that a system can assign users to languages or user can choose their own
    - that texts (graphics, symbols) can be assigned to a language

- **Localization (l10n):** Adaptation of a software product to meet the language, culture, and other requirements of each locale (e.g. adaptation of graphics, currencies, date and time)

- **Internationalization (i18n):** Process of preparing a software-based product for localization (to support global markets)

1.3 Characteristics of Business Applications

- **Multiple Stakeholders and changing requirements:**
  - **Requirements Elicitation and Requirements Management**
    - many stakeholders, different views and concerns
    - Waterfall: upfront requirements document and/or technical specification => Req. Documentation
    - Issue: changing requirements once IT support is implemented
    - Agile: incremental and iterative => Agile Req. Engineering
    - typically, very large number of requirements
    - need for formalization and early consistency checking => Conceptual Modeling
    - need for cost and time prediction => Software Estimation
  - **Programming Challenges**
    - design, implement and test changes in an existing complex system => Change Mgmt.
    - deliver incremental changes without invalidating existing data => Release Mgmt.
    - parallel development at manufacturer and at customer site => Version Mgmt.
    - automated and quality-controlled assembly of application software => Build Mgmt.
- **Persistent Data and Concurrent Data Modification:**
  - **Data consistency** is a must:
    - many users perform **transactions** simultaneously on central databases
    - data must not be lost even in case of system failures
  - **Programming challenges:**
    - database is managed by an independent application, on a different server / hardware
    - object orientation is not supported by common data bases
    - database concepts must be transferred to the application logic (transactions, rights, primary keys)
- **Distributed Actors and Data Repositories:**
  - **Many users access central data concurrently:**
    - users need data in different locations at different times
    - Client-Server architecture => Layered Architectures
    - web clients => REST protocol
  - **Programming challenges:**

    - software components must be able to found in network => Naming services
    - communication always via a network => Serialization[2] & failed execution
    - authentication and authorization => Security
    - concurrent accesses => Transactions

- **Integeration of Data and Application from (Semi-)Autonomous Sources:**
  - **Separation of applications and data repositories:**
    - multiple apps work on independent or shared data resources
    - multiple apps communicate with each other => RPC, Message Passing
    - business processes involve multiple apps => Workflow Mgmt. Systems
    - application landscapes with lots of interacting applications => Enterprise Architecture Mgmt.
  - **Programming challenges:**
    - integration of multiple languages and databases
    - loose coupling through interfaces to avoid code change propagationi
    - error recovery to avoid runtime failure propagation

- **Scalability:**
  - **Growing number of users and data volume**
    - business apps are used by thousands of employees world-wide around the clock
    - customers and business partners interact directly with business apps and expect real-time sub-second response times
    - volatile load (e.g. online shop in christmas season vs. summer season)
  - **Programming challenges:**
    - delayed execution of resource-intesive operations => Batch processing[3]
    - dynamically increasing/decreasing number of users => Instance pools
    - single server cannot handle the load => Load balancing, Caching

[2] **Serialization** is the process of translating a data structure into a format that can be stored or transmitted and reconstructed later.

[3] **Batch processing** is when a computer processes a number of tasks that it has collected in a group. It is designed to be a completely automated process, without human intervention.

2 Requirements Engineering

- **Software requirements** express the needs and constraints placed on a software product.
- **Requirements engineering** is concerned with **elicitation**, **analysis**, **specification** and **validation** of software requirements as well as the management of requirements.
- **Requirements Management** deals with the administration and maintenance of requirements documents, in particular:
  - change requirements (change management)
  - trace and link requirements (requirements tracing)
  - verify requirements

2.1 Traditional Requirements Engineering

- **Objectives of Requirements Management:**
  - **Efficient** preparation of **high quality** requirements and system specifications,
    - coordinated with all stakeholders (different objectives and interests)
    - coordinated with all specifications and constraints
    - evaluated according to profitability and feasibility
  - **Specification documents** are basis for:
    - contract negotiation and contractual agreements
    - coordination between the stakeholders (customers, developers)
    - design, realization, integration
    - software acceptance (test specification)
    - future developments, projects
- **Requirement Classification:** Distinction between functional and non-functional requirements and constraints:
  - **Functional requirements** describe interactions between the system and its environment independent of their realization.
  - **Non-functional requirements** describe general properties of the system.
  - **Restrictions (Constraints)** determine the solution space for the realization.
- **Stakeholder Management:** It includes

  - processes required to identify people that could impact or be impacted by the project
  - to analyze stakeholder expectations and their impact on the project
  - to develop appropriate management strategies for effectively engaging stakeholders in project decisions and execution

- **Requirement Specification:**
  - technical result document of requirement identification phase
  - **contains** stakeholder identification, functional and non-functional requirements, constraints, evaluation plan and metrics
  - list of all deliverables and services to be fulfilled by contractor within contract as defined by customer
  - **what** is to expect from the solution (product)
  - formulation of requirements should be as general as possible and as restrictive as necessary
  - enables the contractor to develop optimal solutions

- **Requirements Validation: Validation**, **Consistency check** (no conflicts), **Completeness check**, **Reality check**, **Verifiability**

- **Functional Specification:**
  - defines the purpose of the system
  - solution proposal created by contractor based on the requirement specification provided by client
  - **contains** target determination, product usage, environment (e.g. hardware), functions, UI, global test cases
  - system description or solution specification, which describes **how** the solutions is to be realized (concrete solution approaches)
  - the **what** from **requirement specification** is detailed

2.2 Agile Requirements Engineering

- **Requirements Engineering and Agile Software Development:**
  - **Agile software development** focuses more on **continuous collabration** (workshops, interviews etc.) with stakeholders instead of relying on **specification documents** (*example: SCRUM*)
  - **Traditional requirements engineering**
    * focuses on customer collabration mainly at an early phase of the project (longer change cycles)
    * emphasizes a heavy-weight process with extensive, **static specification documents**

  - **Agile requirements engineering**
    * fosters communication with the customer during the whole development process to **continuously update requirements**
    * focuses less on extensive documentation, but specification documents **might be necessary** because of legal or contracting reasons etc.
    * includes activities and artifacts that are similar to classical requirements engineering activities

- **Typical Requirement Artifacts in Agile Software Development:**
  - **user story**, **story card**, **use case**, **scenario**, **UML diagram**, **prototype**

- **User Stories:**
  - explanation of a software feature written from the perspective of the end user
  - most frequently used artifact in **agile software development**
  - mnemonic for writing good user stories: INVEST[4]

- **Typical Requirements Engineering Challenges:**
  - different interest groups can raise **conflicting requirements**
  - the people who **pay** for the system are rarely the ones who **use** it
  - the organization and the technical environment may **change** after the system rollout
  - requirements that change during implementation (Change Requests) can lead to additional costs -> project duration/milestones can be affected significantly

3 Conceptual Modeling with UML

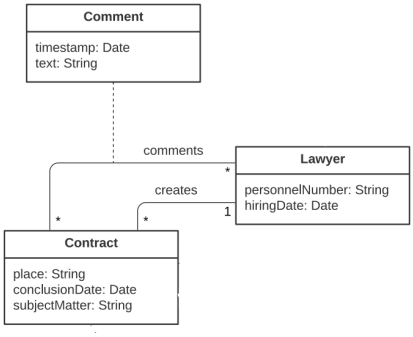
- **Conceptual Class Diagram vs. Implementation-Oriented Diagram:**

	Conceptual	Implementation-Oriented
Visibility (private, public)	No	Yes
Attributes with data types	Yes	Yes
Methods	No	Yes
Generalization / Inheritance	Sparingly	If useful / meaningful
Abstract classes	No	If useful / meaningful
Association classes	Yes	No (resolved)

- **Associations between Classes:**

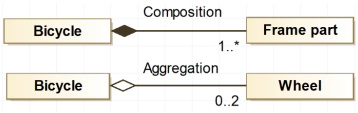
[4] independent, negotiable, valuable, estimable, small, testable

– **Multiplicity:**



A Lawyer can <u>*create*</u> ***multiple*** *Contracts, whereas every Contract has a* ***single*** *Lawyer.* -> <u>creates</u> (action) on the side of Lawyer (actor)

- **Aggregation:** implies a relationship where the child can exist independently of the parent (part of the parent)
- **Composition:** implies a relationship where the child <u>cannot exist</u> independent of the parent
- <u>*Example:*</u>



4 Software Estimation

4.1 Fundamentals of Estimation Methods

- **Software Estimation:**
  - In principle, software estimation relies on **forecasting effort**, from which cost and duration are derived.
  - Regardless of the project and software methodology applied, every initiative requires the definition of a **budget** and a specific **time frame** necessary to deliver a final outcome.
  - These two are obtained during the **early stages** of the project lifecycle through the process of estimation.

  - **Estimation** aims to provide an **approximation** of the amount of recources required to complete project activities and produce a product or service in accordance to specified **functional** and **non-functional characteristics**.
  - **Software estimation conducted in early phases of the project lifecycle:**
    * necessary for contract negotiations
    * predict expected efforts (and derived costs) for a software project before implementation
    * best possible estimation given the available info
  - **Agile estimation:**
    * estimation of individual requirements during project
    * incremental allocation of developers in the most efficient manner
    * cost estimates are made several times during development project with varying degrees of detail

- **Software Estimation: Cone of Uncertainty**
  - At the beginning of the project, not much is known about the product/project -> estimates underly high uncertainty
  - As the project progresses, more information is available -> decrease in uncertainty

- **Software Estimation: Costs**
  - **Cost categories:**
    * **Development costs:** costs to produce a software product
    * **Personnel costs:** major share of development costs for personnel
      · usually low costs for office materials etc. in relation to the personnel costs
      · proportionate allocation of CASE[5] environment costs (including hardware and software) for product development

4.2 Traditional Software Estimation

- **Sneed's Devil's Square:**
  - Quantity
  - Quality
  - Development duration
  - Cost

[5]Computer power-assisted software package Engineering

are mutually dependent.

- **Quantity:**
  - size of program code (example basis of assesment: LOC[6])
  - functional and data scope
  - possible additional weighting with complexity
- **Quality:**
  - higher quality requirements => greater effort
  - no **THE quality**, but different quality characteristics
- **Productivity:**
  - influenced by many different factors
  - number of communication links grows **quadratically** with the team size
- **Development time:**
  - need more members to shorten development time
  - more members => more communication effort
  - higher communication => decrease in productivity
- **Methods for Effort Estimation:**
  - **Estimation Strategies:**
    - **Top-Down:** estimation of the total project effort using mathematical algorithms based on the functional requirements
    - **Bottom-Up:** expenses for each expense item are calculated separately and added to calculate the total project effort
  - **Comparison methods:**
    - estimation based on effort analysis of already accomplished similar developments
  - **Algorithmic methods:**
    - effort calculated with algorithmic methods
    - based on statistical models or actual expenditure of already completed projects
  - **Key figure methods:**
    - total cost of the software product determined by estimating the cost of individual units or project phases
  - None of the listed basic methods alone is sufficient.

[6]Lines of Code

- Depending on the point in time and knowledge of effort-relative data, one or the other method should be used.

- **Concrete Procedures for Effort Estimation:**
  - **Goal:** Combine advantages of several effort estimation methods to deliver accurate results. (*example: Function Point Method*)

- **Function Point Method:** It is a combined relation and weighting method.
  1. **Categorization** of each product requirement (input, query, output, database, reference data)i
     - **Input:** by the user
     - **Output:** displaying query results, calculated data
     - **Query:** performed on the **database** of the system, read and write
     - **Reference data:** used to validate input, generate the output or construct the query (read-only)
  2. **Classification** of each product requirement
     - **simple**
     - **medium**
     - **complex**
  3. **Entry** into calculation form
  4. **Evaluation** of influencing factors
     - the **influence factors** refer to the application as a whole and not to individual functions or function points
  5. **Calculation** of the evaluated Function Points (FP)
  6. **Determination** of the personnel expenses based on a FP-PM curve or table
     - significant productivity decreases in large projects (FP-PM[7]: increase in FP => increase in PM) -> non-linear growth
  7. **Update** of empirical data as an estimation basis for follow-up project
     - After completion of a development estimated with the Function Point Method, the new value pair (FP, Actual PM) is used to update the existing curve.

- **Function Point Method: Requirements:**
  - evaluation once the project requirements are known
  - evaluation by employees with sufficient knowledge of requirements
  - product considered from the perspective of client

[7] **FP:** function points, **PM:** person month (= MM: man month)

  - company-specific training, guidelines are needed to minimize the effect of subjective individual estimates during the classification and evaluation of influencing factors
  - actual efforts must be measured for post-calculation

- **Function Point Method: Advantages**
  - product requirements, not LOC as starting point
  - adaptability to different application areas (change of categories)
  - adaptability to new techniques (change of influencing factors, influence evaluation)
  - adaptability to company-specific environments (if, ie and class factors per class)
  - refinement of the estimate according to the development process
  - first estimate is possible at a very early stage (planning phase)
  - good estimation accuracy

- **Function Point Method: Disadvantages**
  - only total effort can be estimated -> conversion to individual phases must be made using a percentage-based method
  - personnel-intensive, not easy to automate
  - too strongly function-oriented
  - influence factors do not clearly separate project and product characteristics

4.3 Agile Estimation Methods

- **Estimation in the SCRUM Framework:**
  1. Estimation of **Story Points**[8] for each item in the **Product Backlog**
     - an **ordered list** of everything that is known to be needed in the product
     - **Product Backlog Refinement:** act of adding detail, **estimates**, and order to items in the **Product Backlog**
     - **User Story** is the unit with which software features are **estimated** and developed.
  2. **Time Estimation** (in days) for each item in the **Sprint Backlog**

- **Estimation with the help of Planning Poker:**

[8] **Story points** are units of measure for expressing an estimate of the overall effort required to fully implement a product backlog item or any other piece of work.

- reason to use **planning poker** is to **avoid the influence of the other participants** (group thinking)
- estimates are **story points** from different members (developers)
- estimates are revealed simultaneously to assure the indepence between group members
- estimates are used during **release** and **sprint planning** meetings to create release and sprint plans

5 Technical Foundation of Business Information System

5.1 Architecture of Business Information Systems

- **Architecture Patterns:**
  - An **architecture pattern** describes a particular recurring design problem that arises in specific **design contexts** and presents a well-proven **generic scheme** for its solution.
  - The solution scheme is specified by describing its constituent **components**, their **responsibilities** and **relationships**, and the ways in which they **collaborate**.
  - *Examples:* Layered Architecture, Tiered Architecture
- **Layered Architectures:**
  - layers define a **logical partitioning** of software components to reduce overall system complexity
  - **Two types of layered architectures:**

Strict Layered Architecture	Open Layered Architecture
Components of a layer may access only components of the layer directly below it.	Components of a layer may access all components of layers below it.
Advantage: Easier maintenance	Advantage: (Possibly) higher efficiency

  - a component of a layer may not access a layer above it
  - **high cohesion** between conponents within a layer, **low coupling** between different layers
  - a layer can have an explicit **interface** that distinguishes public and private components of a layer
- **Tiers in Architectures:**
  - Tiers define a **physical partitioning** of logical software components into different process spaces of a distributed system.

  - a tier identifies an independent **process space** within a distributed application
  - these process spaces can be executed on a single/different computers in a **network**
  - each tier has a particular **responsibility** in the system and addresses a coherent set of **concerns** and **requirements** that may change over time
  - tiers are a concept relevant for structuring software components during **execution**
  - **n-tier architecture** defines how many tiers there are within a distributed application
  - Typical concerns and requirements in an **information system**:
    * **Presentation Tier:** how to interact with the users?
    * **Business Logic Tier:** how to capture and structure business logic and ensure the integrity of data?
    * **Resource Tier:** how to persistently store and efficiently manage data?

- **Client-Server Architecture:**
  - two components: client and server
  - client requests service via network protocol from server, server sends response
  - one server can serve multiple clients
  - a server can be a client of another server

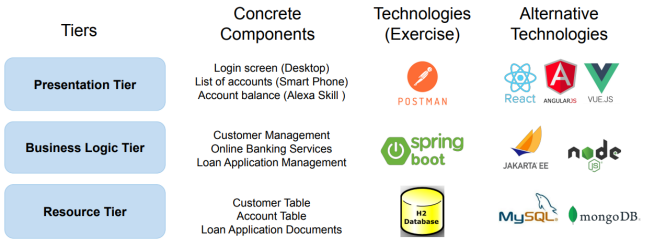
- **Two-Tier Architecture:**
  - client tier and server tier
  - assignment of tasks:
    * Presentation -> Client tier
    * Business logic -> Client tier or server tier, both
    * Resource management -> Server tier
  - Advantages:
    * easy to implement
    * high performance

- **Three-Tier Architecture:**
  - Assignment of tasks:
    * Presentation -> Client tier
    * Business logic -> Middle tier

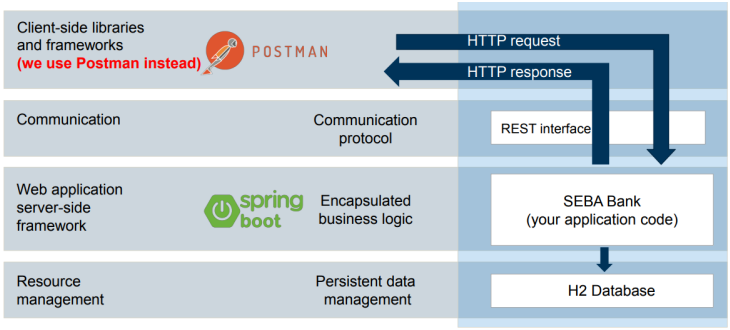
    - Resource management -> Server tier
  - Standard model for simple **web applications**:
    - Client tier -> HTML/CSS/JavaScript (loaded dynamically by a **browser**)
    - Middle tier -> **web application server**
    - Server tier -> off-the-shelf **database management system**

- **Four- and N-Tier Architectures:**
  - extension of three-tier architectures: **business logic** is distributed to several layers
  - Motivation:
    - further complexity reduction of individual tiers
    - improved protection and isolation
    - use of multiple and concurrent application processes

- **Technologies and Tiers Used in the Exercises:**



- **Target Architecture (SEBA Bank, SEBA Mobility Services):**



- **Web Server:**
  - processes incoming requests over various network protocols (HTTP)

  - provides its clients with static or dynamically generated content (HTML, CSS, files, images)
  - **Additional tasks:**
    * resource management (sockets, static files)
    * access control
    * cookie[9] management
    * script execution
    * caching

- **Application Server:**
  - web servers that execute application code to respond to HTTP requests with HTTP responses
  - enterprise software platforms offer their own application servers: Jakarta EE, SAP Web Application Server
  - **Additional tasks:**
    * authentication
    * authorization
    * session management
    * encapsulation of databases
    * transaction processing
    * asynchronous communication

- **Database Server:**
  - **Database server (software)**
    * software to implement data management, query optimization, concurrency control, access control
    * can belong to different categories: Relational DB etc.
    * provides administration tools
  - **Database server (hardware)**
    * database servers usually run on a separate high-performance machines (disk IO, main memory, number of processes and threads)
    * taking in the role of the **server**
  - **Used in the exercises:**
    * H2 database (relational)
    * no separate database server / tier (embedded, in-memory)
    * not suitable for production

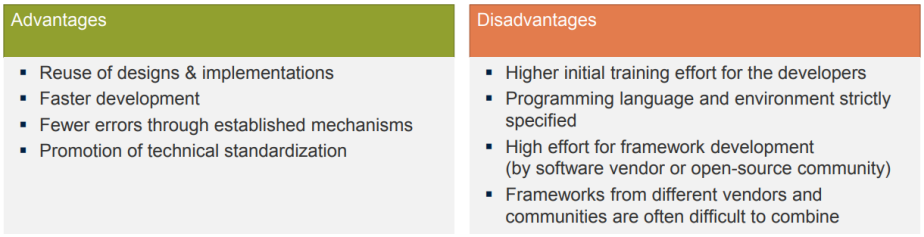
[9] A **cookie** is a small piece of information that a website stores on your computer, and uses it at the time of your iteration on that website.

- **Data Exchange Formats: XML and JSON:**
  - A **Web API** consists of a defined set of HTTP request messages.
  - for each request -> Web API specifies the structure of response messages
  - messages expressed in JSON or XML => **human-readable** data interchange

5.2 Libraries and Frameworks

- **Library: reusable software component** that consists of several classes
  - **functions** of the library are called by the code of the users via its **Application Programming Interface (API)**
  - **API:** the order in which the provided functions are called is determined by the user
  - *Examples:* Log4J (logging), JDBC (database access), dom4j (XML parsing)
- **Framework: partially finished software system** (completed code), which consists of a variety of coordinated software components from which an **adapted software system** can be created with relatively little effort
  - **Frameworks offer**
    - a basic architecture for a software system
    - a high degree of reusability
    - a given set of functions that user can / have to extend
    - whereby the general processing logic
  - **Frameworks are tailored for specific purposes**
    - GUIs: Java Swing
    - Web development: Spring Web
    - Unit testing: JUnit
  - *Framework Examples:* JUnit, Spring, Jakarta EE
- **Inversion of Control (IoC): IoC** distinguishes a **framework** from a **library**
  - Since **developer** is in charge of application flow, he decides when to call the **library**.
  - However, when developer uses a framework, **framework** decides when to call the **library**.
  - This shift in control of calling the library from the **application code** to the **framework** is an inversion of control.

- **Advantages and Disadvantages of Frameworks:**



- **Jakarta EE (Framework):** a set of specifications for different purposes -> an implementation is needed to use them
- **Spring (Framework):** a framework (configuration model) for building web applications
  - **Features:**
    - IoC container with **dependency injection**
    - data access
    - testing
- **Spring Boot:** a project within the **Spring Framework** that provides a simplified way to configure **based on conventions** and run Spring applications
  - **Motivation:** minimize amount of manual configuration (convention over configuration)
  - **Features:**
    - creation of stand-alone Spring apps
    - embedded web servers
    - use of annotations

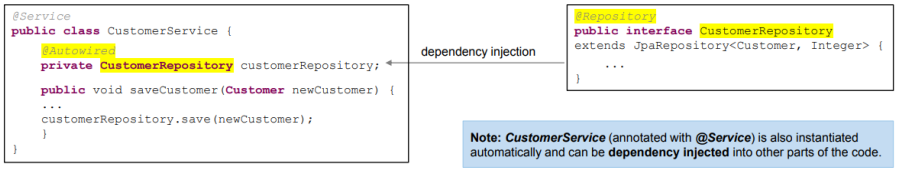
5.3 Java Annotations

- **Motivation: Aspects and Cross-Cutting Concerns:**
  - Software components, libraries and frameworks define **reusable code**
  - functionality separated from user code through API calls
  - user programs remain **unchanged**
  - desirable to extract **repetitive code elements** that address a certain **aspect** of overall system functionality from user programs
  - **Examples** of such aspects which address **cross-cutting concerns**[10] of whole app:

[10] **Cross-cutting concern** relies on or affects many other aspects within that program.

    - component configuration and binding
    - monitoring and logging
    - access control
    - data conversion for data exchange
    - exception and transaction management
  - **combining these aspects freely** which makes it impossible to isolate them from the user code

- **Annotation:** a tag that represents **metadata** i.e. attached with class, interface, methods or fields to indicate some additional information which can be used by java compiler and JVM.
- **Dependency Injection (DI):** a design pattern in which an object (client) receives other objects (services or dependencies) that it depends on.
  - code that passes the service to the client is called **injector** -> injector tells client what service to use (rather than allowing client to choose)
  - intent behind DI is to achieve **separation** of concerns of **construction** and **use** of objects
- **Dependency Injection in Spring (Boot):** The **injector code** is part of the framework and triggered by **annotations**.



CustomerService *is the* ***client****, whereas* ***CustomerRepository*** *is the* ***service****.* ***@Autowired*** *is the* ***injector****.*

- **Use of Annotations in Jakarta EE:**
  - Application servers or persistence frameworks like **Hibernate** provide aspects that implement the specified functionality.
  - *Examples:* ***@Entity*** => for classes to be persisted into database
- **Use of Annotations in Spring (Boot):**
  - ***@Component***: generic stereotype for any Spring-managed components

    Special cases of ***@Component***:
  - ***@Controller***: for classes at presentation layer

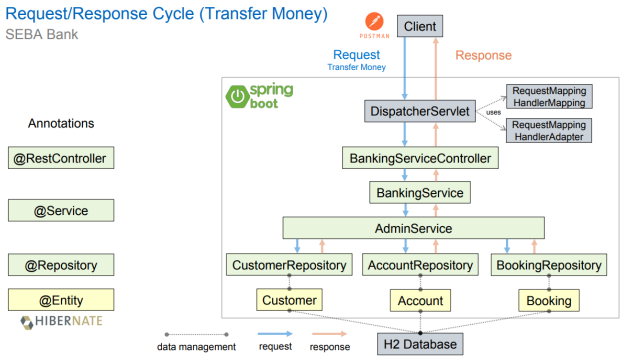
- ***@Service***: for classes at service layer
- ***@Repository***: for classes at persistence layer

  Other Annotations:
- ***@SpringBootApplication***: for Spring Boot apps
- ***@Bean***: for objects which are created by Spring framework when the app starts (DI)
- ***@Autowired***: for DI (automatic instantiation of specific classes (beans))

- **Reflection:** process in which a program accesses info that belongs to the structure of the program itself
  - allows programs to examine, introspect and modify their own structure and behaviour at **compile-time** or **run-time**
  - *Example:* calling a method of an object by its name

```
public class ReflectionTest {
    public String test() {
       Account a = new Account();
       return Account.class.getMethod("getBalance").invoke(a);
    }
}
```

- **Request/Response Cycle:** *Representation of a Software Application => From* ***Persistence Layer*** *(Buttom) to* ***Presentation Layer*** *(Top)*



6 Persistent Data Management

6.1 Motivation

- **Management of Persistent Data in Business Applications:**
  - **Persistent Data:** data that is infrequently accessed, not likely to be modified and stored beyond the lifetime of the user session (non-volatile) (e.g. master data, transactional data, historical data)
- **Impedance Mismatch:** a set of conceptual and technical difficulties that are often encountered because objects or class definitions must be mapped to database tables defined by a relational schema -> RDBMS[11] with object-oriented programming
  1. specialized data structures for specific access patterns
  2. relational data storage for storage of bulk data
- **Databse Management Systems (DBMS):** entirety of programs for accessing database, checking consistency and modifying the data is called a database management system
  - **Persistence related functionalities:**
    - persistent data retention
    - modification of stored data
    - parallel data modifications
    - handling of mass data
    - ensuring compliance with integrity conditions
    - recovery in case of error
  - **Variants:**
    - **Relational Database**
    - **NoSQL Database**
- **Transactions (ACID)**:
  - a **transaction** is a single unit of work, often made up of multiple operations
  - transactions adhere to the **ACID** paradigm
  - **ACID:**
    - **Atomicity:** entire transaction takes place at once or does not happen at all
    - **Consistency:** database must be consistent before and after the transaction

[11] relational database management system

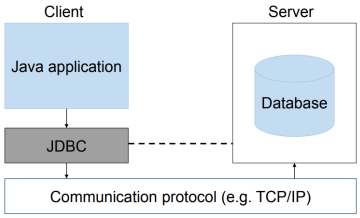
    - **Isolation:** multiple transactions occur independently without interference
    - **Durability:** changes of a successful transaction occurs even if the system fails

6.2 Programmatic Access to Relational Databases

- **Basics of Relational Databases:**
  - a **relational database** is a set of named tables
  - number of rows -> cardinality of relation, number of columns -> arity of relation
  - every relation has a **primary key** which can be a single attribute or can consist of several attributes
  - primary key of a table in another table -> **foreign key**
- **H2 Database:** a relational database written in Java
  - **Main Features:**
    - very fast, open-source, JDBC[12] API
    - embedded mode and server mode
    - in-memory database -> volatile, wiped out after the execution of app
    - browser-based console app (supports SQL)
- **Access to Persistent Relational Databases:**
  - **Goal:** business logic source code accesses persistently stored data
  - **Common Scenario:**
    - business logic developed in object-oriented programming language
    - relational database is used as persistent data storage
  - **Requirements:**
    - ACID for transactions
    - business logic independent of data access
  - **Different Implementation Strategies:**
    - **Direct SQL calls:** using an applicable technology from the programming language
    - **Software for Object-Relational Mapping:** automates aspects of access to the persistent data store

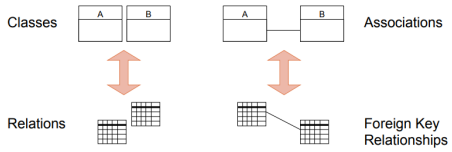
[12] java database connectivity

- **Java Database Connectivity (JDBC): Overview**



- **Advantages and Disadvantages of JDBC:**
  - **Advantages:** direct use of JDBC in applications is appropriate, if
    - stored procedures should be called
    - special queries have to be executed
    - proprietary database functionality is to be accessed
  - **Disadvantages:**
    - during development often error-prune, handling is too complex for developers
    - requires commitment to a certain persistence strategy
  - **JDBC calls should never be integrated directly into business logic code!**
- **Jakarta Persistence API (JPA):** Jakarta Persistence defines a standard API for persistent management of relational data in Java environments.
  - **Main Features:**
    - Object-Relational Mapping (ORM)
    - management of database access
    - JPA itself is only a specification -> part of Jakarta EE
- **Hibernate (Framework):**
  - **Main Features:**
    - **Object-Relational Mapping framework** for Java and RDBMS
    - open-source
    - full support for JPA
    - provides an SQL-like query language: **Hibernate Query Language**
    - serves as **abstraction above JDBC**
    - **easy to integrate** into projects

- **Object-Relational Mapping (ORM):** maps the state of objects to data in relational database to provide transparent persistent data storage and access



- **Software for Object-Relational Mapping:**
  - more complex structured transparently decomposed into flat structures of the RDBMS
  - developer sees only structures of object-oriented programming language -> transparent conversion from object-oriented operations to relational operations
  - features already provided by RDBMS do not need to be realized by the object-oriented application again -> ensuring data integrity
- **Object Serialization and Deserialization:**
  - **Serialization** describes process of converting an object and all its iteratively reachable objects into a **byte or character stream** such that the object can be reconstructed through **deseerialization**.
  - stream contains representations of attribute values, types, associations (links) between objects
  - can be used to store or send complex data structures
  - not all data types can be serialized (e.g. threads, files) -> exception thrown
  - in Java through the interface ***Serializable***

6.3 Persistent Entities

- **Basics of Persistent Entities:**
  - Persistent Entities provide object-oriented access to the persistent info in the database (e.g. customer class/table).
  - An **entity** is a persistent domain object annotated with ***@Entity***:
    - Entity classes are mapped to tables in relational database.
    - Each row represents an instance of that class.
  - multiple clients can use entity instances that represent the same data
  - each entity instance has a **unique primary key**

  - entities exit as long as database exists (secure against server failures) or until they are deleted

- **Specification/Development of an Entity:**
  - Entities obey JPA Specification:
    * class must be annotated with ***@Entity***
    * class must have a **default constructor** without arguments
    * state of an entity available to clients through **entity's methods**, getters/setters
    * class and methods must **not be final**
  - Entities are annotated for ORM:
    * for entity: ***@Entity***
    * for primary key: ***@Id***
    * for generation of primary keys: ***@GenerateValue(strategy = GenerationType.IDENTITY)***
    * for (re)naming a column (attribute) of table: ***@Column(name = "name")***
    * for (re)naming a table: ***@Table(name = "name")***
    * for enums: ***@Enumerated(EnumType.STRING)***
    * for handling circular references: ***@JsonIdentityInfo(generator = ObjectIdGenerators.PropertyGenerator.class, property = "id")***

- **Developer View of a Persistent Entity:** developer requires methods of two different types:
  1. methods to **create**, **read**, **update** and **delete** (CRUD) instances of entities:
     - **EntityManager** in Jakarta
     - **Hibernate** provides its own EntityManager called Session
  2. methods to **read** and **update** attribute values of an entity instance

- **EntityManager:**
  - allows access to the data store by implementing programming interfaces and lifecycle rules defined by JPA
  - associated with a persistence context, within which entity instances and their lifecycles are managed

- **Spring Data:** Since managing **EntityManager** manually is cumbersome, error-prone and leads to boilerplate code, Spring provides **Spring Data**

- **Spring Data and Spring Data JPA:**
  - **Spring Data:**
    - focuses on repository abstraction
    - provides a familiar and consistent Spring-based programming model for data access
    - reduces the amount of boilerplate code required to implement data access layers
    - supports Criteria API
  - **Spring Data Jpa:**
    - part of larger Spring Data family, makes it easy to implement JPA-based repos
    - not a JPA implementation but an abstraction layer to use
- **Spring Data Repositories:**
  - **Annotation: *@Repository***
  - Spring will detect the annotation during component scanning and **provide an instance** at runtime
  - **CrudRepository:** provides CRUD functions for a given entity class
  - **PagingAndSortingRepository:** extends CrudRepository, pagination, sorting records
  - **JpaRepository:** extends PagingAndSortingRepository, flushing/batch deleting records
- **Crud Repository:**
  - a repository must extend ***JpaRepository<EntityClass, TypeOfId>***
  - **CrudRepository** provides the methods:
    - ***save()***, ***delete()***, ***findAll()***, ***findById()***, ***count()***...
    - *Example:*

AccountRepository.java

```
import org.springframework.data.jpa.repository.JpaRepository;
import org.springframework.stereotype.Repository;

import tum.seba.bank.entity.Account;

@Repository
public interface AccountRepository extends JpaRepository<Account, Integer> {

// there is no code missing here
// this is sufficient to use all inherited methods (save(), find(), etc.)
// developers can define their own (more advanced) queries here (see later)

}
```

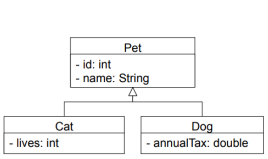
entity class

data type

Account.java

```
@Entity
public class Account {
    @Id
    @GeneratedValue
    private int id;
    private String iban;
    private double balance;
    {...}
}
```

- **Spring Data Repositories-Advantages and Disadvantages:**
  - **Advantages:**
    - less boilerplate code
    - easy configuration
    - simple queries out-of-the-box
  - **Disadvantages:**
    - code is coupled to library and its specific abstractions
    - complete set of persistence methds are exposed -> loss of control
- **Relational Mapping of Inheritance Hierarchies:**
  - **Single Table Strategy:** ***@Inheritance(strategy = InheritanceType.SINGLE_TABLE)***
    - all classes of inheritance hierarchy mapped to **one (same) table**
    - all attributes mapped to **colums**
    - **Advantages:**
      - easy **primary key** handling
      - good **polymorphic query** performance
    - **Disadvantages:**
      - many **NULL** values
      - **NOT NULL** constraints on subclass entity attributes are not possible

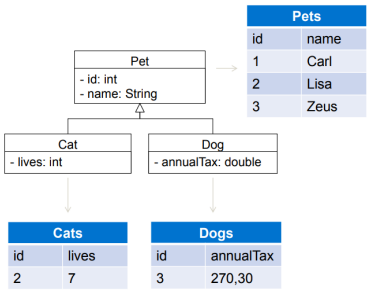


Discriminator

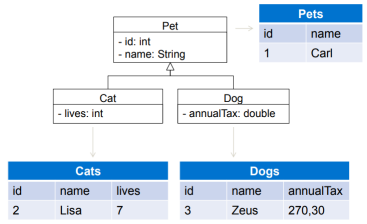
Pets				
id	type	name	lives	annualTax
1	Pet	Carl	NULL	NULL
2	Cat	Lisa	7	NULL
3	Dog	Zeus	NULL	270,30

  - **Joined Table Strategy:** ***@Inheritance(strategy = InheritanceType.JOINED)***
    - each class of inheritance hierarchy mapped to **different tables**
    - only common attributes in **parent's table**, subclass-specific attributes, id in **child's table**
    - **Advantages:**
      - **no NULL** values
      - easy **primary key** handling

    - **Disadvantages:**
        - search for instances of Pet with **JOIN**

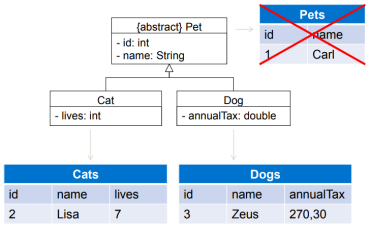


- **Table per Class Strategy:** ***@Inheritance(strategy = InheritanceType.TABLE_PER_CLASS)***
    - each class of inheritance hierarchy mapped to **different tables**
    - respective attributes in **one table**, instances of child **not in** parent's table (nor the opposite)
    - **Advantages:**
        - **no NULL** values
        - search for instances of Pet **without JOIN**
    - **Disadvantages:**
        - complex **primary key** handling



- **Mapped Superclass Strategy:** ***@MappedSuperclass***
    - if parent class is **abstract**, **Mapped Suoerclass Strategy** can be used => no instances of parent
    - each subclass mapped to **different tables**
    - respective attributes in **one table**
    - **Advantages:**
        - **no NULL** values
        - easy **primary key** handling
        - easy way to share **mapping info** between entities
    - **Disadvantages:**

- **polymorphic queries** not possible
- **superclass (parent)** cannot contain associations with other entities



- **ORM for Associations Between Objects:**
  - **Associations in JPA:**
    - ***@OneToOne***
    - ***@OneToMany*** / ***@ManyToOne***
    - ***@ManyToMany***
  - **Parameters for update/delete propagation:** e.g. ***@OneToOne(cascade = CascadeType.REMOVE)***
  - **Different loading strategies:**
    - referenced objects loaded immediately: ***fetch = FetchType.EAGER***
    - referenced objects loaded later on demand: ***fetch = FetchType.LAZY***
  - *Example in Java:* ***Pet*** *Class has the* ***primary key*** *of* ***Owner*** *Class (mappedBy) as a* ***foreign key*** *in its table.*

```java
@Entity
public class Pet implements Serializable {
    @ManyToOne
    private Owner owner;

    public Owner getOwner() { return this.owner; }

    public void setOwner(Owner owner) { this.owner = owner; }

    /* … */
}


@Entity
public class Owner implements Serializable {
    @OneToMany(mappedBy="owner", cascade=CascadeType.REMOVE, fetch=FetchType.EAGER)
    private Collection<Pet> pets;

    public Collection<Pet> getPets() { return this.pets; }

    public void setPets(Collection<Pet> pets) { this.pets = pets; }

    /* … */
`
```

6.4 Query Languages

- **Java Persistence Query Language (JPQL):**

  JPQL is not **type-safe**!

Example JPQL:

```
@Repository
public interface AccountRepository extends JpaRepository<Account, Integer> {

    @Query("SELECT a FROM Account a WHERE a.iban = ?1")
    Account findAccountByIBAN(String iban);

}
```

Advantages	Disadvantages
▪ JPQL is very similar to SQL ▪ Query can simply be formulated as String	▪ Compiler cannot check Strings → error-prone ▪ Long queries quickly difficult to understand

- **Criteria API:**
  - **Motivation:**
    - Neither attributes nor classes are **type-safe** in **JPQL**.
    - Also, compiler cannot check the JPQL keywords (SELECT, FROM).
  - *Example:*

```
// always the same
CriteriaBuilder cb = em.getCriteriaBuilder();                    // Step 1
CriteriaQuery<Customer> cqry = cb.createQuery(Customer. class);  // Step 1

// interesting code is here
Root<Customer> root = cqry.from(Customer.class);        // Step 2 (FROM Customer c)
cqry.select(root);                                      // Step 3 (SELECT *)
// WHERE clause
Predicate pGtAge = cb.gt(root.get("age"),10);           // Step 4 Predicate
cqry.where(pGtAge);                                     // Step 5 (WHERE age > 10)

// always the same
Query qry = em.createQuery(cqry);                       // Step 6 Create Query
List<Customer> results = qry.getResultList();           // Step 6 Execute Query
```

    - **Methods for predicate definition:**
      - ***cb.gt()***: greater than
      - ***cb.equal()***: equal
      - ***cb.between()***: between
      - ***cb.and(Predicate a, Predicate b)***: WHERE a AND b
  - **Type Safety:**
    - **Type safety on attributes not yet ensured:** Reference to attribute with its name as String -> error prune

```
Predicate pGtAge = cb.gt(root.get("age"),10);           // Step 4 Predicate
```

- **Querydsl:** a framework that enables construction of statically typed SQL-like queries
  - *Example:*

```
List<Person> persons = queryFactory.selectFrom(person)
.where(
    person.firstName.eq("John"),
    person.lastName.eq("Doe"))
.fetch();
```

  - **Advantages:**
    * more human-readable than Criteria API
    * open-source
    * statically typed = type-safe queries

6.5 Alternatives for Persistent and Bulk Data Management

- **NoSQL Databases:** a new generation of database systems which considers following points:
  - associated data model **not relational**
  - systems designed for **distributed and horizontal scalability**
  - **schemaless** or weaker schema restrictions
  - due to distributed architecture, **easy data replication**
  - **simple API**
  - **eventually consistent**, but **not ACID**
- **When to use NoSQL instead of Relational Databases:**
  - performance problems in relational databases:
    * indexing of large amount of documents
  - Relational databases are efficient if they are **optimized for frequent but small transactions** or for **large batch transactions with rare write accesses**.
  - Relational databases are unable to handle **high data requirements** and **frequent data changes** at the same time.
  - NoSQL databases can handle many **write** and **read** requests (e.g. Facebook, Amazon).

7 Architecture of Distributed Information Systems

7.1 Characteristics of Distributed Systems