Software Engineering for Business Applications
Lecture Notes

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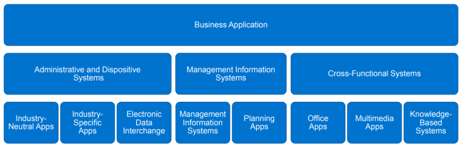
1 IT Support for Business Applications

1.1 Classification of Business Applications

- **Definition ”Business Application”:**
  - <u>in narrower sense:</u> totality of all programs, i.e. **application software**, and associated **data** for a concrete business use case
  - <u>in broader sense:</u> 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:**



  <u>*Examples of*</u>

  - **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

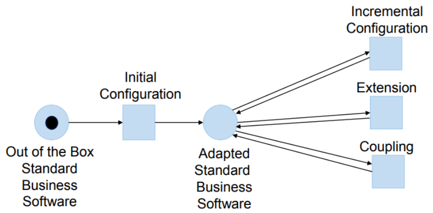
- **Enterprise Resource Planning (ERP): ERP system** is an integrated business application (suite, collection of programs), which supports all essential functions of administration, disposition and management with a common interface and a shared and integrated data management.
    - consists of platform 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**).


Incremental Configuration
Initial Configuration
Extension
Out of the Box Standard Business Software
Adapted Standard Business Software
Coupling

  - **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

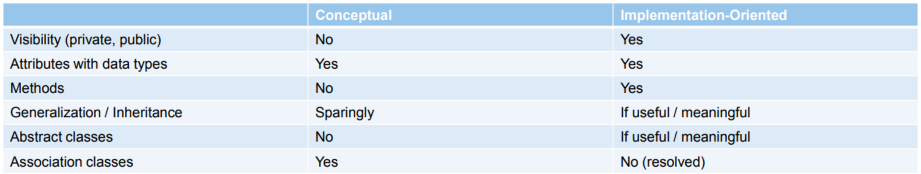
- **Typical Requirement Artifacts in Agile Software Development:**
  - **user story**, **story card**, **use case**, **scenario**, **UML diagram**, **prototype**

- **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:**

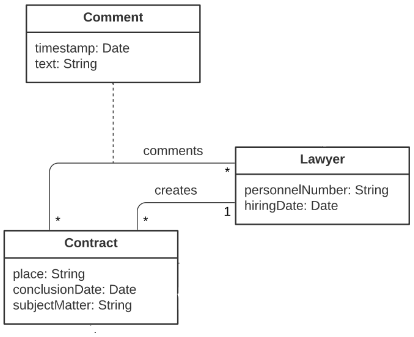


	Conceptual	Implementation-Oriented
Visibility (private, public)	No	Yes
Attributes with data types	Yes	Yes
Methods	No	Yes
Generalization / Inheritance	Sparingly	If useful / meaningful
Abstract classes	No	If useful / meaningful
Association classes	Yes	No (resolved)

- **Associations between Classes:**

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

  - **Multiplicity:**

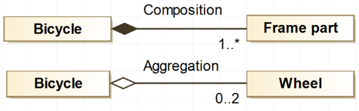


*A Lawyer can <u>create</u> **multiple** Contracts, whereas every Contract has a **single** Lawyer.* -> <u>creates</u> (action) on the side of Lawyer (actor)

- **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:**

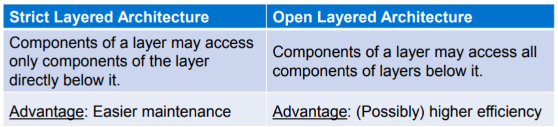
[8] **Story points** are units of measure for expressing an estimate of the overall effort required to fully implement a product backlog item or any other piece of work.

- 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

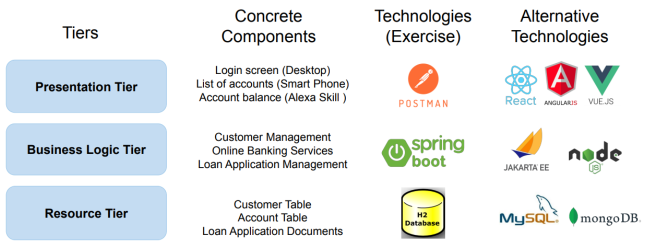
- **Two-Tier Architecture:**
  - client tier and server tier
  - assignment of tasks:
    - Presentation -> Client tier
    - Business logic -> Client tier or server tier, both
    - Resource management -> Server tier
  - Advantages:
    - easy to implement
    - high performance

- **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**

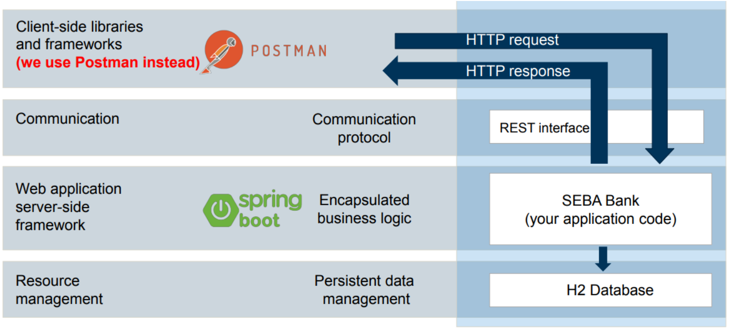
- **Four- and N-Tier Architectures:**
    - extension of three-tier architectures: **business logic** is distributed to several layers
    - Motivation:
        - further complexity reduction of individual tiers
        - improved protection and isolation
        - use of multiple and concurrent application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

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



Tiers	Concrete Components	Technologies (Exercise)	Alternative Technologies
Presentation Tier	Login screen (Desktop) List of accounts (Smart Phone) Account balance (Alexa Skill)	POSTMAN	React ANGULARJS VUE.JS
Business Logic Tier	Customer Management Online Banking Services Loan Application Management	spring boot	JAKARTA EE node JS
Resource Tier	Customer Table Account Table Loan Application Documents	H2 Database	MySQL mongoDB

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



Client-side libraries and frameworks
(we use Postman instead)

Communication
Communication protocol

Web application server-side framework

Encapsulated business logic

Resource management
Persistent data management

- **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

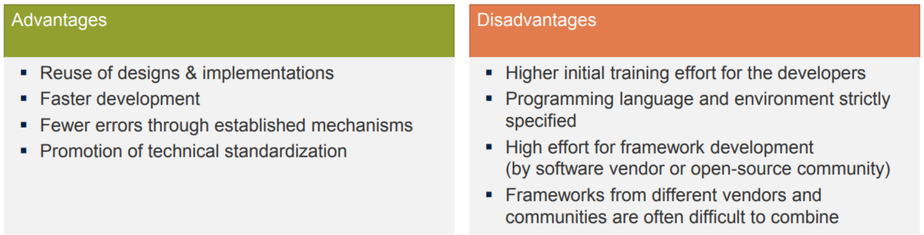
[9] A **cookie** is a small piece of information that a website stores on your computer, and uses it at the time of your iteration on that website.

- **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:**



Advantages	Disadvantages
▪ Reuse of designs & implementations ▪ Faster development ▪ Fewer errors through established mechanisms ▪ Promotion of technical standardization	▪ Higher initial training effort for the developers ▪ Programming language and environment strictly specified ▪ High effort for framework development (by software vendor or open-source community) ▪ Frameworks from different vendors and communities are often difficult to combine

- **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:

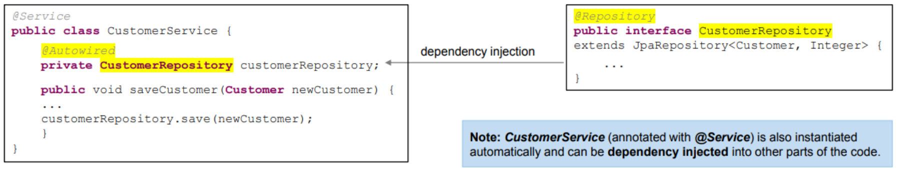
[10] **Cross-cutting concern** relies on or affects many other aspects within that program.

        - 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**.



```
@Service
public class CustomerService {
    @Autowired
    private CustomerRepository customerRepository;

    public void saveCustomer(Customer newCustomer) {
    ...
    customerRepository.save(newCustomer);
    }
}
```

```
@Repository
public interface CustomerRepository
extends JpaRepository<Customer, Integer> {
    ...
}
```

Note: ***CustomerService*** (annotated with ***@Service***) is also instantiated automatically and can be **dependency injected** into other parts of the code.

__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

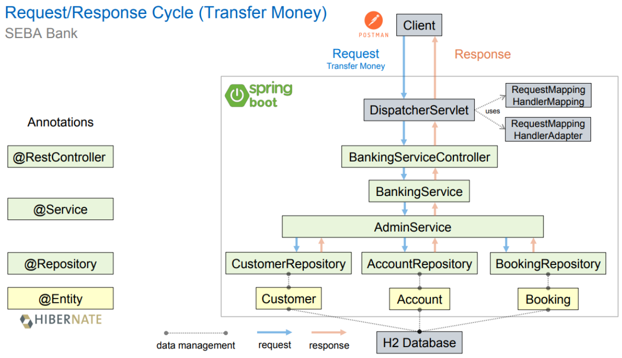
Other Annotations:

- ***@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

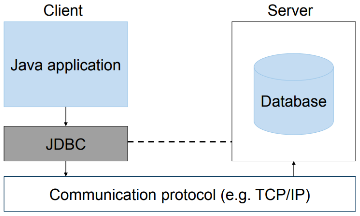
        - **Isolation:** multiple transactions occur independently without interference
        - **Durability:** changes of a successful transaction occurs even if the system fails

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**

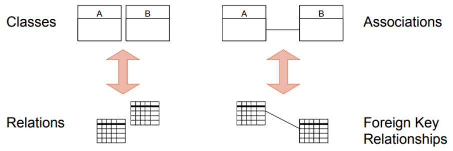


- **Advantages and Disadvantages of JDBC:**
  - **Advantages:** direct use of JDBC in applications is appropriate, if
    - stored procedures should be called
    - special queries have to be executed
    - proprietary database functionality is to be accessed
  - **Disadvantages:**
    - during development 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

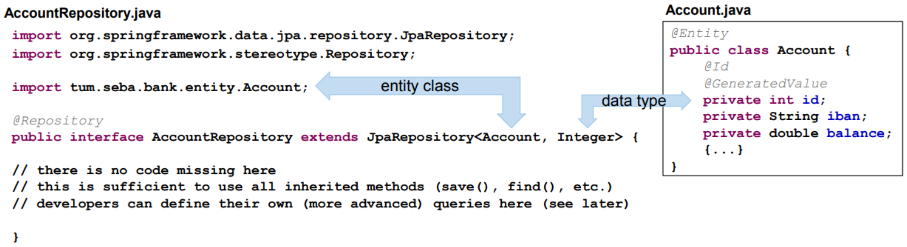
- **EntityManager:**
  - allows access to the data store by implementing programming interfaces and lifecycle rules defined by JPA
  - associated with a persistence context, within which entity instances and their lifecycles are managed

- **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:*



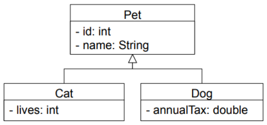
AccountRepository.java

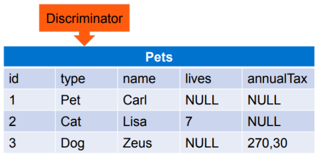
```
import org.springframework.data.jpa.repository.JpaRepository;
import org.springframework.stereotype.Repository;

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)

}
```

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

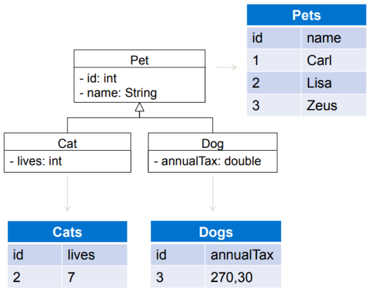



Discriminator

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**

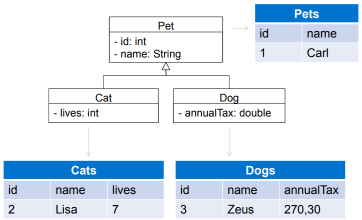


Pets	
id	name
1	Carl
2	Lisa
3	Zeus

Cats	
id	lives
2	7

Dogs	
id	annualTax
3	270,30

- **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



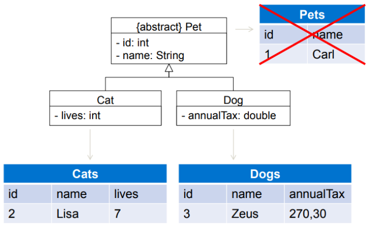
Pets	
id	name
1	Carl

Cats		
id	name	lives
2	Lisa	7

Dogs		
id	name	annualTax
3	Zeus	270,30

- **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

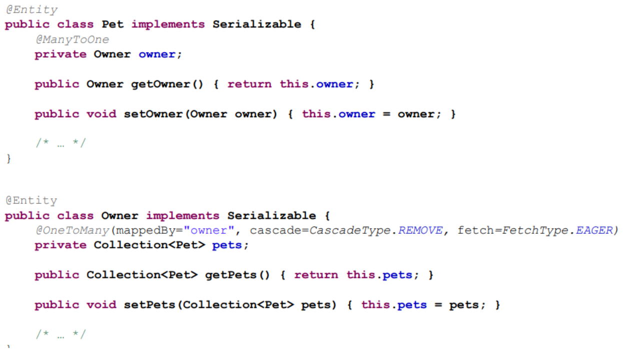


Pets	
~~id~~	~~name~~
~~1~~	~~Carl~~

Cats		
id	name	lives
2	Lisa	7

Dogs		
id	name	annualTax
3	Zeus	270,30

- **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.*

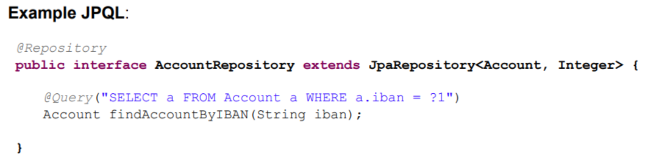


```
@Entity
public class Pet implements Serializable {
    @ManyToOne
    private Owner owner;

    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

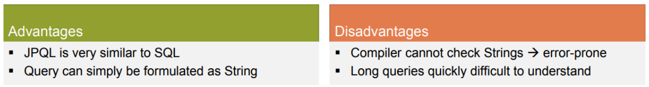
- **Java Persistence Query Language (JPQL):**

  JPQL is not **type-safe**!



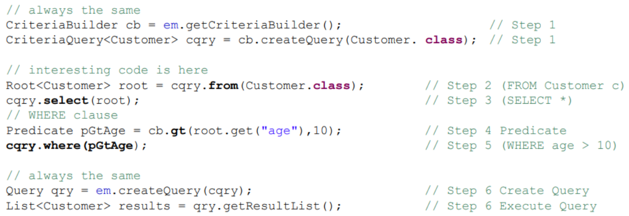
Example JPQL:

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

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

}
```



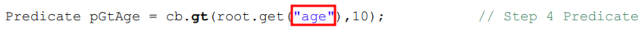
Advantages	Disadvantages
▪ JPQL is very similar to SQL ▪ Query can simply be formulated as String	▪ Compiler cannot check Strings → error-prone ▪ Long queries quickly difficult to understand

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



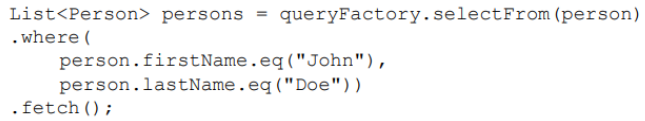
```
// always the same
CriteriaBuilder cb = em.getCriteriaBuilder();                  // Step 1
CriteriaQuery<Customer> cqry = cb.createQuery(Customer. class); // Step 1

// 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

- **Foundations:**
  - **Distributed system:** a system that is comprised of several physically disjoint compute resources interconnected by a network
  - **Distributed Application:** an application consisting of severeal processes that run distributed in several process spaces
  - **Characteristics of a distributed system:**
    - resource sharing
    - openness (communication protocols and interfaces)
    - concurrency
    - scalability
    - failure tolerance
    - distribution transparency
- **A Centralized Information System Architecture:**
  - *Example:* Central mainframe
    - multi-user operation
    - optimized for large amounts of data
    - high reliability
    - minimal logic on the terminal, only display of data
- **A Local Area Network of Distributed Clients and Servers:**
  - distributed system within a company, department
    - multi-user operation
    - distributed services and information
  - different functionalities supported by different servers
  - automation of business processes
  - requirement of integration effort and leads to **productivity paradox**:
    - more IT investments do not lead to higher productivity
    - limited realization of compound effects
- **Resource Sharing:**
  - **client-server model** -> based on service-oriented achitecture for resource sharing

  - **server** processes provide **resource managers**, they provide shared resources (e.g. data, code, hardware, processes)
  - **client** processes issue requests to use these remote resources
  - client initiates the communication

- **Opennes and Concurrency:**
  - **Openness**
    - extensibility of the system at the
      - **hardware level:** new peripherals, memory, etc.
      - **software level:** new resource services, communication protocols
    - specifications for **interfaces** of the system are disclosed and documented
  - **Concurrency:**
    - multiple users issue independent and concurrent requests via client processes
    - server processes run concurrently
    - multiple processes may exist for each resource type to improve scalability

- **Scalability and Failure Tolerance:**
  - **Scalability**
    - adapting the system for larger data volumes, workloads, faster throughput
    - increase in complexity
    - ideally without changing application architecture
    - **Goal:** constant performance with increasing load
  - **Failure tolerance**
    - ability of distributed system to provide functionalities even if a number of defective subsystems (servers/clients) exist
    - implementation via redundant subsystems, a certain number of which can be defective
    - guarantee of high availability

- **Transparency:**
  - **distributed system apppears as a single computer system** -> structure hidden from programmer
  - **Forms of transparency**
    -