

# 1 Data Persistence

## What “data persistence” means ?

We manipulate data (represented as object state) that need to be stored

**persistently** to survive a single run of the application

**queriably** to be able to retrieve/access them

**scalably** to be able to handle large data volumes

**transactionally** to ensure their consistency

## How to achieve persistence

**Serialization** • simple, yet hardly queriable, not transactional, ...

- stream persisting an instance of class C is deprecated once definition of C is modified (e.g. field added/removed).

**Relational Databases** (MySQL, PostgreSQL, Oracle, ...)

- efficient storage for data with rigid schema
- well-established and most popular technology
- efficient search using SQL standard
- secure and Transactional (ACID)

## NoSQL Databases

Key-value storages (MongoDB, Hadoop, ...)

- suitable for data without rigid schema
- Object Databases
  - designed in 90’s to capture complexity of object models (e.g. inheritance)
  - Issues: scalability, standardized queries

**RDF Triple Stores** (SDB, TDB, Sesame, Virtuoso, ...)

- graph stores for distributed semantic web data – RDF(S), OWL

## Programmatic Access to Relational Databases (RDBMS)

- JDBC (JSR 221)
  - Java standard to ensure independence on the particular RDBMS (at least theoretically)
- EJB 2.1 (JSR 153)

- Provides Object Relational Mapping (ORM), but complicated
  - (single entity = several Java files + XMLs)
- distributed transactions, load balancing
- iBatis, Hibernate – ORM driving forces for JPA 2
- JPA 2 (JSR 317)
  - Standardized ORM solution for both standalone and Java EE applications

## 2 From JDBC to JPA

### JDBC

Java standard to ensure independence on the particular RDBMS (at least theoretically)

```

Connection connection = null;
PreparedStatement statement = null;
try {
    Class.forName("org.postgresql.Driver");
    connection = DriverManager.getConnection(jdbcURL,dbUser,dbPassword);
    statement = connection.prepareStatement("SELECT * FROM PERSON WHERE HASNAME LIKE ?");
    statement.setString(1, "%Pepa%");
    ResultSet rs = statement.executeQuery();
} catch (ClassNotFoundException e) {
    e.printStackTrace();
} catch (SQLException e) {
    e.printStackTrace();
    if ( statement != null ) {
        try {
            statement.close();
        } catch (SQLException e1) {
            e1.printStackTrace();
        }
    }
}
if ( connection != null ) {
    try {
        connection.close();
    } catch (SQLException e1) {
        e1.printStackTrace();
    }
}
}

```

### JDBC – entities CRUD

#### Create

```

PreparedStatement statement = connection.prepareStatement("INSERT INTO PERSON (id,hasname)
VALUES (?,?)");
statement.setLong(1,10);
statement.setString(2,"Honza");
statement.executeUpdate();

```

#### Retrieve

```

PreparedStatement statement = connection.prepareStatement("SELECT * FROM PERSON WHERE ID=?");
statement.setLong(1,2);
ResultSet rs = statement.executeQuery();

```

#### Update

```
PreparedStatement statement = connection.prepareStatement("UPDATE PERSON SET HASNAME='Jirka'  
WHERE ID=?");  
statement.setLong(1,2);  
statement.executeUpdate();
```

## Delete

```
PreparedStatement statement = connection.prepareStatement("DELETE FROM PERSON WHERE ID=?");  
statement.setLong(1,1);  
statement.executeUpdate();
```

## Question 1: Why prepared statements ?

```
PreparedStatement statement = connection.prepareStatement(  
    "INSERT INTO PERSON (id,hasname) VALUES (?,?)"  
);  
statement.setLong(1,10);  
statement.setString(2,"Honza");  
statement.executeUpdate();
```

## How to avoid boilerplate code ?

- Boilerplate code
  - Obtaining (pooled) connection
  - SQLException handling
  - creating Java objects out of the query results:

```
ResultSet rs = ...  
while(rs.next()) {  
    Person p = new Person();  
    p.setId(rs.getLong("ID"));  
    p.setHasName(rs.getString("HASNAME"));  
}
```

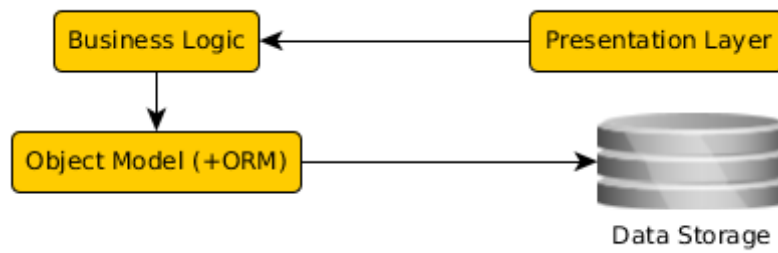
- Although SQL is a standard – there are still differences in implementations (MySQL autoincrement, PostgreSQL serial ...)

solution = Object Relational Mapping (ORM)

## 3 JPA Basics

### ORM Architecture

- idea: “map whole Java classes to database records”
- a typical system architecture with ORM:



```

@Entity
public Person {
    @Id
    private Long id;
    private String hasName;
    // setters+getters
}
  
```

```

CREATE TABLE PERSON (
  ID bigint PRIMARY KEY NOT NULL,
  HASNAME varchar(255)
);
  
```

## CRUD using JPA 2.0

### Initialization

```

EntityManagerFactory f = Persistence.createEntityManagerFactory("pu");
EntityManager em = f.createEntityManager();
EntityTransaction t = em.getTransaction();
t.begin();
  
```

#### Create

```

Person person = new Person();
person.setId(10);
Person.setHasName("Honza");
em.persist(person);
  
```

#### Retrieve

```

Person person = em.find(Person.class, 2);
  
```

#### Update

```

Person person = em.find(Person.class, 2);
person.setHasName("Jirka");
  
```

#### Delete

```

Person person = em.find(Person.class, 1);
em.remove(person);
  
```

### Finalization

```

t.commit();
  
```

## JPA 2.1

- Java Persistence API 2.1 (JSR-338)
- Although part of Java EE 7 specifications, JPA 2.1 can be used both in EE and SE applications.
- Main topics covered:
  - Basic scenarios
  - Controller logic – EntityManager interface
  - ORM strategies
  - JPQL + Criteria API

### JPA 2.1 – Entity Example

- Minimal example (configuration by exception):

```
@Entity
public class Person {

    @Id
    @GeneratedValue
    private Integer id;

    private String name;

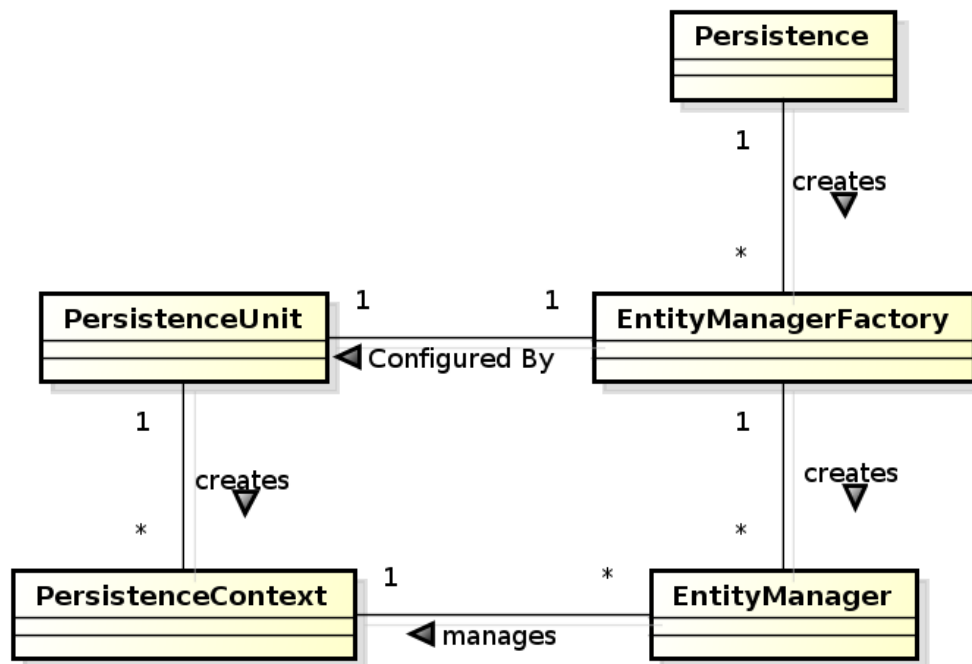
    // setters + getters
}
```

### JPA Basics

- Let's have a set of „suitably annotated“ POJOs, called entities, describing your domain model.
- A set of entities is logically grouped into a persistence unit.
- JPA providers :
  - generate persistence unit from existing database,
  - generate database schema from existing persistence unit.

**Question:** What is the benefit of the keeping Your domain model in the persistence unit entities (OO) instead of the database schema (SQL) ?

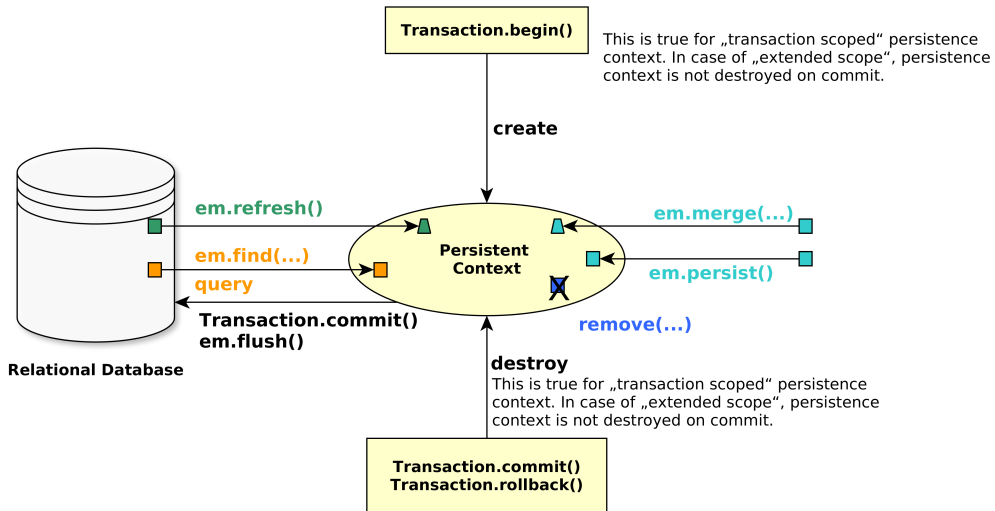
## JPA – Model



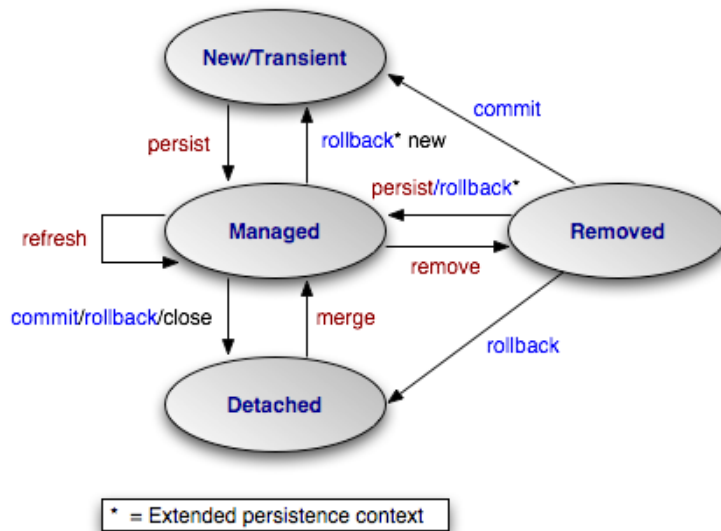
## JPA 2.0 – Persistence Context

- In runtime, the application accesses the object counterpart (represented by entity instances) of the database data. These (managed) entities comprise a **persistence context (PC)**.
  - PC is synchronized with the database on demand (refresh, flush) or at transaction commit.
  - PC is accessed by an EntityManager instance and can be shared by several EntityManager instances.

## JPA – Operations



## JPA – Entity States



source: Wikipedia,

[http://cs.wikipedia.org/wiki/Java\\_Persistence\\_API](http://cs.wikipedia.org/wiki/Java_Persistence_API)

## JPA – Operation Details

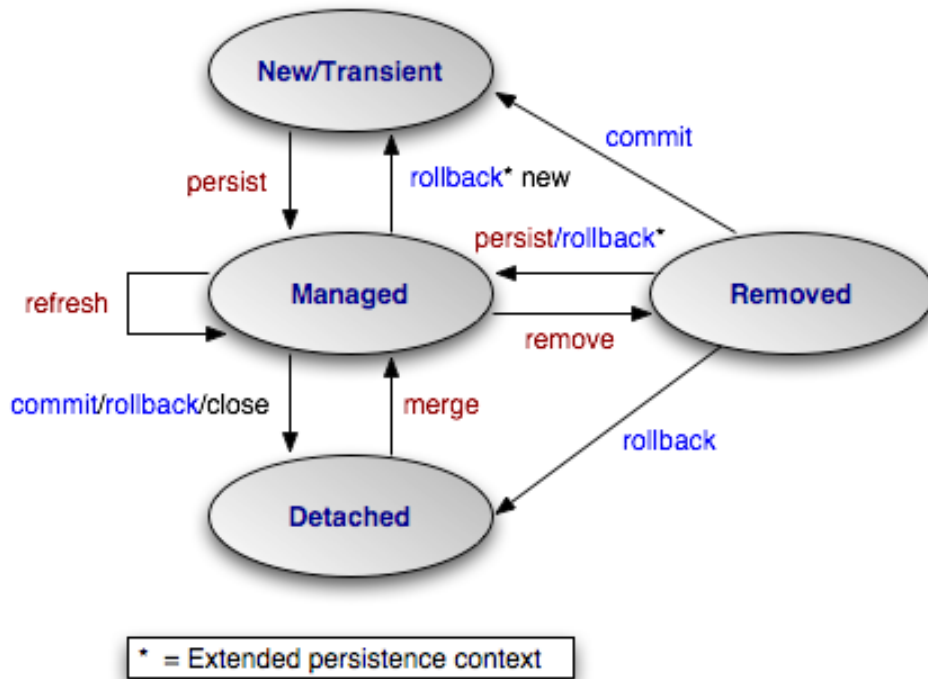
**persist** stores a new entity into persistence context (PC). The PC must not contain an entity with the same id,

**merge** merges a detached entity with its managed version (inside PC),

**find** finds an entity in the DB and fetches it into PC,

**refresh** “reverts” a managed entity state from DB,

**remove** deletes a managed entity from PC.



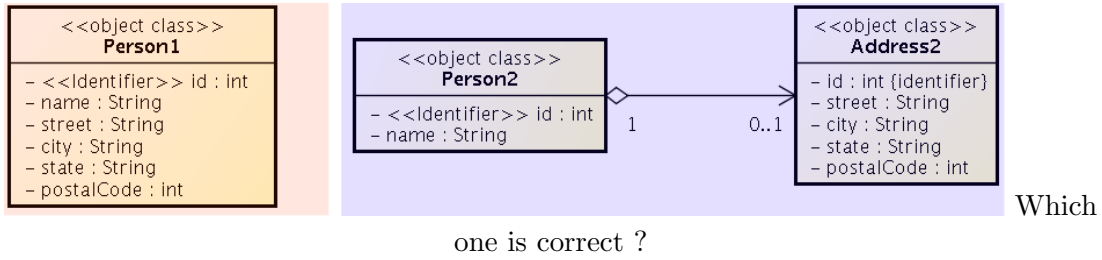
## JPA – EntityManager

- **EntityManager (EM)** instance is in fact a generic DAO, while entities can be understand as DPO (managed) or DTO (detached).
- Selected operations on EM (CRUD) :
  - Create** : `em.persist(Object o)`
  - Read** : `em.find(Object id)`, `em.refresh(Object o)`
  - Update** : `em.merge(Object o)`
  - Delete** : `em.remove(Object o)`
  - native/JPQL queries** : `em.createNativeQuery`, `em.createQuery`, etc.
  - Resource-local transactions** : `em.getTransaction.[begin(),commit(),rollback()]`

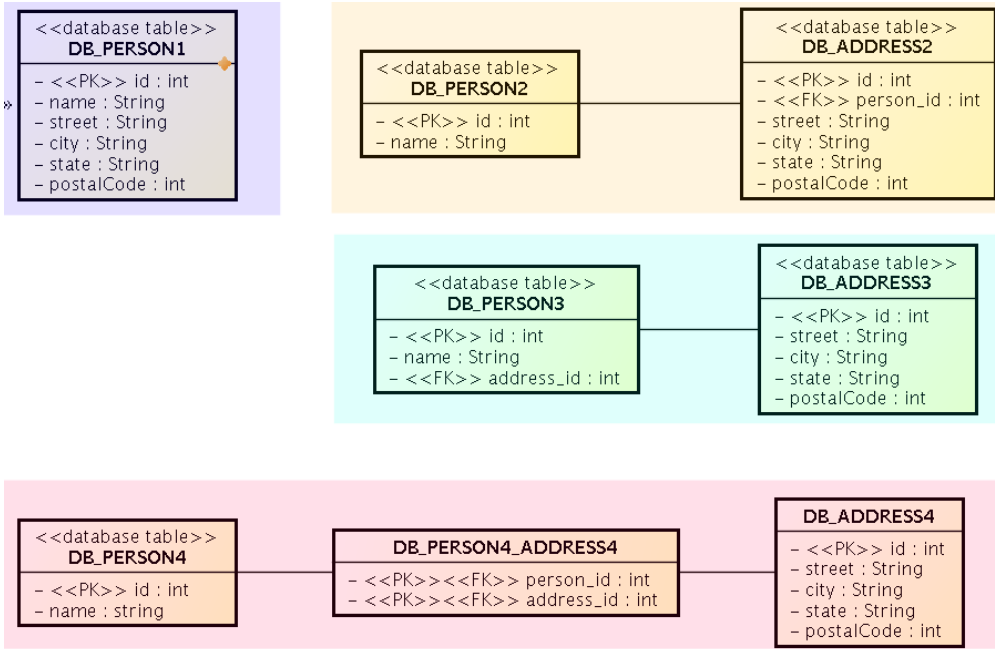
## 4 Object-Relational Mapping (ORM) Basics

### Object model





### Database model



### ORM Basics

#### Simple View

Java Classes = Entities = SQL tables  
 Java Fields/accessors = Entity properties = SQL columns

- The ORM is realized by means of Java annotations/XML.
- Physical Schema annotations
  - @Table, @Column, @JoinColumn, @JoinTable, etc.
- Logical Schema annotations
  - @Entity, @OneToMany, @ManyToMany, etc.
- Each property can be fetched lazily/eagerly.

## Mapping basic types

Primitive Java types:

- String → varchar/text,
- Integer → int,
- byte[] → blob,
- etc.
- @Column – physical schema properties of the particular column (insertable, updatable, precise data type, defaults, etc.)
- @Lob – large objects
- Default EAGER fetching (except @Lobs)

```
@Column(name="id")
private String getName();
```

## Mapping enums/temporals

### Enums

```
@Enumerated(value=EnumType.STRING)
private EnumPersonType type;
```

Stored either in a text column, or in an int column

### Temporals

```
@Temporal(TemporalType.DATE)
private java.util.Date datum;
```

Stored in respective column type according to the TemporalType.

## ORM – Identifiers

- Single-attribute: @Id
- Multiple-attribute – an identifier class must exist
  - Id. class: @IdClass, entity ids: @Id
  - Id. class: @Embeddable, entity id: @EmbeddedId

```
@Id
@GeneratedValue(strategy=GenerationType.SEQUENCE)
private int id;
```

**Question:** How to write hashCode, equals for entities ?

## ORM – Generating Identifiers

Strategies

**AUTO** – the provider picks its own strategy

**TABLE** – special table keeps the last generated values

**SEQUENCE** – using the database native SEQUENCE functionality (PostgreSQL)

**IDENTITY** – some DBMSs implement autonumber column

For database-related strategies, the value of id is set only on

- `Transaction.commit()`
- `em.flush()`
- `em.refresh()`

## ORM – Generated Identifiers TABLE strategy

```
@TableGenerator(  
    name="Address_Gen",  
    table="ID_GEN",  
    pkColumnName="GEN_NAME",  
    valueColumnName="GEN_VAL",  
    initialValue=10000,  
    allocationSize=100)  
@Id  
@GeneratedValue(generator=AddressGen)  
private int id;
```

## 5 ORM Relationship Mapping

### ORM – Relationships

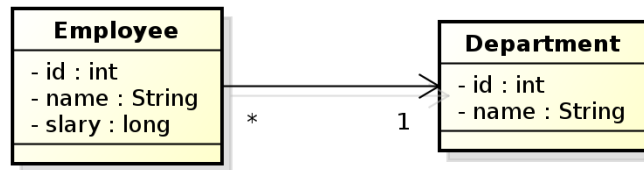
#### Unidirectional

- accessed from **one side** only
  - `emp.getProjects()`
  - `prj.getEmployees()`

## Bidirectional

- accessed from **both sides** sides
  - `empl.getProjects()`
  - `prj.getEmployees()`
- **owning side** = side used for changing the relationship
- **inverse side** = read-only side

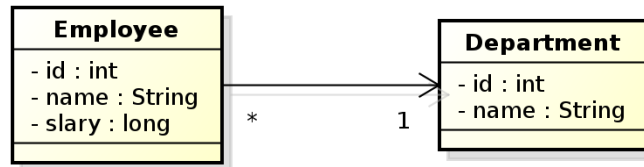
## Unidirectional many-to-one relationship



```
@Entity
public class Employee {
    // ...
    @ManyToOne
    private Department department;
    // ...
}
```

### owning side = Employee

In DB, the N:1 relationship is implemented using a foreign key inside the Employee table. In this case, the foreign key has a default name.



```
@Entity
public class Employee {
    @Id
    private int id;
    private String name;
    private long salary;
    @ManyToOne
    @JoinColumn(name=DEPT_ID)
    private Department department;
}
```

### owning side = Employee.

Here, the foreign key is defined using the `@JoinColumn` annotation.

## Bidirectional many-to-one relationship



```
@Entity
public class Employee {
    @Id
    private int id;
    private String name;
    private long salary;
    @ManyToOne
    @JoinColumn(name="DEPT_ID")
    private Department department;
}
```

owning side = **Employee**

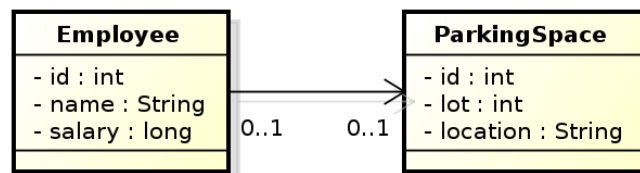
```
@Entity
public class Department {
    @Id
    private int id;
    private String name;

    @OneToMany(mappedBy="department")
    private Collection<Employee> employees;
}
```

inverse side = **Department**

Here, the foreign key is defined using the @JoinColumn annotation.

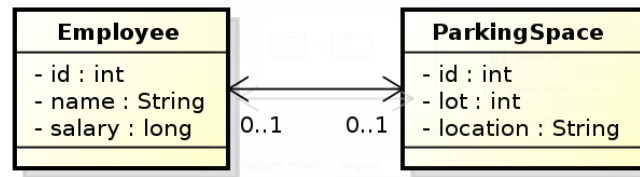
## Unidirectional one-to-one relationship



```
@Entity
public class Employee {
    @Id
    private int id;
    private String name;
    private long salary;
    @OneToOne
    @JoinColumn(name="PSPACE_ID")
    private ParkingSpace parkingSpace;
}
```

owning side = **Employee**.

## Bidirectional one-to-one relationship



```
@Entity
public class Employee {
    @Id
    private int id;
    private String name;
    private long salary;
    @OneToOne
    @JoinColumn(name="PSPACE_ID")
    private ParkingSpace parkingSpace;
}
```

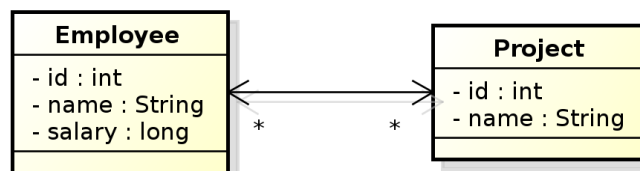
owning side = Employee

```
@Entity
public class ParkingSpace {
    @Id
    private int id;
    private int lot;
    private String location;

    @OneToOne(mappedBy="parkingSpace");
    private Employee employee;
}
```

inverse side = ParkingSpace

## Bidirectional many-to-many relationship



```
@Entity
public class Employee {
    @Id
    private int id;
    private String name;
    private long salary;

    @ManyToMany
    private Collection<Project> project;
}
```

owning side = **Employee**

```
@Entity
public class Project {

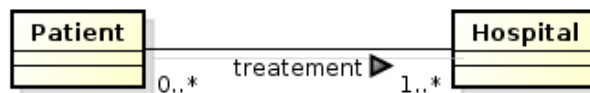
    @Id private int id;
    private String name;

    @ManyToMany(mappedBy="projects");
    private Collection<Employee> employees;
}
```

inverse side = **ParkingSpace**

### Conceptual Modeling Intermezzo

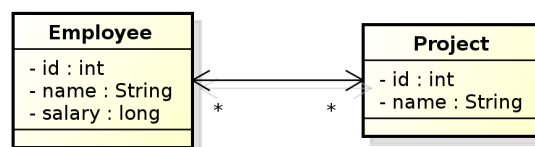
- M:N relationship is a **conceptual modeling** primitive



- Does it mean that
  - A patient has **one** treatment that is handled in **more** hospitals ?
  - A patient has **more** treatments, each handled in a **single** hospital ?
  - A patient has **more** treatments, each handled in **more** hospitals ?
- partialities and cardinalities are too weak in this case.

Careful modeling often leads to decomposing M:N relationships on the **conceptual level** (not on the logical level, like JPA).

### Bidirectional many-to-many relationship



```
@Entity
public class Employee {
    @Id private int id;
    private String Name;
    private long salary;
    @ManyToMany
    @JoinTable(name="EMP_PROJ",
        joinColumns=
```

```

    @JoinColumn(name="EMP_ID"),
    inverseJoinColumns=
    @JoinColumn(name="PROJ_ID"))
    private Collection<Project> projects;
}

```

owning side = Employee

```

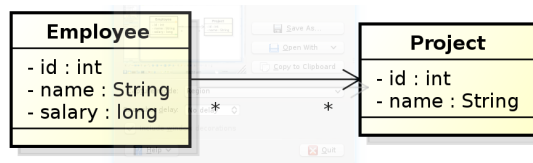
@Entity
public class Project {
    @Id private int id;
    private String name;

    @ManyToMany(mappedBy="projects");
    private Collection<Employee> employees;
}

```

inverse side = ParkingSpace

### Unidirectional many-to-many relationship



```

@Entity
public class Employee {
    @Id private int id;
    private String Name;
    private long salary;
    @ManyToMany
    @JoinTable(name="EMP_PROJ",
        joinColumns=
        @JoinColumn(name="EMP_ID"),
        inverseJoinColumns=
        @JoinColumn(name="PROJ_ID"))
    private Collection<Project> projects;
}

```

owning side = Employee

```

@Entity
public class Project {
    @Id private int id;
    private String name;
}

```

### Unidirectional one-to-many relationship





```

@Entity
public class Employee {
    @Id private int id;
    private String name;
    @OneToMany
    @JoinTable(name=EMP_PHONE,
        joinColumns=
            @JoinColumn(name=EMP_ID),
        inverseJoinColumns=
            @JoinColumn(name=PHONE_ID))
    private Collection<Phone> phones;
}

```

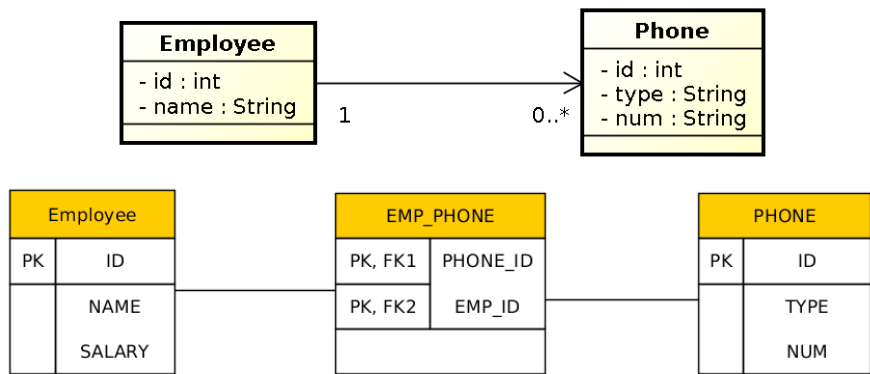
owning side = Employee

```

@Entity
public class Phone {
    @Id private int id;
    private String type;
    private String num;
}

```

### Unidirectional one-to-many relationship



```

@Entity public class Employee {
    @Id private int id;
    private String name;
    @OneToMany @JoinTable(name=EMP_PHONE,
        joinColumns=@JoinColumn(name=EMP_ID),
        inverseJoinColumns=@JoinColumn(name=PHONE_ID))
    private Collection<Phone> phones;
}

```

```

@Entity
public class Phone {
    @Id private int id;
    private String type;
    private String num;
}

```

## Lazy Loading

```
@Entity
public class Employee {
    @Id private int id;
    private String name;

    private ParkingSpace parkingSpace;
}
```

```
@Entity
public class Employee {
    @Id private int id;
    private String name;

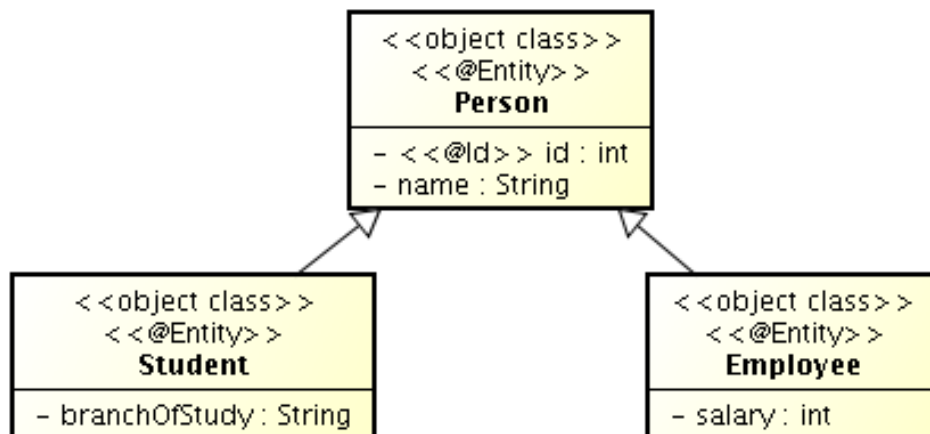
    @OneToOne(fetch=FetchType.LAZY)
    private ParkingSpace parkingSpace;
}
```

parkingSpace instance fetched from the DB at the time of reading the parkingSpace field.

## 6 ORM Inheritance Mapping

### Inheritance

How to map inheritance into DB ?

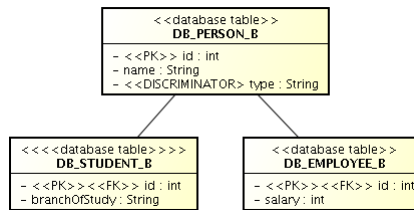


### Strategies for inheritance mapping

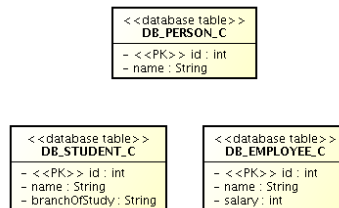
#### single table

```
<<database table>>
DB_PERSON_A
- <<PK>> id : int
- name : String
- branchOfStudy : String
- salary : int
```

## joined



## single table



## Inheritance mapping (single-table)

```
@Entity
@Table(name="DB_PERSON_C")
@Inheritance /* same as @Inheritance(strategy=InheritanceType.SINGLE_TABLE) */
@DiscriminationColumn(name="EMP_TYPE")
public abstract class Person {...}

@Entity
@DiscriminatorValue("Emp")
public class Employee extends Person {...}

@Entity
@DiscriminatorValue("Stud")
public class Student extends Person {...}
```

## Inheritance mapping (joined)

```
@Entity
@Table(name="DB_PERSON_C")
@Inheritance(strategy=InheritanceType.JOINED)
@DiscriminationColumn(name="EMP_TYPE",
    discriminatorType=discriminatorType.INTEGER)
public abstract class Person {...}

@Entity
@Table(name="DB_EMPLOYEE_C")
@DiscriminatorValue("1")
public class Employee extends Person {...}

@Entity
@Table(name="DB_STUDENT_C")
@DiscriminatorValue("2")
public class Student extends Person {...}
```

## Inheritance mapping (table-per-class)

```
@Entity
@Inheritance(strategy=InheritanceType.TABLE_PER_CLASS)
public abstract class Person { }

@Entity
@Table(name=DB_EMPLOYEE_C)
@AttributeOverride(name=name, column=@Column(name=FULLNAME))
public class Employee extends Person {}

@Entity
@Table(name=DB_STUDENT_C)
public class Student extends Person {...}
```