# Database Specification

Databases and Web Applications Laboratory (LBAW)
Bachelor in Informatics Engineering and Computation (L.EIC)

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# Class Outline

- ➔ Requirements Specification (ER) delivery
- ➔ Database Specification (EBD) development
  - ➔ Conceptual Data Modeling
  - ➔ Relational Schema
  - ➔ Schema Validation and Refinement
- ➔ Docker and PostgreSQL

# Requirement Specification (ER) Delivery

# Requirements Specification (ER) Delivery

➔ First component delivery next week — 6th (Sunday!) to 10th Oct.

➔ Deadline is on the day before the lab class, before 12h00 (*midday*). Submission steps:

1. **Fill the group spreadsheet checklist:**
    a. Update the “Group Self-Evaluation” tab;
    b. Fill the ER, A1, A2, and A3 tabs.
2. Verify that the component on the group’s **GitLab wiki is updated with the ER** component.
3. **Export the component wiki page to PDF and submit it on Moodle:**
    a. Only one submission per group is necessary;
    b. Ensure all images were correctly exported;
    c. Only the information included in the PDF will be considered for evaluation.

Questions about the ER component submission?

# Database Specification (EBD) Development

# Database Specification (EBD) Component

- The EBD component groups the artifacts to be made by the development team in order to support the storage and retrieval requirements identified in the requirements specification.

- It consists of three artifacts:
  - A4: Conceptual Data Model
  - A5: Relational Schema, Validation and Schema Refinement
  - A6: Indexes, Triggers, Transactions and Database Population

- Moodle: LBAW Artifacts

# A4. Conceptual Data Model

➔ In this artifact the data requirements of the system are detailed.

➔ The **Conceptual Domain Model** contains the identification and description of the entities of the domain and the relationships between them.

➔ The Conceptual Domain Model is simplified to include only concepts (entities and relationships) of the domain that are stored in the database.

➔ The **Conceptual Data Model** is obtained by using a UML class diagram containing the classes, associations, multiplicity and roles.

➔ For each class, the attributes, associations and constraints are included in the class diagram.

➔ Business rules not included in the class diagram are described by words or using OCL (Object Constraint Language) included as UML notes.

# A4. Data Modeling

➔ To obtain a conceptual model, **iteratively** go through these steps:

- ➔ 1. Identify entity types (a collection of people, places, things, events, or concepts);
- ➔ 2. Identify relationships (entities have relationships with other entities);
- ➔ 3. Identify attributes (each entity type will have one or more data attributes);
- ➔ 4. Apply naming conventions (team standards and guidelines applicable to data modeling).

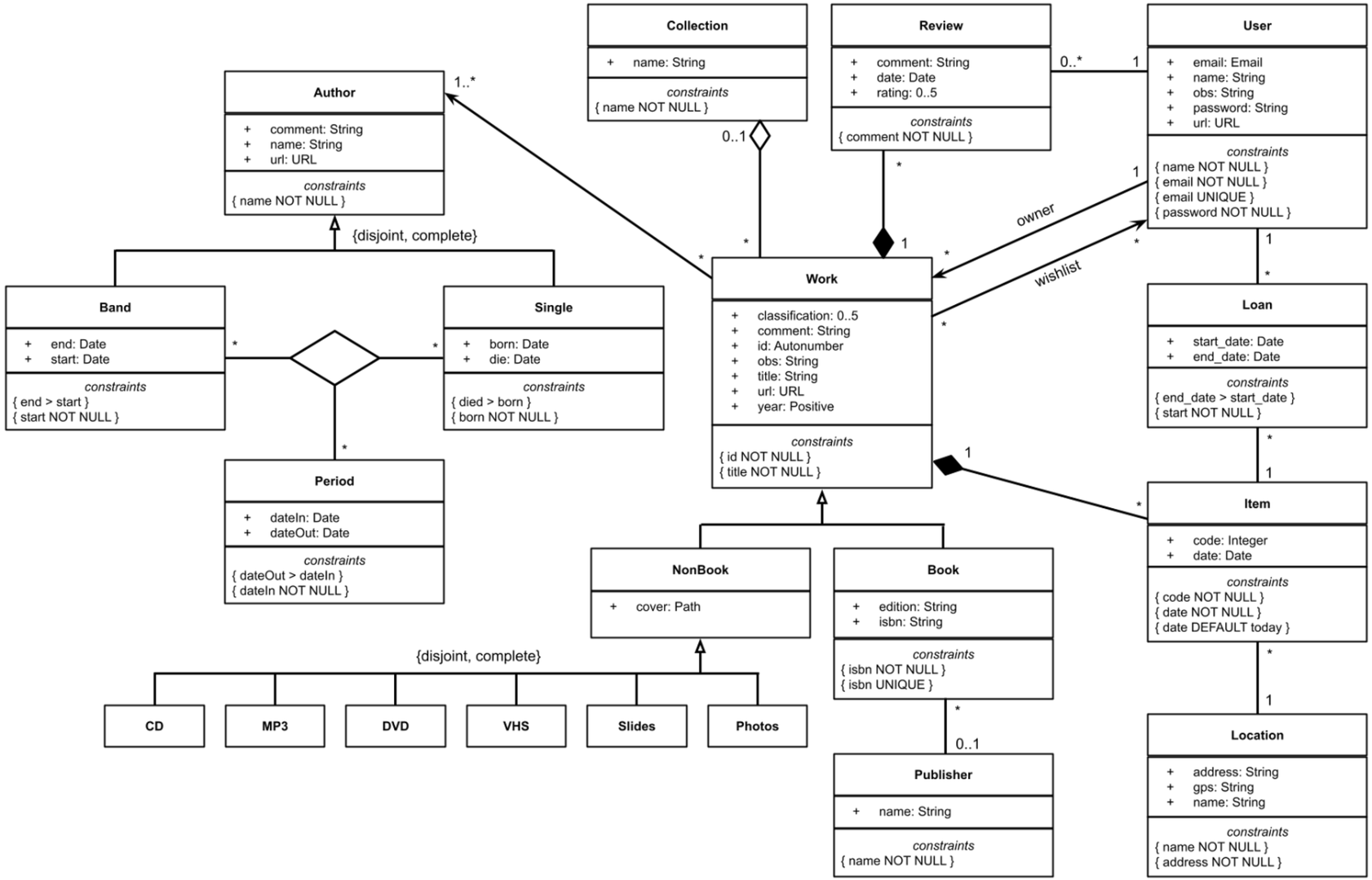
➔ *Scott Ambler. The Object Primer. Cambridge University Press, 3rd Edition, 2004. Section. 8.5*

# A4. Data Modeling

- ➔ Data models are used for a variety of purposes, from conceptual models to physical design models
- ➔ Logical data models are used to **explore domain concepts and their relationships**
- ➔ With data modeling, you **identify data entities and assign data attributes** to them
  - ➔ *whereas with class modeling you identify classes and assign responsibilities to them*
- ➔ Then, you identify the **associations** between entities
  - ➔ relationships, inheritance, and composition
  - ➔ similar to the associations between classes

➔ *Scott Ambler. The Object Primer. Cambridge University Press, 3rd Edition, 2004. Section. 8.5*

# A4. MediaLibrary Class Diagram



# A4. MediaLibrary Business Rules

➔ BR01. A user cannot loan its own items.

➔ BR02. An item can only be lended by its owner.

➔ BR03. An item can only be loaned to one user at a time.

# A4. Checklist

| A4. Conceptual Data Model | | |
|---|---|---|
| **Artefact** | **1.1** | The artefact reference and name are clear |
| | **1.2** | The goal of the artefact is briefly presented (1, 2 sentences) |
| **UML** | **2.1** | UML notation is consistently used |
| | **2.2** | Diagram layout is clear (visual organization) |
| | **2.3** | Classes are correctly represented |
| | **2.4** | Generalizations are correctly represented |
| | **2.5** | Associations are correctly represented |
| | **2.6** | Restrictions and business rules are correctly represented |
| **Classes** | **3.1** | Classes are presented with areas for name and attributes |
| | **3.2** | Classes do not have methods associated |
| | **3.3** | The classes support all high and medium priority user stories defined |
| | **3.4** | Class names are consistent (e.g., always singular, always in English) |
| **Associations, multiplicity, roles** | **4.1** | Automatic primary keys are not presented |
| | **4.2** | Natural keys are not used as primary keys (e.g., NIF) |
| | **4.3** | Multiplicity is defined for all associations |
| | **4.4** | Roles are used to explain how an object participates in the relationship |
| | **4.5** | Mandatory associations (not null) are indicated in the multiplicity |
| | **4.6** | In 1-1 associations, directionality is defined |
| | **4.7** | The associations support all high and medium priority user stories defined |
| | **4.8** | There is an "Authorship" association (e.g., post author, review author) |
| **Attributes, domains and restrictions** | **5.1** | All attributes have a generic type (text, number, date, boolean) |
| | **5.2** | Attribute visibility is omitted (e.g., '+' prefix not included) |
| | **5.3** | Domains are defined for attributes that have predefined fixed values |
| | **5.4** | Not null attributes are indicated in the restrictions |
| | **5.5** | Unique attributes are indicated in the restrictions |
| | **5.6** | Restrictions related to numerical attributes are indicated (e.g., > 0) |
| | **5.7** | Restrictions related to date types are indicated (e.g., > today) |
| | **5.8** | Attributes with default values are indicated |
| | **5.9** | All generalizations have constraints defined |
| | **5.1** | All restrictions and business rules defined are included |

# A4. Discussion

- ➔ Example:
  - ➔ Q&A, modeling likes.
  - ➔ Social network, modeling friends and invitations.
  - ➔ Online store, model keep price history.
  - ➔ Messaging system with possibility of ‘readers deleting messages’.
- ➔ Modeling issues to consider:
  - ➔ Notifications.
  - ➔ Deal with user account deletion while keeping user data.

# A5. Relational Schema, Validation and Schema Refinement

➔ A5 contains the Relational Schema derived from the Conceptual Data Model.

➔ The Relational Schema includes relation schemas, attributes, domains, primary keys, foreign keys, and integrity rules: UNIQUE, DEFAULT, NOT NULL, CHECK.

➔ Relation schemas are presented using a concise notation.

➔ Additionally, the relational schema is provided in SQL format as an annex.

➔ To validate the Relational Schema from the Conceptual Model, we identify all functional dependencies and normalize all relation schemas.

➔ If necessary, the relational schema is refined through normalization to achieve Boyce–Codd Normal Form (BCNF).

# A5. Relational Schema Compact Notation

➔ Relation schemas are specified using the compact notation:

➔ table1(id, attribute NN)
table2(id, attribute → Table1 NN)
table3(id1, id2 → Table2, attribute UK NN)
table4((id1, id2) → Table3, id3, attribute)

➔ Primary keys are underlined. UK means UNIQUE and NN means NOT NULL.

➔ The specification of additional domains can also be made in a compact form, using the notation:

➔ Today DATE DEFAULT CURRENT_DATE
Priority ENUM ('High', 'Medium', 'Low')

➔ **In PostgreSQL use lower case and the *snake_case* convention.**

# A5. Relational Schema Mapping

## Summary of Mapping Rules from Logical UML Models to Relational Schemas

*Translated from:*

**UML – Metodologias e Ferramentas CASE, Vol. 1, 2ª Edição, pp. 314-315**

**Alberto Silva e Carlos Videira, Centro Atlântico (2005)**

| | |
|---|---|
| **Rule 1** | Classes are mapped into relation schemas |
| **Rule 2** | Class attributes are mapped to attributes of relations. |
| **Rule 3** | Operations of classes are generally not mapped. They can nevertheless be mapped to *stored procedures,* stored and executed in the global context of the database involved. |
| **Rule 4** | Objects are mapped into tuples of one or more relations. |
| **Rule 5** | Each object is uniquely identified.<br>If the identification of an object is defined **explicitly** by the OID *(object identifier*) stereotype, associated with one or more attributes, this attribute is mapped to primary key in the relation schema.<br>Otherwise, we assume **implicitly** that the corresponding primary key is derived from a new attribute with the name of the relation and common suffix (e.g. "PK", "ID"). |
| **Rule 6:** | The mapping of many-to-many associations involves the creation of a new relation schema, with attributes acting together as primary key, and individually as foreign key for each of the schemas derived from the classes involved. |
| **Rule 7:** | The mapping of one-to-many associations involves the introduction, in the relation schema corresponding to the class that has the constraint "many", of a foreign key attribute for the other schema. |

*Alberto Manuel Rodrigues da Silva e Carlos Alberto Escaleira Videira, UML, metodologias e ferramentas CASE, 2ª Edição, Volume 1, Centro Atlântico Editora, Maio 2005.*

# A5. Relational Schema Mapping

| | |
|---|---|
| **Rule 8:** | The mapping of one-to-one associations has in general two solutions. The first corresponds to the fusion of the attributes of the classes involved in one common schema. The second solution is to map each of the classes in the corresponding schema and choose one of the schemas as the most suitable for the introduction of a foreign key attribute for the other schema. This attribute should also be defined as unique within that schema. |
| **Rule 9:** | Association navigability in general has no impact on the mapping process. The exception lies in one-to-one associations, when they are complemented with navigation cues it helps in the selection of the schema that should include the foreign key attribute. |
| **Rule 10:** | Aggregation and composition associations have a minimal impact on the mapping process, which may correspond to the definition of constraints cascade ("CASCADE") in changing operations and/or removal of tuples. |
| **Rule 11:** | The mapping of generalization associations in general presents three solutions.<br>The first solution consists in crushing the hierarchy of classes in a single schema corresponding to the original superclass. This solution is appropriate when there is a significant distinction in the structure of sub-classes and/or when the semantics of their identification is not strong.<br>The second solution is to consider only schemas corresponding to the sub-classes and duplicate the attributes of the super-class in these schemas; in particular it works if the super-class is defined as abstract.<br>The third solution is to consider all the schemas corresponding to all classes of the hierarchy, resulting in a mesh of connected schemas and maintained at the expense of referential integrity rules. This solution has the advantage of avoiding duplication of information among different schemas, but suggests a dispersion of information by various schemas, and might involve a performance penalty in query operations or updating of data by requiring the execution of various join operations (i.e. "JOIN") and/or validation of referential integrity. |

*Alberto Manuel Rodrigues da Silva e Carlos Alberto Escaleira Videira, UML, metodologias e ferramentas CASE, 2ª Edição, Volume 1, Centro Atlântico Editora, Maio 2005.*

# A5. MediaLibrary Relational Schema

| | |
|---|---|
| R01 | user(id, email **UK NN**, name **NN**, obs, password **NN**, img, is_admin **NN**) |
| R02 | author(id, name **NN**, img) |
| R03 | collection(id, name **NN**) |
| R04 | work(id, title **NN**, obs, img, year **NN CK** year > 0, id_user -> user **NN**, id_collection -> collection) |
| R05 | author_work(id_author -> author, id_work -> work) |
| R06 | nonbook(id_work -> work, type **NN CK** type **IN** Types) |
| R07 | publisher(id, name **NN**) |
| R08 | book(id_work -> work, edition, isbn **UK NN**, id_publisher -> publisher) |
| R09 | location(id, name **NN**, address **NN**, gps) |
| R10 | item(id, id_work -> work **NN**, id_location -> location **NN**, code **NN**, date **NN DF** Today) |
| R11 | loan(id, id_item -> item **NN**, id_user -> user **NN**, start_date **NN**, end_date **NN CK** end > start) |
| R12 | review(id_user -> user, id_work -> work, date **NN DF** Today, comment **NN**, rating **NN CK** rating > 0 AND rating < = 5) |
| R13 | wish_list(id_user -> user, id_work -> work) |

# A5. Schema Validation and Refinement

➔ To validate the Relational Schema obtained from the Conceptual Model,

  ➔ **all functional dependencies** are identified and

  ➔ relations schemas are normalized if necessary.

➔ Should it be necessary, in case the scheme is not in the Boyce–Codd Normal Form (BCNF), the relational schema is refined using **normalization**.

# A5. Problems of Redundancy

- **Redundancy** is at the root of several problems associated with relational schemas:
  - redundant storage;
  - insert / delete / update anomalies.
- Integrity constraints, in particular **functional dependencies**, can be used to identify schemas with such problems and to suggest refinements.
- Main refinement technique: decomposition (replacing ABCD with, say, AB and BCD, or ACD and ABD).

*R. Ramakrishnan, J. Gehrke. Schema Refinement and Normal Forms. In Database Management Systems. McGRAW-Hill International Editions, 3rd Edition, 2003, Chapter 19.*

# A5. Normal Forms

- If a relation is in a certain normal form (BCNF, 3NF, etc), it is known that certain kinds of problems are avoided / minimized.
- Boyce-Codd normal form (BCNF) is a slightly stronger version of the third normal form (3NF). It deals with certain types of anomalies not addressed by the 3NF.
- A relation R is in BCNF if and only if, for every functional dependency, at least one of the following conditions holds:
  - $X \rightarrow Y$ is a trivial functional dependency ($Y \subseteq X$),
  - X is a superkey for schema R.

*R. Ramakrishnan, J. Gehrke. Schema Refinement and Normal Forms. In Database Management Systems. McGRAW-Hill International Editions, 3rd Edition, 2003, Chapter 19.*

# A5. MediaLibrary Validation and Schema Refinement

| **Table R01** (user) | |
|---|---|
| **Keys**: {id}, {email} | |
| **Functional Dependencies** | |
| FD0101 | {id} → {email, name, obs password, img, is_admin} |
| FD0102 | {email} → {id, name, obs, password, img, is_admin} |
| **Normal Form** | BCNF |

| **Table R02** (author) | |
|---|---|
| **Keys**: {id} | |
| **Functional Dependencies** | |
| FD0201 | {id} → {name, img} |
| **Normal Form** | BCNF |

| **Table R05** (author_work) | |
|---|---|
| **Keys**: {id_author, id_work} | |
| **Functional Dependencies** | *none* |
| **Normal Form** | BCNF |

# A5. MediaLibrary SQL Code

➔ The A5 artifact only includes types and tables creation statements in SQL.

➔ The SQL creation script is expanded in the A6 to include indexes, triggers, and transactions.

➔ Test the SQL creation script in the production server

➔ Include it as a file in the repository, with a reference in the wiki.

# A5. Checklist

| A5. Relational Schema | | |
|---|---|---|
| **Artefact** | **1.1** | The artefact reference and name are clear |
| | **1.2** | The goal of the artefact is briefly presented (1, 2 sentences) |
| **Schema** | **2.1** | The compact notation is correctly used |
| | **2.2** | Each relation has a unique reference |
| | **2.3** | Relation names are lowercase and in snake_case when needed |
| | **2.4** | All UML classes are mapped |
| | **2.5** | All class attributes are mapped |
| | **2.6** | All associations are mapped |
| | **2.7** | All relations have a PK |
| | **2.8** | No natural keys are used as PK |
| | **2.9** | All FK attributes reference a relation |
| | **2.10** | In 1-1 associations, a FK is used considering the directionality |
| | **2.11** | In 1-N associations, a FK is used |
| | **2.12** | In N-N associations, a relation is defined with a composite PK of two FKs |
| | **2.13** | Generalisations are correctly mapped and the choices well justified |
| | **2.14** | Domains are defined and used if necessary |
| **Integrity rules** | **3.1** | All NN attribute restrictions are included |
| | **3.2** | All UK attribute restrictions are included |
| | **3.3** | All date attributes have adequate restrictions |
| | **3.4** | All numeric attributes have adequate restrictions |
| **Schema validation** | **4.1** | Schema validation section is included |
| | **4.2** | For each relation, all candidate keys are listed |
| | **4.3** | For each relation, all FD are listed |
| | **4.4** | Each relation's normal form is identified |
| | **4.5** | The schema's normal form is identified and a justification is provided |
| **SQL Code** | **5.1** | The SQL script is included |
| | **5.2** | The SQL script contains the creation statements |
| | **5.3** | The SQL script cleans up the current database state |
| | **5.4** | The SQL script is cleaned (e.g. excluded from export comments) |
| | **5.5** | Code highlighting is used for readability |
| | **5.6** | All domains are included in the SQL script |
| | **5.7** | All relations are included in the SQL script |
| | **5.8** | PK are defined as SERIAL |
| | **5.9** | FK are not defined as SERIAL |
| | **5.10** | The SQL script works without errors |
| | **5.11** | SQL script is included in the group's repository |
| | **5.12** | The production database (at db.fe.up.pt) has been set up with the SQL script |

# A5. Discussion

- ➔ Mapping generalizations:
  - ➔ Examples:
    - ➔ Media and media types (books, movies, etc);
    - ➔ Students and mobility students;
    - ➔ Post, and different post types (question, answer, comment).
  - ➔ Map the three approaches;
  - ➔ Consider reading, writing, and updating scenarios.

# A6. Indexes, Triggers, Transactions and Database Population

- ➔ This artifact contains the physical schema of the database,
  - ➔ the identification and characterization of the **indexes**,
  - ➔ the support of data integrity rules with **triggers**,
  - ➔ the definition of the database **user-defined functions**,
  - ➔ and the identification and characterization of the database **transactions**.
- ➔ This artifact also includes the complete database creation script, including all SQL code necessary to define all integrity constraints, indexes, triggers and transactions.
- ➔ Also, the database creation script and the database population script should be included as separate elements.

# PostgreSQL

# PostgreSQL

- PostgreSQL is the database management system used in LBAW.
- PostgreSQL is a free and open-source RBDMS that follows a client-server paradigm.
- A PostgreSQL production environment is available, which must be used in the application's production version, at db.fe.up.pt
  - Each group has a user account lbawYYG, and a database lbawYYG.
- This service is managed by UPdigital and is only available using the VPN to FEUP.

# Setup PostgreSQL Connection

➔ To configure a connection to the database, use the following settings:

- ➔ Host: db.fe.up.pt
  Port: 5432
  Database: lbawYYG
  Username: lbawYYG
  Password: <group password, given in class>

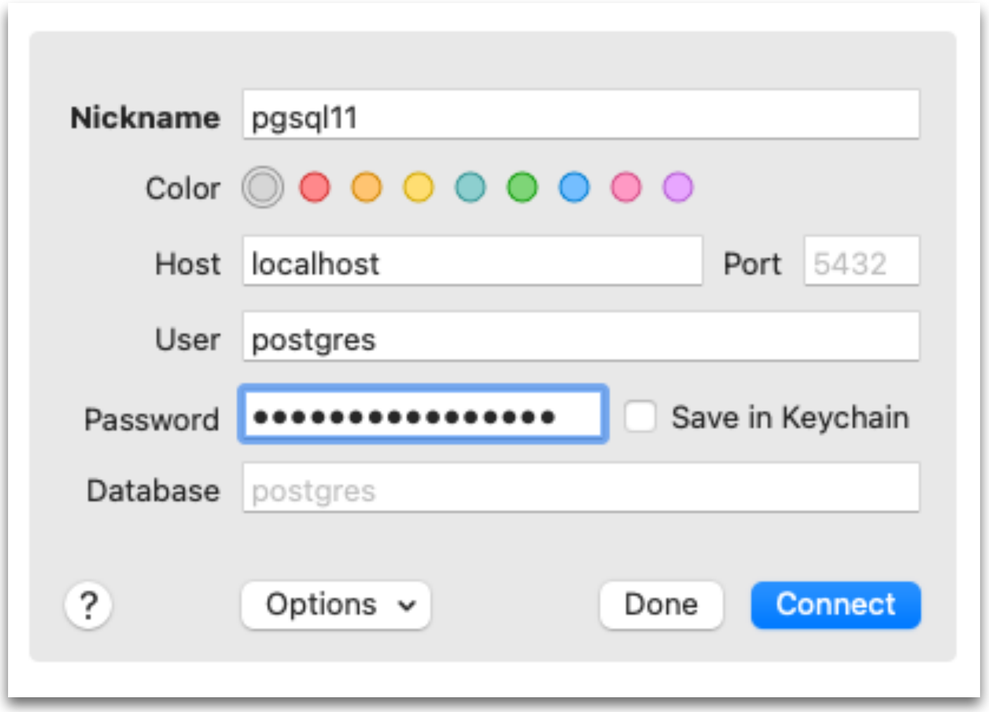
➔ For development, groups can use a local PostgreSQL instance through Docker containers.

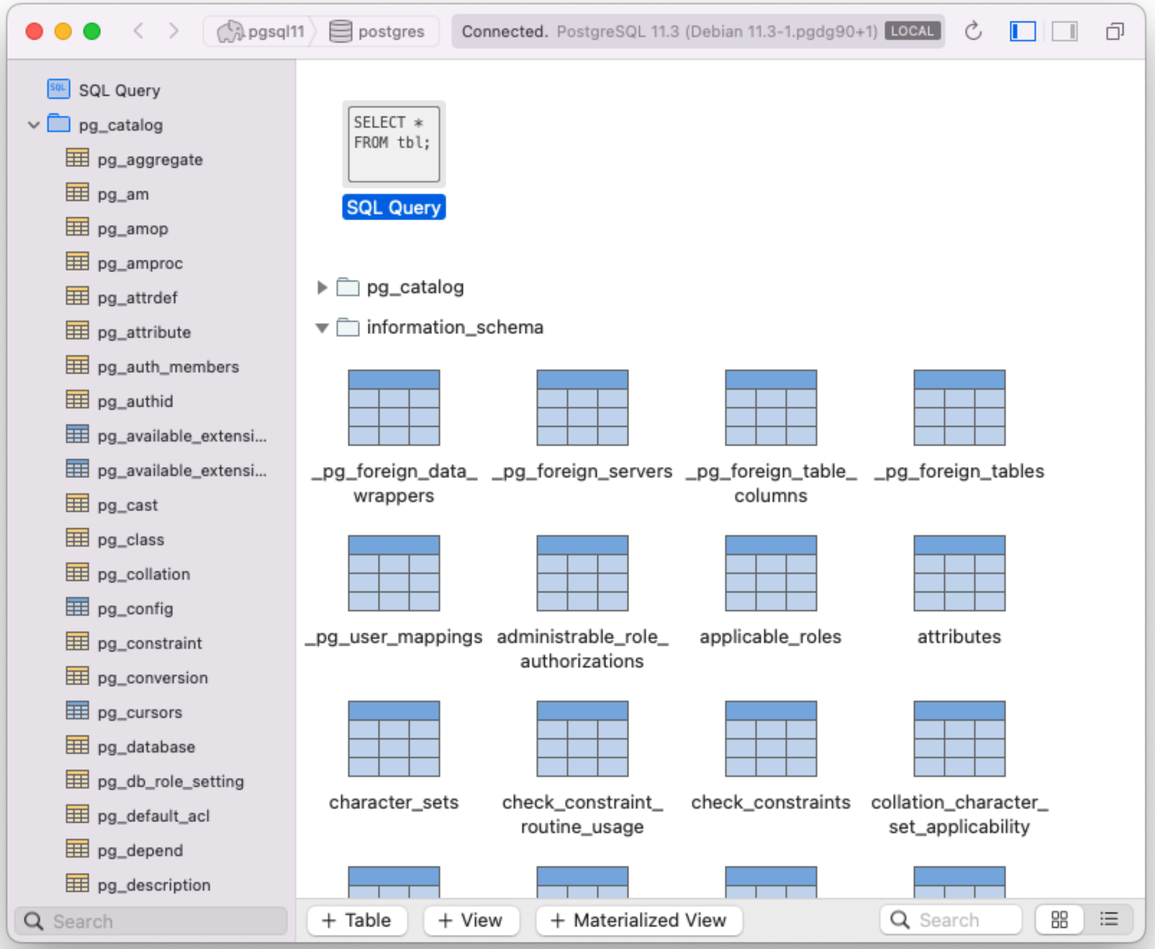
➔ Instructions can be found at: https://gitlab.up.pt/lbaw/template-postgresql

# PostgreSQL Clients

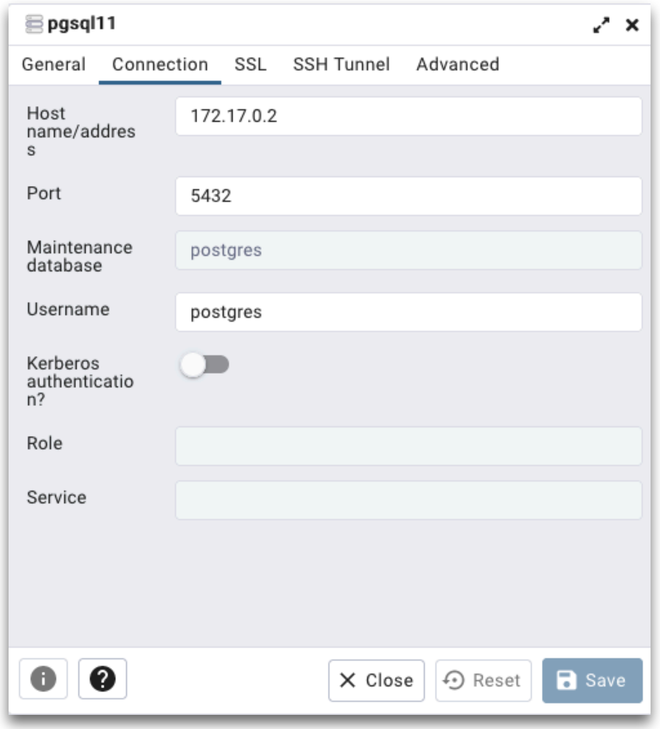
- PostgreSQL clients exist for all major operating system environments.
  - https://wiki.postgresql.org/wiki/PostgreSQL_Clients
- pgAdmin, used in LBAW, is one of the most popular clients - www.pgadmin.org
  - Binary packages exist, but simply use Docker to quickly setup a local instance.
- A command line interface client (CLI) is available with the psql command.
  - Connect with: **`psql -h db.fe.up.pt -d lbawYYG -U lbawYYG`**
  - You need to have PostgreSQL client tools installed.

# Native App (OSX Postico)



# pgAdmin4


pgsql11
General
Connection
SSL
SSH Tunnel
Advanced
Host name/address
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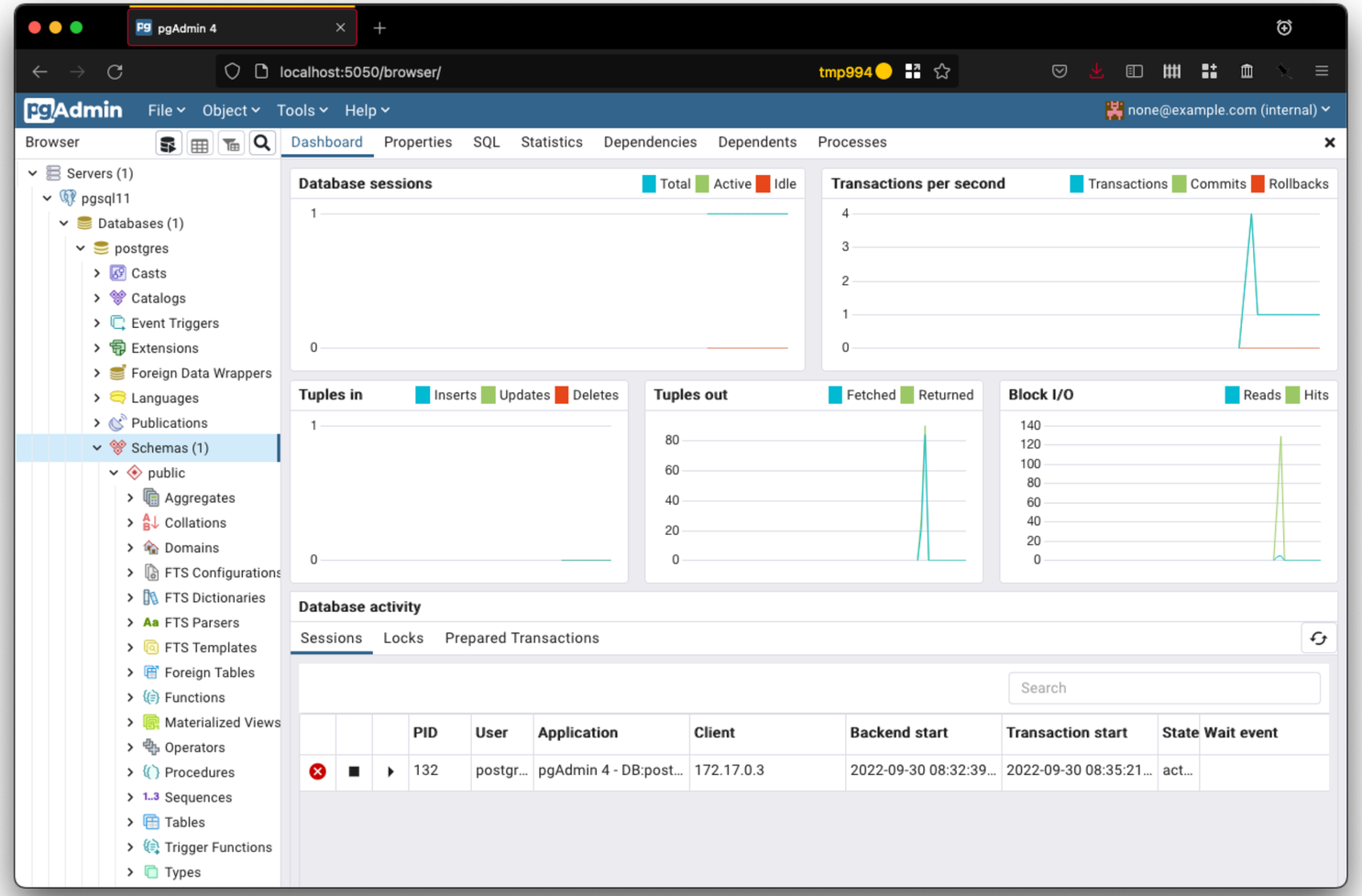
Port
5432
Maintenance database
postgres
Username
postgres
Kerberos authentication?
Role
Service
Close
Reset
Save


pgAdmin 4
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tmp994
pgAdmin
File
Object
Tools
Help
none@example.com (internal)
Browser
Dashboard
Properties
SQL
Statistics
Dependencies
Dependents
Processes
Servers (1)
pgsql11
Databases (1)
postgres
Casts
Catalogs
Event Triggers
Extensions
Foreign Data Wrappers
Languages
Publications
Schemas (1)
public
Aggregates
Collations
Domains
FTS Configurations
FTS Dictionaries
FTS Parsers
FTS Templates
Foreign Tables
Functions
Materialized Views
Operators
Procedures
Sequences
Tables
Trigger Functions
Types
Database sessions
Total
Active
Idle
Transactions per second
Transactions
Commits
Rollbacks
Tuples in
Inserts
Updates
Deletes
Tuples out
Fetched
Returned
Block I/O
Reads
Hits
Database activity
Sessions
Locks
Prepared Transactions
Search
PID
User
Application
Client
Backend start
Transaction start
State
Wait event
132
postgr...
pgAdmin 4 - DB:post...
172.17.0.3
2022-09-30 08:32:39...
2022-09-30 08:35:21...
act...

# About the PostgreSQL Production Environment (**important!**)

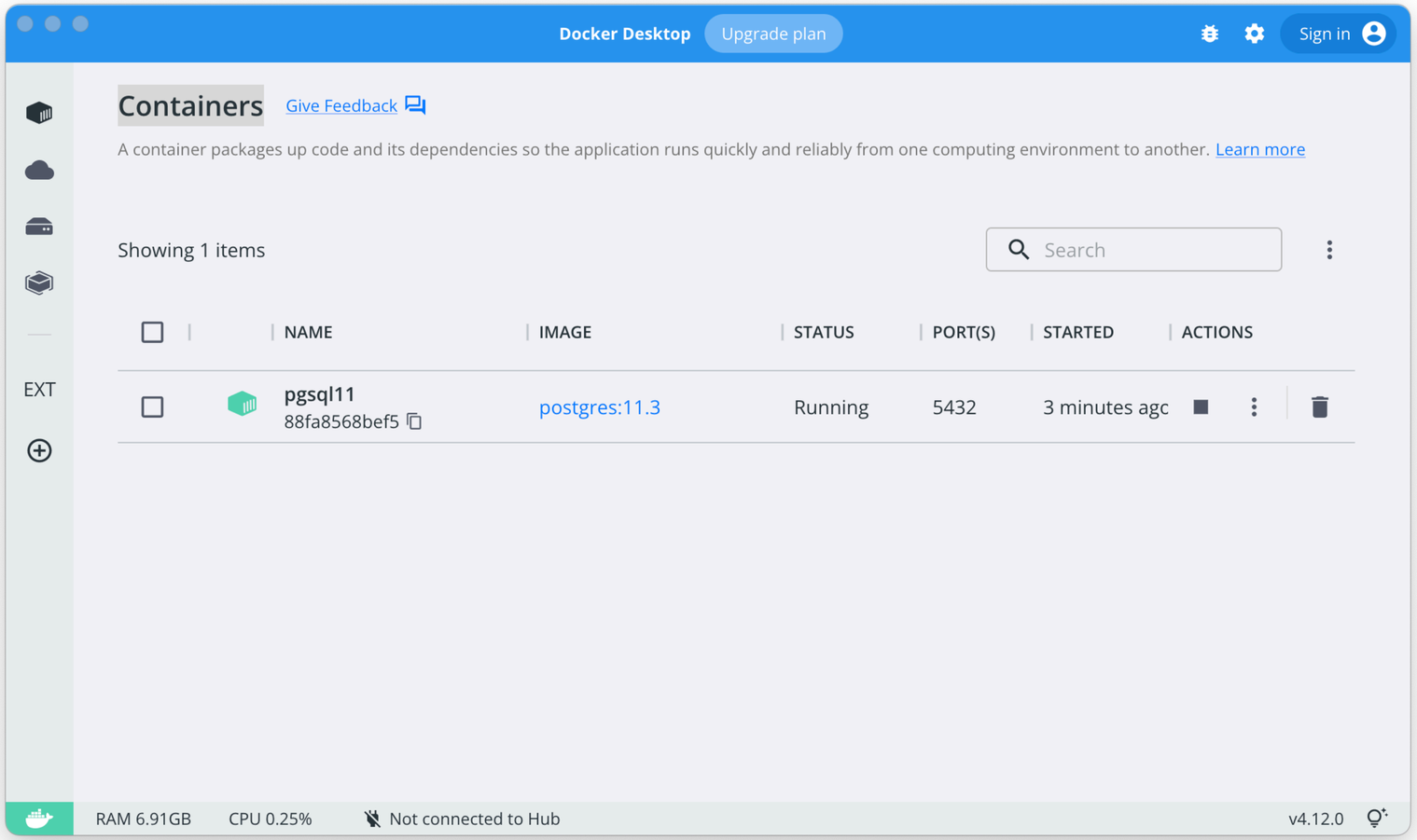
- ➔ A PostgreSQL database contains one or more schemas, which in turn contains one or more tables.
- ➔ All databases contain a public schema, which is used as default.
- ➔ In PostgreSQL's command line interface, you can view the current active schema with: `show search_path;`
- ➔ To change the schema for the current session use: `SET search_path TO <schema>;`
- ➔ **In the PostgreSQL setup at FEUP (db.fe.up.pt), the public schema is shared between all accounts**,
  - ➔ Tables created in the public schema are visible to all users (although not accessible).
    *If you look at the tables in the publish schema, you will find a long list of tables.*
  - ➔ **It is important to not use the public schema and instead create a schema with the name of your group (lbawYYG)**.
- ➔ To create this schema, use the following command: `CREATE SCHEMA <lbawYYG>;`
- ➔ To always use this schema as the default in your project, add the following line to the beginning of your SQL scripts.
  - ➔ `SET search_path TO <lbawYYG>;`

# PostgreSQL Local Development with Docker

# Docker

- ➔ Docker is a lightweight virtualization platform for infrastructure management.
  - ➔ *Manage the infrastructure like software / Program the infrastructure.*
  - ➔ Applications are run in containers, e.g. PostgreSQL, Apache, etc.
  - ➔ Docker Hub ( hub.docker.com ) is a public registry that stores Docker images.
    - ➔ Contains official images, like PostgreSQL, nginx, Apache, etc.
    - ➔ And also user images.
  - ➔ Docker images are used to build Docker containers (an instance of an image).
  - ➔ Gitlab Container Registry is used to store project images.
- ➔ Install Docker: https://docs.docker.com/get-docker/

# Docker Desktop Dashboard



# template-postgresql

➔ Go through the template-postgresql instructions.

  ➔ https://gitlab.up.pt/lbaw/template-postgresql

➔ Clone this repository and set up the infrastructure with [ **docker compose up** ]:

  ➔ **postgres** container with PostgreSQL, version 16

  ➔ **pgadmin** container with pgAdmin, version 8

# References

# Bibliography and Further Reading


➔ Scott Ambler, The Object Primer, Cambridge University Press, 3rd Edition, 2004.

➔ Alberto Rodrigues da Silva, Carlos Videira, UML — Metodologias e Ferramentas CASE, 2ª Edição, Centro Atlântico Editora, Maio 2005.

➔ Raghu Ramakrishnan, Johannes Gehrke. Database Management Systems. McGRAW-Hill International Editions, 3rd Edition, 2003.