TU Graz

SCIENCE
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TECHNOLOGY

Data Management
05 Query Languages (SQL)

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ISDS

Announcements/Org

- **#1 Video Recording**
  - Link in TeachCenter & TUbe (lectures will be public)
  - Due to second lockdown: webex recording
- **#2 Reminder Communication**
  - **Newsgroup:** news://news.tugraz.at/tu-graz.lv.dbase (https://news.tugraz.at/cgi-bin/usenet/nntp.csh?tu-graz.lv.dbase)
  - **Office hours:** Mo 12.30-1.30pm (https://tugraz.webex.com/meet/m.boehm)
- **#3 Exercise Submissions**
  - **Exercise 1:** Nov 03 11.59 + 7 days ends tomorrow midnight
  - **Exercise 2:** published Nov 02, deadline Dec 01

Agenda

- **Structured Query Language (SQL)**
- **Other Query Languages (XML, JSON)**
- **Exercise 2: Query Languages and APIs**

Structured Query Language (SQL)

What is a(n) SQL Query?

```sql
SELECT Firstname, Lastname, Affiliation, Location
FROM Participant AS R, Locale AS S
WHERE R.LID = S.LID
  AND Location LIKE '%, GER'
```

#1 Declarative:
what not how

Firstname	Lastname	Affiliation	Location
Volker	Markl	TU Berlin	Berlin, GER
Thomas	Neumann	TU Munich	Munich, GER

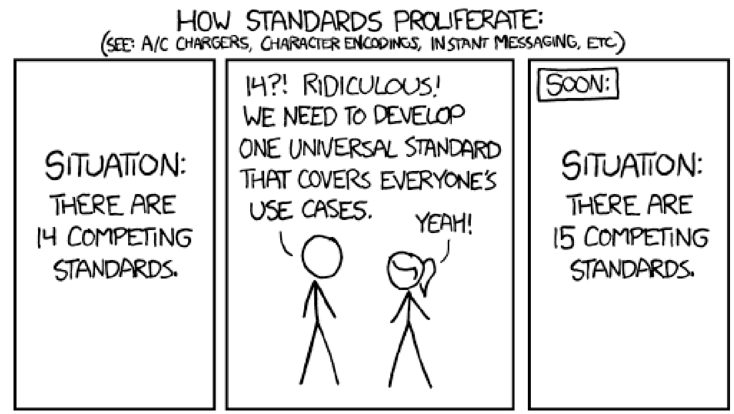
#2 Flexibility:
closed → composability

#3 Automatic Optimization

#4 Physical Data Independence

Why should I care?

- **SQL as a Standard**
  - Standards ensure **interoperability**, avoid **vendor lock-in**, and protect **application investments**
  - **Mature standard** with heavy industry support for decades
  - **Rich eco system** (existing apps, BI tools, services, frameworks, drivers, design tools, systems)



[https://xkcd.com/927/]

- **SQL is here to stay**
  - Foundation of mobile/server **application data management**
  - **Adoption of existing standard** by new systems (e.g., SQL on Hadoop, cloud DBaaS)
  - Complemented by NoSQL abstractions, see lecture **10 NoSQL (key-value, document, graph)**

SQLite

Google BigQuery

amazon REDSHIFT

Microsoft

SQL VS SQL

Overview SQL

- **Structured Query Language (SQL)**
  - Current Standard: ISO/IEC 9075:2016 (SQL:2016)
  - **Data Definition Language (DDL)** → Manipulate the database schema
  - **Data Manipulation Language (DML)** → Update and query database
  - **Data Control Language (DCL)** → Modify permissions

- **Dialects**
  - Spectrum of system-specific dialects for **non-core features**
  - Data types and size constraints
  - Catalog, builtin functions, and tools
  - Support for new/optional features
  - Case-sensitive identifiers

Name	Examples
T-SQL	Microsoft, Sybase
PL/SQL	Oracle, (IBM)
PL/pgSQL	PostgreSQL, derived
Unnamed	**Most systems**

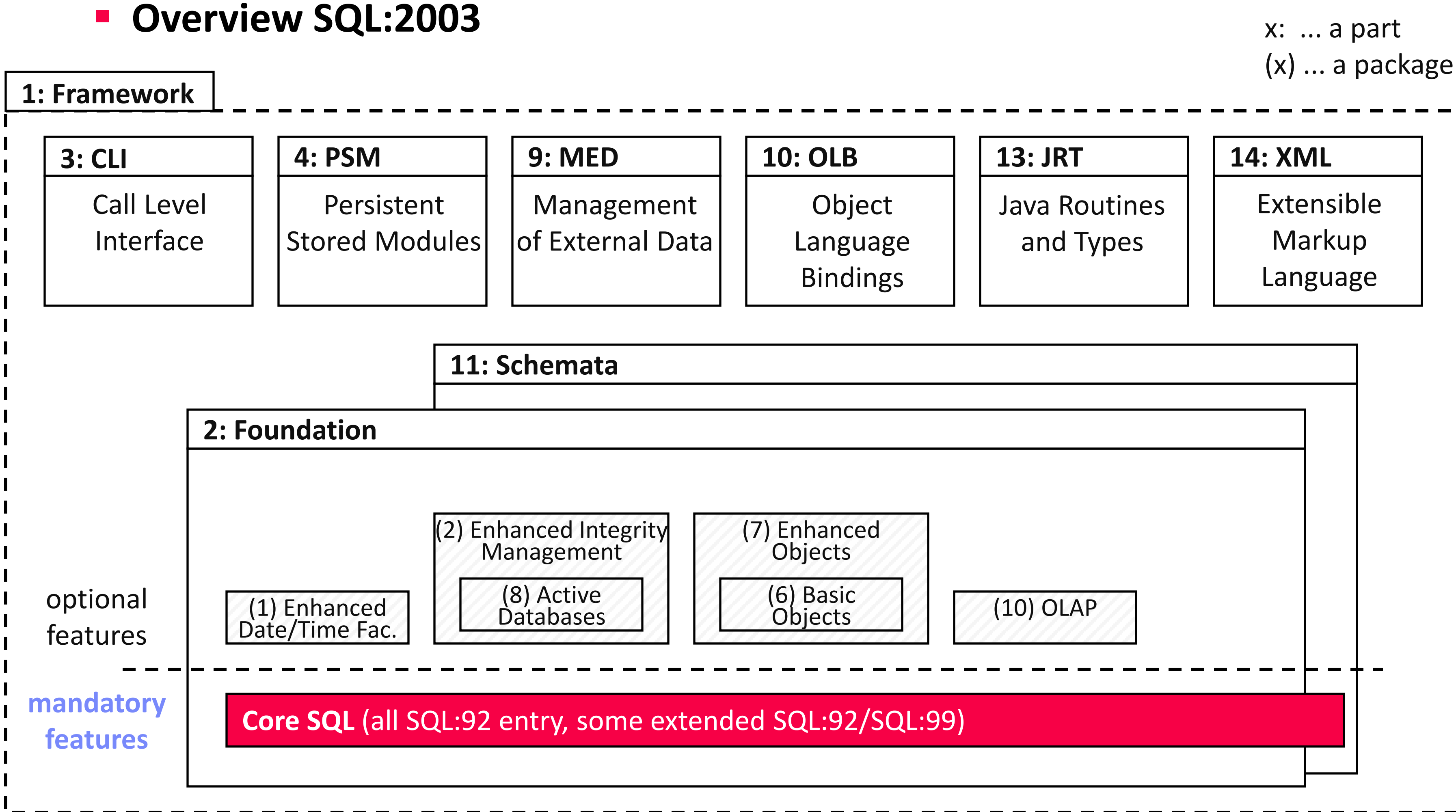
The History of the SQL Standard

[C. J. Date: A Critique of the SQL Database Language. **SIGMOD Record 1984**]

- **SQL:1986**
  - **Database Language SQL**, ANSI X3.135-1986, ISO-9075-1987(E)
  - ‘87 international edition
- **SQL:1989** (120 pages)
  - **Database Language SQL with Integrity Enhancements**, ANSI X3.135-1989, ISO-9075-1989(E)
- **SQL:1992** (580 pages)
  - **Database Language SQL**, ANSI X3-1992, ISO/IEC-9075 1992, DIN 66315
  - ‘95 SQL/CLI (part 3), ‘96 SQL/PSM (part 4)
- **SQL:1999** (2000 pages)
  - **Information Technology – Database Language – SQL**, ANSI/ISO/IEC-9075 1999
  - Complete reorg, ’00 OLAP, ’01 SQL/MED, ’01 SQL/OLB, ‘02 SQL/JRT
- **SQL:2003** (3764 pages)
  - **Information Technology – Database Language – SQL**, ANSI/ISO/IEC-9075 2003

The History of the SQL Standard, cont.

- **Overview SQL:2003**



The History of the SQL Standard, cont.

Since SQL:2003 overall structure remained unchanged ...

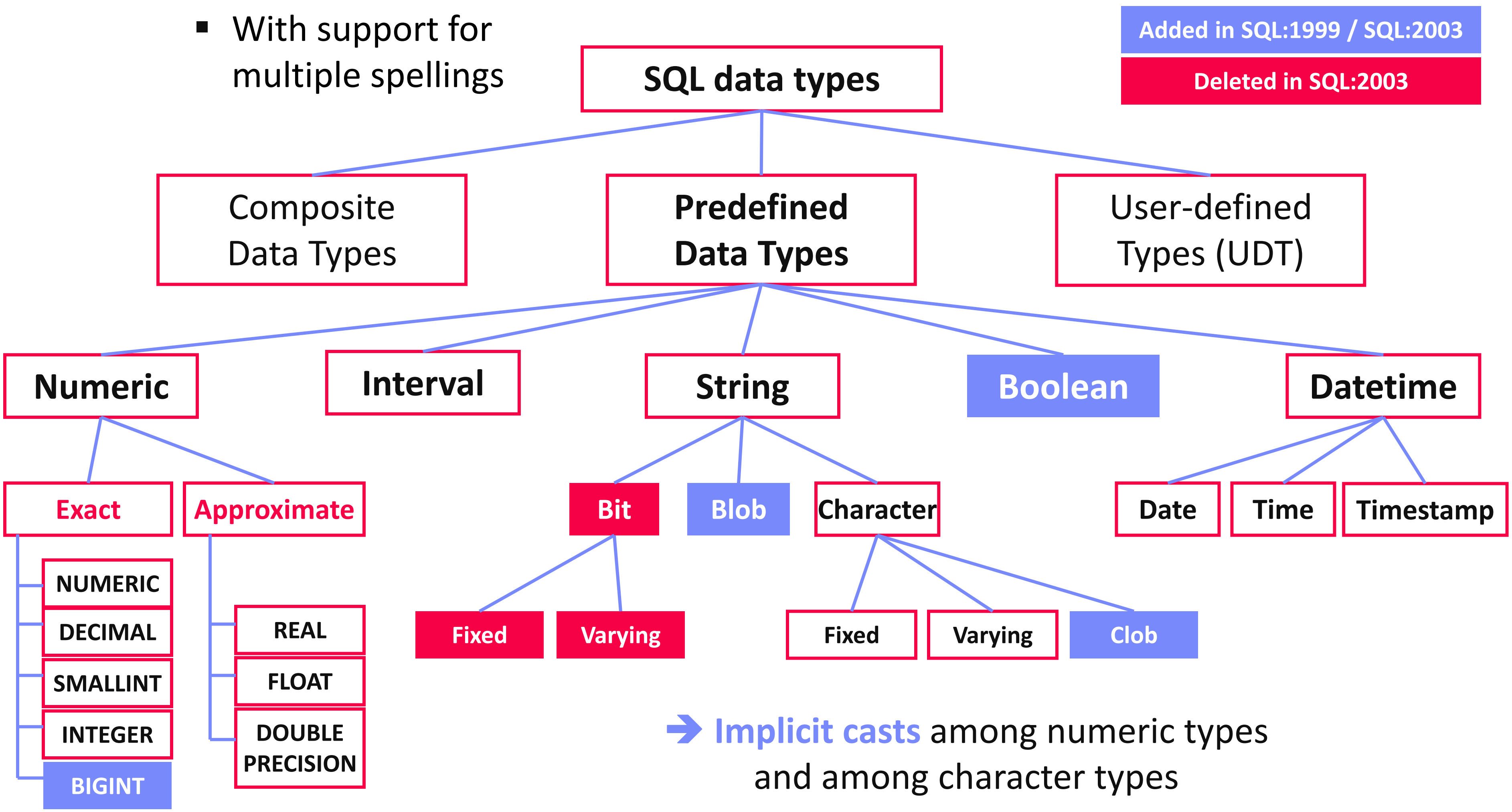
- **SQL:2008** (???? pages)
  - **Information Technology – Database Language – SQL**, ANSI/ISO/IEC-9075 2003
  - E.g., **XML** XQuery extensions, case/trigger extension
- **SQL:2011** (4079 pages)
  - **Information Technology – Database Language – SQL**, ANSI/ISO/IEC-9075 2011
  - E.g., time periods, temporal constraints, time travel queries
- **SQL:2016** (???? pages)
  - **Information Technology – Database Language – SQL**, ANSI/ISO/IEC-9075 2016
  - E.g., **JSON** documents and functions (optional)

➔ **Note: We can only discuss common primitives**

[Working Draft SQL:2011: https://www.wiscorp.com/SQLStandards.html]

Data Types in SQL:2003

- **Large Variety of Types**
  - With support for multiple spellings



➔ **Implicit casts** among numeric types and among character types

Data Types in PostgreSQL

Appropriate, Brief, Complete

- **Strings**
  - **CHAR(n)** → fixed-length character sequence (padded to n)
  - **VARCHAR(n)** → variable-length character sequence (n max)
  - TEXT → variable-length character sequence
- **Numeric**
  - SMALLINT → 2 byte integer (signed short)
  - **INT/INTEGER** → 4 byte integer (signed int)
  - SERIAL → INTEGER w/ auto increment
  - **NUMERIC(p, s)** → exact real with p digits and s after decimal point
- **Time**
  - **DATE** → date
  - TIMESTAMP/TIMESTAMPTZ → date and time, timezone-aware if needed
- **JSON**
  - JSON → text JSON representation (requires reparsing)
  - JSONB → binary JSON representation

Create, Alter, and Delete Tables

Templates in SQL
Examples in PostgreSQL

- **Create Table**
  - Typed attributes
  - Primary and foreign keys
  - NOT NULL, UNIQUE constraints
  - DEFAULT values
  - CHECK constraints

```
CREATE TABLE Students (
   SID INTEGER PRIMARY KEY,
   Fname VARCHAR(128) NOT NULL,
   Lname VARCHAR(128) NOT NULL,
   Mtime DATE DEFAULT CURRENT_DATE
);
CREATE TABLE Students AS SELECT …;
```

- **Alter Table**
  - ADD/DROP columns
  - ALTER data type, defaults, constraints, etc

```
ALTER TABLE Students ADD DoB DATE;
ALTER TABLE Students ADD CONSTRAINT
   PKStudent PRIMARY KEY(SID);
```

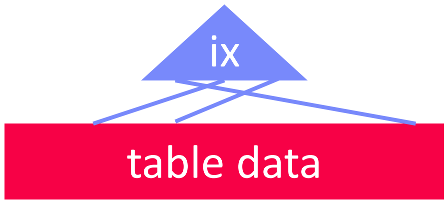
- **Delete Table**
  - Delete table
  - **Note:** order of tables matters due to referential integrity

```
DROP TABLE Students; -- sorry
DROP TABLE Students CASCADE;
DROP TABLE IF EXISTS Countries,
   Cities, Airports, Airlines,
   Routes, Planes, Routes_Planes;
```

Create and Delete Indexes

- **Create Index**
  - Create a secondary (nonclustered) index on a set of attributes
  - **Clustered:** tuples sorted by index
  - **Non-clustered:** sorted attribute with tuple references
  - Can specify uniqueness, order, and indexing method
  - **PostgreSQL methods:** btree, hash, gist, and gin
    - ➔ see lecture **07 Physical Design and Tuning**

```
CREATE INDEX ixStudLname
   ON Students USING btree
   (Lname ASC NULLS FIRST);
```



- **Delete Index**
  - Drop indexes by name

```
DROP INDEX ixStudLname;
```

- **Tradeoffs**
  - Indexes often automatically created for **primary keys** / **unique** attributes
  - **Lookup/scan performance** vs **insert performance**

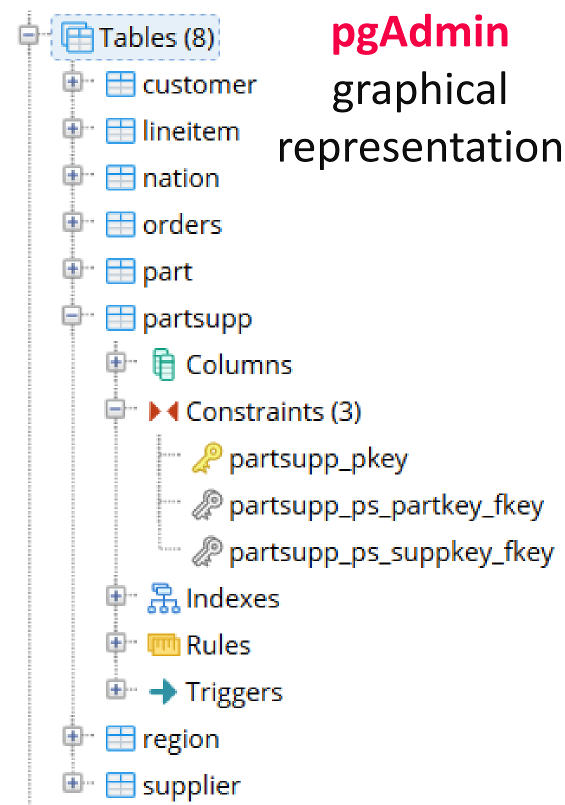
Database Catalog

[Meikel Poess: TPC-H. **Encyclopedia of Big Data Technologies 2019**]

- **Catalog Overview**
  - **Meta data** of all database objects (tables, constraints, indexes) → **mostly read-only**
  - **Accessible through SQL**
  - Organized by schemas (`CREATE SCHEMA tpch;`)
- **SQL `Information_Schema`**
  - Schema with tables for all tables, views, constraints, etc
  - **Example:** check for existence of accessible table

```
SELECT 1 FROM information_schema.tables
WHERE table_schema = 'tpch'
   AND table_name = 'customer'
```

(defined as views over PostgreSQL catalog tables)



pgAdmin graphical representation

Insert

- **Insert Tuple**
  - Insert a single tuple with implicit or explicit attribute assignment

```
INSERT INTO Students (SID, Lname, Fname, MTime, DoB)
   VALUES (7,'Boehm','Matthias','2002-10-01','1982-06-25');
```

  - Insert attribute key-value pairs to use auto increment, defaults, NULLs, etc

```
INSERT INTO Students (Lname, Fname, DoB)
   VALUES ('Boehm','Matthias','1982-06-25'),
          (...), (...);
```

SERIAL SID,
DEFAULT MTime

- **Insert Table**
  - Redirect query result into INSERT (append semantics)

```
INSERT INTO Students
   SELECT * FROM NewStudents;
```

Analogy Linux redirect (append):

```
cat NewStudents.txt >> Students.txt
```

Update and Delete

- **Update Tuple/Table**
  - Set-oriented update of attributes
  - Update single tuple via predicate on **primary key**

```
UPDATE Students
   SET MTime = '2002-10-02'
   WHERE LName = 'Boehm';
```

- **Delete Tuple/Table**
  - Set-oriented delete of tuples
  - Delete single tuple via predicate on **primary key**

```
DELETE FROM Students
   WHERE extract(year
      FROM mtime) < 2010;
```

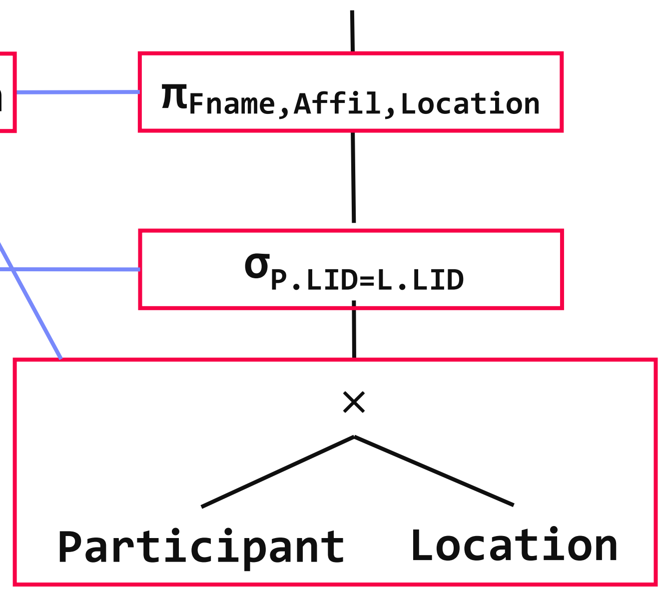
- **Note: Time travel and multi-version concurrency control**
  - Deleted tuples might be just **marked as inactive**
  - See lecture 09 Transaction Processing and Concurrency

Basic Queries

- **Basic Query Template**
  - Select-From-Where
  - Grouping and Aggregation
  - Having and ordering
  - Duplicate elimination

```
SELECT [DISTINCT] <column_list>
   FROM [<table_list> |
     <table1> [RIGHT | LEFT | FULL] JOIN
     <table2> ON <condition>]
   [WHERE <predicate>]
   [GROUP BY <column_list>]
     [HAVING <grouping predicate>]
   [ORDER BY <column_list> [ASC | DESC]]
```

- **Example**
  - ```
    SELECT Fname, Affil, Location
    FROM Participant AS P,
         Locale AS L
    WHERE P.LID = L.LID;
    ```


    ```

Basic Queries, cont.

- **Distinct and All**
  - Distinct and all alternatives
  - Projection w/ **bag semantics** by default

```
SELECT DISTINCT Lname, Fname
   FROM Students;
```

- **Sorting**
  - Convert a bag into a **sorted list** of tuples; order lost if used in other ops
  - Single order: `(Lname, Fname) DESC`
  - Evaluated last in a query tree

```
SELECT * FROM Students
   ORDER BY Lname DESC,
            Fname DESC;
```

- **Set Operations**
  - See 04 Relational Algebra and Calculus → `UNION, INTERSECT, EXCEPT`
  - Set operations **set semantics** by default → `DISTINCT` (set) vs `ALL` (bag)

```
SELECT Firstname, Lastname
FROM Participant2018
  UNION DISTINCT
SELECT Firstname, Lastname
FROM Participant2013
```

Grouping and Aggregation

- **Grouping and Aggregation**
  - **Grouping:** determines the distinct groups
  - **Aggregation:** compute aggregate f(B) per group
  - Column list can only contain **grouping columns**, **aggregates**, or **literals**
  - **Having:** selection predicate on groups and aggregates

- **Example**
  - Sales (Customer, Location, Product, Quantity, Price)
  - **Q: Compute number of sales and revenue per product**

```
SELECT Product, sum(Quantity), sum(Quantity*Price)
   FROM Sales
   GROUP BY Product
```

BREAK (and Test Yourself)

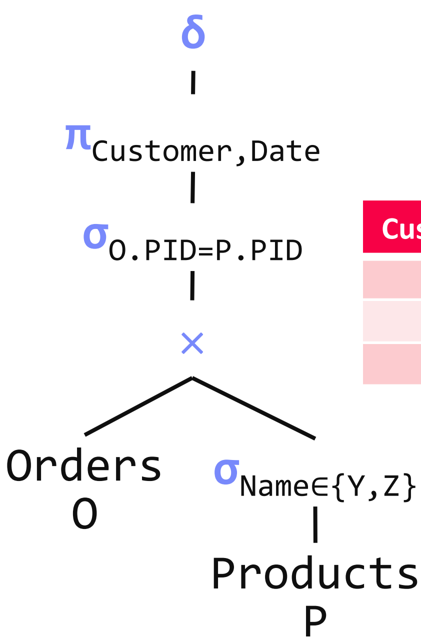
- **Task: SQL queries for the following query trees.**

Orders

<u>OID</u>	Customer	Date	Quantity	PID
1	A	‘2019-06-22’	3	2
2	B	‘2019-06-22’	1	3
3	A	‘2019-06-22’	1	4
4	C	‘2019-06-23’	2	2
5	D	‘2019-06-23’	1	4
6	C	‘2019-06-23’	1	1

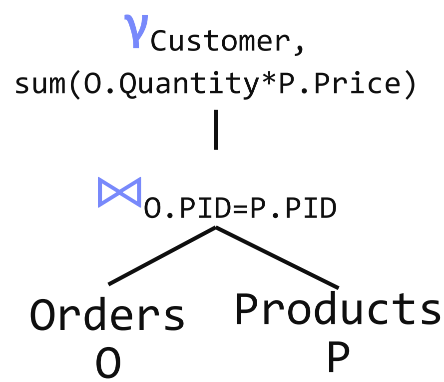
Products

<u>PID</u>	Name	Price
1	X	100
2	Y	15
4	Z	75
3	W	120



Customer	Date
A	‘2019-06-22’
C	‘2019-06-23’
D	‘2019-06-23’

```
SELECT DISTINCT Customer, Date
  FROM Orders O, Products P
  WHERE O.PID = P.PID
    AND Name IN('Y','Z')
```



Customer	Sum
A	120
B	120
C	130
D	75

```
SELECT Customer,
    sum(O.Quantity * P.Price)
  FROM Orders O, Products P
  WHERE O.PID = P.PID
  GROUP BY Customer
```

Subqueries

- **Subqueries in Table List**
  - Use a subquery result like a base table
  - Modularization with `WITH C AS (SELECT …)`

```
SELECT S.Fname, S.Lname, C.Name
FROM Students AS S,
  (SELECT CID, Name FROM Country
  WHERE …) AS C
WHERE S.CID=C.CID;
```

- **Subqueries w/ IN**
  - Check containment of values in result set of sub query

```
SELECT Product, Quantity, Price
FROM Sales
WHERE Product NOT IN(
   SELECT Product FROM Sales
   GROUP BY Product
   HAVING sum(Quantity*Price)>1e6)
```

- **Other subqueries**
  - **EXISTS:** existential quantifier **∃x** for correlated subqueries
  - **ALL:** comparison (w/ universal quantifier **∀x**)
  - **SOME/ANY:** comparison (w/ existential quantifier **∃x**)

Correlated and Uncorrelated Subqueries

- **Correlated Subquery**
  - **Evaluated subquery for every tuple** of outer query
  - Use of attribute from table bound in outer query inside subquery

```
SELECT P.Fname, P.Lname
FROM Professors P,
WHERE NOT EXISTS(
   SELECT * FROM Courses C
   WHERE C.PID=P.PID);
```

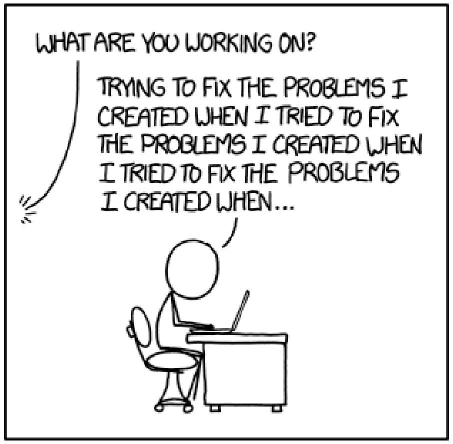
- **Uncorrelated Subquery**
  - Evaluate subquery just once
  - No attribute correlations between subquery and outer query

```
SELECT P.Fname, P.Lname
FROM Professors P,
WHERE P.PID NOT IN(
   SELECT PID FROM Courses);
```

- **Query Unnesting (de-correlation)**
  - Rewrite during query compilation
  - See lecture 08 Query Processing

[Thomas Neumann, Alfons Kemper: Unnesting Arbitrary Queries. **BTW 2015**]

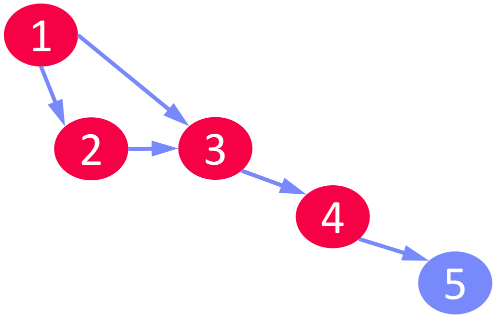
Recursive Queries



[https://xkcd.com/1739/]

- **Approach**
  - `WITH RECURSIVE <name> (<arguments>)`
  - Compose recursive table from **non-recursive term**, **union all/distinct**, and **recursive term**
  - Terminates when recursive term yields empty result

- **Example**
  - Courses(CID, Name), Precond(pre REF CID, suc REF CID)
  - Dependency graph (pre→suc)




```
WITH RECURSIVE rPrereq(p,s) AS(
   (SELECT pre, suc
      FROM Precond WHERE suc=5)
  UNION DISTINCT                              4
   (SELECT B.pre, B.suc
    FROM Precond B, rPrereq R                 3
    WHERE B.suc = R.p)                        1
)
SELECT DISTINCT p FROM rPrereq                2
```

Procedures and Functions

- **Overview Procedures and Functions**
  - Stored programs, written in **PL/pgSQL** or other languages
  - **Control flow (loops, branches) and SQL queries**

- **(Stored) Procedures**
  - Can be called standalone via `CALL <proc_name>(<args>);`
  - Procedures return no outputs

```
CREATE PROCEDURE prepStud(a INT)
LANGUAGE PLPGSQL AS $$
BEGIN
   DELETE FROM Students;
   INSERT INTO Students
      SELECT * FROM NewStudents;
END; $$;
```

- **Functions**
  - Can be called standalone or inside queries
  - Functions are value mappings
  - Table functions can return sets of records with multiple attributes

```
CREATE FUNCTION sampleProp(FLOAT)
   RETURNS FLOAT
   AS 'SELECT $1 * (1 - $1);'
   LANGUAGE SQL;
```

Triggers

- **Overview Trigger**
  - Similar to stored procedure but register ON INSERT, DELETE, or UPDATE
  - Allows complex check constraints and active behavior such as replication, auditing, etc (good and bad)

- **Trigger Template**

```
CREATE TRIGGER <triggername>
   BEFORE | AFTER | INSTEAD OF
   INSERT | DELETE | (UPDATE OF <column_list>)
   ON <tablename>
   [REFERENCING <old_new_alias_list>]
   [FOR EACH {ROW | STATEMENT}]
   [WHEN (<search condition>)]
   <SQL procedure statement> |
   BEGIN ATOMIC
     {<SQL Procedure statement>;}...
   END
```

Event

Condition

Action

Not supported in PostgreSQL (need single UDF)

Views and Authorization

- **Creating Views**
  - Create a logical table from a query
  - Inserts can be propagated back to base relations only in special cases
  - Allows authorization for subset of tuples

```
CREATE VIEW TeamDM AS
  SELECT * FROM
    Employee E, Employee M
  WHERE E.MgrID = M.EID
    AND M.login = 'mboehm';
```

- **Access Permissions Tables/Views**
  - Grant query/modification rights on database objects for specific users, roles
  - Revoke access rights from users, roles (recursively revoke permissions of dependent views via **CASCADE**)

```
GRANT SELECT
   ON TABLE TeamDM
   TO mboehm;

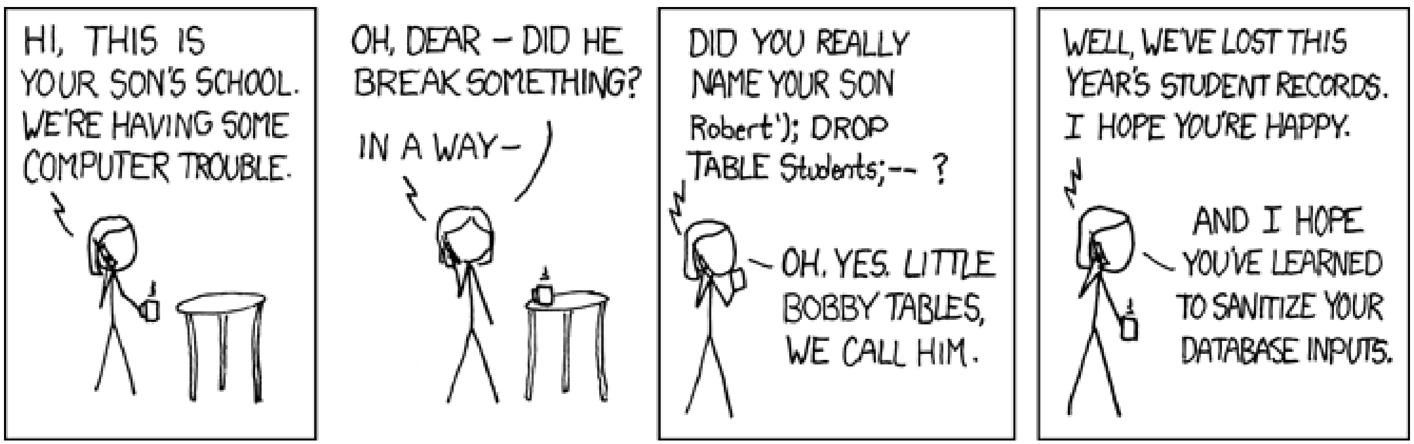
REVOKE SELECT
   ON TABLE TeamDM
   FROM mboehm;
```

Beware of SQL Injection

- **Problematic SQL String Concatenation**

```
INSERT INTO Students (Lname, Fname)
   VALUES (‘“+ @lname +”‘,’“+ @fname +”’);”;
```

- **Possible SQL-Injection Attack**



[https://xkcd.com/327/]

```
INSERT INTO Students (Lname, Fname) VALUES (‘Smith‘,’Robert’);
DROP TABLE Students; --’);
```

Other Query Languages (XML, JSON)

No really, why should I care?

- **Semi-structured XML and JSON**
  - **Self-contained documents** for representing nested data
  - **Common data exchange formats** without redundancy of flat files
  - Human-readable formats → often used for SW configuration

- **Goals**
  - **Awareness of XML and JSON** as data models
  - Query languages and embedded querying in SQL

XML (Extensible Markup Language)

- **XML Data Model**
  - Meta language to define specific **exchange formats**
  - Document format for **semi-structured data**
  - Well formedness
  - XML schema / DTD

```
<?xml version="1.0" encoding="UTF-8"?>
<data>
  <student id="1">
    <course id="INF.01017UF" name="DM"/>
    <course id="706.550" name="AMLS"/>
  </student>
  <student id="5">
    <course id="706.520" name="DIA"/>
  </student>
</data>
```

- **XPath** (XML Path Language)
  - Query language for **accessing collections of nodes** of an XML document
  - Axis specifies for ancestors, descendants, siblings, etc

```
/data/student[@id='1']/course/@name
```

"DM"
"AMLS"

- **XSLT** (XML Stylesheet Language Transformations)
  - Schema mapping (transformation) language for XML documents
- **XQuery**
  - Query language to extract, transform, and analyze XML documents

XML in PostgreSQL, cont.

- **Overview XML in PostgreSQL**
  - Data types **TEXT** or **XML** (well-formed, type-safe operations)
  - ISO/IEC 9075-14 XML-related specifications (SQL/XML)

- **Creating XML**
  - Various **built-in functions** to parse documents, and create elements/attributes
  - XMLPARSE(<xml_document>) → **XML type**
  - XMLELEMENT / XMLATTRIBUTES

```
INSERT INTO Students
  (Fname,Lname,Doc)
  VALUES('John','Smith',
  xmlparse(<source_doc>));
```

- **Processing XML**
  - Execute **XPath** expressions on XML types
  - XMLEXIST with **XPath instead of XQuery**
  - XPATH with optional namespace handling

```
SELECT Fname, Lname,
  xpath('/student/@id',Doc)
  FROM Students
```

JSON (JavaScript Object Notation)

- **JSON Data Model**
  - Data exchange format for **semi-structured data**
  - **Not as verbose as XML** (especially for arrays)
  - Popular format (e.g., Twitter)

```
{"students:"[
  {"id": 1, "courses":[
    {"id":"INF.01017UF", "name":"DM"},
    {"id":"706.550", "name":"AMLS"}]},
 {"id": 5, "courses":[
    {"id":"706.520", "name":"DIA"}]},
]}
```

- **Query Languages**
  - **Most common: libraries** for tree traversal and data extraction
  - **JSONig:** XQuery-like query language
  - **JSONPath:** XPath-like query language

JSONiq Example:

```
declare option jsoniq-version "…";
for $x in collection("students")
  where $x.id lt 10
  let $c := count($x.courses)
  return {"sid":$x.id, "count":$c}
```

[http://www.jsoniq.org/docs/JSONiq/html-single/index.html]

JSON in PostgreSQL, cont.

- **Overview JSON in PostgreSQL**
  - Alternative data types: JSON (text), JSONB (binary, with restrictions)
  - Implements RFC 7159, built-ins for conversion and access
- **Creating JSON**
  - Built-in functions for creating JSON from tables and tables from JSON input

```
SELECT row_to_json(t) FROM
  (SELECT Fname, Lname
   FROM Students) t
```

- **Processing JSON**
  - Specialized operators for **tree traversal and data extraction**

```
SELECT Fname, Lname,
   Doc->students->>id
   FROM Students
```

  - **-> operator:** get JSON array element/object
  - **->> operator:** get JSON array element/object as text
  - Built-in functions for extracting json (e.g., json_each)

Exercise 2:
Query Languages and APIs

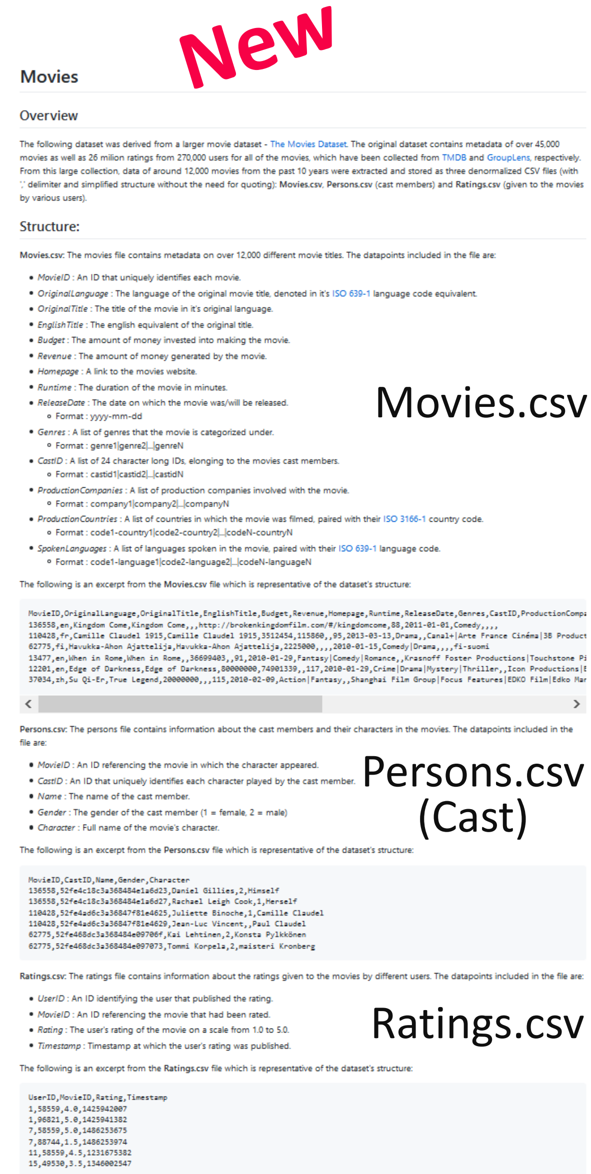
Published: **Nov 09, 2020**
(online since Nov 02)

Deadline: **Dec 01, 2020**

Exercises: The Movies Dataset

- **Dataset**
  - Derived (extracted, cleaned) from **The Movies Dataset** for movies year ≥ 2011
  - Clone or download your copy from https://github.com/tugraz-isds/datasets.git
  - Find CSV files in <datasets>/movies

- **Exercises**
  - **01** Data modeling (relational schema)
  - **02** **Data ingestion and SQL query processing**
  - **03** Physical design tuning, query processing, and transaction processing
  - **04** Large-scale data analysis (distributed query processing and ML model training)



Movies

Overview

The following dataset was derived from a larger movie dataset - The Movies Dataset. The original dataset contains metadata of over 45,000 movies as well as 26 milion ratings from 270,000 users for all of the movies, which have been collected from TMDB and GroupLens, respectively. From this large collection, data of around 12,000 movies from the past 10 years were extracted and stored as three denormalized CSV files (with ',' delimiter and simplified structure without the need for quoting): Movies.csv, Persons.csv (cast members) and Ratings.csv (given to the movies by various users).

Structure:

Movies.csv: The movies file contains metadata on over 12,000 different movie titles. The datapoints included in the file are:

- *MovieID* : An ID that uniquely identifies each movie.
- *OriginalLanguage* : The language of the original movie title, denoted in it's ISO 639-1 language code equivalent.
- *OriginalTitle* : The title of the movie in it's original language.
- *EnglishTitle* : The english equivalent of the original title.
- *Budget* : The amount of money invested into making the movie.
- *Revenue* : The amount of money generated by the movie.
- *Homepage* : A link to the movies website.
- *Runtime* : The duration of the movie in minutes.
- *ReleaseDate* : The date on which the movie was/will be released.
  - Format : yyyy-mm-dd
- *Genres* : A list of genres that the movie is categorized under.
  - Format : genre1|genre2|...|genreN
- *CastID* : A list of 24 character long IDs, elonging to the movies cast members.
  - Format : castid1|castid2|...|castidN
- *ProductionCompanies* : A list of production companies involved with the movie.
  - Format : company1|company2|...|companyN
- *ProductionCountries* : A list of countries in which the movie was filmed, paired with their ISO 3166-1 country code.
  - Format : code1-country1|code2-country2|...|codeN-countryN
- *SpokenLanguages* : A list of languages spoken in the movie, paired with their ISO 639-1 language code.
  - Format : code1-language1|code2-language2|...|codeN-languageN

The following is an excerpt from the **Movies.csv** file which is representative of the dataset's structure:

```
MovieID,OriginalLanguage,OriginalTitle,EnglishTitle,Budget,Revenue,Homepage,Runtime,ReleaseDate,Genres,CastID,ProductionCompa
136558,en,Kingdom Come,Kingdom Come,,,http://brokenkingdomfilm.com/#/kingdomcome,88,2011-01-01,Comedy,,,,
110428,fr,Camille Claudel 1915,Camille Claudel 1915,3512454,115860,,95,2013-03-13,Drama,,Canal+|Arte France Cinéma|3B Product
62775,fi,Havukka-Ahon Ajattelija,Havukka-Ahon Ajattelija,2225000,,,,2010-01-15,Comedy|Drama,,,,fi-suomi
13477,en,When in Rome,When in Rome,,36699403,,91,2010-01-29,Fantasy|Comedy|Romance,,Krasnoff Foster Productions|Touchstone Pi
12201,en,Edge of Darkness,Edge of Darkness,80000000,74901339,,117,2010-01-29,Crime|Drama|Mystery|Thriller,,Icon Productions|E
37034,zh,Su Qi-Er,True Legend,20000000,,,115,2010-02-09,Action|Fantasy,,Shanghai Film Group|Focus Features|EDKO Film|Edko Mar
```

Persons.csv: The persons file contains information about the cast members and their characters in the movies. The datapoints included in the file are:

- *MovieID* : An ID referencing the movie in which the character appeared.
- *CastID* : An ID that uniquely identifies each character played by the cast member.
- *Name* : The name of the cast member.
- *Gender* : The gender of the cast member (1 = female, 2 = male)
- *Character* : Full name of the movie's character.

The following is an excerpt from the **Persons.csv** file which is representative of the dataset's structure:

```
MovieID,CastID,Name,Gender,Character
136558,52fe4c18c3a368484e1a6d23,Daniel Gillies,2,Himself
136558,52fe4c18c3a368484e1a6d27,Rachael Leigh Cook,1,Herself
110428,52fe4ad6c3a36847f81e4625,Juliette Binoche,1,Camille Claudel
110428,52fe4ad6c3a36847f81e4629,Jean-Luc Vincent,,Paul Claudel
62775,52fe468dc3a368484e09706f,Kai Lehtinen,2,Konsta Pylkkönen
62775,52fe468dc3a368484e097073,Tommi Korpela,2,maisteri Kronberg
```

Ratings.csv: The ratings file contains information about the ratings given to the movies by different users. The datapoints included in the file are:

- *UserID* : An ID identifying the user that published the rating.
- *MovieID* : An ID referencing the movie that had been rated.
- *Rating* : The user's rating of the movie on a scale from 1.0 to 5.0.
- *Timestamp* : Timestamp at which the user's rating was published.

The following is an excerpt from the **Ratings.csv** file which is representative of the dataset's structure:

```
UserID,MovieID,Rating,Timestamp
1,58559,4.0,1425942007
1,96821,5.0,1425941382
7,58559,5.0,1486253675
7,88744,1.5,1486253974
11,58559,4.5,1231675382
15,49530,3.5,1346002547
```

Task 2.1: Schema Creation via SQL (3/25 points)

- **Schema creation via SQL**
  - Relies on lectures **04 Relational Algebra** and **05 Query Languages (SQL)**
  - Setup DBMS PostgreSQL, and start `pgAdmin` (UI), or `psql` (terminal)
  - Create database `db<studentID>` and setup relational schema
    - Ignore (1) **derived budget classification of movies**, and (2) **location of actors** (countries they live in)
    - Primary keys, foreign keys, `NOT NULL`, `UNIQUE`
- **Recommended Schema**
  - Feel free to use and submit the provided schema
- **Partial Results**
  - `CreateSchema.sql`

Task 2.2 Data Ingestion via CLI (10/25 points)

- **Data Ingestion Program via ODBC/JDBC**
  - Relies on lectures **05 Query Languages (SQL)** and **06 APIs (ODBC, JDBC)**
  - Write a program that performs **deduplication and data ingestion**
  - Programming language of your choosing (Python, Java, C#, C++ recommended)

- **Data Ingestion Process**
  - Data: https://github.com/tugraz-isds/datasets/tree/master/movies
  - Invoke your ingestion program as follows → script to compile and run

```
./runIngestData.sh ./Movies.csv ./Persons.csv ./Ratings.csv \
  <host> <port> <database> <user> <password>
```

(e.g., `127.0.0.1 5432 db1234567 postgres postgres`)

- **Partial Results**
  - Source code `IngestData.*`, and
  - Script `runIngestData.sh`

Task 2.3: SQL Query Processing (10/25 points)

- **SQL Query Processing**
  - Relies on lecture **05 Query Languages (SQL)**

New:
Expected result sets provided on website

- **List of Queries**
  - **Q01:** Obtain the details of the movie(s) with English title Interstellar. (return English title, release date, runtime, budget, and revenue)
  - **Q02:** Which movies were produced in Austria? (return original title, release date; sorted ascending by original title)
  - **Q03:** How many movies were filmed per year? (return year, count; sorted ascending by year)
  - **Q04:** Which movie had the most unique actors? (return English title, actor count)
  - **Q05:** Compute the top-20 highest-rated movies by average rating. (return English title, release date, average rating; sorted descending by the average rating, and for equal ratings, sorted ascending by English title)

Task 2.3: SQL Query Processing (10/25 points)

- **List of Queries, cont.**
  - **Q06:** How many movies of genre Science Fiction have been released each year between 2012 and 2016 (both inclusive)?
    (return year, count; sorted ascending by year)
  - **Q07:** Who are the top-10 most successful actors by number of movies they played in, and profits these movies generated?
    (return actor name, count, profit as union distinct of top-10 actors by maximum count and top-10 actors by maximum profit).
  - **Q08:** Which pairs of actors co-appeared most-frequently in movies each year between 2010 and 2013 (both inclusive)? (return name of actor1, name of actor2, year, count, sorted ascending by year)

- **Partial Results**
  - SQL Script for each query: `Q01.sql`, `Q02.sql`, …, `Q08.sql`

Task 2.4: Query Plans (2/25 points)

- **Explain Query Plans**
  - Relies on lecture **04 Relational Algebra** and **05 Query Languages (SQL)**
  - Obtain and **analyze execution plans** of Q06

- **Example**

```
EXPLAIN VERBOSE
SELECT L.location, count(*)
  FROM Participant P,
       Locale L
  WHERE P.lid = L.lid
  GROUP BY L.location
  HAVING count(*)>1
```

```
"HashAggregate  (...)"      // grouping
" Output: l.location, count(*)"
" Group Key: l.location"
" Filter: (count(*) > 1)"   // selection
" -> Hash Join  (...)"      // join
"      Output: l.location"  // projection
"      Hash Cond: (l.lid = p.lid)"
"      -> Seq Scan on Locale l  (...)"
"          Output: l.lid, l.location"
"      -> Hash  (...)"
"          Output: p.lid"   // projection
"          -> Seq Scan on Participant p  (...)"
"              Output: p.lid"
```

- **Partial Results**
  - `ExplainQ06.sql`

Conclusions and Q&A

- **Summary**
  - History and fundamentals of the **Structured Query Language (SQL)**
  - Awareness of **XML and JSON** (data model and querying)

- **Exercise Submissions**
  - **Exercise 1:** Nov 03 11.59 + 7 days ends tomorrow midnight
  - **Exercise 2:** published Nov 02, deadline Dec 01

- **Next Lectures**
  - **06 APIs (ODBC, JDBC, OR frameworks)** [Nov 16]
  - **07 Physical Design and Tuning** [Nov 23]
  - **08 Query Processing** [Nov 30]
  - **09 Transaction Processing and Concurrency** [Dec 07]