SCIENCE
PASSION
TECHNOLOGY

Data Management
05 Query Languages (SQL)

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Announcements/Org

- **#1 Video Recording**
  - Link in **TeachCenter** & **TUbe** (lectures will be public)
  - Hybrid: HSi13 / https://tugraz.webex.com/meet/m.boehm
- **#2 Exercise 1**
  - Deadline: **Mar 29 + 7 late days** in TeachCenter
  - Grading starts Apr 06, **drafts are fine** – do not resubmit
- **#3 Exercise 2**
  - Task description published last weekend, discussed today
  - Deadline: **May 03 + 7 late days** in TeachCenter
- **#4 (Tentative) Exams Dates**
  - July 07, 2.30pm-4.30pm in HS i13 + HS i12 (108 → 213 seats)
  - July 07, 5.30pm-7.30pm in HS i13 + HS i12 (108 → 213 seats)
  - July 28, 5.30pm-7.30pm in HS i13 (76 → 151 seats)

Q&A

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?

```
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

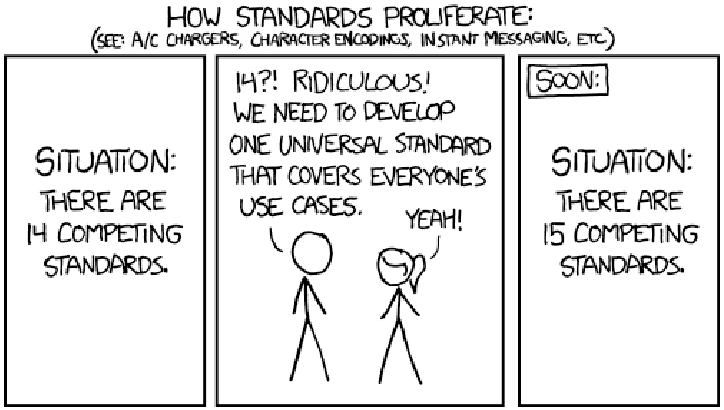
#2 Flexibility:
closed → composability

#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)


HOW STANDARDS PROLIFERATE:
(SEE: A/C CHARGERS, CHARACTER ENCODINGS, INSTANT MESSAGING, ETC.)
SITUATION: THERE ARE 14 COMPETING STANDARDS.
14?! RIDICULOUS! WE NEED TO DEVELOP ONE UNIVERSAL STANDARD THAT COVERS EVERYONE'S USE CASES.
YEAH!
SOON:
SITUATION: THERE ARE 15 COMPETING STANDARDS.

[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)**

Microsoft

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

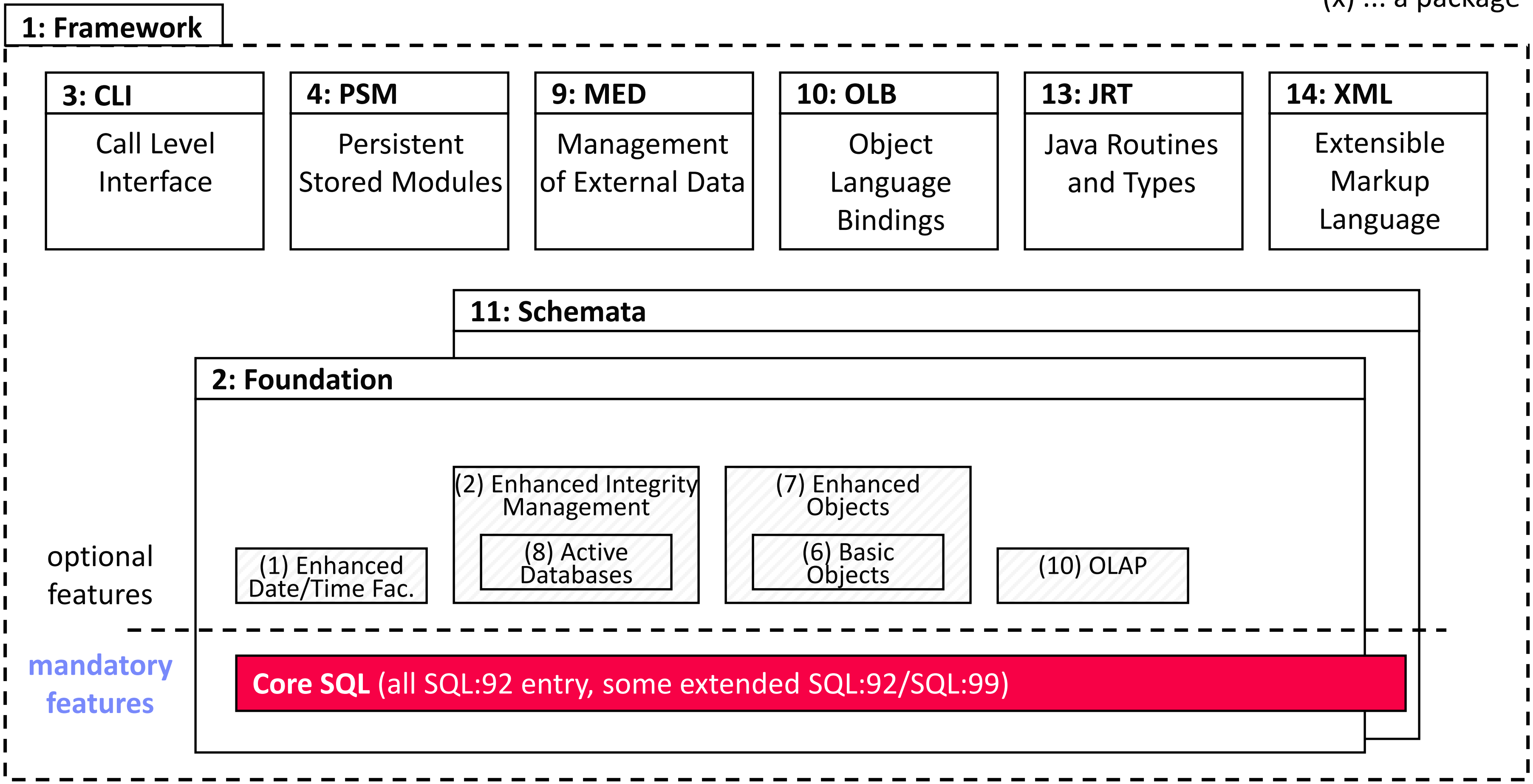
[C. J. Date: A Critique of the SQL Database Language. **SIGMOD Record 1984**]

- **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**

x: ... a part
(x) ... a package

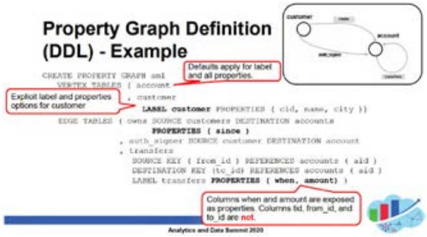


The History of the SQL Standard, cont.

Since SQL:2003 overall structure remained unchanged ...

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

- **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)
- **SQL:2023** (upcoming)
  - E.g., SQL:PGQ (property **graph** definition and querying)



Property Graph Definition (DDL) - Example

```
CREATE PROPERTY GRAPH aml
  VERTEX TABLES ( account
                , customer
                  LABEL customer PROPERTIES ( cid, name, city ))
  EDGE TABLES ( owns SOURCE customers DESTINATION accounts
                  PROPERTIES ( since )
              , auth_signer SOURCE customer DESTINATION account
              , transfers
                SOURCE KEY ( from_id ) REFERENCES accounts ( aid )
                DESTINATION KEY (to_id) REFERENCES accounts ( aid )
                LABEL transfers PROPERTIES ( when, amount) )
```

Defaults apply for label and all properties.

Exploit label and properties options for customer

Columns when and amount are exposed as properties. Columns tid, from_id, and to_id are not.

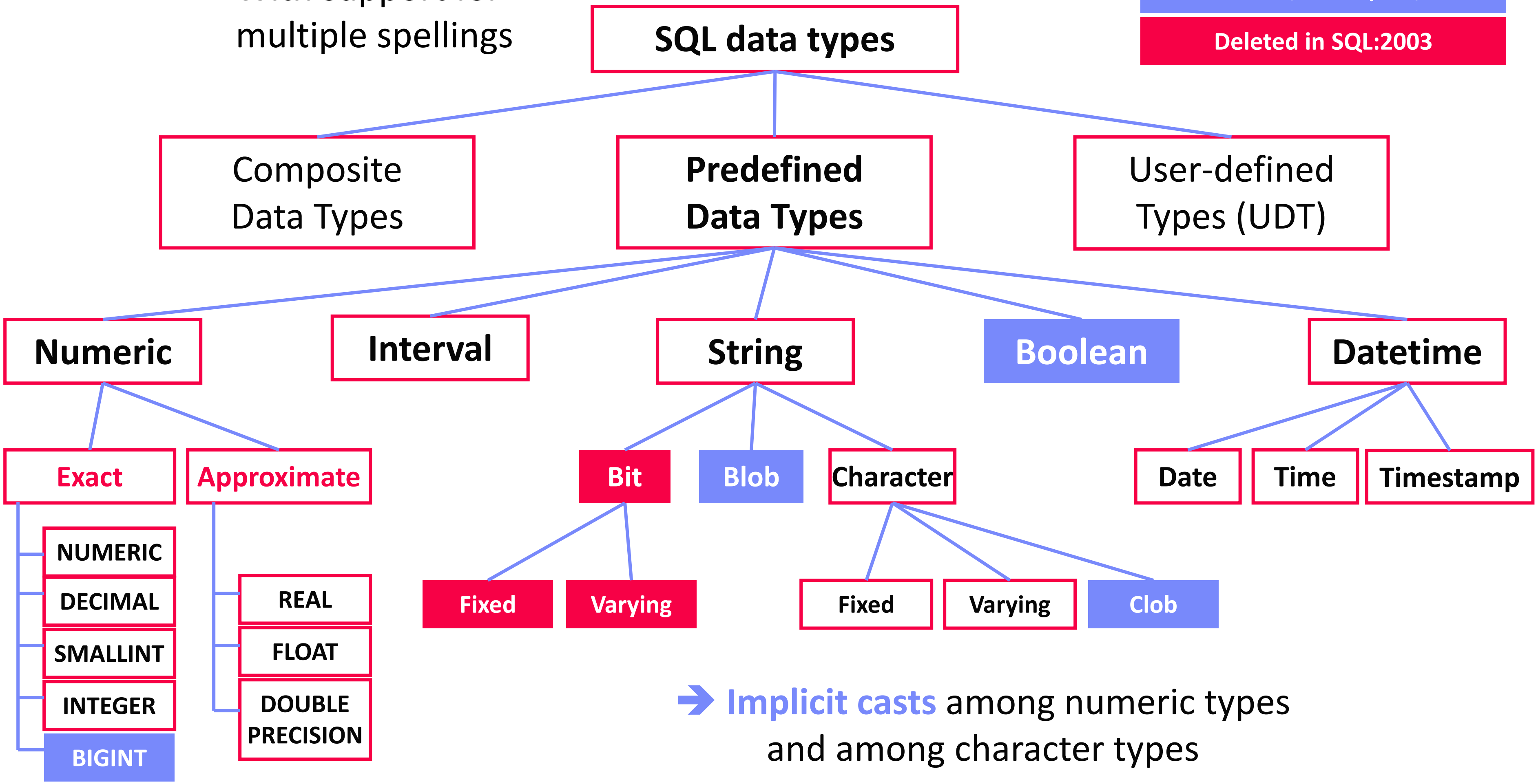
Analytics and Data Summit 2020

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

[https://download.oracle.com/otndocs/products/spatial/pdf/AnD2020/AD_Develop_Graph_Apps_SQL_PGQ.pdf]

Data Types in SQL:2003

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



Added in SQL:1999 / SQL:2003

Deleted in SQL:2003

SQL data types

Composite Data Types

Predefined Data Types

User-defined Types (UDT)

Numeric

Interval

String

Boolean

Datetime

Exact

Approximate

NUMERIC

DECIMAL

SMALLINT

INTEGER

BIGINT

REAL

FLOAT

DOUBLE PRECISION

Bit

Blob

Character

Fixed

Varying

Fixed

Varying

Clob

Date

Time

Timestamp

➔ 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

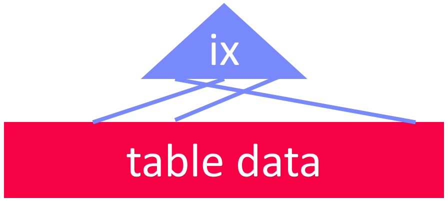
```
DROP TABLE Students; -- sorry
DROP TABLE Students CASCADE;
DROP TABLE IF EXISTS Countries,
   Cities, Airports, Airlines,
   Routes, Planes, Routes_Planes;
```

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**

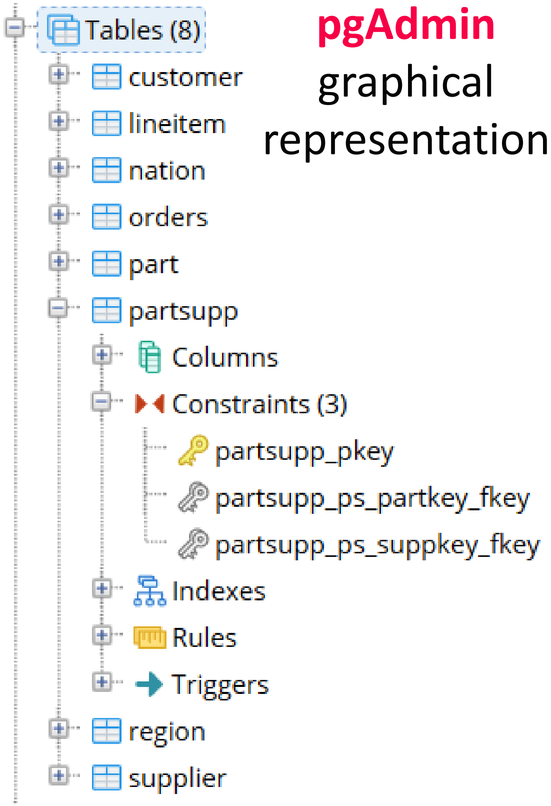
Database Catalog

[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)



```
Tables (8)
  customer
  lineitem
  nation
  orders
  part
  partsupp
    Columns
    Constraints (3)
      partsupp_pkey
      partsupp_ps_partkey_fkey
      partsupp_ps_suppkey_fkey
    Indexes
    Rules
    Triggers
  region
  supplier
```

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**

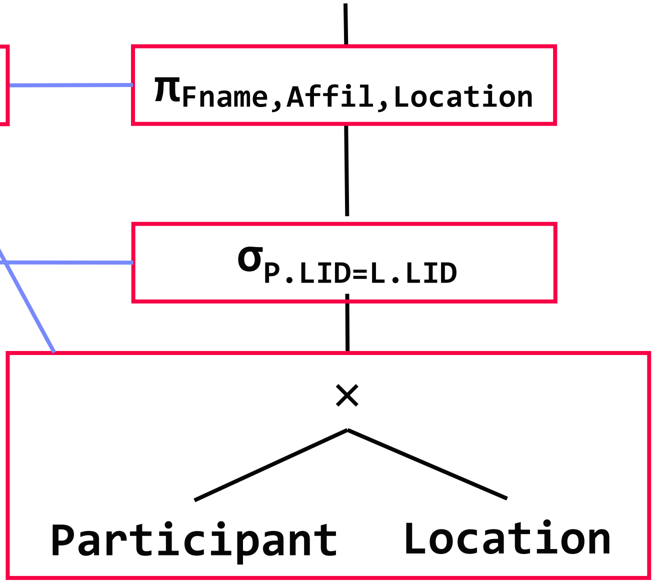
Basic Queries

- **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** sumQ **and revenue per product** sumQP

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

Product	Quantity	Price
A	1	10
B	3	20
A	2	10
B	1	20

Product	SumQ	SumQP
A	3	30
B	4	80

BREAK (and Test Yourself)

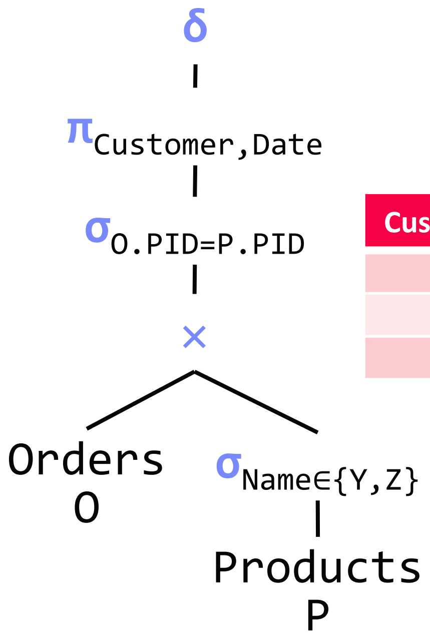
- **Task: SQL queries for the following query trees.**

Orders

OID	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

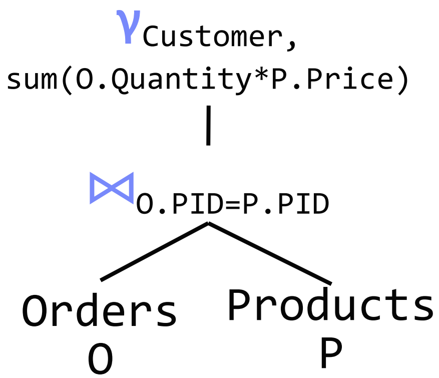
Products

PID	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);
```

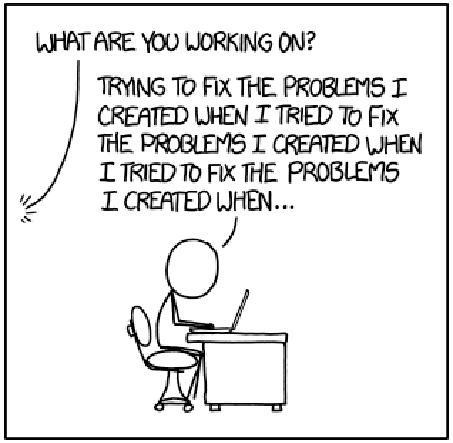
- **Uncorrelated Subquery**
  - Evaluate subquery just once
  - No attribute correlations between subquery and outer query

```
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**]

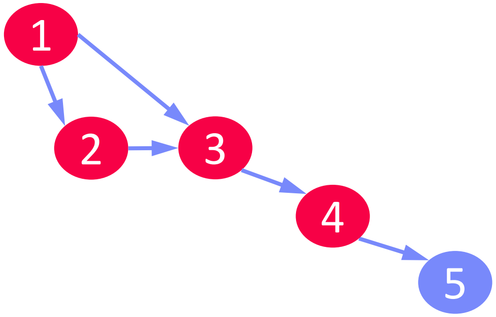
Recursive Queries


WHAT ARE YOU WORKING ON?
TRYING TO FIX THE PROBLEMS I CREATED WHEN I TRIED TO FIX THE PROBLEMS I CREATED WHEN I TRIED TO FIX THE PROBLEMS I CREATED WHEN...

[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**

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

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

- **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**)

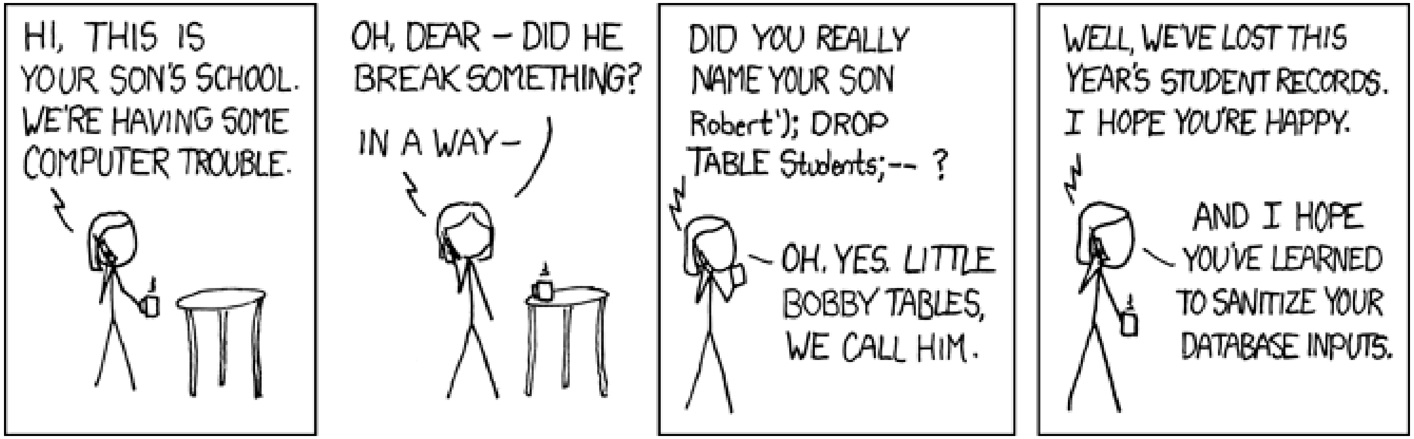
```
GRANT SELECT
   ON TABLE TeamDM
   TO mboehm;

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**


HI, THIS IS YOUR SON'S SCHOOL. WE'RE HAVING SOME COMPUTER TROUBLE.
OH, DEAR – DID HE BREAK SOMETHING?
IN A WAY–
DID YOU REALLY NAME YOUR SON Robert'); DROP TABLE Students;-- ?
OH. YES. LITTLE BOBBY TABLES, WE CALL HIM.
WELL, WE'VE LOST THIS YEAR'S STUDENT RECORDS. I HOPE YOU'RE HAPPY.
AND I HOPE YOU'VE LEARNED TO SANITIZE YOUR DATABASE INPUTS.

[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
  - **JSONiq:** 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]

[Ingo Müller, Ghislain Fourny, Stefan Irimescu, Can Berker Cikis, Gustavo Alonso: Rumble: Data Independence for Large Messy Data Sets. **PVLDB 2020**, https://github.com/RumbleDB/rumble]

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

https://mboehm7.github.io/teaching/ss22_dbs/02_ExerciseQueriesAPIs.pdf

Published: **Apr 03, 2022**

(data cleaning / ref solutions already completed)

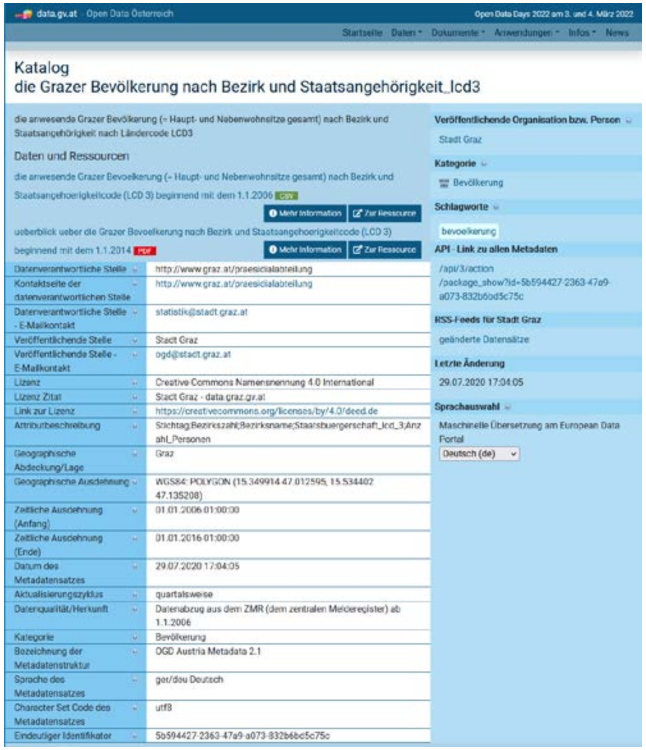
Deadline: **May 03, 2022**

Exercises: Graz Districts

New

- **Dataset**
  - Graz districts, streets, schools, universities, population counts by age and country (to be cleaned and prepared → Ex 02)
  - Clone or download your copy from https://github.com/tugraz-isds/datasets.git
  - Find CSV files in <datasets>/districts_graz
- **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 – anomalies?)

www.data.gv.at



Katalog
die Grazer Bevölkerung nach Bezirk und Staatsangehörigkeit_lcd3

die anwesende Grazer Bevölkerung (= Haupt- und Nebenwohnsitze gesamt) nach Bezirk und Staatsangehörigkeit nach Ländercode LCD3

Daten und Ressourcen

die anwesende Grazer Bevoelkerung (= Haupt- und Nebenwohnsitze gesamt) nach Bezirk und Staatsangehoerigkeitcode (LCD 3) beginnend mit dem 1.1.2006 CSV

ueberblick ueber die Grazer Bevoelkerung nach Bezirk und Staatsangehoerigkeitcode (LCD 3) beginnend mit dem 1.1.2014 PDF

Datenverantwortliche Stelle	http://www.graz.at/praesidialabteilung
Kontaktseite der datenverantwortlichen Stelle	http://www.graz.at/praesidialabteilung
Datenverantwortliche Stelle - E-Mailkontakt	statistik@stadt.graz.at
Veröffentlichende Stelle	Stadt Graz
Veröffentlichende Stelle - E-Mailkontakt	ogd@stadt.graz.at
Lizenz	Creative Commons Namensnennung 4.0 International
Lizenz Zitat	Stadt Graz - data.graz.gv.at
Link zur Lizenz	https://creativecommons.org/licenses/by/4.0/deed.de
Attributbeschreibung	Stichtag;Bezirkszahl;Bezirksname;Staatsbuergerschaft_lcd_3;Anzahl_Personen
Geographische Abdeckung/Lage	Graz
Geographische Ausdehnung	WGS84: POLYGON (15.349914 47.012595, 15.534402 47.135208)
Zeitliche Ausdehnung (Anfang)	01.01.2006 01:00:00
Zeitliche Ausdehnung (Ende)	01.01.2016 01:00:00
Datum des Metadatensatzes	29.07.2020 17:04:05
Aktualisierungszyklus	quartalsweise
Datenqualität/Herkunft	Datenabzug aus dem ZMR (dem zentralen Melderegister) ab 1.1.2006
Kategorie	Bevölkerung
Bezeichnung der Metadatenstruktur	OGD Austria Metadata 2.1
Sprache des Metadatensatzes	ger/deu Deutsch
Character Set Code des Metadatensatzes	utf8
Eindeutiger Identifikator	5b594427-2363-47a9-a073-832b6bd5c75c

Veröffentlichende Organisation bzw. Person
Stadt Graz

Kategorie
Bevölkerung

Schlagworte
bevoelkerung

API - Link zu allen Metadaten
/api/3/action/package_show?id=5b594427-2363-47a9-a073-832b6bd5c75c

RSS-Feeds für Stadt Graz
geänderte Datensätze

Letzte Änderung
29.07.2020 17:04:05

Sprachauswahl
Maschinelle Übersetzung am European Data Portal

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)
  - Docker container w/ basic setup in next days
  - Create database db<studentID> and setup relational schema, including primary keys, foreign keys, NOT NULL, UNIQUE

- **Recommended Schema**
  - Feel free to use and submit the provided schema
  - https://mboehm7.github.io/teaching/ss22_dbs/CreateSchema.sql

- **Partial Results**
  - CreateSchema.sql

```
CREATE TABLE PopByCitizenship(
  DKey INT REFERENCES Districts,
  CKey INT REFERENCES Countries,
  PopDate DATE,
  PopCount INT NOT NULL,
  PRIMARY KEY(DKey, CKey, PopDate)
)
```

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/districts_graz
  - Invoke your ingestion program as follows → script to compile and run

```
./runIngestData.sh ./Districts.csv ./Institutions.csv ./Streets.csv \
    ./PopulationByCitizenship.csv ./PopulationByGender.csv \
    <host> <port> <database> <user> <password>
```

(e.g., `localhost 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)**
  - Expected results: https://mboehm7.github.io/teaching/ss22_dbs/Results.zip

TODO: this week

- **List of Queries**
  - **Q01:** Which districts have the postal code 8051? (return Districts.Name)
  - **Q02:** Which institutions have an address on Leonhardstrasse? (return Institutions.Name, Addresses.PostalCode, Addresses.StNumber)
  - **Q03:** Compute, for each district, its relative area (in percent) of the total Graz area (sum of district areas). (return Districts.Name, relative area)
  - **Q04:** Count, for each district, the number of streets that belong entirely to this district(filter out streets that belong to more than one district). (return Districts.Name, Districts.Area, street count; sorted descending by street count)
  - **Q05:** How many distinct countries were represented (by people's citizenships) between 2010-01-01 and 2014-12-31 in each district? (return Districts.Name, country count; sorted descending by country count)

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

- **List of Queries, cont.**
  - **Q06:** Obtain the population count for all N-EU countries represented in Jakomini as of 2022-01-01? (return Countries.Name, PopByCitizenship.PopCount; sorted descending by PopCount)
  - **Q07:** Compute the top-10 countries (by people's citizenship) with the largest absolute change in total population count over time. (return Countries.Name, date maximum, maximum, date minimum, minimum, difference max-min; sorted descending by difference)
  - **Q08:** Find all pairs of distinct districts that had at the same date, the same population count of the same gender (e.g. Wetzelsdorf and Strassgang both having 6970 males as of 2008-04-01). (return PByG.Date, Districts.Name 1, Districts.Name 2, PByG.Gender, PByG.PopCount)

- **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:** Mar 29 + 7 late days, grading starts soon
  - **Exercise 2:** May 03, published Apr 03

- **Next Lectures** (Part A)
  - **06 APIs (ODBC, JDBC, OR frameworks)** [Apr 25]
  - **07 Physical Design and Tuning** [May 02]
  - **08 Query Processing** [May 09]
  - **09 Transaction Processing and Concurrency** [May 16]