

Declarative Programming: Query Languages

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Language

Query languages: the class of programming languages for searching and (sometimes) manipulating data in data-base management systems (DBMSs) or any other software focused on data.

Unlike C/Java/Haskell and other “general purposes” languages, query languages are domain-specific languages (DSLs) and are not intended for the regular programming. They are typically used as inclusion into other languages instead.

SQL: Structures Query Language (pronounces as “sequel”) – standard language for searching and manipulating data in **relational** DBMS.



Software

DBMS: SQLite – tiny embedded DBMS

Language: SQL, SQLite dialect

Software: DB Browser for SQLite, <https://sqlitebrowser.org/>



Hello, world!

What is the capital of Russia?



Hello, world?

Is it Moscow? Really?

What about an answer for the same question asked 200 years ago?

Let's pretend that we do not know the answer. How shall we find it?

How to ask the same question to the computer and how it shall be answered?



Manual searching

1. Go to library
2. Take a sort of geographic handbook or encyclopedia
3. Find a page with the appropriate country
(do we really need to do it page-by-page?)
4. Get the answer



SQL: Hello, world! Finally...

Here and below the SQLite dialect of SQL will be used.

```
SELECT CAPITAL          --what do we want to get
FROM COUNTRY_HANDBOOK   --handbook to use
WHERE COUNTRY='Russia'; --conditions
```

```
>> Moscow
```

```
    Saint Petersburg
```

```
    Petrograd
```

```
    ...
```



More precise query

```
SELECT CAPITAL
FROM COUNTRY_HANDBOOK
WHERE COUNTRY='Russia'
      AND 2021 BETWEEN PERIOD_START AND PERIOD_END;
--alternative to previous line
      AND 2021>=PERIOD_START AND 2021<=PERIOD_END;
```

>> Moscow



Basic terms (not so formal)

n-tuple (tuple) – sequence of **n** elements: $(\mathbf{x}_1, \mathbf{x}_2, \dots, \mathbf{x}_n)$

If \mathbf{x}_i is of type \mathbf{T}_i , then the whole tuple is of type $\mathbf{T}_1 \times \mathbf{T}_2 \times \dots \times \mathbf{T}_n$

The tuple with named positions is **record** (or structure in terms of C)

Table – unordered multiset of **records** of the same type (**rows**, **entries**)

Column (field, attribute...) – a **multiset** of elements on the particular position (identified by its name) of all the rows



COUNTRY_HANDBOOK definition

```
CREATE TABLE COUNTRY_HANDBOOK (  
  COUNTRY TEXT,           --TEXT is type in SQLite  
  CAPITAL TEXT,  
  PERIOD_START INTEGER,   --as well as INTEGER  
  PERIOD_END INTEGER  
...);
```

```
INSERT INTO COUNTRY_HANDBOOK ...
```

```
INSERT INTO COUNTRY_HANDBOOK ...
```

```
...
```



Wares DB structure

--wares classification table

CATEGORY:

WARE TEXT
CLASS TEXT

Ex.: ('Charcoal', 'Fuel')

--manufacturing "recipes" table

MANUFACTURER:

BILL_ID INTEGER
COMPANY TEXT

Ex.: (20, 'Zogenix')

--materials for "recipes"

MATERIAL:

BILL_ID INTEGER
WARE TEXT
AMOUNT INTEGER

Ex.: (19, 'Water', 7)

--outputs of "recipes"

PRODUCT:

BILL_ID INTEGER
WARE TEXT
AMOUNT INTEGER
PRICE REAL

Ex.: (19, 'Paper', 8, 4.6)



SELECT statement

SELECT ...	--projection definition, essential
FROM ...	--tables(-s) section, essential
WHERE ...	--selection/filter section
ORDER BY ...	--ordering section
LIMIT ...	--paging section
OFFSET ...	

GROUP BY ...
HAVING ...
...



Projection

Projection never affects the number of result rows, only the structure of rows.

```
--simple projection,  
--select subset of columns
```

```
SELECT WARE  
FROM CATEGORY
```

```
>> Water  
    Coal  
    Paper  
    Water  
    ...
```

```
--more complex projection  
--with derivative column
```

```
SELECT BILL_ID, WARE,  
        AMOUNT*PRICE  
FROM PRODUCT
```

```
>> 3, Wood, 10.8  
    4, Meat, 151.5  
    4, Leather, 87.0  
    ...
```



Selection

Selection affects the number of result rows and never affects structure of result.
It is defined as predicate on columns.

```
--simple selection
```

```
SELECT *      --no projection  
FROM CATEGORY  
WHERE WARE LIKE 'W%'
```

```
>> Wood, Material  
    Water, Mineral
```

```
--selection with composite  
--filter and projection
```

```
SELECT CAPITAL  
FROM COUNTRY_HANDBOOK  
WHERE COUNTRY='Russia'  
      AND 2021 BETWEEN  
PERIOD_START AND PERIOD_END;
```



Unique projection

Regular projection doesn't guarantee that all the result rows are unique.

```
SELECT WARE, CLASS  
FROM CATEGORY  
WHERE WARE LIKE 'C%'
```

```
>> Charcoal, Material  
    Charcoal, Fuel
```

```
SELECT WARE  
FROM CATEGORY  
WHERE WARE LIKE 'C%'
```

```
>> Charcoal  
    Charcoal
```

```
SELECT DISTINCT WARE, CLASS  
FROM CATEGORY  
WHERE WARE LIKE 'C%'
```

```
>> Charcoal, Material  
    Charcoal, Fuel
```

```
SELECT DISTINCT WARE  
FROM CATEGORY  
WHERE WARE LIKE 'C%'
```

```
>> Charcoal
```



Basic operations

- Arithmetic: + - * / %
- String concatenation: 'a' || 'b'
- Ordering and equality predicates: >, >=, <, <=, <> (!=), = (==),
x BETWEEN y AND z, x IS NULL, x IS NOT NULL
- Set predicates: x IN (y1, y2, y3, ...)
- String predicates: x LIKE y (case insensitive in SQLite, % as wildcard)
- Logical: OR, AND, NOT
- Other useful: GLOB, REGEXP, CASE



Ordering

By default the order of result rows is arbitrary. But it could be explicitly sorted.

```
--order by single column  
--in reverse alphabetical  
--order
```

```
SELECT DISTINCT WARE  
FROM CATEGORY  
ORDER BY WARE DESC;
```

```
>> Wood  
    Water  
    Paper  
    ...
```

```
--order by two columns in  
--alphabetical order
```

```
SELECT WARE, CLASS  
FROM CATEGORY  
ORDER BY CLASS ASC, WARE ASC;
```

```
>> Drinking water, Food  
    Grain, Food  
    Meat, Food  
    Charcoal, Fuel  
    ...
```



Paging

Sometimes only a part of the result is necessary, typically to visualize it page-by-page.

In this case the ordering by all the output columns (or at least the column that forms the unique projection) is recommended (however, not required)

--Get the first page of size 3

```
SELECT DISTINCT WARE  
FROM CATEGORY  
ORDER BY WARE ASC  
LIMIT 3;
```

```
>> Charcoal  
    Drinking water  
    Grain
```

--Get the second one

```
SELECT DISTINCT WARE  
FROM CATEGORY  
ORDER BY WARE ASC  
LIMIT 3  
OFFSET 3;
```

```
>> Leather  
    Meat  
    Meat cow
```



Set and multiset operations

Each query produces sequence of records.

It also could be viewed as sequence of tuples, or **multiset** of tuples, so set/multiset operations are applicable.

The general pattern for query with set operation:

```
SELECT ... FROM ... WHERE ...    --q1  
<SET_OPERATION>  
SELECT ... FROM ... WHERE ...    --q2
```

Both queries must produce the tuples of the same type.



Set operations in SQL

- `q1 INTERSECT q2` – intersection of results of two queries (as sets)
- `q1 UNION q2` – union
- `q1 UNION ALL q2` – union of two multisets (all other operations consider `q1` and `q2` as sets and produce also the set)
- `q1 EXCEPT q2` – subtracts `q2` from `q1`



Set examples

```
SELECT WARE FROM CATEGORY
WHERE WARE LIKE 'C%'
UNION
SELECT WARE FROM CATEGORY
WHERE WARE LIKE 'D%';
```

```
>> Charcoal
    Drinking water
```

```
--the equivalent query
--DISTINCT is essential
```

```
SELECT DISTINCT WARE
FROM CATEGORY
WHERE WARE LIKE 'C%'
      OR WARE LIKE 'D%'
```

```
--union of selections from
--different tables
```

```
SELECT WARE FROM PRODUCT
UNION
SELECT WARE FROM MATERIAL
```

```
--incorrect query
```

```
SELECT WARE FROM PRODUCT
UNION
SELECT WARE, CLASS
FROM CATEGORY
```



Simple aggregation

Aggregate functions acts as reduce/fold/collect in other languages.

Using aggregate functions in projection section (under **SELECT**) causes query to produce exactly one tuple (until **GROUP BY** clause is in use) and prohibits the usage of columns without other aggregate functions.

```
--surprisingly counts rows in
--CATEGORY table
SELECT COUNT(WARE) FROM CATEGORY;
```

```
>> 16
```

```
SELECT COUNT(*),
        COUNT(),
        COUNT(DISTINCT WARE),
        COUNT(DISTINCT CLASS)
FROM CATEGORY;
```

```
>> 16, 16, 12, 7
```

```
--incorrect query
SELECT COUNT(), WARE
FROM CATEGORY;
```



Notable aggregate functions

- `COUNT()`, `COUNT(x)` – counts the rows; when provided with argument, counts all the rows where argument **IS NOT NULL**
- `MIN(num)`, `MAX(num)` – minimum and maximum of values
- `SUM(num)` – sum of values
- `AVG(num)` – average of values
- `GROUP_CONCAT(str)`
`GROUP_CONCAT(str, separator)` – concatenates text values

