Database Technology

Topic 3: SQL

Olaf Hartig
olaf.hartig@liu.se

LINKÖPING UNIVERSITY

Structured Query Language

- **Declarative** language (what data to get, not how)
- Considered one of the major reasons for the commercial success of relational databases
- Statements for data definitions, queries, and updates
  - Both DDL and DML
- Terminology:

Relational Model	SQL
relation	table
tuple	row
attribute	column

- *Syntax notes*:
  - Some interfaces require each statement to end with a semicolon
  - SQL is not case-sensitive

SQL DDL

Creating Tables

```
CREATE TABLE <tablename> (
   <colname> <datatype> [<constraint>],
   …,
   [<constraint>],
   …
);
```

- Data types: integer, decimal, number, varchar, char, etc.
- Constraints: not null, primary key, foreign key, unique, etc.

Creating Tables (Example)

```
CREATE TABLE WORKS_ON (
   ESSN     integer,
   PNO      integer,
   HOURS    decimal(3,1),

   constraint pk_workson
     primary key (ESSN, PNO),

   constraint  fk_works_emp
     FOREIGN KEY (ESSN) references EMPLOYEE(SSN),

   constraint  fk_works_proj
     FOREIGN KEY (PNO) references PROJECT(PNUMBER)
 );
```


Modifying Table Definitions

- Add, delete, and modify columns and constraints

```
ALTER TABLE EMPLOYEE ADD COLUMN JOB VARCHAR(12);
ALTER TABLE EMPLOYEE DROP COLUMN ADDRESS CASCADE;

ALTER TABLE WORKS_ON DROP FOREIGN KEY fk_works_emp;

ALTER TABLE WORKS_ON ADD CONSTRAINT fk_works_emp
      FOREIGN KEY (ESSN) REFERENCES EMPLOYEE(SSN);
```

- Delete a table and its definition

```
DROP TABLE EMPLOYEE;
```

SQL Queries

Basic SQL Retrieval Queries

- All retrievals use SELECT statement:

```
SELECT  <return list>
FROM    <table list>
[ WHERE <condition> ] ;
```

where

`<return list>` is a list of column names (or expressions) whose values are to be retrieved

`<table list>` is a list of table names required to process the query

`<condition>` is a Boolean expression that identifies the tuples to be retrieved by the query (if no WHERE clause, all tuples to be retrieved)

Example

```
SELECT title, year, genre
FROM Film
WHERE director = 'Steven Spielberg'
```

1. Start with the relation named in the FROM clause
2. Consider each tuple one after the other, eliminating those that do not satisfy the WHERE clause
3. For each remaining tuple, create a return tuple with columns for each expression (column name) in the SELECT clause

Film

title	genre	year	director	minutes	budget	gross
The Company Men	drama	2010	John Wells	104	15,000,000	4,439,063
Lincoln	biography	2012	Steven Spielberg	150	65,000,000	181,408,467
War Horse	drama	2011	Steven Spielberg	146	66,000,000	79,883,359
Argo	drama	2012	Ben Affleck	120	44,500,000	136,179,251

All Attributes

- List all information about the employees of department 5.

SELECT *FNAME, MINIT, LNAME, SSN, BDATE, ADDRESS, SEX, SALARY, SUPERSSN, DNO*
FROM *EMPLOYEE*
WHERE *DNO = 5*;

or

SELECT *
FROM *EMPLOYEE*
WHERE *DNO = 5*;

Other comparison operators that we may use: =, <>, >, =>, etc.

(assuming that table *EMPLOYEE* has only the attributes *FNAME, MINIT, LNAME, SSN, BDATE, ADDRESS, SEX, SALARY, SUPERSSN, DNO)*

Logical Operators

- List the last name, birth date and address for all employees whose name is `Alicia J. Zelaya‘

(assuming that table *EMPLOYEE* has the attributes *FNAME, MINIT, LNAME, BDATE, ADDRESS, etc.)*

SELECT *LNAME, BDATE, ADDRESS*
FROM *EMPLOYEE*
WHERE *FNAME = ‘Alicia’*
AND *MINIT = ‘J’*
AND *LNAME = ‘Zelaya’*;

Other logical operators that we may use: and, or, not

Pattern Matching in Strings

- List the birth date and address for all employees whose last name contains the substring ‘aya’

SELECT *BDATE, ADDRESS*
FROM *EMPLOYEE*
WHERE *LNAME* **LIKE** ‘%aya%’;

LIKE *comparison operator*
% *represents 0 or more characters*
_ represents a single character

NULLs

- List all employees that do not have a boss.

SELECT *FNAME, LNAME*
FROM *EMPLOYEE*
WHERE *SUPERSSN* ***IS NULL*****;**

'SUPERSSN = NULL' and
'SUPERSSN <> NULL'
will not return any matching tuples,
because NULL is **incomparable** to
any value, including another NULL

Tables as Sets

SALARY
30000
40000
25000
43000
38000
25000
25000
55000

- List all salaries:

  SELECT *SALARY*
  FROM *EMPLOYEE*;

- SQL considers a table as a multi-set (bag), i.e. tuples may occur more than once in a table
  - This is different from the relational data model
- Why?
  - Removing duplicates is expensive
  - User may want information about duplicates
  - Aggregation operators (e.g., sum)

Removing Duplicates

- List all salaries:

  SELECT *SALARY*
  FROM *EMPLOYEE*;

SALARY
30000
40000
25000
43000
38000
25000
25000
55000

- List all salaries without duplicates

  SELECT DISTINCT *SALARY*
  FROM *EMPLOYEE*;

SALARY
30000
40000
25000
43000
38000
55000

Set Operations

Duplicate tuples are removed.

Queries can be combined by set operations: UNION, INTERSECT, EXCEPT (*MySQL only supports UNION*)

- Example: retrieve the first names of all people in the database.

SELECT *FNAME* **FROM** *EMPLOYEE*
UNION
SELECT *DEPENDENT_NAME* **FROM** *DEPENDENT*;

- Example: Which department managers have dependents? Show their SSN.

SELECT *MGRSSN* **FROM** *DEPARTMENT*
INTERSECT
SELECT *ESSN* **FROM** *DEPENDENT*;

Join: Cartesian Product

- List all employees and the names of their departments.

SELECT *LNAME, DNAME*
FROM *EMPLOYEE, DEPARTMENT*;

EMPLOYEE

LNAME	DNO
Smith	5
Wong	5
Zelaya	4
Wallace	4
Narayan	5
English	5
Jabbar	4
Borg	1

DEPARTMENT

DNAME	DNUM
Research	5
Administration	4
Headquarters	1

LNAME	DNAME
Smith	Research
Wong	Research
Zelaya	Research
Wallace	Research
Narayan	Research
English	Research
Jabbar	Research
Borg	Research
Smith	Administration
Wong	Administration
Zelaya	Administration
Wallace	Administration
Narayan	Administration
English	Administration
Jabbar	Administration
Borg	Administration
Smith	Headquarters
Wong	Headquarters
Zelaya	Headquarters
Wallace	Headquarters
Narayan	Headquarters
English	Headquarters
Jabbar	Headquarters
Borg	Headquarters

Join: Equijoin

- List all employees and the names of their departments.

SELECT *LNAME, DNAME*
FROM *EMPLOYEE, DEPARTMENT*
WHERE *DNO = DNUM*;

Equijoin

EMPLOYEE

LNAME	DNO
Smith	5
Wong	5
Zelaya	4
Wallace	4
Narayan	5
English	5
Jabbar	4
Borg	1

DEPARTMENT

DNAME	DNUM
Research	5
Administration	4
Headquarters	1

Foreign key in EMPLOYEE

Primary key in DEPARTMENT

LNAME	DNO	DNAME	DNUM
Smith	5	*Research*	5
Wong	5	*Research*	5
Zelaya	4	Research	5
Wallace	4	Research	5
Narayan	5	*Research*	5
English	5	*Research*	5
Jabbar	4	Research	5
Borg	1	Research	5
Smith	5	Administration	4
Wong	5	Administration	4
Zelaya	4	*Administration*	4
Wallace	4	*Administration*	4
Narayan	5	Administration	4
English	5	Administration	4
Jabbar	4	*Administration*	4
Borg	1	Administration	4
Smith	5	Headquarters	1
Wong	5	Headquarters	1
Zelaya	4	Headquarters	1
Wallace	4	Headquarters	1
Narayan	5	Headquarters	1
English	5	Headquarters	1
Jabbar	4	Headquarters	1
Borg	1	*Headquarters*	1

Cartesian product

Inner Join

- List all employees and the names of their departments.

SELECT *LNAME, DNAME*
FROM *EMPLOYEE, DEPARTMENT*
WHERE *DNO = DNUM*;

As an alternative, the join condition may be given in the FROM clause by using the keywords INNER JOIN and ON as follows:

SELECT *LNAME, DNAME*
FROM *EMPLOYEE* **INNER JOIN** *DEPARTMENT* **ON** *DNO = DNUM*;

Ambiguous Names: Aliasing

- What if the same attribute name is used in different relations ?
  - No alias

```
SELECT NAME, NAME
FROM EMPLOYEE, DEPARTMENT
WHERE DNO=DNUM;
```

  - Whole name

```
SELECT EMPLOYEE.NAME, DEPARTMENT.NAME
FROM EMPLOYEE, DEPARTMENT
WHERE EMPLOYEE.DNO=DEPARTMENT.DNUM;
```

  - Alias

```
SELECT E.NAME, D.NAME
FROM EMPLOYEE E, DEPARTMENT D
WHERE E.DNO=D.DNUM;
```


Self-Join

- List the last name for all employees together with the last names of their bosses

SELECT *E.LNAME* **AS** *"Employee"*,
S.LNAME **AS** *"Boss"*
FROM *EMPLOYEE E, EMPLOYEE S*
WHERE *E.SUPERSSN = S.SSN*;

Employee	Boss
Smith	Wong
Wong	Borg
Zelaya	Wallace
Wallace	Borg
Narayan	Wong
English	Wong
Jabbar	Wallace

Self-Joins may also be written as Inner Join

- List the last name for all employees together with the last names of their bosses

SELECT *E.LNAME* **AS** *"Employee"*,
S.LNAME **AS** *"Boss"*
FROM *EMPLOYEE E, EMPLOYEE S*
WHERE *E.SUPERSSN = S.SSN*;

Employee	Boss
Smith	Wong
Wong	Borg
Zelaya	Wallace
Wallace	Borg
Narayan	Wong
English	Wong
Jabbar	Wallace

SELECT *E.LNAME "Employee",*
S.LNAME "Boss"
FROM *EMPLOYEE E* **INNER JOIN** *EMPLOYEE S*
ON *E.SUPERSSN = S.SSN*;

Left Outer Join

- Every tuple in left table appears in result
- If there exist matching tuples in right table, works like inner join
- If no matching tuple in right table, one tuple in result with left tuple values padded with NULL values for columns of right table

Customer

custid	name	address	phone
1205	Lee	633 S. First	555-1219
3122	Willis	41 King	555-9876
2134	Smith	213 Main	555-1234
1697	Ng	5 Queen N.	555-0025
3982	Harrison	808 Main	555-4829

Sale

saleid	date	custid
A17	5 Dec	3122
B823	5 Dec	1697
B219	9 Dec	3122
C41	15 Dec	1205
X00	23 Dec	NULL

```
SELECT *
FROM Customer LEFT JOIN Sale ON Customer.custid = Sale.custid
```

Customer.custid	name	address	phone	saleid	date	Sale.custid
1205	Lee	633 S. First	555-1219	C41	15 Dec	1205
3122	Willis	41 King	555-9876	A17	5 Dec	3122
3122	Willis	41 King	555-9876	B219	9 Dec	3122
2134	Smith	213 Main	555-1234	NULL	NULL	NULL
1697	Ng	5 Queen N.	555-0025	B823	5 Dec	1697
3982	Harrison	808 Main	555-4829	NULL	NULL	NULL

Joins Revisited

A

A1	A2
100	A
null	B
300	C
null	D

B

B1	B2
100	W
200	X
null	Y
null	Z

Cartesian product
SELECT * FROM a, b;

A2	A1	B1	B2
A	100	100	W
B	null	100	W
C	300	100	W
D	null	100	W
A	100	200	X
B	null	200	X
C	300	200	X
D	null	200	X
A	100	null	Y
B	null	null	Y
C	300	null	Y
D	null	null	Y
A	100	null	Z
B	null	null	Z
C	300	null	Z
D	null	null	Z

Equijoin, inner join
SELECT * from A, B WHERE A1=B1;

A2	A1	B1	B2
A	100	100	W

Thetajoin
SELECT * from A, B WHERE A1>B1;

A2	A1	B1	B2
C	300	100	W
C	300	200	X

Joins Revisited (cont'd)

Right outer join

SELECT * FROM A RIGHT JOIN B on A1=B1;

A2	A1	B1	B2
A	100	100	W
null	null	200	X
null	null	null	Y
null	null	null	Z

A

A1	A2
100	A
null	B
300	C
null	D

B

B1	B2
100	W
200	X
null	Y
null	Z

Left outer join

SELECT * FROM A LEFT JOIN B on A1=B1;

A2	A1	B1	B2
A	100	100	W
C	300	null	null
B	null	null	null
D	null	null	null

Full outer join ("union" of right+left)

SELECT * FROM A FULL JOIN b on A1=B1;

A2	A1	B1	B2
A	100	100	W
null	null	200	X
null	null	null	Y
null	null	null	Z
C	300	null	null
B	null	null	null
D	null	null	null

Subqueries

- List all employees that do not have any project assignment with more than 10 hours
  - ~~**SELECT** *LNAME* **FROM** *EMPLOYEE*, *WORKS_ON* **WHERE** *SSN = ESSN* **AND** *HOURS <= 10.0*;~~

SELECT *LNAME*
FROM *EMPLOYEE*
WHERE *SSN* **NOT IN** (**SELECT** *ESSN* **FROM** *WORKS_ON*
WHERE *HOURS > 10.0*);

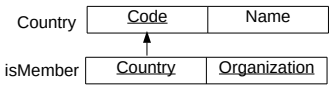
{>, >=, <, <=, <>} + {ANY, SOME, ALL}

Or, as a *correlated* subquery

SELECT *LNAME*
FROM *EMPLOYEE*
WHERE **NOT EXISTS** (**SELECT** * **FROM** WORKS_ON
WHERE *SSN = ESSN* **AND** *HOURS > 10.0*);

EXISTS

Quiz



- Consider the following two SQL queries:

```
SELECT Name
FROM Country
WHERE Code IN ( SELECT Country
                FROM IsMember
                WHERE Organization = 'EU' );

SELECT Name
FROM Country, IsMember
WHERE Code = Country
  AND Organization = 'EU';
```

- Are these queries equivalent?

(yes) (no)

Additional Features

Extended SELECT Syntax

SELECT *<attribute-list and function-list>*
FROM *<table-list>*
[**WHERE** *<condition>*]
[**GROUP BY** *<grouping attribute-list>*]
[**HAVING** *<group condition>*]
[**ORDER BY** *<attribute-list>*];

Aggregate Functions

- Used to accumulate information from multiple tuples, forming a single-tuple summary
- Built-in aggregate functions: `SUM`, `MAX`, `MIN`, `AVG`, `COUNT`
- Example: *What is the average budget of all movies ?*

```
SELECT AVG(budget) FROM Film;
```

- Used in the `SELECT` clause and the `HAVING` clause
  - Hence, cannot be used in the `WHERE` clause!
- NULL values are not considered in the computations; e.g.,:

	50	50
	100	100
	NULL	0
AVG:	75	50

Aggregate Functions (cont'd)

- Example
  How many movies were directed by Steven Spielberg?

```
SELECT COUNT(*) FROM Film
WHERE director='Steven Spielberg';
```

  - All tuples in the result are counted, *with duplicates*!
    - i.e., `COUNT(title)` or `COUNT(director)` give same result
  - To explicitly ignore duplicates, use the DISTINCT
    - e.g., `COUNT(DISTINCT year)` would include each year only once

Grouping Before Aggregation

- How can we answer a query such as
  "*How many films were directed by each director after 2001?*"
- Need to produce a result with one tuple per director
  1. Partition relation into subsets based on **grouping column(s)**
  2. Apply aggregate function to each such group independently
  3. Produce one tuple per group

Grouping Before Aggregation

- How can we answer a query such as
  "*How many films were directed by each director after 2001?*"
- **`GROUP BY`** clause to specify grouping attributes

```
SELECT director, COUNT(*)
FROM Film
WHERE year > 2001
GROUP BY director;
```

- **Important**: Every element in `SELECT` clause must be a grouping column or an aggregation function
  - e.g., `SELECT director, year, COUNT(*)` would not be allowed (in the query above) unless *also* grouping by year: i.e., `GROUP BY director, year`

Filtering Out Whole Groups

- After partitioning into groups, whole groups can be discarded by a HAVING clause, which specifies a condition on the groups

SELECT *DNO, **COUNT**(*), **AVG**(SALARY)*
FROM *EMPLOYEE*
GROUP BY *DNO*
HAVING COUNT(*) > 2;

- HAVING clause cannot reference individual tuples within a group
  - Instead, can reference grouping column(s) and aggregates only
- Contrast WHERE clause to HAVING clause

Note: As for aggregation, no GROUP BY clause means relation treated as one group

Sorting Query Results

- Show the department names and their locations in alphabetical order

SELECT *DNAME, DLOCATION*
FROM *DEPARTMENT D, DEPT_LOCATIONS DL*
WHERE *D.DNUMBER = DL.DNUMBER*
ORDER BY *DNAME **ASC**, DLOCATION **DESC***;

DNAME	*DLOCATION*
Administration	Stafford
Headquarters	Houston
Research	Sugarland
Research	Houston
Research	Bellaire

SQL Data Manipulation

Inserting Data

INSERT INTO <*table*> **(**<*attr*>,…**) VALUES (** <*val*>, …**) ;**
INSERT INTO <*table*> **(**<*attr*>, …**)** <*subquery*> **;**

- Example: Store information about how many hours an employee works for the project '1' into WORKS_ON

INSERT INTO WORKS_ON **VALUES** (123456789, 1, 32.5);

Integrity constraint!
Referential integrity constraint!

Updating Data

UPDATE <*table*> **SET** <*attr*> = <*val*> **,…**
WHERE <condition> **;**
UPDATE <table> **SET (**<attr>, ….**) = (** <subquery> **)**
WHERE <condition> **;**

Integrity constraint!
Referential integrity constraint!

- Example: Give all employees in the 'Research' department a 10% raise in salary

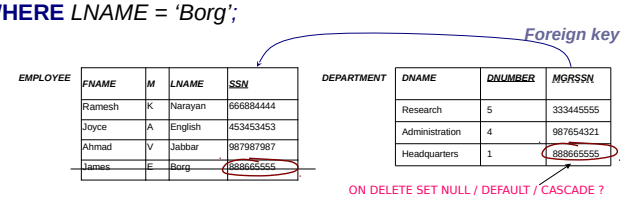
UPDATE *EMPLOYEE*
SET *SALARY = SALARY*1.1*
WHERE *DNO IN* (**SELECT** *DNUMBER*
FROM *DEPARTMENT*
WHERE *DNAME = 'Research'*);

Deleting Data

DELETE FROM <*table*> **WHERE** <*condition*> **;**

- Delete the employees having the last name 'Borg' from the EMPLOYEE table.

DELETE FROM *EMPLOYEE*
WHERE *LNAME = 'Borg';*



Referential integrity constraint!

Views

What are Views?

- A **virtual** table **derived** from other (possibly virtual) tables, i.e. always up-to-date

CREATE VIEW *dept_view* **AS**
SELECT *DNO, COUNT(*)* **AS** *C, AVG(SALARY)* **AS** *S*
FROM *EMPLOYEE*
GROUP BY *DNO;*

- Why?
  - Simplify query commands
  - Provide data security
  - Enhance programming productivity

www.liu.se

LINKÖPING UNIVERSITY