Database Technology

Topic 3: SQL

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Structured Query Language

- Considered one of the major reasons for the commercial success of relational DBMSs such as IBM DB2, Oracle, MySQL, etc.
- **Declarative** language (what data to get, not how)
- Statements for data definitions, queries, and updates
  - both a *data definition language* (DDL) and a *data manipulation language* (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

Defining SQL Databases

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

Retrieving data from an SQL database

Basic SQL Retrieval Queries

- All retrievals return a result in the form of a table
- The requested result table is described using a SELECT statement

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

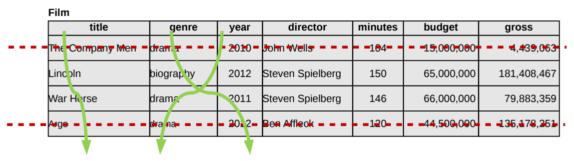
where

`<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
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Argo	drama	2012	Ben Affleck	120	44,500,000	135,178,251

All Attributes

- List all information about the employees of department 5.

SELECT *Fname, Minit, Lname, Ssn, Bdate, Address, Sex, Salary, Super_ssn, Dno*
FROM *EMPLOYEE*
WHERE *Dno* = *5*;

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

or

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

all attributes of the table (in the order in which they occurred in the corresponding CREATE TABLE statements)

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno

Logical Operators

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

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

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno

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*

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno

NULLs

- List all employees that do not have a supervisor.

SELECT *Fname, Lname*
FROM *EMPLOYEE*
WHERE *Super_ssn* ***IS NULL*****;**

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

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno

Tables as Sets

- 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)

SALARY
30000
40000
25000
43000
38000
25000
25000
55000

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***;**

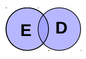
SALARY
30000
40000
25000
43000
38000
55000

Set Operations

Duplicate tuples are removed.

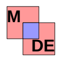
Queries can be combined by set operations: UNION, INTERSECT, EXCEPT (*MySQL only supports UNION*)

- 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

Employee

EmpName	Dept
Jennifer	5
Paul	4

Department

DeptName	DNO
Research	5
Administration	4

- List all employees and the names of their departments
  SELECT *EmpName, DeptName*
  FROM *Employee, Department***;**
- Intermediate result before SELECT:

EmpName	Dept	DeptName	DNO
Jennifer	5	Research	5
Jennifer	5	Administration	4
Paul	4	Research	5
Paul	4	Administration	4

- Result:

EmpName	DeptName
Jennifer	Research
Jennifer	Administration
Paul	Research
Paul	Administration

Join: Equijoin

Employee

EmpName	Dept
Jennifer	5
Paul	4

Department

DeptName	DNO
Research	5
Administration	4

- List all employees and the names of their departments
  SELECT *EmpName, DeptName*
  FROM *Employee, Department*
  WHERE *Dept = DNO* **;**
- Intermediate result before SELECT:

EmpName	Dept	DeptName	DNO
Jennifer	5	Research	5
~~Jennifer~~	~~5~~	~~Administration~~	~~4~~
~~Paul~~	~~4~~	~~Research~~	~~5~~
Paul	4	Administration	4

- Result:

EmpName	DeptName
Jennifer	Research
Paul	Administration

Inner Join

Employee

EmpName	Dept
Jennifer	5
Paul	4

Department

DeptName	DNO
Research	5
Administration	4

- List all employees and the names of their departments

  SELECT *EmpName, DeptName*
  FROM *Employee, Department*
  WHERE *Dept = DNO* **;**

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

  SELECT *EmpName, DeptName*
  FROM *Employee* **INNER JOIN** *Department* **ON** *Dept = DNO* **;**

Ambiguous Names: Aliasing

Employee

Name	Dept
Jennifer	5
Paul	4

Department

Name	DNO
Research	5
Administration	4

- What if the same attribute name is used in different relations?

  ~~**SELECT** *Name, Name*~~
  ~~**FROM** *Employee, Department*~~
  ~~**WHERE** *Dept = DNO* **;**~~

  SELECT *Employee.Name, Department.Name*
  FROM *Employee, Department*
  WHERE *Dept = DNO* **;**

  SELECT *E.Name, D.Name*
  FROM *Employee* **AS** *E, Department* **AS** *D*
  WHERE *Dept = DNO* **;**

alias

Self-Join

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

SELECT *E.Lname* **AS** *"Employee",*
S.Lname **AS** *"Boss"*
FROM *EMPLOYEE E, EMPLOYEE S*
WHERE *E.Super_ssn = S.Ssn*;

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno

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.Super_ssn = S.Ssn*;

SELECT *E.Lname "Employee",*
S.Lname "Boss"
FROM *EMPLOYEE E* **INNER JOIN** *EMPLOYEE S*
ON *E.Super_ssn = 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)

A

A1	A2
100	A
null	B
300	C
null	D

B

B1	B2
100	W
200	X
null	Y
null	Z

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

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 (Motivation)

EMPLOYEE

SSN	FNAME	LNAME
20	Jennifer	Li
7	Paul	Smith

WORKS_ON

ESSN	PRJ	HOURS
20	A	8
20	B	11
7	A	7

- 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* ;

- Intermediate result after join:

SSN	FNAME	LNAME	ESSN	PRJ	HOURS
20	Jennifer	Li	20	A	8
20	Jennifer	Li	20	B	11
7	Paul	Smith	7	A	7

Subqueries (Motivation)

EMPLOYEE

SSN	FNAME	LNAME
20	Jennifer	Li
7	Paul	Smith

WORKS_ON

ESSN	PRJ	HOURS
20	A	8
20	B	11
7	A	7

- 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* ;~~

- Intermediate result after filtering based on HOURS <= 10

not expected

SSN	FNAME	LNAME	ESSN	PRJ	HOURS
20	Jennifer	Li	20	A	8
7	Paul	Smith	7	A	7

Subqueries

EMPLOYEE

SSN	FNAME	LNAME
20	Jennifer	Li
7	Paul	Smith

WORKS_ON

ESSN	PRJ	HOURS
20	A	8
20	B	11
7	A	7

- List all employees that do not have any project assignment with more than 10 hours

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

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

- Result of the subquery:

ESSN
20

- Result of the main query:

LNAME
Smith

Correlated Subqueries

EMPLOYEE

SSN	FNAME	LNAME
20	Jennifer	Li
7	Paul	Smith

WORKS_ON

ESSN	PRJ	HOURS
20	A	8
20	B	11
7	A	7

- List all employees that do not have any project assignment with more than 10 hours

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

EXISTS

- Result of the correlated subquery...
  - for the first EMPLOYEE tuple:

ESSN	PRJ	HOURS
20	B	11

  - for the second EMPLOYEE tuple:

ESSN	PRJ	HOURS

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;
```

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	135,178,251

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

Film

title	genre	year	director	minutes	budget	gross
The Company Men	drama	2010	John Wells	104	15,000,000	4,439,063
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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

Film

title	genre	year	director	minutes	budget	gross
The Company Men	drama	2010	John Wells	104	15,000,000	4,439,063
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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;
```

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
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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';*

Foreign key

EMPLOYEE

FNAME	*M*	*LNAME*	*SSN*
Ramesh	K	Narayan	666884444
Joyce	A	English	453453453
Ahmad	V	Jabbar	987987987
~~James~~	~~E~~	~~Borg~~	~~888665555~~

DEPARTMENT

DNAME	*DNUMBER*	*MGRSSN*
Research	5	333445555
Administration	4	987654321
Headquarters	1	888665555

ON DELETE SET NULL / DEFAULT / CASCADE ?

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

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