SQL – Data Manipulation Language

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Based on Jennifer Widom slides

Agenda

Introduction

Basic SQL Statement

Table Variables and Set Operators

Subqueries in WHERE clauses

Subqueries in FROM and SELECT clauses

The JOIN family of operators

Aggregation

Null values

Data Modification statements

SQL

Stands for **S**tructured **Q**uery **L**anguage

Pronounced “sequel”

Supported by all major commercial database systems

Standardized – many features over time

Interactive via GUI or prompt, or embedded in programs

Declarative, based on relational algebra

SQL History

1970 “A Relational Model of Data for Large Shared Data Banks” by Edgar Codd

Early **70's** SEQUEL Developed at IBM by Donald Chamberlin e Raymond Boyce

1979 First commercial version by Relational Software (now Oracle)

1986 SQL-86 and SQL-87. Ratified by ANSI and ISO

1989 SQL-891992 SQL-92. Also known as SQL2

1999 SQL:1999. Also known as SQL3. Includes regular expressions, recursive queries, triggers, non-scalar data types and some object-oriented expressions

2003 SQL:2003 XML support and auto-generated values

2006 SQL:2006 XQuery support

2008 SQL:2008

2011 SQL:2011

SQL is a ...

Data Definition Language (DDL)

Define relational schemata

Create/alter/delete tables and their attributes

Data Manipulation Language (DML)

Insert/delete/modify tuples in tables

Query one or more tables

Standard

Many standards out there

Database management systems implement something similar, but not identical to the standard for SQL

These slides will try to adhere to the standard as much as possible

- Primarily the SQL2 standard and some constructs from the SQL3 standard

Sometimes we'll talk specifically about SQL as understood by SQLite

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~~Introduction~~

Basic SELECT Statement

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The Basic SELECT Statement (SFW)

SELECT $A_1, A_2, \ldots, A_n$ → What to return

FROM $R_1, R_2, \ldots, R_m$ → Identifies the relations to query

WHERE condition → Combines and filters relations

Produto cartesiano

What's the equivalent in Relational Algebra?

$$\pi_{A_1,\ldots,An}\left(\sigma_{condition}\left(R_1\times \ldots \times Rm\right)\right)$$

The result is a relation with the schema $A_1, A_2, \ldots, A_n$

SQL is compositional

Relational query languages are compositional

When a query is run over relations, the result is a relation

- The schema of the obtained relation is the set of attributes that are returned

The output of one query can be used as the input to another (nesting)

This is extremely powerful

College Admission Database

Apply

sID	cName	major	dec
123	Stanford	CS	Y
123	Stanford	EE	N
123	Berkeley	CS	Y
123	Cornell	EE	Y
234	Berkeley	biology	N
345	MIT	bioengineering	Y
345	Cornell	bioengineering	N
345	Cornell	CS	Y
345	Cornell	EE	N
678	Stanford	history	Y
987	Stanford	CS	Y
987	Berkeley	CS	Y
876	Stanford	CS	Y
876	MIT	biology	Y
876	MIT	marine biology	N
765	Stanford	history	Y
765	Cornell	history	N
765	Cornell	psychology	Y
543	MIT	CS	N

College

cName	state	enr
Stanford	CA	15000
Berkeley	CA	36000
MIT	MA	10000
Cornell	NY	21000

Student

sID	sName	GPA	HS
123	Amy	3.9	1000
234	Bob	3.6	1500
345	Craig	3.5	500
456	Doris	3.9	1000
567	Edward	2.9	2000
678	Fay	3.8	200
789	Gary	3.4	800
987	Helen	3.7	800
876	Irene	3.9	400
765	Jay	2.9	1500
654	Amy	3.9	1000
543	Craig	3.4	2000

SQL query with one relation

```
SELECT  sID, sName, GPA

FROM   Student

WHERE GPA > 3.6;
```

Interrogação com uma única relação

este atributo não tem de estar no resultado

sID	sName	GPA
123	Amy	3.9
456	Doris	3.9
678	Fay	3.8
987	Helen	3.7
876	Irene	3.9
654	Amy	3.9

Not necessary to include GPA in the result even if we filter on the GPA

College(cName, state, enr)

Student(sID, sName, GPA, sizeHS)

Apply(sID, cName, major, decision)

A Few Details

SQL commands are case insensitive → O mesmo para os nomes das tabelas

Same: SELECT, Select, select

Same: Student, student

Values are not → Cuidado

Different: ‘Stanford’, ‘stanford’

→ Use single quotes for constants

‘abc’ - yes

“abc” - no

SQL query combining two relations

```
SELECT  sName, major
FROM   Student, Apply
WHERE Student.sID=Apply.sID;
```

This would happen automatically in a natural join of RA

What does it computes?

estudantes que se candidataram

Devido ao SQL ser baseado em múltiplos sets (Bags)

Duplicate values

College(cName, state, enr)

Student(sID, sName, GPA, sizeHS)

Apply(sID, cName, major, decision)

sName	major
Amy	CS
Amy	EE
Amy	CS
Amy	EE
Bob	biology
Craig	bioengineering
Craig	bioengineering
Craig	CS
Craig	EE
Fay	history
Helen	CS
Helen	CS
Irene	CS
Irene	biology
Irene	marine biology
Jay	history
Jay	history
Jay	psychology
Craig	CS

SQL query excluding duplicate values

Para remover conjuntos (sName, major) duplicados

```
SELECT DISTINCT sName, major
FROM   Student, Apply
WHERE Student.sID=Apply.sID;
```

sName	major
Amy	CS
Amy	EE
Bob	biology
Craig	bioengineering
Craig	CS
Craig	EE
Fay	history
Helen	CS
Irene	CS
Irene	biology
Irene	marine biology
Jay	history
Jay	psychology

No duplicate values

College(cName, state, enr)

Student(sID, sName, GPA, sizeHS)

Apply(sID, cName, major, decision)

Another SQL query combining two relations

Podemos juntar condições

SELECT sName, GPA, decision

FROM Student, Apply

WHERE Student.sID=Apply.sID AND sizeHS<1000 AND
major=‘CS’ AND cName=‘Stanford’;

What does it compute?

sName	GPA	decision
Helen	3.7	Y
Irene	3.9	N

College(cName, state, enr)

Student(sID, sName, GPA, sizeHS)

Apply(sID, cName, major, decision)

One more SQL query combining two relations

```
SELECT cName
FROM   College, Apply
WHERE  College.cName=Apply.cName AND
       enr>20000 AND major=‘CS’;
```

→ Apenas 1 atributo → Vai dar ERRO, pois não especificamos de que tabela é que vem o cName, tal como aqui ⊛

→ Duas tabelas

⊛ College.cName

SQLite Error: ambiguous column name: cName

What does it compute?

How can we correct it?

College(cName, state, enr)

Student(sID, sName, GPA, sizeHS)

Apply(sID, cName, major, decision)

One more SQL query combining two relations

```
SELECT College.cName
FROM   College, Apply
WHERE College.cName=Apply.cName AND
           enr>20000 AND major=‘CS’;
```

cName
Berkeley
Berkeley
Cornell

utilizar DISTINCT

How can we eliminate duplicates?

College(cName, state, enr)

Student(sID, sName, GPA, sizeHS)

Apply(sID, cName, major, decision)

Order of the results

SQL is based on an unordered model

The order of the results may change each time we run a query

We can ask for a result to be sorted, in ascending or descending order, by an attribute or set of attributes

ORDER BY <attributes> ASC

ORDER BY <attributes> DESC

Ordering is ascending, unless you specify the DESC keyword

College(cName, state, enr)

Student(sID, sName, GPA, sizeHS)

Apply(sID, cName, major, decision)

Order of the results

```
SELECT Student.sID, sName, GPA,
         Apply.cName, enr
FROM   Student, College, Apply
WHERE Student.sID=Apply.sID AND
         Apply.cName=College.cName;
```

```
SELECT Student.sID, sName, GPA,
         Apply.cName, enr
FROM   Student, College, Apply
WHERE Student.sID=Apply.sID AND
         Apply.cName=College.cName
ORDER BY GPA DESC;
```

sID	sName	GPA	cName	enr
123	Amy	3.9	Stanford	15000
123	Amy	3.9	Stanford	15000
123	Amy	3.9	Berkeley	36000
123	Amy	3.9	Cornell	21000
234	Bob	3.6	Berkeley	36000
345	Craig	3.5	MIT	10000
345	Craig	3.5	Cornell	21000
345	Craig	3,5	Cornell	21000
345	Craig	3.5	Cornell	21000
678	Fay	3.8	Stanford	15000

Muda → a ordem

sID	sName	GPA	cName	enr
123	Amy	3.9	Stanford	15000
123	Amy	3.9	Stanford	15000
123	Amy	3.9	Berkeley	36000
123	Amy	3.9	Cornell	21000
876	Irene	3.9	Stanford	15000
876	Irene	3.9	MIT	10000
876	Irene	3.9	MIT	10000
678	Fay	3.8	Stanford	15000
987	Helen	3.7	Stanford	15000
987	Helen	3.7	Berkeley	36000

Order of the results

```
SELECT Student.sID, sName, GPA, Apply.cName, enr
FROM   Student, College, Apply
WHERE Student.sID=Apply.sID AND Apply.cName=College.cName
ORDER BY GPA DESC, enr;
```

Primeiro ordena por GPA e depois pois enr

sID	sName	GPA	cName	enr
876	Irene	3.9	MIT	10000
876	Irene	3.9	MIT	10000
123	Amy	3.9	Stanford	15000
123	Amy	3.9	Stanford	15000
876	Irene	3.9	Stanford	15000
123	Amy	3.9	Cornell	21000
123	Amy	3.9	Berkeley	36000
678	Fay	3.8	Stanford	15000
987	Helen	3.7	Stanford	15000
987	Helen	3.7	Berkeley	36000

Descending GPA as primary sort order and, within each of those, ascending enrollment

College(cName, state, enr)

Student(sID, sName, GPA, sizeHS)

Apply(sID, cName, major, decision)

Like operator: pattern matching on strings

Built-in operator that allows string matching on attribute values

SELECT sID, major

FROM Apply

WHERE major like '%bio%';

operador para comparar strings

curso tem de ter bio

Match any major containing bio

sID	major
234	biology
345	bioengineering
345	bioengineering
876	biology
876	marine biology

% = any sequence of characters

_ = any single character

College(cName, state, enr)

Student(sID, sName, GPA, sizeHS)

Apply(sID, cName, major, decision)

Selecting all attributes

```
SELECT *
FROM  Apply
WHERE major like ‘%bio%’;
```

→ Selecionar todos os atributos

sID	cName	major	decision
234	Berkeley	biology	N
345	MIT	bioengineering	Y
345	Cornell	bioengineering	N
876	MIT	biology	Y
876	MIT	marine biology	N

College(cName, state, enr)

Student(sID, sName, GPA, sizeHS)

Apply(sID, cName, major, decision)

Arithmetic within SQL clauses

podemos ainda colocar cálculos aritméticos

```
SELECT sID, sName, GPA, HS, GPA*(HS/1000)
FROM   Student;
```

sID	sName	GPA	HS	GPA*(HS/1000)
123	Amy	3.9	1000	3.9
234	Bob	3.6	1500	5.4
345	Craig	3.5	500	1.75
456	Doris	3.9	1000	3.9
567	Edward	2.9	2000	5.8
678	Fay	3.8	200	0.76
789	Gary	3.4	800	2.72
987	Helen	3.7	800	2.96
876	Irene	3.9	400	1.56
765	Jay	2.9	1500	4.35
654	Amy	3.9	1000	3.9
543	Craig	3.4	2000	6.8

Boosts GPA if student is from a big high school and reduces it, if he is from a small one

→ Can we improve this result?

College(<u>cName</u>, state, enr)

Student(<u>sID</u>, sName, GPA, sizeHS)

Apply(<u>sID</u>, <u>cName</u>, <u>major</u>, decision)

Renaming columns

```
SELECT sID, sName, GPA, HS, GPA*(HS/1000) AS scaledGPA
FROM   Student;
```

permite renomear os atributos

sID	sName	GPA	HS	scaledGPA
123	Amy	3.9	1000	3.9
234	Bob	3.6	1500	5.4
345	Craig	3.5	500	1.75
456	Doris	3.9	1000	3.9
567	Edward	2.9	2000	5.8
678	Fay	3.8	200	0.76
789	Gary	3.4	800	2.72
987	Helen	3.7	800	2.96
876	Irene	3.9	400	1.56
765	Jay	2.9	1500	4.35
654	Amy	3.9	1000	3.9
543	Craig	3.4	2000	6.8

College(cName, state, enr)

Student(sID, sName, GPA, sizeHS)

Apply(sID, cName, major, decision)

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Table variables → Usadas nos froms para ter interrogações menos verbosas Para Renomear

Used in the FROM clause for two purposes

- Make queries more readable
- Rename relations when we have two instances of the same relation

```
SELECT Student.sID, sName, GPA, Apply.cName, enr
FROM   Student, College, Apply
WHERE Student.sID=Apply.sID AND Apply.cName=College.cName;
```

```
SELECT S.sID, sName, GPA, A.cName, enr
FROM   Student S, College C, Apply A
WHERE S.sID=A.sID AND A.cName=C.cName;
```

→ Not changing the result, only making the query more readable

Table variables

How to list the pairs of students who have the same GPA?

Student(sID,sName,GPA,sizeHS)

SELECT S1.sID, S1.sName, S1.GPA, S2.sID, S2.sName, S2.GPA

FROM Student S1, Student S2 → para desambiguar

WHERE S1.GPA=S2.GPA;

Mesmo GPA

sID	sName	GPA	sID1	sName1	GPA1
123	Amy	3.9	123	Amy	3.9
123	Amy	3.9	456	Doris	3.9
123	Amy	3.9	876	Irene	3.9
123	Amy	3.9	654	Amy	3.9
234	Bob	3.6	234	Bob	3.6
345	Craig	3.5	345	Craig	3.5
456	Doris	3.9	123	Amy	3.9
456	Doris	3.9	456	Doris	3.9
…	…	…	…	…	…

How to list only pairs of different students?

Diferentes IDs

Table variables

```
SELECT S1.sID, S1.sName, S1.GPA, S2.sID, S2.sName, S2.GPA
FROM   Student S1, Student S2
WHERE S1.GPA=S2.GPA AND S1.sID <> S2.sID;
```

sID	sName	GPA	sID1	sName1	GPA1
123	Amy	3.9	456	Doris	3.9
123	Amy	3.9	876	Irene	3.9
123	Amy	3.9	654	Amy	3.9
456	Doris	3.9	123	Amy	3.9
456	Doris	3.9	876	Irene	3.9
456	Doris	3.9	654	Amy	3.9
567	Edward	2.9	765	Jay	2.9
…	…	…	…	…	…

How to exclude the same pairs in different order?

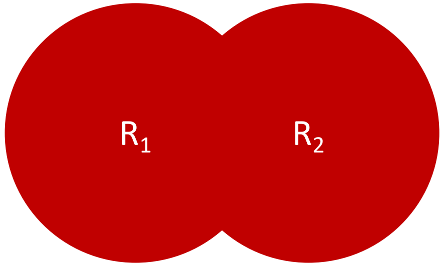
<> → < ou >

Table variables

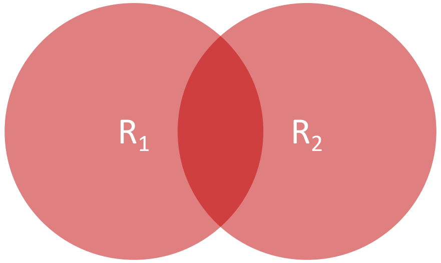
```
SELECT S1.sID, S1.sName, S1.GPA, S2.sID, S2.sName, S2.GPA
FROM   Student S1, Student S2
WHERE S1.GPA=S2.GPA AND S1.sID < S2.sID;
```

sID	sName	GPA	sID1	sName1	GPA1
123	Amy	3.9	456	Doris	3.9
123	Amy	3.9	876	Irene	3.9
123	Amy	3.9	654	Amy	3.9
456	Doris	3.9	876	Irene	3.9
456	Doris	3.9	654	Amy	3.9
567	Edward	2.9	765	Jay	2.9
654	Amy	3.9	876	Irene	3.9
543	Craig	3.4	789	Gary	3.4

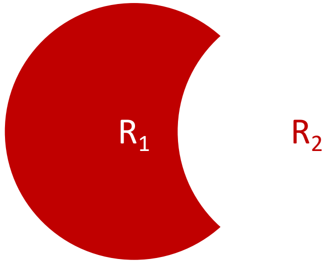
Set operators



Union



Intersect



Except

Sets, Bags and Lists

Sets

Only one occurrence of each element

Unordered elements

Bags (or multisets) → O que utilizamos

More than one occurrence of an element

Unordered elements and their occurrences

Lists

More than one occurrence of an element

Occurrences are ordered

Recall Bags

Multiset X

Tuple	
(1, a)	2x
(1, a)	
(1, b)	
(2, c)	3x
(2, c)	
(2, c)	
(1, d)	2x
(1, d)	

λ(X) = "Count of tuple in X"

Multiset X

Tuple	$\lambda(X)$
(1, a)	2
(1, b)	1
(2, c)	3
(1, d)	2

Número de ocorrências de cada elemento

In a set all counts are (0,1).

Union as a bag operation

Multiset X

Tuple	$\lambda(X)$
(1, a)	2
(1, b)	0
(2, c)	3
(1, d)	0

$\cup$

Multiset Y

Tuple	$\lambda(Y)$
(1, a)	5
(1, b)	1
(2, c)	2
(1, d)	2

$=$

Multiset Z

Tuple	$\lambda(Z)$
(1, a)	7
(1, b)	1
(2, c)	5
(1, d)	2

$$\lambda(Z) = \lambda(X) + \lambda(Y)$$

Na união o número de ocorrências é a soma

Intersect as a bag operation

Multiset X

Tuple	$\lambda(X)$
(1, a)	2
(1, b)	0
(2, c)	3
(1, d)	0

$\cap$

Multiset Y

Tuple	$\lambda(Y)$
(1, a)	5
(1, b)	1
(2, c)	2
(1, d)	2

$=$

Multiset Z

Tuple	$\lambda(Z)$
(1, a)	2
(1, b)	0
(2, c)	2
(1, d)	0

$$\lambda(\boldsymbol{Z}) = \min(\lambda(\boldsymbol{X}), \lambda(\boldsymbol{Y}))$$

Na interseção o número de ocorrên-
cias é o mínimo

Except as a bag operation

Multiset X

Tuple	$\lambda(X)$
(1, a)	2
(1, b)	0
(2, c)	3
(1, d)	0

$-$

Multiset Y

Tuple	$\lambda(Y)$
(1, a)	5
(1, b)	1
(2, c)	2
(1, d)	2

$=$

Multiset Z

Tuple	$\lambda(Z)$
(1, a)	0
(1, b)	0
(2, c)	1
(1, d)	0

If $\lambda(X) > \lambda(Y)$

$\lambda(Z) = \lambda(X) - \lambda(Y)$

Else

0

Union operator

College(cName, state, enr)

Student(sID, sName, GPA, sizeHS)

Apply(sID, cName, major, decision)

```
SELECT cName FROM College
UNION
SELECT sName FROM Student;
```

União

In SQL, the two sides of the union don't have to be the same

How to unify the two schemas?

```
SELECT cName AS name FROM College
UNION
SELECT sName AS name FROM Student;
```

Renomeamos para o mesmo

cName
Amy
Berkeley
Bob
Cornell
Craig
Doris
Edward
Fay
Gary
Helen
Irene
Jay
MIT
Stanford

Union operator

College(cName, state, enr)

Student(sID, sName, GPA, sizeHS)

Apply(sID, cName, major, decision)

By default, in SQL, the union operator eliminates duplicates

If we want to have duplicates in our result

```
SELECT cName AS name FROM College
UNION ALL → Devolve tudo independentemente de serem duplicados
SELECT sName AS name FROM Student;
```

Result is not sorted anymore

Why? → O Algoritmo que utiliza para remover os duplicados implica ordenar as instâncias

How can we sort the result?

```
SELECT cName AS name FROM College
UNION ALL
SELECT sName AS name FROM Student
ORDER BY name;
```

name
Stanford
Berkeley
MIT
Cornell
Amy
Bob
Craig
Doris
Edward
Fay
Gary
Helen
Irene
Jay
Amy
Craig

Kahoot time!

Any doubts?

Readings

Jeffrey Ullman, Jennifer Widom, A first course in Database Systems 3rd Edition

- Section 6.1 – Simple Queries in SQL
- Section 6.2 – Queries Involving More Than One Relation
- Section 6.3 - Subqueries
- Section 6.4 – Full-Relation Operations
- Section 6.5 – Database Modifications

Philip Greenspun, SQL for Web Nerds,
http://philip.greenspun.com/sql/