SQL: Part I

CPS 216 Advanced Database Systems

Announcements (January 25)

- * Reading assignment for this week (Ailamaki et al., *VLDB* 2001) has been posted
 - Due Wednesday night
 - Hunt for related/follow-up work too!
- ❖ Homework #1 due in two weeks

SQL

- * SQL: Structured Query Language
 - Pronounced "S-Q-L" or "sequel"
 - The standard query language support by most commercial DBMS
- * A brief history
 - IBM System R
 - ANSI SQL89
 - ANSI SQL92 (SQL2)
 - ANSI SQL99 (SQL3)
 - ANSI SQL 2003 (+OLAP, XML, etc.)

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Creating and dropping tables

- ❖ CREATE TABLE table name (..., column_name; column_type;, ...);
- ❖ DROP TABLE table_name;
- Examples

```
create table Student (SID integer,
name varchar(30), email varchar(30),
age integer, GPA float);
create table Course (CID char(10), title varchar(100));
create table Enroll (SID integer, CID char(10));
drop table Student;
```

- drop table Course; drop table Enroll;
- -- everything from -- to the end of the line is ignored.
- -- SQL is insensitive to white space.
- -- SQL is case insensitive (e.g., ...Course... is equivalent to
- -- ...COURSE...)

Basic queries: SFW statement

- \star SELECT A_1 , A_2 , ..., A_n FROM R_1 , R_2 , ..., R_m WHERE condition;
- * Also called an SPJ (select-project-join) query
- * Equivalent (not really!) to relational algebra query $\pi_{A_1, A_2, \dots, A_n}$ ($\sigma_{condition}$ ($R_1 \times R_2 \times \dots \times R_m$))

Example: reading a table

- ❖ SELECT * FROM Student;
 - Single-table query, so no cross product here
 - WHERE clause is optional
 - * is a short hand for "all columns"

Example: selection and projection Name of students under 18 SELECT name FROM Student WHERE age < 18; When was Lisa born? SELECT 2004 – age FROM Student WHERE name = 'Lisa'; SELECT list can contain expressions Can also use built-in functions such as SUBSTR, ABS, etc. String literals (case sensitive) are enclosed in single quotes

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Examp.	le:	10	ากเ

- SID's and name's of students taking courses with the word "Database" in their titles
 - SELECT Student.SID, Student.name FROM Student, Enroll, Course WHERE Student.SID = Enroll.SID AND Enroll.CID = Course.CID AND title LIKE '%Database%';
 - LIKE matches a string against a pattern
 - % matches any sequence of $\boldsymbol{0}$ or more characters
 - Okay to omit table_name in table_name.column_name if column_name is unique

Example: rename

- * SID's of students who take at least two courses
 - Relational algebra query:

 $((\rho_{e1} \, Enroll) \bowtie_{e1.SID} = {}_{e2.SID} \land {}_{e1.CID} \neq {}_{e2.CID} (\rho_{e2} \, Enroll))$

- SQL: SELECT e1.SID AS SID FROM Enroll AS e1, Enroll AS e2 WHERE e1.SID = e2.SID AND e1.CID <> e2.CID;
- AS keyword is completely optional

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A more complicated example		
 Titles of all courses that Bart and Lisa are taking together 		
	l —	
Tip: Write the FROM clause first, then WHERE, and then SELECT		
]	
Why SFW statements?]	
* Out of many possible ways of structuring SQL		
statements, why did the designers choose SELECT-FROM-WHERE?		
FROM-WILKE:		
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Sat arrange has a series	1	
Set versus bag semantics		
❖ Set■ No duplicates		
 Relational model and algebra use set semantics Bag 		
 Duplicates allowed 		
Number of duplicates is significantSQL uses bag semantics by default		
	J	

Set versus bag ex	ample	13
Enroll SID CID	π_{SID} Enroll	51D 142 123 857 456
857 CPS230 456 CPS214	SELECT SID FROM Enroll;	51D 142 142 123 857 857 456

A	case	for	bag	semantics
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* Besides, SQL provides the option of set semantics with DISTINCT keyword

Operational semantics of SFW

- \star SELECT [DISTINCT] E_1 , E_2 , ..., E_n FROM R_1 , R_2 , ..., R_m WHERE condition;
- ❖ For each t_1 in R_1 :

For each t_2 in R_2 : ...

For each t_m in R_m :

If *condition* is true over $t_1, t_2, ..., t_m$:

Compute and output $E_1, E_2, ..., E_n$

If DISTINCT is present

Eliminate duplicate rows in output

 $t_1, t_2, ..., t_m$ are often called tuple variables

Example: forcing set semantics SID's of students who take at least two courses ■ SELECT e1.SID AS SID FROM Enroll AS e1, Enroll AS e2 WHERE e1.SID = e2.SID AND e1.CID <> e2.CID; • What if Bart takes CPS216 and CPS214? • Changing <> to > may help in this case • But what if Bart takes CPS216, CPS214, and CPS230? SELECT DISTINCT e1.SID AS SID · Duplicate SID values are removed from the output SQL set and bag operations ❖ UNION, EXCEPT, INTERSECT ■ Set semantics Exactly like set ∪, −, and ∩ in relational algebra ❖ UNION ALL, EXCEPT ALL, INTERSECT ALL ■ Bag semantics ■ Think of each row as having an implicit count (the number of times it appears in the table) ■ Bag union: sum up the counts from two tables ■ Bag difference: proper-subtract the two counts ■ Bag intersection: take the minimum of the two counts Examples of bag operations Bag1 Bag2 fruit apple apple orange fruit apple orange orange Bag1 UNION ALL Bag2 Bag1 INTERSECT ALL Bag2 fruit fruit apple apple Bag1 EXCEPT ALL Bag2 apple fruit orange apple orange

orange

Examples of set versus bag operations * Enroll(SID, CID), ClubMember(club, SID) • (SELECT SID FROM ClubMember) **EXCEPT** (SELECT SID FROM Enroll); • (SELECT SID FROM ClubMember) EXCEPT ALL (SELECT SID FROM Enroll); Table expression * Use query result as a table ■ In set and bag operations, FROM clauses, etc. ■ A way to "nest" queries * Example: names of students who are in more clubs than classes SELECT DISTINCT name FROM Student, ((SELECT SID FROM ClubMember) EXCEPT ALL (SELECT SID FROM Enroll)) AS S WHERE Student.SID = S.SID; Summary of SQL features covered so far ❖ Basic CREATE/DROP TABLE ❖ SELECT-FROM-WHERE statements (select-project-join queries)

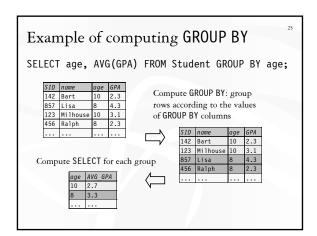
Set and bag operations

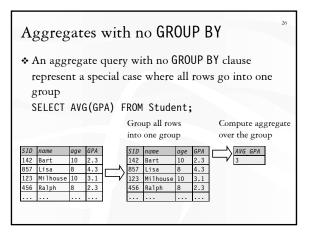
☞ Next: aggregation

Nesting queries using table expressions

☞ So far, not much more than relational algebra

Standard SQL aggregate functions: COUNT, SUM, AVG, MIN, MAX Example: number of students under 18, and their average GPA • SELECT COUNT(*), AVG(GPA) FROM Student WHERE age < 18; • COUNT(*) counts the number of rows SELECT FROM WHERE GROUP BY Its of column; • Example: find the average GPA for each age group FROM Student GROUP BY age; Operational semantics of GROUP BY SELECT FROM WHERE GROUP BY; • Compute MERE GROUP BY; • Compute WHERE (\sigma) • Compute WHERE (\sigma) • Compute GROUP BY; group rows according to the values of GROUP BY group rows according to the values of GROUP BY group in the final output	Aggregates	
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Restriction on SELECT If a query uses aggregation/group by, then every column referenced in SELECT must be either Aggregated, or A GROUP BY column

Examples of invalid queries * SELECT Mage FROM Student GROUP BY age; • Recall there is one output row per group ■ There can be multiple SID values per group ♦ SELECT MAX(GPA) FROM Student; • Recall there is only one group for an aggregate query with no GROUP BY clause ■ There can be multiple SID values • Wishful thinking (that the output SID value is the one associated with the highest GPA) does NOT work HAVING Used to filter groups based on the group properties (e.g., aggregate values, GROUP BY column values) ❖ SELECT ... FROM ... WHERE ... GROUP BY ... HAVING condition; ■ Compute FROM (×) ■ Compute WHERE (σ) ■ Compute GROUP BY: group rows according to the values of GROUP BY columns • Compute HAVING (another σ over the groups) • Compute SELECT (π) for each group that passes HAVING HAVING examples * Find the average GPA for each age group over 10 SELECT age, AVG(GPA) FROM Student GROUP BY age HAVING age > 10; * List the average GPA for each age group with more than a hundred students SELECT age, AVG(GPA) FROM Student GROUP BY age HAVING COUNT(*) > 100;

Summary of SQL features covered so far	
❖ Basic CREATE/DROP TABLE	
❖ SELECT-FROM-WHERE statements	
❖ Set and bag operations	
❖ Table expressions	
❖ Aggregation and grouping	
 More expressive power than relational algebra 	
☞ Next: NULL's	
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Incomplete information	
incomplete information	
❖ Example: Student (<u>SID</u> , name, age, GPA)	
❖ Value unknown	
• We do not know Nelson's age	
 ❖ Value not applicable ■ Nelson has not taken any classes yet; what is his GPA? 	
- Nelson has not taken any classes yet, what is his GFA:	
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Solution 1	
❖ A dedicated special value for each domain (type)	
 ■ GPA cannot be -1, so use -1 as a special value to indicate a missing or invalid GPA 	
Leads to incorrect answers if not carefulSELECT AVG(GPA) FROM Student;	
 Complicates applications SELECT AVG(GPA) FROM Student WHERE GPA <> -1; 	
Remember the pre-Y2K bug?	
• 09/09/99 was used as a missing or invalid date value	

Solution 2 * A valid-bit for every column ■ Student (SID, name, name is valid, age, age_is_valid, GPA, GPA_is_valid) Still complicates applications • SELECT AVG(GPA) FROM Student WHERE GPA_is_valid; SQL's solution * A special value NULL ■ Same for every domain Special rules for dealing with NULL's * Example: Student (SID, name, age, GPA) ■ 〈 789, "Nelson", NULL, NULL 〉 Rules for NULL's $\boldsymbol{\diamondsuit}$ When we operate on a NULL and another value (including another NULL) using +, -, etc., the result is NULL ❖ Aggregate functions ignore NULL, except COUNT(*) (since it counts rows)

Three-valued logic	
❖ When we compare a NULL with another value (including another NULL) using =, >, etc., the result is UNKNOWN	
* TRUE = 1, FALSE = 0, UNKNOWN = 0.5	
$ \Rightarrow x \text{ AND } y = \min(x, y) $	
$ \Rightarrow x \text{ OR } y = \max(x, y) $	
\bullet NOT $x = 1 - x$	
❖ WHERE and HAVING clauses only select rows for	-
output if the condition evaluates to TRUE	
UNKNOWN is insufficient	
T. I C t	
Unfortunate consequences	
❖ SELECT AVG(GPA) FROM Student;	
SELECT SUM(GPA)/COUNT(*) FROM Student;	
❖ SELECT * FROM Student;	
SELECT * FROM Student WHERE GPA = GPA;	
☞ Be careful: NULL breaks many equivalences	
39	
Another problem	
❖ Example: Who has NULL GPA values?	
■ SELECT * FROM Student WHERE GPA = NULL;	
- SELECT TROM SEGUENT WHERE GIA - NOLE,	
 Introduced built-in predicates IS NULL and IS NOT NULL 	
• SELECT * FROM Student WHERE GPA IS NULL;	

Summary of SQL features covered so far * Basic CREATE/DROP TABLE * SELECT-FROM-WHERE statements * Set and bag operations * Table expressions * Aggregation and grouping * NULL's * Next: subqueries, modifications, constraints, and views