CS150: Database & Datamining
Lecture 2: SQL Part I

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Acknowledgement: Slides are adopted from the Berkeley course CS186 by Joey Gonzalez and Joe Hellerstein, Stanford CS145 by Peter Bailis.

Reference

- Classic

  R/G: Database Management Systems

- Modern

  E/N: Fundamentals of Database Systems

- Data Mining
  - Murphy, Kevin P. Machine learning: a probabilistic perspective. MIT press, 2012.

Today's Lecture

1. Review SQL schema definitions
   - ACTIVITY: Table creation
2. Basic single-table queries
   - ACTIVITY: Single-table queries!
3. Multi-table queries
   - ACTIVITY: Multi-table queries!

1. Review SQL Definitions

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 – discussed next!

Tables in SQL

Product

PName	Price	Manufacturer
Gizmo	$19.99	GizmoWorks
Powergizmo	$29.99	GizmoWorks
SingleTouch	$149.99	Canon
MultiTouch	$203.99	Hitachi

A **relation** or **table** is a multiset of tuples having the attributes specified by the schema

Data Types in SQL

- Atomic types:
  - Characters: CHAR(20), VARCHAR(50)
  - Numbers: INT, BIGINT, SMALLINT, FLOAT
  - Others: MONEY, DATETIME, …

- Every attribute must have an atomic type
  - Hence tables are flat

Table Schemas

- The **schema** of a table is the table name, its attributes, and their types:

Product(Pname: *string*, Price: *float*, Category: *string*, Manufacturer: *string*)

- A **key** is an attribute whose values are unique; we underline a key

Product(Pname: *string*, Price: *float*, Category: *string*, Manufacturer: *string*)

Key constraints

A **key** is a **minimal subset of attributes** that acts as a unique identifier for tuples in a relation

- A key is an implicit constraint on which tuples can be in the relation

Students(sid:string, name:string, gpa: float)

  - i.e. if two tuples agree on the values of the key, then they must be the same tuple!

1. Which would you select as a key?
2. Is a key always guaranteed to exist?
3. Can we have more than one key?

NULL and NOT NULL

- To say “don’t know the value” we use NULL
  - NULL has (sometimes painful) semantics, more detail later

Students(sid:string, name:string, gpa: float)

sid	name	gpa
123	Bob	3.9
143	Jim	NULL

Say, Jim just enrolled in his first class.

In SQL, we may constrain a column to be NOT NULL, e.g., “name” in this table

General Constraints

- We can actually specify arbitrary assertions
  - E.g. "*There cannot be 25 people in the DB class*"

- In practice, we don't specify many such constraints. Why?
  - Performance!

Whenever we do something ugly (or avoid doing something convenient) it's for the sake of performance

Create a relation/table: Examples

- Simple table

```
CREATE TABLE  students (
        sid      INTEGER       PRIMARY KEY,
        name  VARCHAR(30)    NOT NULL,
        birthdate  DATE
);
```

Create a relation/table: Examples

- Simple table 2

```
CREATE TABLE  global_addresses (
        postal_code CHAR(6),
        country       VARCHAR(30),
        name          VARCHAR(60),
        PRIMARY KEY (postal_code, country)
);
```

Summary of Schema Information

- Schema and Constraints are how databases understand the semantics (meaning) of data
- They are also useful for optimization
- SQL supports general constraints:
  - Keys and foreign keys are most important
  - We'll give you a chance to write the others

ACTIVITY: Activity-2-1.ipynb

2. Single-table queries

What you will learn about in this section

1. The SFW query
2. Other useful operators: LIKE, DISTINCT, ORDER BY
3. ACTIVITY: Single-table queries

SQL Query

- Basic form (there are many many more bells and whistles)

```
SELECT <attributes>
FROM   <one or more relations>
WHERE  <conditions>
```

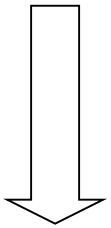
Call this a **SFW** query.

Simple SQL Query: Selection

Selection is the operation of filtering a relation's tuples on some condition

PName	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks
SingleTouch	$149.99	Photography	Canon
MultiTouch	$203.99	Household	Hitachi

```
SELECT *
FROM   Product
WHERE  Category = 'Gadgets'
```



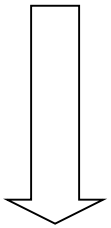
PName	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks

Simple SQL Query: Projection

Projection is the operation of producing an output table with tuples that have a subset of their prior attributes

PName	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks
SingleTouch	$149.99	Photography	Canon
MultiTouch	$203.99	Household	Hitachi

```
SELECT Pname, Price, Manufacturer
FROM   Product
WHERE  Category = 'Gadgets'
```



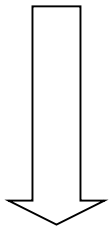
PName	Price	Manufacturer
Gizmo	$19.99	GizmoWorks
Powergizmo	$29.99	GizmoWorks

Notation

Input schema

Product(PName, Price, Category, Manfacturer)

```
SELECT Pname, Price, Manufacturer
FROM   Product
WHERE  Category = 'Gadgets'
```



Output schema

Answer(PName, Price, Manfacturer)

A Few Details

- SQL **commands** are case insensitive:
  - Same: SELECT, Select, select
  - Same: Product, product
- **Values** are **not:**
  - Different: ‘Seattle’, ‘seattle’
- Use single quotes for constants:
  - ‘abc’ - yes
  - “abc” - no

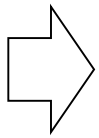
LIKE: Simple String Pattern Matching

```
SELECT *
FROM   Products
WHERE  PName LIKE '%gizmo%'
```

- s **LIKE** p: pattern matching on strings
- p may contain two special symbols:
  - % = any sequence of characters
  - _ = any single character

DISTINCT: Eliminating Duplicates

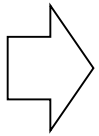
```
SELECT DISTINCT Category
FROM   Product
```



Category
Gadgets
Photography
Household

Versus

```
SELECT Category
FROM   Product
```



Category
Gadgets
Gadgets
Photography
Household

ORDER BY: Sorting the Results

```
SELECT   PName, Price, Manufacturer
FROM     Product
WHERE    Category='gizmo' AND Price > 50
ORDER BY Price, PName
```

Ties are broken by the second attribute on the ORDER BY list, etc.

Ordering is ascending, unless you specify the DESC keyword.

SQL Query – general form

- SELECT [DISTINCT] <column expression list>
  FROM <single table>
  [WHERE <predicate>]
  [GROUP BY <column list>
  [HAVING <predicate>]]
  [ORDER BY <column list>];

Basic Single-Table Queries

```
SELECT [DISTINCT] <column expression list>
  FROM <single table>
[WHERE <predicate>]
[GROUP BY <column list>
 [HAVING <predicate>] ]
[ORDER BY <column list>] ;
```

- Simplest version is straightforward
  - Produce all tuples in the table that satisfy the predicate
  - Output the expressions in the SELECT list
  - Expression can be a column reference, or an arithmetic expression over column refs

ACTIVITY: Activity-2-2.ipynb

3. Multi-table queries

What you will learn about in this section

1. Foreign key constraints
2. Joins: basics
3. Joins: SQL semantics
4. ACTIVITY: Multi-table queries

Foreign Key constraints

- Suppose we have the following schema:

Students(sid: *string*, name: *string*, gpa: *float*)

Enrolled(student_id: *string*, cid: *string*, grade: *string*)

- And we want to impose the following constraint:
  - 'Only bona fide students may enroll in courses' i.e. a student must appear in the Students table to enroll in a class

Students

sid	name	gpa
101	Bob	3.2
123	Mary	3.8

Enrolled

student_id	cid	grade
123	564	A
123	537	A+

student_id alone is not a key- what is?

We say that student_id is a **foreign key** that refers to Students

Declaring Foreign Keys

Students(sid: *string,* name: *string,* gpa: *float*)
Enrolled(student_id: *string*, cid: *string,* grade: *string*)

```
CREATE TABLE Enrolled(
        student_id CHAR(20),
        cid                CHAR(20),
        grade      CHAR(10),
        PRIMARY KEY (student_id, cid),
        FOREIGN KEY (student_id) REFERENCES Students(sid)
)
```

Foreign Keys and update operations

Students(sid: *string*, name: *string*, gpa: *float*)

Enrolled(student_id: *string*, cid: *string*, grade: *string*)

- What if we insert a tuple into Enrolled, but no corresponding student?
  - INSERT is rejected (foreign keys are constraints)!

- What if we delete a student?

DBA chooses (syntax in the book)

1. Disallow the delete
2. Remove all of the courses for that student
3. *SQL allows a third via NULL (not yet covered)*

Keys and Foreign Keys

Company

CName	StockPrice	Country
GizmoWorks	25	USA
Canon	65	Japan
Hitachi	15	Japan

Product

PName	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks
SingleTouch	$149.99	Photography	Canon
MultiTouch	$203.99	Household	Hitachi

What is a foreign key vs. a key here?

Joins

Product(PName, Price, Category, Manufacturer)

Company(CName, StockPrice, Country)

Ex: Find all products under $200 manufactured in Japan;
return their names and prices.

```
SELECT PName, Price
FROM   Product, Company
WHERE  Manufacturer = CName
           AND Country='Japan'
      AND Price <= 200
```

Note: we will often omit attribute types in schema definitions for brevity, but assume attributes are always atomic types

Joins

Product(PName, Price, Category, Manufacturer)

Company(CName, StockPrice, Country)

Ex: Find all products under $200 manufactured in Japan;
return their names and prices.

```
SELECT PName, Price
FROM   Product, Company
WHERE  Manufacturer = CName
       AND Country='Japan'
   AND Price <= 200
```

A join between tables returns all unique combinations of their tuples **which meet some specified join condition**

Joins

Product(PName, Price, Category, Manufacturer)

Company(CName, StockPrice, Country)

Several equivalent ways to write a basic join in SQL:

```
SELECT PName, Price
FROM   Product, Company
WHERE  Manufacturer = CName
           AND Country='Japan'
      AND Price <= 200
```

```
SELECT PName, Price
FROM   Product
JOIN   Company ON Manufacturer = Cname
                  AND Country='Japan'
WHERE  Price <= 200
```

A few more later on…

Joins

Product

PName	Price	Category	Manuf
Gizmo	$19	Gadgets	GWorks
Powergizmo	$29	Gadgets	GWorks
SingleTouch	$149	Photography	Canon
MultiTouch	$203	Household	Hitachi

Company

Cname	Stock	Country
GWorks	25	USA
Canon	65	Japan
Hitachi	15	Japan

```
SELECT PName, Price
FROM   Product, Company
WHERE  Manufacturer = CName
           AND Country='Japan'
       AND Price <= 200
```

PName	Price
SingleTouch	$149.99

Tuple Variable Ambiguity in Multi-Table

Person(name, address, worksfor)

Company(name, address)

```
SELECT DISTINCT name, address
FROM        Person, Company
WHERE         worksfor = name
```

Which "address" does this refer to?

Which "name"s??

Tuple Variable Ambiguity in Multi-Table

Person(name, address, worksfor)

Company(name, address)

Both equivalent ways to resolve variable ambiguity

```
SELECT DISTINCT Person.name, Person.address
FROM Person, Company
WHERE Person.worksfor = Company.name
```

```
SELECT DISTINCT p.name, p.address
FROM Person p, Company c
WHERE p.worksfor = c.name
```

Meaning (Semantics) of SQL Queries

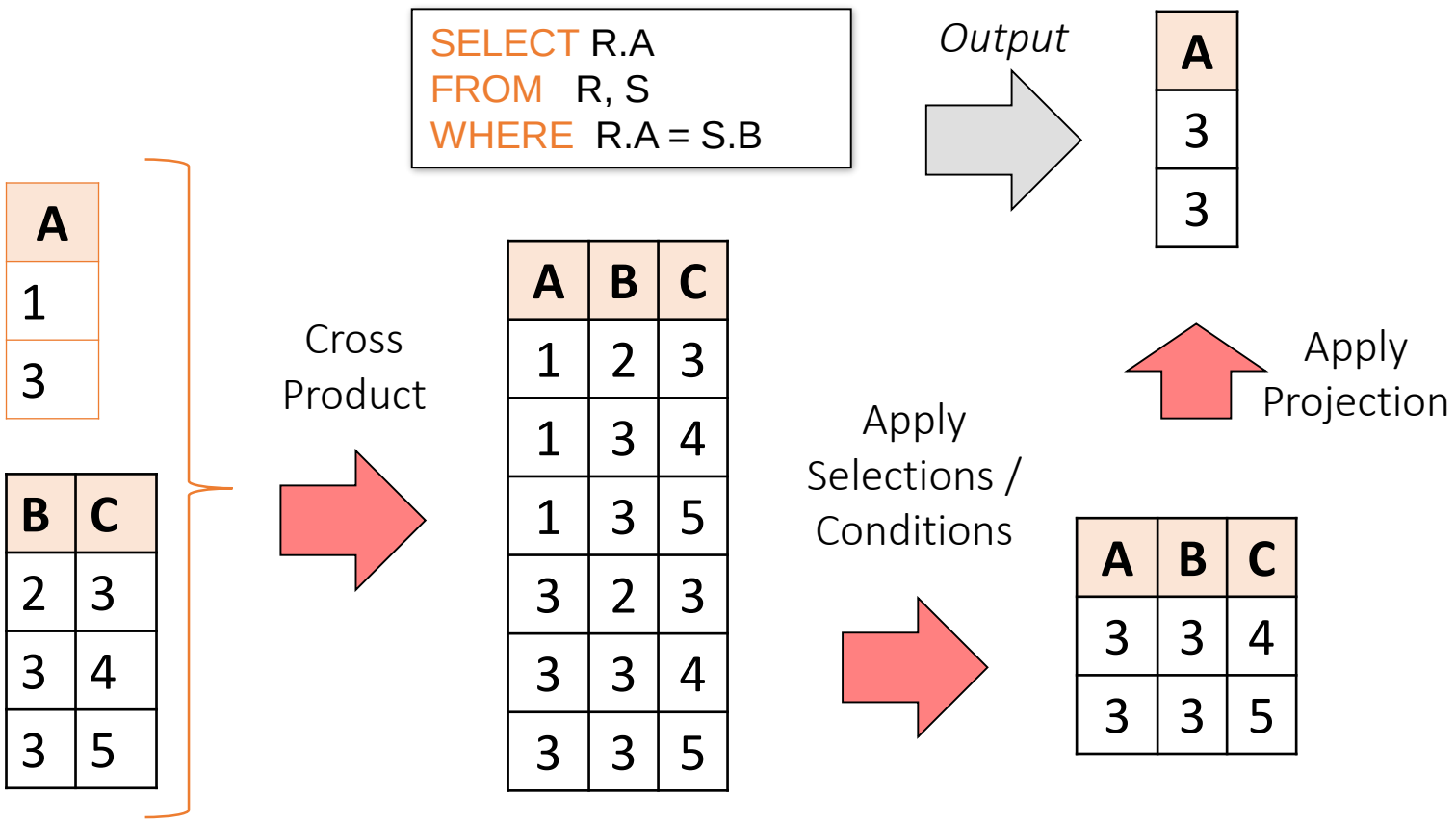
SELECT $x_1.a_1$, $x_1.a_2$, …, $x_n.a_k$
FROM R_1 AS x_1, R_2 AS x_2, …, R_n AS x_n
WHERE Conditions(x_1,…, x_n)

Almost never the *fastest* way to compute it!

```
Answer = {}
for x1 in R1 do
    for x2 in R2 do
        .....
            for xn in Rn do
                if Conditions(x1,..., xn)
                    then Answer = Answer ∪ {(x1.a1, x1.a2, ..., xn.ak)}
return Answer
```

Note: this is a *multiset* union

An example of SQL semantics



Note the ***semantics*** of a join

```
SELECT R.A
FROM   R, S
WHERE  R.A = S.B
```

1. Take **cross product**:

$$X = R \times S$$

Recall: Cross product (A X B) is the set of all unique tuples in A,B

Ex: {a,b,c} X {1,2}
= {(a,1), (a,2), (b,1), (b,2), (c,1), (c,2)}

2. Apply **selections / conditions**:

$$Y = \{(r, s) \in X \mid r.A == r.B\}$$

= Filtering!

3. Apply **projections** to get final output:

$$Z = (y.A,) \; for \; y \in Y$$

= Returning only *some* attributes

Remembering this order is critical to understanding the output of certain queries (see later on…)

Note: we say “semantics” not “execution order”

- The preceding slides show *what a join means*
- Not actually how the DBMS executes it under the covers

A Subtlety about Joins

Product(PName, Price, Category, Manufacturer)

Company(CName, StockPrice, Country)

Find all countries that manufacture some product in the 'Gadgets' category.

```
SELECT Country
FROM   Product, Company
WHERE  Manufacturer=CName AND Category='Gadgets'
```

A subtlety about Joins

Product

PName	Price	Category	Manuf
Gizmo	$19	Gadgets	GWorks
Powergizmo	$29	Gadgets	GWorks
SingleTouch	$149	Photography	Canon
MultiTouch	$203	Household	Hitachi

Company

Cname	Stock	Country
GWorks	25	USA
Canon	65	Japan
Hitachi	15	Japan

```
SELECT Country
FROM   Product, Company
WHERE  Manufacturer=Cname
  AND Category='Gadgets'
```

Country
?
?

What is the problem ?
What's the solution ?

Join Queries

- SELECT [DISTINCT] <column expression list>
  FROM <table1 [AS t1], ... , tableN [AS tn]>
  [WHERE <predicate>]
  [GROUP BY <column list>
   [HAVING <predicate>]]
  [ORDER BY <column list>];

Query Semantics

SELECT [DISTINCT] *target-list*
FROM *relation-list*
WHERE *qualification*

1. FROM : compute *cross product* of tables.
2. WHERE : Check conditions, discard tuples that fail.
3. SELECT : Specify desired fields in output.
4. DISTINCT (optional) : eliminate duplicate rows.

- Note: likely a terribly inefficient strategy!
  - Query optimizer will find more efficient plans.

ACTIVITY: Lecture-2-3.ipynb

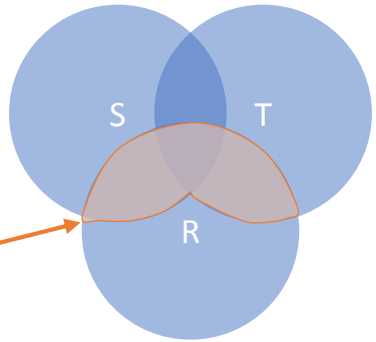
An Unintuitive Query

```
SELECT DISTINCT R.A
FROM   R, S, T
WHERE  R.A=S.A OR R.A=T.A
```

What does it compute?

An Unintuitive Query

```
SELECT DISTINCT R.A
FROM   R, S, T
WHERE  R.A=S.A OR R.A=T.A
```



Computes R ∩ (S ∪ T)

But what if S = ϕ?

Go back to the semantics!

An Unintuitive Query

```
SELECT DISTINCT R.A
FROM   R, S, T
WHERE  R.A=S.A OR R.A=T.A
```

- Recall the semantics**!**
  1. Take cross-product
  2. Apply selections / conditions
  3. Apply projection
- If S = {}, then the cross product of R, S, T = {}, and the query result = {}!

Must consider semantics here.
Are there more explicit way to do set operations like this?

Summary

- SQL is a rich programming language that handles the way data is processed *declaratively*

- Next: Advanced SQL