Introduction to Database Systems CSEP544

Lecture #1

January 5, 2007

About Me

Dan Suciu:

- Bell Labs, AT&T Labs, UW in 2000

Research:

- Past: XML and semi-structured data:
  - Query language: XML-QL (later XQuery)
  - Compressor: XMill
  - Theory: XPath containment, XML typechecking
- Present: Probabilistic databases: MystiQ

Staff

- Instructor: Dan Suciu
  - Allen, Room 662, suciu@cs.washington.edu
    Office hours: Tuesdays, 5:30 (appointment strongly recommended)
  - Next week: away, chairing ICDT'2007

- TAs:
  - Bao Nguyen Nguyen

Communications

- Web page:
  http://www.cs.washington.edu/p544/ □□
  - Lectures will be available here
  - Homeworks will be posted here (HW1 is posted)
  - The project description will be here

- Mailing list:
  - Announcements, group discussions
  - Please subscribe

Textbook(s)

Main textbook, available at the bookstore:

- *Database Management Systems*
  Ramakrishnan and Gehrke

Gives colloquium talk on Feb.8, 3:30pm

Also recommended:

- *Database Systems: The Complete Book*, Garcia-Molina, Ullman, Widom

Other Texts

Available at the Engineering Library (<u>not</u> on reserve):

- *XQuery from the Experts*, Katz, Ed.
- *Foundations of Databases*, Abiteboul, Hull, Vianu
- *Data on the Web*, Abiteboul, Buneman, Suciu

Outline of Today's Lecture

1. Overview of DBMS, Course outline

2. Assignment 1, Homework 1, Project phase 1

3. SQL

Database

What is a database ?

Give examples of databases

Database

What is a database ?

- A collection of files storing related data

Give examples of databases

- Accounts database; payroll database; UW's students database; Amazon's products database; airline reservation database

Database Management System

What is a DBMS ?

Give examples of DBMS

Database Management System

What is a DBMS ?

- *A big C program written by someone else that allows us to manage efficiently a large database and allows it to persist over long periods of time*

Give examples of DBMS

- DB2 (IBM), SQL Server (MS), Oracle, Sybase
- MySQL, Postgres, …

Market Shares

From 2004 www.computerworld.com

- IMB: 35% market with $2.5BN in sales
- Oracle: 33% market with $2.3BN in sales
- Microsoft: 19% market with $1.3BN in sales

An Example

The Internet Movie Database
http://www.imdb.com

- Entities:
  Actors (800k), Movies (400k), Directors, …

- Relationships:
  who played where, who directed what, …

Tables

Directors:

id	fName	lName
15901	Francis Ford	Coppola
. . .		

Movie_Directors:

id	mid
15901	130128
. . .	

Movies:

mid	Title	Year
130128	The Godfather	1972
. . .		

What the Database Systems Does

1. Create/store large datasets
2. Search/query/update
3. Change the structure
4. Concurrent access to many user
5. Recover from crashes
6. Security

Possible Organizations

- Files
- Spreadsheets
- DBMS

1. Create/store Large Datasets

- Files — Yes, but…
- Spreadsheets — Not really…
- DBMS — Yes

2. Search/Query/Update

- Files

Simple queries (grep);
Updates are difficult

- Spreadsheets

Simple queries;
Simple updates

- DBMS

All

Updates: generally OK

3. Change the Structure

Add *Address* to each Actor

- Files

Very hard

- Spreadsheets

Yes

- DBMS

Yes

4. Concurrent Access

Multiple users access/update the data concurrently

Lost updates; inconsistent reads,…

- What can go wrong ?
- How do we protect against that in OS ?

locks

- This is insufficient in databases; why ?

A logical action consists of multiple updates

5. Recover from crashes

- Transfer $100 from account #4662 to #7199:

```
X = Read(Account, #4662);
X.amount = X.amount - 100;
Write(Account, #4662, X);

Y = Read(Account, #7199);
Y.amount = Y.amount + 100;
Write(Account, #7199, Y);
```

CRASH !

What is the problem ?

6. Security

- Files
- Spreadsheets
- DBMS

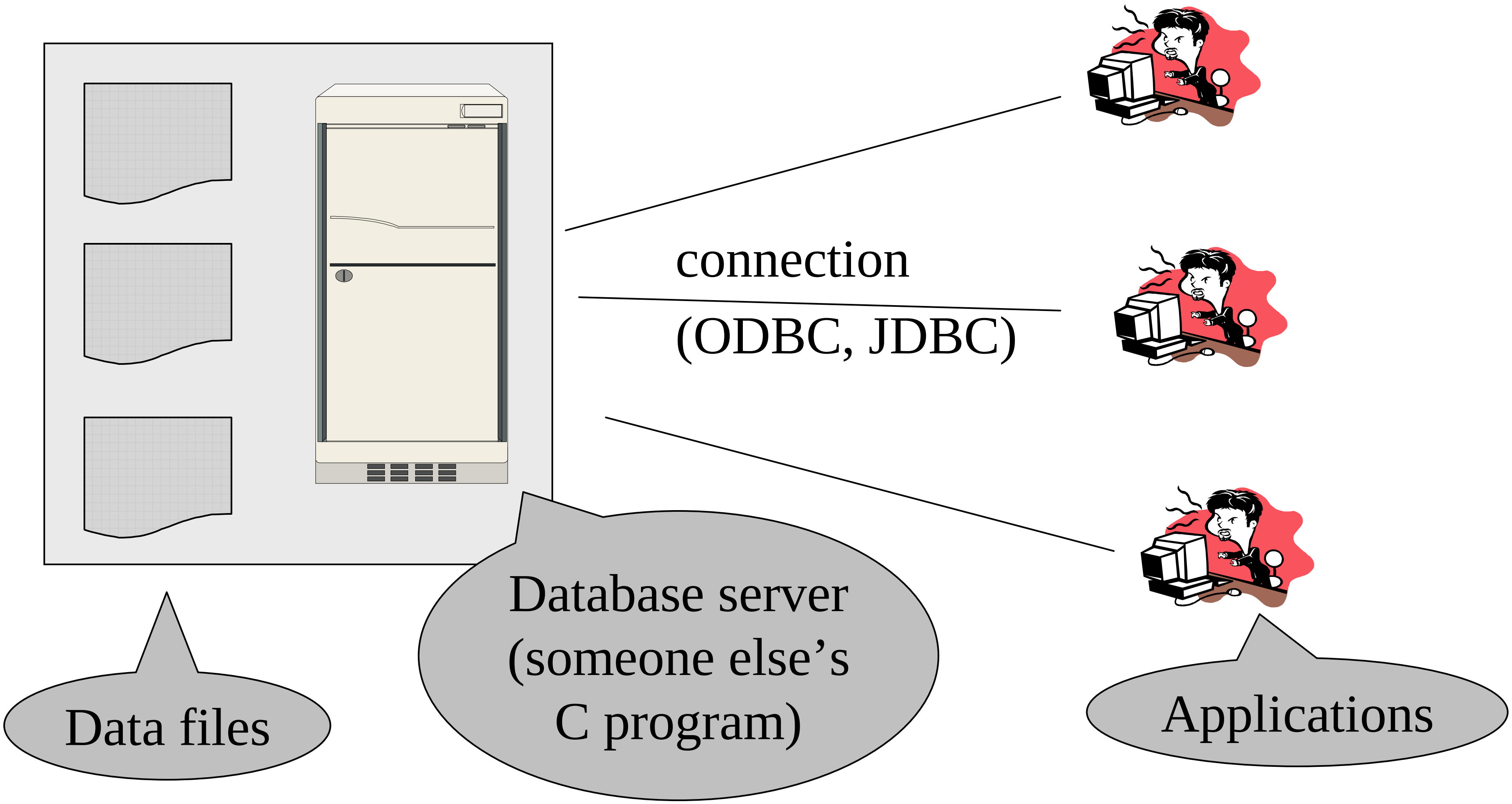
File-level access control

Same [?]

Table/attribute-level access control

Enters a DMBS

"Two tier system" or "client-server"



Data Independence

Logical view

Directors:

id	**fName**	**lName**
15901	Francis Ford	Coppola
. . .		

Movie_Directors:

id	**mid**
15901	130128
. . .	

Movies:

mid	**Title**	**Year**
130128	The Godfather	1972
. . .		

Directors_file

Moviews_title_index_file

Directors_fname_index_file

Movies_file

Physical view

What the Database Systems Does

1. Create/store large datasets
2. Search/query/update
3. Change the structure
4. Concurrent access to many user
5. Recover from crashes
6. Security

SQL DML

SQL DDL

Transactions
ACID

Grant, Revoke, Roles

Course Outline - TENTATIVE !!

1. January 5: SQL
2. January 16: SQL in C#; Database Design: E/R, NF
3. January 23: Views, Constraints, Security
4. January 30: XML/XPath/XQuery
5. Feburary 6: Transactions
6. Feburary 13: Database storage, indexes
7. Feburary 20: Physical operators, optimization
8. Feburary 27: Statistics, Database tuning
9. March 6: Advanced topics

Grading

- Homework: 35%
- Project: 35%
- Final: 30%

Reading Assignment

- Reading assignment for Tuesday, Jan 16
  - **Introduction** from **SQL for Web Nerds,** by Philip Greenspun, http://philip.greenspun.com/sql/

- This is a one-time assignment, no grading, BUT *very* instructive and lots of fun reading

Homework 1

- Homework 1:
  - SQL Queries
  - Due Tuesday, January 16
  - It is posted already!
- Homework 2:
  - Conceptual design: E/R diagrams, Normal Forms
  - Due Tuesday, January 30
- Homework 3:
  - XML/Xquery
  - Due Tuesday, February 13
- Homework 4:
  - Transactions: concurrency control and recovery
  - Due Tuesday, February 27

The Project: Boutique Online Store

- Phase 1:
  - Design a Database Schema, Build Related Data Logic
  - Due January 23
- Phase 2:
  - Import data, Web Inventory Data Logic
  - Due February 6
- Phase 3:
  - Checkout Logic
  - Due February 20
- Phase 4:
  - Database Tuning
  - Due March 6

Project

SQL Server, C#, ASP.NET

- Supported
- Will provide starter code in C#, ASP.NET
- The import data is in SQL/XML on SQL Server

Alternative technologies: MySQL, postgres, PHPs

- Not supported (you are on your own)
- Worry about the SQL/XML part…

Accessing SQL Server

SQL Server Management Studio

- Server Type = Database Engine
- Server Name = IPROJSRV
- Authentication = SQL Server Authentication
  - Login = your UW email address (*not* the CSE email)
  - Password = 12345

Change your password !!

Then play with IMDB

Today’s Lecture: SQL

- Chapters 5.1 - 5.5
- If we don’t finish today please read the slides at home: you need this material for the Homework due next time.

SQL Introduction

Standard language for querying and manipulating data

Structured **Q**uery **L**anguage

Many standards out there:

- ANSI SQL, SQL92 (a.k.a. SQL2), SQL99 (a.k.a. SQL3), ….
- Vendors support various subsets: watch for fun discussions in class !

SQL

- Data Definition Language (DDL)
  - Create/alter/delete tables and their attributes
  - Following lectures...
- Data Manipulation Language (DML)
  - Query one or more tables – discussed next !
  - Insert/delete/modify tuples in tables

Table name

Attribute names

Tables in SQL

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

Tuples or rows

Tables Explained

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

Product(PName, Price, Category, Manfacturer)

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

Product(PName, Price, Category, Manfacturer)

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
  - Why ?

Tables Explained

- A tuple = a record
  - Restriction: all attributes are of atomic type

- A table = a set of tuples
  - Like a list…
  - …but it is unorderd:
    no **first()**, no **next()**, no **last()**.

SQL Query

Basic form: (plus many many more bells and whistles)

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

Simple SQL Query

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

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

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

"selection"

Simple SQL Query

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

```
SELECT   PName, Price, Manufacturer
FROM     Product
WHERE    Price > 100
```

PName	Price	Manufacturer
SingleTouch	$149.99	Canon
MultiTouch	$203.99	Hitachi

“selection” and “projection”

Notation

Input Schema

Product(PName, Price, Category, Manfacturer)

```
SELECT   PName, Price, Manufacturer
FROM     Product
WHERE    Price > 100
```

Answer(PName, Price, Manfacturer)

Output Schema

Details

- Case insensitive:
  - Same: SELECT Select select
  - Same: Product   product
  - Different: ‘Seattle’ ‘seattle’

- Constants:
  - ‘abc’ - yes
  - “abc” - no

The **LIKE** operator

```
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

Eliminating Duplicates

```
SELECT   DISTINCT category
FROM     Product
```

Category
Gadgets
Photography
Household

Compare to:

```
SELECT   category
FROM     Product
```

Category
Gadgets
Gadgets
Photography
Household

Ordering 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.

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   DISTINCT category
FROM     Product
ORDER BY category
```

⇨ ?

```
SELECT   Category
FROM     Product
ORDER BY  PName
```

⇨ ?

```
SELECT   DISTINCT category
FROM     Product
ORDER BY PName
```

⇨ ?

Keys and Foreign Keys

Company

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

Key

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

Foreign key

Joins

Product (<u>pname</u>, price, category, manufacturer)
Company (<u>cname</u>, stockPrice, country)

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

Join between Product and Company

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

Joins

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

Company

Cname	StockPrice	Country
GizmoWorks	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

More Joins

Product (<u>pname</u>, price, category, manufacturer)
Company (<u>cname</u>, stockPrice, country)

Find all Chinese companies that manufacture products both in the ‘electronic’ and ‘toy’ categories

```
SELECT   cname

FROM

WHERE
```

A Subtlety about Joins

Product (<u>pname</u>, price, category, manufacturer)
Company (<u>cname</u>, 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

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

Company

Cname	StockPrice	Country
GizmoWorks	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 ?

Tuple Variables

Person(pname, address, worksfor)

Company(cname, address)

```
SELECT   DISTINCT pname, address
FROM     Person, Company
WHERE    worksfor = cname
```

Which address ?

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

```
SELECT   DISTINCT x.pname, y.address
FROM     Person AS x, Company AS y
WHERE    x.worksfor = y.cname
```

Meaning (Semantics) of SQL Queries

```
SELECT a1, a2, …, ak
FROM   R1 AS x1, R2 AS x2, …, Rn AS xn
WHERE  Conditions
```

SELECT $a_1, a_2, \ldots, a_k$
FROM R_1 AS x_1, R_2 AS x_2, …, R_n AS x_n
WHERE Conditions

Answer = {}
for x_1 **in** R_1 **do**
    for x_2 **in** R_2 **do**
        …..
            for x_n **in** R_n **do**
                if Conditions
                    then Answer = Answer $\cup$ $\{(a_1,\ldots,a_k)\}$
return Answer

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 ?

Computes $R \cap (S \cup T)$ most of the time

When does it not compute $R \cap (S \cup T)$?

Subqueries Returning Relations

Company(<u>name</u>, city)

Product(<u>pname</u>, maker)

Purchase(<u>id</u>, product, buyer)

Return cities where one can find companies that manufacture products bought by Joe Blow

```
SELECT  Company.city
FROM    Company
WHERE   Company.name  IN
            (SELECT Product.maker
             FROM   Purchase , Product
             WHERE  Product.pname=Purchase.product
                AND Purchase .buyer = 'Joe Blow');
```

Subqueries Returning Relations

Is it equivalent to this ?

```
SELECT  Company.city
FROM      Company, Product, Purchase
WHERE   Company.name= Product.maker
          AND  Product.pname  = Purchase.product
          AND  Purchase.buyer = ‘Joe Blow’
```

Removing Duplicates

```
SELECT DISTINCT Company.city
FROM     Company
WHERE  Company.name  IN
                   (SELECT Product.maker
                     FROM   Purchase , Product
                     WHERE Product.pname=Purchase.product
                          AND Purchase .buyer = ‘Joe Blow‘);
```

```
SELECT DISTINCT Company.city
FROM      Company, Product, Purchase
WHERE   Company.name= Product.maker
           AND  Product.pname  = Purchase.product
           AND  Purchase.buyer = ‘Joe Blow’
```

Now
they are
equivalent

Subqueries Returning Relations

You can also use: s > ALL R
s > ANY R
EXISTS R

Product (pname, price, category, maker)

Find products that are more expensive than all those produced By “Gizmo-Works”

```
SELECT  name
FROM    Product
WHERE   price >  ALL (SELECT price
                      FROM   Product
                      WHERE  maker='Gizmo-Works')
```

Question for Database Fans and their Friends

- Can we express this query as a single SELECT-FROM-WHERE query, without subqueries ?

Monotone Queries

Let Q be a query over tables R, S, T, …; denote its answer with Q(R, S, T, …).

Definition Q is called monotone if :
$\forall\ R \subseteq R', S \subseteq S', \ldots \quad \Rightarrow\ Q(R, S, \ldots) \subseteq Q(R',S',\ldots)$

Theorem Every select-from-where query is monotone

Observation The ALL query on previous slide is not monotone

Correlated Queries

Movie (title, year, director, length)

Find movies whose title appears more than once.

correlation

```
SELECT DISTINCT title
FROM   Movie AS x
WHERE  year <> ANY
                 (SELECT  year
                  FROM    Movie
                  WHERE   title =  x.title);
```

Note (1) scope of variables (2) this can still be expressed as single SFW

Complex Correlated Query

Product (pname, price, category, maker, year)

- Find products (and their manufacturers) that are more expensive than all products made by the same manufacturer before 1972

```
SELECT DISTINCT  pname, maker
FROM      Product AS x
WHERE  price > ALL  (SELECT  price
                     FROM    Product AS y
                     WHERE  x.maker = y.maker AND y.year < 1972);
```

Very powerful ! Also much harder to optimize.

Aggregation

```
SELECT  avg(price)
FROM    Product
WHERE   maker="Toyota"
```

```
SELECT  count(*)
FROM    Product
WHERE   year > 1995
```

SQL supports several aggregation operations:

sum, count, min, max, avg

Except count, all aggregations apply to a single attribute

Aggregation: Count

COUNT applies to duplicates, unless otherwise stated:

```
SELECT  Count(category)
FROM    Product
WHERE   year > 1995
```

same as Count(*)

We probably want:

```
SELECT  Count(DISTINCT category)
FROM    Product
WHERE   year > 1995
```

More Examples

Purchase(product, date, price, quantity)

```
SELECT  Sum(price * quantity)
FROM    Purchase
```

What do they mean ?

```
SELECT  Sum(price * quantity)
FROM    Purchase
WHERE   product = 'bagel'
```

Simple Aggregations

Purchase

Product	Date	Price	Quantity
Bagel	10/21	1	20
Banana	10/3	0.5	10
Banana	10/10	1	10
Bagel	10/25	1.50	20

```
SELECT  Sum(price * quantity)
FROM    Purchase
WHERE   product = 'bagel'
```

→ 50 (= 20+30)

Grouping and Aggregation

Purchase(product, date, price, quantity)

Find total sales after 10/1/2005 per product.

```
SELECT      product, Sum(price*quantity) AS TotalSales
FROM        Purchase
WHERE       date > ‘10/1/2005’
GROUP BY    product
```

Let’s see what this means…

Grouping and Aggregation

1. Compute the FROM and WHERE clauses.

2. Group by the attributes in the GROUPBY

3. Compute the SELECT clause: grouped attributes and aggregates.

1&2. FROM-WHERE-GROUPBY

Product	Date	Price	Quantity
Bagel	10/21	1	20
Bagel	10/25	1.50	20
Banana	10/3	0.5	10
Banana	10/10	1	10

3. SELECT

Product	Date	Price	Quantity
Bagel	10/21	1	20
Bagel	10/25	1.50	20
Banana	10/3	0.5	10
Banana	10/10	1	10

Product	TotalSales
Bagel	50
Banana	15

```
SELECT     product, Sum(price*quantity) AS TotalSales
FROM       Purchase
WHERE      date > '10/1/2005'
GROUP BY   product
```

GROUP BY v.s. Nested Quereis

```
SELECT     product, Sum(price*quantity) AS TotalSales
FROM       Purchase
WHERE      date > '10/1/2005'
GROUP BY   product
```

```
SELECT DISTINCT  x.product, (SELECT Sum(y.price*y.quantity)
                             FROM    Purchase y
                             WHERE x.product = y.product
                                   AND y.date > '10/1/2005')
                            AS TotalSales
FROM        Purchase x
WHERE       x.date > '10/1/2005'
```

Another Example

What does it mean ?

```
SELECT     product,
           sum(price * quantity) AS SumSales
           max(quantity) AS MaxQuantity
FROM       Purchase
GROUP BY   product
```

HAVING Clause

Same query, except that we consider only products that had at least 100 buyers.

```
SELECT      product, Sum(price * quantity)
FROM        Purchase
WHERE       date > '10/1/2005'
GROUP BY    product
HAVING      Sum(quantity) > 30
```

HAVING clause contains conditions on aggregates.

General form of Grouping and Aggregation

SELECT S
FROM $R_1,\ldots,R_n$
WHERE C1
GROUP BY $a_1,\ldots,a_k$
HAVING C2

Why ?

S = may contain attributes $a_1,\ldots,a_k$ and/or any aggregates but NO OTHER ATTRIBUTES

C1 = is any condition on the attributes in $R_1,\ldots,R_n$

C2 = is any condition on aggregate expressions

General form of Grouping and Aggregation

```
SELECT    S
FROM      R1,…,Rn
WHERE     C1
GROUP BY  a1,…,ak
HAVING    C2
```

Evaluation steps:

1. Evaluate FROM-WHERE, apply condition C1
2. Group by the attributes $a_1,\ldots,a_k$
3. Apply condition C2 to each group (may have aggregates)
4. Compute aggregates in S and return the result

Advanced SQLizing

1. Getting around INTERSECT and EXCEPT

2. Quantifiers

3. Aggregation v.s. subqueries

4. Two examples (study at home)

INTERSECT and EXCEPT: not in SQL Server

1. INTERSECT and EXCEPT:

If R, S have no duplicates, then can write without subqueries (HOW ?)

```
(SELECT R.A, R.B
FROM    R)
   INTERSECT
(SELECT S.A, S.B
FROM    S)
```

```
SELECT R.A, R.B
FROM    R
WHERE
     EXISTS(SELECT *
               FROM S
               WHERE R.A=S.A and R.B=S.B)
```

```
(SELECT R.A, R.B
FROM    R)
   EXCEPT
(SELECT S.A, S.B
FROM    S)
```

```
SELECT R.A, R.B
FROM    R
WHERE
  NOT  EXISTS(SELECT *
               FROM S
               WHERE R.A=S.A and R.B=S.B)
```

2. Quantifiers

Product (pname, price, company)
Company(cname, city)

Find all companies that make <u>some</u> products with price < 100

```
SELECT DISTINCT  Company.cname
FROM     Company, Product
WHERE  Company.cname = Product.company and Product.price < 100
```

Existential: easy ! ☺

2. Quantifiers

Product (pname, price, company)
Company(cname, city)

Find all companies that make <u>only</u> products with price < 100

same as:

Find all companies s.t. <u>all</u> of their products have price < 100

Universal: hard ! ☹

2. Quantifiers

1. Find *the other* companies: i.e. s.t. some product ≥ 100

```
SELECT DISTINCT  Company.cname
FROM     Company
WHERE  Company.cname IN (SELECT Product.company
                         FROM Product
                         WHERE Produc.price >= 100
```

2. Find all companies s.t. all their products have price < 100

```
SELECT DISTINCT  Company.cname
FROM     Company
WHERE  Company.cname NOT IN (SELECT Product.company
                             FROM Product
                             WHERE Produc.price >= 100
```

3. Group-by v.s. Nested Query

Author(<u>login</u>,name)

Wrote(login,url)

- Find authors who wrote ≥ 10 documents:
- Attempt 1: with nested queries

SQL by
a novice

```
SELECT DISTINCT Author.name
FROM        Author
WHERE       count(SELECT Wrote.url
                  FROM Wrote
                  WHERE Author.login=Wrote.login)
            > 10
```

3. Group-by v.s. Nested Query

- Find all authors who wrote at least 10 documents:
- Attempt 2: SQL style (with GROUP BY)

```
SELECT      Author.name
FROM        Author, Wrote
WHERE       Author.login=Wrote.login
GROUP BY    Author.name
HAVING      count(wrote.url) > 10
```

SQL by an expert

No need for DISTINCT: automatically from GROUP BY

3. Group-by v.s. Nested Query

Author(login,name)

Wrote(login,url)

Mentions(url,word)

Find authors with vocabulary ≥ 10000 words:

```
SELECT     Author.name
FROM       Author, Wrote, Mentions
WHERE      Author.login=Wrote.login AND Wrote.url=Mentions.url
GROUP BY   Author.name
HAVING     count(distinct Mentions.word) > 10000
```

4. Two Examples

Store(sid, sname)
Product(pid, pname, price, sid)

Find all stores that sell *only* products with price > 100

same as:

Find all stores s.t. all their products have price > 100)

```
SELECT Store.name
FROM    Store, Product
WHERE  Store.sid = Product.sid
GROUP BY  Store.sid, Store.name
HAVING 100 < min(Product.price)
```

Why both ?

Almost equivalent…

```
SELECT Store.name
FROM    Store
WHERE
   100 < ALL (SELECT Product.price
              FROM product
              WHERE Store.sid = Product.sid)
```

```
SELECT Store.name
FROM    Store
WHERE  Store.sid NOT IN
            (SELECT Product.sid
             FROM Product
             WHERE  Product.price <= 100)
```

Two Examples

Store(sid, sname)
Product(pid, pname, price, sid)

For each store,
find its most expensive product

Two Examples

This is easy but doesn't do what we want:

```
SELECT Store.sname, max(Product.price)
FROM   Store, Product
WHERE  Store.sid = Product.sid
GROUP BY  Store.sid, Store.sname
```

Better:

```
SELECT Store.sname, x.pname
FROM   Store, Product x
WHERE  Store.sid = x.sid and
       x.price >=
           ALL (SELECT y.price
                FROM Product y
                WHERE Store.sid = y.sid)
```

But may return multiple product names per store

Two Examples

Finally, choose some pid arbitrarily, if there are many with highest price:

```
SELECT Store.sname, max(x.pname)
FROM   Store, Product x
WHERE  Store.sid = x.sid and
       x.price >=
          ALL (SELECT y.price
               FROM Product y
               WHERE Store.sid = y.sid)
GROUP BY Store.sname
```

NULLS in SQL

- Whenever we don't have a value, we can put a NULL
- Can mean many things:
  - Value does not exists
  - Value exists but is unknown
  - Value not applicable
  - Etc.
- The schema specifies for each attribute if can be null (*nullable* attribute) or not
- How does SQL cope with tables that have NULLs ?

Null Values

- If x= NULL then 4*(3-x)/7 is still NULL
- If x= NULL then x="Joe" is UNKNOWN
- In SQL there are three boolean values:

FALSE	=	0
UNKNOWN	=	0.5
TRUE	=	1

Null Values

- C1 AND C2 = min(C1, C2)
- C1 OR C2 = max(C1, C2)
- NOT C1 = 1 – C1

```
SELECT *
FROM Person
WHERE  (age < 25) AND
       (height > 6 OR weight > 190)
```

E

E.g.
age=20
heigth=NULL
weight=200

Null Values

Unexpected behavior:

```
SELECT *
FROM   Person
WHERE  age < 25  OR  age >= 25
```

Some Persons are not included !

Null Values

Can test for NULL explicitly:

- x IS NULL
- x IS NOT NULL

```
SELECT *
FROM    Person
WHERE  age < 25  OR  age >= 25 OR age IS NULL
```

Now it includes all Persons

Outerjoins

Explicit joins in SQL = “inner joins”:

Product(name, category)
Purchase(prodName, store)

```
SELECT Product.name, Purchase.store
FROM   Product JOIN Purchase ON
              Product.name = Purchase.prodName
```

Same as:

```
SELECT Product.name, Purchase.store
FROM   Product, Purchase
WHERE  Product.name = Purchase.prodName
```

But Products that never sold will be lost !

Outerjoins

Left outer joins in SQL:

Product(name, category)

Purchase(prodName, store)

```
SELECT Product.name, Purchase.store
FROM   Product LEFT OUTER JOIN Purchase ON
            Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz
OneClick	NULL

Application

Compute, for each product, the total number of sales in 'September'

Product(name, category)

Purchase(prodName, month, store)

```
SELECT Product.name, count(*)
FROM    Product, Purchase
WHERE   Product.name = Purchase.prodName
        and  Purchase.month = 'September'
GROUP BY Product.name
```

What's wrong ?

Application

Compute, for each product, the total number of sales in 'September'

Product(name, category)

Purchase(prodName, month, store)

```
SELECT Product.name, count(*)
FROM    Product LEFT OUTER JOIN Purchase ON
                 Product.name = Purchase.prodName
            and  Purchase.month = 'September'
GROUP BY Product.name
```

Now we also get the products who sold in 0 quantity

Outer Joins

- Left outer join:
  - Include the left tuple even if there’s no match
- Right outer join:
  - Include the right tuple even if there’s no match
- Full outer join:
  - Include the both left and right tuples even if there’s no match

Modifying the Database

Three kinds of modifications

- Insertions
- Deletions
- Updates

Sometimes they are all called “updates”

Insertions

General form:

```
INSERT INTO R(A1,…., An) VALUES (v1,…., vn)
```

Example: Insert a new purchase to the database:

```
INSERT INTO Purchase(buyer, seller, product, store)
        VALUES ('Joe', 'Fred', 'wakeup-clock-espresso-machine',
                'The Sharper Image')
```

Missing attribute → NULL.
May drop attribute names if give them in order.

Insertions

```
INSERT   INTO   PRODUCT(name)

    SELECT  DISTINCT  Purchase.product
    FROM       Purchase
    WHERE   Purchase.date > “10/26/01”
```

The query replaces the VALUES keyword.
Here we insert *many* tuples into PRODUCT

Insertion: an Example

Product(name, listPrice, category)
Purchase(prodName, buyerName, price)

prodName is foreign key in Product.name

Suppose database got corrupted and we need to fix it:

Product

name	listPrice	category
gizmo	100	gadgets

Purchase

prodName	buyerName	price
camera	John	200
gizmo	Smith	80
camera	Smith	225

Task: insert in Product all prodNames from Purchase

Insertion: an Example

```
INSERT   INTO   Product(name)

 SELECT  DISTINCT  prodName
 FROM     Purchase
 WHERE   prodName  NOT IN (SELECT  name FROM  Product)
```

name	listPrice	category
gizmo	100	Gadgets
camera	-	-

Insertion: an Example

```
INSERT  INTO  Product(name, listPrice)

 SELECT  DISTINCT  prodName, price
 FROM  Purchase
 WHERE   prodName  NOT IN (SELECT  name FROM  Product)
```

name	listPrice	category
gizmo	100	Gadgets
camera	200	-
camera ??	225 ??	-

← Depends on the implementation

Deletions

Example:

```
DELETE   FROM   PURCHASE

WHERE   seller = 'Joe'   AND
        product = 'Brooklyn Bridge'
```

Factoid about SQL: there is no way to delete only a single occurrence of a tuple that appears twice in a relation.

Updates

Example:

```
UPDATE   PRODUCT
SET    price = price/2
WHERE  Product.name  IN
                (SELECT product
                 FROM    Purchase
                 WHERE  Date ='Oct, 25, 1999');
```

Data Definition in SQL

So far we have see the ***Data Manipulation Language***, DML
Next: ***Data Definition Language*** (DDL)

Data types:

Defines the types.

Data definition: defining the schema.

- Create tables
- Delete tables
- Modify table schema

Indexes: to improve performance

Creating Tables

```
CREATE    TABLE Person(

        name                            VARCHAR(30),
        social-security-number          INT,
        age                             SHORTINT,
        city                            VARCHAR(30),
        gender                          BIT(1),
        Birthdate                       DATE

  );
```

Deleting or Modifying a Table

Deleting:

Example:

```
DROP Person;
```

Exercise with care !!

Altering: (adding or removing an attribute).

Example:

```
ALTER TABLE Person
      ADD phone CHAR(16);

ALTER TABLE Person
      DROP age;
```

What happens when you make changes to the schema?

Default Values

Specifying default values:

```
CREATE  TABLE Person(
        name                    VARCHAR(30),
        social-security-number  INT,
        age         SHORTINT   DEFAULT 100,
        city     VARCHAR(30) DEFAULT   'Seattle',
        gender        CHAR(1)  DEFAULT  '?',
        Birthdate                  DATE
```

The default of defaults: NULL

Indexes

REALLY important to speed up query processing time.

Suppose we have a relation

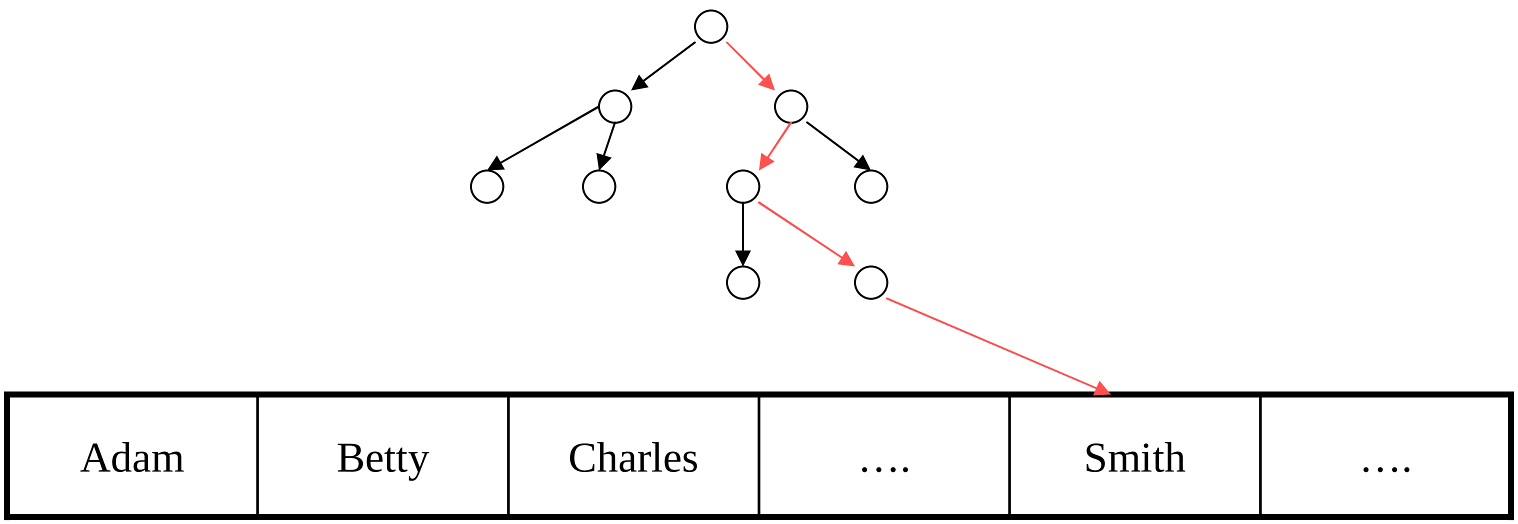
Person (name, age, city)

```
SELECT *
FROM    Person
WHERE   name = "Smith"
```

Sequential scan of the file Person may take long

Indexes

- Create an index on name:



B+ trees have fan-out of 100s: max 4 levels !

Will discuss in the second half of this course

Creating Indexes

Syntax:

```
CREATE INDEX  nameIndex ON Person(name)
```

Creating Indexes

Indexes can be useful in range queries too:

```
CREATE INDEX ageIndex ON  Person (age)
```

B+ trees help in:

```
SELECT *
FROM Person
WHERE age > 25 AND age < 28
```

Why not create indexes on everything?

Creating Indexes

Indexes can be created on more than one attribute:

Example:

```
CREATE INDEX doubleindex ON
                    Person (age, city)
```

Helps in:

```
SELECT *
FROM    Person
WHERE age = 55 AND city = "Seattle"
```

and even in:

```
SELECT *
FROM    Person
WHERE age = 55
```

But not in:

```
SELECT *
FROM    Person
WHERE city = "Seattle"
```

The Index Selection Problem

- Why not build an index on every attribute ? On every pair of attributes ? Etc. ?

- The index selection problem is hard: balance the query cost v.s. the update cost, in a large application workload