# SQL

INTRODUCTION TO DATA SCIENCE

TIM KRASKA

# THE 1ST PROJECT

- Goal: get started to develop a data product
- Projects can range from gathering and cleaning a data set, over repeating an existing study or web-site to visualize a data set to testing an entirely new hypothesis.
- Groups of 4 (use Piazza if you still need a group)

| | |
|---|---|
| 2/16/2016 | Pre-Proposal Handin |
| 3/3/2016 | Advisor Checkin |
| 3/22/2016 | Mid-term report |
| 4/12/2016 | Full Project Proposal |
| 4/21/2016 | Advisor Checkin |
| 5/3/2016 | Advisor Checkin |
| 5/12/2016 | Final Project Due |

- Mid-term report has to be a public blog post
- 2nd project can be a continuations of the 1st, but doesn't have to be
- 10% of your grade (the final project will be 25%).
- **List of potential data sources and some project ideas are online** http://cs.brown.edu/courses/csci1951-a/final_project.shtml
- **You are encouraged to find your own data and create your own project**
- Pre-proposal is not binding even for the mid-term report
- We will have a competition for the best Mid-term report/project

# LAST LECTURE

- SQL basics:

  Select
  From
  Where
  Group By
  Having
  Order By

- Nested queries
- Set operations
- Null values

# CLICKER: EXISTENTIAL QUANTIFICATION: EXISTS SUB-QUERIES

```
select p.Name
from Professor p
where not exists ( select *
                   from Lecture l
                   where l.Person-ID = p.Person-ID );
```

Professor

| Person-Id | Name |
|---|---|
| 1 | Stan |
| 2 | Ugur |
| 3 | Eli |

Lecture

| Person-Id | Course-ID |
|---|---|
| 1 | CS127 |
| 1 | CS227 |
| 3 | CS155 |

What is the result of the query?

(a) {Stan, Eli}

(b) {Ugur}

(c) {Eli}

# EXISTENTIAL QUANTIFICATION: EXISTS SUB-QUERIES

```
select p.Name
from Professor p
where not exists ( select *
                   from Lecture l
                   where l.Person-ID = p.Person-ID );
```

Professor

| Person-Id | Name |
|---|---|
| 1 | Stan |
| 2 | Ugur |
| 3 | Eli |

Lecture

| Person-Id | Course-ID |
|---|---|
| 1 | CS127 |
| 1 | CS227 |
| 3 | CS155 |

# EXISTENTIAL QUANTIFICATION: EXISTS SUB-QUERIES

```
select p.Name
from Professor p
where not exists ( select *
                   from Lecture l
                   where l.Person-ID = 1);
```

Professor

| Person-Id | Name |
|---|---|
| 1 | Stan |
| 2 | Ugur |
| 3 | Eli |

Lecture

| Person-Id | Course-ID |
|---|---|
| 1 | CS127 |
| 1 | CS227 |
| 3 | CS155 |

# EXISTENTIAL QUANTIFICATION: EXISTS SUB-QUERIES

```
select p.Name
from Professor p
where not exists ( select *
                   from Lecture l
                   where l.Person-ID = p.Person-ID );
```

Professor

| Person-Id | Name |
|---|---|
| 1 | Stan |
| 2 | Ugur |
| 3 | Eli |

Lecture

| Person-Id | Course-ID |
|---|---|
| 1 | CS127 |
| 1 | CS227 |
| 3 | CS155 |

# EXISTENTIAL QUANTIFICATION: EXISTS SUB-QUERIES

```
select p.Name
from Professor p
where not exists ( select *
                   from Lecture l
                   where l.Person-ID = 2);
```

Professor

| Person-Id | Name |
|---|---|
| 1 | Stan |
| 2 | Ugur |
| 3 | Eli |

Lecture

| Person-Id | Course-ID |
|---|---|
| 1 | CS127 |
| 1 | CS227 |
| 3 | CS155 |

# EXISTENTIAL QUANTIFICATION: EXISTS SUB-QUERIES

```
select p.Name
from Professor p
where not exists ( select *
                   from Lecture l
                   where l.Person-ID = 2);
```

Professor

| Person-Id | Name |
|---|---|
| 1 | Stan |
| 2 | Ugur |
| 3 | Eli |

Lecture

| Person-Id | Course-ID |
|---|---|
| 1 | CS127 |
| 1 | CS227 |
| 3 | CS155 |

Result: {Ugur}

# EXISTENTIAL QUANTIFICATION: EXISTS SUB-QUERIES

```
select p.Name
from Professor p
where not exists ( select *
                   from Lecture l
                   where l.Person-ID = 3);
```

Professor

| Person-Id | Name |
|---|---|
| 1 | Stan |
| 2 | Ugur |
| 3 | Eli |

Lecture

| Person-Id | Course-ID |
|---|---|
| 1 | CS127 |
| 1 | CS227 |
| 3 | CS155 |

Result: {Ugur}

# UNCORRELATED SUB-QUERY

```
select Name
from Professor
where Person-ID not in ( select Person-ID
                         from Lecture);
```

Professor

| Person-Id | Name |
|---|---|
| 1 | Stan |
| 2 | Ugur |
| 3 | Eli |

Lecture

| Person-Id | Course-ID |
|---|---|
| 1 | CS127 |
| 1 | CS227 |
| 3 | CS155 |

# UNCORRELATED SUB-QUERY

```
select Name
from Professor
where Person-ID not in ( select Person-ID
                         from Lecture);
```

| Person-Id | Name |
|---|---|
| 1 | Stan |
| 2 | Ugur |
| 3 | Eli |

| Person-Id | Course-ID |
|---|---|
| 1 | CS127 |
| 1 | CS227 |
| 3 | CS155 |

# UNCORRELATED SUB-QUERY

```
select Name
from Professor
where Person-ID not in ( select Person-ID
                         from Lecture);
```

| Person-Id | Name |
|---|---|
| 1 | Stan |
| 2 | Ugur |
| 3 | Eli |

| Person-Id | Course-ID |
|---|---|
| 1 | CS127 |
| 1 | CS227 |
| 3 | CS155 |

# SYNTACTIC SUGAR

```
select *
from Student
where 1 <= Semester  and Semester < = 6;
```

```
select *
from Student
where Semester between 1 and 6;
```

```
select *
from Student
where Semester in (2,4,6);
```

# COMPARISONS WITH **LIKE**

"%„ represents any sequence of characters (0 to n)

"_„ represents exactly one character

N.B.: For comparisons with = , % and _ are normal chars.

```
select *
from Student
where Name like ´Tim%´;
```

```
select distinct Name
from Lecture l, attends a, Student s
where s.Student-ID = a.Student-ID and a.CID = l.CID
        and  l.Title like ´%science%´;
```

# CLICKER

Given the following tables

Runners

| id | name |
|---|---|
| 1 | John |
| 2 | Tim |
| 3 | Alice |
| 4 | Lisa |

Races

| Event_id | Event | Winner_id |
|---|---|---|
| 1 | Tough mudder | 2 |
| 2 | 500m | 3 |
| 3 | Cross-country | 2 |
| 4 | Triathlon | null |

What will be the result of the query:

```
SELECT *
FROM runners
WHERE id NOT IN (SELECT winner_id FROM races)
```

A) 1
B) Empty set
C) (1,4)

# JOINS IN SQL-92

- **cross join**: Cartesian product
- **natural join**
- **join** or **inner join**
- **left, right** or **full outer join**
- (union join: not discussed here)

```
select *
from R1, R2
where R1.A = R2.B;
```

```
select *
from R1 join R2 on R1.A = R2.B;
```

# LEFT OUTER JOINS

```
select p.Person-ID, p.Name, t.Person-ID, t.Grade, t.Student-ID,
s.Student-ID, s.Name
from Professor p left outer join
        (tests t left outer join Student s
        on t.Student-ID= s.Student-ID)
        on p.Person-ID=t.Person-ID;
```

| Person-ID | p.Name | t.Person-ID | t.Grade | t.Student-ID | s.Student-ID | s.Name |
|---|---|---|---|---|---|---|
| 2126 | Stan | 2126 | 1 | 28106 | 28106 | Carnap |
| 2125 | Ugur | 2125 | 2 | 25403 | 25403 | Jonas |
| 2137 | Jeff | 2137 | 2 | 27550 | 27550 | Schopen-hauer |
| 2136 | Curie | - | - | - | - | - |
| : | : | : | : | : | : | : |

# RIGHT OUTER JOINS

```
select p.Person-ID, p.Name, t.Person-ID, t.Grade, t.Student-ID, s.Student-ID, s.Name
from Professor p right outer join
                    (tests t right outer join Student s on
                    t.Student-ID= s.Student-ID)
     on p.Person-ID=t.Person-ID;
```

| Person-ID | p.Name | t.Person-ID | t.Grade | t.Student-ID | s.Student-ID | s.Name |
|---|---|---|---|---|---|---|
| 2126 | Stan | 2126 | 1 | 28106 | 28106 | Carnap |
| 2125 | Ugur | 2125 | 2 | 25403 | 25403 | Jonas |
| 2137 | Jeff | 2137 | 2 | 27550 | 27550 | Schopen-hauer |
| - | - | - | - | - | 26120 | Fichte |
| : | : | : | : | : | : | : |

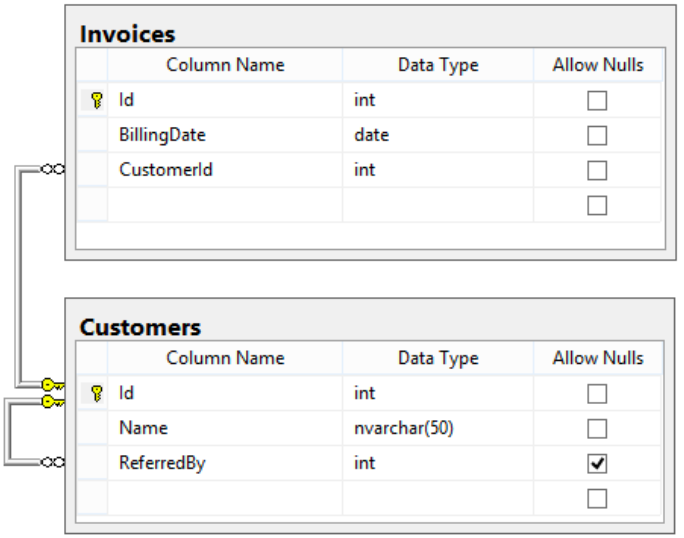
# FULL OUTER JOINS

```
select p.Person-ID, p.Name, t.Person-ID, t.Grade, t.Student-ID,
s.Student-ID, s.Name
from Professor p full outer join
                (tests t full outer join Student s on
                t.Student-ID= s.Student-ID)
                on p.Person-ID=t.Person-ID;
```

| p.Person-ID | p.Name | t.Person-ID | t.Grade | t.Student-ID | s.Student-ID | s.Name |
|---|---|---|---|---|---|---|
| 2126 | Stan | 2126 | 1 | 28106 | 28106 | Carnap |
| 2125 | Ugur | 2125 | 2 | 25403 | 25403 | Jonas |
| 2137 | Jeff | 2137 | 2 | 27550 | 27550 | Schopen-hauer |
| - | - | - | - | - | 26120 | Fichte |
| | | | | | | |
| 2136 | Curie | - | - | - | - | - |
| | | | | | | |

# CLICKER

You have your first day as a Data Scientist at TheShop LLC. TheShop uses SQL server. A quick look using VisualStudio shows the simply database schema on the right. In order to analyze all the orders in Python, your first task is to write a SQL query to return a list of all the invoices. For each invoice, you want the Invoice ID, the billing date, the customer's name, and the name of the customer who referred that customer (if any). The list should be ordered by billing date.




A)

```
SELECT i.Id, i.BillingDate, c.Name, r.Name AS ReferredByName
FROM (Invoices i JOIN Customers c ON i.CustomerId = c.Id)
                 JOIN Customers r ON c.ReferredBy = r.Id
ORDER BY i.BillingDate;
```

B)

```
SELECT i.Id, i.BillingDate, c.Name, r.Name AS ReferredByName
FROM (Invoices I JOIN Customers c ON i.CustomerId = c.Id)
                 LEFT JOIN Customers r ON c.ReferredBy = r.Id
ORDER BY i.BillingDate;
```

C)

```
SELECT i.Id, i.BillingDate, c.Name, r.Name AS ReferredByName
FROM (Invoices i Right JOIN Customers c ON i.CustomerId = c.Id)
                 Right JOIN Customers r ON c.ReferredBy = r.Id
ORDER BY i.BillingDate;
```

# HOW DOES THE DB PROCESS A SQL QUERY?

# SQL is the “WHAT” not the “HOW”

Product(pid, name, price)
Purchase(pid, cid, store)
Customer(cid, name, city)

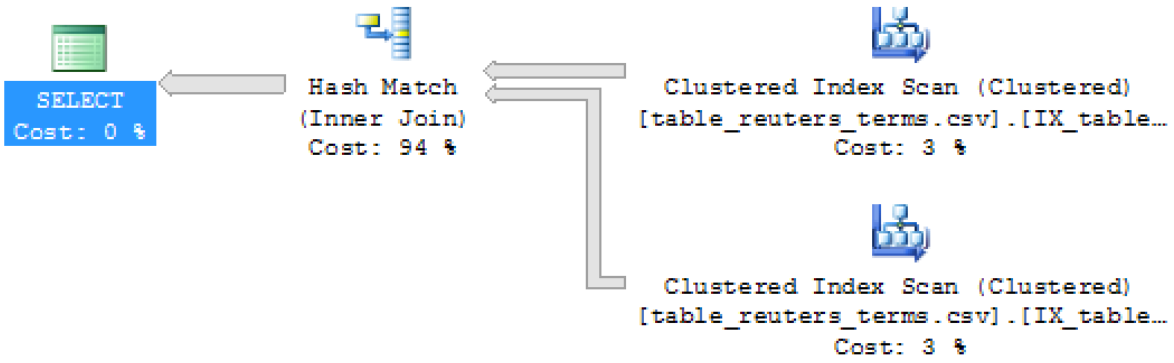
```
SELECT DISTINCT x.name, z.name
FROM Product x, Purchase y, Customer z
WHERE x.pid = y.pid and y.cid = y.cid and
        x.price > 100 and z.city = ‘Providence’
```

It’s clear WHAT we want, unclear HOW to get it

# Exposing the Algebra: Microsoft SQL Server

```
1  select a.term_id, b.term_id
2  from [billhowe].[reuters] a, [billhowe].[reuters] b
3  where a.doc_id = b.doc_id
4    and a.term_id != b.term_id
```

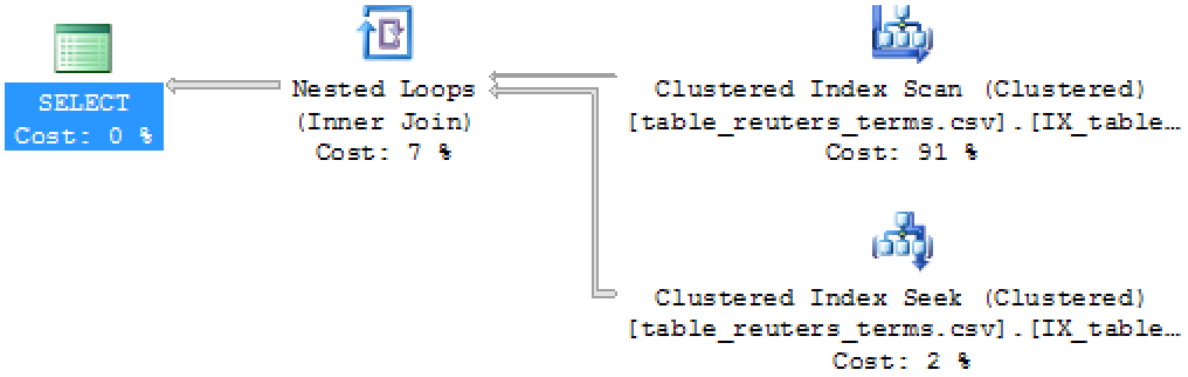
EXPLAIN



# Exposing the Algebra: Microsoft SQL Server

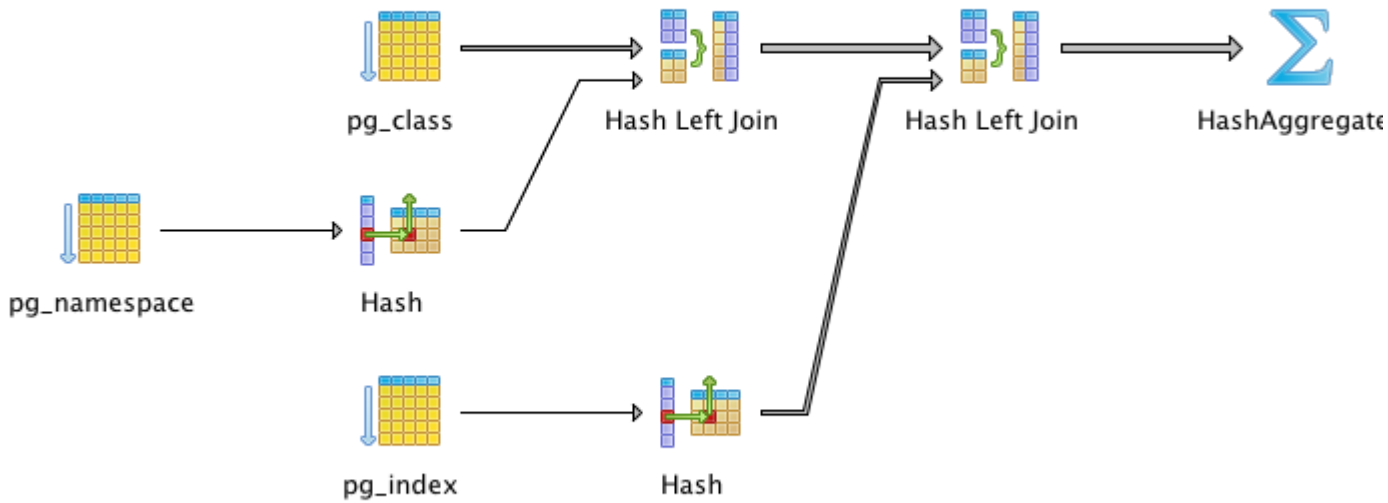
```
1  select a.term_id, b.term_id
2  from [billhowe].[reuters] a, [billhowe].[reuters] b
3  where a.doc_id = b.doc_id
4    and a.term_id != b.term_id
5    and a.term_id = 'parliament'
```

*EXPLAIN*



# Exposing the Algebra: PostgreSQL

EXPLAIN SELECT ….



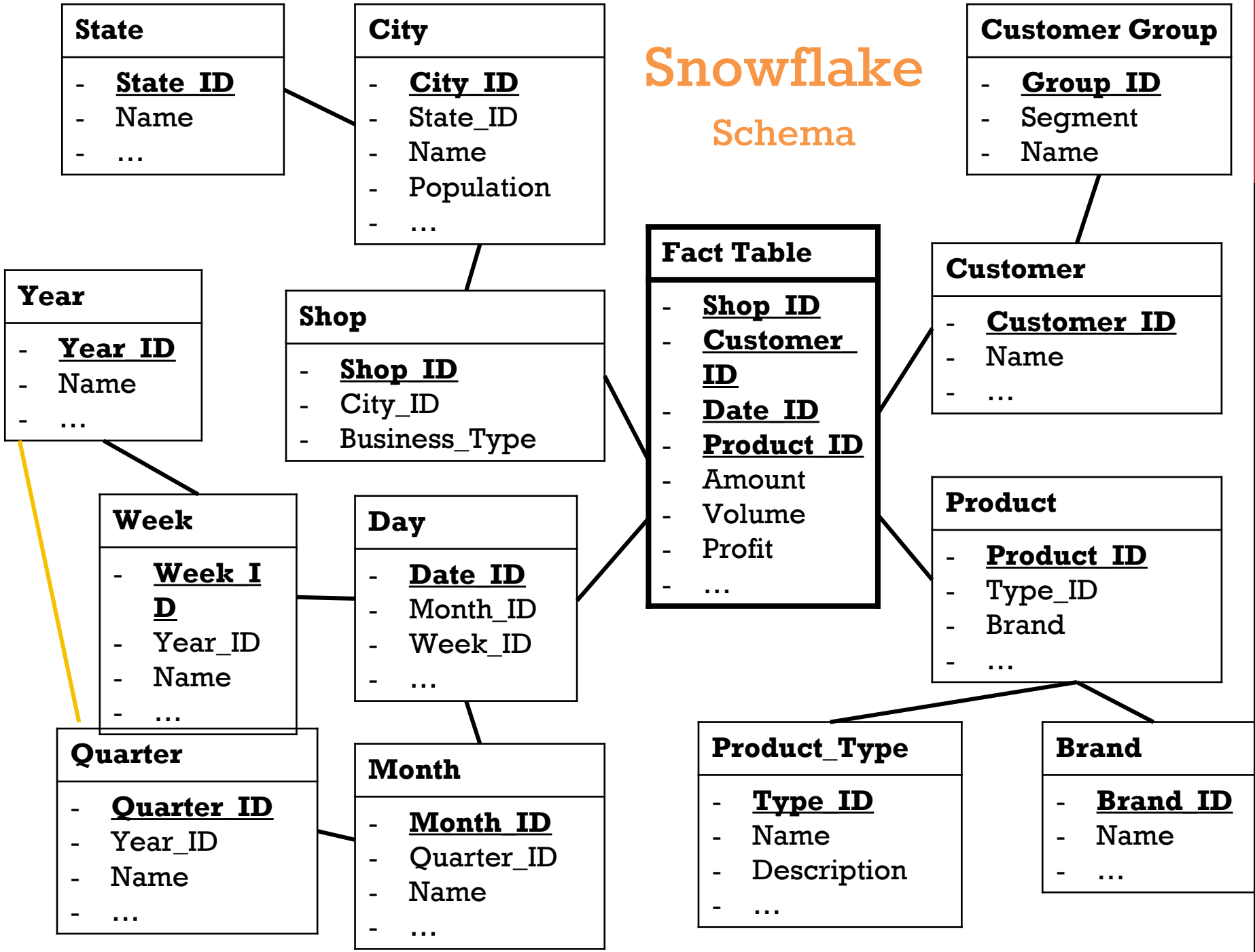

*screenshot from pgAdmin3*

# STAR VS SNOWFLAKE SCHEMA

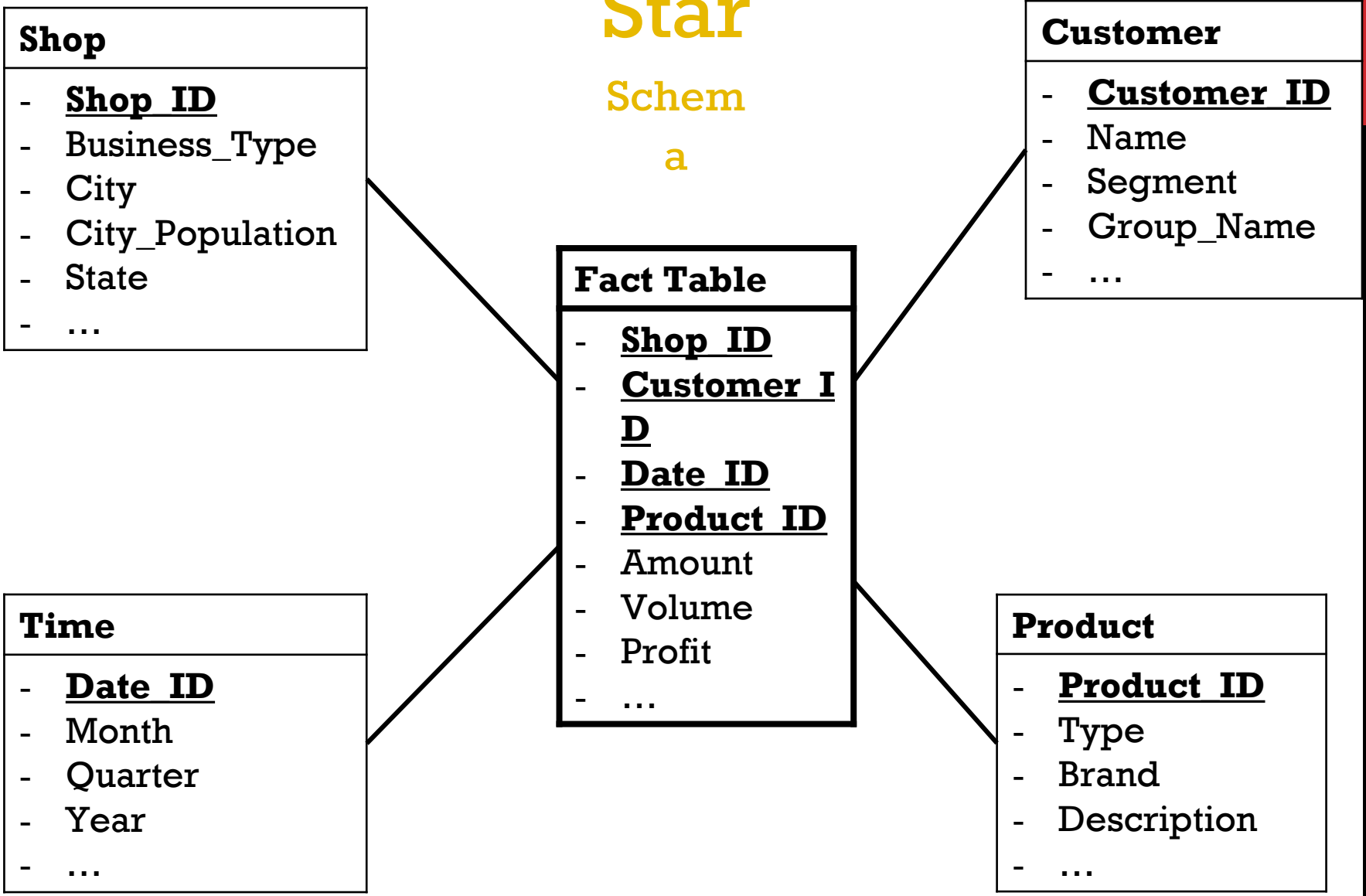
DATA WAREHOUSES

# Snowflake

## Schema



# Star Schema

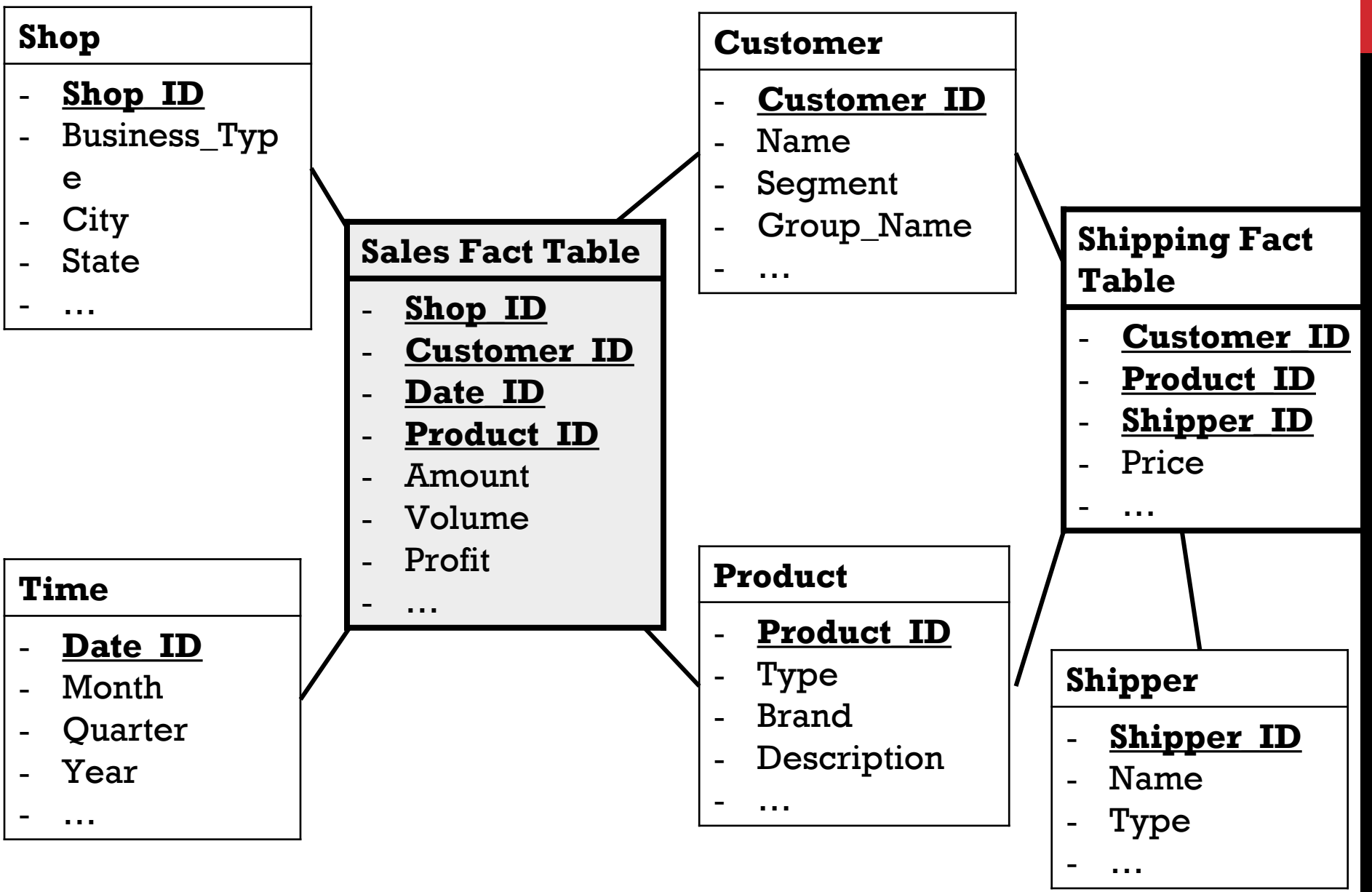

Shop
- Shop_ID
- Business_Type
- City
- City_Population
- State
- …
Customer
- Customer_ID
- Name
- Segment
- Group_Name
- …
Fact Table
- Shop_ID
- Customer_ID
- Date_ID
- Product_ID
- Amount
- Volume
- Profit
- …
Time
- Date_ID
- Month
- Quarter
- Year
- …
Product
- Product_ID
- Type
- Brand
- Description
- …

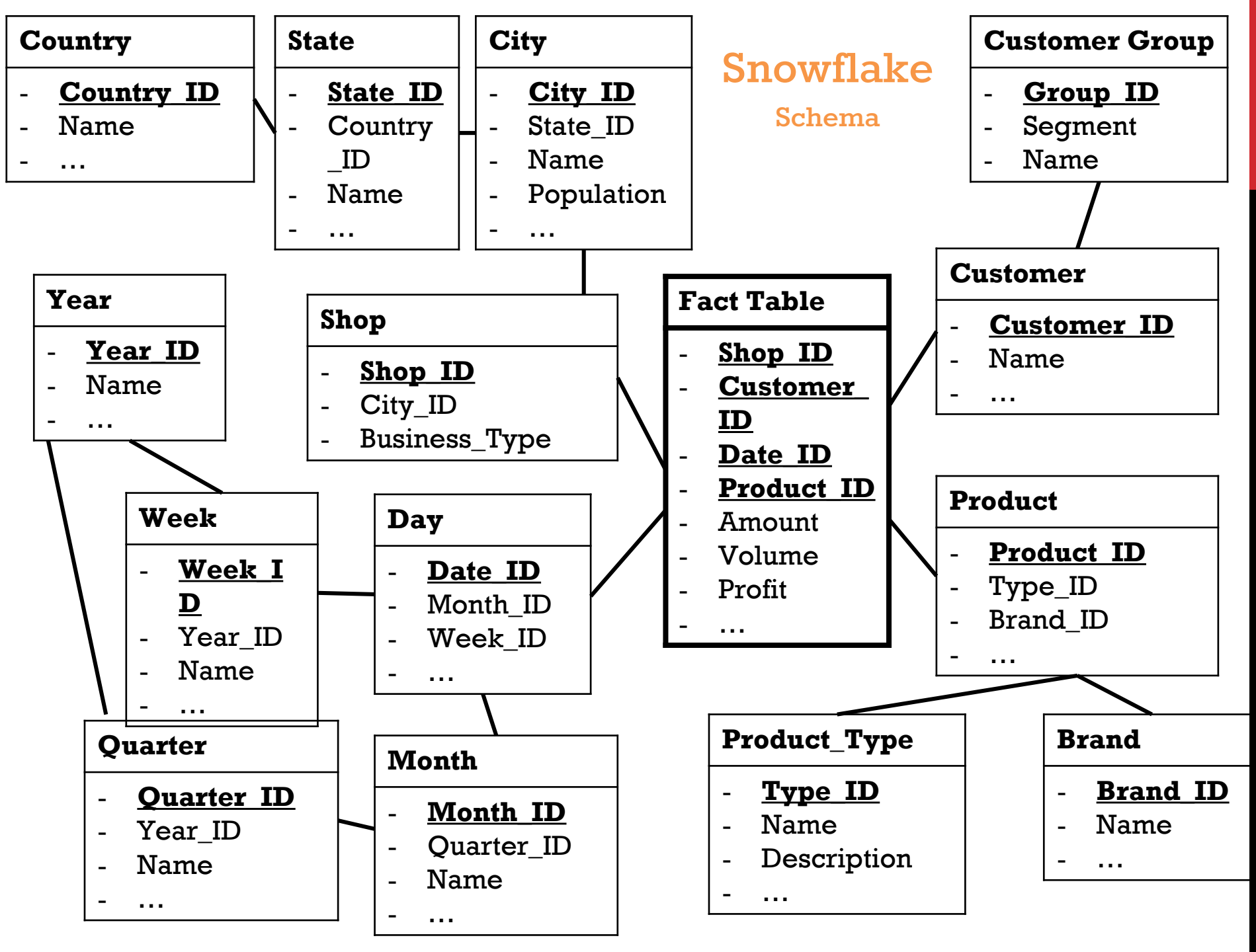
# STAR VS. SNOWFLAKE SCHEMA

| | Snowflake | Star |
|---|---|---|
| **Normalization/ De-Normalization** | Dimension Tables are in Normalized form but Fact Table is still in De-Normalized form | Both Dimension and Fact Tables are in De-Normalized form |
| **Space** | Smaller | Bigger (Redundancy) |
| **Query Performance** | More Joins → slower | Fewer Joins → faster |
| **Ease of Use** | Complex Queries | Pretty Simply Queries |
| **When to use** | When dimension table is relatively big in size, snowflaking is better as it reduces space. | When dimension table contains less number of rows, we can go for Star schema. |

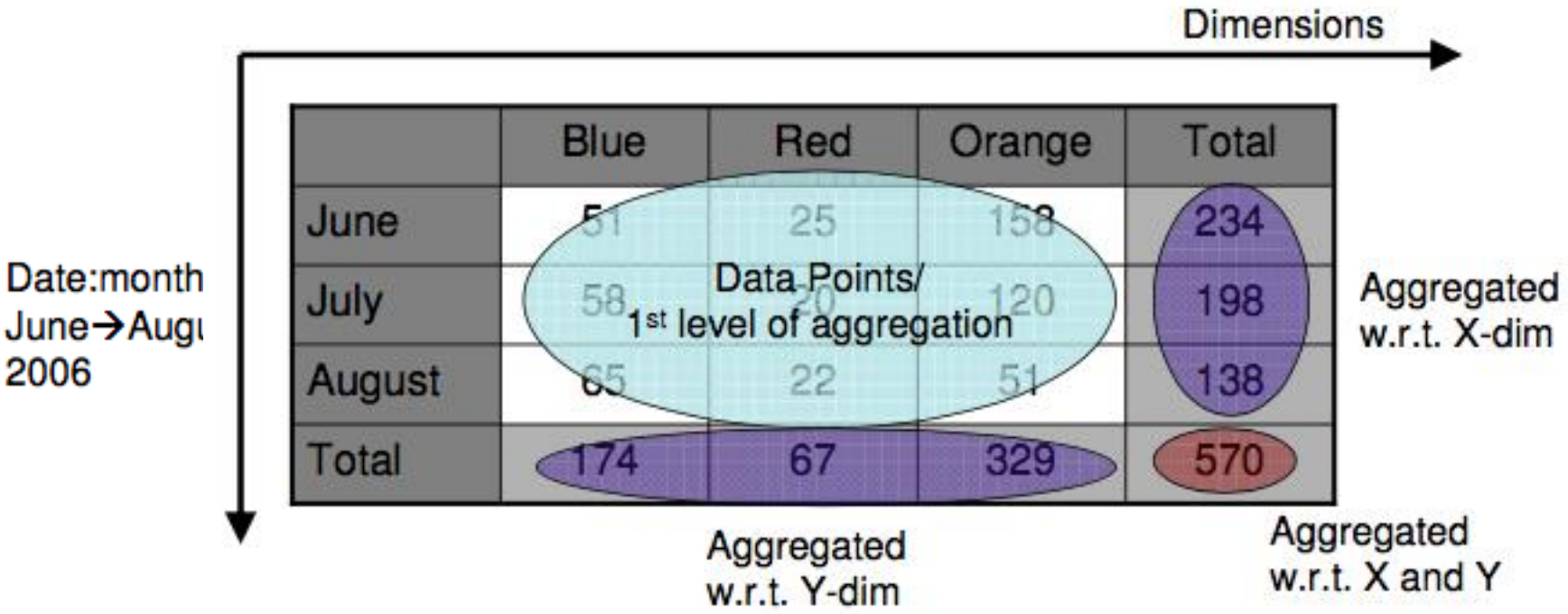
# Galaxy / Fact Constellation

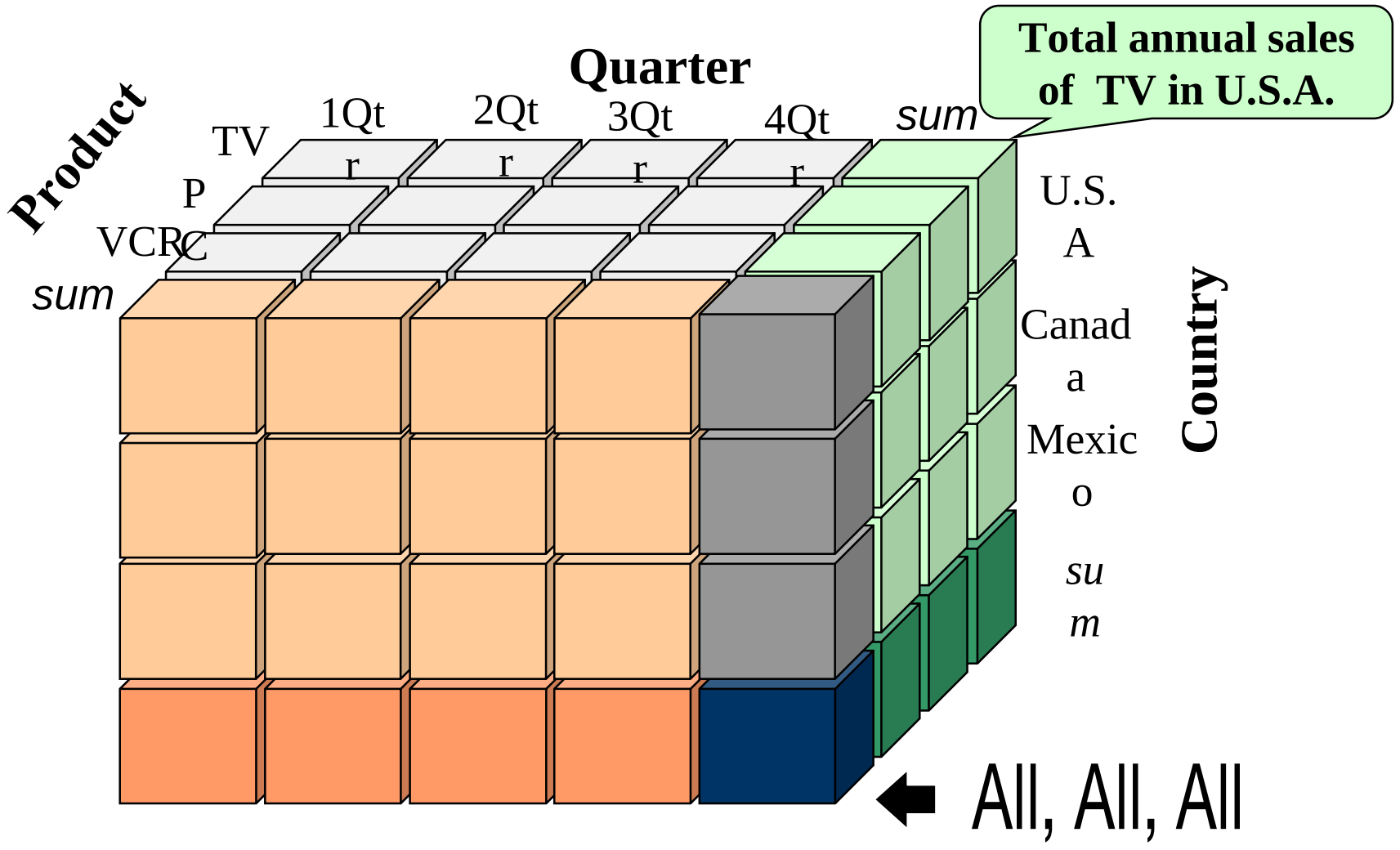
## Schema




Snowflake
Schema
Country
- Country_ID
- Name
- …
State
- State_ID
- Country_ID
- Name
- …
City
- City_ID
- State_ID
- Name
- Population
- …
Customer Group
- Group_ID
- Segment
- Name
Year
- Year_ID
- Name
- …
Shop
- Shop_ID
- City_ID
- Business_Type
Fact Table
- Shop_ID
- Customer_ID
- Date_ID
- Product_ID
- Amount
- Volume
- Profit
- …
Customer
- Customer_ID
- Name
- …
Week
- Week_ID
- Year_ID
- Name
- …
Day
- Date_ID
- Month_ID
- Week_ID
- …
Product
- Product_ID
- Type_ID
- Brand_ID
- …
Quarter
- Quarter_ID
- Year_ID
- Name
- …
Month
- Month_ID
- Quarter_ID
- Name
- …
Product_Type
- Type_ID
- Name
- Description
- …
Brand
- Brand_ID
- Name
- …

# 2 DIMENSIONAL CASE




Total annual sales of TV in U.S.A.
Quarter
Product
1Qt
2Qt
3Qt
4Qt
sum
TV
PC
VCR
sum
r
U.S.A
Canada
Mexico
sum
Country
All, All, All

# TYPICAL OLAP OPERATIONS

What does OLAP stand for?
What OLTP?

**Roll up (drill-up):** summarize data

*by climbing up hierarchy or by dimension reduction*

**Drill down (roll down):** reverse of roll-up

*from higher level summary to lower level summary or detailed data, or introducing new dimensions*

**Slice and dice:** *project and select*

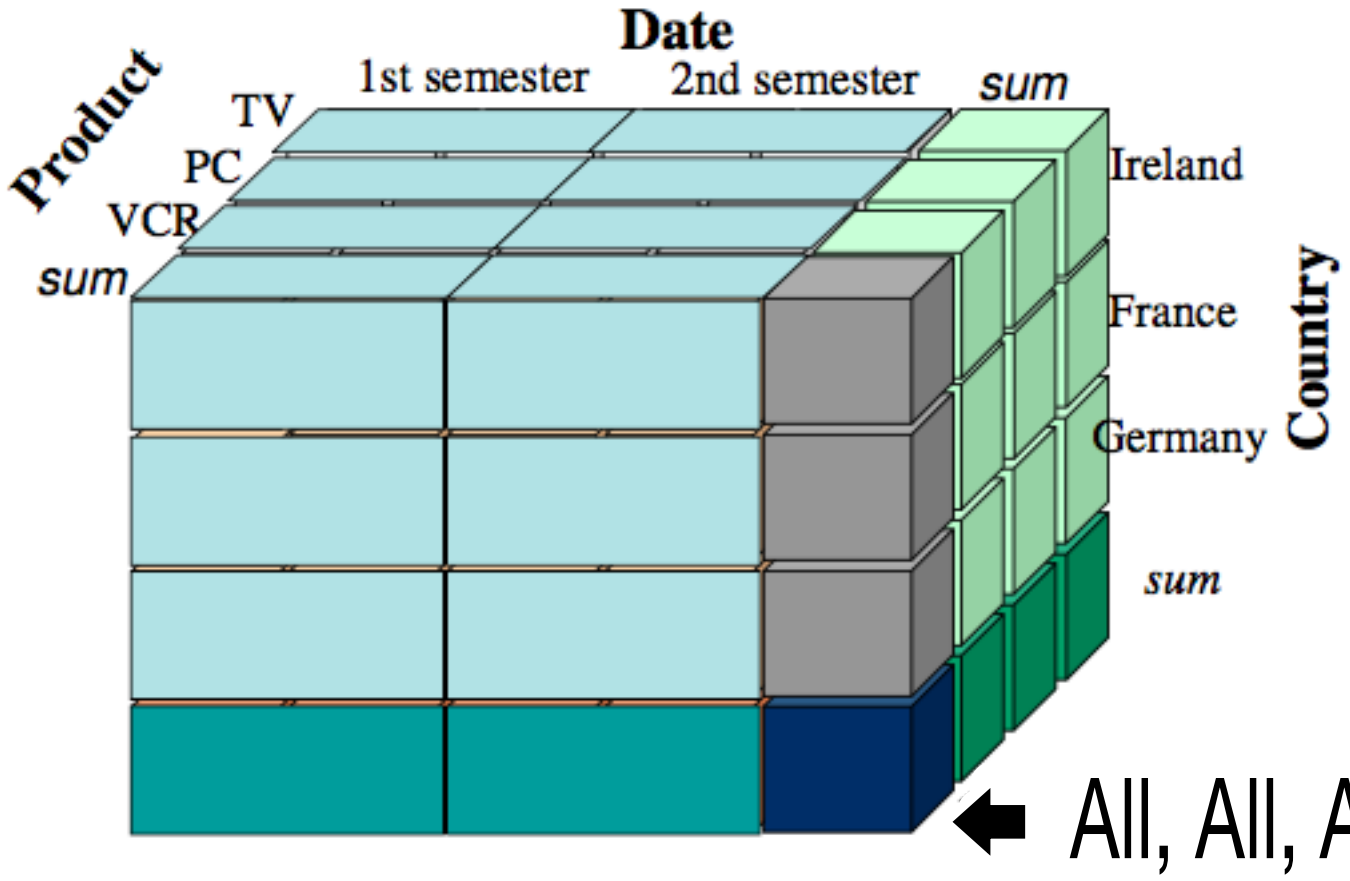
**Pivot (rotate):** *reorient the cube, visualization, 3D to series of 2D planes.*

Other operations

*drill across: involving (across) more than one fact table*

*drill through: through the bottom level of the cube to its back-end relational tables (using SQL)*

# ROLLUP


Date
1st semester
2nd semester
sum
Product
TV
PC
VCR
sum
Ireland
France
Germany
sum
Country
All, All, All

# REPRESENTING A CUBE

select *semester as date*, country, sum(sales)
from *sales*
group by cube(*semester,country*)

| Date | Country | Sales |
|---|---|---|
| 1st semester | Ireland | 20 |
| 1st semester | France | 126 |
| 1st semester | Germany | 56 |
| 1st semester | **null** | 202 |
| 2nd semester | Ireland | 23 |
| 2nd semester | France | 138 |
| 2nd semester | Germany | 48 |
| 2nd semester | **null** | 209 |
| **null** | Ireland | 43 |
| **null** | France | 264 |
| **null** | Germany | 104 |
| **null** | **null** | 411 |

# REPRESENTING A CUBE

select *semester as date*, country, sum(sales)
from *sales*
group by roll-up(*semester,country*)

| Date | Country | Sales |
|---|---|---|
| 1st semester | Ireland | 20 |
| 1st semester | France | 126 |
| 1st semester | Germany | 56 |
| 2nd semester | Ireland | 23 |
| 2nd semester | France | 138 |
| 2nd semester | Germany | 48 |
| 1st semester | **null** | 202 |
| 2nd semester | **null** | 209 |
| **null** | **null** | 411 |

# MDX

**Multidimensional Expressions (MDX) is a query language for cubes**

- Supported by many data warehouses
- Input and output are cubes

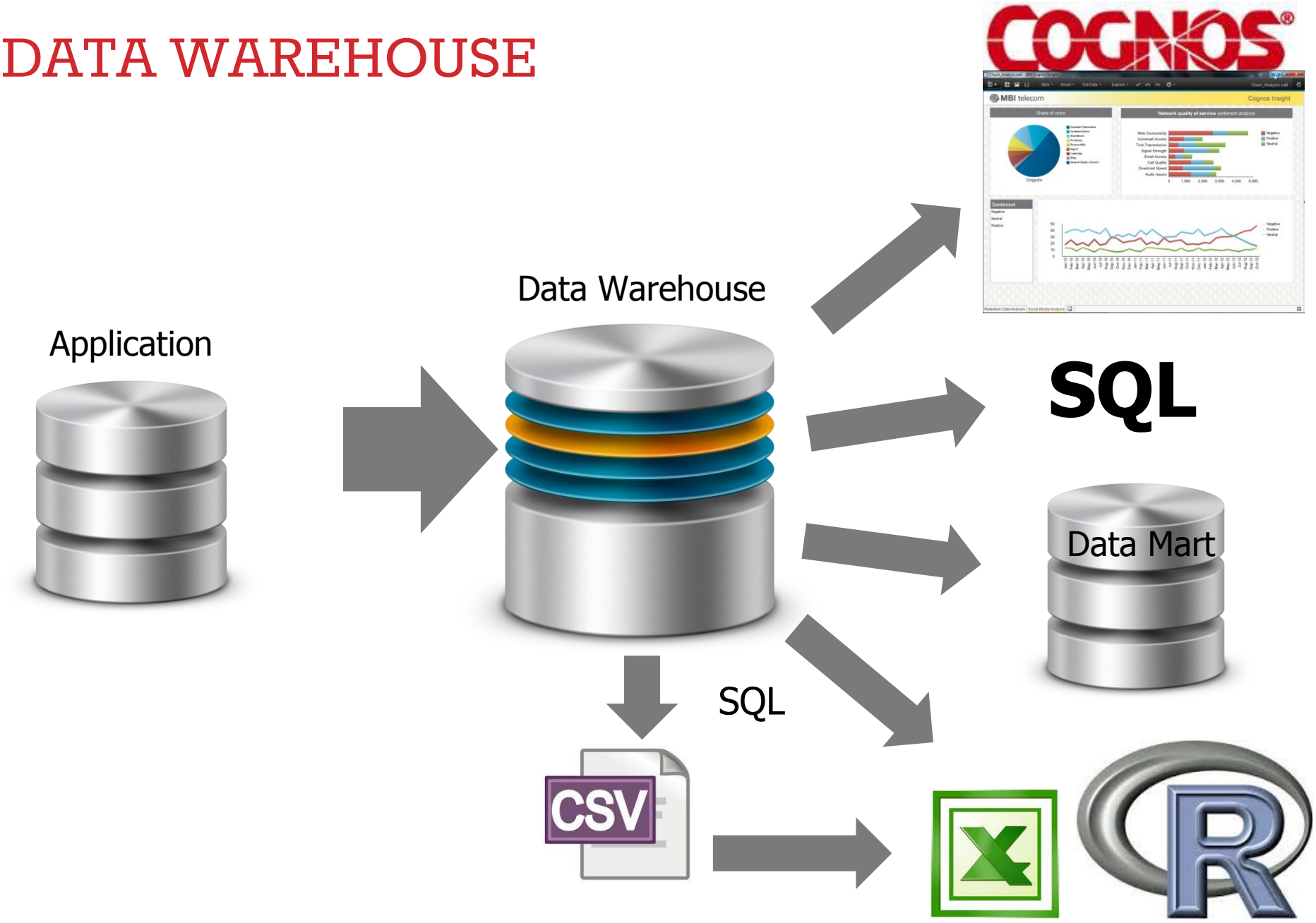
```
SELECT { [Measures].[Store Sales] } ON COLUMNS, { [Date].[2002], [Date].[2003] }
ON ROWS FROM Sales
WHERE ( [Store].[USA].[CA] )
```

# ENTITY RESOLUTION

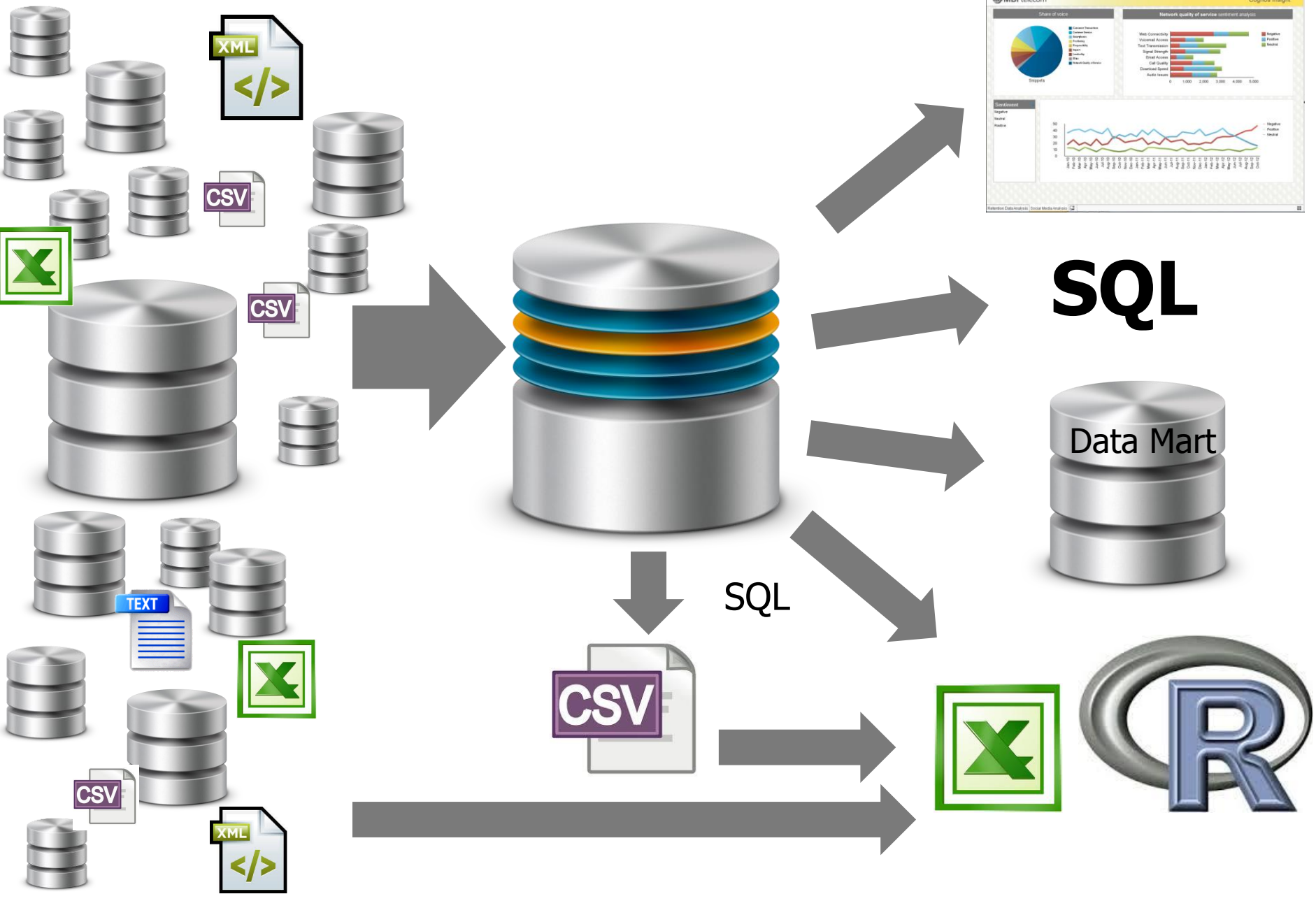
## CS1951A INTRO TO DATA SCIENCE

Tim Kraska <tim_kraska@brown.edu>

# DATA WAREHOUSE



# DATA WAREHOUSE



# DATA INTEGRATION

- **E**xtract-**T**ransform-**L**oad
  - “Old” term
  - Schema-centric
  - Batch-oriented
- Data Wrangling
  - Hipster term
  - Less structured
  - Ad-hoc

# DATA INTEGRATION

# SCHEMA MATCHING

| ID | Name | Address | Zip | State | City | Phone | E-Mail |
|---|---|---|---|---|---|---|---|
| 1 | Tim Kraska | 135 Watermann St, | 02906 | Providence | RI | +1 234234 234 | Tim_kraska@brown.edu |
| … | … | … | | | | .. | .. |

| ID | Name | Address | Phone | E-Mail |
|---|---|---|---|---|
| 1 | Tim Kraska | 135 Watermann St, 02906 Providence, RI | +1 234234 234 | Tim_kraska@brown.edu |
| … | … | … | .. | .. |

| ID | Name |
|---|---|
| 1 | Tim Kraska |
| … | … |

| AddressID | Person-ID | Address | Phone-Nb | E-Mail |
|---|---|---|---|---|
| 1 | 1 | 135 Watermann St, 02906 Providence | +1 234234 234 | Tim_kraska@brown.edu |
| 1 | 1 | 222 Hope St, 02906 Providence | 980 – 0803284 | tim_kraska@brown.edu |

## CLICKER:

# HOW MANY TABLES HAS A (TYPICAL) SAP'S ERP INSTALLATION?

(a) 100 - 1.000

(b) 1.000 - 10.000

(c) 10.000 - 100.000

(d) > 100.000

# SCHEMA MATCHING: IDEAS?

| ID | Name | Address | Zip | State | City | Phone | E-Mail |
|---|---|---|---|---|---|---|---|
| 1 | Tim Kraska | 135 Watermann St, | 02906 | Providence | RI | +1 234234 234 | Tim_kraska @brown.edu |
| … | … | … | | | | .. | .. |

| ID | Name | Addr | Mobile | E-Mail |
|---|---|---|---|---|
| 1 | Tim Kraska | 135 Watermann St, 02906 Providence, RI | +1 234234 234 | Tim_kraska @brown.edu |
| … | … | … | .. | .. |

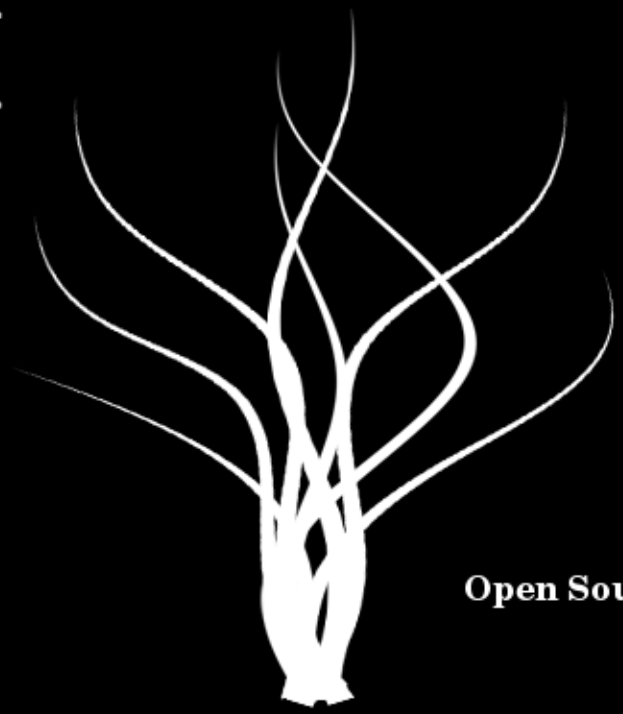
| ID | Name |
|---|---|
| 1 | Tim Kraska |
| … | … |

| Address ID | Person-ID | Address | Phone-Nb | E-Mail |
|---|---|---|---|---|
| 1 | 1 | 135 Watermann St, 02906 Providence | +1 234234 234 | Tim_kraska @brown.edu |
| 1 | 1 | 222 Hope St, 02906 Providence | 980 – 0803284 | tim_kraska @brown.edu |

# SCHEMA MATCHING – TECHNIQUES

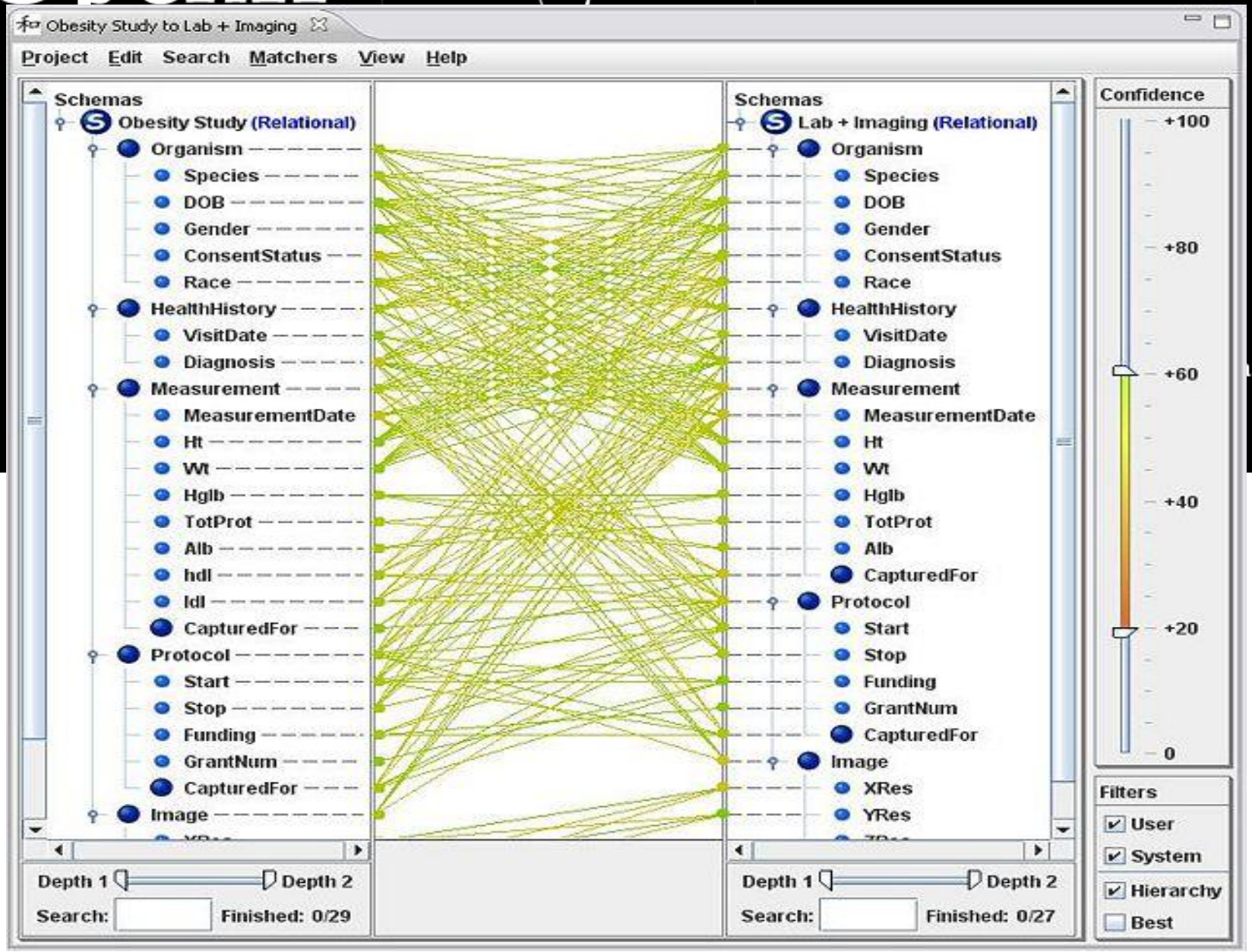
- **Instance vs Schema**: consider instance data or schema information.
- **Element vs Structure**: matching performed for individual schema element (attribute), or for combinations of elements (structure).
- **Language vs Constraint**: use linguistic information (names and textual description) or constraint information (key, relationship)
- **Matching Cardinality**: the overall match result may relate one or more elements of one schema to one or more elements of the other (1:1, 1:n, m:n).
- **Auxiliary Information**: the use of auxiliary information (dictionaries, pervious matching results, user input,..)
- Semantic difference are especially problematic (e.g., Price in Euro vs Dollar, Fahrenheit vs Celsius, etc.)

# OpenII



Open Source Tools for Faster Data Integration

# OpenII




ation

# DATA INTEGRATION


Schema Alignment

deduplication, entity clustering, merge/purge, fuzzy match, record linkage, approximate match...

# EXAMPLE

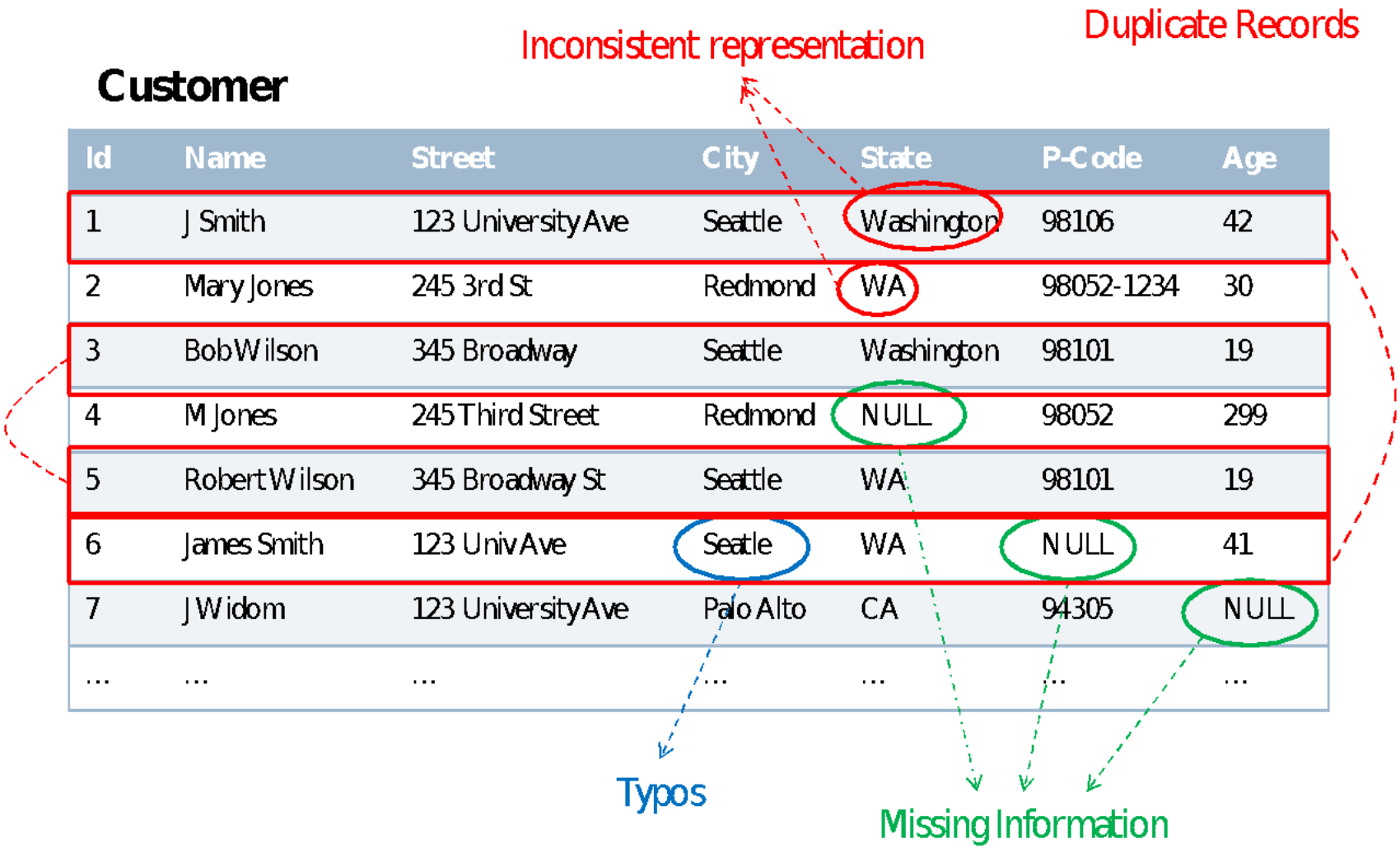
| ID | Product Name | Price |
|---|---|---|
| r1 | iPad Two 16GB WiFi White | $490 |
| r2 | iPad 2nd generation 16GB WiFi White | $469 |
| r3 | iPhone 4th generation White 16GB | $545 |
| r4 | Apple iPhone 4 16GB White | $520 |
| r5 | Apple iPhone 3rd generation Black 16GB | $375 |
| r6 | iPhone 4 32GB White | $599 |
| r7 | Apple iPad2 16GB WiFi White | $499 |
| r8 | Apple iPod shuffle 2GB Blue | $49 |
| r9 | Apple iPod shuffle USB Cable | $19 |

# REAL WORLD DATA

What is wrong here?

| Id | Name | Street | City | State | P-Code | Age |
|---|---|---|---|---|---|---|
| 1 | J Smith | 123 University Ave | Seattle | Washington | 98106 | 42 |
| 2 | Mary Jones | 245 3rd St | Redmond | WA | 98052-1234 | 30 |
| 3 | Bob Wilson | 345 Broadway | Seattle | Washington | 98101 | 19 |
| 4 | M Jones | 245 Third Street | Redmond | NULL | 98052 | 299 |
| 5 | Robert Wilson | 345 Broadway St | Seattle | WA | 98101 | 19 |
| 6 | James Smith | 123 Univ Ave | Seatle | WA | NULL | 41 |
| 7 | J Widom | 123 University Ave | Palo Alto | CA | 94305 | NULL |
| … | … | … | … | … | … | … |

# REAL WORLD DATA



# REAL WORLD DATA

- How many customers do I have?

```
select count(*)
from customer
```

Wrong answer because of duplicate records!

- How many customers by state?

```
select count(*)
from customer
group by state
```

| State | Count |
|---|---|
| AL | 60 |
| … | … |
| … | … |
| WA | 1200 |
| Washington | 50 |
| Wasington | 2 |

What about if you give this data to a ML algorithm?