DATA INTEGRATION

CS561-SPRING 2012
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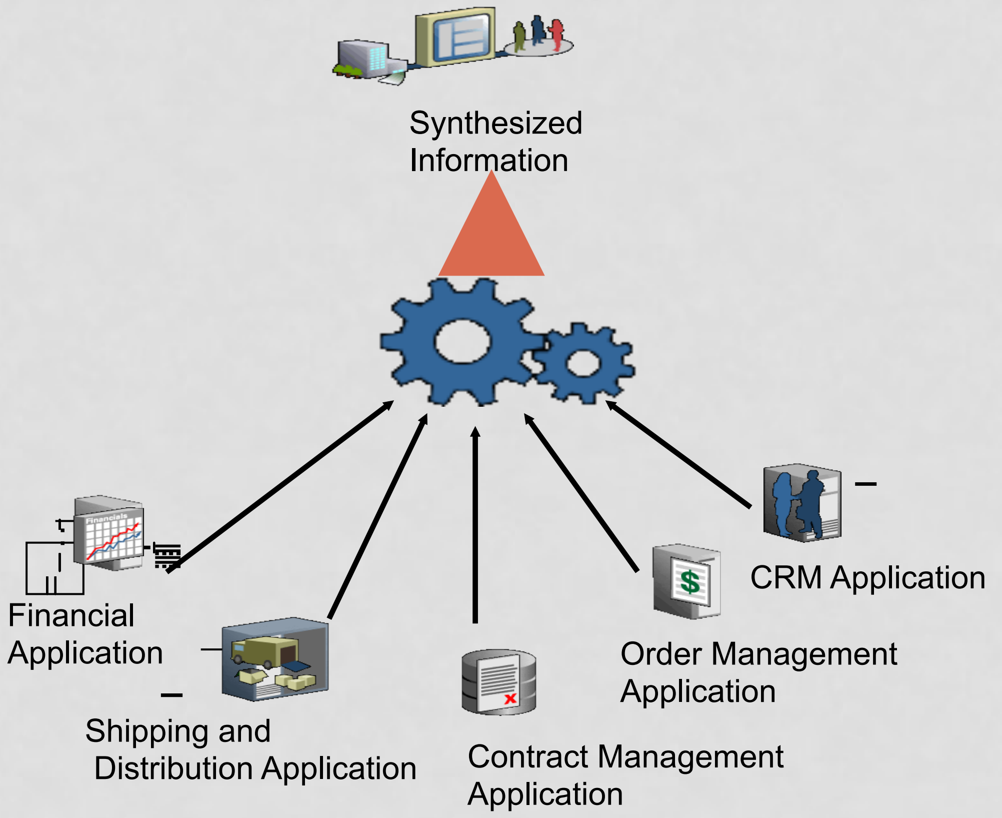
DATA INTEGRATION

- **Motivation**
  - Many databases and sources of data that need to be integrated to work together
  - Almost all applications have many sources of data

- **Data Integration**
  - Is the process of integrating data from multiple sources and probably have a single view over all these sources
    - And answering queries using the combined information
  - Integration can be ***physical*** or ***virtual***
    - ***Physical:*** Coping the data to warehouse
    - ***Virtual:*** Keep the data only at the sources

DATA INTEGRATION

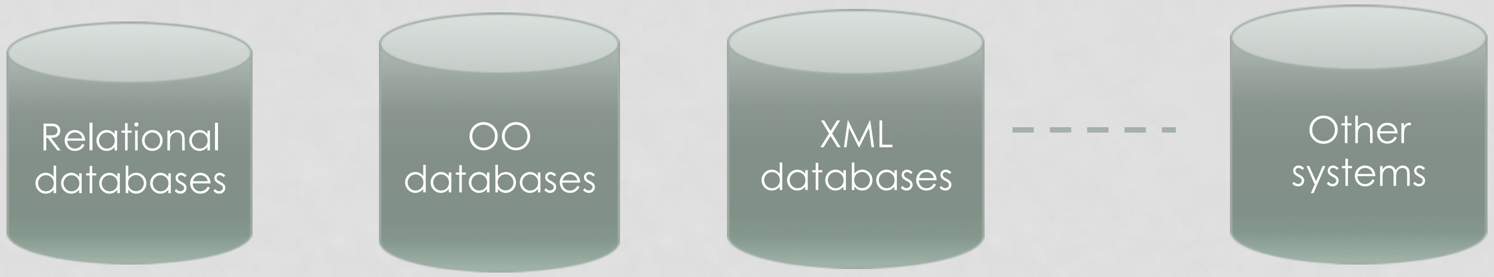
- Data integration is also valid within a single organization
  - Integrating data from different departments or sectors


Synthesized Information
Financial Application
Shipping and Distribution Application
Contract Management Application
Order Management Application
CRM Application

HETEROGENEITY PROBLEMS

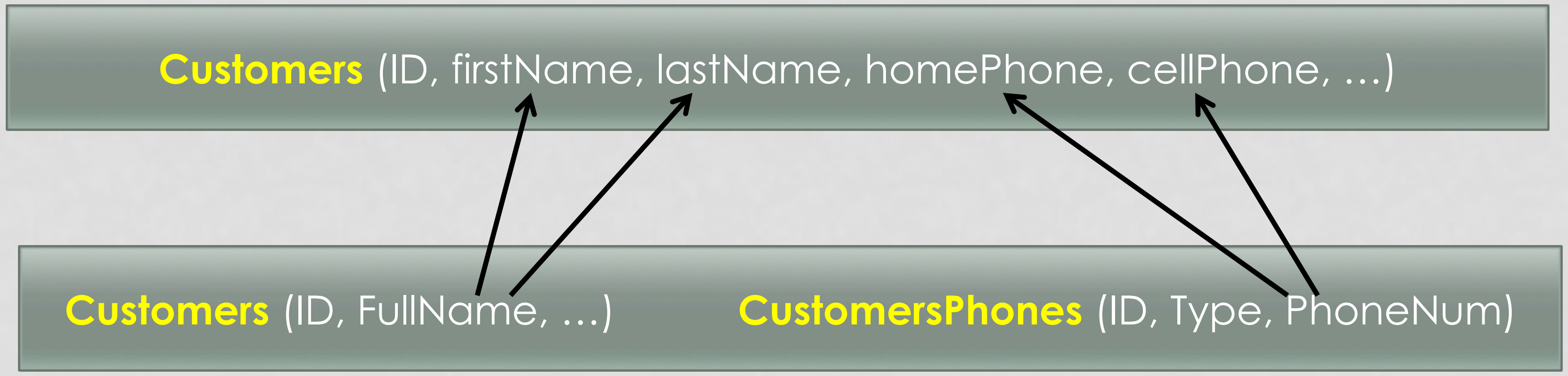
- The main problem is the ***heterogeneity*** among the data sources

- **Source Type Heterogeneity**
  - Systems storing the data can be different



HETEROGENEITY PROBLEMS

- **Communication Heterogeneity**
  - Some systems have web interface others do not
  - Some systems allow direct query language others offer APIs
- **Schema Heterogeneity**
  - The structure of the tables storing the data can be different (even if storing the same data)


Customers (ID, firstName, lastName, homePhone, cellPhone, …)
Customers (ID, FullName, …)
CustomersPhones (ID, Type, PhoneNum)

HETEROGENEITY PROBLEMS

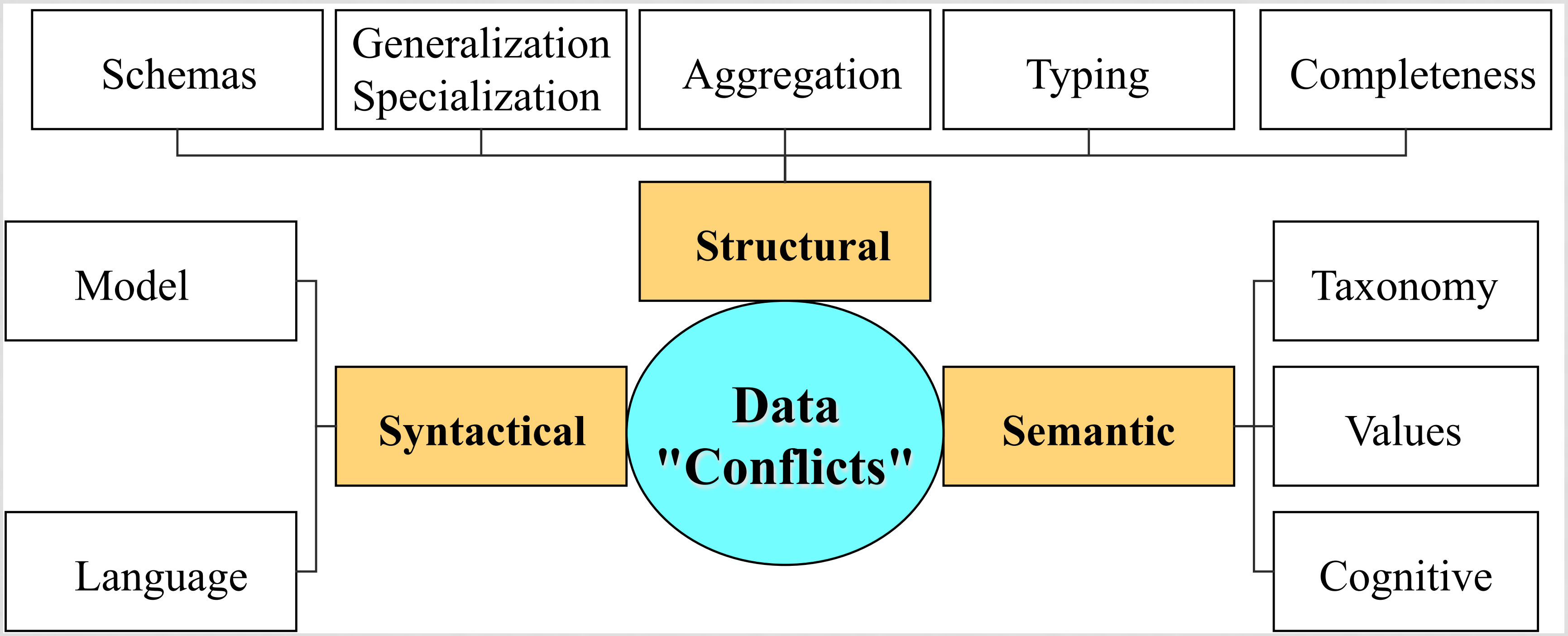
- **Data Type Heterogeneity**
  - Storing the same data (and values) but with different data types
  - E.g., Storing the phone number as ***String*** or as **Number**
  - E.g., Storing the name as ***fixed length*** or ***variable length***
- **Value Heterogeneity**
  - Same logical values stored in different ways
  - E.g., 'Prof', 'Prof.', 'Professor'
  - E.g., 'Right', 'R', '1' ……… 'Left', 'L', '-1'

HETEROGENEITY PROBLEMS

- **Semantic Heterogeneity**
  - Same values in different sources can mean different things
  - E.g., Column ‘Title’ in one database means ‘Job Title’ while in another database it means ‘Person Title’

Data integration has to deal with all such issues and more

REASONS OF HETEROGENEITY

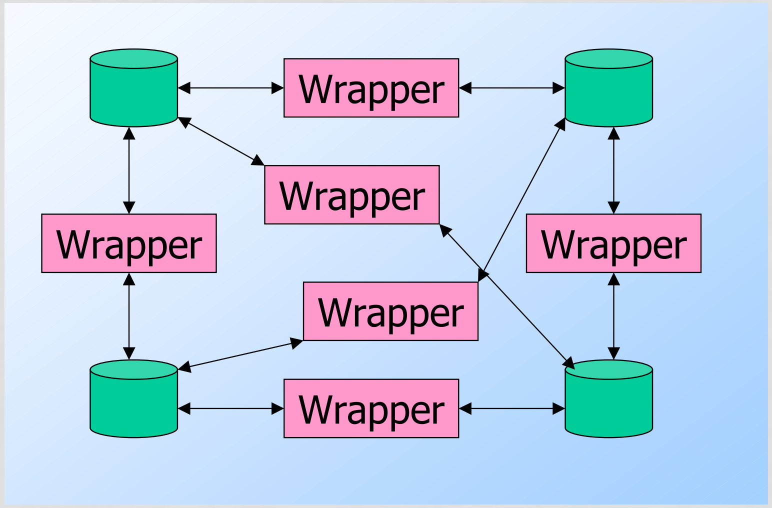


MODELS OF DATA INTEGRATION

- **Federated Databases**
- **Data Warehousing**
- **Mediation**

FEDERATED DATABASES

- Simplest architecture
- Every pair of sources can build their own mapping and transformation
- Source X needs to communicate with source Y → build a mapping between X and Y
  - Does not have to be between all sources (on demand)



Advantages

1- if many sources and only very few are communicating

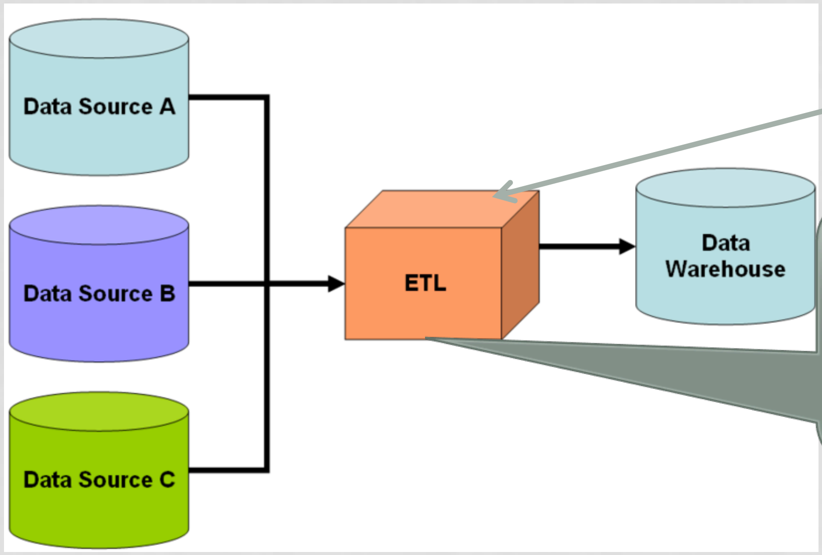
Disadvantages

1- if most sources are communicating (n^2 mappings)

2- If sources are dynamic (need to change many mappings)

DATA WAREHOUSING

- Very common approach
- Data from multiple sources are ***copied and stored*** in a warehouse
  - Data is materialized in the warehouse
- Users can then query the warehouse database only



ETL: Extract-Transform-Load process

- ETL is totally performed outside the warehouse

- Warehouse only stores the data

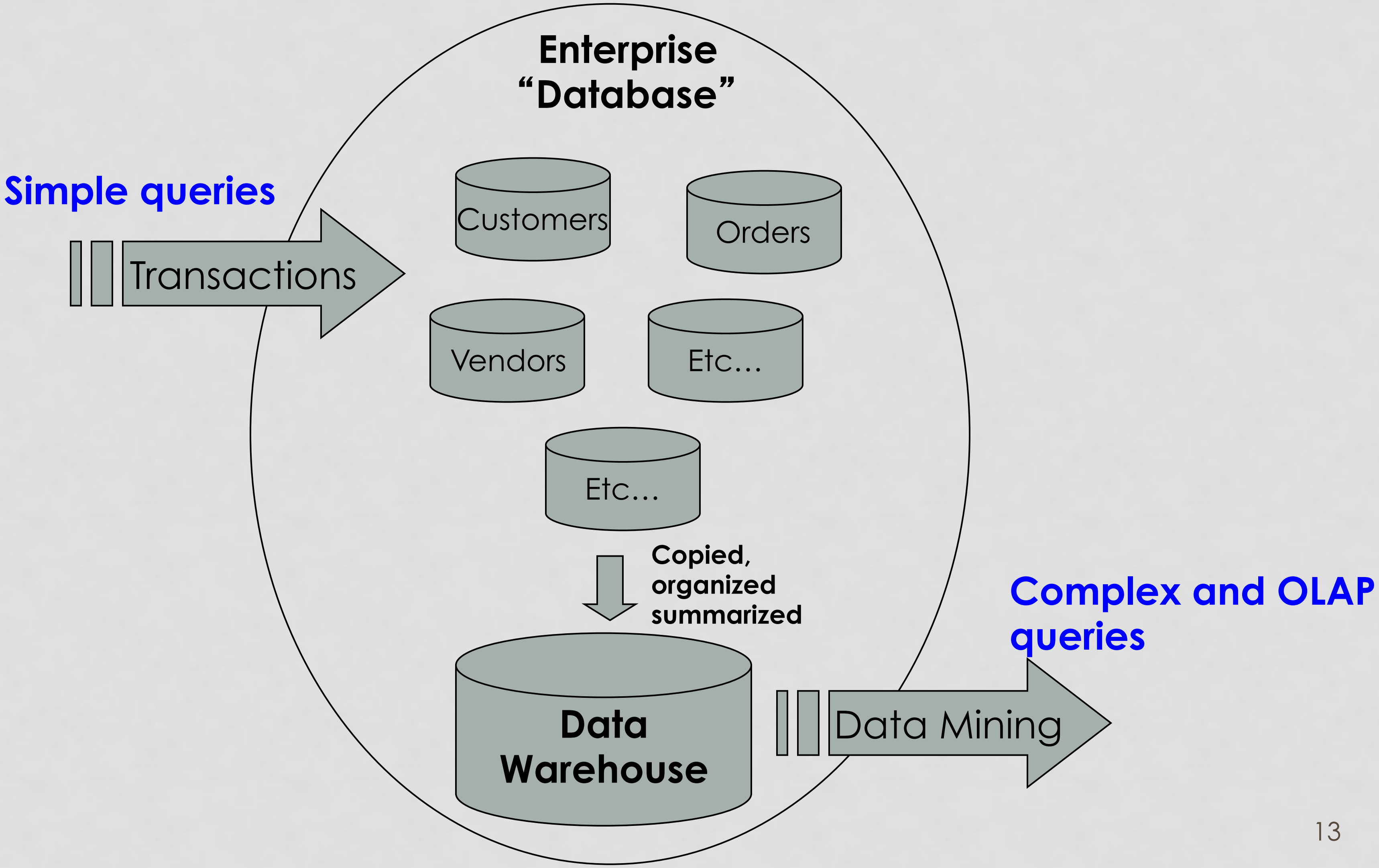
DATA WAREHOUSING: SYNCHRONIZATION

- **How to synchronize the data between the sources and the warehouse???**

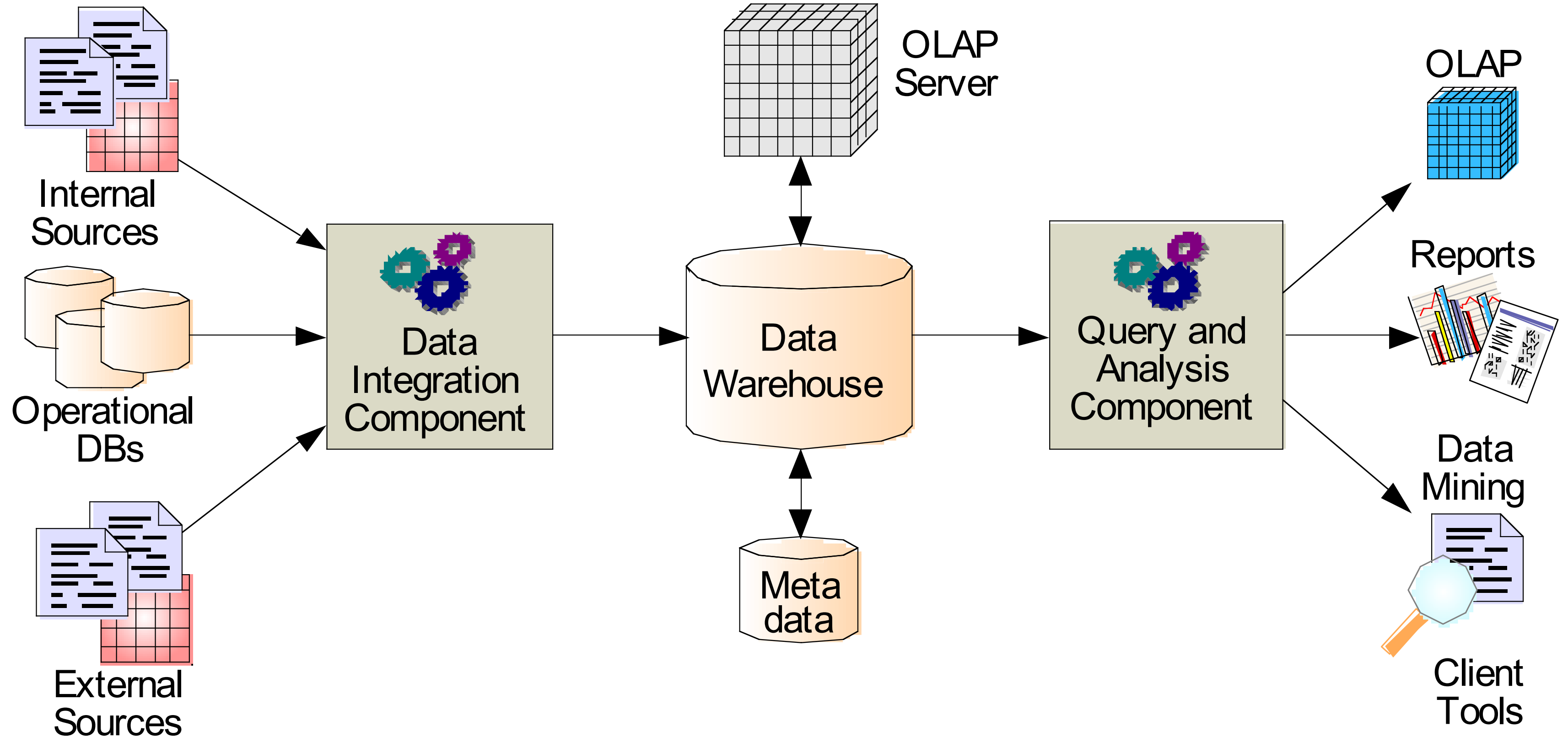
- **Two approaches**
  - **Complete rebuild**
    - Periodically re-build the warehouse from the sources (e.g., every night or every week)
    - (+) The procedure is easy
    - (-) Expensive and time consuming
  - **Incremental update**
    - Periodically update the warehouse based on the changes in the sources
    - (+) Less expensive and efficient
    - (-) More complex to perform incremental update
    - (-) Requires sources to keep track of their updates

In both approaches the warehouse is not up-to-date at all times

DATA WAREHOUSING

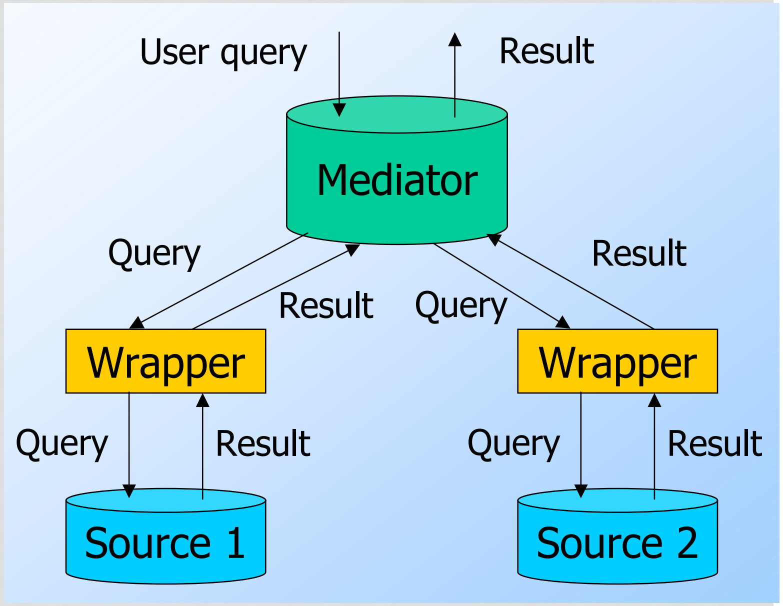


TRADITIONAL DW ARCHITECTURE

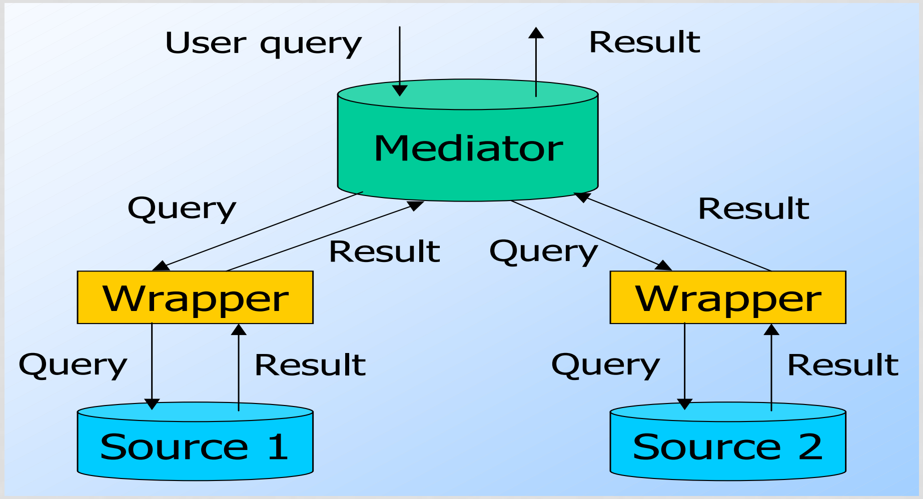


MEDIATION

- Mediator is a virtual view over the data (it does not store any data)
  - Data is stored only at the sources
- Mediator has a virtual schema that combines all schemas from the sources
- The mapping takes place at query time
  - This is unlike warehousing where mapping takes place at upload time



MEDIATION: DATA MAPPING



Given a user query

- Query is mapped to multiple other queries
- Each query (or set of queries) are sent to the sources
- Sources evaluate the queries and return the results
- Results are merged (combined) together and passed to the end-user

MEDIATION: EXAMPLE

- Mediator Schema

Cust (ID, firstName, LastName, …)
CustPhones (ID, Type, PhoneNum, …)

- Source 1 Schema

Customers (ID, firstName, lastName, homePhone, cellPhone, …)

- Source 2 Schema

Customers (ID, FullName, …)
CustomersPhones (ID, Type, PhoneNum)

What if we need, first name, last name, and cell phone of customer ID =100?

MEDIATION: EXAMPLE

- Mediator Schema

Cust (ID, FirstName, LastName, …)
CustPhones (ID, Type, PhoneNum, …)

```
Select C.FirstName, C.LastName, P.PhoneNum
From Cust C, CustPhones P
Where C.ID = P.ID
And C.ID = 100
And P.Type = “celll”;
```

Map to source 1

```
Select firstName, lastName, cellPhone
From Customers
Where C.ID = 100;
```

- Source 1 Schema

Customers (ID, firstName, lastName, homePhone, cellPhone, …)

MEDIATION: EXAMPLE

- Mediator Schema

Cust (ID, FirstName, LastName, …)
CustPhones (ID, Type, PhoneNum, …)

```
Select C.FirstName, C.LastName, P.PhoneNum
From Cust C, CustPhones P
Where C.ID = P.ID
And C.ID = 100
And P.Type = "celll";
```

Map to source 2

Function that returns the first name

```
Select First(C.FullName), Last(C.FullName),
           P.PhoneNum
From Customers C, CustomersPhones P
Where C.ID = P.ID
And C.ID = 100
And P.Type = "celll";
```

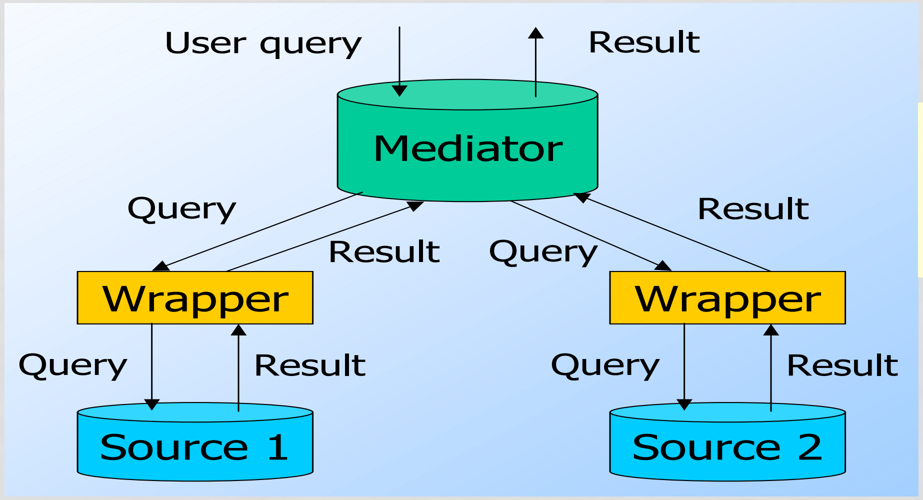
- Source 2 Schema

Customers (ID, FullName, …)
CustomersPhones (ID, Type, PhoneNum)

MEDIATION: WRAPPERS

- Usually ***wrappers*** are the components that perform the mapping of queries

- One approach is to use ***templates with parameters***
  - If the mediator query matches a template, then replace the parameters and execute the query
  - If no template is found, return empty results



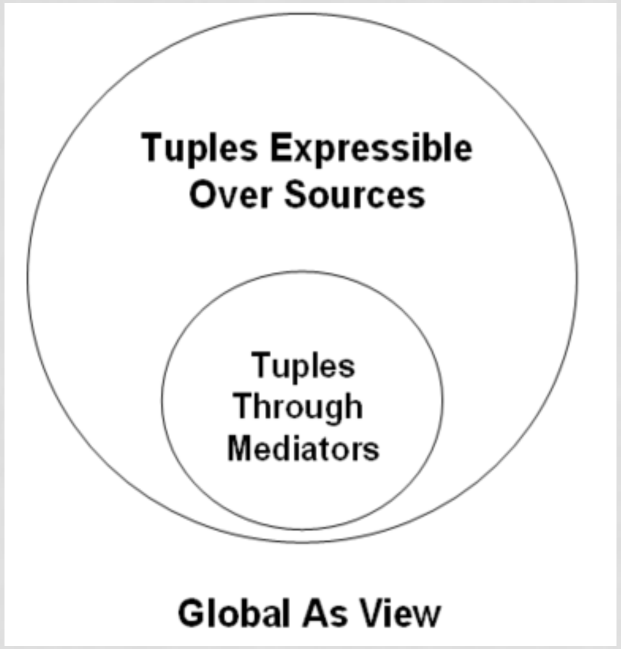
Designing these template is a complex process because they need to be flexible and represent many queries

MEDIATOR TYPES

- **Global As View (GAV)**
- **Local As View (LAV)**

GLOBAL AS VIEW (GAV)

- Mediator schema acts as a view over the source schemas
- Rules that map a mediator query to source queries
- Like regular views, what we see through the mediator is a subset of the available world

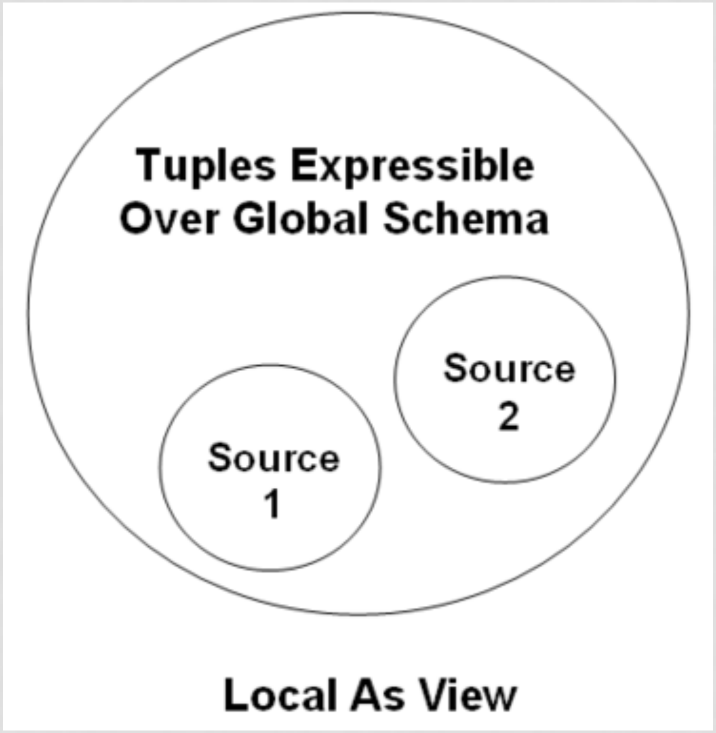


-- Limited view over the data

-- Cannot integrate/combine data from multiple sources to create new data beyond each source

LOCAL AS VIEW

- Sources are defined in terms of the global schema using expression
- Every source provides expressions on how it can generate pieces of the global schema
- Mediator can combine these expressions to find all possible ways to answer a query



-- Covers more data beyond each source individually

-- more complex than GAV

QUERY PROCESSING

Given a user query over the global schema:

- **Global AS view (GAV)**
  - Mediator follows the existing rules and templates to translate the query into source-specific queries
  - Send new queries to wrappers for execution

- **Global AS view (GAV)**
  - Mediator searches all possible expressions and how they can be combined to answer the given query

LAV EXAMPLE

- Assume the mediator has virtual relation ***Par(c,p)*** that links child objects (c) with their parent objects (p)

- Source S1 can provide some info about Par(c,p)

  V1(c,p) ← Par(c,p)

- Source S2 can provide info only about grandparents

  V2(c,g) ← Par(c,p) And Par(p,g)

Notice that V1 and V2 (which are the sources) are expressed using Par (which is the global view)

LAV EXAMPLE (CONT'D)

- Now given a query asking for great-grandparent

  Q(x,w): Par(x,y) And Par(y,z) And Par(z,w)

How to answer this query???

Q(x,w): V1(x,y) And V1(y,z) And V1(z,w) +

Q(x,w): V2(x,z) And V1(z,w) +

Q(x,w): V1(x,y) And V2(y,w)

That is all possible answers from sources S1 and S2 for Q(x,w)

GAV vs. LAS

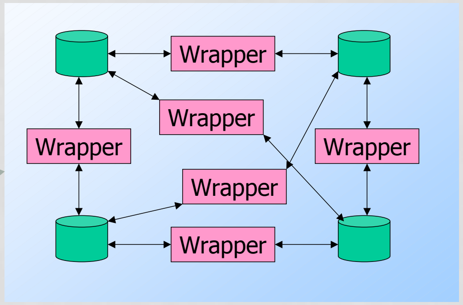
- **GAV**
  - (+) Simpler to design and implement
  - (-) Narrows the view of all possible data that can be generated

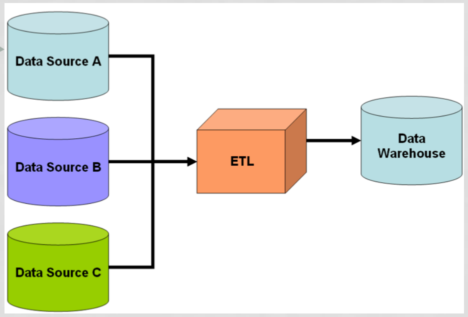
- **LAV**
  - (+) More extensible. New sources just define what can they contribute to the global schema
  - (-) More complex to design and implement

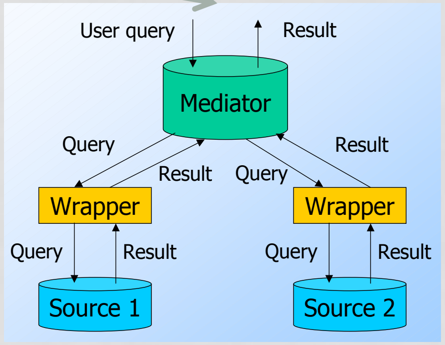
WHAT WE COVERED SO FAR …

- **Data integration** is the process of integrating data from multiple sources And answering queries using the combined information

- **Models of Data Integration**
  - **Federated Database**
  - **Data Warehouse**
  - **Mediators**
    - Global As View (GAV)
    - Local As View (LAV)







ENTITY RESOLUTION

- Data coming from different sources may be different even if representing the same objects

- ***Entity resolution*** is the process of:
  - Figuring out which records represent the same thing
  - Linking relevant records together

(John William, 252 Star rd., MA, 01609, 508-543-2222)

(John Will., 252 Star road, MA, 01609, 508-543-2222)

All of these are the same objects but they are not identical

(John William, 252 Star rd., Massachusetts , 01609-3321, 508-543-2222)

(John William, 252 Star rd., MA, 01609, (508)543-2222)

If structure is different, it becomes even harder

REASONS OF MISMATCHING

- **Misspelling**
  - "Smith", "Smeth", "Snith"
- **Variant names, synonyms, and abbreviations**
  - "St.", "St", "Street"....."Prof", "Professor"...."car", "vehicle"
- **Different systems**
  - "Chin Le", "Le, Chin"… "10/02/2000", "10-02-2000", "02-10-2000"
- **Different domains**
  - "YES/NO", "1/0", "T/F"

MECHANISMS FOR ENTITY RESOLUTION

- **Edit Distance**
  - Compare string fields using edit distance function
  - Can assign different weights to different fields
- **Normalization & Ontology**
  - Using a dictionary, replace all abbreviations with a standard forms
  - Ontology helps in synonyms
- **Clustering and Partitioning**
  - Run a clustering-based algorithm over the returned records
  - Tuples belonging to the same cluster can be further tested for matching

MERGING SIMILAR RECORDS

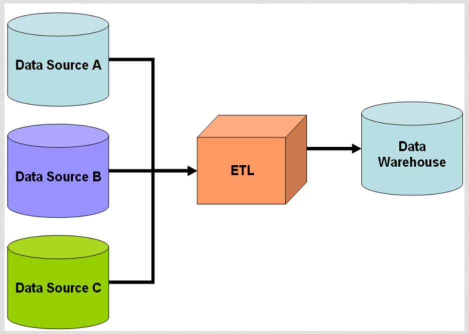
- **How to merge similar records???**
- In some cases, e.g., misspelling synonyms , it is possible to merge results
- In other cases, e.g., conflicts, there is no easy way to find the correct values
    - Report all the results we have

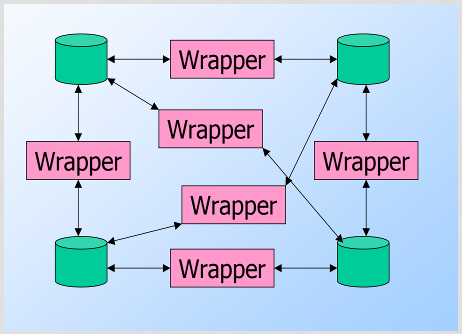
ID	Name	Address	phone
100	Susan Williams	123 Oak St.	818-457-1245
100	Susan Will.	456 Maple St.	818-457-1245

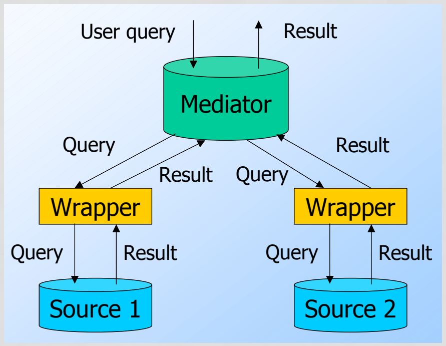
ID	Name	Address	phone
100	Susan Williams	{123 Oak St., 456 Maple St.}	818-457-1245

AUTOMATED DATA INTEGRATION

- **Data integration requires a lot of manual effort**
  - **Data warehouse** → designing and implementing the ETL module
  - **Mediators** → designing and implementing the wrappers
  - **Federated database** → designing and implementing the mapping modules (wrappers)



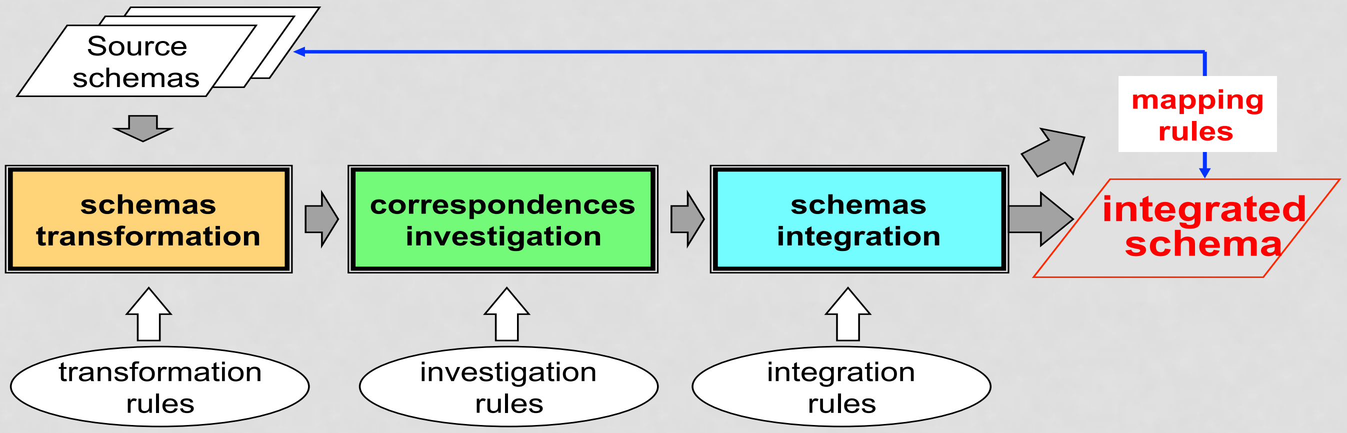




Can we automate this process ???

WORK IN PROGRESS + RECENT RESEARCH

A Generic Framework for Integration



Consider several database schemas for different bookstores

- How to match their schemas automatically ← **schema matching techniques**
- How to find matching records ← **record linkage techniques**
- How to find errors, synonyms, etc. and correct them ← **data cleansing techniques**