UNIVERSITY OF MANNHEIM

Web Data Integration

Introduction and Course Organization

Hallo

- **Prof. Dr. Christian Bizer**
- Professor for Information Systems V
- Research Interests:
  - Web-based Systems
  - Large-Scale Data Integration
  - Data and Web Mining
- Room: B6, 26 - B1.15
- Consultation: Wednesday 13:30-14:30
- eMail: chris@informatik.uni-mannheim.de

Hallo

- **M. Sc. Wi-Inf. Anna Primpeli**
- Graduate Research Associate
- Research Interests:
  - Semantic Annotations in Web Pages
  - Active Learning for Identity Resolution
  - Product Data Integration
- Room: B6, 26, C 1.04
- eMail: anna@informatik.uni-mannheim.de

- Will teach the exercises and will supervise student projects.

Hallo

- **M. Sc. Wi-Inf. Ralph Peeters**
- Graduate Research Associate
- Research Interests:
  - Entity Matching using Deep Learning
  - Product Data Integration
- Room: B6, 26, C 1.04
- eMail: ralph@informatik.uni-mannheim.de

- Will teach the exercises and will supervise student projects.

Outline

1. Course Organization
2. What is Data Integration?
3. Application Areas
4. Types of Heterogeneity
5. The Data Integration Process
6. Data Integration Architectures
7. The Data Integration Software Market

1. Course Organization

The Lecture (IE670)

- introduces the principle methods of data integration
- discusses how to evaluate data integration results
- presents practical examples of how the methods are applied
- Topics
  1. Introduction to Data Integration
  2. Structured Data on the Web
  3. Data Exchange Formats
  4. Schema Mapping and Data Translation
  5. Identity Resolution
  6. Data Quality and Data Fusion
- no restriction on the number of participants
- lecture is concluded with a written exam (60 minutes)
- 3 ECTS

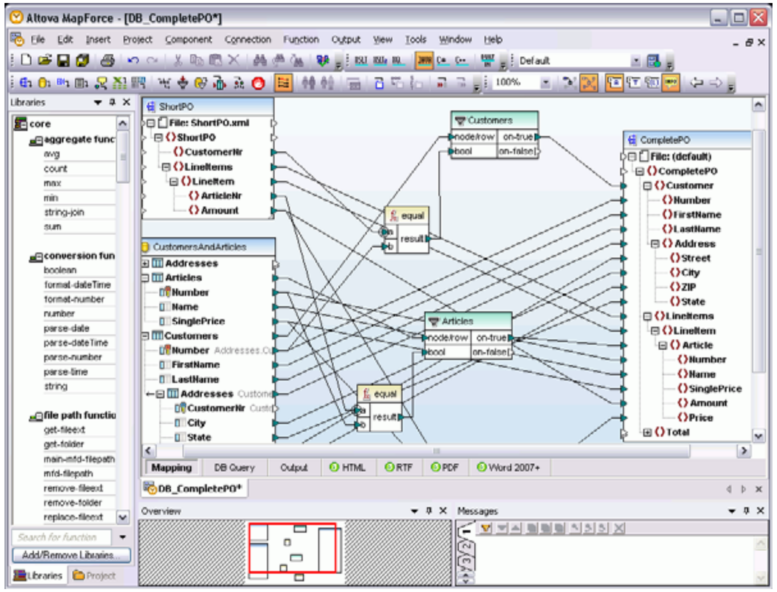
The Student Projects (IE683)

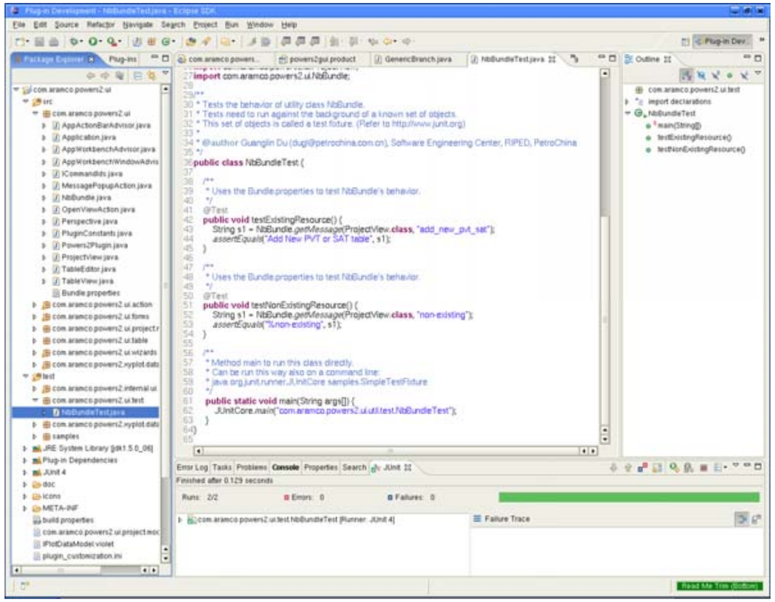
- teams of **five students** realize a data integration project including
  1. data gathering
  2. schema mapping and data translation
  3. identity resolution
  4. data quality assessment and data fusion
- teams write a 12 page report about their project, present project results
- you may choose their own application domain and data sets
  - minimum 4 data sets with a good degree of overlap in attributes and instances
- in addition, we will propose some suitable data sets from the domains of
  - films and actors, products and e-shops, restaurants, geographic information
- the number of participants in the projects is restricted to 60
- you need to register via Portal2 for the projects
- 3 ECTS (70 % written project report, 30 % presentation of project results)

Tools for Your Projects

In the exercise sessions, Anna and Ralph give you an introduction to tools that you can use for your projects. You experiment with the tools along the use case of integrating data about films.

1. **Data Translation**
   - Altova MapForce
   - graphical mapping and data translation tool
2. **Identity Resolution**
   - Winte.r Data Integration Framework
   - provides the necessary methods
3. **Data Fusion**
   - Winte.r Data Integration Framework
   - provides the necessary methods


Altova MapForce - [DB_CompletePO*]
File Edit Insert Project Component Connection Function Output View Tools Window Help
Libraries
ShortPO
Customers
CompletePO
CustomersAndArticles
Articles
equal
Mapping DB Query Output HTML RTF PDF Word 2007+
Overview
Messages



```
import com.aramco.powers2.ui.NbBundle;

/**
 * Tests the behavior of utility class NbBundle.
 * Tests need to run against the background of a known set of objects.
 * This set of objects is called a test fixture. (Refer to http://www.junit.org)
 *
 * @author Guanglin Du (dugl@petrochina.com.cn), Software Engineering Center, RIPED, PetroChina
 */
public class NbBundleTest {

   /**
    * Uses the Bundle.properties to test NbBundle's behavior.
    */
   @Test
   public void testExistingResource() {
      String s1 = NbBundle.getMessage(ProjectView.class, "add_new_pvt_sat");
      assertEquals("Add New PVT or SAT table", s1);
   }

   /**
    * Uses the Bundle.properties to test NbBundle's behavior.
    */
   @Test
   public void testNonExistingResource() {
      String s1 = NbBundle.getMessage(ProjectView.class, "non-existing");
      assertEquals("%non-existing", s1);
   }

   /**
    * Method main to run this class directly.
    * Can be run this way also on a command line:
    * java org.junit.runner.JUnitCore samples.SimpleTestFixture
    */
    public static void main(String args[]) {
      JUnitCore.main("com.aramco.powers2.ui.util.test.NbBundleTest");
    }
}
```

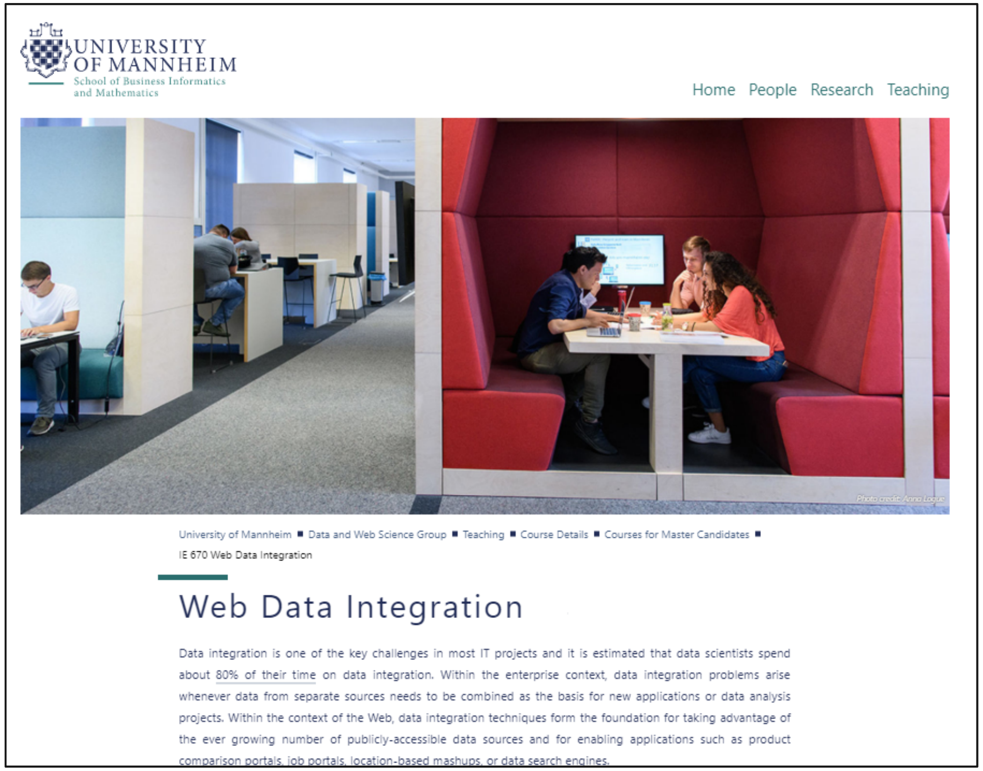
```
Finished after 0.129 seconds
Runs: 2/2    Errors: 0    Failures: 0
```

Schedule

Week	Wednesday	Thursday
4.9.2019	Lecture: Introduction to Web Data Integration	Lecture: Structured Data on the Web
11.9.2019	Lecture: Data Exchange Formats	Lecture: Data Exchange Formats
18.9.2019	Lecture: Schema Mapping	Lecture: Schema Mapping
25.9.2019	Project: Introduction to Student Projects	Tool Intro: MapForce
02.10.2019	Project: Feedback about Project Outlines	- Holiday -
09.10.2019	Project Work: Data Translation	Lecture: Identity Resolution
16.10.2019	Lecture: Identity Resolution	Tool Intro: Winte.r Identity Resolution
23.10.2019	Project Work: Identity Resolution	Project Work: Identity Resolution
30.10.2019	Project Work: Identity Resolution	- Holiday -
06.11.2019	Lecture: Data Fusion	Lecture: Data Fusion
08.11.2019	Excursion to SAP in Walldorf. Topic: Data Integration @ SAP	
13.11.2019	Tool Intro: Winte.r Data Fusion	Project Work: Data Fusion
20.11.2019	Project Work: Data Fusion	Project Work: Data Fusion
27.11.2019	Project Work: Data Fusion	Project Work: Data Fusion
04.12.2019	Presentation of project results	Presentation of project results
12.12.2019	Final Exam	

Course Organization

- Course Webpage
  - https://www.uni-mannheim.de/dws/teaching/course-details/courses-for-master-candidates/ie-670-web-data-integration/
  - The lecture slides will be published on this webpage.
  - Exercise materials will be provided on this webpage.



University of Mannheim ■ Data and Web Science Group ■ Teaching ■ Course Details ■ Courses for Master Candidates ■ IE 670 Web Data Integration

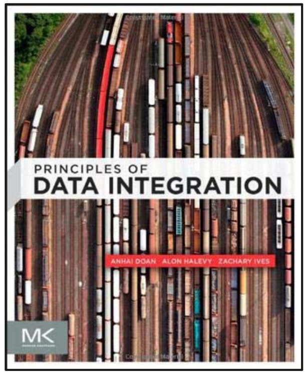
Web Data Integration

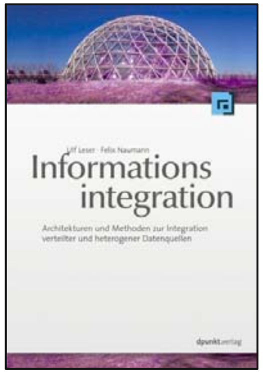
Data integration is one of the key challenges in most IT projects and it is estimated that data scientists spend about 80% of their time on data integration. Within the enterprise context, data integration problems arise whenever data from separate sources needs to be combined as the basis for new applications or data analysis projects. Within the context of the Web, data integration techniques form the foundation for taking advantage of the ever growing number of publicly-accessible data sources and for enabling applications such as product comparison portals, job portals, location-based mashups, or data search engines.

- Time and Location
  - Wednesday, 15:30 to 17:00. Building: B6, Room: A 101
  - Thursday, 10:15 to 11:45. Building: A5, Room: C 014
  - Start: 4.9.2019

Literature and Credits

1. AnHai Doan, Alon Halevy, Zachary Ives: **Principles of Data Integration**. Morgan Kaufmann, 2012. (Online access via the library)
2. Xin Luna Dong, Divesh Srivastava: **Big Data Integration**, Morgan & Claypool, 2015 (Online access via the library)
3. Ulf Leser, Felix Naumann: **Informationsintegration**. Dpunkt Verlag, 2007. (Several copies in the library,
PDF version at https://www.dpunkt.de/openbooks/informationsintegration.pdf,
Video lecture at http://www.tele-task.de/archive/series/overview/892/)
4. Jérôme Euzenat, Pavel Shvaiko: **Ontology Matching**. Springer, 2013.
5. Lecture **videos** from HWS2015 on DWS page.




Ulf Leser · Felix Naumann
Informations integration
Architekturen und Methoden zur Integration verteilter und heterogener Datenquellen
dpunkt.verlag

MORGAN & CLAYPOOL PUBLISHERS
Big Data Integration
Xin Luna Dong
Divesh Srivastava
SYNTHESIS LECTURES ON DATA MANAGEMENT

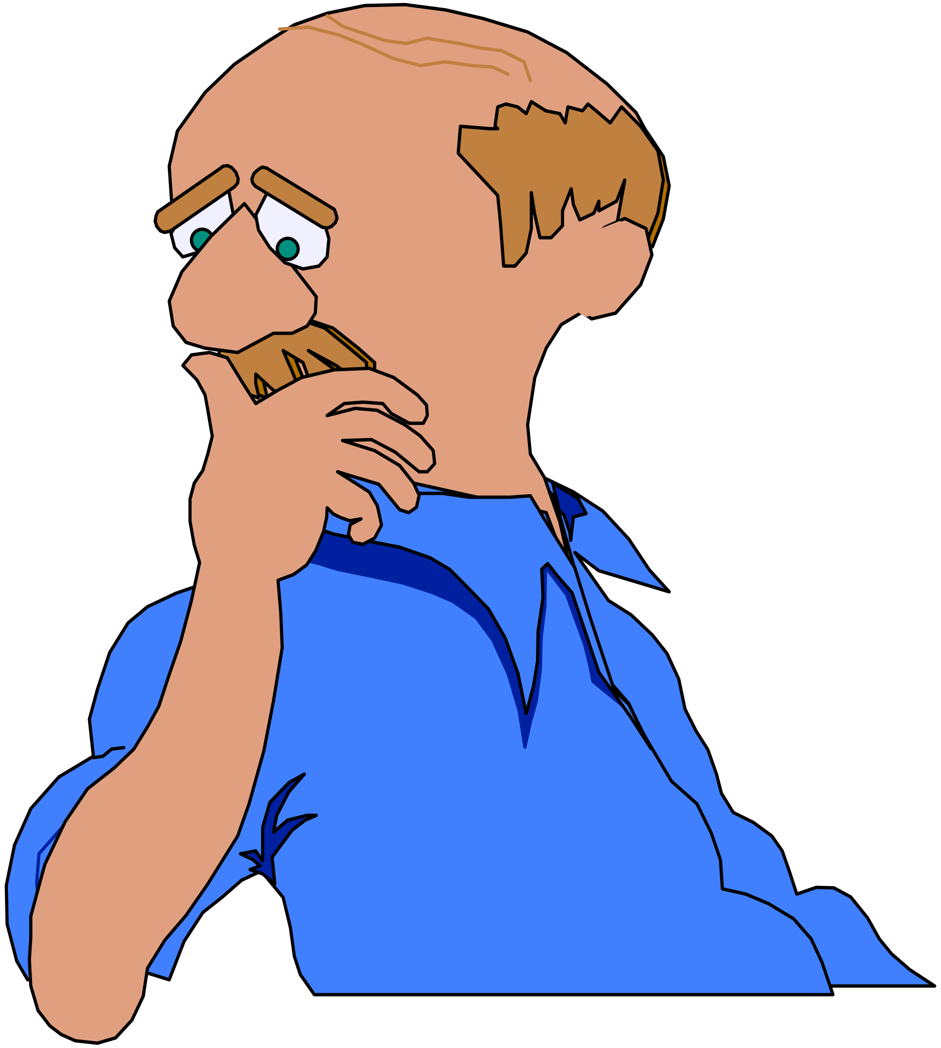
Credits

The slide set of this lecture builds on slides from:

- **Ulf Leser, Felix Naumann**
- **AnHai Doan, Alon Halevy, Zachary Ives**

Lots of thanks to all of you!

Questions about the Course Organization?



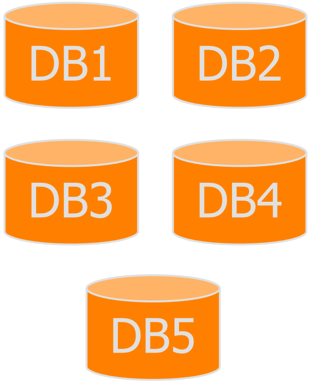
2. What is Data Integration?

– Databases and data mining tools are great: They let us manage and analyze huge amounts of data

1. assuming you've put it all into a single schema
2. assuming the database doesn't contain duplicate records
3. assuming that data is current and contains no data conflicts

– In reality, applications often need to work with data from multiple independently created data sources

1. different sources use different data models
2. different sources use different schemata
3. different sources describe the same real-world entity
4. different sources provide conflicting data about a single entity
5. different sources provide different limited query interfaces to their data

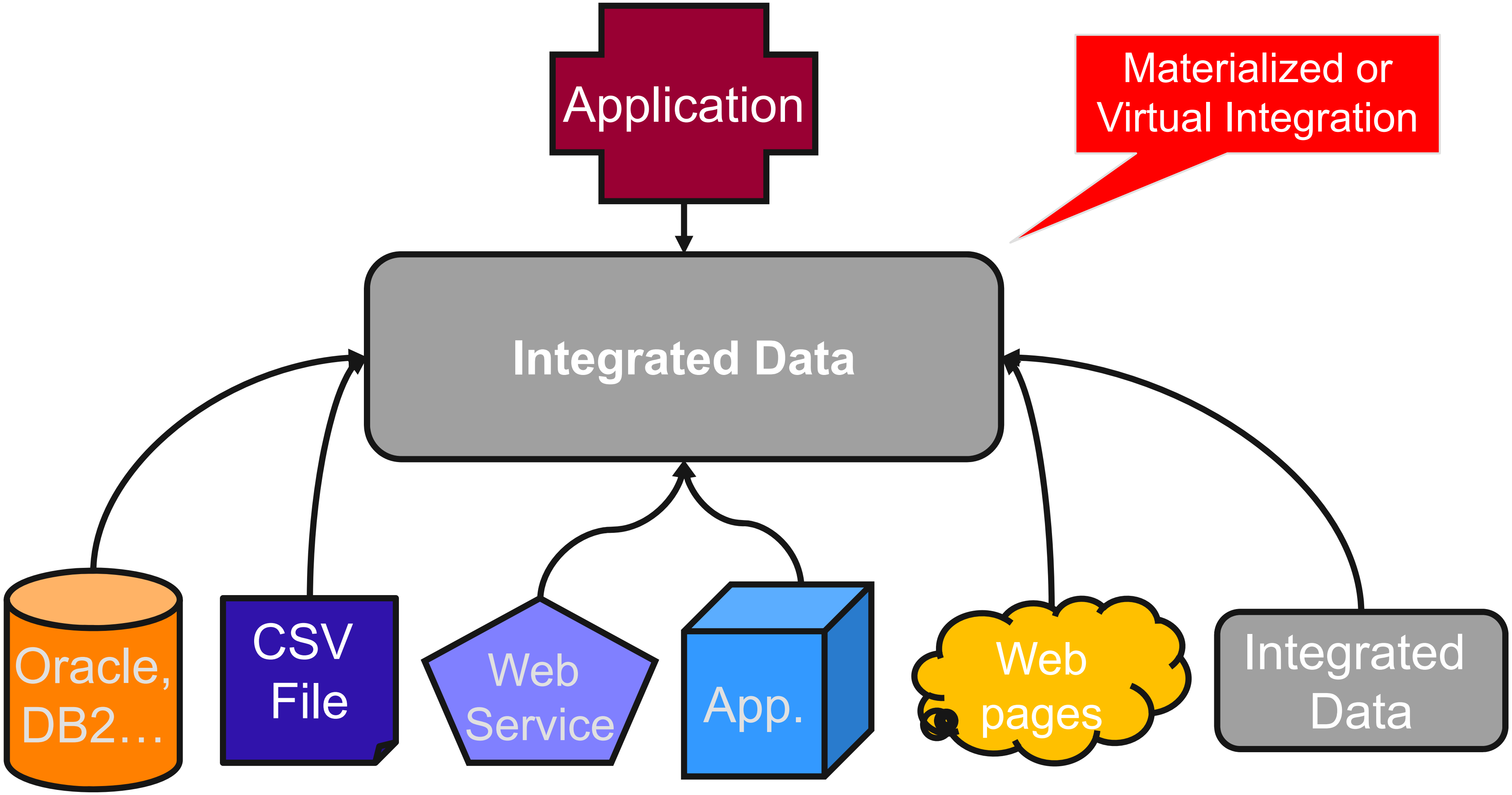


Definition of Data Integration

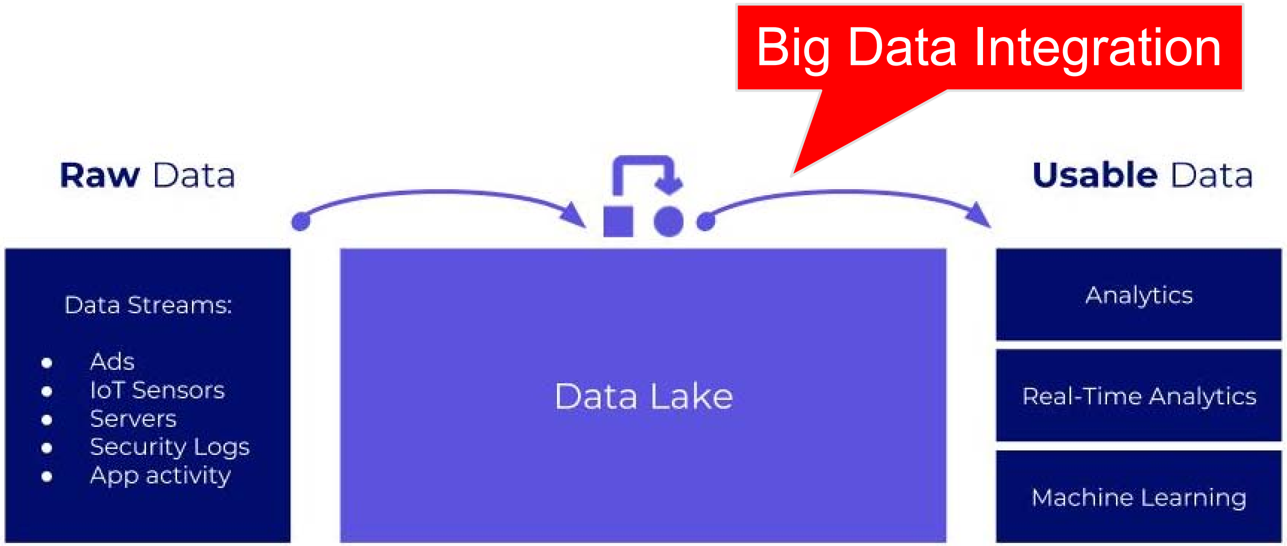
Data integration is the process of consolidating data from a set of heterogeneous data sources into a single uniform data set (materialized integration) or view on the data (virtual integration).

- The integrated data should:
  1. correctly and completely represent the content of all data sources
  2. use a single data model and a single schema
  3. only contain a single representation of each real-world entity
  4. not contain any conflicting data about single entities
- To achieve this, data integration needs to resolve various types of heterogeneity that exist between data sources

Overview: Data Integration



Big Data Integration: Draining the Data Lake



Big Data Integration

Raw Data

Data Streams:

- Ads
- IoT Sensors
- Servers
- Security Logs
- App activity

Data Lake

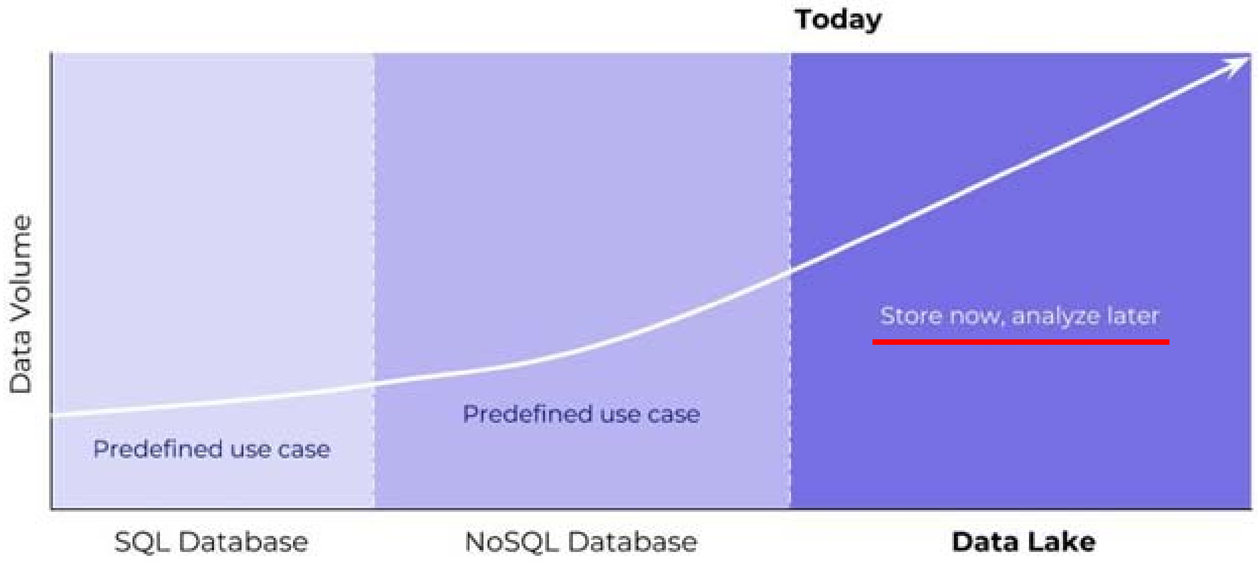
Usable Data

Analytics

Real-Time Analytics

Machine Learning

Data Lake: Unintegrated pool of potentially relevant raw data which might have different degrees of structuredness

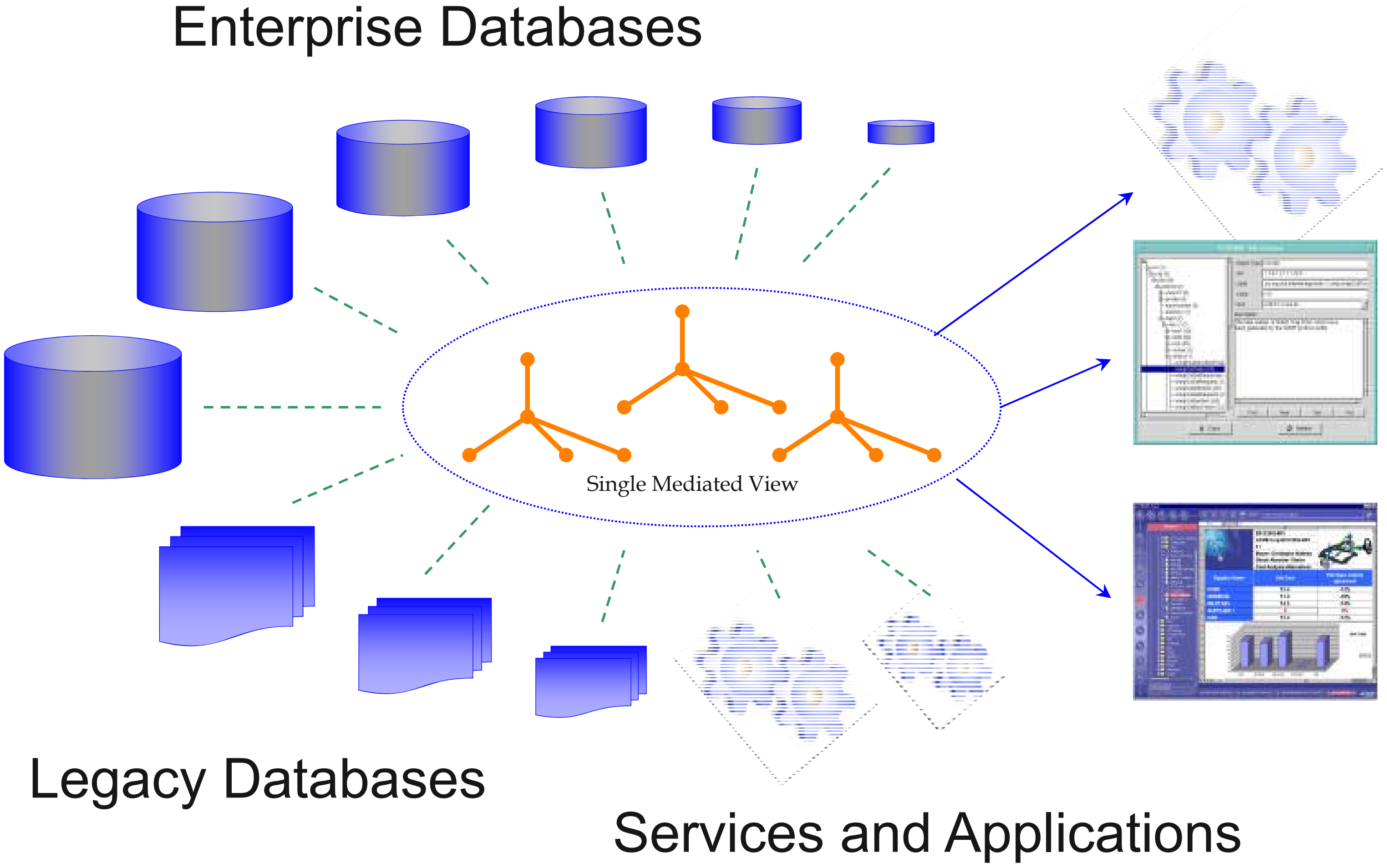


Source: https://www.kdnuggets.com/2018/06/why-data-lake-matters.html

3. Application Areas of Data Integration

1. Business
2. Science
3. Government
4. Data Journalism
5. The Web
6. …. pretty much every application area

Application Area: Business


Enterprise Databases

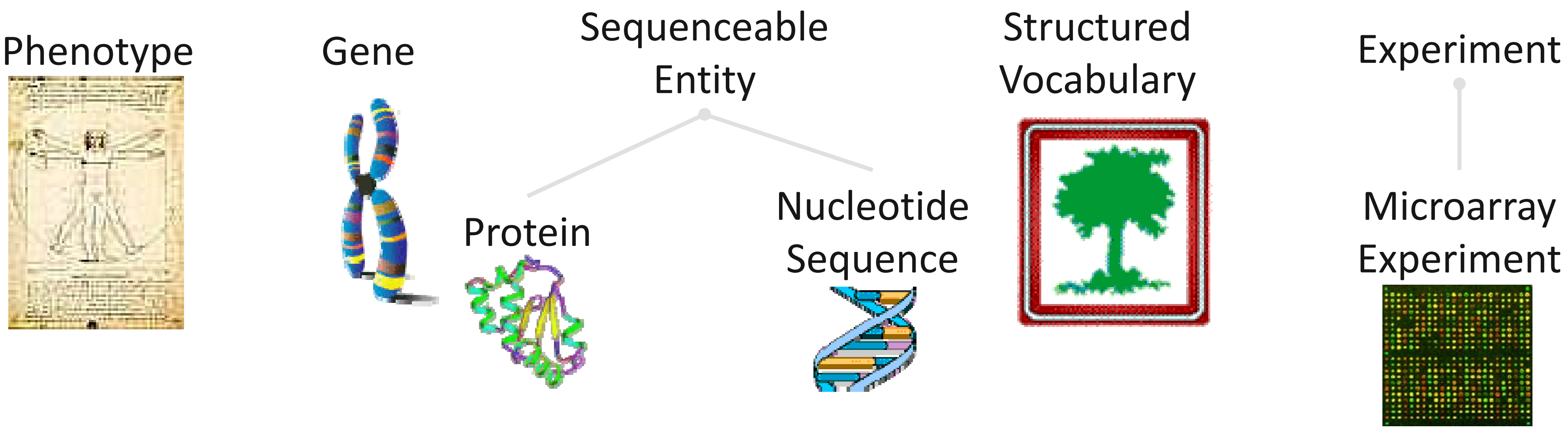
Legacy Databases

Services and Applications

- CRM
- SCM
- Business Intelligence
- Company Mergers
- …

Oracle estimate: 50% of all IT $$$ are spent here!

Application Area: Science



OMIM

HUGO

Swiss-Prot

GO

Gene-Clinics

Locus-Link

Entrez

GEO

Hundreds of biomedical data sources available; growing rapidly!

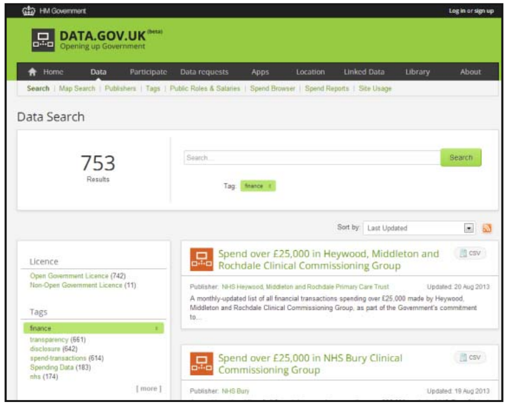
Application Area: Government

Law enforcement agencies mine unknown amounts of data from various sources in order to identify individuals.

- Cell phone calls
- Location data
- Online profiles (Facebook)
- Web browsing behavior
- Credit card transactions
- Intelligence from other agencies
- …

Application Area: Data Journalism

- Government data is increasingly published under open licenses on the Web.
- Journalists discover stories by combining data from different sources.



Data Search

753
Results

Tag: finance

Licence
Open Government Licence (742)
Non-Open Government Licence (11)

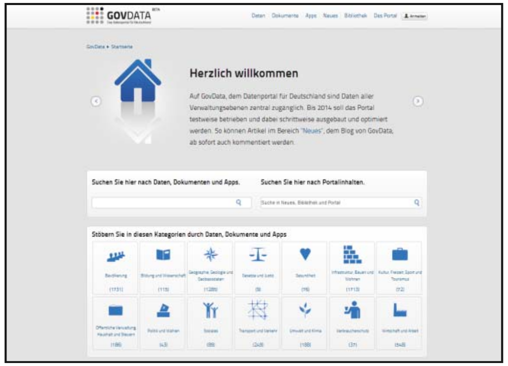
Tags
finance
transparency (661)
disclosure (642)
spend-transactions (614)
Spending Data (183)
nhs (174)
[more]

Spend over £25,000 in Heywood, Middleton and Rochdale Clinical Commissioning Group
CSV
Publisher: NHS Heywood, Middleton and Rochdale Primary Care Trust
Updated: 20 Aug 2013
A monthly-updated list of all financial transactions spending over £25,000 made by Heywood, Middleton and Rochdale Clinical Commissioning Group, as part of the Government's commitment to...

Spend over £25,000 in NHS Bury Clinical Commissioning Group
CSV
Publisher: NHS Bury
Updated: 19 Aug 2013

EU subsidies

- received for renovating a ship
- received for scraping the same ship



Herzlich willkommen

Auf GovData, dem Datenportal für Deutschland sind Daten aller Verwaltungsebenen zentral zugänglich. Bis 2014 soll das Portal testweise betrieben und dabei schrittweise ausgebaut und optimiert werden. So können Artikel im Bereich "Neues", dem Blog von GovData, ab sofort auch kommentiert werden.

Suchen Sie hier nach Daten, Dokumenten und Apps.

Suchen Sie hier nach Portalinhalten.

Stöbern Sie in diesen Kategorien durch Daten, Dokumente und Apps

Members of parliament

- donations / membership in company boards
- voting behavior

theguardian
News | Sport | Comment | Culture | Business | Money | Life & style | Travel
News | Datablog | Show & Tell | Big Data | Data journalism | Twitter | Flickr

DATA STORE
Facts are sacred

Latest from the Datablog

Scottish independence: English voters oppose shared pound

More than half of English voters oppose sharing the pound with an independent Scotland, according to a

Editor's picks

Life and style

The top 100 baby names in England and Wales in 2013

Amelia ren

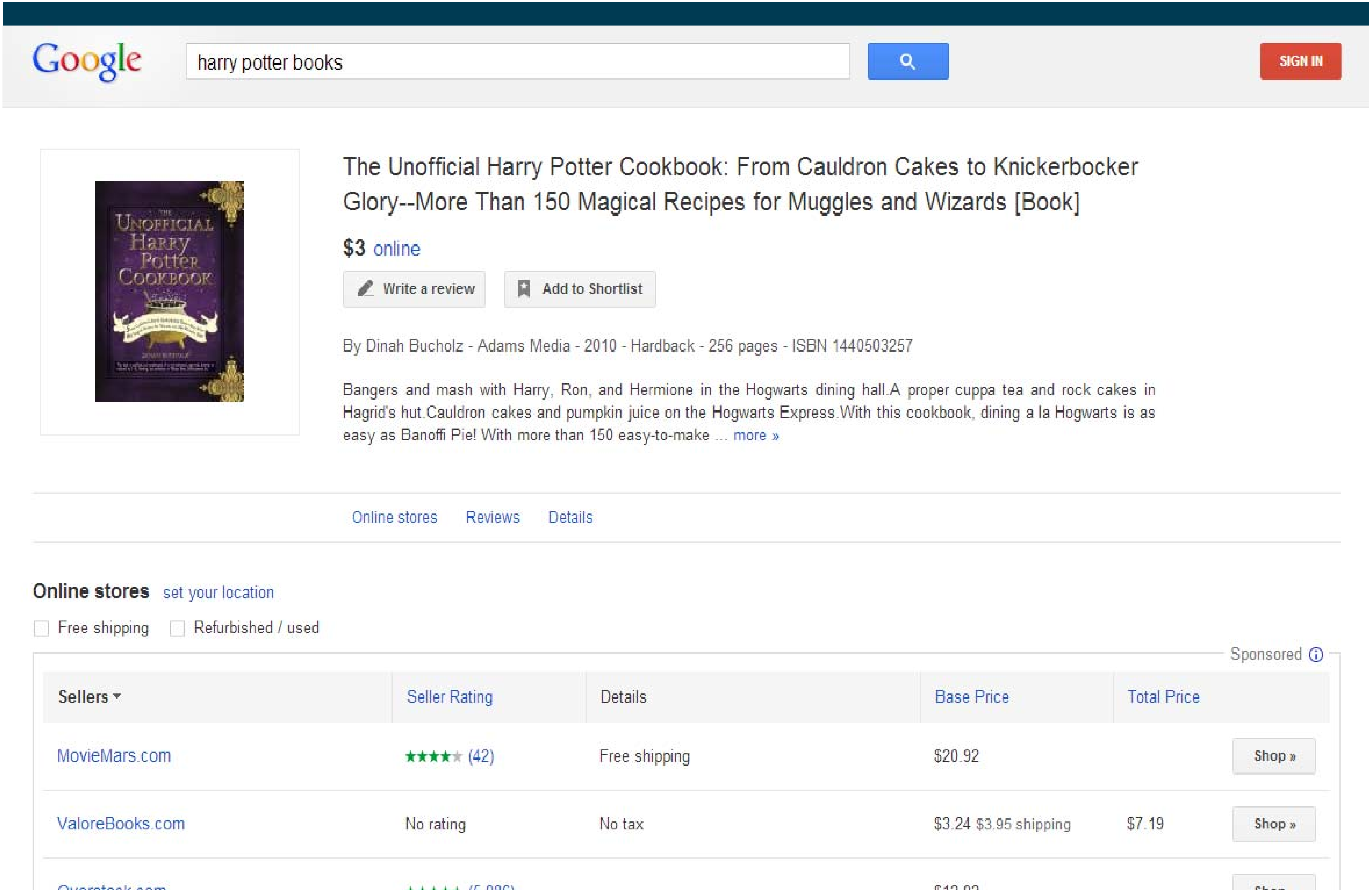
Panama Papers

- ownership information about company networks
- discussable financial transactions

Application Area: The Web

for instance online shopping

Comparison Shopping



The Unofficial Harry Potter Cookbook: From Cauldron Cakes to Knickerbocker Glory--More Than 150 Magical Recipes for Muggles and Wizards [Book]

$3 online

By Dinah Bucholz - Adams Media - 2010 - Hardback - 256 pages - ISBN 1440503257

Bangers and mash with Harry, Ron, and Hermione in the Hogwarts dining hall.A proper cuppa tea and rock cakes in Hagrid's hut.Cauldron cakes and pumpkin juice on the Hogwarts Express.With this cookbook, dining a la Hogwarts is as easy as Banoffi Pie! With more than 150 easy-to-make ... more »

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Sponsored ⓘ

Sellers ▾	Seller Rating	Details	Base Price	Total Price	
MovieMars.com	★★★★☆ (42)	Free shipping	$20.92		Shop »
ValoreBooks.com	No rating	No tax	$3.24 $3.95 shipping	$7.19	Shop »
Overstock.com	★★★★★ (5,986)		$12.92		Shop »

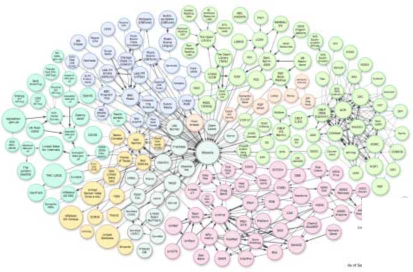
Structured Data on the Web

More and more Websites

- semantically markup the content of their HTML pages
- publish structured data in addition to HTML pages

Microformats

RDFa



Linked Data

Microdata

Web APIs

4. Types of Heterogeneity

We distinguish five types of heterogeneity:

1. Technical Heterogeneity
2. Syntactical Heterogeneity
3. Data Model Heterogeneity
4. Structural Heterogeneity
5. Semantic Heterogeneity

The goal of data integration is to bridge all these types of heterogeneity.

Data source autonomy is the main reason for heterogeneity:

- Data sources independently decide how to store things and how to provide access
- Agreeing on standards partly reduces heterogeneity

Technical Heterogeneity

Technical heterogeneity comprises all differences in the means to access data, not the data itself.

Level	Possibilities
Communication Protocol	HTTP, ODBC/JDBC, SOAP
Data Exchange Format	XML, JSON, CSV, RDF, HTML, binary data
Query Language	Full query language: SQL, XQuery, SPARQL Canned queries: Web APIs, Web Forms Download of complete data set dumps
Additional Restrictions	Number of queries Cost per query / data set Access rights

Syntactical Heterogeneity

Syntactical heterogeneity comprises all differences in the encoding of values.

Level	Possibilities
Character format	ASCII versus Unicode
Number format	Little endian versus big endian
Delimiter format	Tab-delimited versus Comma-separated values

Syntactical heterogeneity does not comprise

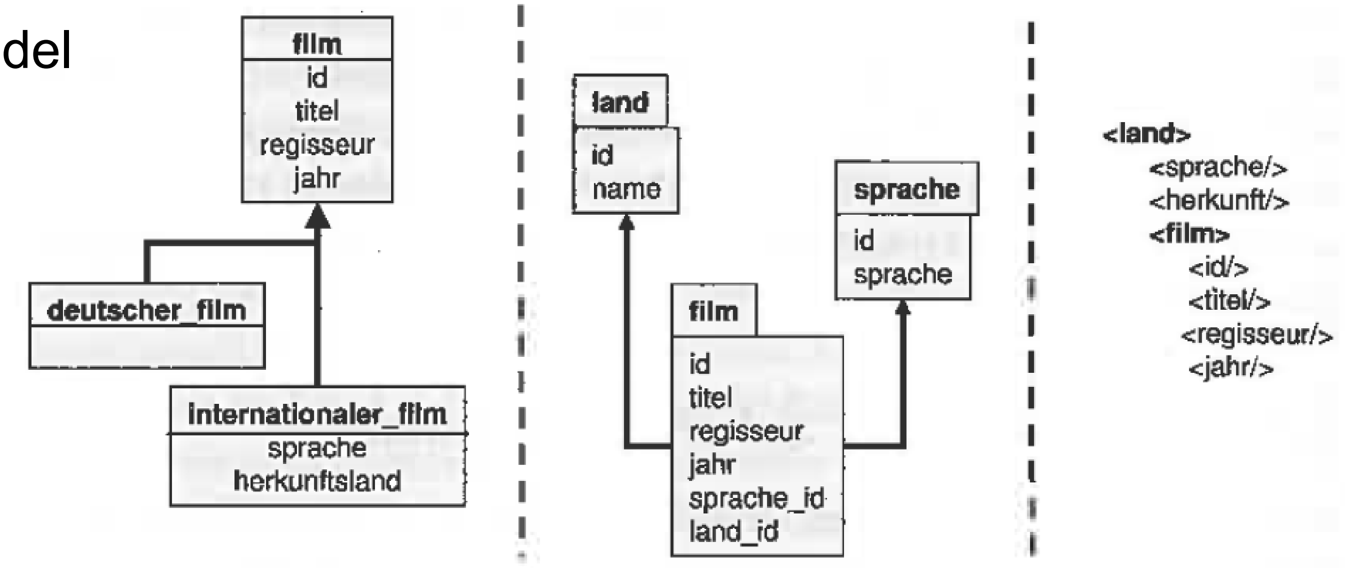
- Synonymous values
  - 1GB versus 1000MB ➔ Semantic heterogeneity
- Structural differences
  - First name: Chris, last name: Bizer versus name: Chris Bizer ➔Structural heterogeneity

Data Model Heterogeneity

Data model heterogeneity comprises differences in the data model that is used to represent data.

Data Models:

1. Relational data model
2. XML data model
3. Object-oriented data model
4. RDF graph data model



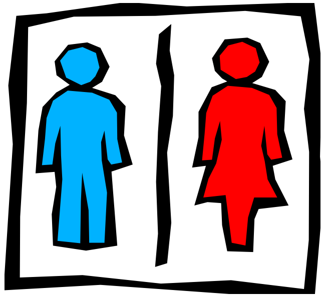
Object-oriented relational XML

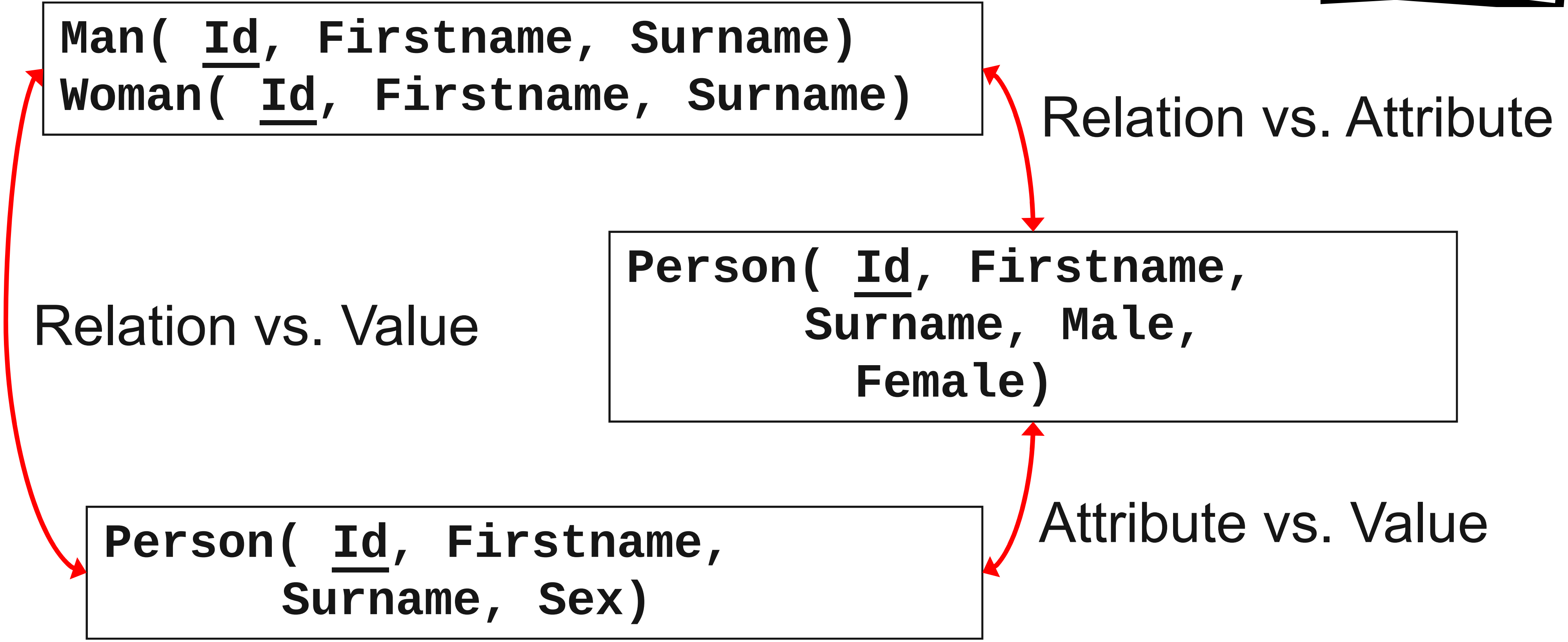
Structural Heterogeneity

Structural heterogeneity comprises differences in the way different schemata represent the same part of reality.

1. Normalized versus Denormalized
2. Nested versus Foreign Key Relationship
3. Alternative Modeling
   - Relation vs. Attribute
   - Attribut vs. Value
   - Relation vs. Value

Example: Alternative Modelling





Man(Id, Firstname, Surname)
Woman(Id, Firstname, Surname)

Relation vs. Attribute

Person(Id, Firstname, Surname, Male, Female)

Relation vs. Value

Attribute vs. Value

Person(Id, Firstname, Surname, Sex)

Semantic Heterogeneity

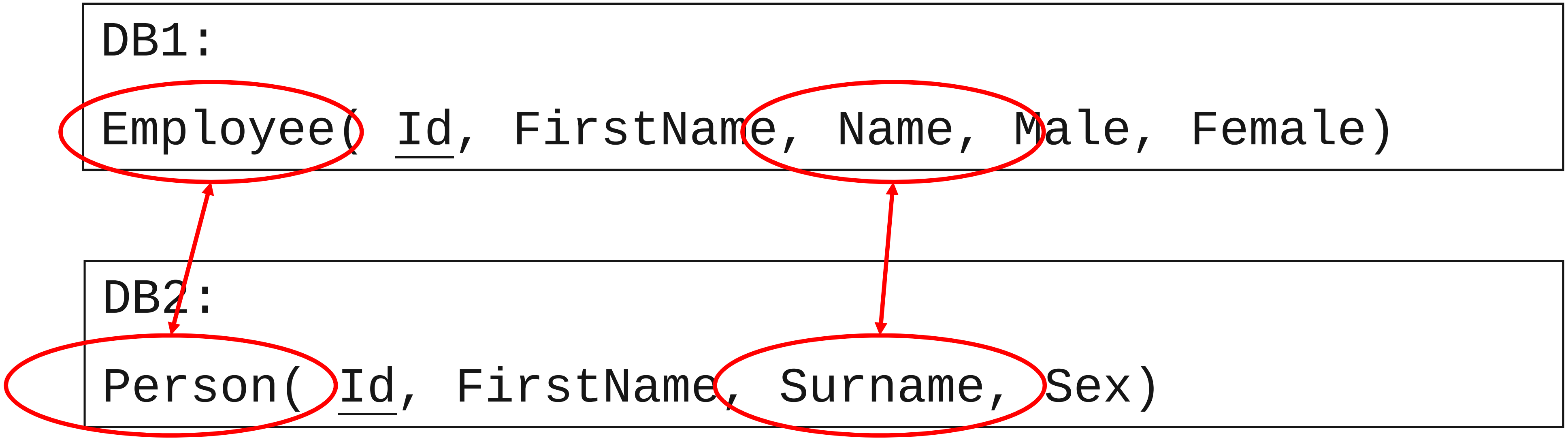
Semantic heterogeneity comprises differences concerning the meaning of data and schema elements.

1. Naming Conflicts
   - Synonyms, homonyms, slightly deviating concepts
2. Object Identity / Duplicates
   - Multiple data sources as well as multiple records within one data source may describe the same real-world entity
   - Which “Marie Müller” does a record describe?
3. Data Conflicts
   - Conflicting data about the same real-world entity in different data sources as well as within different records in the same data source

Semantic Heterogeneity: Synonyms

Different words having the same meaning.

1. Synonymous schema element names:



DB1:

Employee(Id, FirstName, Name, Male, Female)

DB2:

Person(Id, FirstName, Surname, Sex)

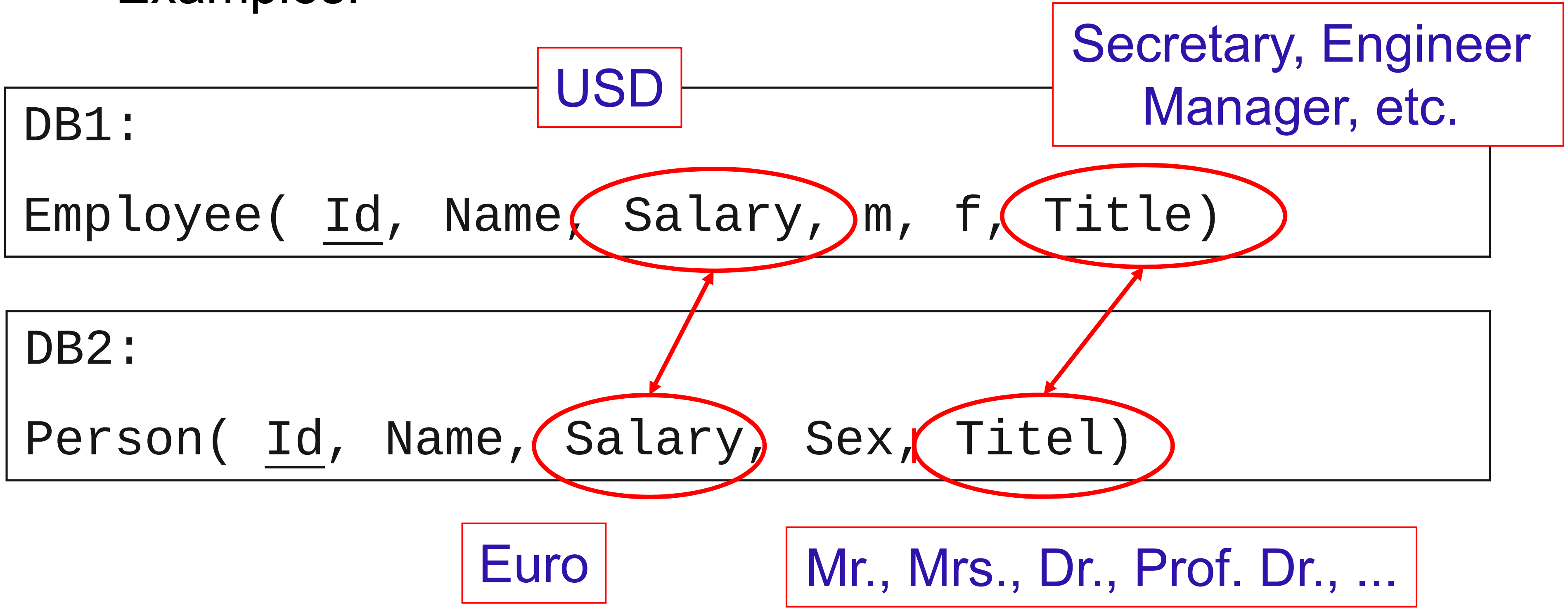
2. Synonymous attribute values:
   - Different value coding schemas: Manager vs. 2
   - Different spellings / abbreviations: Kantstr. vs. Kantstraße vs. Kantstrasse
   - Different units of measurement: 1 GB vs. 1000 MB

Semantic Heterogeneity: Homonyms

Same words having different meanings.

– Reason: Different people (in different situations) associate different meanings with the same word.

– Examples:



USD

Secretary, Engineer Manager, etc.

DB1:

Employee(Id, Name, Salary, m, f, Title)

DB2:

Person(Id, Name, Salary, Sex, Titel)

Euro

Mr., Mrs., Dr., Prof. Dr., ...

Problem: Slightly Deviating Concept Definitions

Business question: How many employees has IBM?

- Definition of Employee:
  - Temporary employees?
  - Students writing master theses?
  - External consultants?
  - Positions in organization chart or currently employed people?
- Definition of IBM
  - Which global region? Which business unit?
  - Include companies that are partly owned by IBM?
- Which point in time?
- How to count people that work part-time?

Semantic Heterogeneity: Object Identity / Duplicates

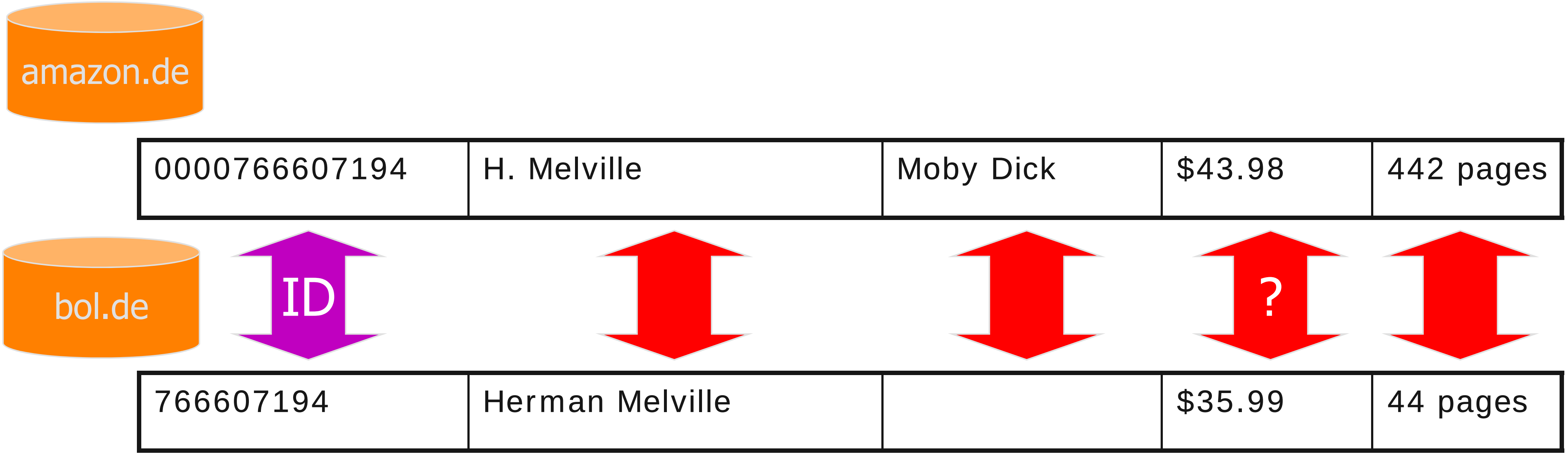
Problem: The same real-world entity is often represented

- **within multiple data sources.**
- **by multiple records within the same data base.**

- Relevant for: Product data, customer contact data, scientific data, …
- Business question: How much hardware did we sell to the University of Mannheim?
- Problem: CRM database likely contains multiple records referring to the university itself as well as the different faculties/chairs.
- Reasons for duplicates in the same data base:
  - different people enter data without identity checks
  - same entity observed several times
  - no consistent global IDs in input data (ISBN, GTIN, EAN, DUNS, …)

Semantic Heterogeneity: Data Conflicts

Problem: Two duplicate records contain different values for the same attribute.



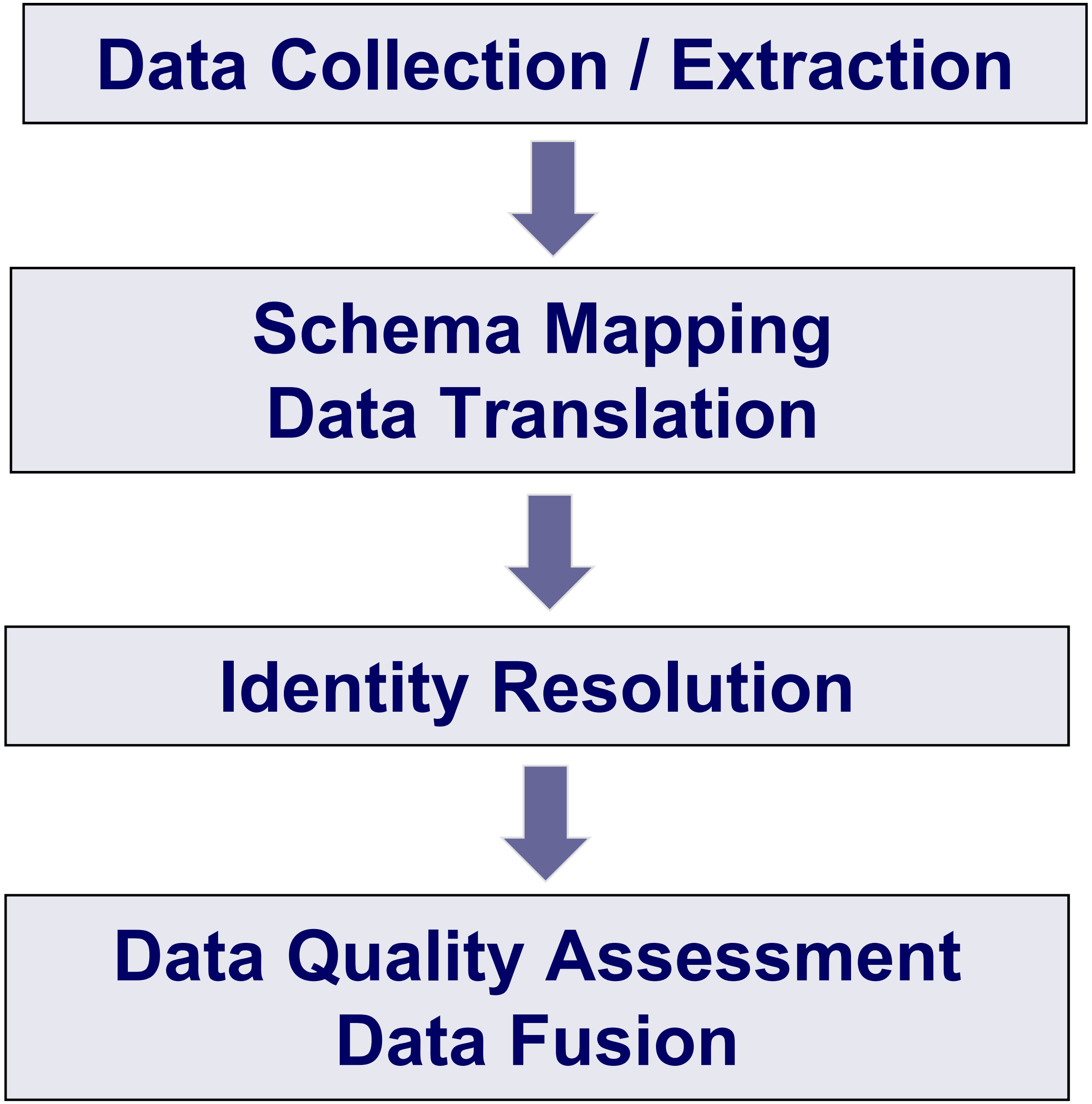
0000766607194	H. Melville	Moby Dick	$43.98	442 pages

766607194	Herman Melville		$35.99	44 pages

Reasons for data conflicts

1. Errors: Typos and other errors when data is entered
2. Outdated data: One source/record is older than the other one
3. Disagreement: Different sources actually disagree on the correct value / the truth

5. The Data Integration Process



Data Collection / Extraction

Schema Mapping
Data Translation

Identity Resolution

Data Quality Assessment
Data Fusion

5.1 Data Collection

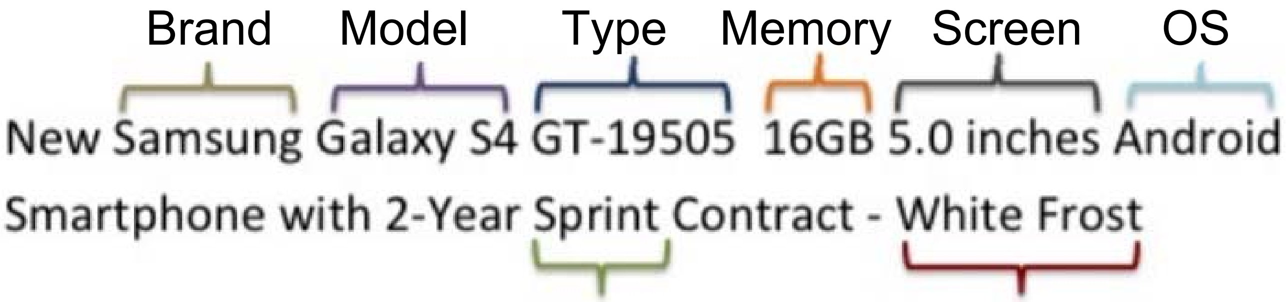
Goal: Resolve technical and data model heterogeneity so that data from all sources can be accessed / gathered and is represented in the same data model.

- Using middleware libraries that provide
  - different communication protocols (HTTP, ODBC, …)
  - readers for different data exchange formats (CSV, JSON, XML, …)
  - for querying remote data sources using different query languages (SQL, SPARQL, …)
  - for crawling remote data sources (HTML pages, Web APIs, Linked Data)
  - for translating data between different data models (XML-2-Relational, …)

Information Extraction

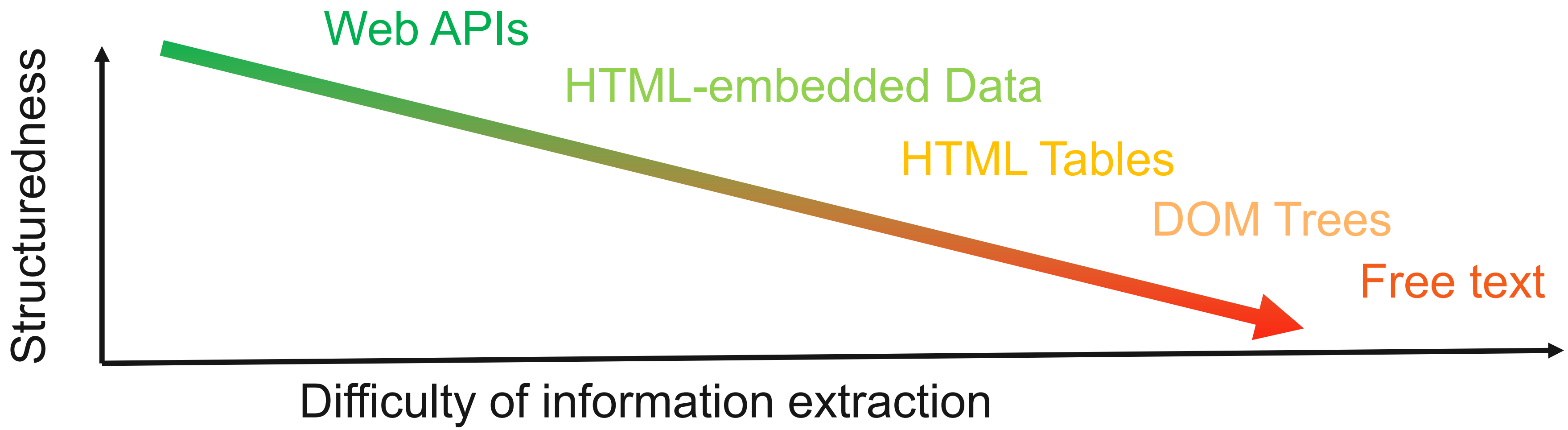
Goal: Automatic extraction of structured information from unstructured or semi-structured content.

- Example:



New Samsung Galaxy S4 GT-19505 16GB 5.0 inches Android Smartphone with 2-Year Sprint Contract - White Frost

- The difficulty of the extraction depends on the structuredness



Web APIs

HTML-embedded Data

HTML Tables

DOM Trees

Free text

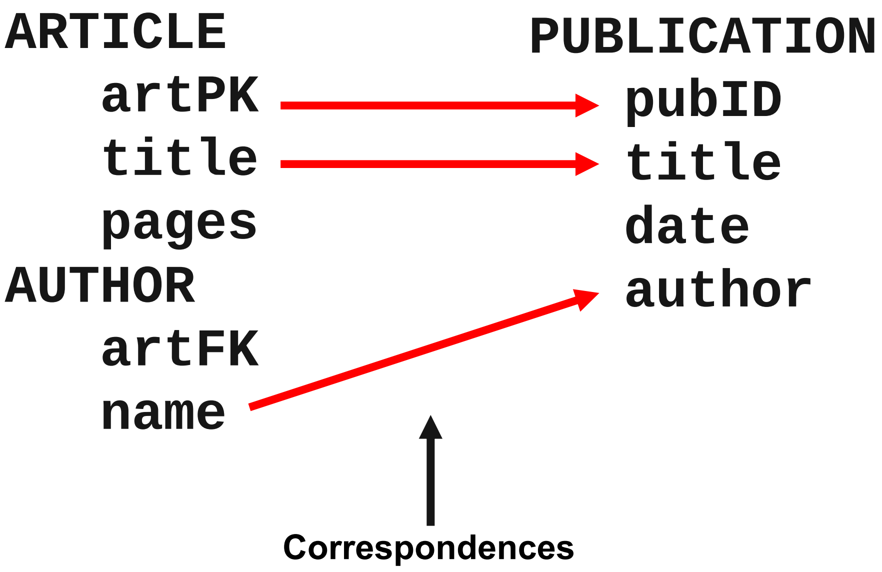
Structuredness

Difficulty of information extraction

5.2 Schema Mapping and Data Translation

Goal: Resolve structural and schema-related semantic heterogeneity by

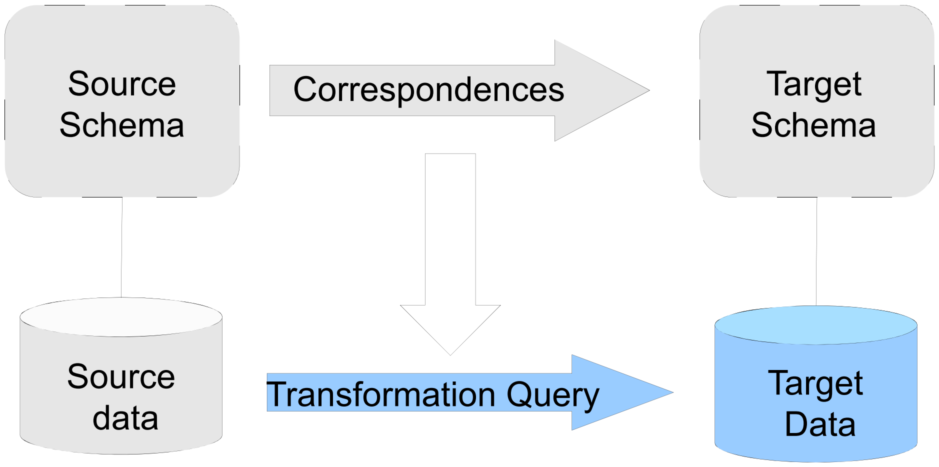
1. **finding correspondences between elements within different schemata.**
2. **translate data to a single target schema based on these correspondences.**



ARTICLE
artPK
title
pages
AUTHOR
artFK
name

PUBLICATION
pubID
title
date
author

Correspondences



Source Schema

Correspondences

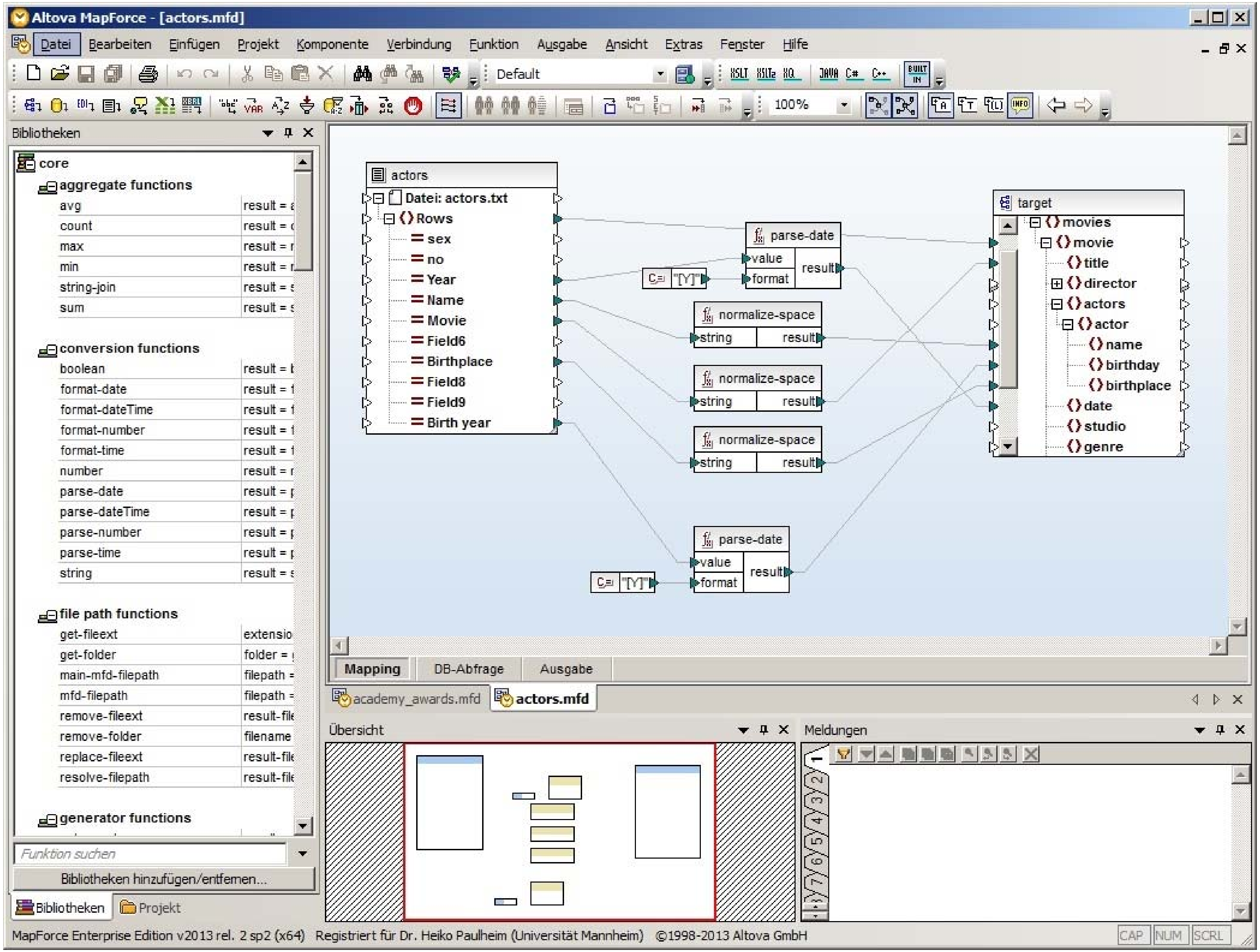
Target Schema

Source data

Transformation Query

Target Data

Example: Defining Correspondences



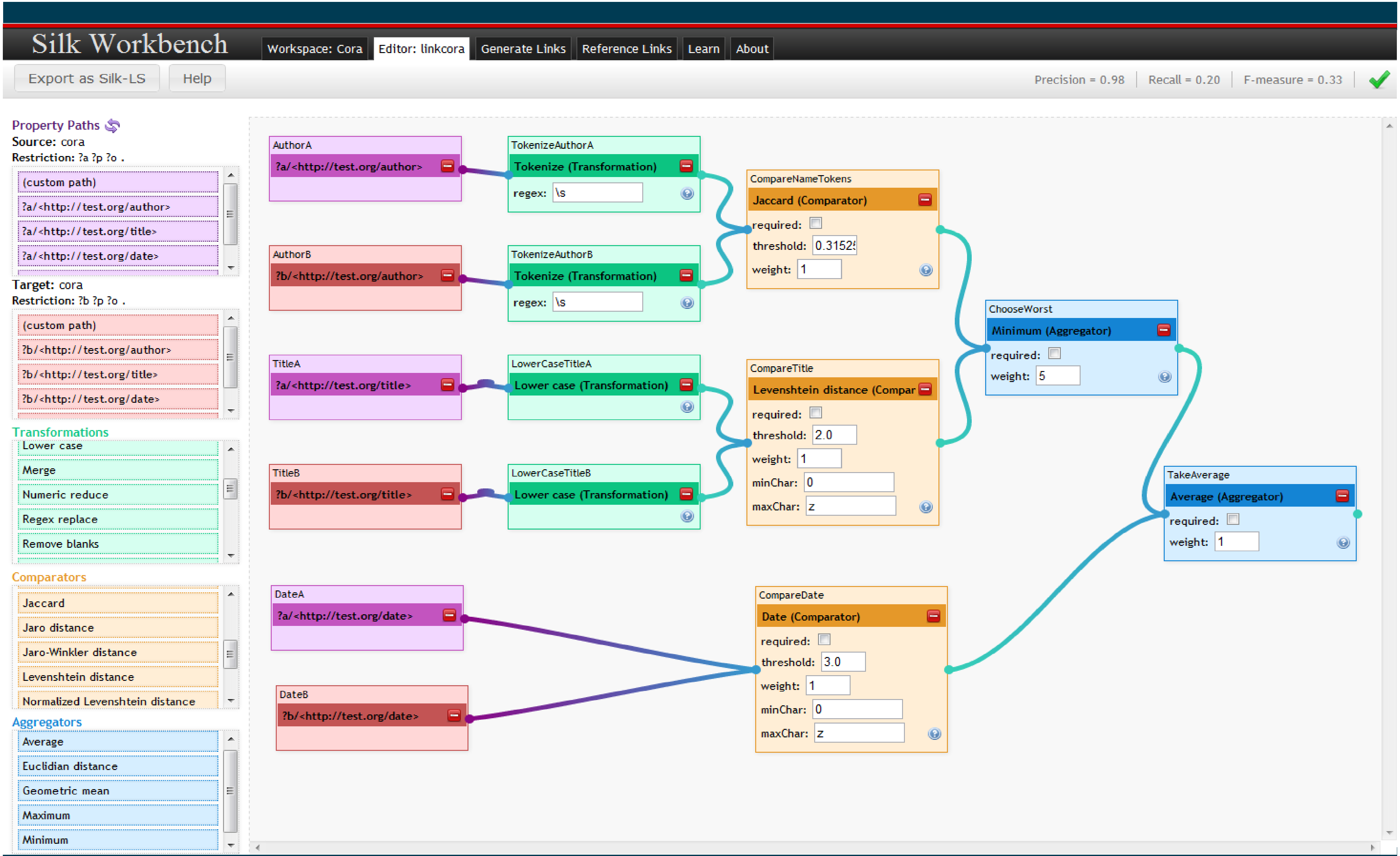
5.3 Identity Resolution

Goal: Resolve semantic heterogeneity by identifying all records in all data sources that describe the same real-world entity.

- **Other names for the task:**
  - **Duplicate Detection, Record Linkage, Entity Matching, Data Matching**
- **Basic Approach:**
  1. **Compare records using a combination of different similarity metrics**
  2. **If overall record similarity is above a threshold → Consider records to describe the same real-world entity**

DB1	CID1243	Chris Miller	12/20/1982	Bardon Street, Melville	32 sales
DB2	34	Christian Miller	2/20/1982	7 Bardon St., Melwille	24 sales
DB3	427859	Chris Miller	12/14/1973	7 Bardon St., Madison	13 sales

Example: Combining different Similarity Metrics



Precision = 0.98 | Recall = 0.20 | F-measure = 0.33 ✓

Property Paths

Source: cora

Restriction: ?a ?p ?o .

- (custom path)
- ?a/<http://test.org/author>
- ?a/<http://test.org/title>
- ?a/<http://test.org/date>

Target: cora

Restriction: ?b ?p ?o .

- (custom path)
- ?b/<http://test.org/author>
- ?b/<http://test.org/title>
- ?b/<http://test.org/date>

Transformations

- Lower case
- Merge
- Numeric reduce
- Regex replace
- Remove blanks

Comparators

- Jaccard
- Jaro distance
- Jaro-Winkler distance
- Levenshtein distance
- Normalized Levenshtein distance

Aggregators

- Average
- Euclidian distance
- Geometric mean
- Maximum
- Minimum

AuthorA: ?a/<http://test.org/author>

AuthorB: ?b/<http://test.org/author>

TitleA: ?a/<http://test.org/title>

TitleB: ?b/<http://test.org/title>

DateA: ?a/<http://test.org/date>

DateB: ?b/<http://test.org/date>

TokenizeAuthorA: Tokenize (Transformation) — regex: \s

TokenizeAuthorB: Tokenize (Transformation) — regex: \s

LowerCaseTitleA: Lower case (Transformation)

LowerCaseTitleB: Lower case (Transformation)

CompareNameTokens: Jaccard (Comparator) — required: □ threshold: 0.3152 weight: 1

CompareTitle: Levenshtein distance (Compar — required: □ threshold: 2.0 weight: 1 minChar: 0 maxChar: z

CompareDate: Date (Comparator) — required: □ threshold: 3.0 weight: 1 minChar: 0 maxChar: z

ChooseWorst: Minimum (Aggregator) — required: □ weight: 5

TakeAverage: Average (Aggregator) — required: □ weight: 1

5.4 Data Fusion

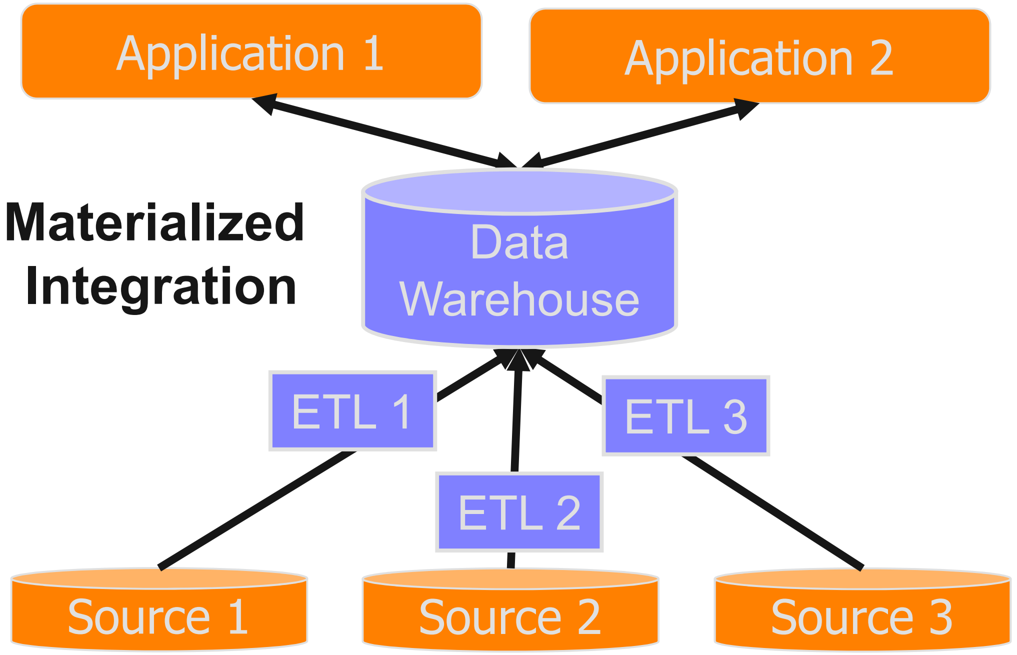
Goal: Resolve data conflicts by combining attribute values from duplicate records into a single consolidated description of an entity.

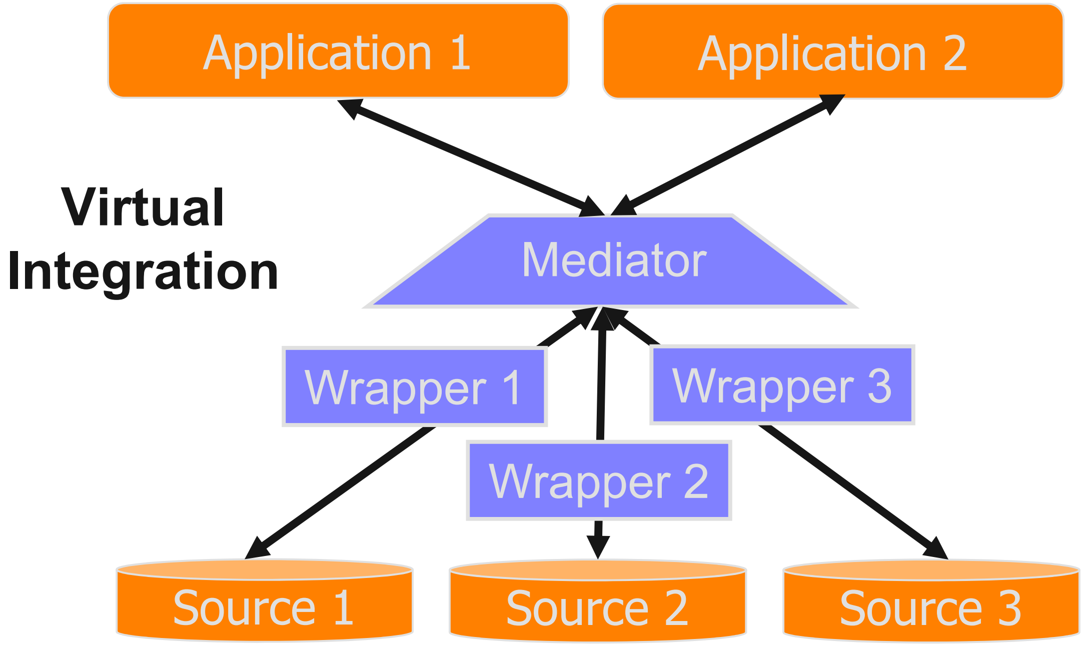
- **Basic Approach:**
  1. **Assess the quality of data sources / records / values**
     - **Quality dimensions: timeliness, reputation of source, …**
  2. **Apply a conflict resolution function to choose most promising values or to correct values**
     - **Example functions: highest estimated quality, voting, average, …**

DB1	EAN1243	Chris Miller	12/20/1982	Bardon Street, Melville	32 sales
DB2	34	Christian Miller	2/20/1982	7 Bardon St., Melwille	24 sales
Fused Data	EAN1243	Christian Miller	12/20/1982	7 Bardon Street, Melville	56 sales

6. Data Integration Architectures

1. **Materialized Integration**
   - integrate sources by bringing the data into a single physical database (data warehouse).
2. **Virtual Integration**
   - leave the data at the sources and access it at query time via wrappers (integrated view).
3. **Numerous intermediate architectures**





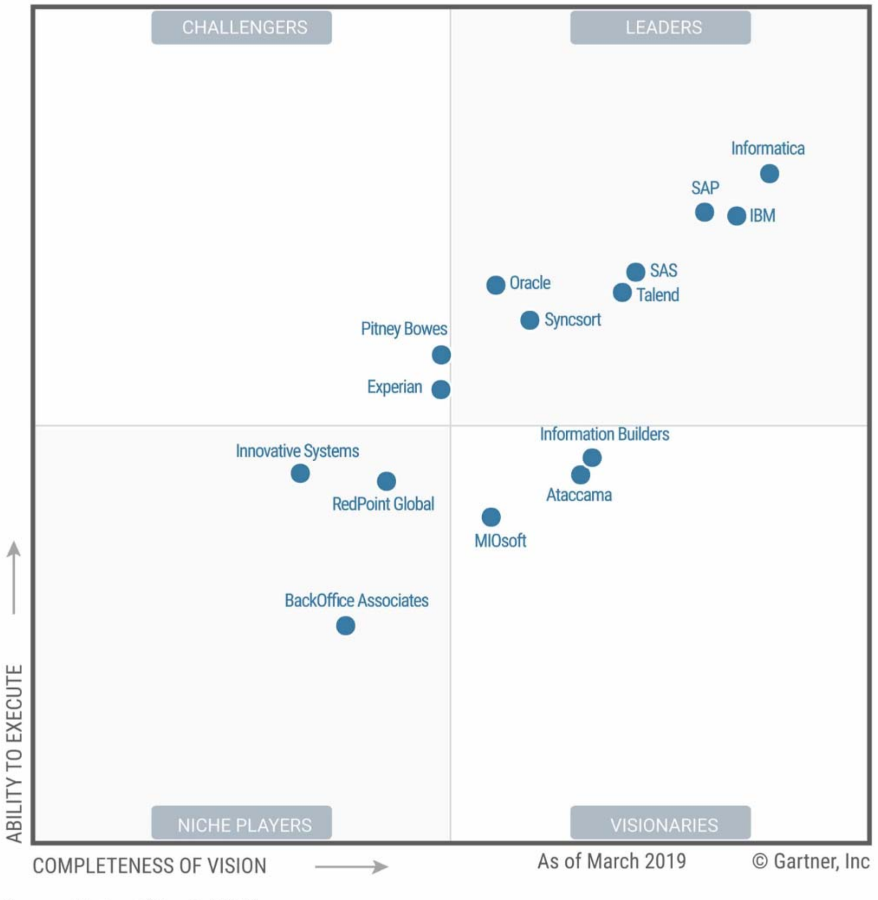
Materialized versus Virtual Integration

	Materialized Integration	**Virtual Integration**
Data currency	Low (regular updates)	High (always current)
Storage requirements	High (copy all data locally)	Low (data remains in sources)
Query processing time	Low (local query processing)	High (slow network traffic)
System Complexity	Low (like normal DB)	High (planning of distributed queries)
Query Expressiveness	High (like normal DB)	Low (as sources might be restricted)
Workload on data source	Can be planned	Hard to plan
Identity Resolution / Data Fusion	possible	difficult (often too slow)

- Rule of thumb: Virtual integration not applicable
  - if 5+ data sources need to be joined.
  - identity resolution and data fusion are important.
- This course illustrates data integration through the materialized architecture.

7. The Data Integration Software Market

- Market size 2017:
  7.45 billion US$ (growth: 14.4%)
- Tools for specific tasks
  - Altova Map Force
- Comprehensive solutions covering the complete data integration process
  - Informatica Plattform
  - IBM InfoSphere Information Server
  - SAP Data Hub, SAP Data Services
  - Microsoft SQL Server Integration Services
  - Talend Data Integration



Source: Gartner (March 2019)

- New challengers aiming at big data integration
  - Tamr Data Unification Platform

Source: Gartner, Magic Quadrant for Data Integration Tools. Zaidi, Beyer, Thoo, March 2019.

Getting an Impression of the Tools

Video tutorials on YouTube

- **SAP Data Hub**
  https://www.youtube.com/watch?v=CjLc4eDNpso
- **SAP Information Steward**
  https://www.youtube.com/watch?v=xrnrtWXI3nc
- **Informatica PowerCenter**
  https://www.youtube.com/watch?v=u6oLXidGoqs
- **Microsoft SQL Server Integration Services**
  https://www.youtube.com/watch?v=0ikNnenDyNw
- **Tamr Unify**
  https://www.youtube.com/watch?v=7jz740cdtDE

Setting Expectations

Alon Halevy: ”Data Integration is AI-Complete”

- Meaning that completely automated solutions are unlikely.
- Reasons:
  1. System Level: Managing different platforms, distributed query processing
  2. Logical reasons: Schema and data heterogeneity
  3. Social reasons: Locating relevant data, convincing people to share (data fiefdoms)

Goal 1:

- Reduce the effort needed to set up an integration application

Goal 2:

- Enable the system to perform gracefully with uncertainty (e.g., on the Web)

Summary

- Goal of Data Integration: Abstract away the fact that data comes from multiple sources in varying schemata
- The problem occurs everywhere: Handling it is curial for many applications in business, science, government, and the Web
- Architectures range from warehousing to virtual integration
- Regardless of the architecture, bridging heterogeneity is the key issue
- Goal: Reduce the human effort involved