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CS520
Data Integration, Warehousing, and Provenance

Course Info

IIT DBGroup

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Outline

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0) Course Info

1) Introduction
2) Data Preparation and Cleaning
3) Data Translation: Schema mappings, Virtual Data Integration, and Data Exchange
4) Data Warehousing
5) Big Data Analytics
6) Data Provenance

What is information integration?

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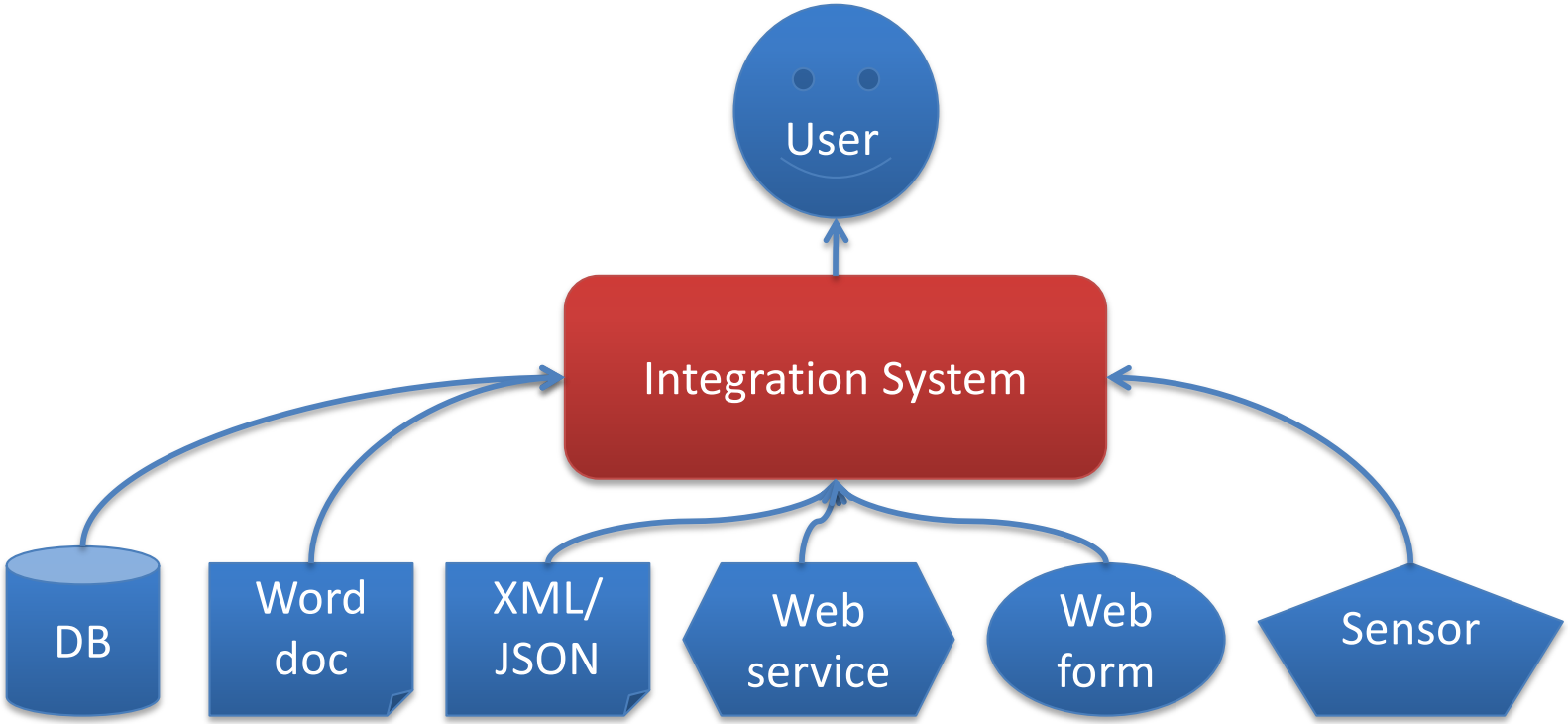
- Combination of data and content from multiple sources into a common format
  - Completeness
  - Correctness
  - Efficiency



Why Information Integration?

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- Data is already available, right?
- …, but
- **Heterogeneity**
  - Structural
    - Data model (relational, XML, unstructured)
    - Schema (if exists)
  - Semantic
    - Naming and identity conflicts
    - Data conflicts
  - Syntactic
    - Interfaces (web form, query language, binary file)

Why Information Integration?

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- **Autonomy**
  - Sources may not give you unlimited access
    - Web form only support a fixed format of queries
    - Does not allow access to unlimited amounts of data
  - Source may not be available all the time
  - Data, schema, and interfaces of sources may change
    - Potentially without notice

"Real World" Examples?

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- **Portal websites**
  - Flight websites (e.g., Expedia) gather data from multiple airlines, hotels
- **Google News**
  - Integrates information from a large number of news sources
- **Science**
  - Biomedical data sources
- **Business**
  - Warehouses: integrate transactional data

Example Integration Problem [1]

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- Integrate stock ticker data from two web services A and B
  - **Service A**: Web form (Company name, year)
  - **Service B**: Web form (year)

Steps

1) Interfaces
2) Schema integration
3) Translate queries
4) Optimization
5) Send queries to sources
6) Gather query results
7) Entity resolution
8) Fusion
9) Curation / Cleaning
10) Return final results

Example Integration Problem [2]

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- **Service A**:

```
<Stock>
        <Company>IBM</Company>
        <DollarValue>155.8</DollarValue>
        <Month>12</Month>
</Stock>
```

- **Service B**:

```
<Stock>
        <Company>International Business Machines</Company>
        <Date>2014-08-01</Date>
        <Value>106.8</Value>
        <Currency>Euro</Currency>
</Stock>
```

Steps

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Example Integration Problem [2]

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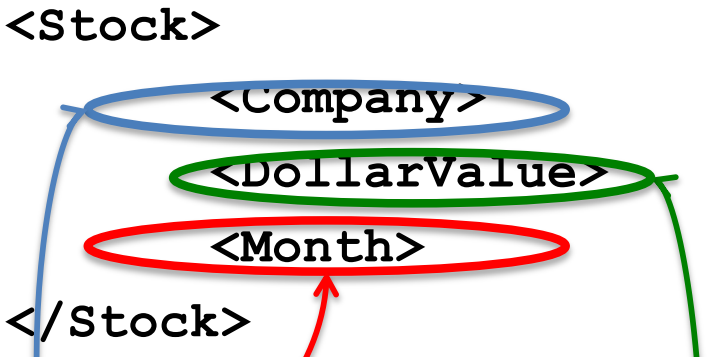
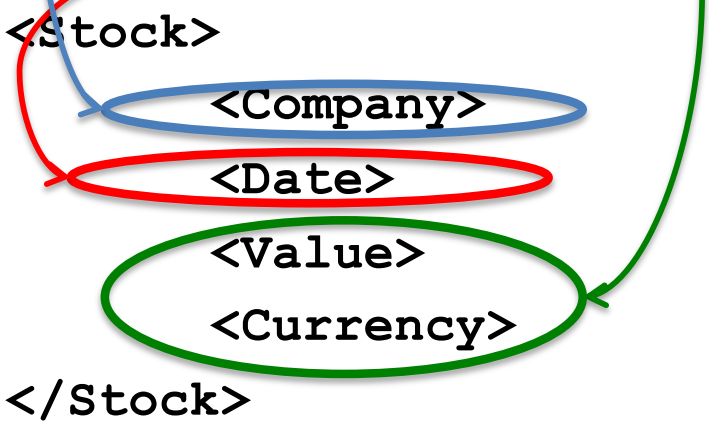
- **Service A**:



- **Service B**:



Steps

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Example Integration Problem [2]

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- **Service A**:

<Stock>
<Company>
<DollarValue>
<Month>
</Stock>

- **Service B**:

<Stock>
<Company>
<Date>
<Value>
<Currency>
</Stock>

Global Schema

<Stock>
<Company>
<Value>
<Month>
<Year>
</Stock>

Steps

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Example Integration Problem [3]

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- SQL interface for integrated service

```
SELECT month, value
FROM ticker
WHERE year = 2014
      AND cmp = 'IBM'
```

- Service A: **(IBM, 2014)**
- Service B: **(2014)**

Steps

1) Interfaces
2) Schema integration
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Example Integration Problem [4]

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- For web service A we can either
  - Get stocks for **IBM** in **all years**
  - Get stocks for **all companies** in **2014**
  - Get stocks for **IBM** in **2014**
- Trade-off between amount of processing that we have to do locally, amount of data that is shipped, …

Steps

1) Interfaces
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Example Integration Problem [5]

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- **Service A**: (IBM, 2014)
- **Service B**: (2014)

Steps

1) Interfaces
2) Schema integration
3) Translate queries
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5) Send queries to sources
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7) Entity resolution
8) Fusion
9) Curation / Cleaning
10) Return final results

Example Integration Problem [6]

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- **Service A**:

```
<Stock>
        <Company>IBM</Company>
        <DollarValue>155.8</DollarValue>
        <Month>12</Month>
```

…

- **Service B**:

```
<Stock>
        <Company>International Business
Machines</Company>
        <Date>2014-12-01</Date>
        <Value>106.8</Value>
        <Currency>Euro</Currency>
```

…

Steps

1) Interfaces
2) Schema integration
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Example Integration Problem [7]

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- IBM vs. Integrated Business Machines

Steps

1) Interfaces
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5) Send queries to sources
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Example Integration Problem [8]

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- Granularity of time attribute
  - Month vs. day
- What if both services return different values (after adapting granularity)
  - Average?
  - Median?
  - Trust-based?

Steps

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Example Integration Problem [9]

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- **"Dirty Data"**
  - **Outliers**
    - E.g., $10M / unit not realistic
  - **Violations of constraints**
    - E.g., stock value has to be positive
  - **Format and type errors**
    - E.g., include $ in value or not
    - Value has to be a number
- **Service A**:

```
<DollarValue>-15</DollarValue>
<DollarValue>10000000.8</DollarValue>
<DollarValue>$24</DollarValue>
<DollarValue>five dollar</DollarValue>
<DollarValue>fad23e19hasd</DollarValue>
```

…

Steps

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10) Return final results

Example Integration Problem [10]

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- Return final results:

```
<Stock>
        <Month>01</Month>
        <Value>105</Value>
</Stock>
…
<Stock>
        <Month>12</Month>
        <Value>107</Value>
</Stock>
```

Steps

1) Interfaces
2) Schema integration
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Why hard?

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- System challenges
  - Different platforms (OS/Software)
  - Efficient query processing over multiple heterogeneous systems
- Social challenges
  - Find relevant data
  - Convince people to share their data
- Heterogeneity of data and schemas
  - A problem that even exists if we use same system

Why hard? Cont.

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- Often called **AI-complete**
  - Meaning: "It requires human intelligence to solve the problem"
  - Unlikely that general completely automated solutions will exist
- So why do you still sit here
  - There exist automated solutions for relevant less general problems
  - Semi-automated solutions can reduce user effort (and may be less error prone)

AI completeness

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- Yes, but still why is this problem really so hard?
  - **Lack of information**: e.g., the attributes of a database schema have only names and data types, but no machine interpretable information on what type of information is stored in the attribute
  - **Undecidable computational problems**: e.g., to decide whether a user query can be answered from a set of sources that provide different views on the data requires **query containment** checks which are undecidable for certain query types

Relevant less general problems

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- **Data Extraction**
  - Extract data from unstructured sources / text
- **Data cleaning**:
  - Clean dirty data before integration
  - Conformance with a set of constraints
  - Deal with missing and outlier values
- **Entity resolution**
  - Determine which objects from multiple dataset represent the same real world entity
- **Data fusion**
  - Merge (potentially conflicting) data for the same entity

Relevant less general problems

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- **Schema matching**
  - Given two schemas determine which elements store the same type of information
- **Schema mapping**
  - Describe the relationships between schemas
    - Allows us to rewrite queries written against one schema into queries of another schema
    - Allows us to translate data from one schema into

Relevant less general problems

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- **Virtual data integration**
  - Answer queries written against a **global mediated schema** by running queries over **local sources**
- **Data exchange**
  - Map data from one schema into another
- **Warehousing: Extract, Transform, Load**
  - Clean, transform, fuse data and load it into a data warehouse to make it available for analysis

Relevant less general problems

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- **Integration in Big Data Analytics**
  - Often "pay-as-you-go":
    - No or limited schema
    - Engines support wide variety of data formats
- **Provenance**
  - Information about the origin and creation process of data
  - Very important for integrated data
    - E.g., "from which data source is this part of my query result"

Webpage and Faculty

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- **Course Info**
  - **Course Webpage**: http://cs.iit.edu/~glavic/cs520
  - **Discord**:
    - Used for announcements
    - Use it to discuss with me, TA, and fellow students
  - **Syllabus: http://www.cs.iit.edu/~glavic/cs520/2023-fall/syllabus/**
- **Faculty**
  - **Boris Glavic** (http://cs.iit.edu/~glavic)
  - **Email:** bglavic@iit.edu
  - **Phone**: 312.567.5205
  - **Office**: SB 206B

Workload and Grading

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- **Exams (60%)**
  - Final (30%), Midterm (30%)
- **Homework Assignments** (preparation for exams!)
  - **Theory part**: Practice theory for final exam
  - **Lab part**: Practice the tools we discuss in class
- **Literature Review (20%)**
  - In groups of 3 students
  - Topics will be announced soon
  - You have to read a research paper
  - Papers will be assigned in the first few weeks of the course
  - You will give a short presentation (15min) on the topic in class
  - You will write a report summarizing and criticizing the paper (up to 4 pages)

Workload and Grading

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- **Data Curation Project(20%)**
  - In groups of 3 students (same groups as for literature review)
  - You will acquire and curate (clean, integrate, …) a real world dataset
  - This is open-ended, you can choose whatever tools you need, whatever domain you think is interesting, …
    - Only limitation is that you need to document your cleaning workflow using a **Vizier notebook** (so at lease some python is required)
    - https://vizierdb.info/
  - Steps:
    - Acquire or extract one or more real world datasets for a domain of choice
    - Gain an understanding of the data and identify data quality issues
    - Research tools that are suited for the data cleaning, integration, extraction tasks that you need to apply to create a correct and clean output dataset
    - Apply the tools and produce an output
  - Work will be submitted through git repositories on bitbucket.org that we will create for each group

Workload and Grading

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- **Timeline:**
  - See course webpage for detailed dates
    - You are required to meet with the TA/Prof. several times for discussing the progress for the literature review and data curation project
  - Literature reviews and project presentations will be done in a block seminar towards the end of the semester (1-2 days)

Course Objectives

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- Understand the problems that arise with querying heterogeneous and autonomous data sources
- Understand the differences and similarities between the data integration/exchange, data warehouse, and Big Data analytics approaches
- Be able to build parts of a small data integration pipeline by “glueing” existing systems with new code

Course Objectives cont.

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- Have learned formal languages for expressing schema mappings
- Understand the difference between virtual and materialized integration (data integration vs. data exchange)
- Understand notions of data provenance and know how to compute provenance

Fraud Policies

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- All work has to be original!
  - Cheating = 0 points for review/exam
  - Possibly E in course and further administrative sanctions
  - Every dishonesty will be reported to office of academic honesty
- Late policy:
  - -20% per day
  - You have to give your presentation to pass the course!
  - No exceptions!

Fraud Policies cont.

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- Literature Review:
  - Every student has to contribute in the presentation, report, and data curation project!
  - **Don't let others freeload on you hard work!**
    - Inform me or TA immediately

Reading and Prerequisites

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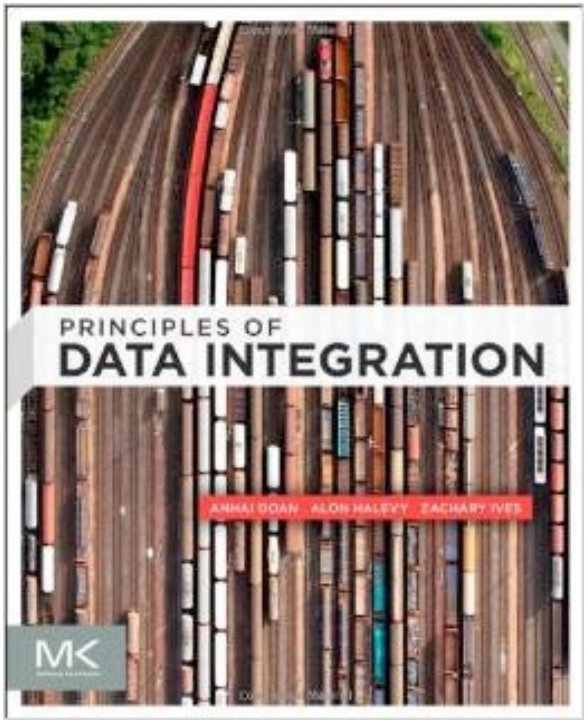
- **Textbook:** Doan, Halevy, and Ives.
  - **Principles of Data Integration**, 1st Edition
  - Morgan Kaufmann
  - Publication date: 2012
  - ISBN-13: 978-0124160446
  - Prerequisites:
    - CS 425



Additional Reading

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- Papers assigned for literature review
- Optional: Standard database textbook

Outline

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3) Schema mappings and Virtual Data Integration
4) Data Exchange
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6) Big Data Analytics
7) Data Provenance