

Theory and Practice of Data Cleaning

Relational Data



From Syntax to Schema & Semantics

- **Regular expressions**

- Define *patterns* (***syntax***) for matching and extracting data
- Check conformance (e.g., ISO date format YYYY-MM-DD)
 - ... otherwise: ***bring into canonical form***

- **OpenRefine**

- Profile and clean data, one column at a time
- Powerful similarity-based clustering
 - ... ***bring into canonical form***

- **What about complex issues, spanning multiple columns?**

- What about ***logical errors***?
- How to deal with data quality at the ***schema*** and ***semantic*** level?

... after OpenRefine, “dirty data” can still make it into our database tables ...

PERSON

Id	Name	DOB	Age	Sex	Phone	Zip	Email
43	Doe, Joe	1970-02-27	56	M	(999)-999-999	94102	
43	Jane Dunbar	1.1.1990	26	W	NULL	61820	jdunbar@foobar.com
27	Joe Doe	2/30/70	46	F	+1-530-777-1234	D-6951	joe.doe@gargle.edu

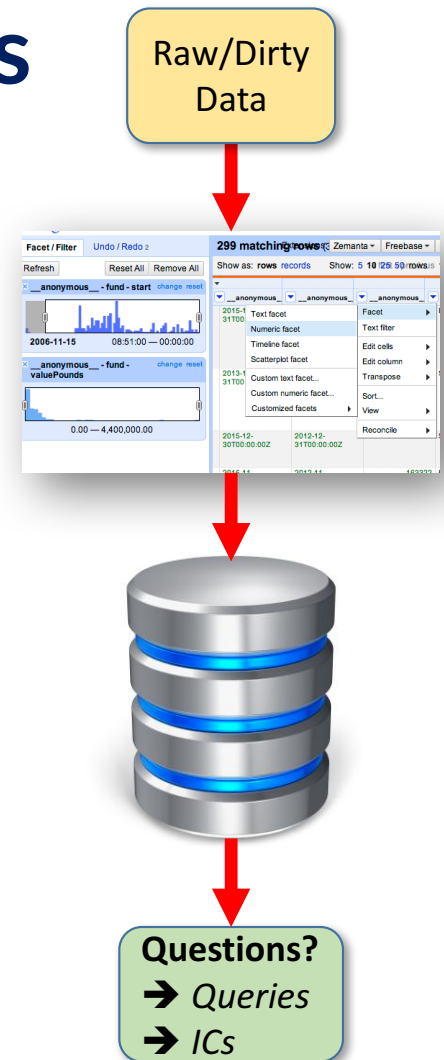
ADDRESS

ZIP	City	State
94102	San Francisco	CA
61821	Champagne	IL
D-6951	Obrigheim	Deutschland

- Errors and IC Violations:
 - Different representations & formats
 - Duplicates
 - Incompleteness
 - Incorrect values (typos, domain, ...)
 - **Uniqueness (primary key) violation**
 - **Contradictions**
 - **Referential Integrity (FK → PK)**
 - PERSON.ZIP → ADDRESS.ZIP
 - ...

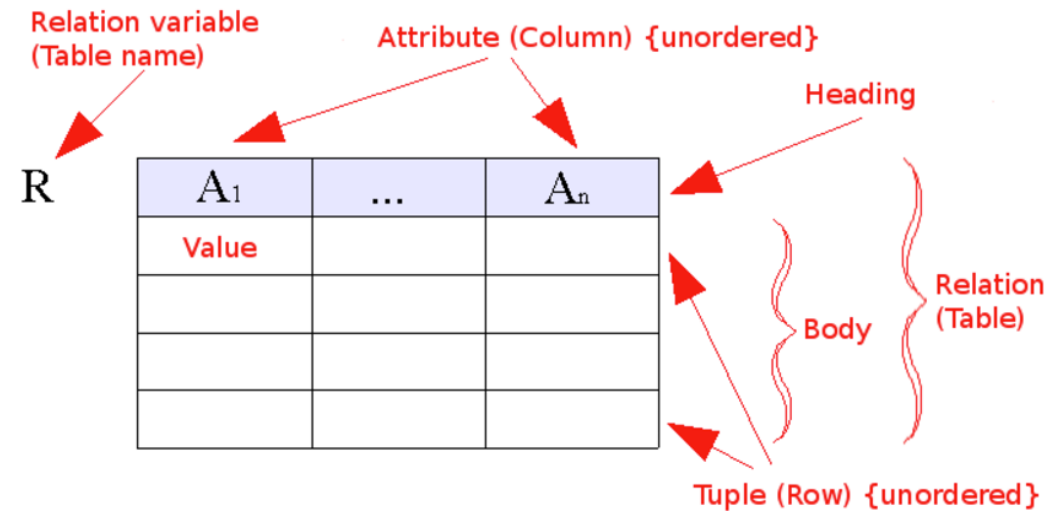
From Syntax to Schema & Semantics

- After *pattern-based cleaning*
 - regular expressions, OpenRefine, ...
- ... load data into a database system!
- ... and then exploit database technology:
 - *queries & integrity constraints!*
- **Relational Databases**
 - *Logic-based* approach first: **Datalog**
 - Facts, rules, queries, integrity constraints
 - Rich body of research; theory & practice!
 - *Relational data everywhere*: **SQL**



Relational Model

- Data in *relations* (tables) with ...
 - ... rows (tuples)
 - ... columns (attributes)
 - ... header (schema)
 - ... body (instances)

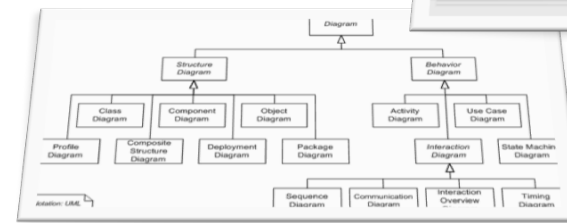
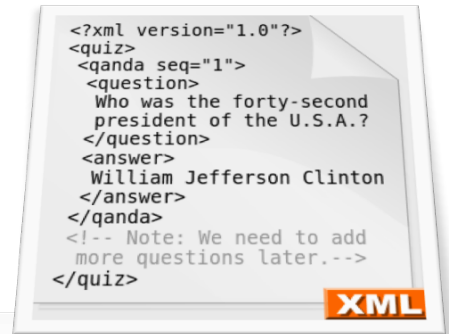
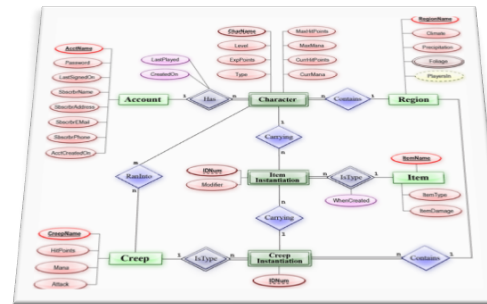
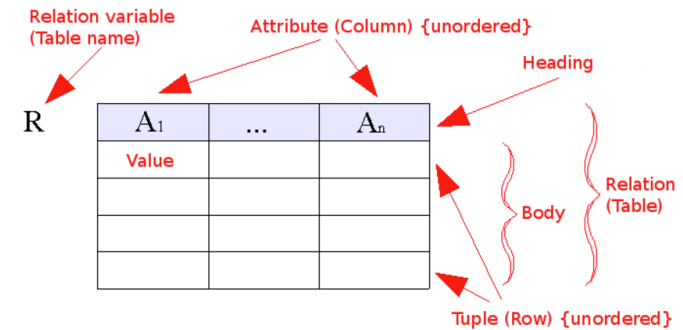


- Pioneered by Edgar F. Codd in the 1970s
- Some more **Terminology**:
 - **Relational Model**
 - Relational **Schema**
 - Relational **Database (Instance)**
 - **RDBMS**
 - Relational Database Management System



Relational Model ...

- ... is closely related to:
 - *Predicate Logic*
 - *Entity-Relationship (ER) model*
- ... can represent other data:
 - *Object-oriented / object-relational model*
 - *XML data, graph data,*
 - ...
- ... has powerful **query languages**:
 - *First-order predicate logic (FOL, RC)*
 - **Datalog**
 - *Relational Algebra (RA)*
 - *Structured Query Language (SQL)*
- ... for checking of **integrity constraints**



So many query languages, so little time: 4-in-1

- SQL SELECT ... FROM ... WHERE ...
- Relational Algebra (RA) $\sigma, \pi, \bowtie, \delta, \cup, \setminus$
- Relational Calculus (RC) $\forall x F, \exists x F, F \wedge G, F \vee G, \neg F$
- **Datalog** $\approx \text{RC} + \text{Recursion}$

EXAMPLE: Given relations `employee(Emp, Salary, DeptNo)` and `dept(DeptNo, Mgr)`,
find all (employee, manager) pairs:

- SQL:

```
SELECT Emp, Mgr
FROM employee, dept
WHERE employee.DeptNo = dept.DeptNo
```
- RA: $\pi_{\text{Emp,Mgr}}(\text{employee} \bowtie \text{dept})$
- RC: $F(\text{Emp,Mgr}) = \exists \text{Salary, DeptNo} : (\text{employee}(\text{Emp, Salary, DeptNo}) \wedge \text{dept}(\text{DeptNo,Mgr}))$
- **Datalog**: $\text{boss}(\text{Emp,Mgr}) \leftarrow \text{employee}(\text{Emp, Salary, DeptNo}), \text{dept}(\text{DeptNo,Mgr})$

Summary

- Syntax

- Regular expressions define *patterns* that can be used to *match, extract, and transform* data, i.e., deal with syntactic variations
- OpenRefine: open source tool for data wrangling

```
^[a-zA-Z][\w\.-]*[a-zA-Z0-9]@[a-zA-Z0-9][\w\.-]*[a-zA-Z0-9]\.[a-zA-Z][a-zA-Z\.-]*[a-zA-Z]$
```

- Schema & Semantics

- Using database technologies for **querying** and profiling; **integrity constraint** (IC) checking; and repair
- **Relational Model**
- Querying relational data: **Datalog** and **SQL**



- Synthesis

- Workflow automation (ETL, scripts)
- Provenance (data lineage and processing history)
- YesWorkflow: modeling scripts as workflows, provenance

