Transforming Unstructured Data to Structured: Standards, Logic, and Language Models

LaCo track | ESSLLI 2025 | Bochum

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Structured and Unstructured Data - From stories to graphs

Retrieval Championship

. . . Morgan was face to face with the accumulated art and knowledge of all mankind.

*In his student days, he had won several retrieval championships, racing against the clock while digging out obscure items of information on lists prepared by ingeniously sadistic judges. (**"What was the rainfall in the capital of the world's smallest national state on the day when the second largest number of home runs was scored in college baseball?"** was one that he recalled with particular affection.) His skill had improved with years, and this was a perfectly straightforward question. The display came up in thirty seconds, in far more detail than he really needed.*

How would you Solve the Problem...

... with todays' tools?

"What was the rainfall in the capital of the world's smallest national state on the day when the second largest number of home runs was scored in college baseball?"

- fulltext engine (old school) Google in 1998
- modern search engine (linked to knowledge sources)
- faceted search, e.g. SemFacet
- multi-hop search
- large language model (LLM)

Structured and Unstructured data

two views on data:

- structured: database view (tables, relations, graphs, . . .)
- unstructured: documents as streams of characters

Klan, 2017

"Unstructured" means unstructured from computational point of view.
Unstructured data have no predefined data model.
However, unstructured data are structured from the human POV.

A Closer Look to Structured Data

A record

```
{
  "firstName": "John",
  "lastName": "Smith",
  "age": 25
}
```

A Closer Look to Structured Data

Table of records

firstName	lastName	age
Jane	Doe	26
John	Smith	25

What information do we put in columns?

What Makes Structured Data Valuable?

firstName	lastName	age	city
Jane	Doe	26	Bochum
John	Smith	25	Bochum

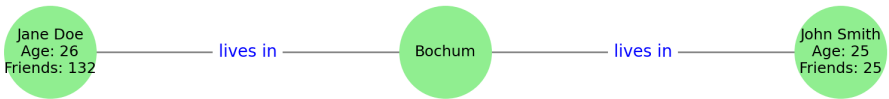
What information do we put in columns?

- the whole column is typically of the same data type (entities)
- the information in the column can connect the records (relations)

Graphs: Entities + Relations

firstName	lastName	age	city	#friends
Jane	Doe	26	Bochum	132
John	Smith	25	Bochum	25

Jane Doe lives in Bochum. So does John Smith. Jane has a lot of friends, while John has only 25 of them.



Knowledge Graph Properties

Knowledge graph (KG) is a **model**.
The designer has to make **design choices**.

- decide what is the scope of the model (e.g., domain of the Bochum community)
  - what entities will be in the graph?
  - what relations will be in the graph?
  - will the graph be enriched by some implicit knowledge (e.g., Jane is female, John is male)?
- decide what entities are the same (i.e., point to the same object in the real world)

KGs provide **inference** to:

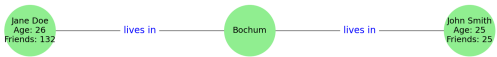
- check logical consistency
- infer new facts via deduction (general $\rightarrow$ specific)

Software Standards to Model Knowledge Graphs

- there are several but let's stick to what is called **semantic web technologies**

Model and Schema for Graphs = RDF(S)

- Resource description framework (RDF)
- Resource description framework schema (RDFS)



- Describe how to model knowledge
- Provides *basic concepts* (in a **vocabulary**)
  - **resource** = node that can be connected to another node
  - **literal** = it makes no sense to connect it to other nodes
  - **statement** = a triple

The Triple

resource - predicate - resource
resource - predicate - literal
Resources have **unique identifier**. For **human readability**, they have labels. Labels can be in different languages. Literals can have **data types**.

Example Labels

```
<TheMonaLisa> <rdfs:label> "The Mona Lisa"@en .
<TheMonaLisa> <rdfs:label> "La Joconde"@fr .
<TheMonaLisa> <rdfs:label> "Mona Lisa"@cs .
<TheMonaLisa> <rdfs:label> "La Gioconda"@it .
```

Now What? Structured Data Use Cases

- Structured data can be **converted to** natural language.
  - check what GPT generated
- Structured data can easily be **reused** in other situations.
  - Who is in Bochum?
  - What is the average age of people in Bochum?
  - How many friends do people have at maximum?
  - Is it true that older people have more friends?
- Tabular data can be converted to knowledge graphs using large language models
  - Let's try and visualize

Why KGs? Aren't tables enough?

- Yes, in many cases.
- KGs can easily model complex relationships.
- Tables have to be designed *a priori*, extension is difficult.
- KGs can *reveal* existing but hidden information by connecting records (rows) in tables.

Automatic Conversion? Yes!

- Let's try OpenRefine

Summary

- Unstructured data mean streams of characters, but still they can be structured for us - humans.
- Structured data are used to model a domain/event/part of our world.
- Knowledge graphs are a popular model because they are:
  - easily processed by algorithms
  - still readable for humans
- Tables can be a source for knowledge graphs