



Ontologies in the Semantic Web

An Introduction to Knowledge Modeling & Sharing

University of Oldenburg, Germany

Wolfram Wingerath

Dec. 07, 2022

Overview

1

Semantic Web

What is the Semantic Web?

2

Ontologies

What is (an) ontology and how does it relate to the Semantic Web?

3

Use Cases & Applications

Where are ontologies used in practice?

The Early Internet and the Web 1.0

- Information access in the **early internet was complicated**:
 - terminal-based (download file ⇒ open file)
 - Required expert knowledge
- In 1990, the **Web 1.0 introduced easy exploration**:
 - Graphical user interface via browsers
 - Linked documents
 - High flexibility (no predefined structure)
 - Keyword search via **search engines**

Jerry and Dave's WWW Interface... (*Always Under construction*)

Welcome, visitor from

Last modified on Fri May 20 17:55:16 1994
There are currently 1909 entries in the hotlist database

Vous pouvez lancer des recherches dans cet index. Pour cela, entrez des mots clés de recherche :

- [Art](#)
- [Computers](#)
- [Economy](#)
- [Education](#)
- [Entertainment](#)
- [Environment and Nature](#)
- [Events](#)
- [Geography](#)
- [Government](#)
- [Health](#)
- [Humanities](#)
- [Journalism](#)
- [Law](#)
- [News](#)
- [Politics](#)
- [Reference](#)
- [Research](#)
- [Science](#)
- [Society and Culture](#)
- [todo](#)

The Web 2.0: The Social Web

- In the early 2000s, users became **content producers**:
 - Blogs & microblogging
 - Social networks
 - Collaborative projects
 - Dynamic content



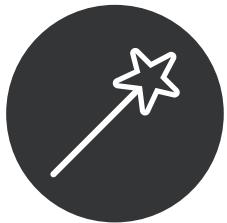
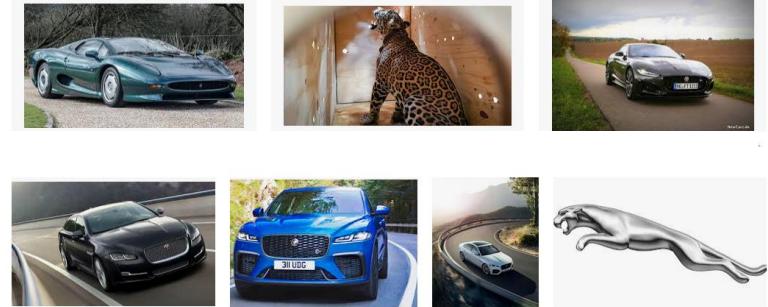
Original by Markus Angermeier Vectorised and linked version by Luca Cremonini - Based on [web20map.png](#) Vectorised and linked version from [Web_2.0_Map.svg](#)

Challenges for Information Management



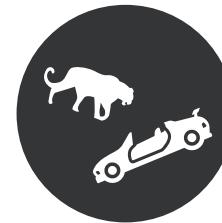
Internet Scale

automation is required for
today's amounts of data



Implicit Knowledge

meaning often depends on
context and “common sense”

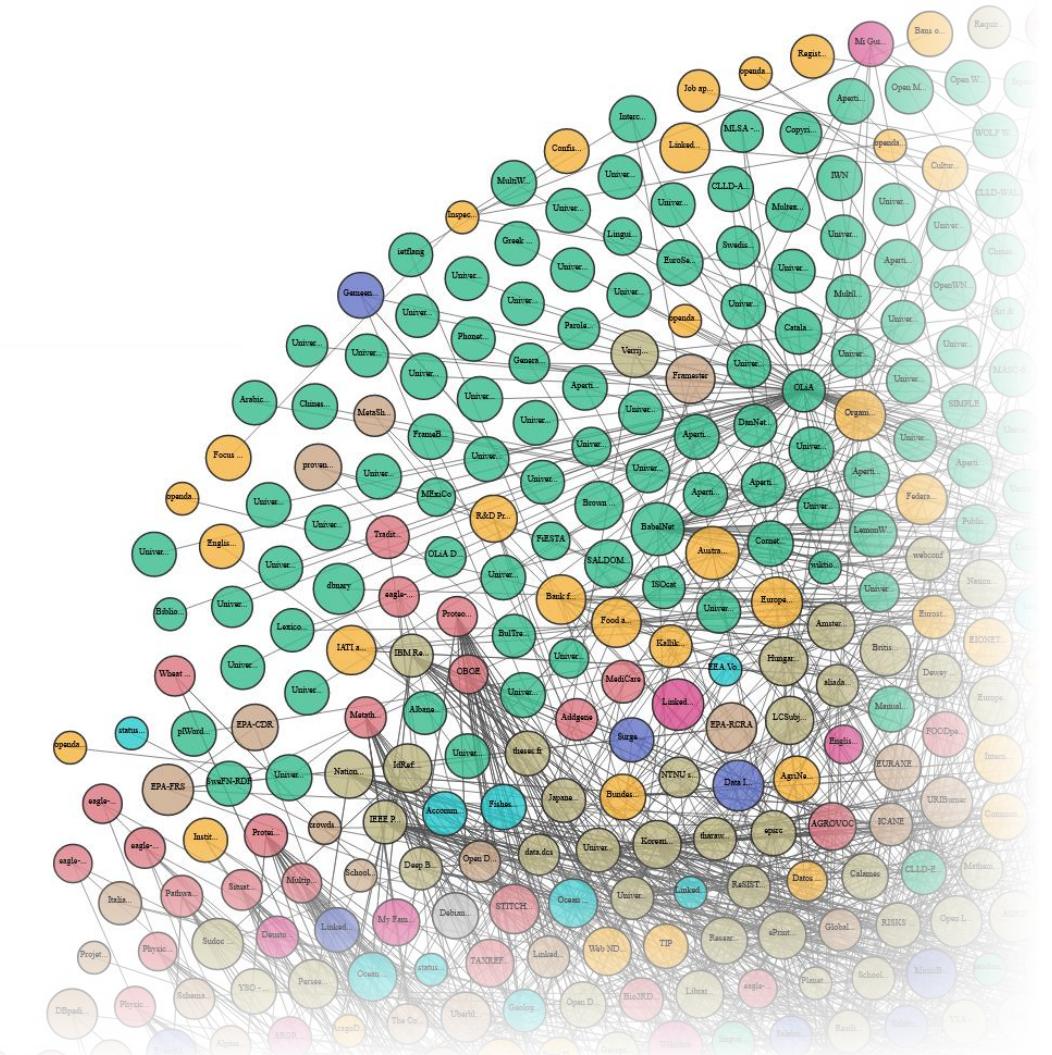


Polysemy

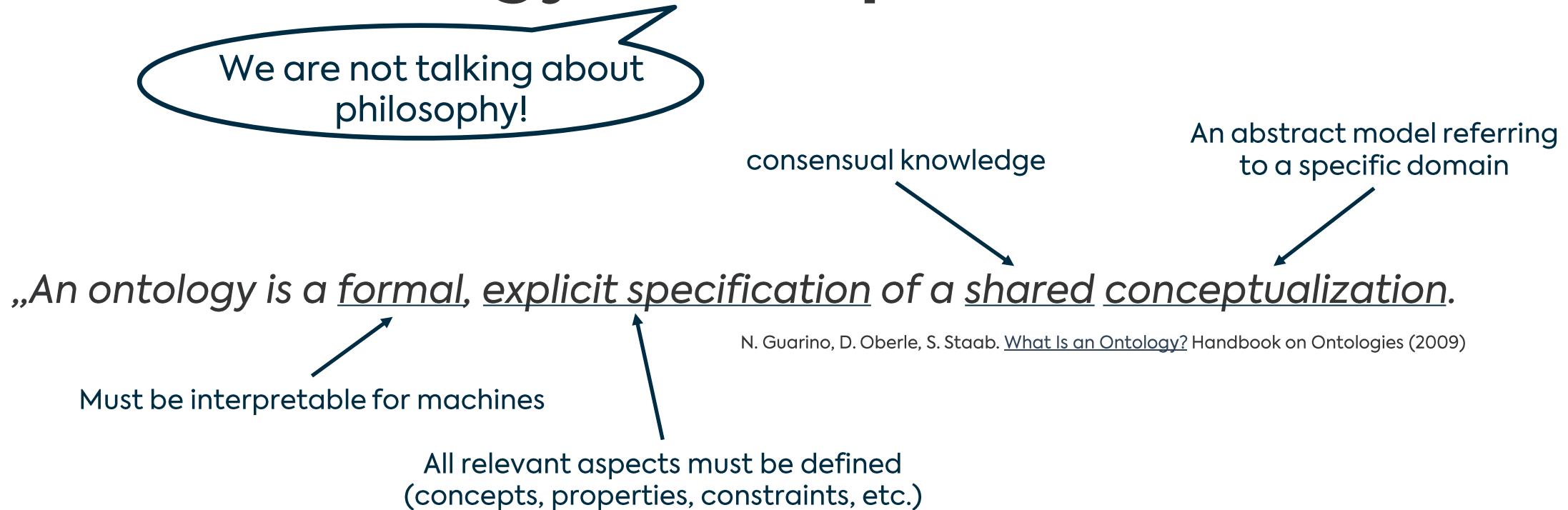
natural language is ambiguous
(synonyms, metaphors, etc.)

The Web 3.0: The Semantic Web

- Organized to be **interpretable by machines**
- Semantics can be derived through syntactic rules
⇒ **Meaning** can be computed!
- **World Wide Web ⇒ Giant Global Graph**
 - Standards for knowledge exchange
 - Linked datasets
 - “Smart Data”

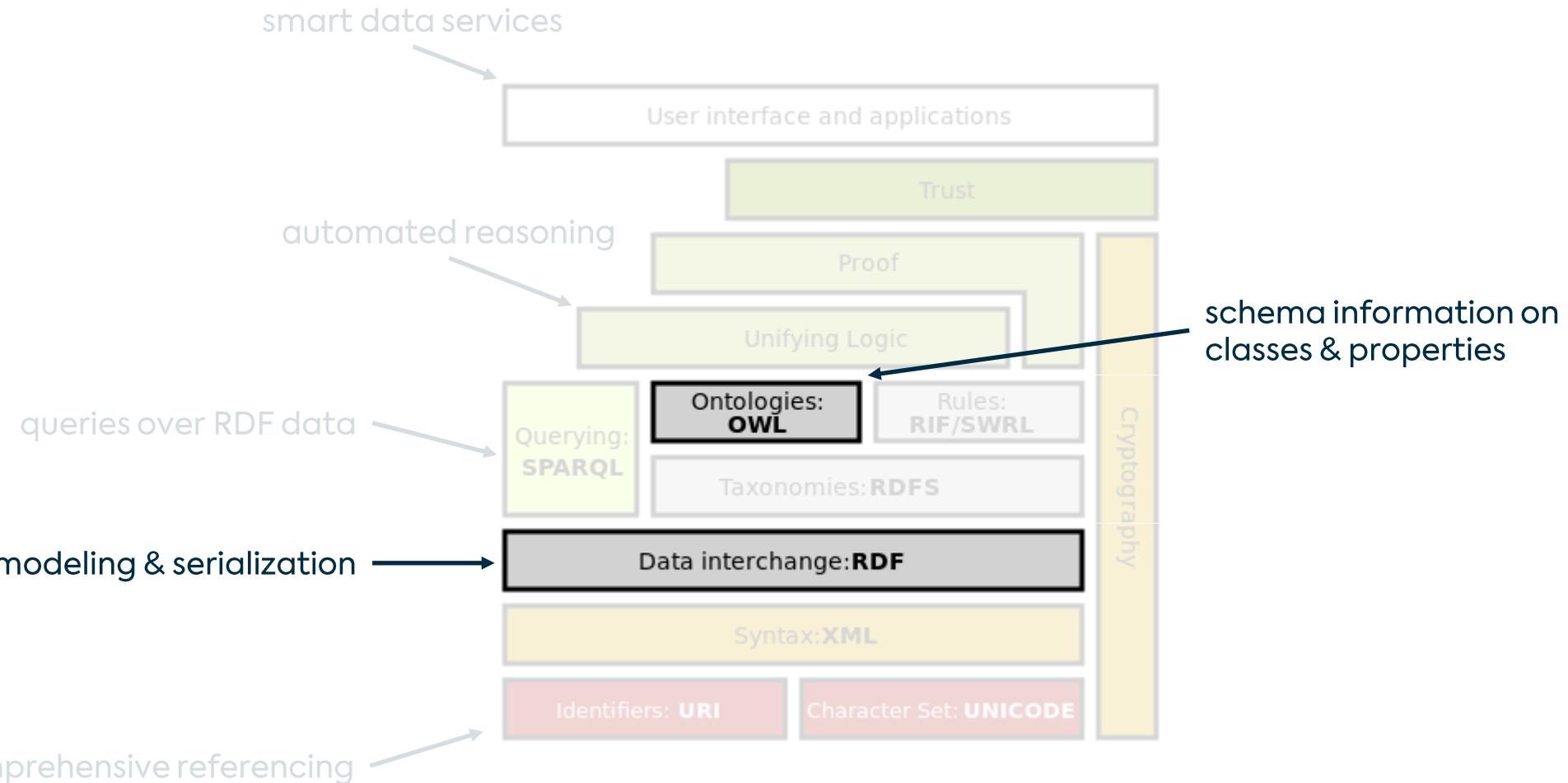


An Ontology in Computer Science



- **Knowledge model:** defines a set of concepts and the relationship between them
- Purpose: capture human knowledge and **common sense**
- ⇒ enable **automated reasoning** and logical inference

The Semantic Web Stack (Simplified)

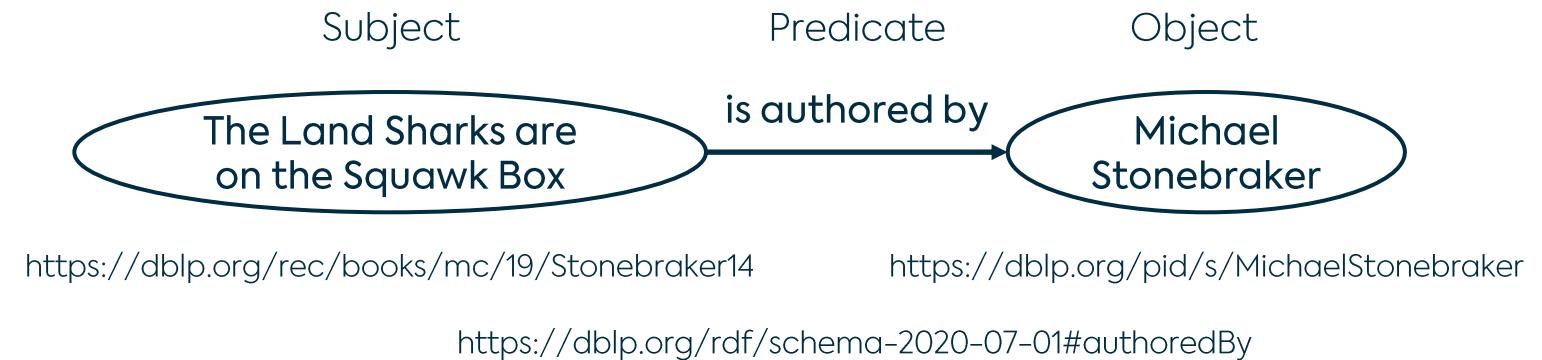


RDF: Resource Description Framework

- The standard method for describing information in a **knowledge graph**

- **Triple-based** data model

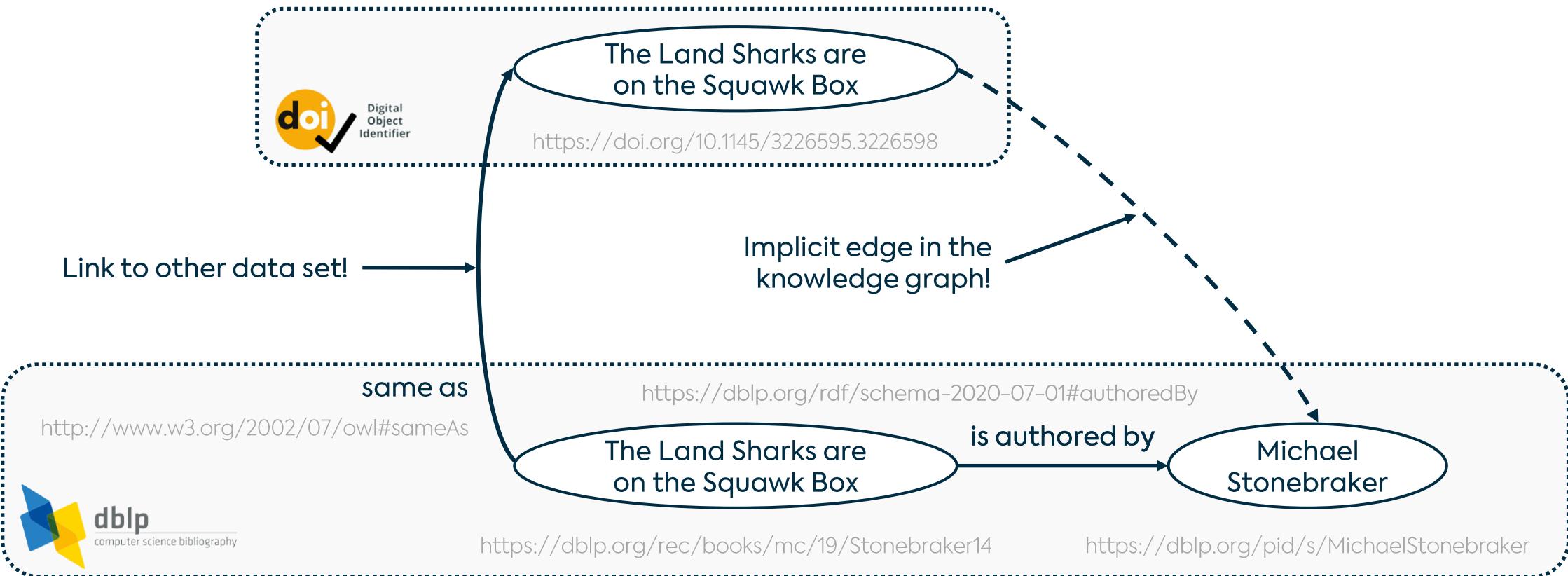
- **No schema**
(everything is a triple)



- Mostly everything has a **unique identifier** to allow reusing data

- Various serialization formats for **easy exchange** (XML, JSON, Turtle, ...)

Semantic Data Integration With RDF



OWL: Web Ontology Language

- **De facto standard** language for expressing ontologies
- **Schema** layer for (RDF) knowledge graphs for specifying
 - (Hierarchies of) classes and properties
 - Equivalence
 - Inverse relations
 - Value ranges
 - ...
- Includes **entailment rules** to enable inferring new triples from existing ones
- Different versions (current: 2) and sublanguages (OWL Lite < OWL DL < OWL Full)
- Various serialization formats (XML, JSON, Turtle, ...)

OWL extends RDF

```
<owl:Class rdf:ID="Class">
  <rdfs:subClassOf rdf:resource="OtherClass" />
  ...
</owl:Class>
```

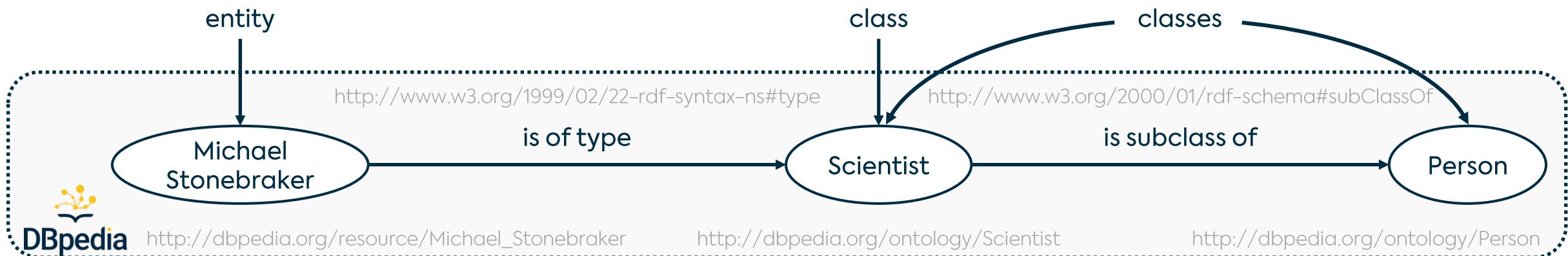
Applying Domain Knowledge to Data

- **Consistency** checks: Are there inconsistencies?
- **Satisfiability** checks: Can all classes have instances?
- **Relationships** between entities and classes
(same/different, intersection, disjunction, ...)

Schema info on Person:

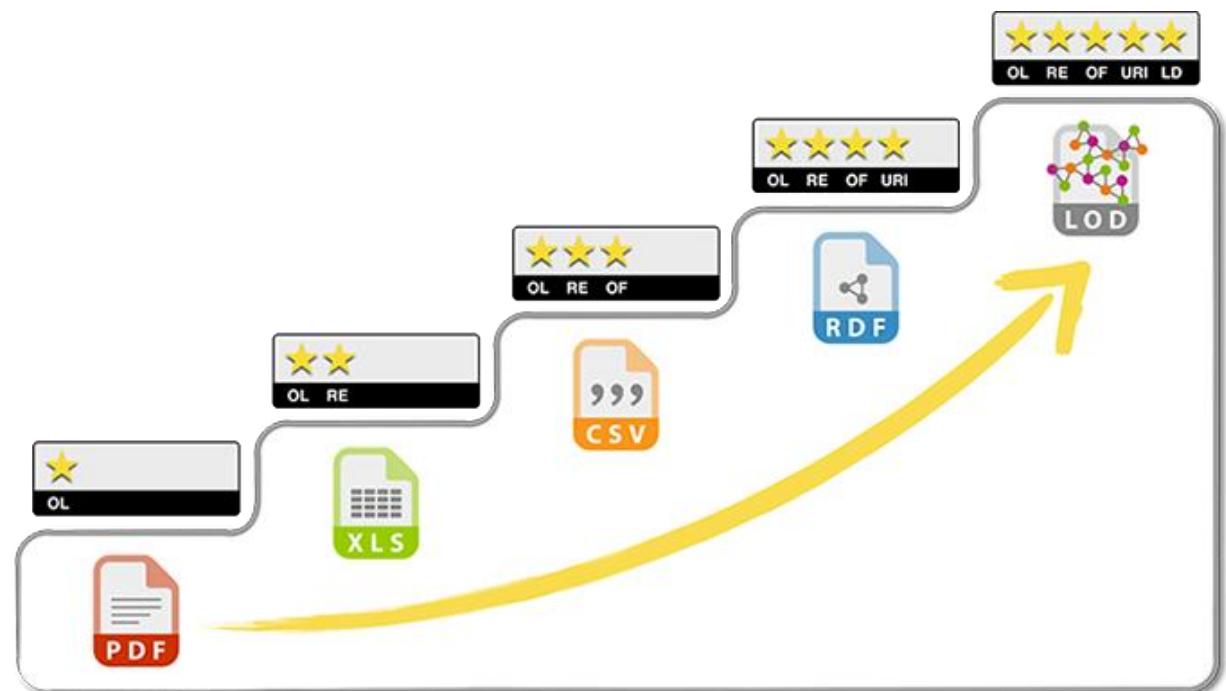
- Can have a Mother
- Disjoint with Activity
- ...

⇒ Michael is an instance of Scientist
(and by proxy an instance of Person),
so the same implicitly applies to him!



Linked (Open) Data

- **Open Data** is available for free and may be used by anyone for any purpose
- **Linked Data** follows three principles:
 1. Use HTTP URIs for referencing entities and concepts
 2. Use standards (e.g. RDF format & SPARQL query API)
 3. Provide links to other URIs
- **5-Star Grading Scheme:**
 1. Open data
 2. Available as machine-readable structure data
 3. In a non-proprietary format
 4. Follows W3C standards (RDF, URIs)
 5. Links to other LOD sources



Linked Open Data (LOD)

 Tim Berners-Lee. [Linked Data \(Design Issues\)](#), W3C (2019)

Linked Open Data Cloud

Challenge: How to avoid **terminology bloat**?

⇒ **Upper Ontologies** to provide shared vocabulary

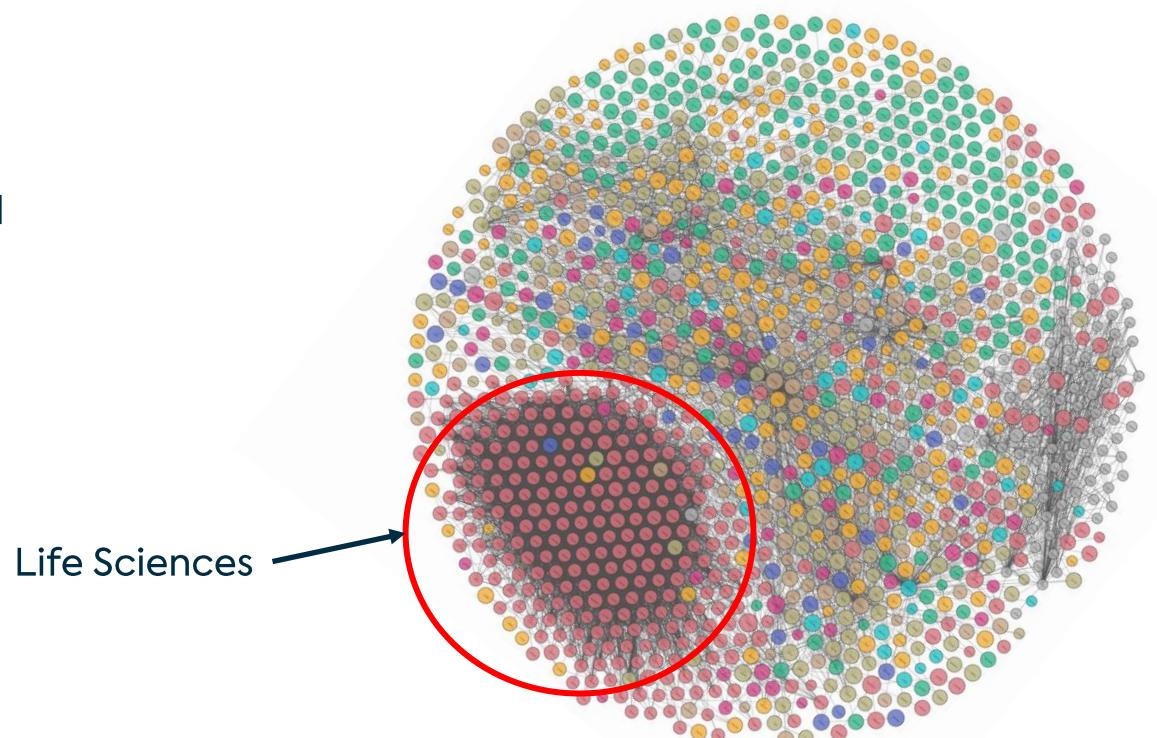
Notable datasets:

- **DBpedia**: crawled Wikipedia content
- **Wikidata**: metadata to amend Wikipedia
- **BFO**: upper ontology for life sciences

Legend
Cross Domain
Geography
Government
Life Sciences
Linguistics
Media
Publications
Social Networking
User Generated

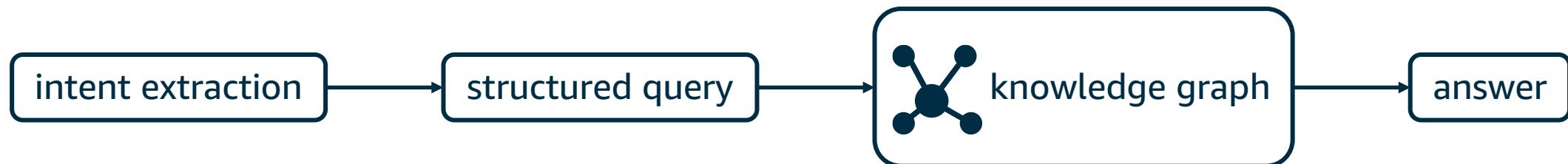
2021:

- >1300 data collections
- >16000 links



Barry Smith. [Ontologies for Space and Ground Systems \(Tutorial\)](#), Ground System Architectures Workshop (2020)

Use Case: Internet Search



A screenshot of a Google search results page for the query "How old is David Hasselhoff?". The search bar at the top contains the question. Below it, the search interface shows various filters like "Alle", "Bilder", "Shopping", "News", "Videos", "Mehr", "Einstellungen", and "Suchfilter". The search results indicate approximately 1.550.000 results found in 1.03 seconds. The first result is for "David Hasselhoff / Alter", with a birth date of "17. Juli 1952" and an age of "68 Jahre". A red box highlights the question in the search bar and the answer "68 Jahre". To the right, a detailed knowledge graph card for David Hasselhoff is shown, containing his profession ("Schauspieler"), a biography mentioning his roles in "Knight Rider" and "Baywatch", and links to his Wikipedia page. The card also lists his birth date ("Geboren: 17. Juli 1952") and height ("Größe: 1,93 m"). A red box highlights the knowledge graph card. Labels "question" and "answer" point to the respective highlighted areas.

How old is David Hasselhoff?

question

answer

related information from Google Knowledge Graph

David Hasselhoff

Schauspieler

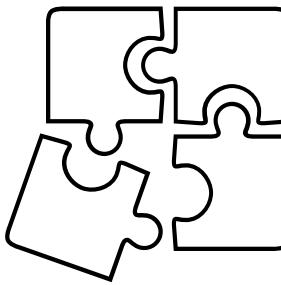
David Michael Hasselhoff ist ein US-amerikanischer Schauspieler und Sänger. Bekannt wurde er durch seine Hauptrollen in den Fernsehserien Knight Rider und Baywatch sowie musikalische Veröffentlichungen. [Wikipedia](#)

Geboren: 17. Juli 1952 (Alter 68 Jahre), Baltimore, Maryland, Vereinigte Staaten

Größe: 1,93 m

Ehepartnerin: Hayley Roberts (verh. 2018), Pamela Bach (verh. 1989–2006), Catherine Hickland (verh. 2018)

Wrapup: Ontologies in the Semantic Web



- **The Semantic Web** extends the WWW by machine-readable information
- **Ontologies** help share meaning between humans and computers
 - Linked Open Data allows standardized structured queries
 - Semantic interoperability remains a major challenge
- **Use cases** revolve around inference and (derived) meaning, e.g.:
 - Information consumption (search, discovery, recommendation, etc.)
 - Semantic data integration & governance
 - Virtual assistants like Siri or Google Assistant