

“With Knowledge Doubt Increases”- The Significance of Knowledge in Knowledge Graphs

Prof. Dr. Harald Sack
Graphs & Networks in the Humanities 2022
04.02.2022

Knowledge Graphs @ FIZ Karlsruhe

Projects, Services & NFDIs



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Die erste deutsche
Demokratie



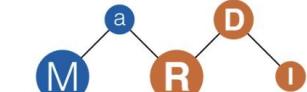
archivportal



2019



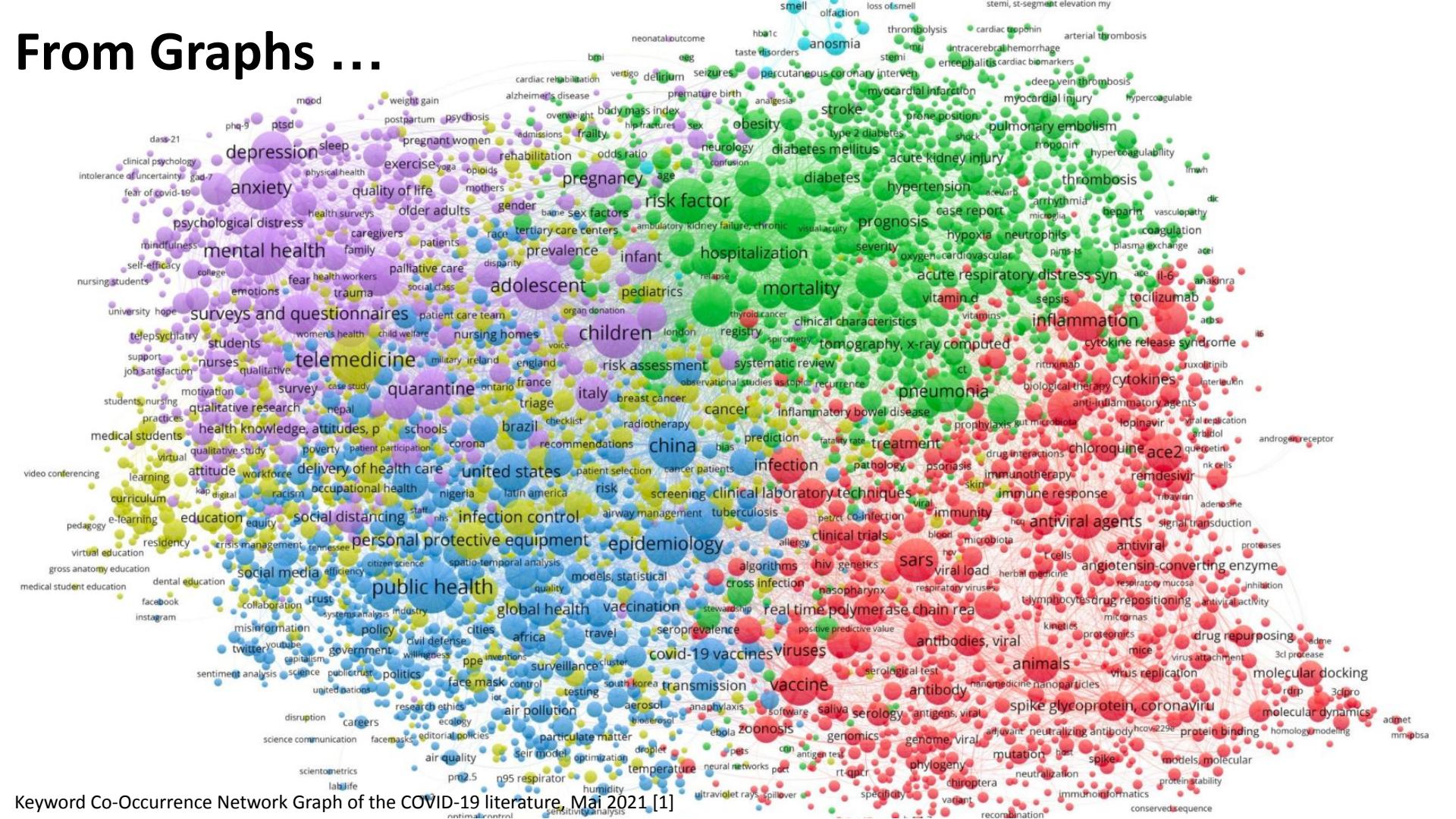
2020



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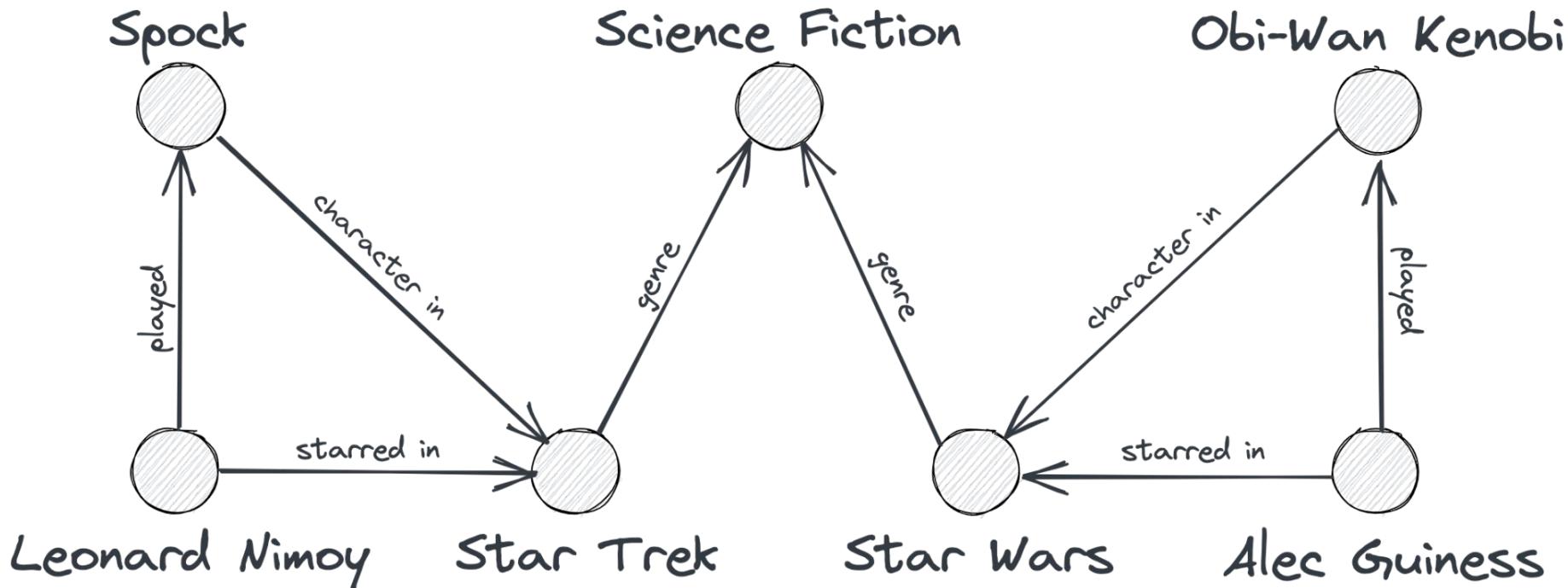


From Graphs ...

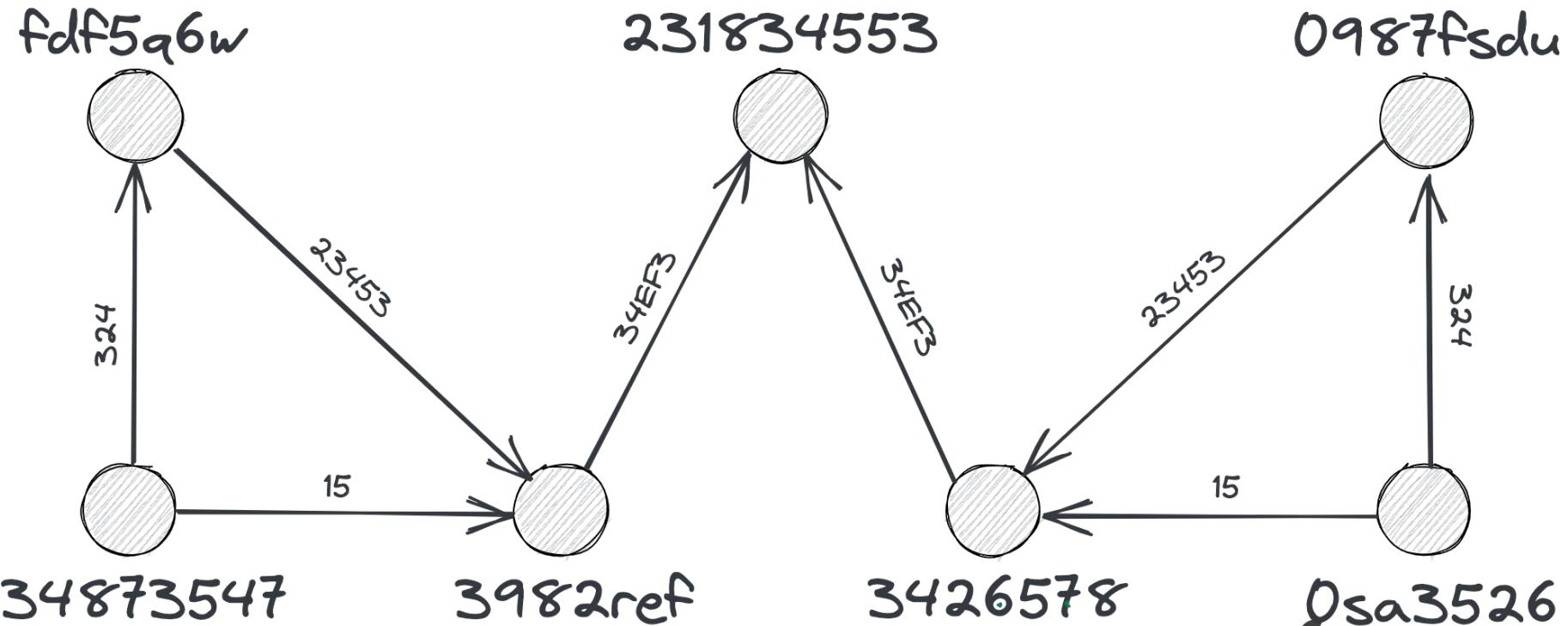


Keyword Co-Occurrence Network Graph of the COVID-19 literature, Mai 2021 [1]

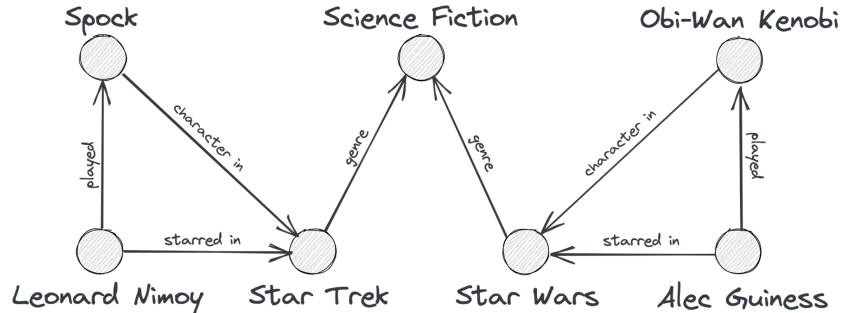
...to labelled Graphs



But what is the Meaning?



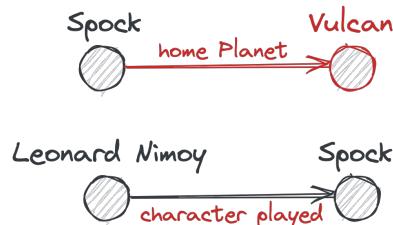
The Traditional Solution



- The **(human)** programmer reads (and understands) the labels
- The programmer encodes the meaning (as far as she understood it) into **software**
- Thereby the software can **interpret the data correctly**

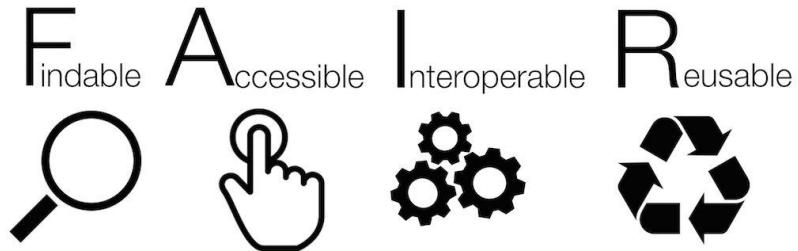
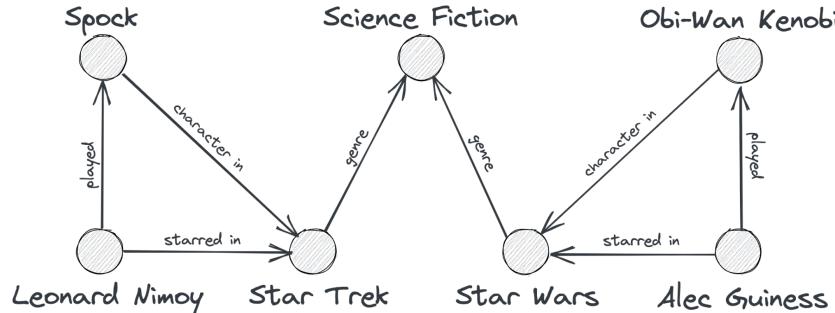
But beware: **πάντα ῥεῖ; "everything flows"** (Heraclitus, 6th century BCE)

- What if new labels are introduced?
- What if labels are changing?



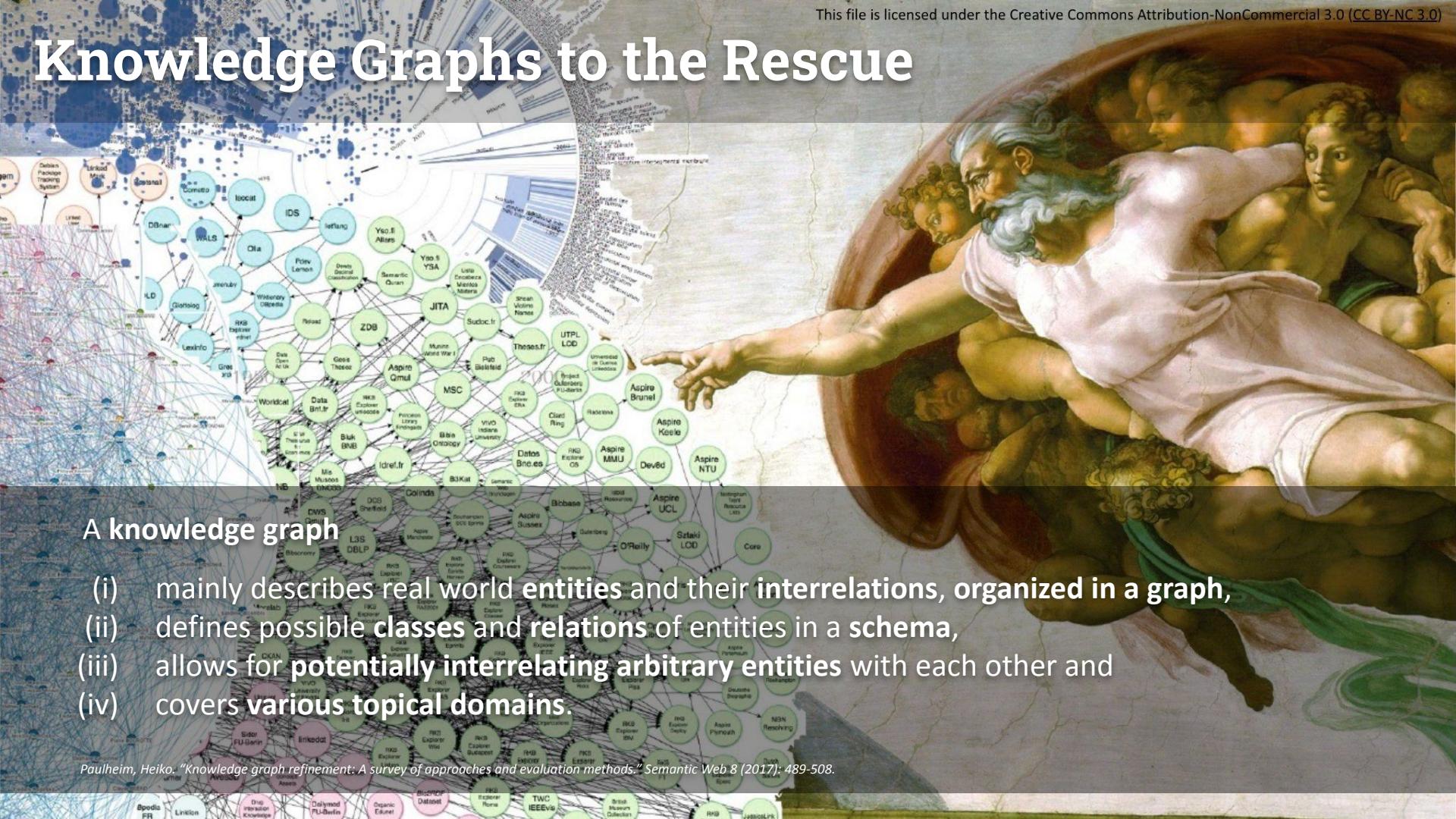
Data Interoperability and Reuse

The Traditional Solution...



- The Semantics is given **implicitly** encoded via **natural language**
- Prerequisites for **Interoperability**:
 - People are preparing natural language definitions for the used terms (**terminology/glossary**)
 - Everybody agrees to apply those terminologies/glossaries (**metadata standardization**)
 - Everybody **interprets** natural language **uniquely in the same way**

Knowledge Graphs to the Rescue

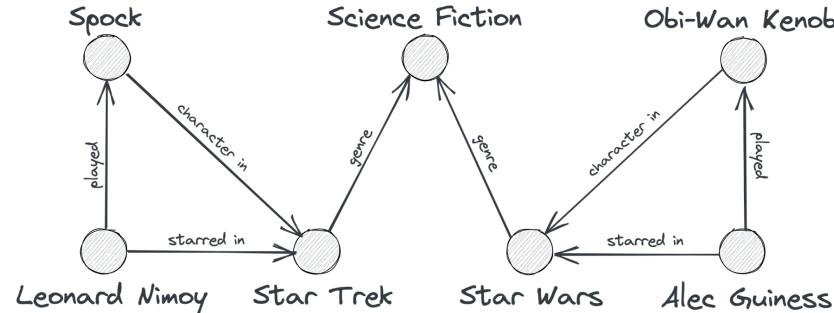


A knowledge graph

- (i) mainly describes real world **entities** and their **interrelations**, organized in a graph,
- (ii) defines possible **classes** and **relations** of entities in a **schema**,
- (iii) allows for potentially interrelating arbitrary **entities** with each other and
- (iv) covers various **topical domains**.

Paulheim, Heiko. "Knowledge graph refinement: A survey of approaches and evaluation methods." *Semantic Web* 8 (2017): 489-508.

Let's Create a Knowledge Graph

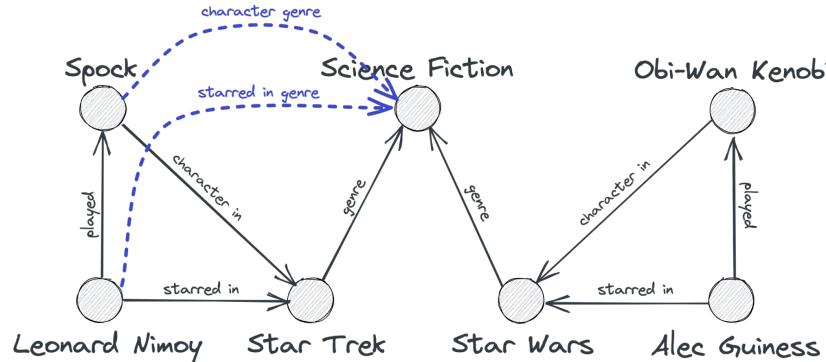


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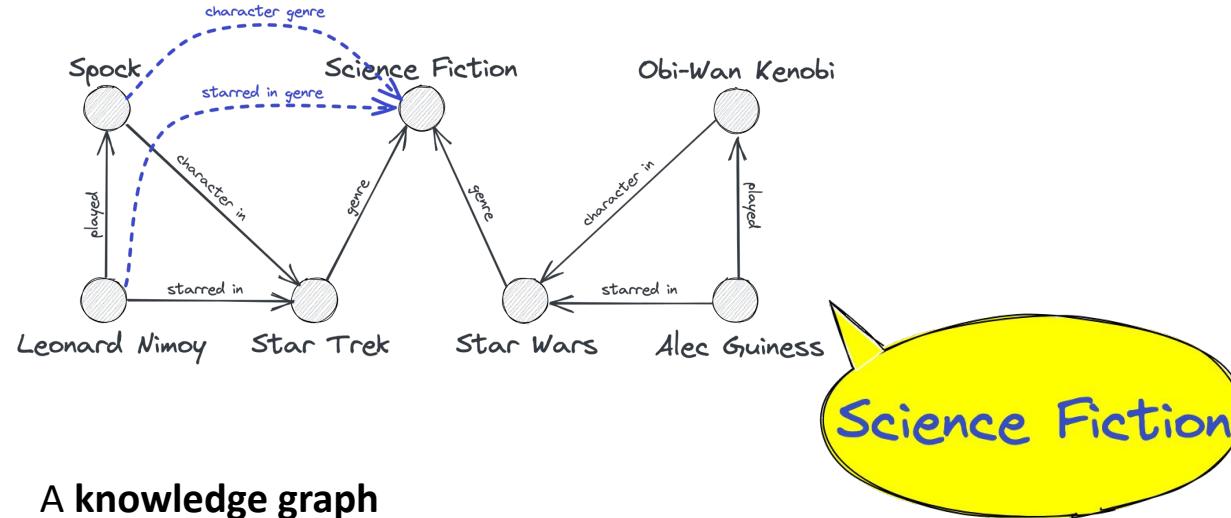


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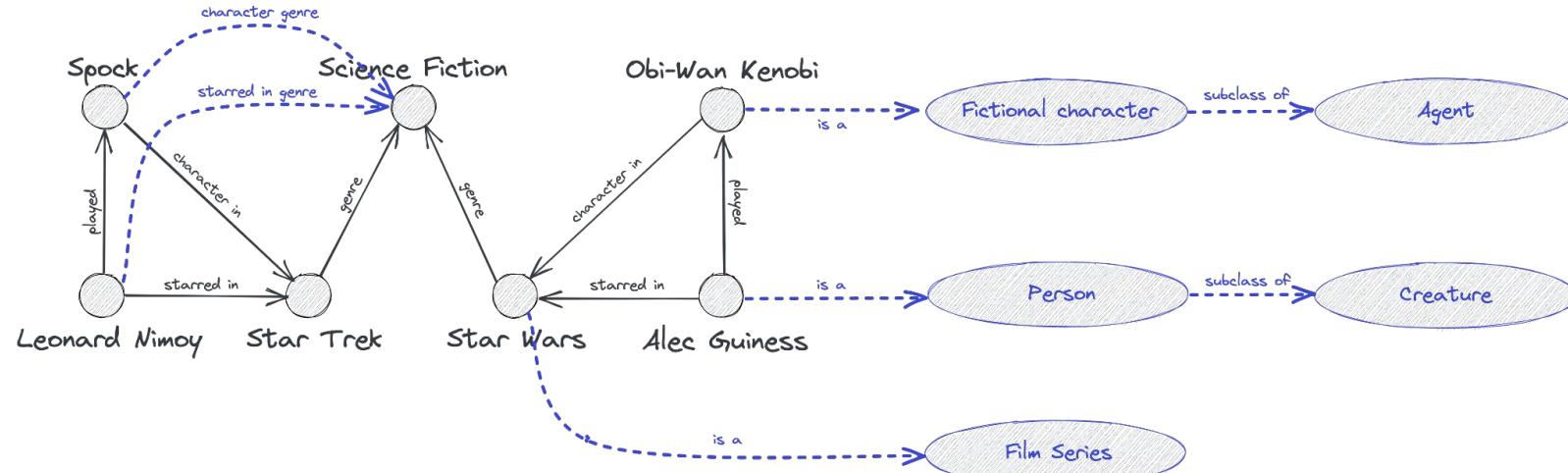


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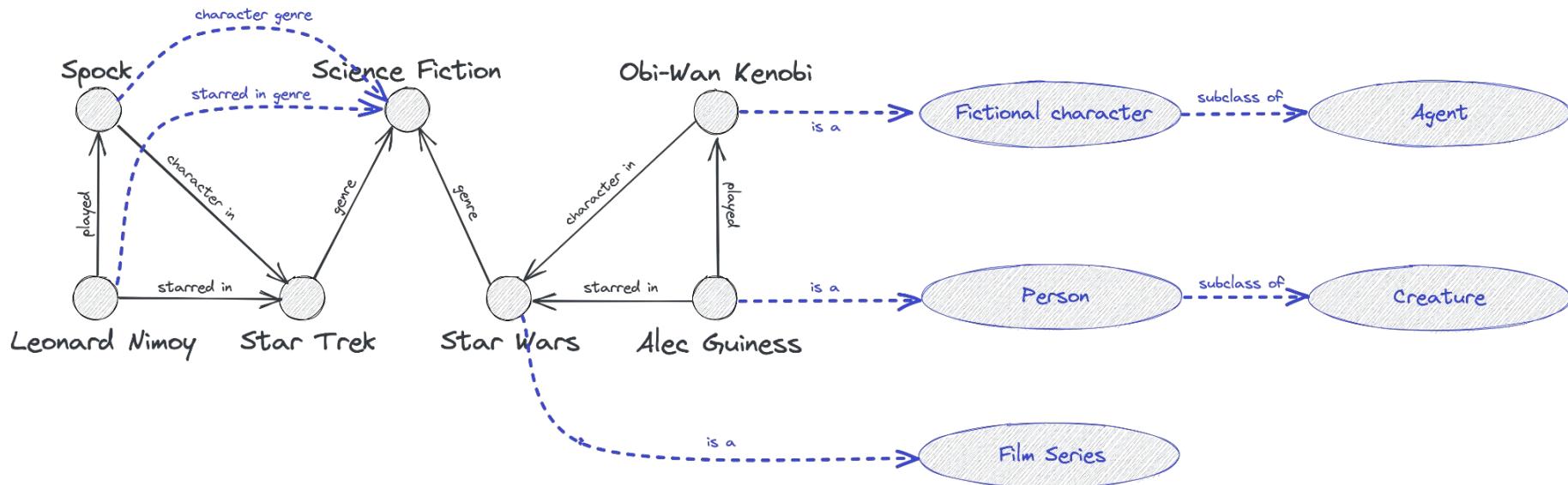


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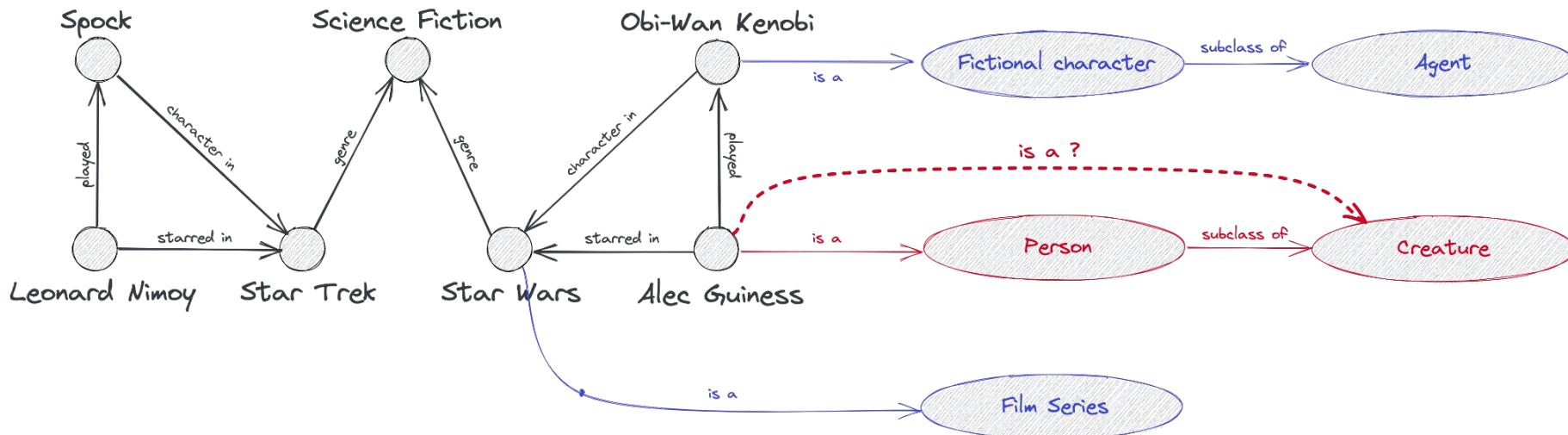
Is this already enough?



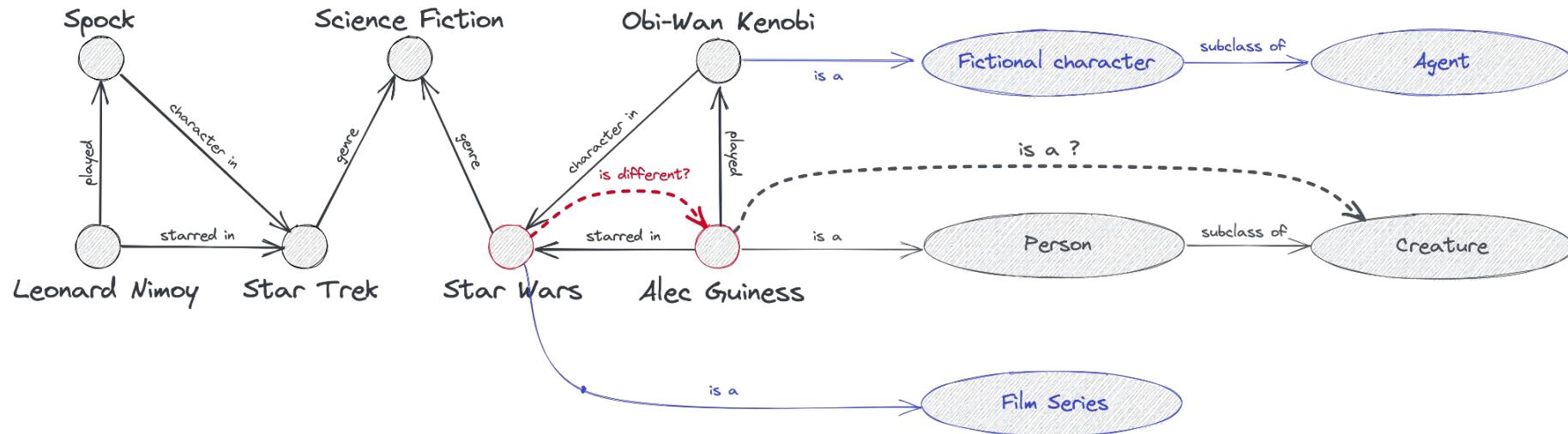
Can we deduce that Alec Guinness is also a Creature?

Can be solved via individual software code:

```
IF ((Alec Guinnes, is a, Person) AND (Person, subclass of, Creature))  
THEN  
    (Alec Guinnes, is a, Creature)
```



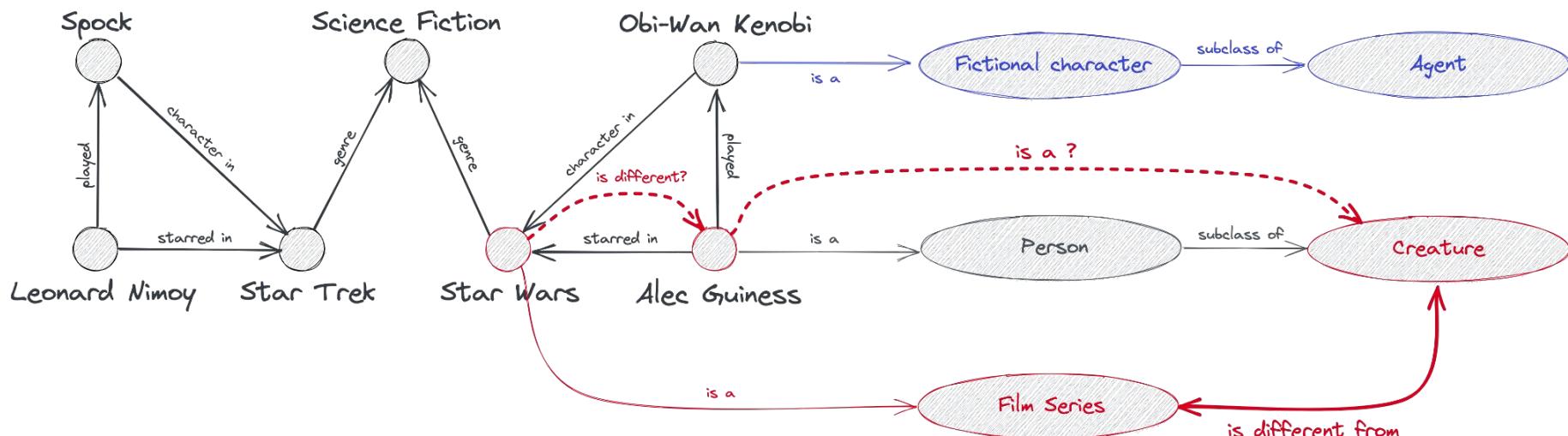
Is Alec Guinness different from Star Wars?



Is Alec Guinness different from Star Wars?

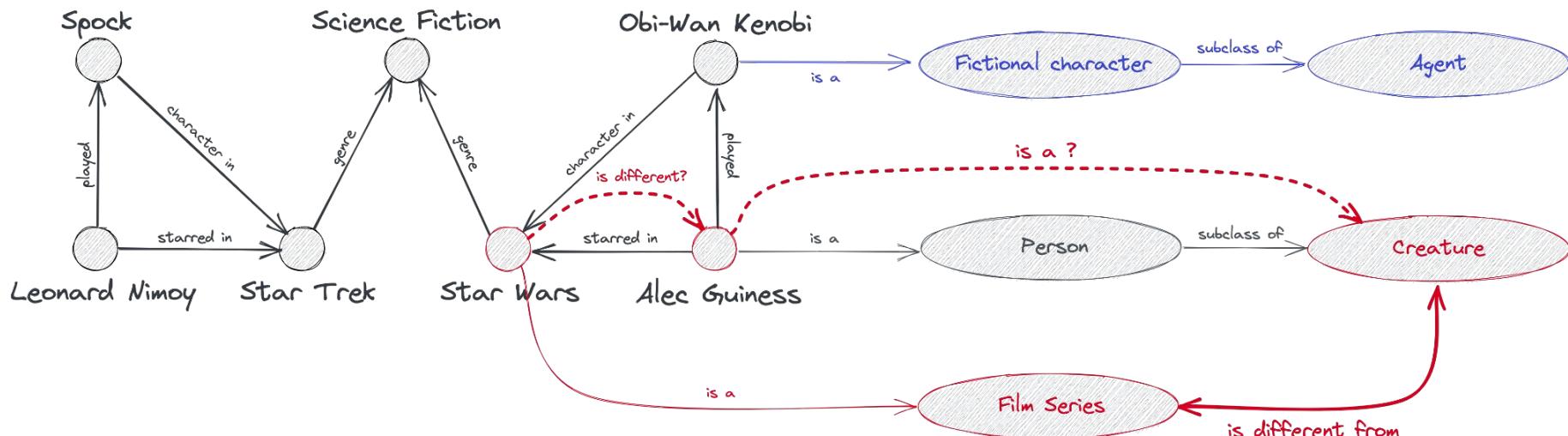
Can also be solved via individual software code:

```
IF ((Alec Guinness, is a, Person) AND (Person, subclass of, Creature))
  AND
  (Star Wars, is a, Film Series) AND (Film Series, is different from, Creature)
THEN
  (Star Wars, is different from, Alec Guinness)
```



Is Alec Guinness different from Star Wars?

Again: How do we (or the Computer) know the Meaning of the Labels?



A Step Back in Time...

Semantic Networks:

"A semantic network or net is a graph structure for representing knowledge in patterns of interconnected nodes and arcs. Computer implementations of semantic networks were first developed for artificial intelligence and machine translation, but earlier versions have long been used in philosophy, psychology, and linguistics."

– John Sowa, *Encyclopedia of Artificial Intelligence*, Wiley, 1987

A Step Back in Time...

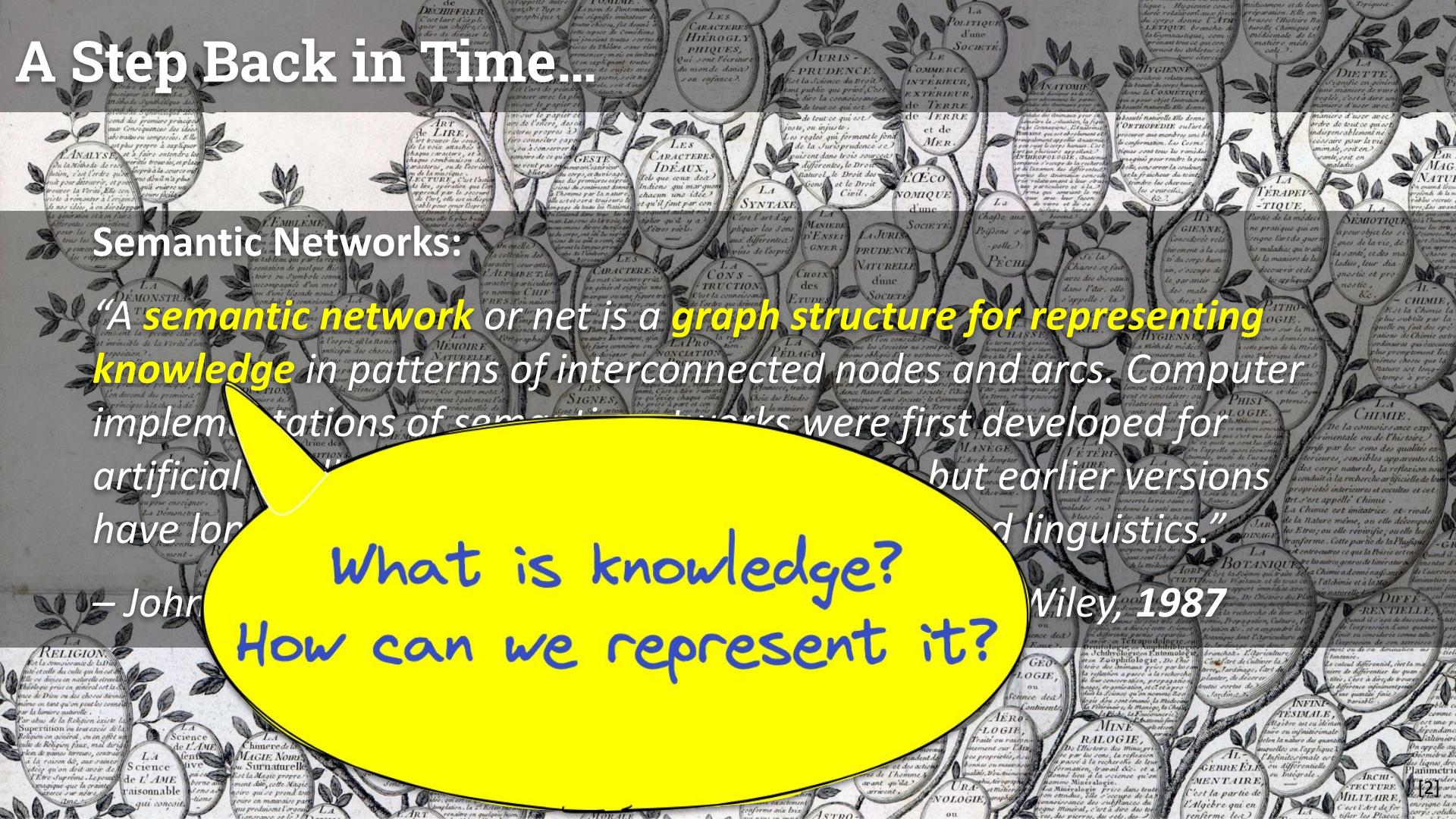
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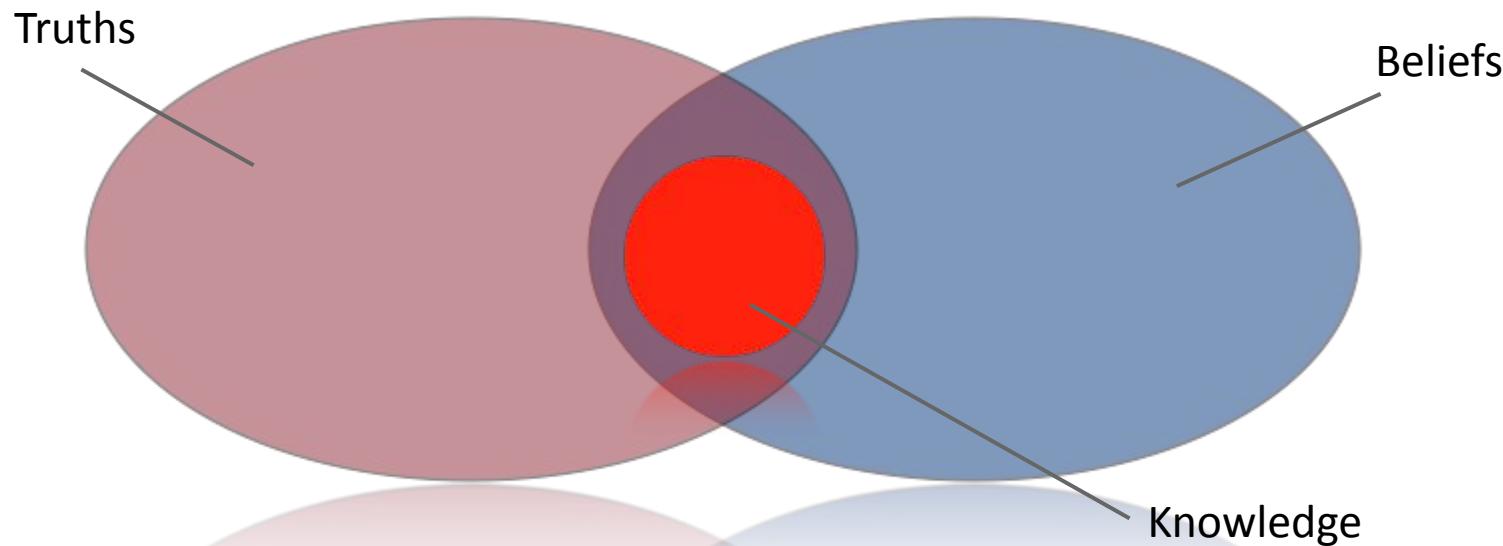
— John

What is knowledge?
How can we represent it?

Niley, 1987



What is Knowledge?



Traditional Definition: „Knowledge is a subset of all true beliefs“



„People can't share knowledge if they don't speak a common language“

Thomas Davenport (1997)

...to speak a common Language:

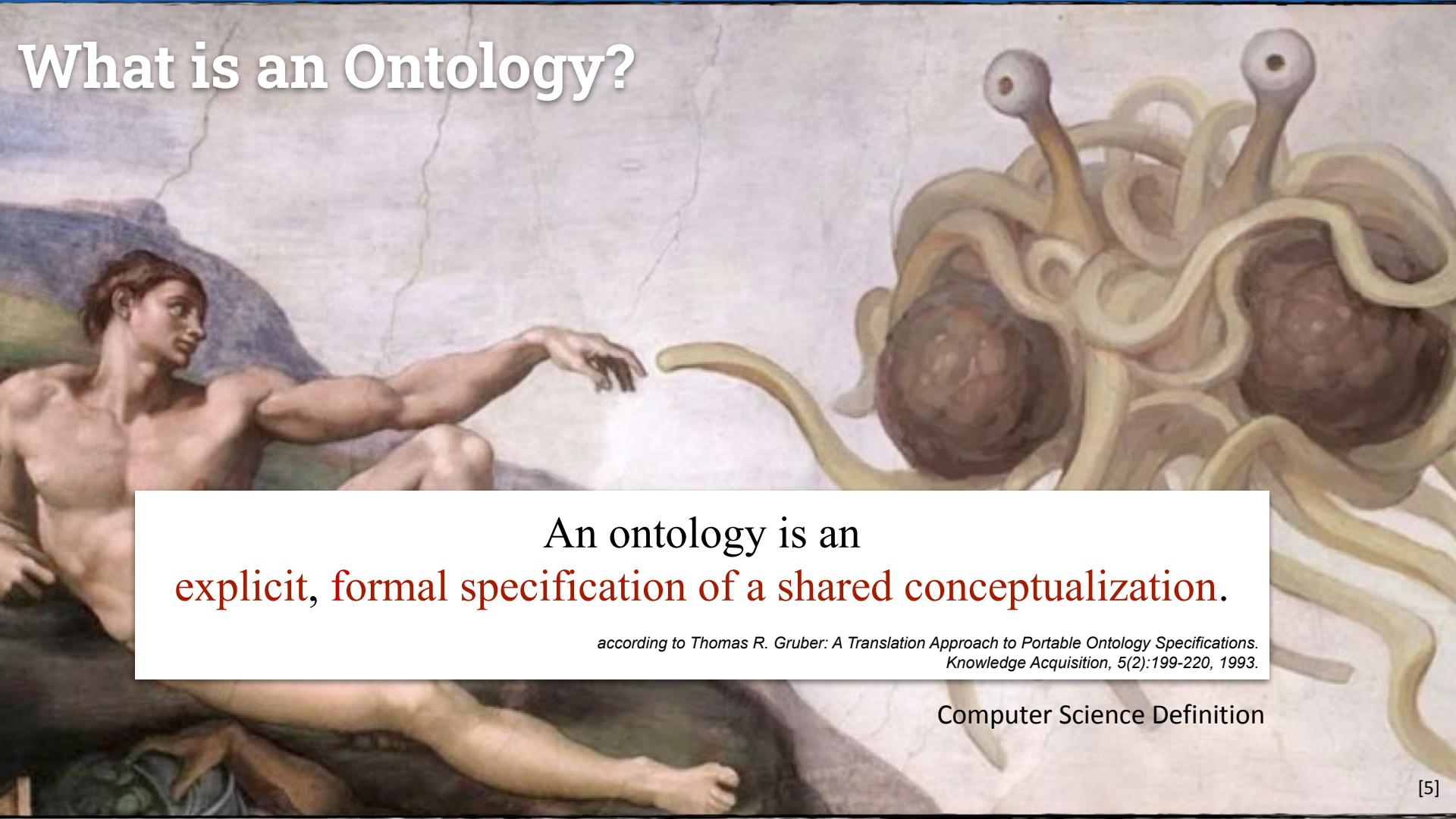
- common symbols and concepts (**Syntax**)
- agreement about their meaning (**Semantics**)
- classification of concepts (**Taxonomy**)
- associations and relations of concepts (**Thesauri**)
- rules and knowledge about which relations are allowed and make sense (**Ontologies**)

What is Ontology?

„A **theory of being**, which tries to **explain the being itself**, by developing a **system of universal categories** and their intrinsic **relationships...**“

Philosophy Definition

What is an Ontology?

A reproduction of Michelangelo's 'The Creation of Adam' fresco from the Sistine Chapel. It depicts the moment when Adam reaches out his hand towards the finger of the seated God. In the upper right corner, a large, multi-headed, tentacle-like creature with dark, bulbous eyes is depicted, partially obscuring the scene.

An ontology is an
explicit, formal specification of a shared conceptualization.

*according to Thomas R. Gruber: A Translation Approach to Portable Ontology Specifications.
Knowledge Acquisition, 5(2):199-220, 1993.*

Computer Science Definition

What is an Ontology?

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- | | |
|---------------------------|---|
| conceptualization: | abstract model (domain, identified relevant concepts, relations) |
| explicit: | meaning of all concepts must be defined |
| formal: | machine understandable |
| shared: | consensus about ontology |

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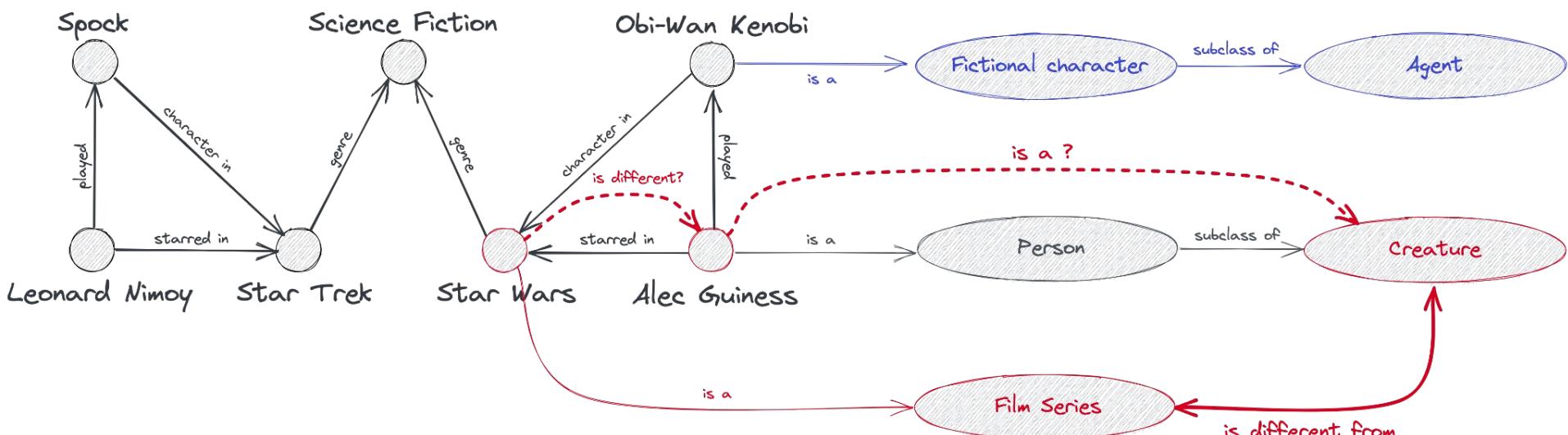
P A R E N T A L
A D V I S O R Y
E X P L I C I T S E M A N T I C S

Knowledge Representation with Ontologies and Knowledge Graphs

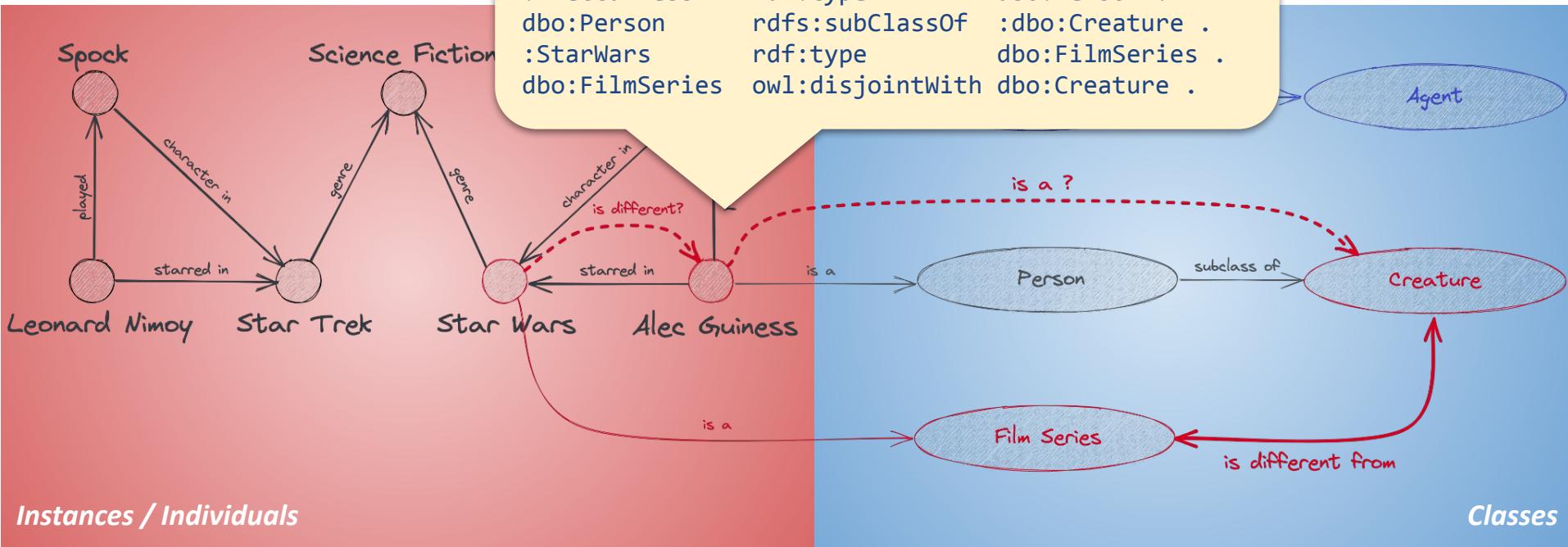
Description Logics

$\{ \begin{array}{l} \text{Person(AlecGuiness)} \\ \text{Person} \sqsubseteq \text{Creature} \end{array} \} \Rightarrow \text{Creature(AlecGuiness)}$

$\{ \begin{array}{l} \text{FilmSeries(StarWars)} \\ \text{FilmSeries} \sqcap \text{Creature} \equiv \emptyset \end{array} \} \Rightarrow \text{AlecGuiness} \neq \text{StarWars}$



Knowledge Representation with Ontologies and Knowledge Graphs



Assertional Knowledge

Terminological Knowledge

First Take Away

- Less software maintenance (regarding changes in the data structure)
- Less error prone
- Simpler data integration
- Simpler data reuse

<data>

- The **semantics** is in the **data**
- Written by **data provider**
- Depending on the original **understanding/interpretation of the data by its provider**

Knowledge Driven

- Extensive software maintenance necessary (for any data structure changes)
- Error prone (understanding / interpretation of the programmer)

<software>

- The **semantics** is in the **programme code**
- Written by **programmers**
- Depending on the **understanding/interpretation of the individual programmer**

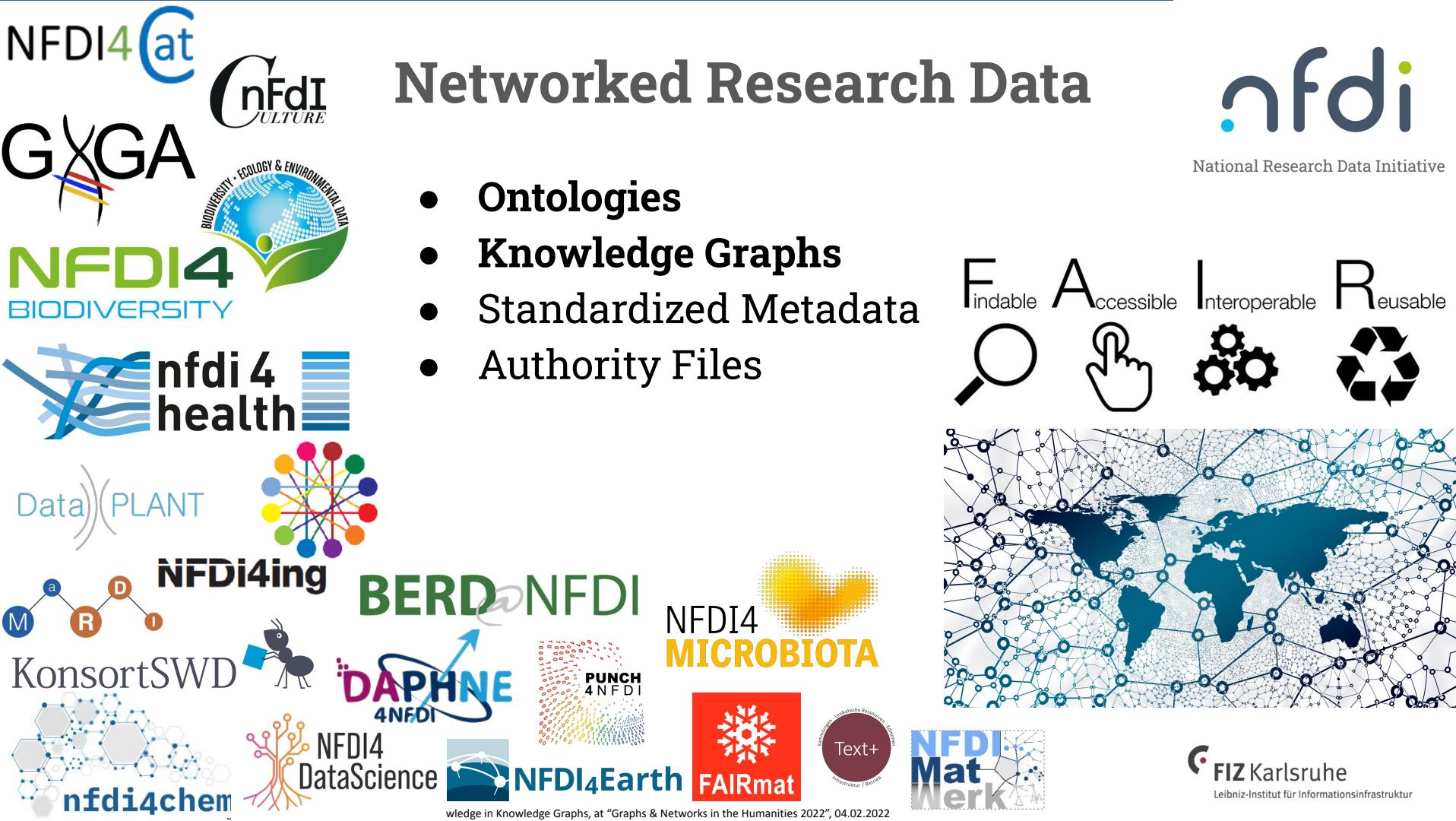
Traditional

Potential Benefits - or how shall we make use of it ?



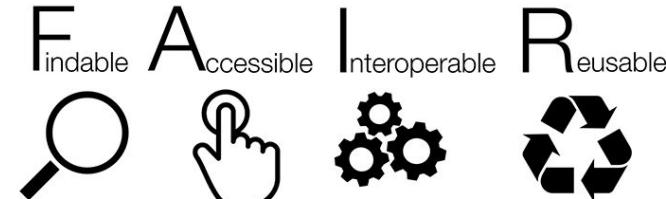


Data Integration



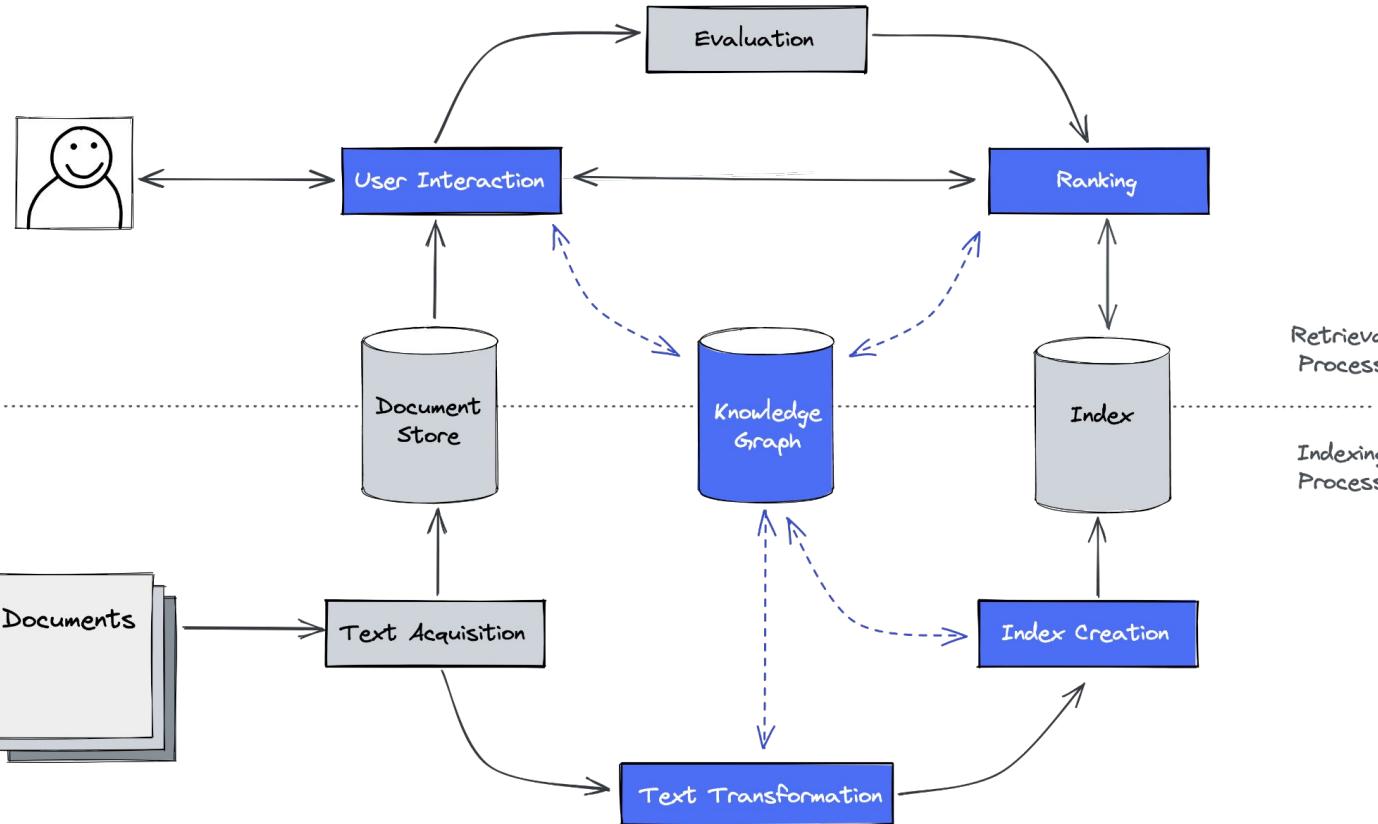
Networked Research Data

- **Ontologies**
- **Knowledge Graphs**
- Standardized Metadata
- Authority Files



Semantic Search & Retrieval

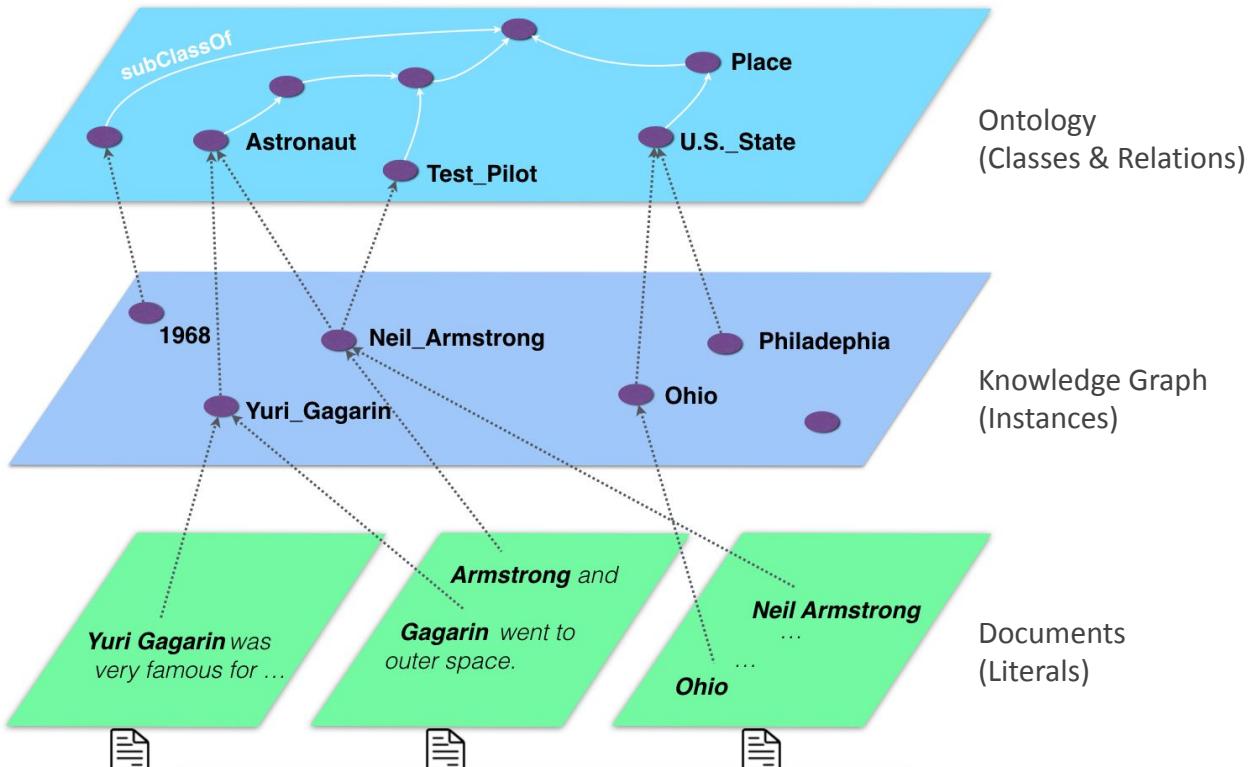
Things and not Strings



- **Knowledge Graph** as central element of search & retrieval
- KG guides **Index Creation** and **Usage, Ranking** and **User Interaction**
- Enables **Semantic** and **Exploratory** Search

Semantic Search & Retrieval

Things and not Strings



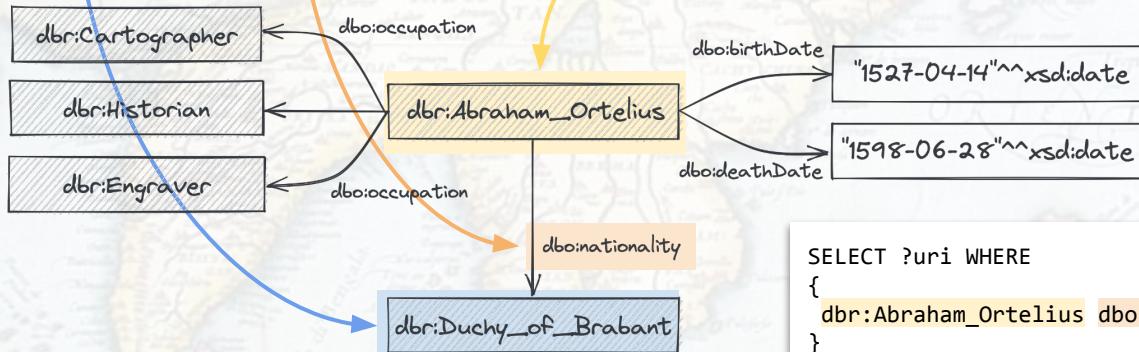
Semantic Search is about

- going **beyond** documents and queries as **bag of words**,
- having a **deeper understanding** of document contents by leveraging **world knowledge** as structured data,
- going **beyond 10 blue links** and providing users with **direct answers** to their (natural language) questions.

Question Answering over Knowledge Graphs

Factoid Questions

What was the nationality of Abraham Ortelius?



```
SELECT ?uri WHERE
{
    dbr:Abraham_Ortelius dbo:nationality ?uri.
}
```

which Popes were in office during the lifetime of Abraham Ortelius?

which Frisian colleague of Ortelius is considered one of the co-founders of cartography?

which colleague of Ortelius died of kidney stones?

which places in Antarctica or the Moon are named after pioneers in cartography?

...



Abraham Ortelius (1527 - 1598) [10]

Exploration & Recommendation

Find what you actually didn't look for in the first place - Serendipity

Surprise!

Exploratory Search:

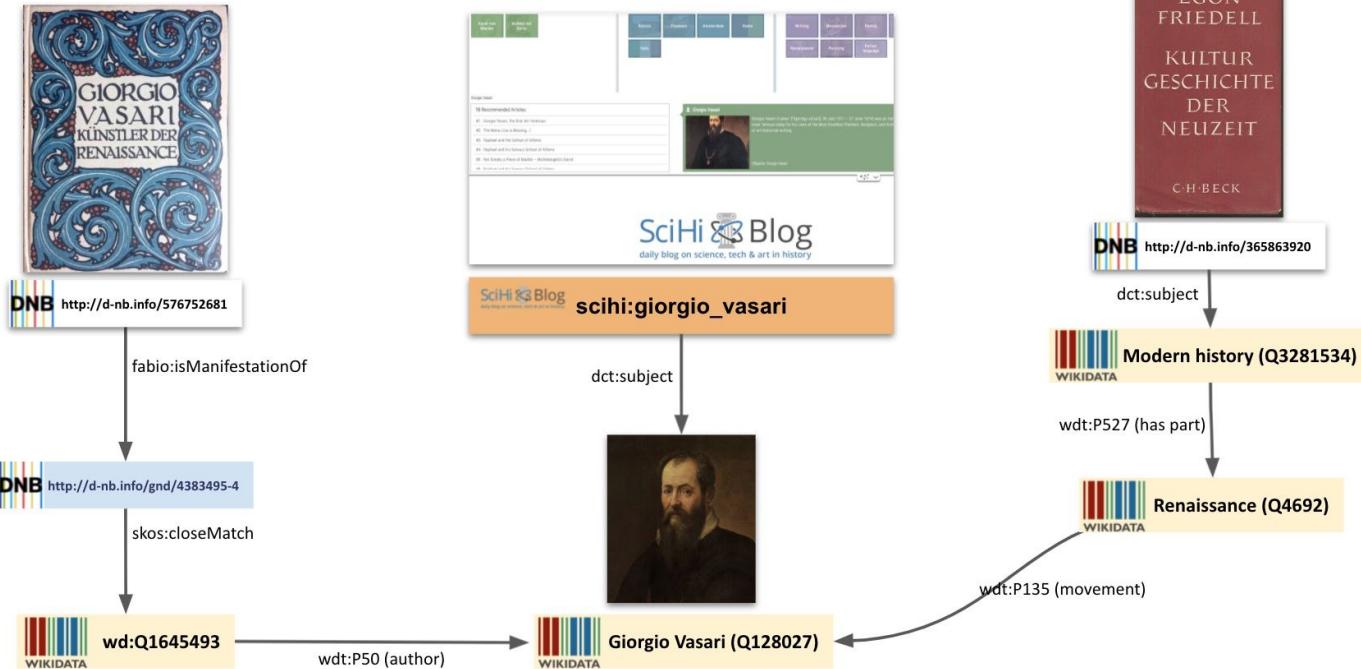
- Search in unknown terrain
- unclear search target
- complex information needs
- "Rummaging around" instead of targeted search



Exploration & Recommendation

Find what you actually didn't look for in the first place - Serendipitous Discoveries

- Serendipitous discoveries
- The “Google Effect”
or
...how to visualize it

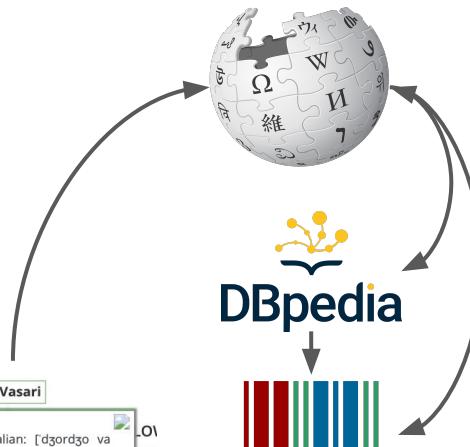


Exploration & Recommendation

Find what you actually didn't look for in the first place - Serendipitous Discoveries



e.g. via refer.cx WordPress Plugin at <http://scih.org/>



On July 30, 1511, Italian Renaissance painter, architect, writer and historian Giorgio Vasari was born. He is best known today for his *Lives of the Most Eminent Painters* considered the ideological foundation of art-historical writing.

One of the Lesser Known Renaissance Artists

From all the great Renaissance artist, Giorgio Vasari might be one of the less this might be that although an artist of considerable repute, there were so many Renaissance artists that Vasari's art didn't stand out among them. But, on the Vasari's major merits that we know about so many Renaissance artists a authored and published the very first collection of biographies of famous artist

Born in Arezzo

Vasari was born in Arezzo, Tuscany. Recommended at an early age by his cousin Luca Signorelli, he became a pupil of Guglielmo da Marsiglia, a skillful painter of stained glass. Sent to Florence at the age

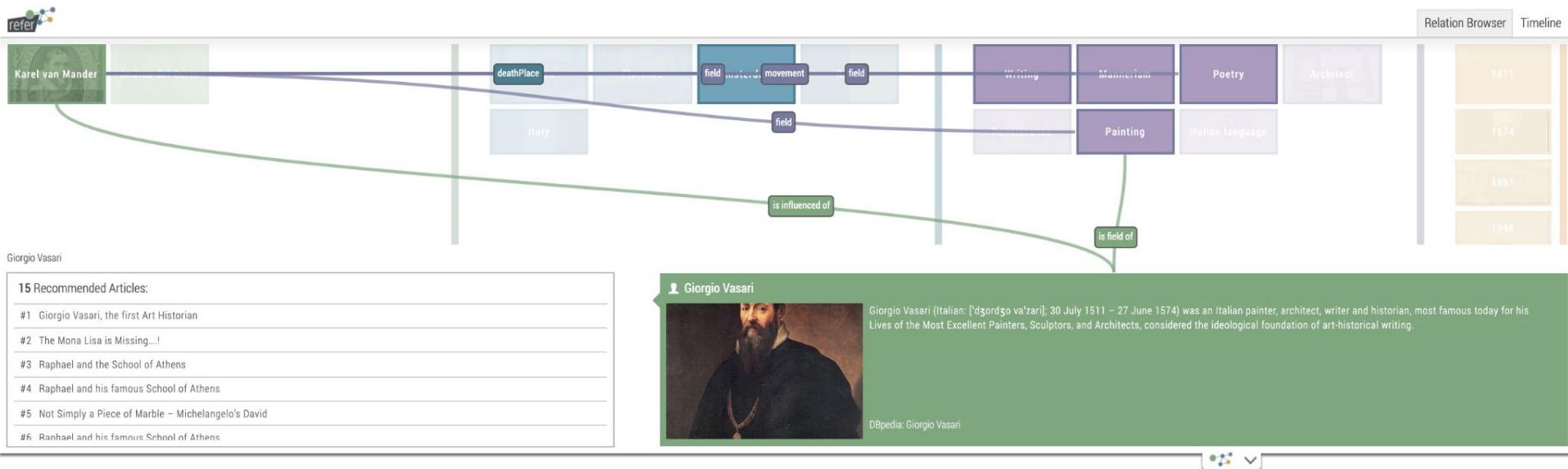
Networks in the Humanities 2022", 04.02.2022

Prerequisites for Exploratory Search:

- Semantic Annotation
- “Appropriate” Visualization & User Interface

Exploration & Recommendation

Find what you actually didn't look for in the first place - Serendipitous Discoveries



- e.g. via refer.cx WordPress Plugin at <http://scihi.org/>

Explainable AI

Why did my Experiment/Simulation/Prediction return this result?



- **Justification** of experimental Results
- Checking for **Plausibility** of experimental Results
- Checking for **Flaws** in your experimental Setup
- Checking for **Flaws** in the **Representation** of your Experiment
- Explain your **Predictions**

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MATERIALDIGITAL

The Material Digitalization Platform

<https://www.materialdigital.de/>

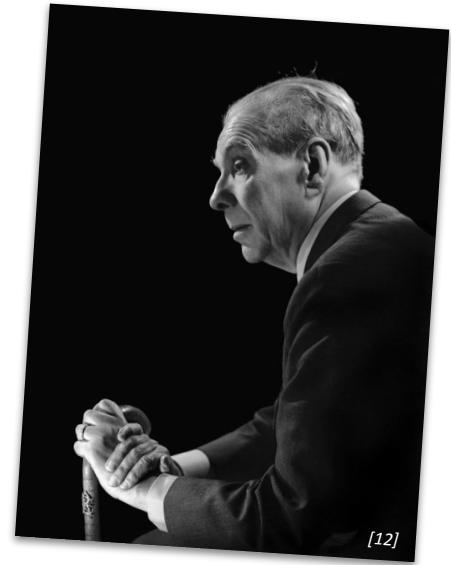
Potential Pitfalls - and how to avoid them...



Ontologies as Interpretations of Reality

Various categories of animals from "a certain Chinese encyclopedia"
according to Jorge Luis Borges:

- Those that belong to the emperor
- Embalmed ones
- Those that are trained
- Suckling pigs
- Mermaids (or Sirens)
- Fabulous ones
- Stray dogs
- Those that are included in this classification
- Those that tremble as if they were mad
- Innumerable ones
- Those drawn with a very fine camel hair brush
- Et cetera
- Those that have just broken the flower vase
- Those that, at a distance, resemble flies



Jorge Luis Borges
(1899-1986)

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*according to Thomas R. Gruber: A Translation Approach to Portable Ontology Specifications.
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The Wikidata/Wikibase Case

Not all Knowledge Graphs are created equal...

Item [Discussion](#)

Semantic Web (Q54837)

extension of the Web to facilitate data exchange

[Sem Web](#) | [SemWeb](#)

▼ In more languages [Configure](#)

| Language | Label | Description | Also known as |
|----------|------------------|---|---------------------------------|
| English | Semantic Web | extension of the Web to facilitate data exchange | Sem Web SemWeb |
| German | Semantic Web | formales Modell von Begriffen und ihren Beziehungen | Semantisches Web Wissensnetz |
| French | Web sémantique | réseau de concepts interdépendants, où les dépendances sont classifiées en types distincts avec des interprétations spécifiques | Web des données |
| Bavarian | No label defined | No description defined | |

[All entered languages](#)

Statements

instance of [information system](#)

▼ 0 references

subclass of [World Wide Web](#)

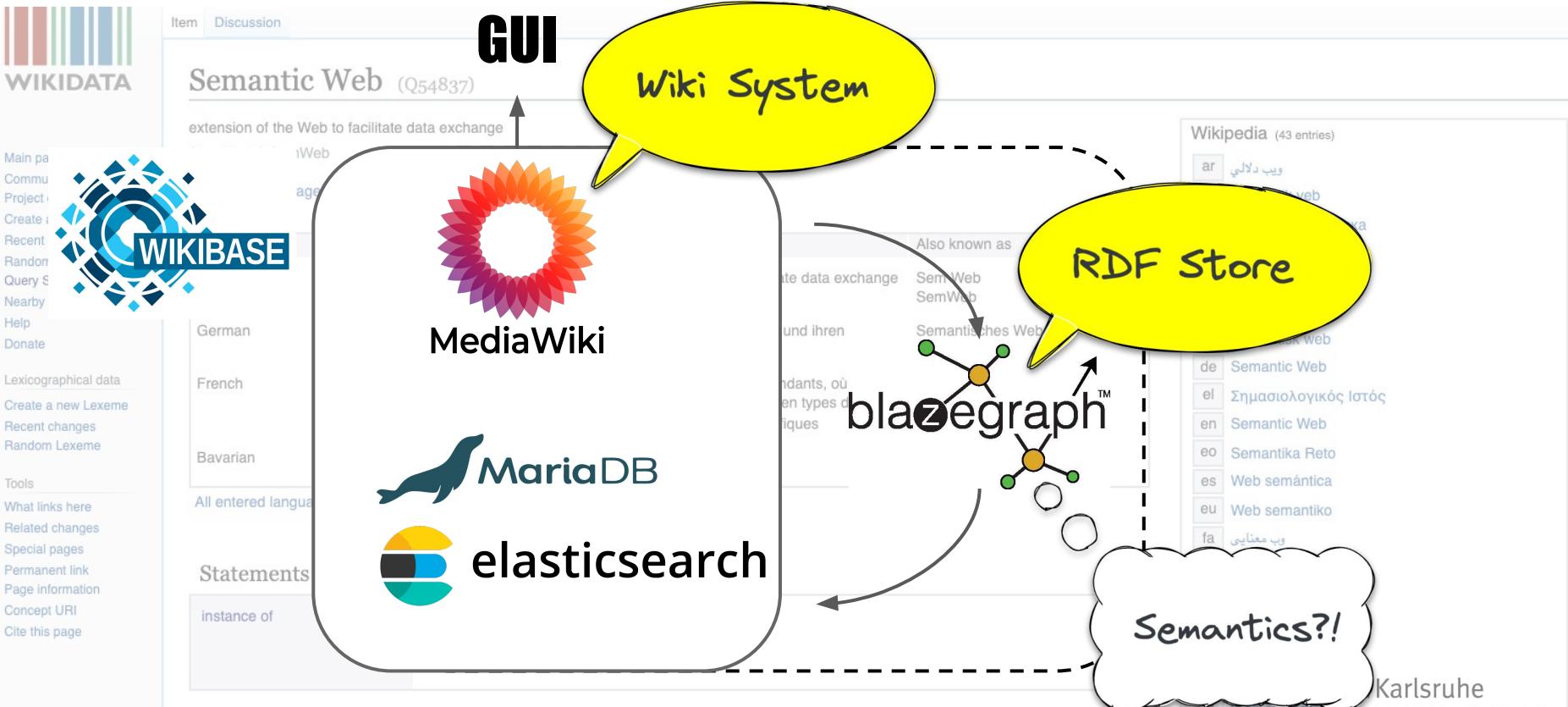
It's a Wiki!

(53 entries)

| | |
|----|----------------------|
| ar | ويب دلائي |
| az | Semantik veb |
| bg | Семантична мрежа |
| bn | সেমাটিক ওয়েব |
| ca | Web semàntic |
| cs | Sémantický web |
| da | Semantisk web |
| de | Semantic Web |
| el | Σημασιολογικός Ιστός |
| en | Semantic Web |
| eo | Semantika Reto |
| es | Web semántica |
| eu | Web semantiko |
| fa | وب معنایی |
| fi | Semantinen Web |
| fr | Web sémantique |
| gl | Web semántica |
| he | רשת סטננטית |
| hu | Szemantikus web |
| id | Web semantik |
| is | Merkingarvefur |

The Wikidata/Wikibase Case

Not all Knowledge Graphs are created equal...



The Wikidata/Wikibase Case

Not all Knowledge Graphs are created equal...



Item Discussion

- Wikibase is originally a **Wiki only** and **no native RDF triple store**
- Data is only **relational data** (MariaDB/mysql)
- Triple Store (blazegraph) is **only an addOn**
- Attached Triple Store only contains "**flat**" triples without explicit semantics
 - **No use of standard W3C Semantic Web vocabularies (RDF, RDFS, OWL)**
- **No transparent synchronous bidirectional interaction** between Wikibase and blazegraph

Also known as
exchange
n
iù les
distincts

Sem Web
SemWeb
Semantisches Web
Wissensnetz

**No formal
Semantics!**

| Wikipedia (43 entries) | |
|------------------------|----------------------|
| ar | ويب دلالي |
| az | Semantik veb |
| bg | Семантична мрежа |
| bn | সেমাটিক ওয়েব |
| ca | Web semàntic |
| cs | Sémantický web |
| da | Semantisk web |
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| el | Σημασιολογικός ιστός |
| en | Semantic Web |
| eo | Semantika Reto |
| es | Web semántica |
| eu | Web semantiko |
| fa | وب معنایی |
| fi | Semantilinen Web |
| fr | Web sémantique |
| gl | Web semántica |
| he | רשת סטטוטית |
| hu | Szemantikus |
| id | Web semantik |
| is | Merkingarvefur |

The Complexity Trap

Perfect, but unusable Knowledge Graphs...



- Semantic Expressivity vs. Computational Complexity
- Limited Scalability

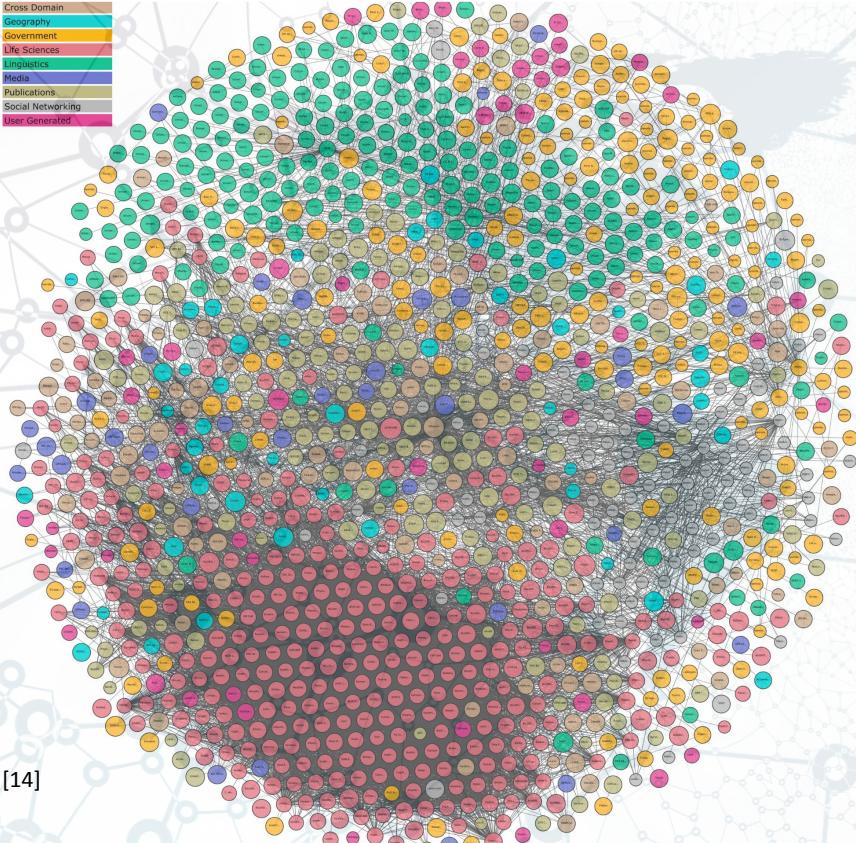
The Complexity Trap

...how it can be (potentially) avoided

Ontology & Knowledge Graph Design Pragmatics:

- What is the **intended Use Case** of your ontology?
- Properly phrase your **Requirements**
- Represent **only what you really need**
- **Nobody** really needs a **Swiss Army Knife** ontology
- Don't underestimate **Query Efficiency**

A Little Semantics has gone a Long Way



The Linked Open Data Cloud

- is a huge distributed network of knowledge graphs
- it currently contains 1561 knowledge graphs with 16283 interlinks (as of February 2022)

But there is much more semantic data on the Web:

- JSON-LD usage from **Web Commons Crawl** (Oct 2021):
 - 8,342,031 Web Sites
 - 793,347,572 URLs
 - 7,952,535,579 Entities
 - 37,872,880,504 Triples

<http://webdatacommons.org/structureddata/2021-12/stats/stats.html>



Take Home Messages:

- Not all Knowledge Graphs are created equal.
- Ontologies are **Formal Knowledge Representations**
- **Knowledge can be represented in different ways**
- Ontologies and Knowledge Graphs enable
 - **Interoperability**
 - **Semantic & Exploratory Search**
 - **Explainable AI**

Prof. Dr. Harald Sack

"With Knowledge Doubt Increases"-

The Significance of Knowledge in Knowledge Graphs

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twitter: [lysander07](#)

Graphs & Networks in the Humanities 2022

04.02.2022

Image References:

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