(Geo)Knowledge Graphs for Semantic Annotation of Spatial Phenomena

Johannes Scholz

TU Graz, Institute of Geodesy
Research Group Geoinformation

johannes.scholz@tugraz.at
ifg.tugraz.at || www.johannesscholz.net
@Joe_GISc

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The data deluge

Miller, H. J., & Goodchild, M. F. (2015). Data-driven Geography. *GeoJournal*, *80*(4), 449-461.

Introduction | Datafication

FOURSQUARE

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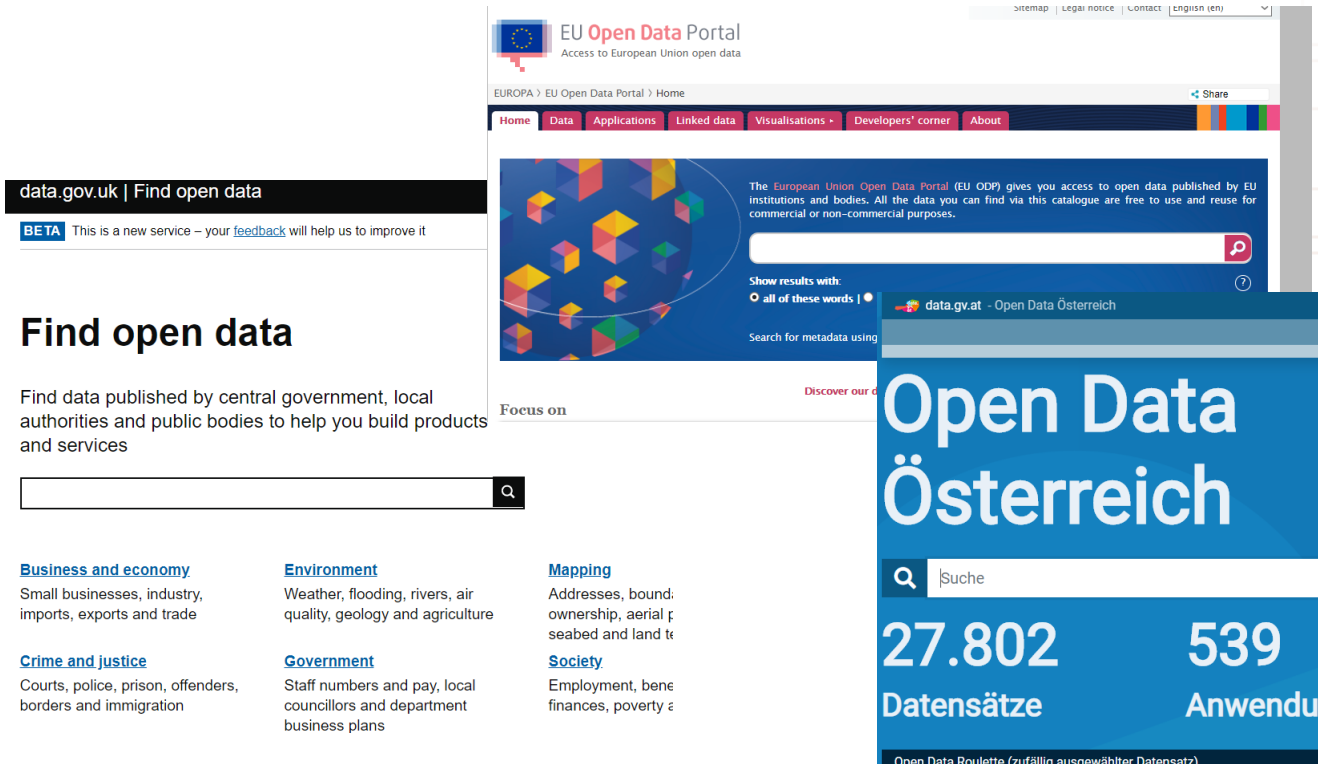


Geospatial Artificial Intelligence

*"**Geospatial Artificial Intelligence (GeoAI)** as a subfield of **spatial data science** utilizes advancements in techniques and data cultures to support the creation of more intelligent geographic information as well as methods, systems, and services for a variety of downstream tasks.*

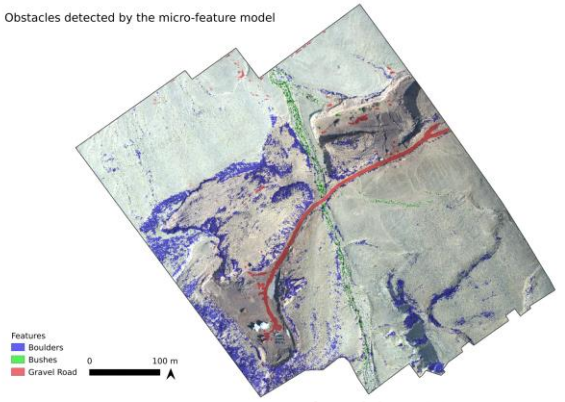
*These include **image classification**, **object detection**, **scene segmentation**, **simulation** and **interpolation**, **link prediction**, (natural language based) retrieval and **question answering**, **on-the-fly data integration**, **geo-enrichment**, and many others."*

(Janowicz et al. 2019)

GeoAI

- **Location is a key**
  - to integrate and synthesize multi-source data layers,
  - geographic domain knowledge
  - and spatial concepts contribute to the development of different contextual spaces (i.e., mobility space and social space).

- **Spatially explicit models incorporating spatial contexts** (Yan, et al. 2018) can **outperform traditional nonspatial machine learning** models in many tasks:
  - image classification,
  - geographic knowledge graph summarization (Yan, et al. 2019),
  - and geographic question-answering problems (Mai,et al. 2019).



Linked Data & Knowledge Graphs

Linked Data describes a methodology of publishing **structured data** so that data from different sources can be **interlinked with typed links.**

- published in a **machine-readable form**
- published in a way that their **meaning is explicitly defined**
- linked to other data sets
- data that **can be linked from other data sets**

Paving the way from a *document oriented* Web to a *data driven* Web

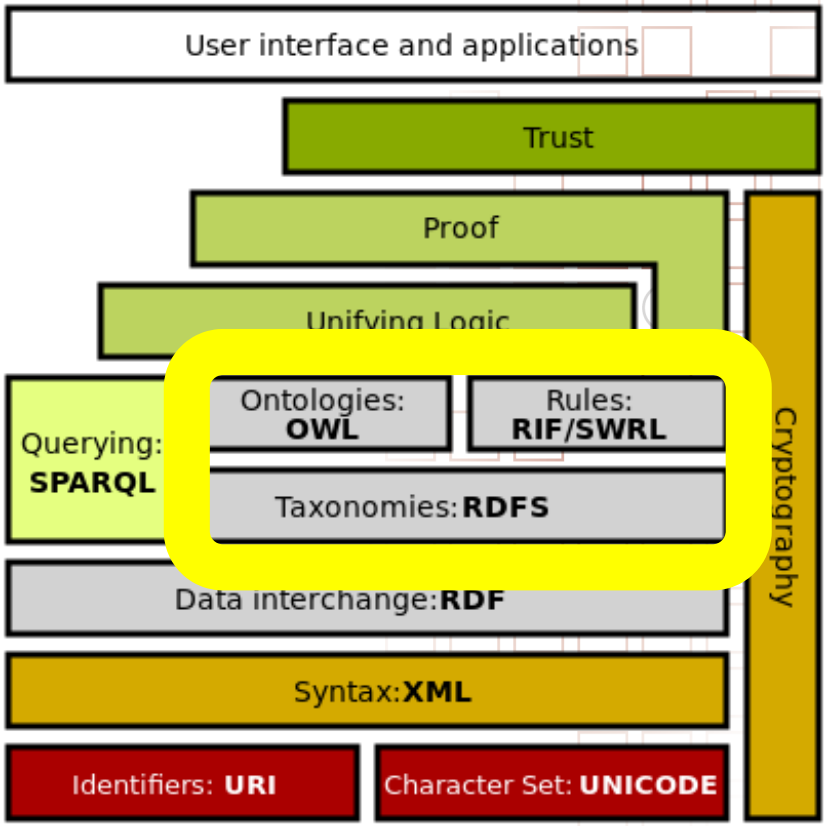
>> Web of Data <<

Linked Data & Knowledge Graphs

- Information seeking by allowing exploration, editing and interlinking of heterogeneous information sources with a spatial dimension (Janowicz et al. 2013; Egenhofer 2002).

- Combining Linked Data and Geoinformation can lead to a geospatially enriched Semantic Web
  - Geographic information can easily be integrated and processed.
  - But: requires semantics (Ontologies, Taxonomies)

- A number of Linked Data repositories with spatial data already available!



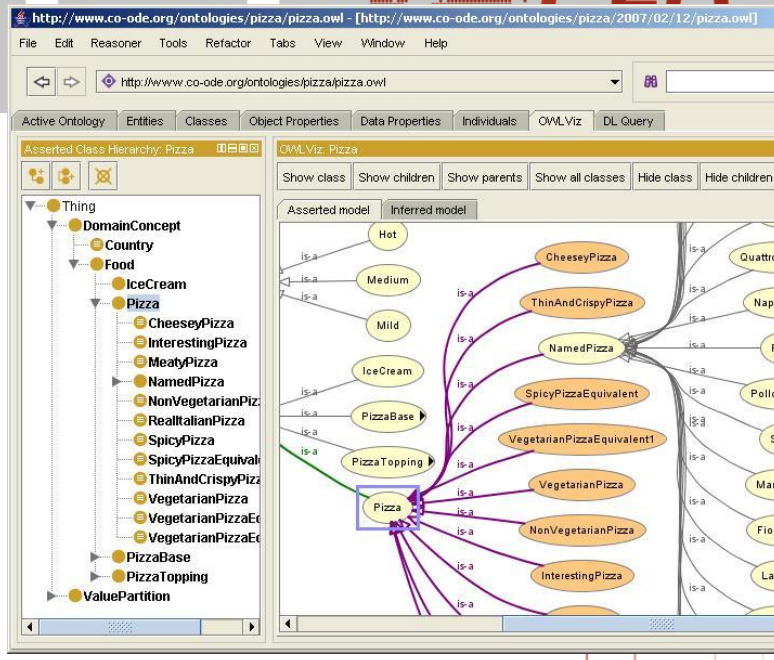
Knowledge Graphs & Ontologies

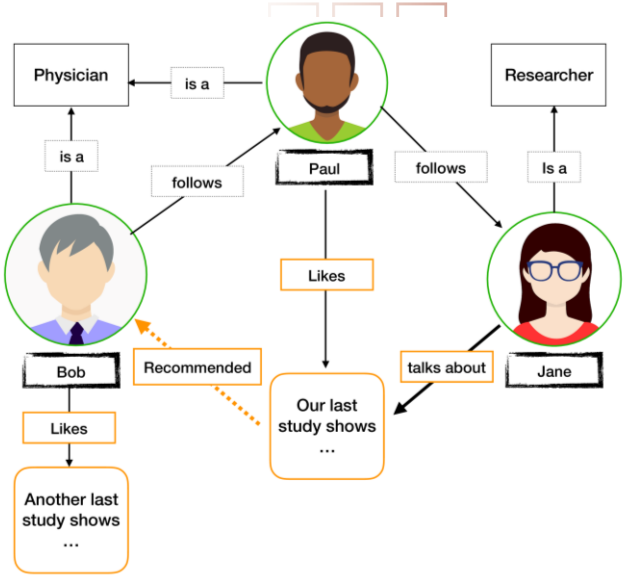
- Ontology:
  - Formal, explicit specification of a shared conceptualization (Gruber, 1993)
  - Description of the concepts and their relations existing in a Universe of Discourse (Uschold & Gruninger, 1996)

- Knowledge Graphs

  "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, 2017)

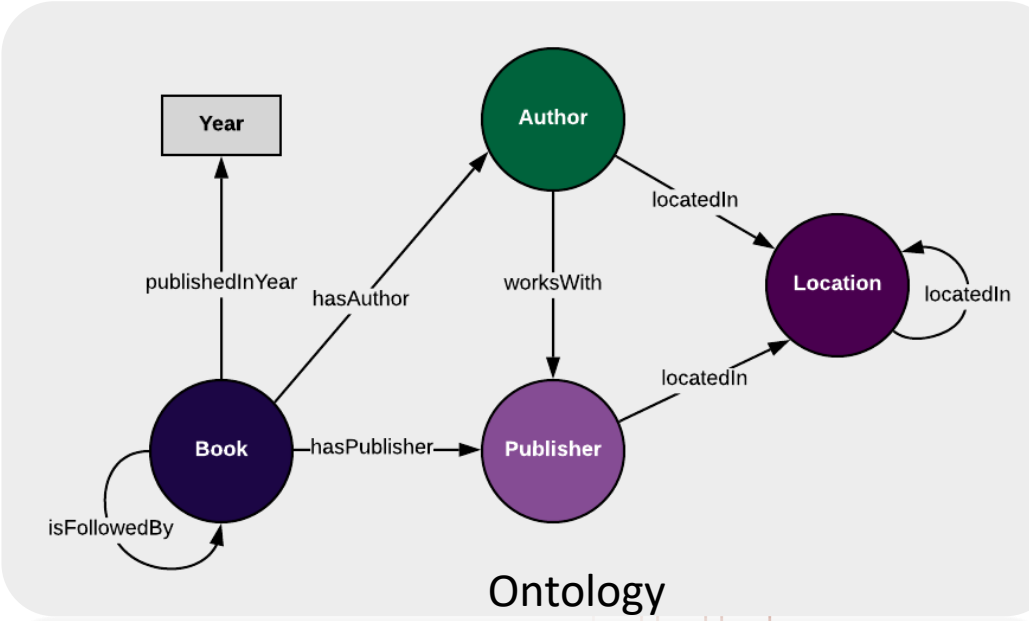




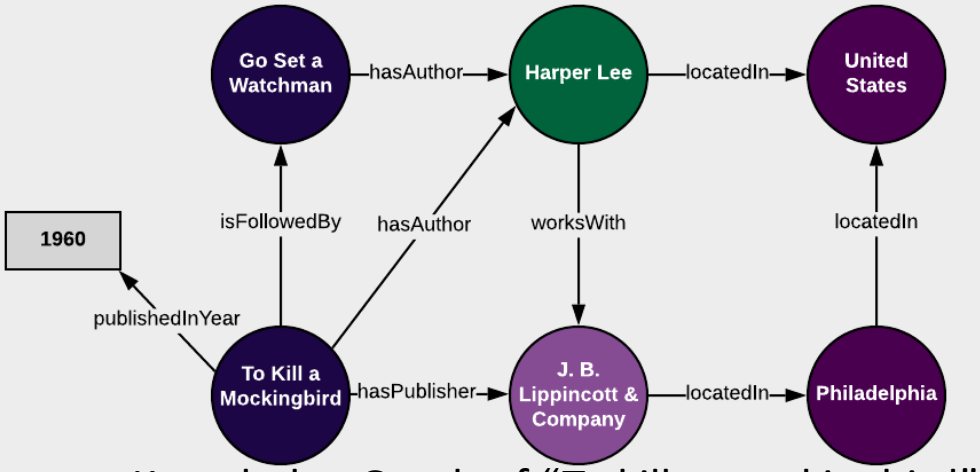
Knowledge Graphs & Ontologies

- Ontologies are used for
  - Definitions of shared vocabularies **(>> Interoperability)**
  - Actionable knowledge fragments **(>> inferencing [i.e. creating new knowledge])**

- Knowledge Graphs:
  - All “features” of ontologies
  - Create specific instances of each of the relationships



Ontology



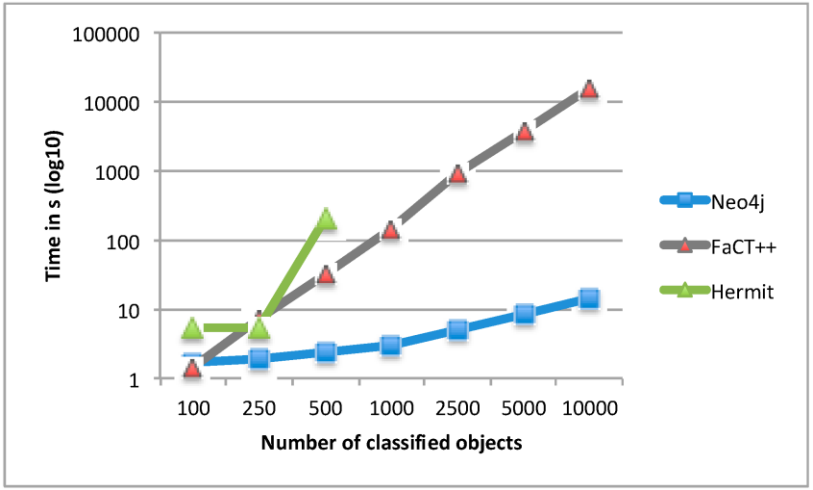
Knowledge Graph of “To kill a mockingbird”

(Geo)Knowledge Graphs

- Basic “equation”:

Ontology + (Geo)Data = (Geo)Knowledge Graph

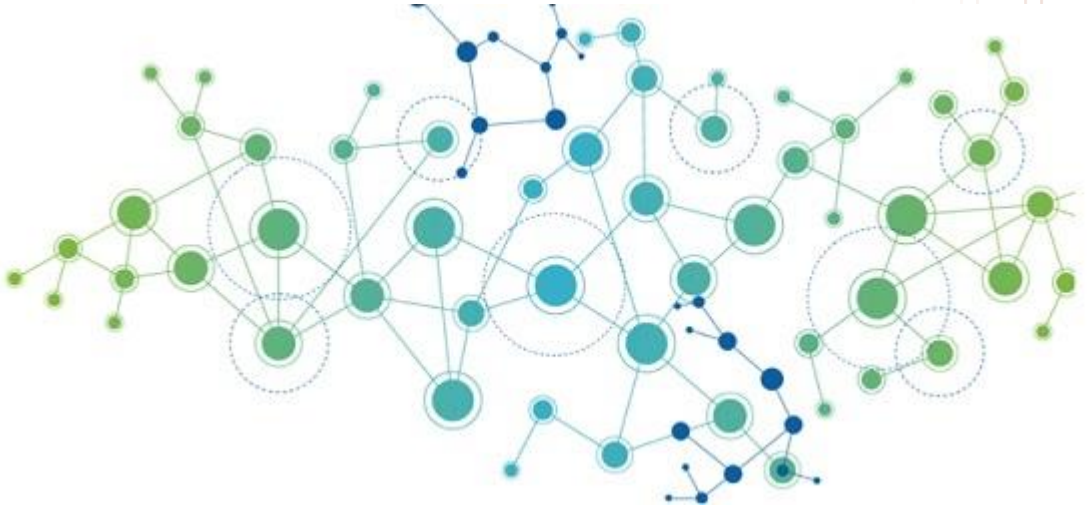
- Graphs are an **efficient data structure** in terms of storage and analysis
- Graphs are supported by **Semantic Web approaches** and contemporary **NoSQL databases**
- In comparison to OWL-Ontologies and Reasoners the **reasoning speed is significantly higher** (see Lampoltshammer & Wiegand 2015)



Classification speed of EO data (Lampoltshammer & Wiegand 2015)

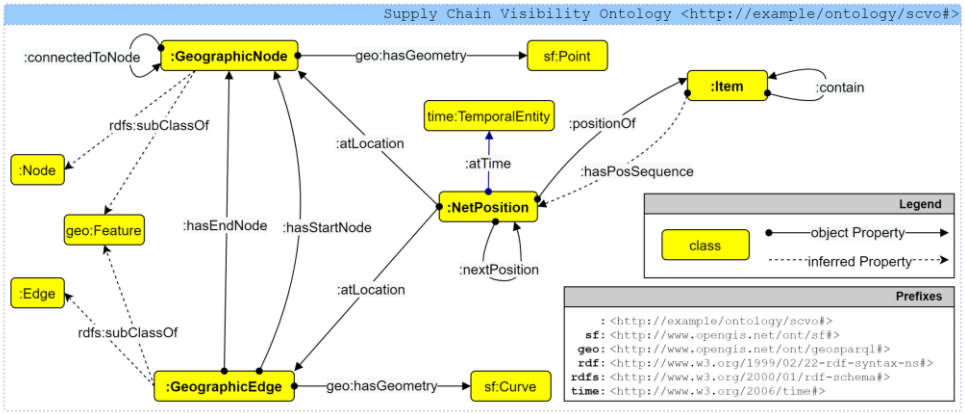
GeoKGs and Standardization

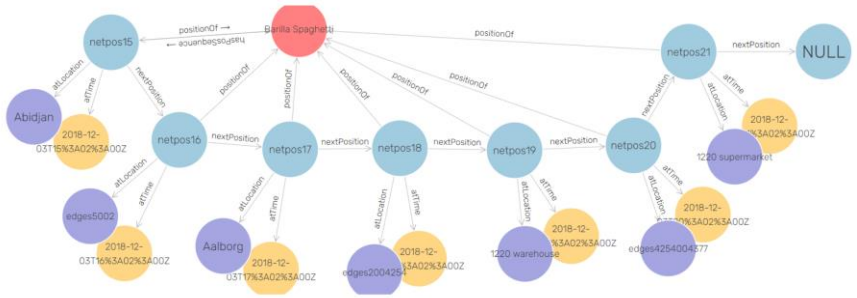
- Geometry representation (Simple Features)
- Geographical Names
- Addresses
- Geographic Information – Temporal schema
- Metadata (in Geospatial Semantic Web – part of the data!)
- Place identifier architecture
- Geographic information – Ontology 1/2



Examples (1)

- GeoKG for Supply Chain Visibility
  - Geospatial semantics of Supply Chain Visibility (SCV)
  - GeoKGs role to answer spatio-temporal questions related to the supply chain
  - Questions:
    - *How many items were moved between two nodes within a certain time span?*
    - *How long did a certain item reside in a certain node or edge?*
    - State of the Supply Chain (with a multitude of actors)





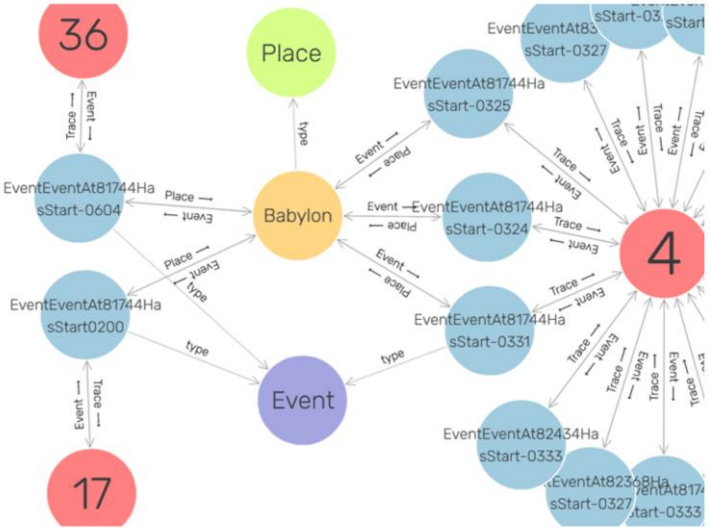
Dopler, S., & Scholz, J. (2021). A Prototypical Geospatial Knowledge Graph And Spatio-Temporal Question Answering for Supply Chain Visibility. *UC Santa Barbara: Center for Spatial Studies*. http://dx.doi.org/10.25436/E2JS3V Retrieved from https://escholarship.org/uc/item/80w0147g

Examples (2)

- GeoKG for Digital Humanities
  - World Historical Gazetteer (Grossner & Mostern, 2021)
  - Linked Traces model the events of geographic movement (Grossner, 2021)
  - GeoKG of Linked Traces with the help of Standards (Hübl & Scholz, 2021)

World Historical Gazetteer
linking knowledge about the past via place

Travels of monk Xuanzang (629AD-645AD)



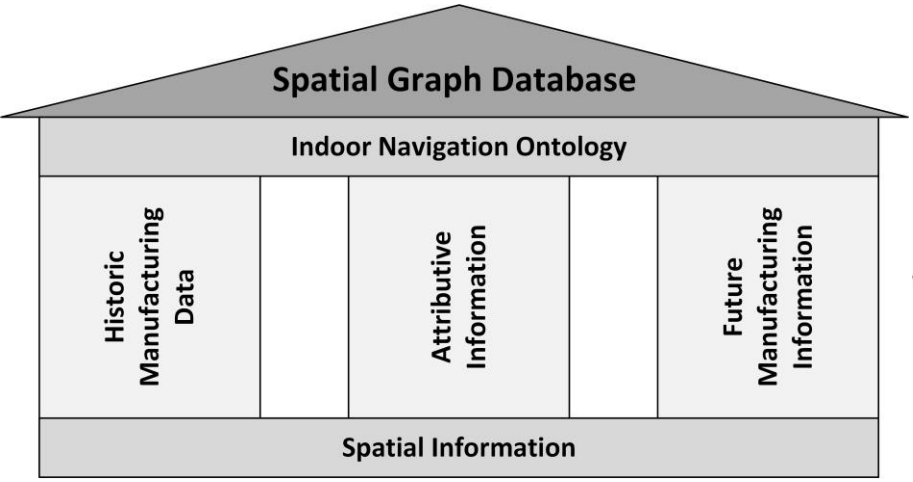
Hübl, F., & Scholz, J. (2021). Spatial Linked Data Approach for Trace Data in Digital Humanities. *UC Santa Barbara: Center for Spatial Studies*. http://dx.doi.org/10.25436/E2T882 Retrieved from https://escholarship.org/uc/item/57z4w749

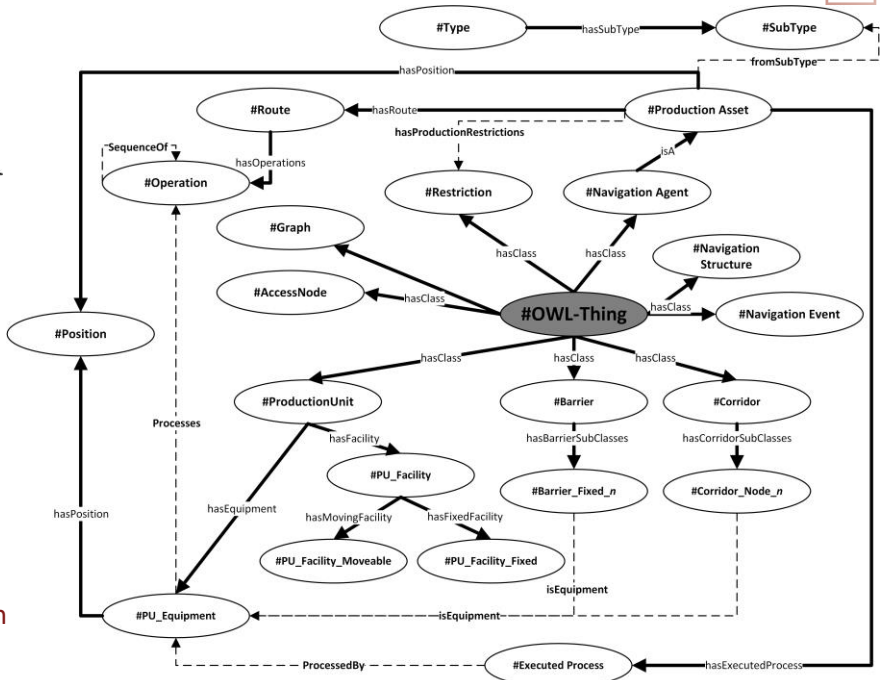
Examples (3)

Indoor Geography and Smart Manufacturing



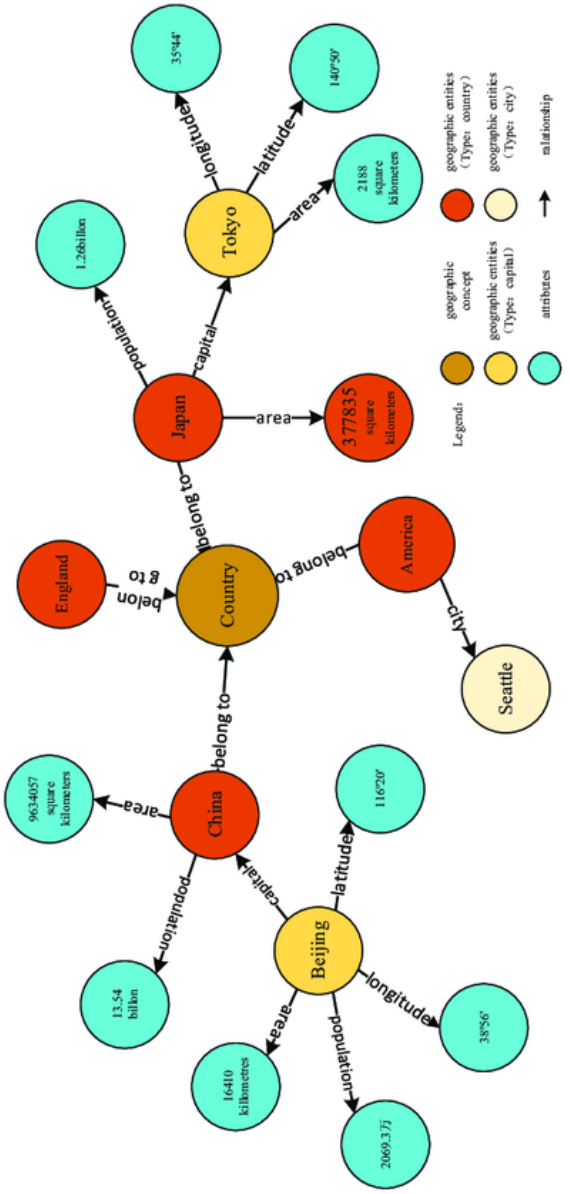
Schabus & Scholz (2017a), Schabus & Scholz (2017b)





Conclusion

- Geospatial Knowledge Graphs are an innovative way **to combine data with semantics**
- GeoKGs help to denote the semantics of the digital abstraction of the reality
- (Geo)Semantics helps to infer new knowledge!
- Enhance interoperability through the utilization of **standards** (e.g. semantic web, simple features, ….)
- **GeoKGs require a solid semantic foundation – which standards can provide**



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