Knowledge Graphs

Lecture 5 – Ontological Engineering for Smarter Knowledge Graphs 5.4 Ontological Engineering

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AIFB – Karlsruhe Institute of Technology Autumn 2023





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5.1 Beyond the Limits of OWL

Excursion 7: The Semantic Web Rule Language SWRL

- 5.2 How to design your own Ontology
- 5.3 How to design better Ontologies
- 5.4 Ontological Engineering
- 5.5 Knowledge Graph Construction
- 5.6 Ontologies & Knowledge Graphs Best Practices

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Ontology in Computer Science

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.

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Computer Science Definition

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Ontology Types and Categories

According to their Level of Generality

general, cross domain ontologies;

Top-Level Ontology (Upper Ontology, Foundation Ontology) represent very general concepts as: Time, Space, Event; independent of a specific domain or problem

Task Ontology

Domain Ontology

fundamental concepts according to a generic domain; specializes terms introduced in top-level ontology

Application Ontology

specialized ontology focussed on a specific task and domain; often a specialization of both task and domain ontology; often specify roles played by domain entities for specific activity

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5. Ontological Engineering for Smarter Knowledge Graphs / 5.4 Ontological Engineering Ontological Engineering

- Ontologies enable **interoperability** among metadata
- Therefore, we need
 - Methods for efficient **development** of ontologies
 - Methods for efficient **comparison** of ontologies
 - Methods for efficient **combination** of ontologies
- There are automated methods to support Ontological Engineering:
 - Learning new ontologies from a given set of information resources
 - Populating existing ontologies with individuals from information resources

(Ontology Design) (Ontology Evaluation) (Ontology Alignment)

(Ontology Learning)

(Knowledge Graph Population)





Ontology Design & Knowledge Graph Population



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5. Ontological Engineering for Smarter Knowledge Graphs / 5.4 Ontological Engineering How Ontologies can differ



• the same term describes different concepts

e.g. Author – writer of a book vs. creator of a document

• different terms describe the same concept

e.g. Author vs. Writer

- different modelling conventions and paradigms

 e.g. intervals vs. points to describe temporal aspects
- different level of granularity

e.g. Fiction vs. PoliticalFiction, ScienceFiction, RomanticFiction, etc. as literary genres

- different coverage or different point of view
- etc.

5. Ontological Engineering for Smarter Knowledge Graphs / 5.4 Ontological Engineering Heterogeneity of Ontologies



- Syntactical Heterogeneity:
 - Ontologies are available in **different ontology representation languages**.
 - Can be resolved on the conceptual level, most times preserving the semantics.
- Terminological Heterogeneity:
 - **Naming differences** for the identification of entities in different ontologies (E.g.: Author vs. Writer).
 - Might occur because different (natural) languages are used.
- Conceptional (Semantic) Heterogeneity:
 - Ontologies model the same domain, but in different ways.
 - Differences might occur in coverage, granularity, perspective, etc.
- Semiotic (Pragmatic) Heterogeneity:

Differences in interpretation of the domain to be modelled by humans (difficult).



Ontologies Alignment or Ontology Matching is the process of determining

correspondences between ontological concepts:



5. Ontological Engineering for Smarter Knowledge Graphs / 5.4 Ontological Engineering Correspondences & Mappings



 Given the ontologies O₁ and O₂, a correspondence or mapping among the entities e₁ and e₂ from O₁ respectively O₂, is defined as

$$\langle id, e_1, e_2, r, n \rangle$$

• with

- **id** ... a unique **identifier** of the correspondence
- r ... a relation, as e.g. equivalence (=), more general (⊒,≥), less general (⊑,≤), disjointness(⊥), part-of, etc...
- **n** ... a **confidence measure** (typically in the range of [0,1]) holding for the correspondence between e_1 and e_2
- the correspondence $\langle id, e_1, e_2, r, n \rangle$ asserts that the relation *r* holds between the entities e_1 and e_2 with confidence *n*

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Examples of simple correspondences:

- o dbpedia:George_Orwell = wikidata:Q3335
- :Author = :Writer
- :Fiction $≥_{1.0}$:ScienceFiction
- o rdfs:label ≥_{0.9} dc:title

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Examples of more complex correspondences:

- o :speed = :velocity × 2.237 0.477 × :speed = :velocity
- Book(x) ∧ author(x,y) ∧ Writer(y) ⇒_{.85}
 writtenBy(x,concat(y.firstname, y.lastname))

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Ontology Alignment Example

Book $=_{1.0}$ Volume id $\ge_{0.9}$ isbd Person $=_{0.9}$ Human name $\ge_{1.0}$ title author $=_{1.0}$ author Science $\le_{0.9}$ Essay



Euzenat, Shvaiko: Ontology Matching, Springer, 2013. 18 Knowledge Graphs 2023, Prof. Dr. Harald Sack, FIZ Karlsruhe – Leibniz Institute for Information Infrastructure & Karlsruhe Institute of Technology

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(Ontology Learning)

(Knowledge Graph Population)

Ontology Learning



• Ontology Learning from Text

automatic or semi-automatic generation of lightweight ontologies by means of text mining and information extraction

• Linked Data Mining

detecting meaningful patterns in RDF graphs via statistical schema induction or statistical relational learning

• Concept Learning in Description Logics and OWL

learning schema axioms from existing ontologies and instance data mostly based on Inductive Logic Programming

• Crowdsourcing Ontologies

combines the speed of computers with the accuracy of humans, e.g. taxonomy construction via Amazon Turk or games with a purpose

Ontology Learning from Text

Asim (2018)





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5. Ontological Engineering for Smarter Knowledge Graphs / 5.4 Ontological Engineering The Ontology Learning Layer Cake

General Axioms Country $\subseteq \leq 1$ hasCapital. \top Axiomatic Schemata River \sqcap Mountain $\sqsubseteq \bot$ **Relation Hierarchies** capitalOf \sqsubseteq locatedIn Relations flowThrough(dom:River, range:GeoEntity) **Concept Hierarchies** Capital \sqsubseteq City , City \sqsubseteq InhabitedGeoEntity **Concept Description** c:=country:=<description(c), uri(c)> Multilingual Synonyms {country, nation, land} Terms river, country, nation, city, capital, ...

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Picture References:

- [1] "On this scifi movie poster we see the vibrant construction site of a gigantic space ship in the vast deserts of planet Mars exposing many small details.", created via ArtBot, Deliberate, 2023, [CC-BY-4.0], https://tinybots.net/artbot
- [2] "A Scifi movie poster depicting Raphael's "School of Athens" with all the important classical Philosophers including their significant tools set into a retro futuristic urban environment of planet Mars with spaceships in the sky.", created via ArtBot, Deliberate, 2023, [CC-BY-4.0], https://tinybots.net/artbot
- [3] "On this hyperrealistic scifi movie poster we see the scenery of Hans Holbein the Younger's famous painting "The Ambassadors" set into a retro futuristic environment on planet Mars showing countless small strange artifacts belonging to the ambassadors including a large distorted skull.", created via ArtBot, Deliberate, 2023, [CC-BY-4.0], https://tinybots.net/artbot

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