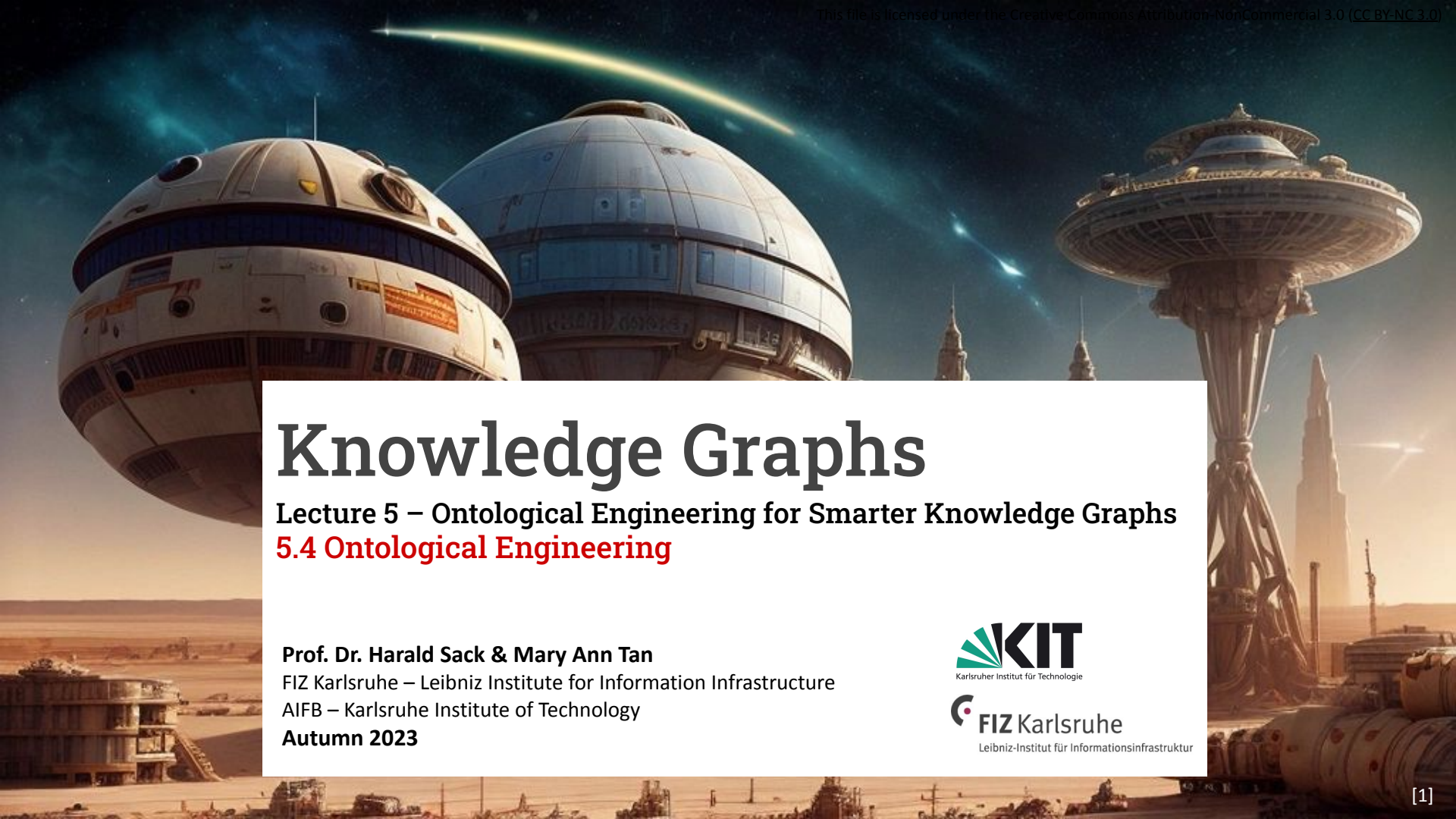


Knowledge Graphs

Lecture 5 – Ontological Engineering for Smarter Knowledge Graphs

5.4 Ontological Engineering

Prof. Dr. Harald Sack & Mary Ann Tan
FIZ Karlsruhe – Leibniz Institute for Information Infrastructure
AIFB – Karlsruhe Institute of Technology
Autumn 2023

Karlsruher Institut für Technologie

FIZ Karlsruhe
Leibniz-Institut für Informationsinfrastruktur

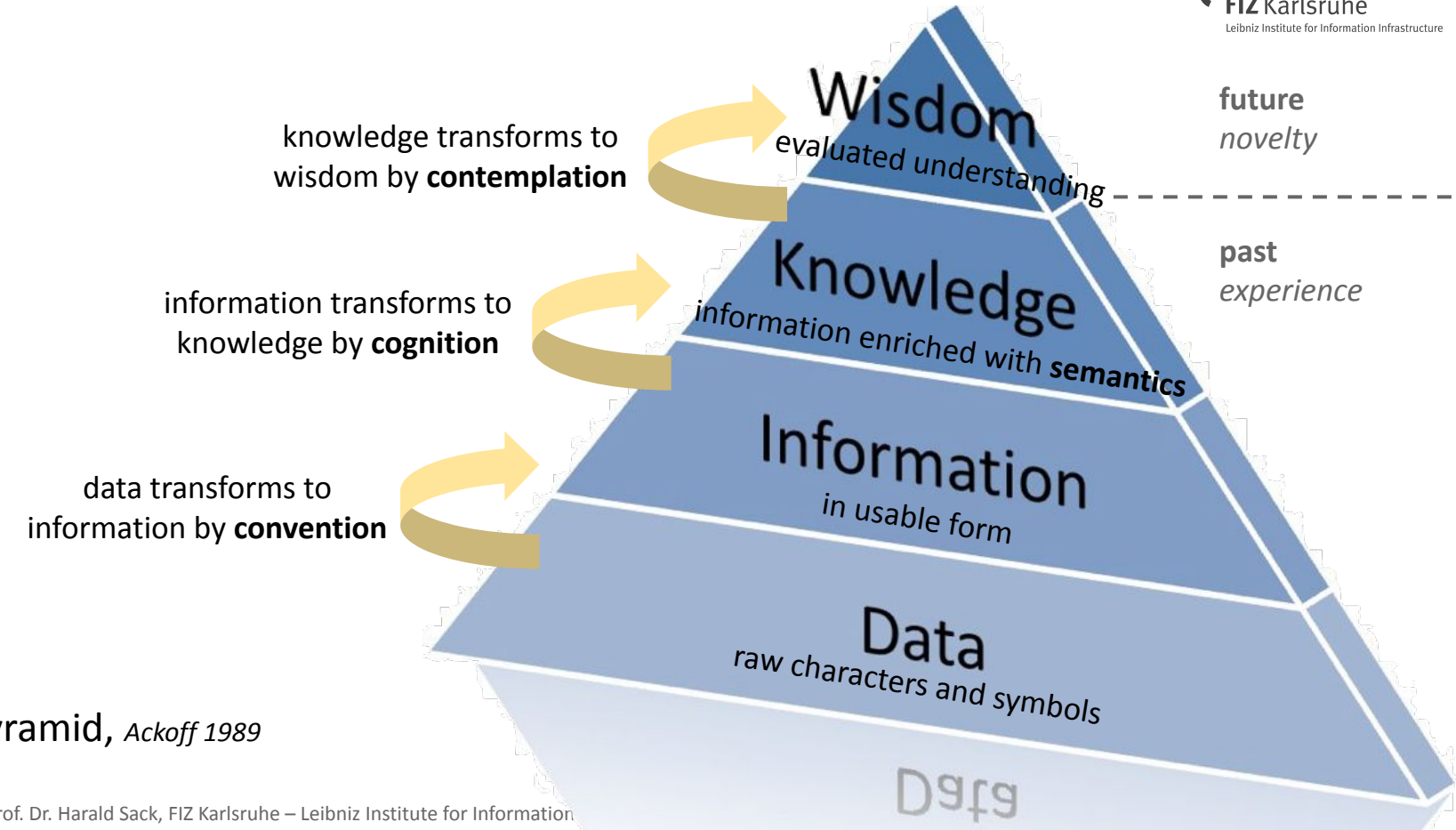
Knowledge Graphs

Lecture 5: Ontological Engineering for Smarter Knowledge Graphs

Karlsruher Institut für Technologie

FIZ Karlsruhe
Leibniz Institute for Information Infrastructure

Knowledge Management



DIKW Pyramid, *Ackoff 1989*

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.

Computer Science Definition

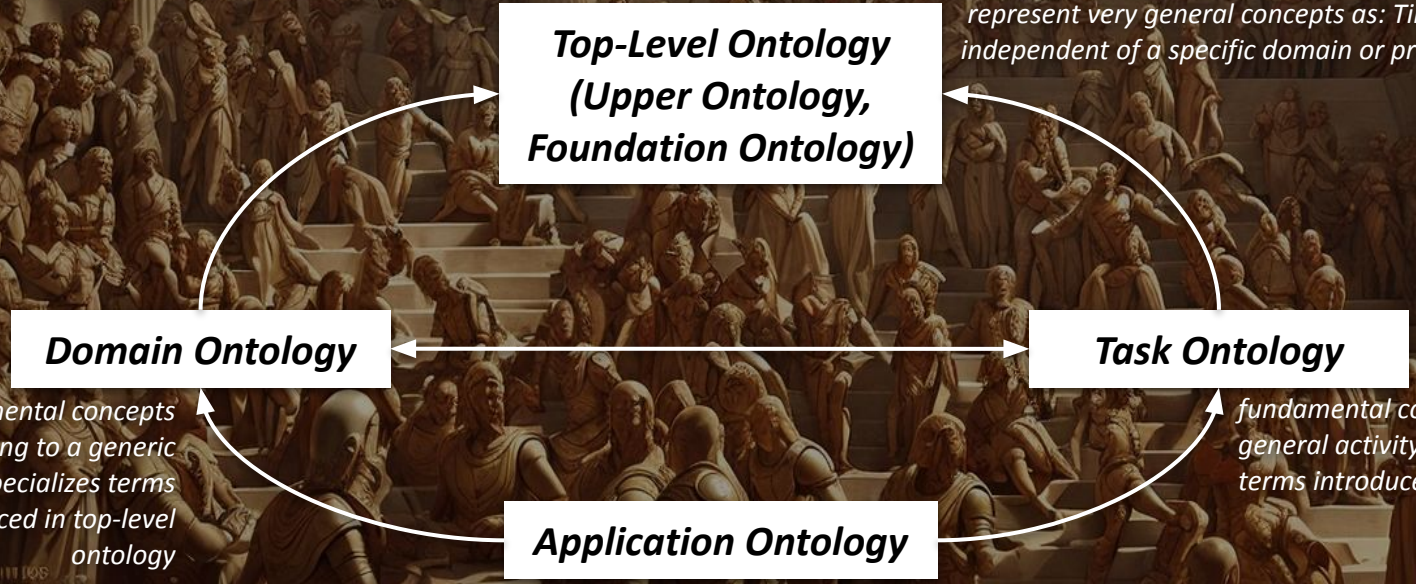
DIKW Pyramid

[2]

[3]

Ontology Types and Categories

According to their Level of Generality



[2]

(according to Guarino: Formal Ontology in Information Systems, 1998)

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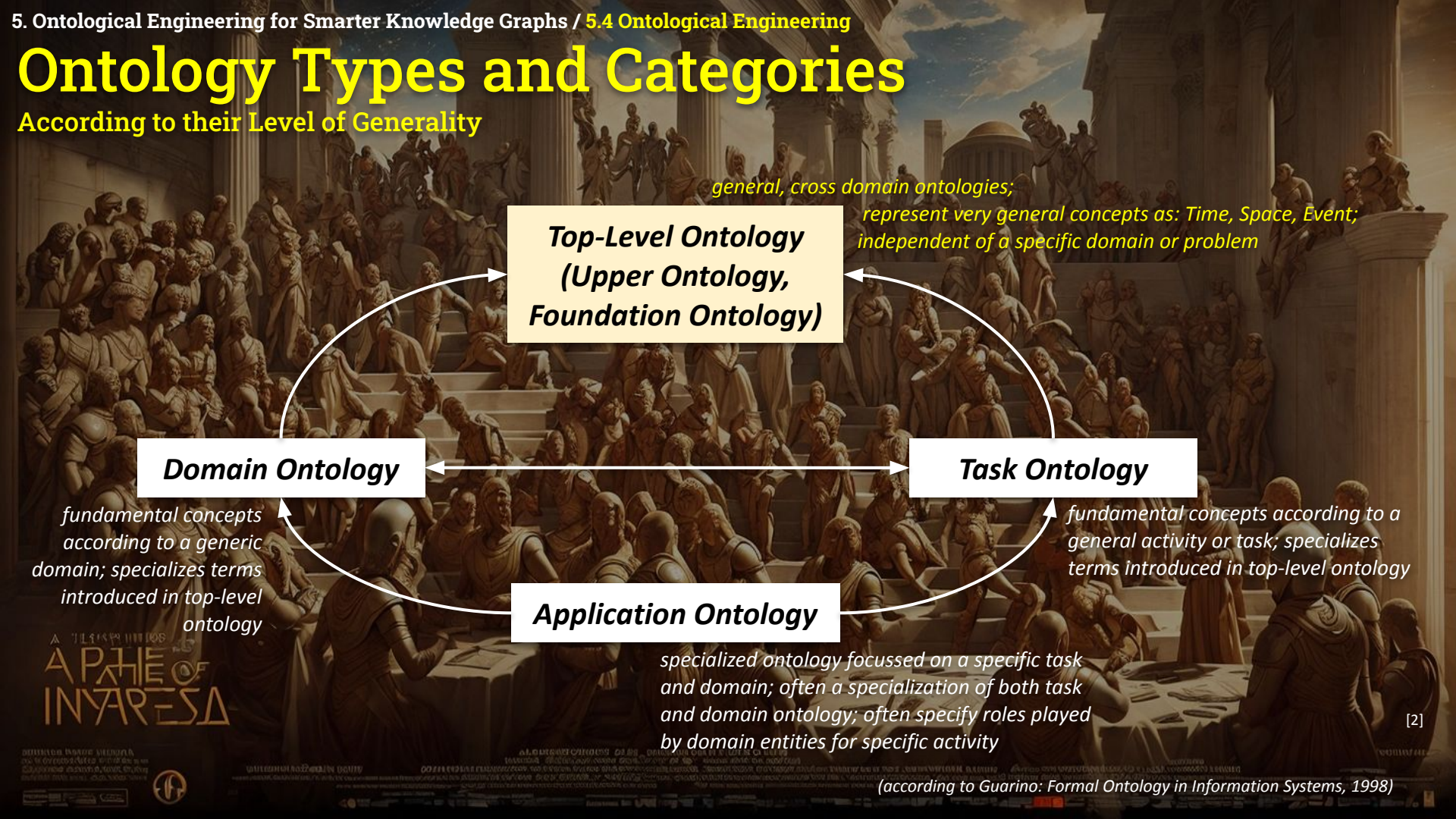

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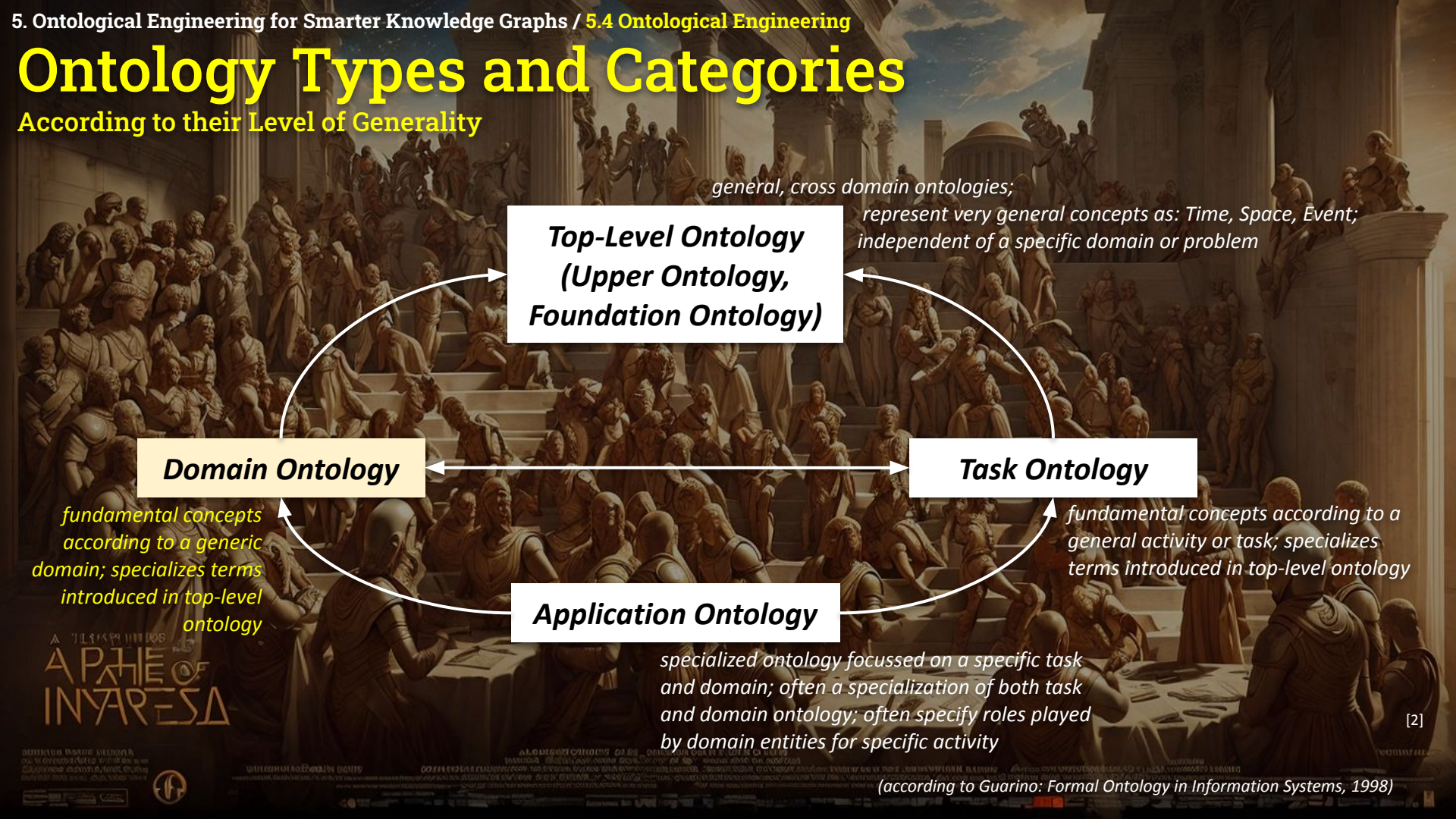

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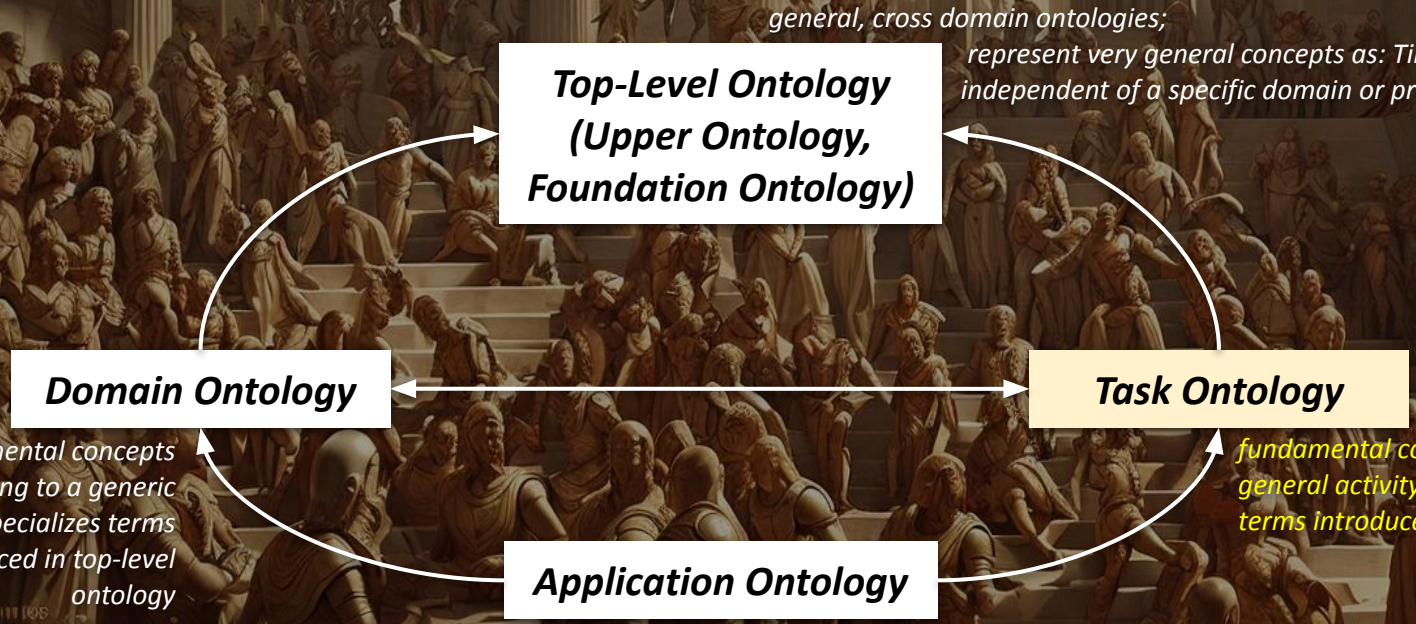

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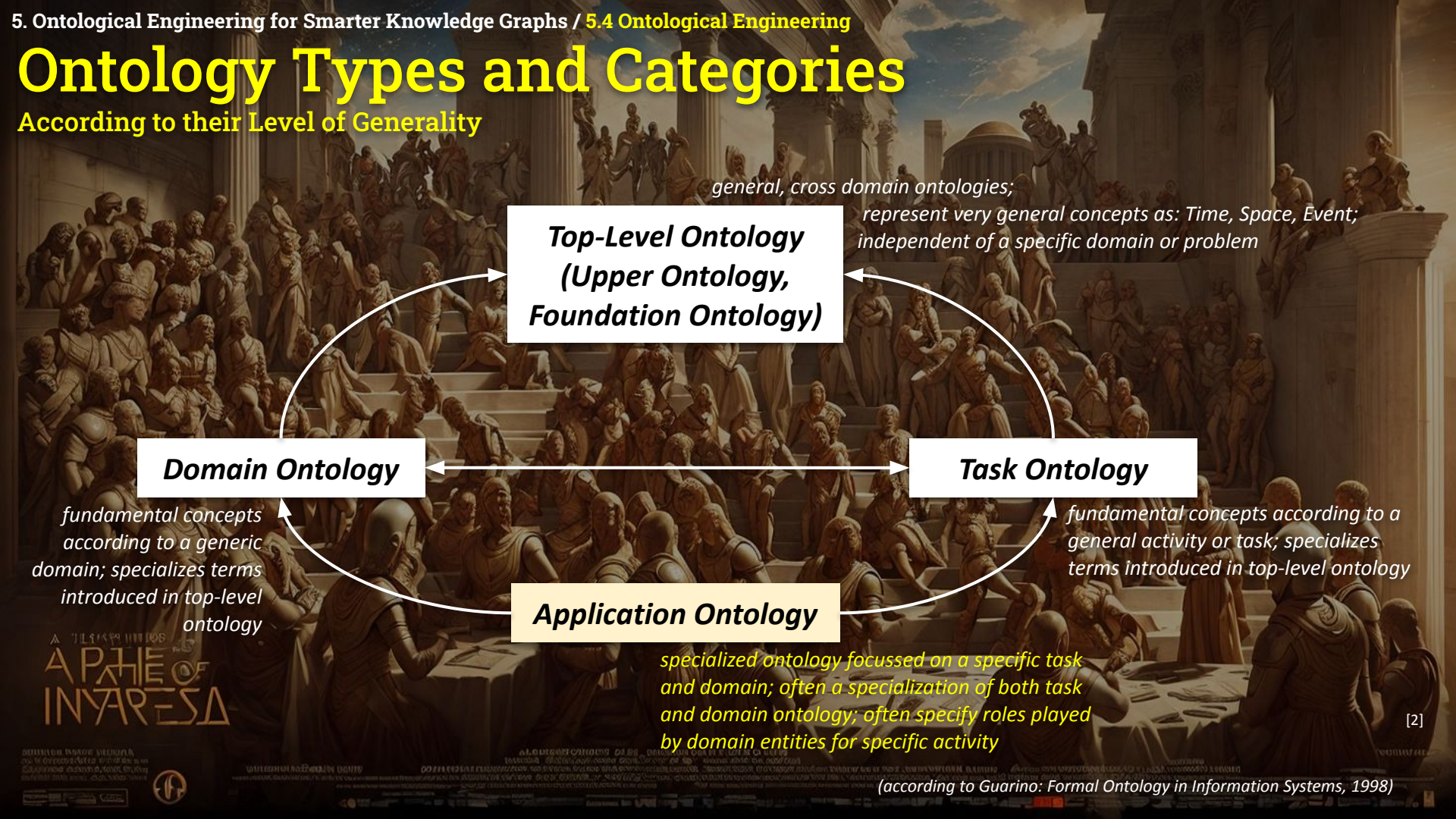

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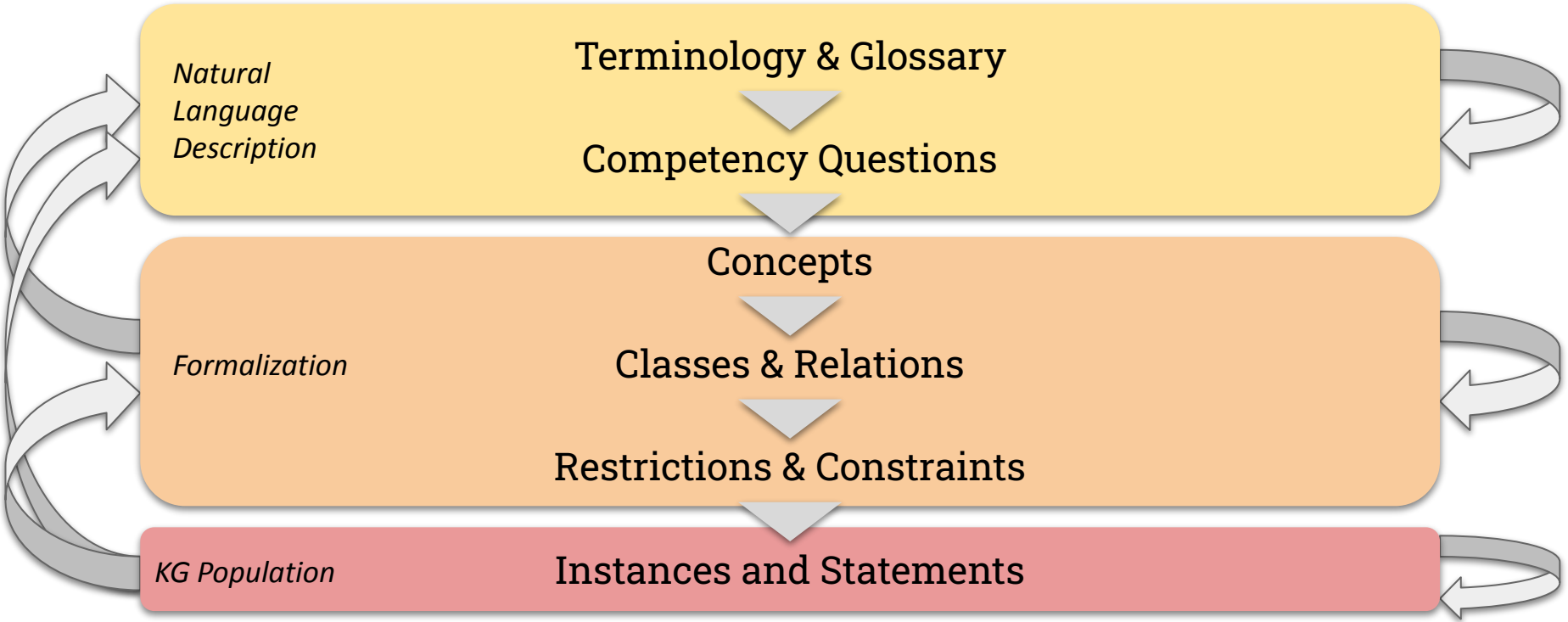
(according to Guarino: Formal Ontology in Information Systems, 1998)

Ontological Engineering

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

Ontology Design & Knowledge Graph Population



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.

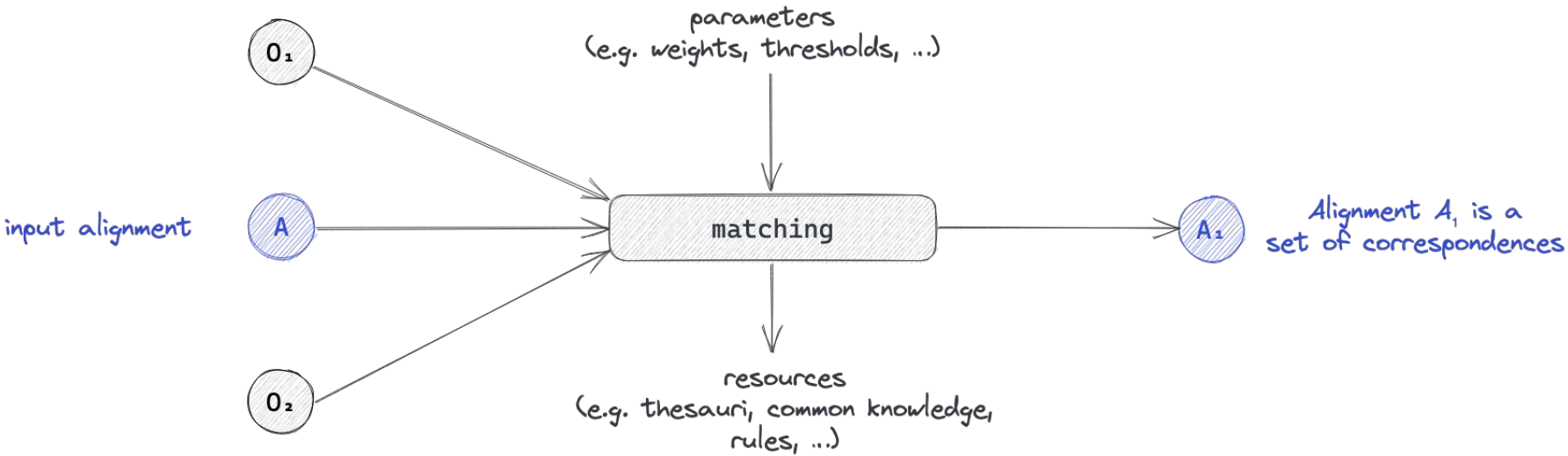
Heterogeneity of Ontologies

- **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).

Ontology Alignment

Ontologies Alignment or **Ontology Matching** is the process of determining *correspondences* between ontological concepts:



Correspondences & Mappings

- Given the **ontologies O_1 and O_2**, a **correspondence** or **mapping** among the **entities e_1 and e_2** from O_1 respectively O_2, 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***

Correspondences & Mappings

Examples of **simple correspondences**:

- `dbpedia:George_Orwell = wikidata:Q3335`
- `:Author = :Writer`
- $:\text{Fiction} \geq_{1.0} :\text{ScienceFiction}$
- $\text{rdfs:label} \geq_{0.9} \text{dc:title}$

Correspondences & Mappings

Examples of **more complex correspondences**:

- `:speed = :velocity × 2.237`
  `0.477 × :speed = :velocity`
- $\text{Book}(x) \wedge \text{author}(x,y) \wedge \text{Writer}(y) \Rightarrow_{.85}$
  $\text{writtenBy}(x,\text{concat}(y.\text{firstname}, y.\text{lastname}))$

Ontology Alignment Example

Book $=_{1.0}$ Volume

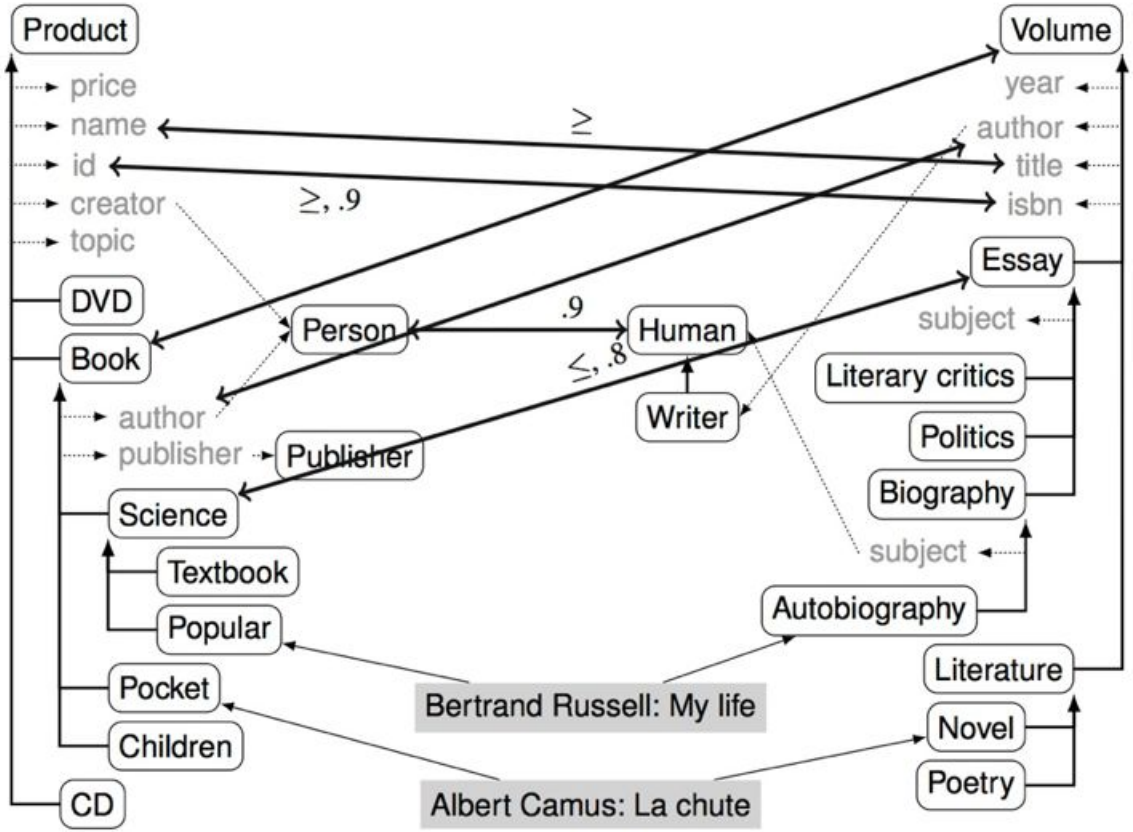
id $\geq_{0.9}$ isbd

Person $=_{0.9}$ Human

name $\geq_{1.0}$ title

author $=_{1.0}$ author

Science $\leq_{0.9}$ Essay



Euzenat, Shvaiko: Ontology Matching, Springer, 2013.

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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

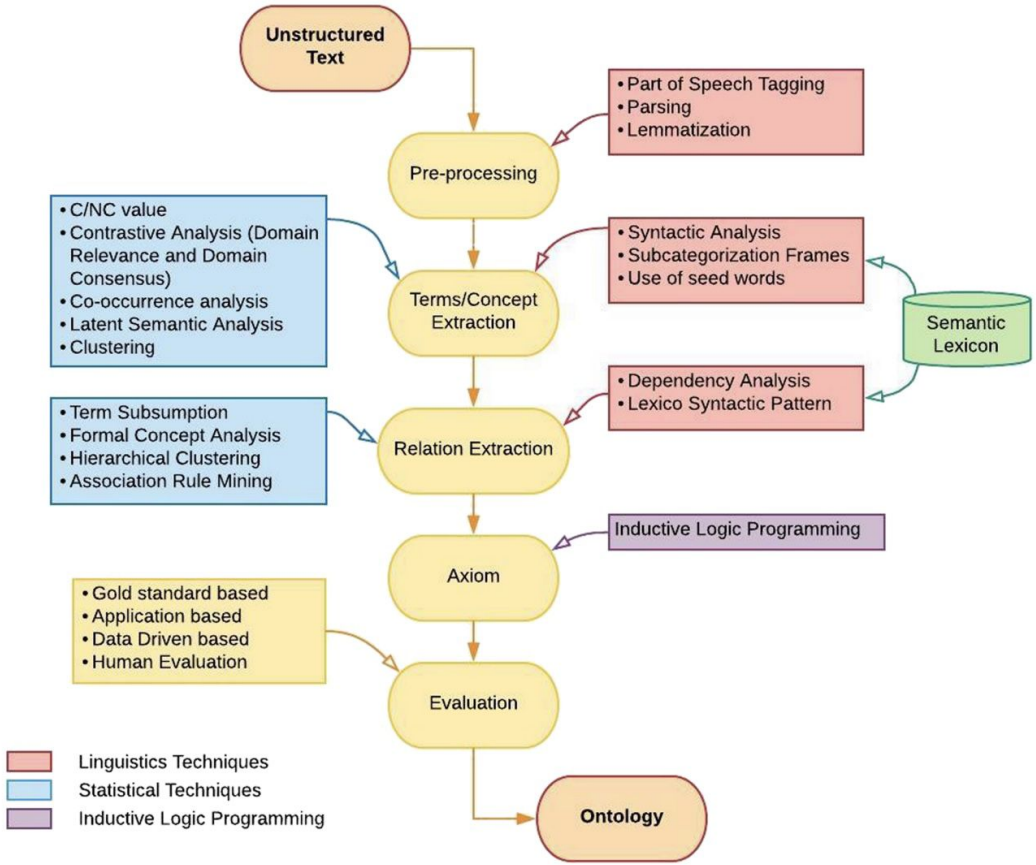
- Concept Learning in Description Logics and OWL

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

- Crowdsourcing Ontologies

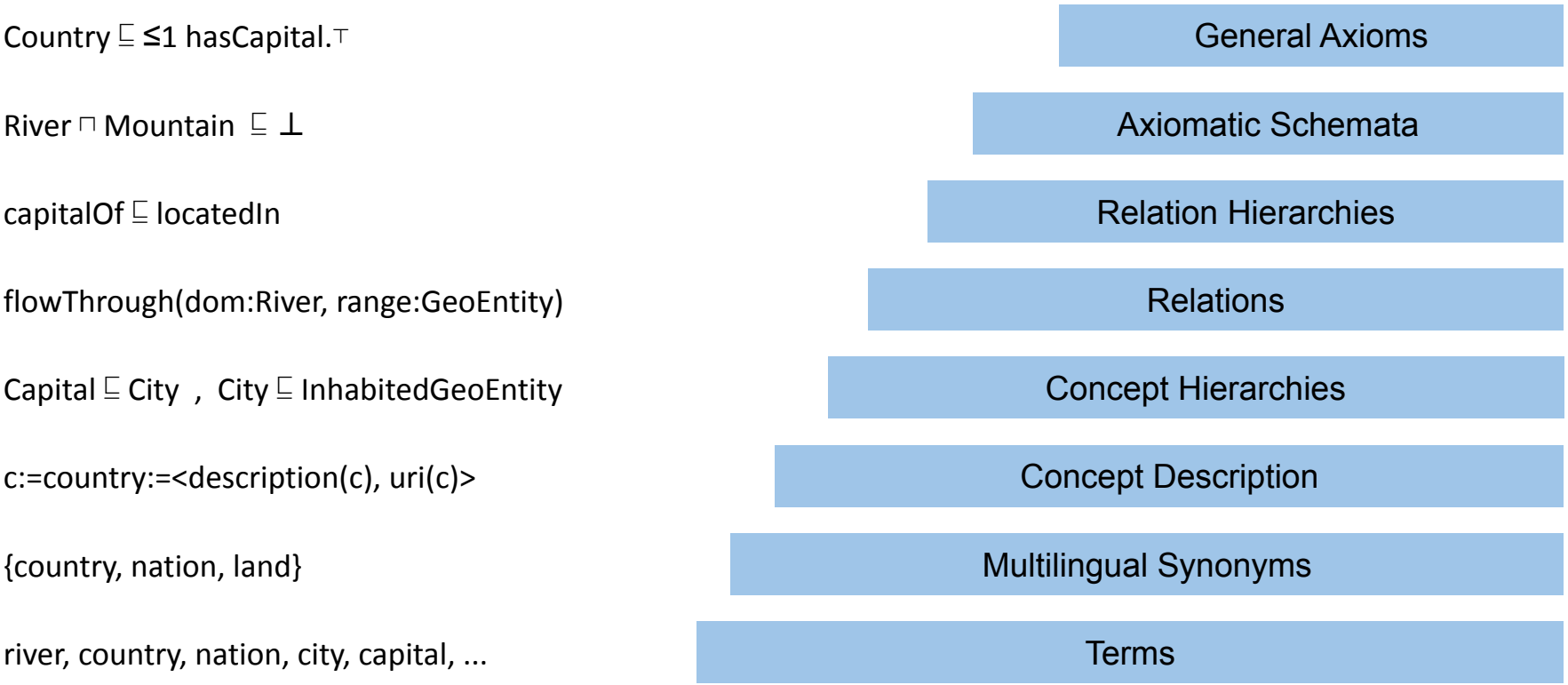
  combines the speed of computers with the accuracy of humans, e.g. taxonomy construction via Amazon Turk or games with a purpose

Ontology Learning from Text



Asim (2018)

The Ontology Learning Layer Cake



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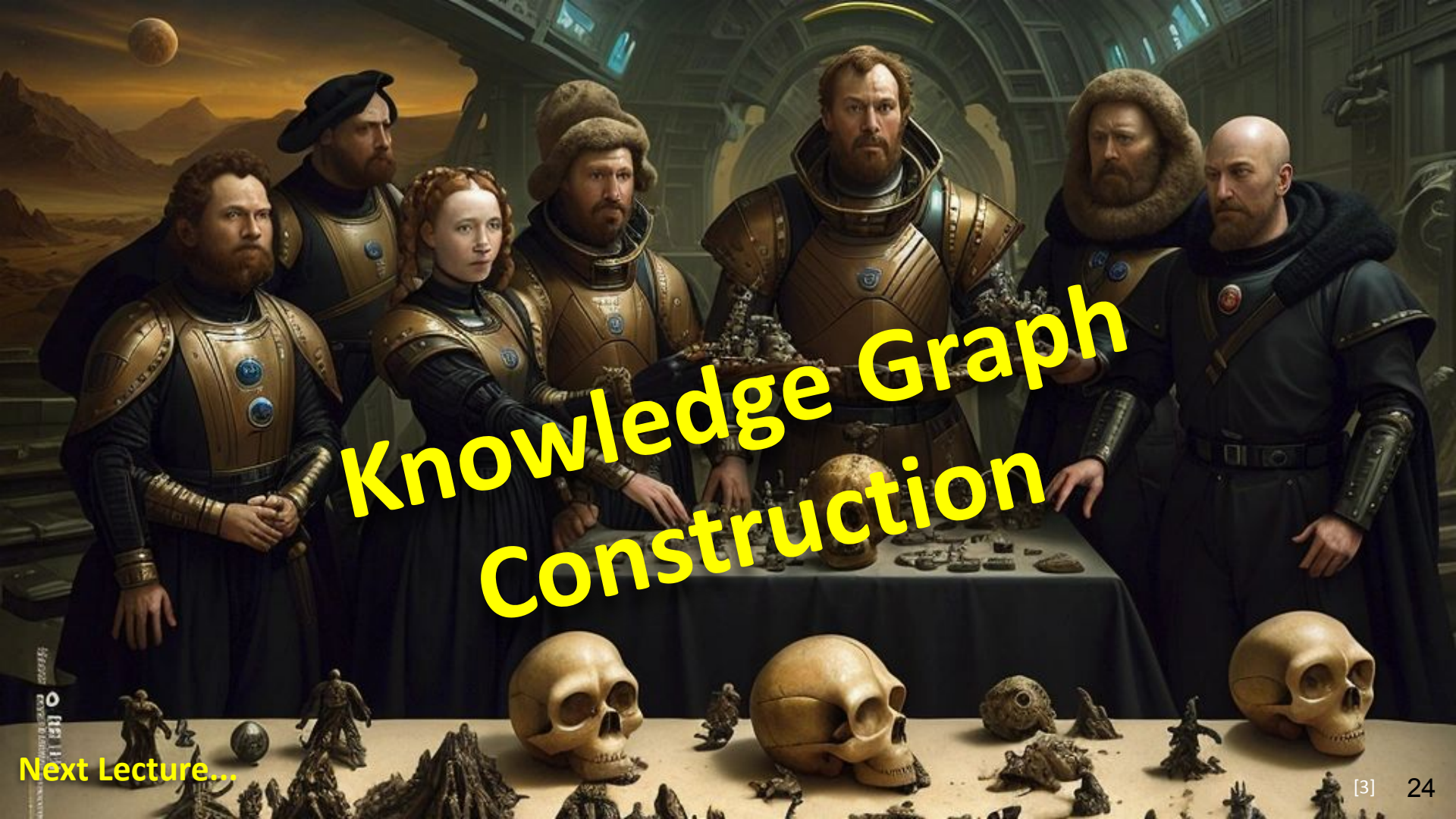

Next Lecture...

Bibliographic References:

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- Nicola Guarino. (1998). *Formal Ontology in Information Systems*: Proceedings of the 1st International Conference June 6-8, 1998, Trento, Italy (1st. ed.). IOS Press, NLD.
- Jérôme Euzenat , Pavel Shvaiko (2013), *Ontology Matching*, Springer.
- Jens Lehmann, Johanna Völker, *Perspectives on Ontology Learning*. Studies on the Semantic Web 18, IOS Press 2014.
- Muhammad Nabeel Asim, Muhammad Wasim, Muhammad Usman Ghani Khan, Waqar Mahmood, Hafiza Mahnoor Abbasi (2018). *A survey of ontology learning techniques and applications*. Database : the journal of biological databases and curation, bay101.

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