TECHNISCHE UNIVERSITÄT WIEN

INSTITUTE OF MANAGEMENT SCIENCE
Research Group of Production and Maintenance Management

Knowledge Management 4.0

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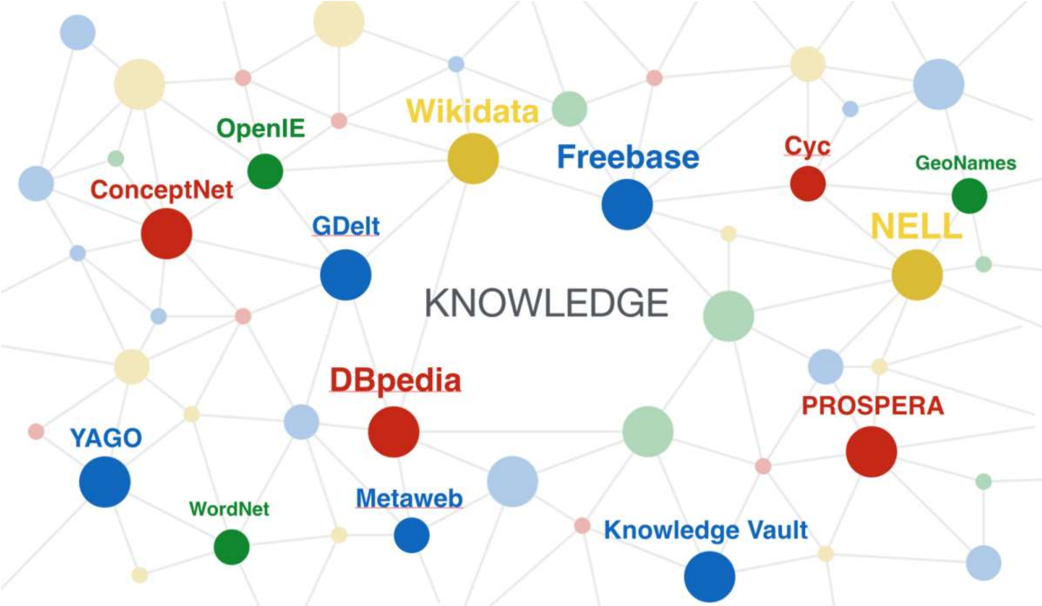
Priv.-Doz. Dr.-Ing. Fazel Ansari

May 9, 2023

WHY ONTOLOGY IN INDUSTRY 4.0?



https://www.linkedin.com/pulse/knowledge-graphs-end-user-products-from-cyc-ai-part-daniel-kornev/

https://giphy.com/explore/knowledge-is-power

KNOWLEDGE REPRESENTATION & REASONING

Knowledge Representation

How an Artificiality becomes Intelligent?

- “**An artificial intelligence** system can **think** and **have a mind**. “ (John Searle 1986)
- “Machine intelligence with the **full range of human intelligence**” (Kurzweil 2005)

An artificiality needs a Knowledge-base to become intelligent!

Knowledge-Base: A collection of **symbolic structures representing** what **it believes** and **reasons** with, during the operation of the system

Knowledge Representation & Reasoning

Meaning - Breakdown

Knowledge Representation and Reasoning

„John **knows** that…“
Knowledge can be true or false

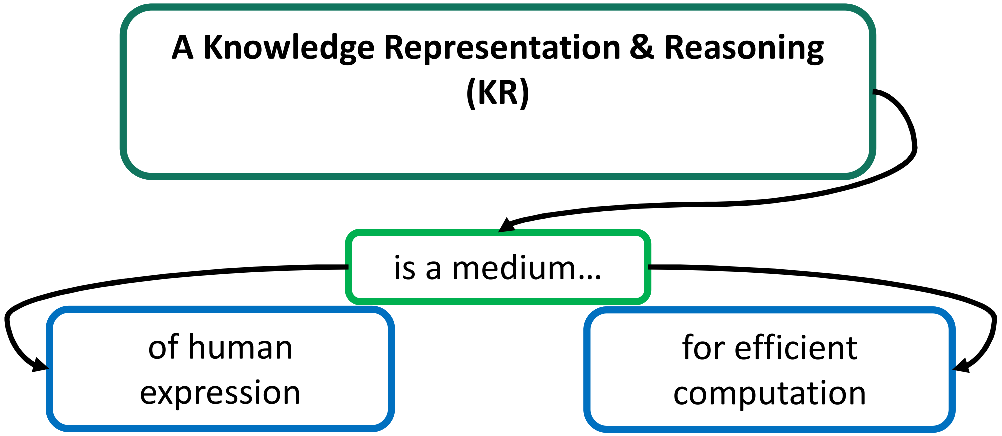
Symbolic encoding of propositions believed.
Symbols **represent** things in the world!

Manipulation of symbols encoding propositions to **produce** representations of **new propositions**

→ Any discussion of **representation** unavoidably carries along with it a view of **intelligent reasoning**.

Knowledge Representation & Reasoning

KR – Knowledge Representation and Reasoning



- KR are also the **means** by which we express things about the world, the medium of **expression** and **communication** in which we tell the machine
- A KR is a fragmentary theory of intelligent reasoning

Root of KR

Biology: Reasoning emerges from parallel interconnection of a large collection of very simple processors - Connectionism

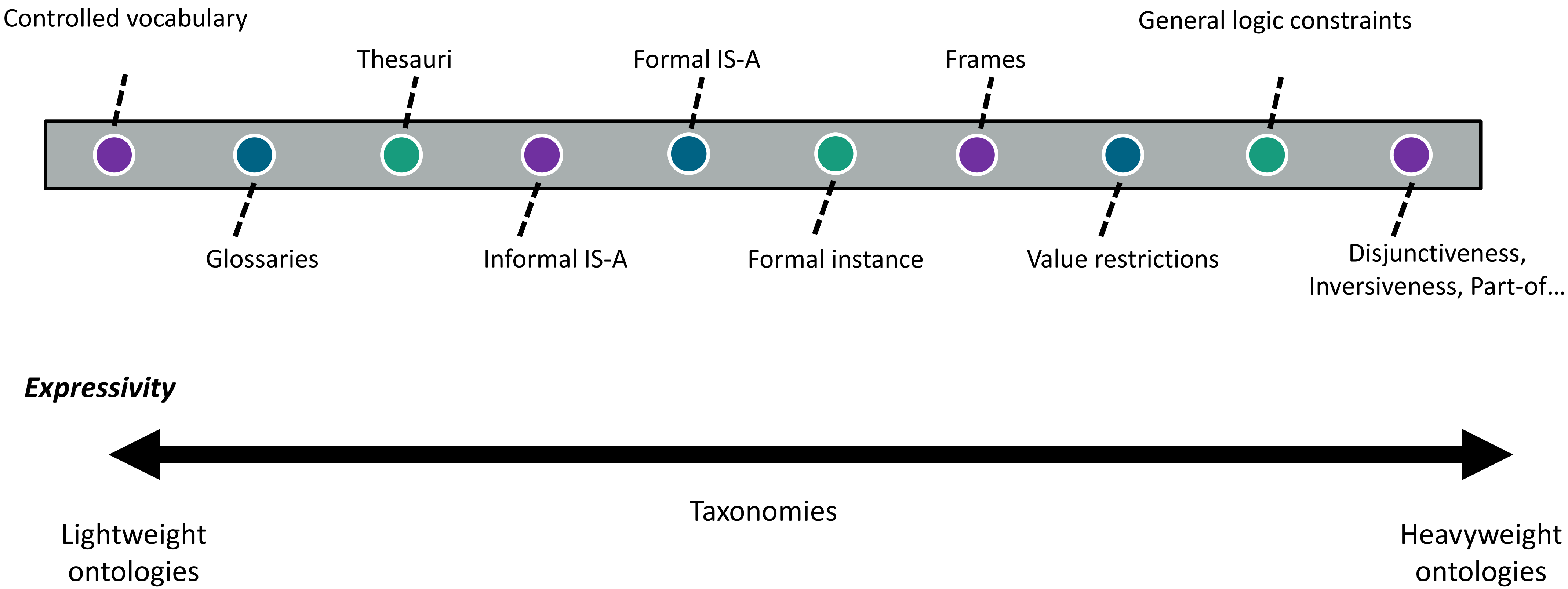
Mathematical Logic: Intelligent reasoning is some variety of deduction – First order logic

Psychology: Reasoning as a characteristic human behavior – Capturing human expert reasoning

Statistics: It adds to logic the notion of uncertainty – Casual networt

Ontology Types and Categories

Overview

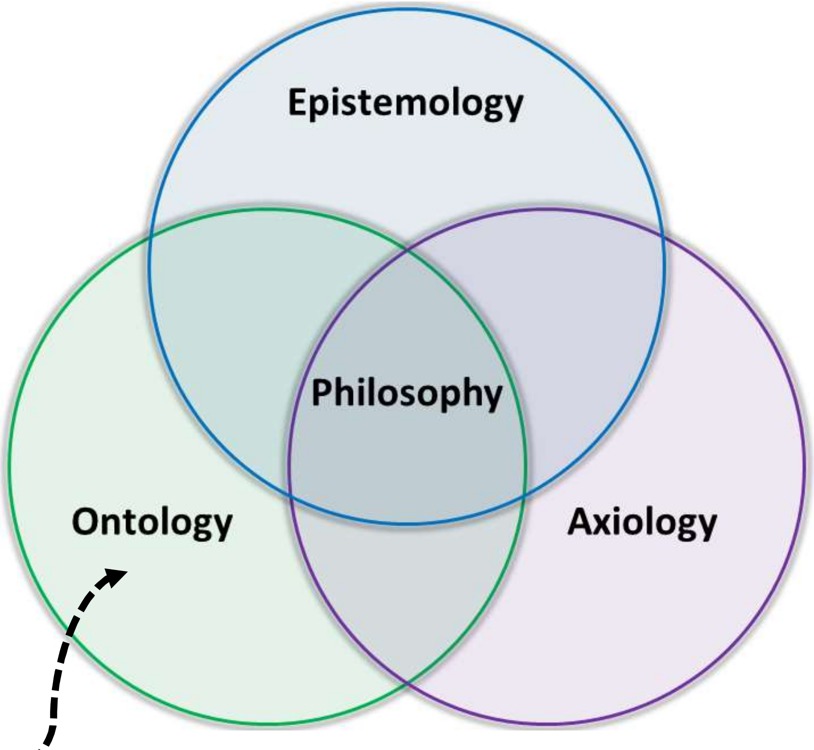


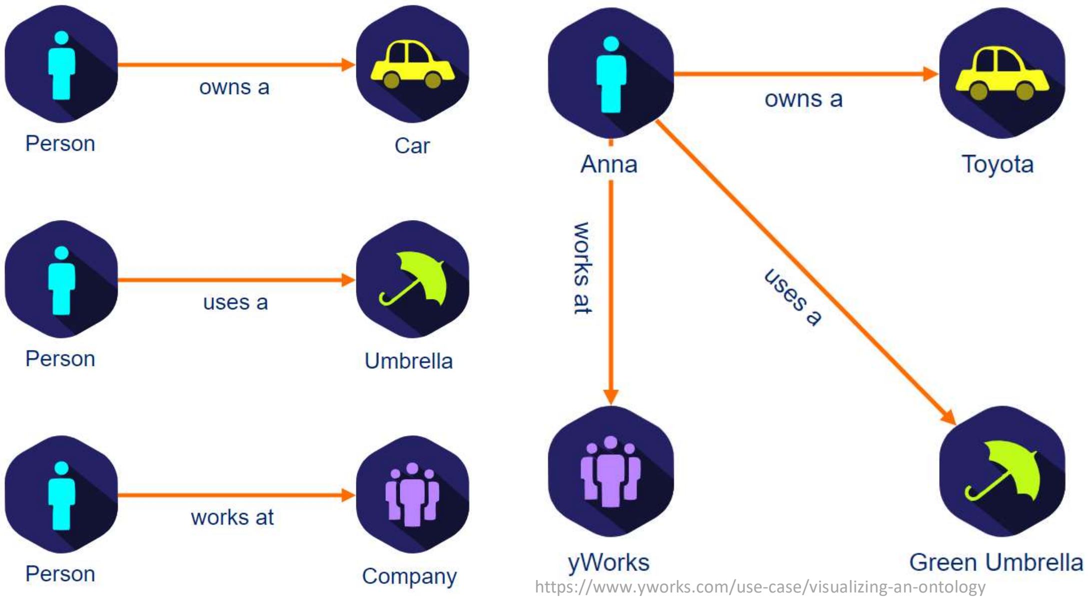
Knowledge Representation & Ontology Development

A KR is a Set of Ontological Commitments

- **Complexity of the natural world is overwhelming** (example → self driving car)**:**
  - Making a set of decisions about **how and what to see in the world**
  - A strong pair of glasses that determine what we can see
  - Bringing some part of the world into sharp focus, at the expense of blurring other parts

- **Ontology**
  - The set of concepts offered as a **way of thinking about the world**
- A degree of **ontological commitment**
  - The **selection** will have a significant impact on our perception of and approach to the task and our **perception of the world** being modeled





https://www.yworks.com/use-case/visualizing-an-ontology

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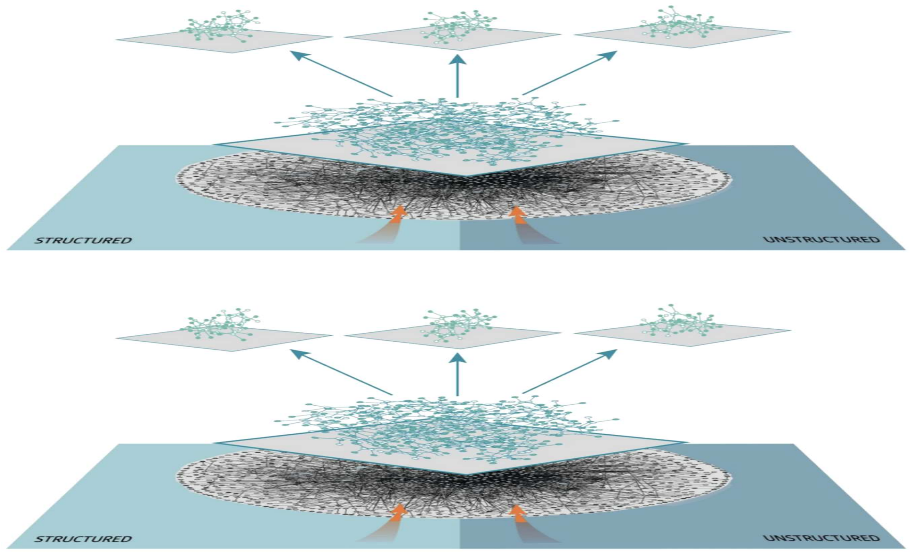


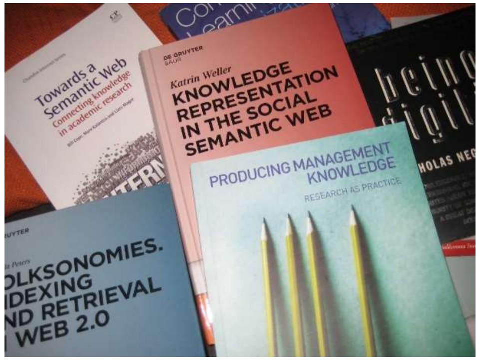
https://towardsdatascience.com/ontology-and-data-science-45e916288cc5

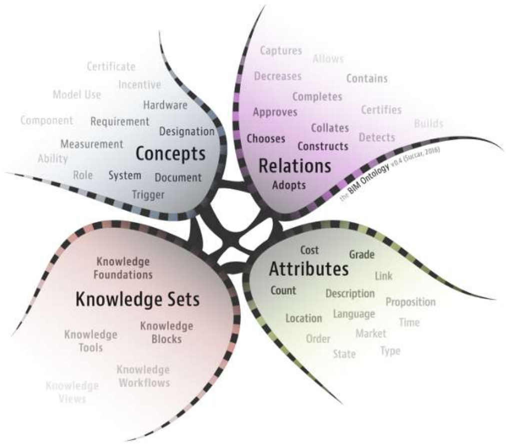
ONTOLOGIES

Knowledge Representation & Ontology Development

Ontology

- Ontology serves as the basis for
  - Structuring the metadata of informal knowledge sources
  - Information Gathering
  - Integration





https://www.bimframework.info/2015/08/bim-ontology.html

- Ontology supports Knowledge
  - Search
  - Retrieval
  - Personalization
  - Visualization

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Knowledge Representation & Ontology Development

Ontology

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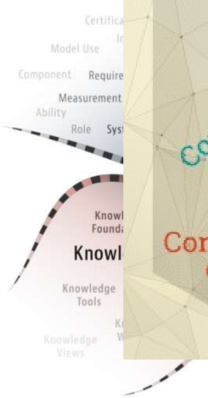
  - Int



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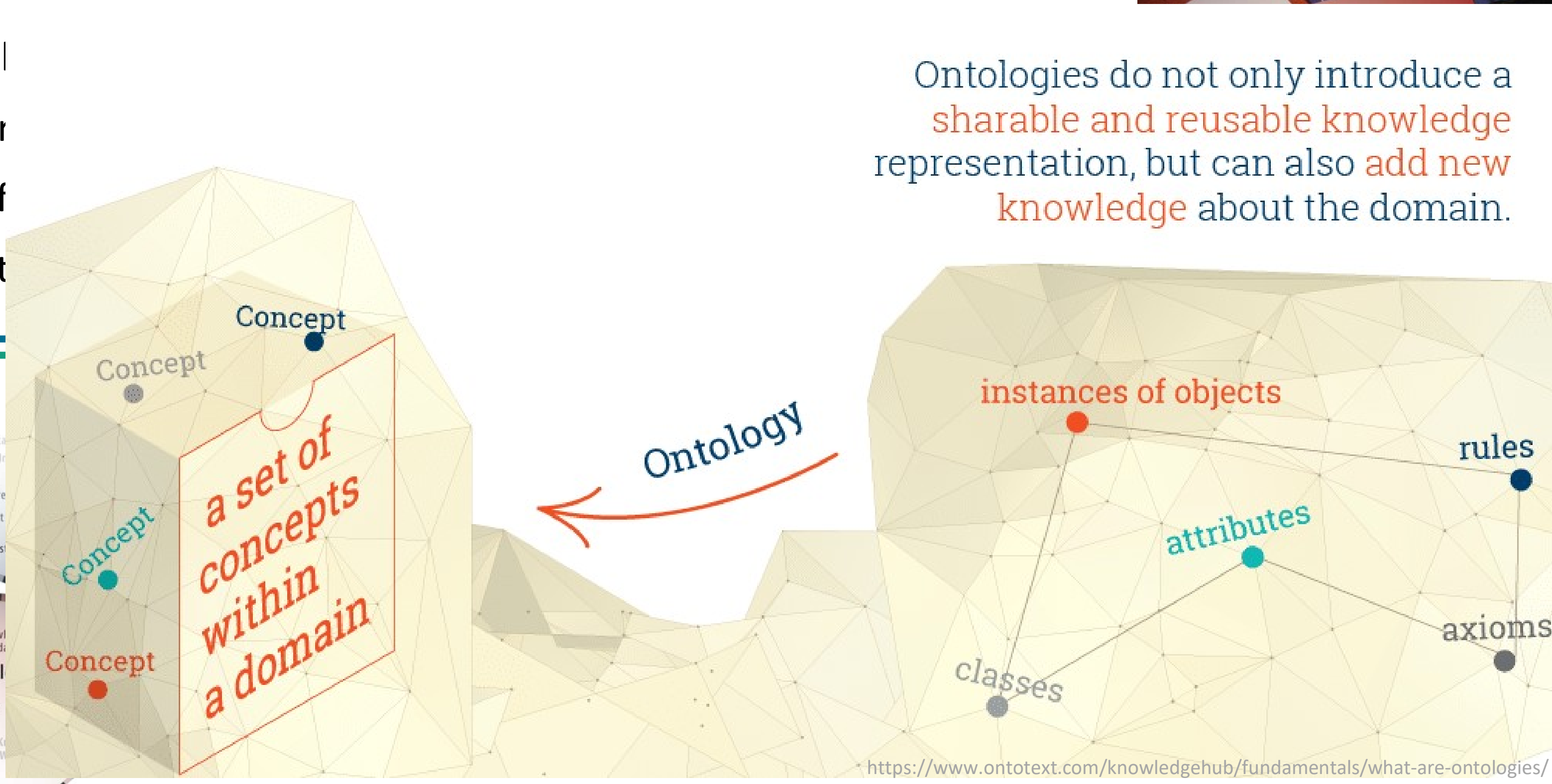

https://www.ontotext.com/knowledgehub/fundamentals/what-are-ontologies/

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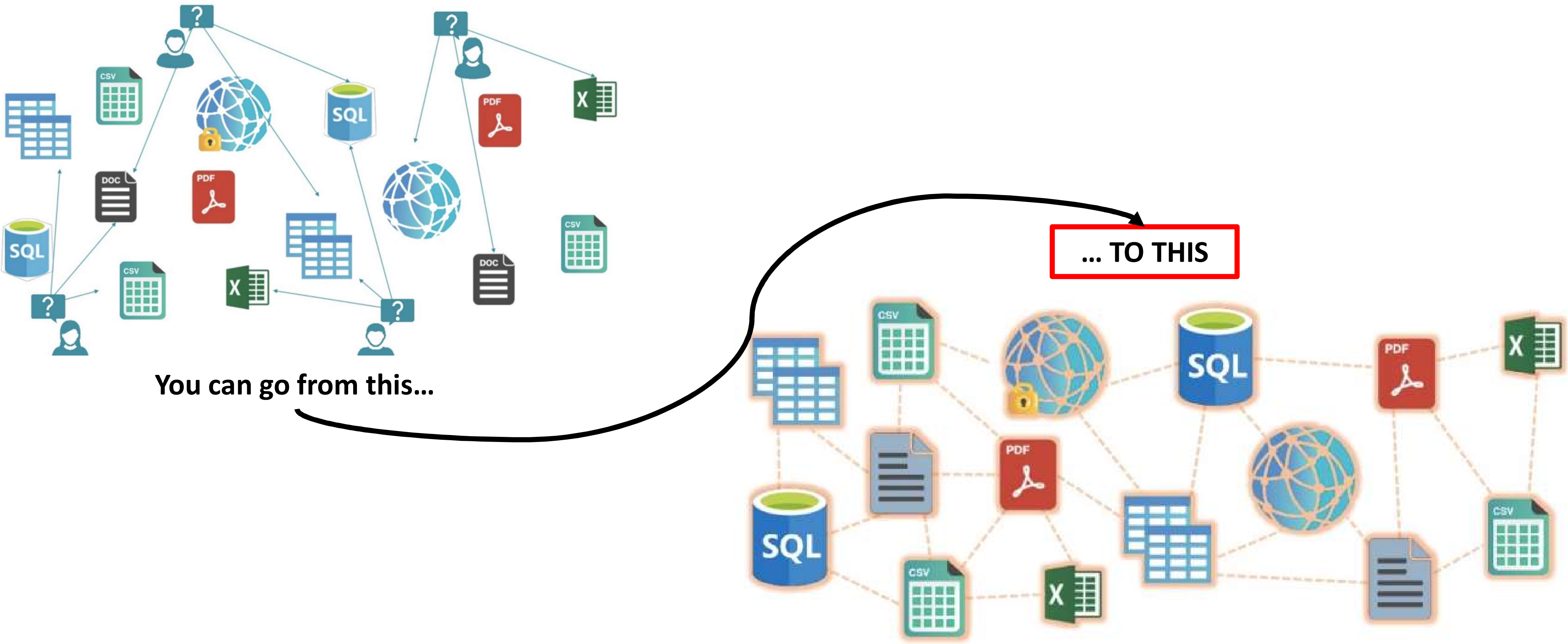
Knowledge Representation & Ontology Development

Ontology



https://www.linkedin.com/pulse/ontology-data-science-favio-v%C3%A1zquez/

Knowledge Representation & Ontology Development

Definition

Ontology…

- Is an **explicit specification** of a **conceptualization***
- Defines the **basic terms** and **relations** comprising the **vocabulary of a topic area**, as well as the **rules** for combining terms and relations to define extensions to the vocabulary**
- Provides the **means for describing** explicitly the **conceptualization** behind the **knowledge** represented in a knowledge base***

*Gruber, T. A translation Approach to portable ontology specifications. Knowledge Acquisition. Vol. 5. 1993. 199-220
**Neches, R.; Fikes, R.; Finin, T.; Gruber, T.; Patil, R.; Senator, T.; Swartout, W.R. Enabling Technology for Knowledge Sharing. AI Magazine. Winter 1991. 36-56
*** A. Bernaras;I. Laresgoiti; J. Correra. Building and Reusing Ontologies for Electrical Network ApplicationsECAI96. 12th European conference on Artificial Intelligence. Ed. John Wiley& Sons, Ltd. 298-302

Knowledge Representation & Ontology Development

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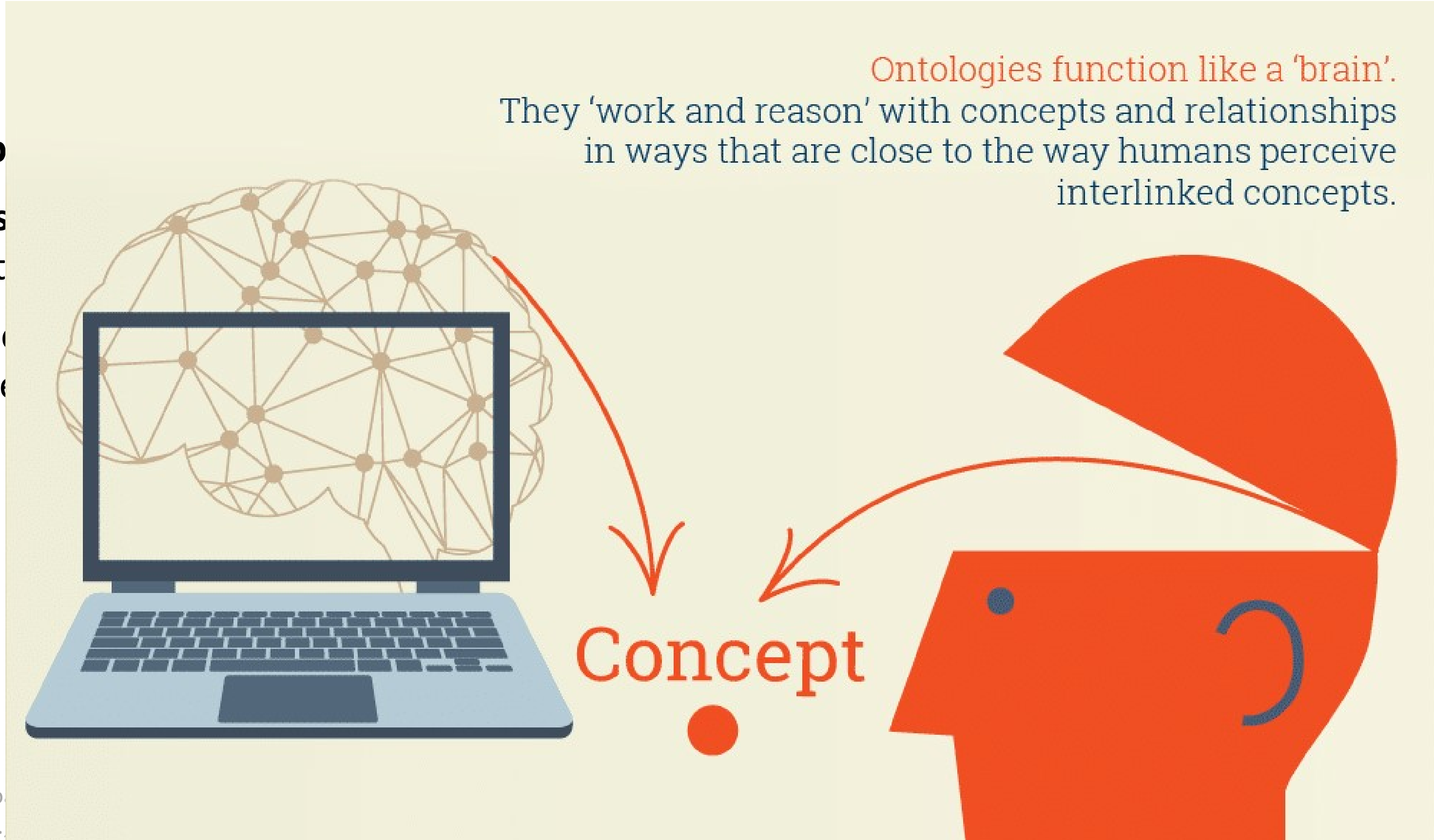

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Ontologies allow to…

- Represent a domain of interest
- Process the meaning of information automatically
- Relate and integrate heterogeneous data
- Automatically deduce implicit (non-evident) information from existing (evident) information (through **Reasoning**)

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Knowledge Representation & Ontology Development

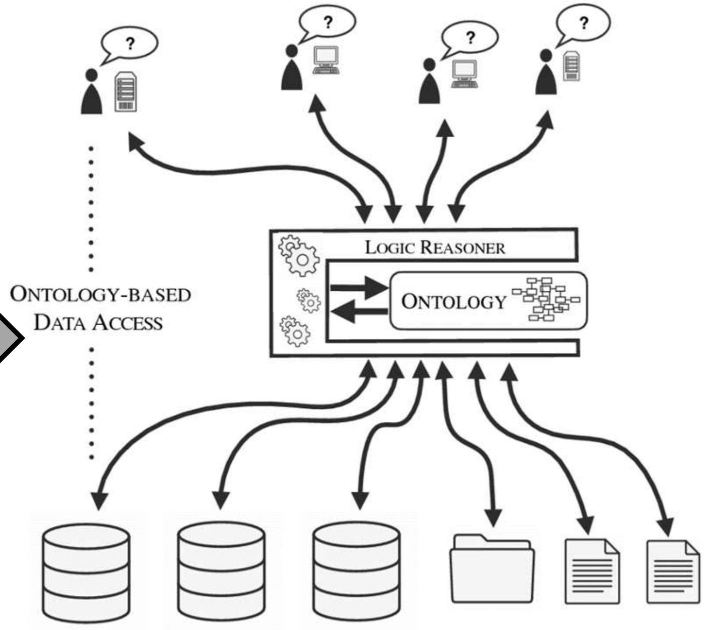
Ontology

Idea:

Explicitly express meaning in a machine-understandable manner using formal and standardized knowledge representations

Goal:

- Knowledge sharing and reuse
- Make domain knowledge explicit
- Facilitate communication among people and machines
- Create interoperability between software agents



Schneider, T., Šimkus, M. Ontologies and Data Management: A Brief Survey. Künstl Intell 34, 329–353 (2020)

Knowledge Representation & Ontology Development

Shared Concept - Breakdown

An ontolo… …tualization

Machine…

What is Maintenance?

Checks, measurements, adjustments, parts replacement, and cleaning, performed specifically to prevent faults from occurring [Wikipedia]

A fault is defined as an abnormal condition or defect at the component, equipment, or sub-system level which may lead to a failure [Wikipedia].

Studer, Benjamins, Fensel. Knowledge Engineering: Principles and Methods. Data and Knowledge Engineering. 25 (1998) 161-197

Knowledge Representation & Ontology Development

Shared Concept - Breakdown

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

Machine-readable

Concepts, properties relations, functions, constraints, axioms…are explicitly defined

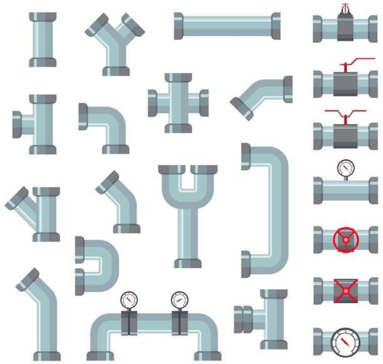
Consensual Knowledge

Studer, Benjamins, Fensel. Knowledge Engineering: Principles and Methods. Data and Knowledge Engineering. 25 (1998) 161-197

Knowledge Representation & Ontology Development

Shared Knowledge - Example

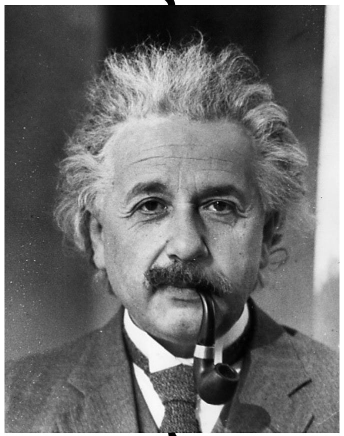
- **Agreement** on the meaning of the vocabulary used to **share knowledge**



A tube used to convey water, gas, oil, or other fluid substance

"We might need a pipe"

"I need a new pipe"



A device for smoking tobacco

"People [and machines!] can't share knowledge if they don't speak a common language." [Davenport, Prusak 98]

Knowledge Representation & Ontology Development

Shared Concept - Breakdown

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

Machine-readable

Concepts, properties relations, functions, constraints, axioms…are explicitly defined

Consensual Knowledge

Abstract model and simplified view of some phenomenon in the world that we want to represent

Studer, Benjamins, Fensel. Knowledge Engineering: Principles and Methods. Data and Knowledge Engineering. 25 (1998) 161-197

Knowledge Representation & Ontology Development

Shared Concept - Breakdown

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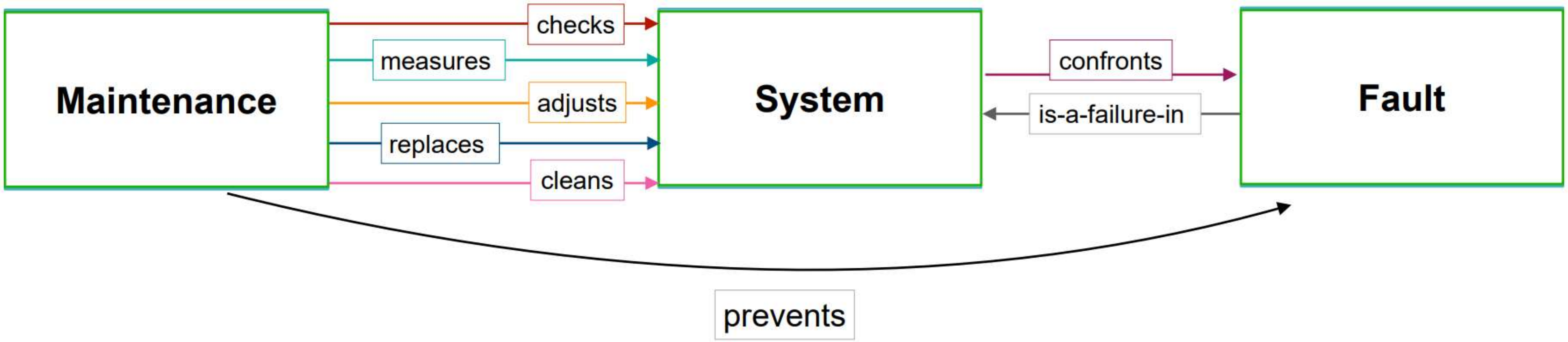

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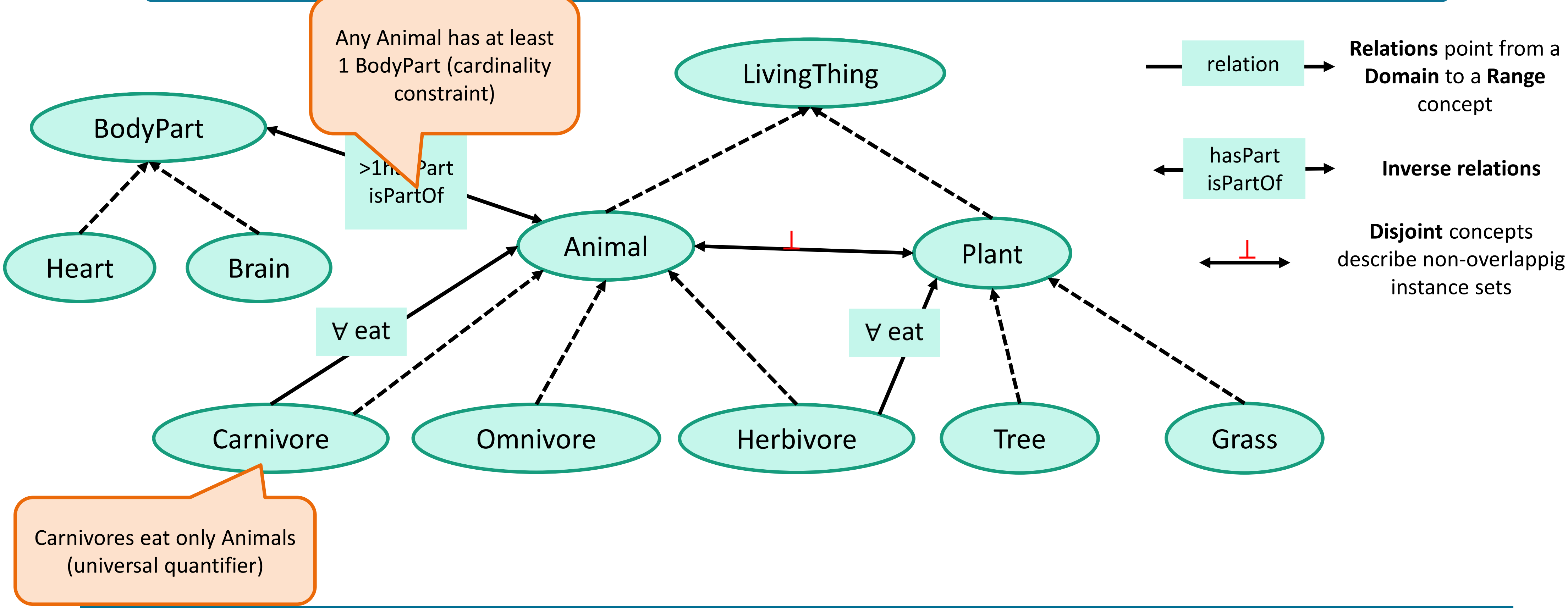
Studer, Benjamins, Fensel. Knowledge Engineering: Principles and Methods. Data and Knowledge Engineering. 25 (1998) 161-197

Ontology Development

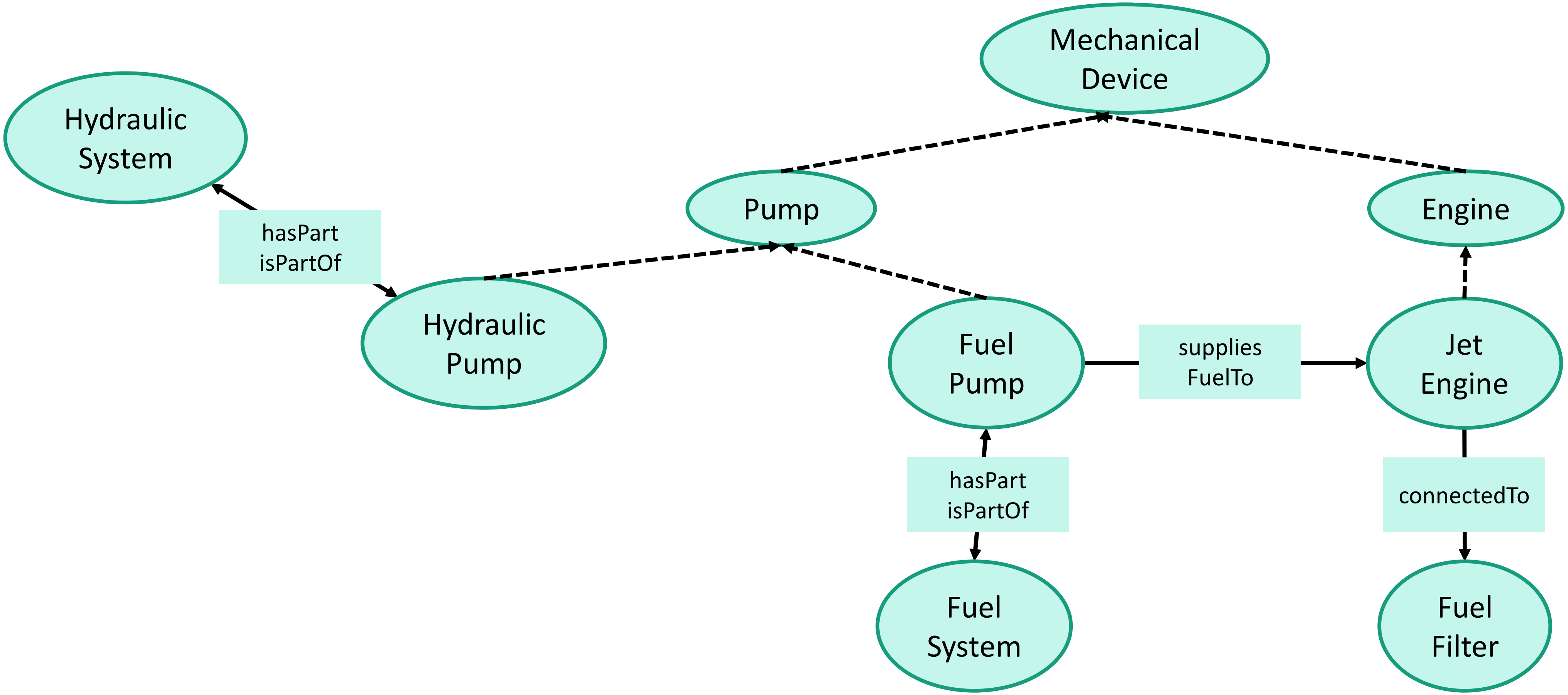
A Taxonomy

An **Ontology** could also be viewed as: a taxonomy extended with other relations and further constraints



Ontology Development

Example



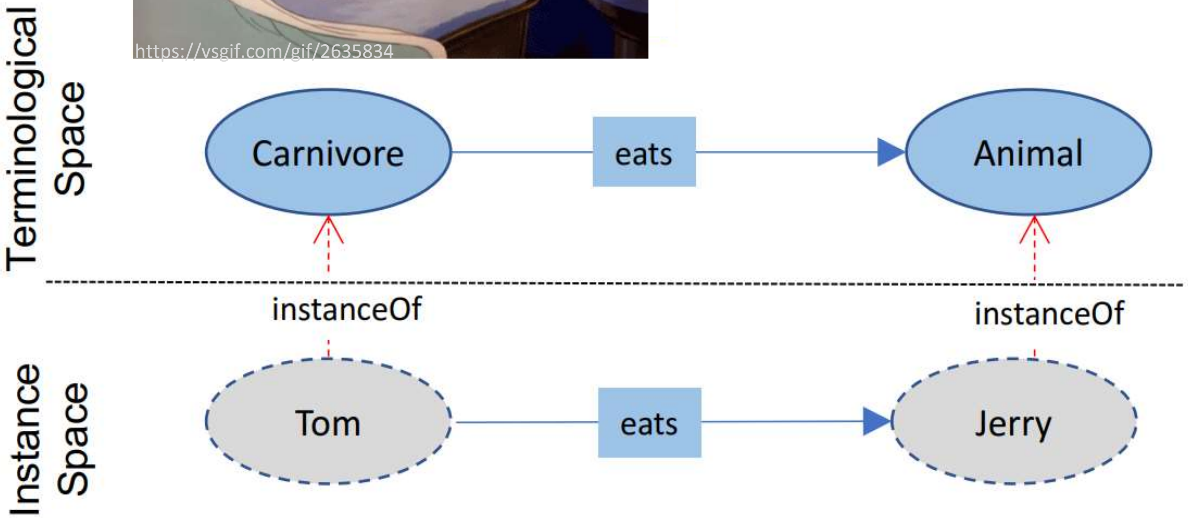
Ontology Development

Instances/Entities

https://vsgif.com/gif/2635834

Metadata to describe the image:

- *Tom is a Carnivore*
- *Jerry is an Animal*
- *Tom eats Jerry*

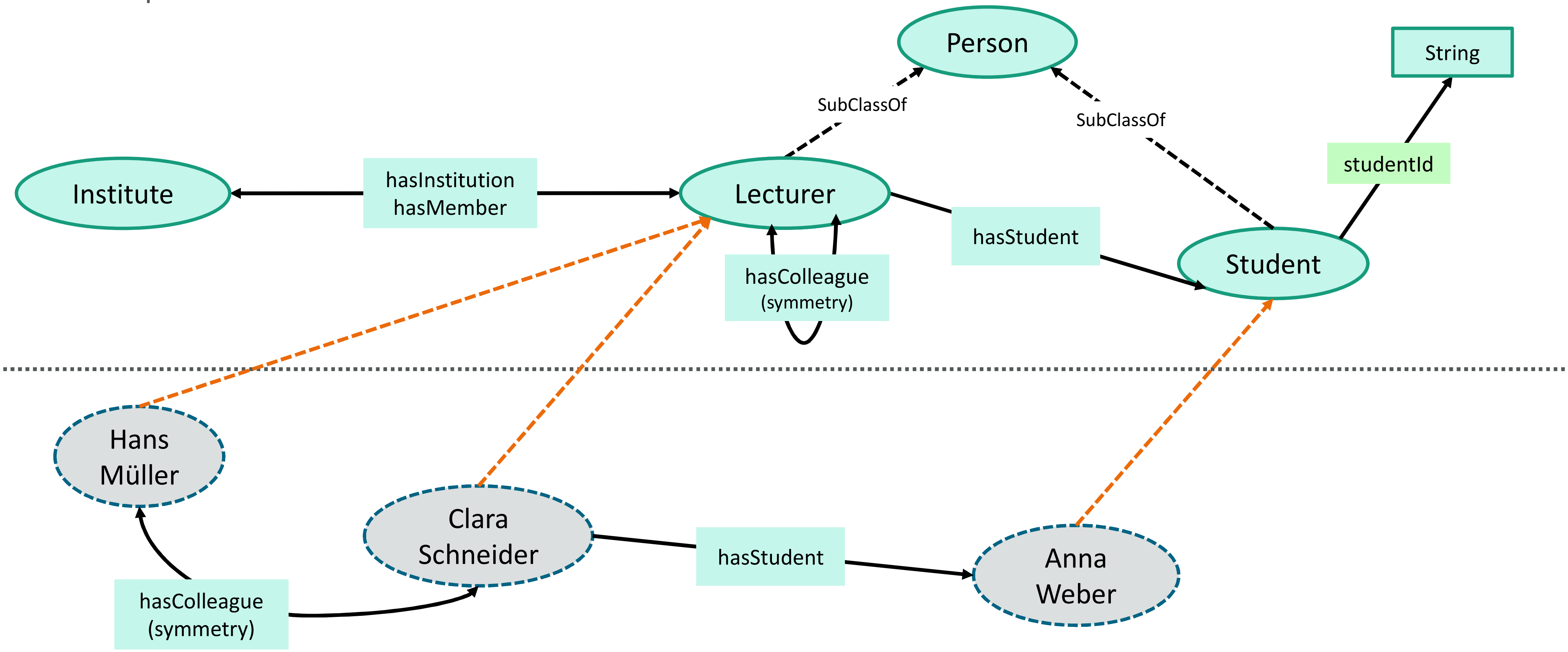


Instance represents an entity in the universe of discourse.

Types the instance with respect to a concept (the instance is of type concept).

Ontology Development

Example



Ontology Development

What is inside an ontology? - Recap

Concepts:

- Denote the main concepts of the domain
  - Carnivore, animal, pump, engine

Restrictions on relations:

- Type, cardinality
  - Any animal has at least one body part

Concept hierarchy:

- Denotes specialization/generalizations
  - Carnivore is a kind of animal

Instances:

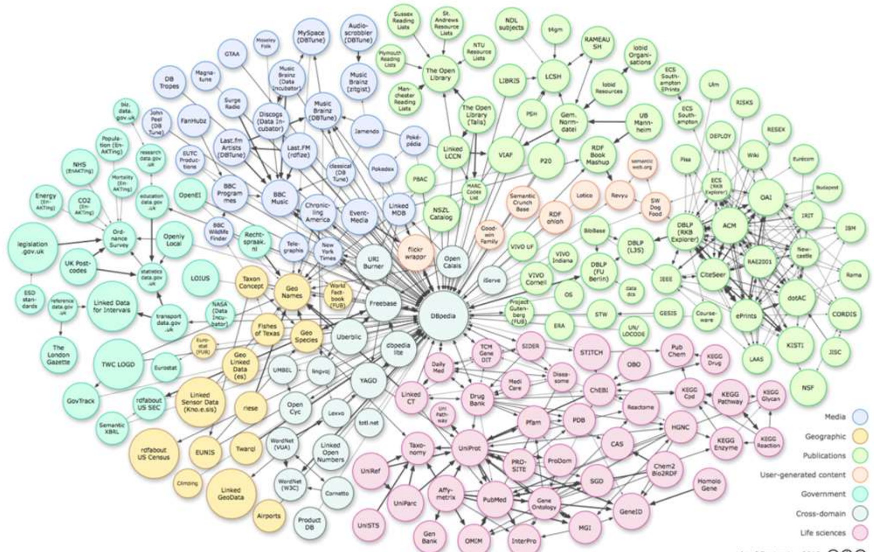
- Denote concrete entities in the domain
  - Tom, Jerry

Relations between classes:

- Denotes specialization/generalizations
  - Carnivore eats animal

https://medium.com/analytics-vidhya/ontologies-in-detail-2916f9226133

…

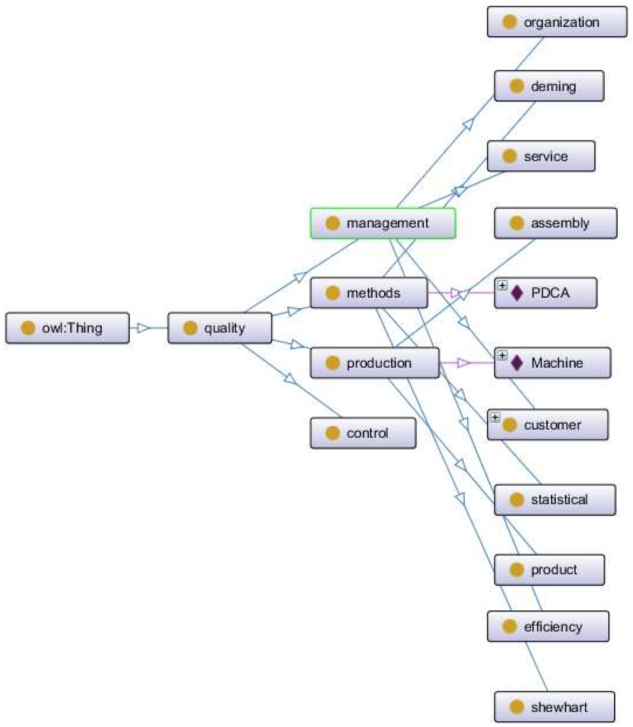

https://hangingtogether.org/linked-data-survey-results-why-and-what-institutions-are-publishing/

BUILDING AN ONTOLOGY

Building an Ontology

Methodologies for Building Ontology

- METHONTOLOGY
- Ontology Development 101
- On-To-Knowledge
- TOrontoVirtual Enterprise (TOVE)
- DILIGENT
- UPON Lite
- Adapted from NeOn
- Uscholdand King Methodology
- Holsappleand Joshi‘s approach
- UPON
- HCOME

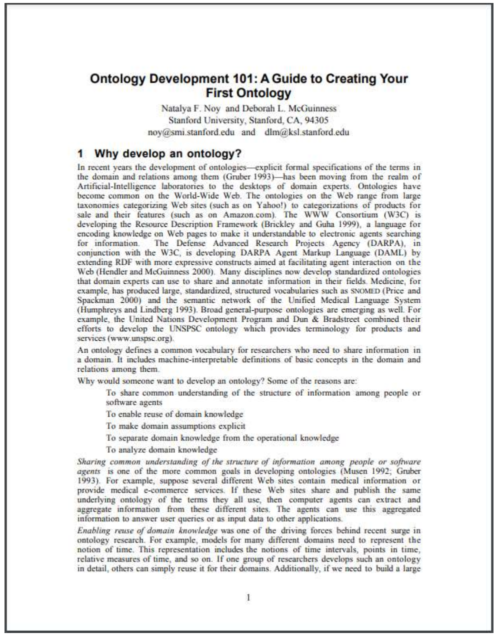


Building an Ontology

Ontology 101

1. Determine the scope
2. Consider reuse
3. Enumerate terms
4. Define classes
5. Define properties
6. Define constraints
7. Create instances

Closely interwined



Ontology Development 101: A Guide to Creating Your First Ontology

Natalya F. Noy and Deborah L. McGuinness
Stanford University, Stanford, CA, 94305
noy@smi.stanford.edu and dlm@ksl.stanford.edu

1 Why develop an ontology?

In recent years the development of ontologies—explicit formal specifications of the terms in the domain and relations among them (Gruber 1993)—has been moving from the realm of Artificial-Intelligence laboratories to the desktops of domain experts. Ontologies have become common on the World-Wide Web. The ontologies on the Web range from large taxonomies categorizing Web sites (such as on Yahoo!) to categorizations of products for sale and their features (such as on Amazon.com). The WWW Consortium (W3C) is developing the Resource Description Framework (Brickley and Guha 1999), a language for encoding knowledge on Web pages to make it understandable to electronic agents searching for information. The Defense Advanced Research Projects Agency (DARPA), in conjunction with the W3C, is developing DARPA Agent Markup Language (DAML) by extending RDF with more expressive constructs aimed at facilitating agent interaction on the Web (Hendler and McGuinness 2000). Many disciplines now develop standardized ontologies that domain experts can use to share and annotate information in their fields. Medicine, for example, has produced large, standardized, structured vocabularies such as SNOMED (Price and Spackman 2000) and the semantic network of the Unified Medical Language System (Humphreys and Lindberg 1993). Broad general-purpose ontologies are emerging as well. For example, the United Nations Development Program and Dun & Bradstreet combined their efforts to develop the UNSPSC ontology which provides terminology for products and services (www.unspsc.org).

An ontology defines a common vocabulary for researchers who need to share information in a domain. It includes machine-interpretable definitions of basic concepts in the domain and relations among them.

Why would someone want to develop an ontology? Some of the reasons are:

- To share common understanding of the structure of information among people or software agents
- To enable reuse of domain knowledge
- To make domain assumptions explicit
- To separate domain knowledge from the operational knowledge
- To analyze domain knowledge

Sharing common understanding of the structure of information among people or software agents is one of the more common goals in developing ontologies (Musen 1992; Gruber 1993). For example, suppose several different Web sites contain medical information or provide medical e-commerce services. If these Web sites share and publish the same underlying ontology of the terms they all use, then computer agents can extract and aggregate information from these different sites. The agents can use this aggregated information to answer user queries or as input data to other applications.

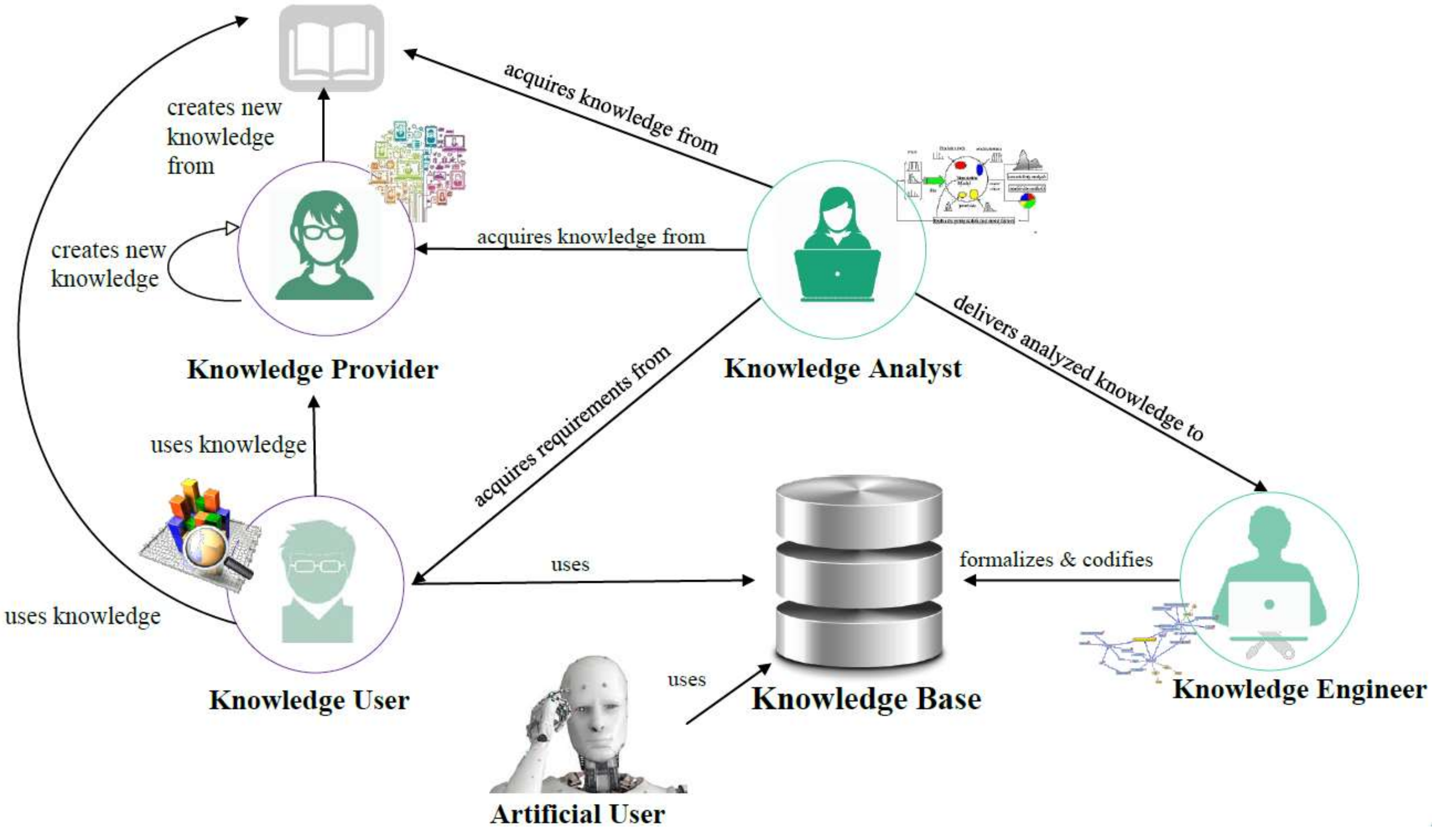
Enabling reuse of domain knowledge was one of the driving forces behind recent surge in ontology research. For example, models for many different domains need to represent the notion of time. This representation includes the notions of time intervals, points in time, relative measures of time, and so on. If one group of researchers develops such an ontology in detail, others can simply reuse it for their domains. Additionally, if we need to build a large

1

N. Noy, D. McGuiness "Ontology Development 101: A Guide to Creating Your First Ontology", 2001

Knowledge Representation

Who are involved in Representing Knowledge



M. Khobreh, Ontology Enhanced Representing and Reasoning of Job Specific Knowledge to Identify Skill Balance, University of Siegen, Germany, 2017

Knowledge Representation & Ontology Development

Building an Ontology - Class

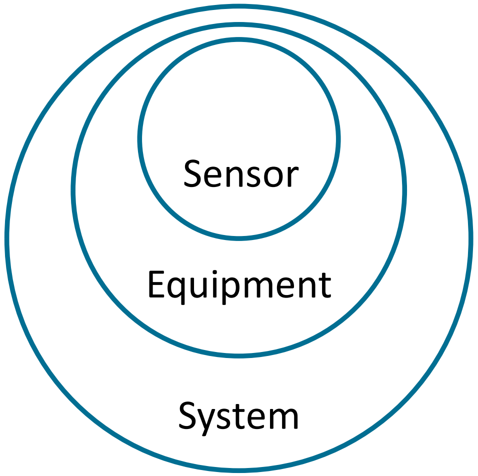
- Defining **concepts** in the domain (classes)
- Typical **candidates** for classes are **NOUNS**, however…
  - actors of use cases do not necessarily correspond to classes

    →Example: “Oil leakage is a **type of** Leakage”
  - Recap: Knowledge Acquisition in METHONTOLOGY
- **How to define classes:**
  - **Interview**: Talk to subject matter experts
  - **Documentation**: read what experts have written about the subject matter, read the requirements documentation, read proposals and invitations to tender
  - **Observation**
  - **Reflection**

Knowledge Representation & Ontology Development

Building an Ontology - Class

Class Hierarchy



- Classes represent **concepts** in the domain and **not** the **words** that denote these concepts

  → Synonyms for the same concept do not represent different classes

- All the **siblings** in the hierarchy (except for the ones at the root) must be at the **same level** of generality

- A **sub-class** of a class represents a concept that is a “**kind of**” the concept that the super-class represents

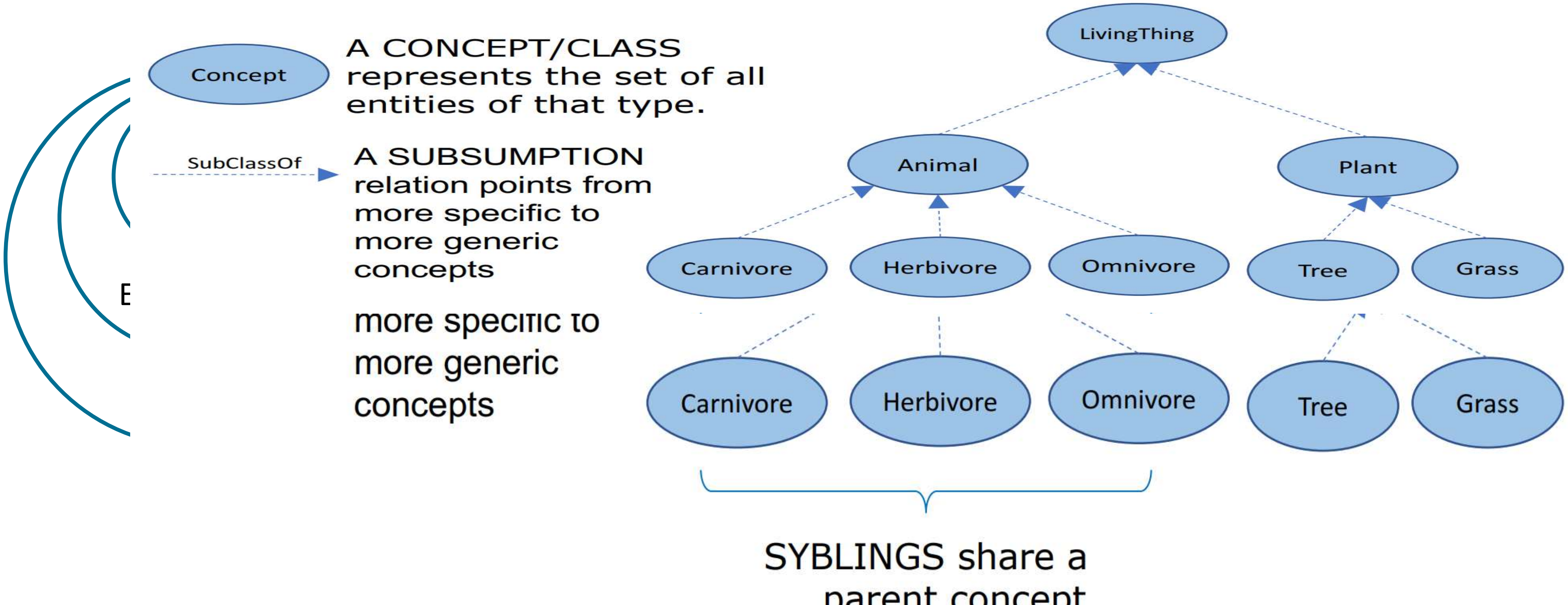
- If a class has only **one direct sub-class** there may be a **modeling problem** or the ontology is not complete

- If there are **more than a dozen sub-classes** for a given class then **additional intermediate** categories may be **necessary**

Knowledge Representation & Ontology Development

Building an Ontology - Class

Class Hierarchy



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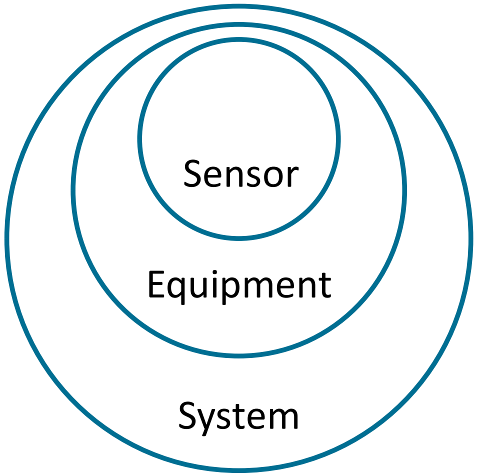
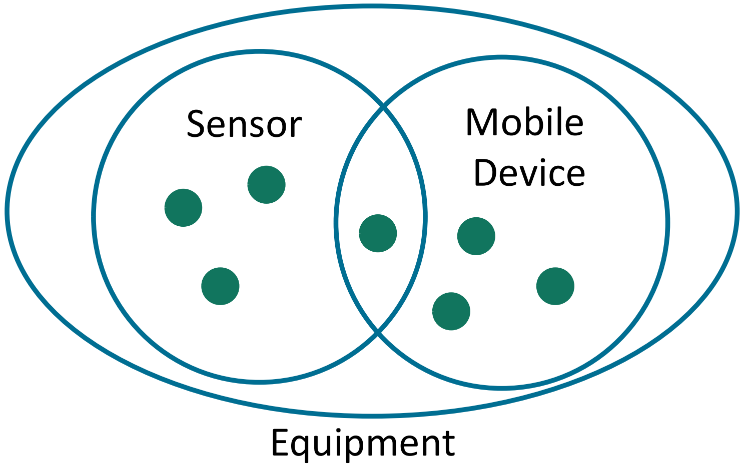
Based on: M. Sabou & E. Fajar “Introduction to Semantic Systems", 2019

Knowledge Representation & Ontology Development

Building an Ontology - Class

Class Hierarchy	**Overlap Classes**





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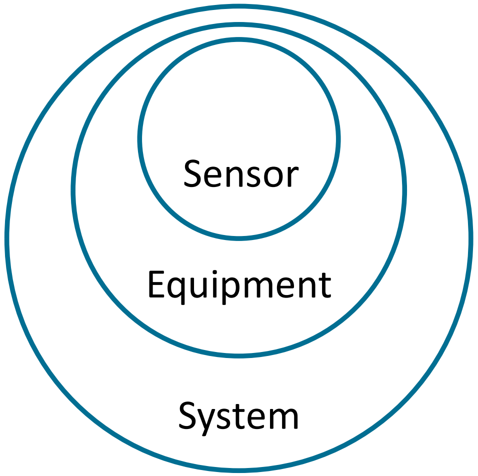
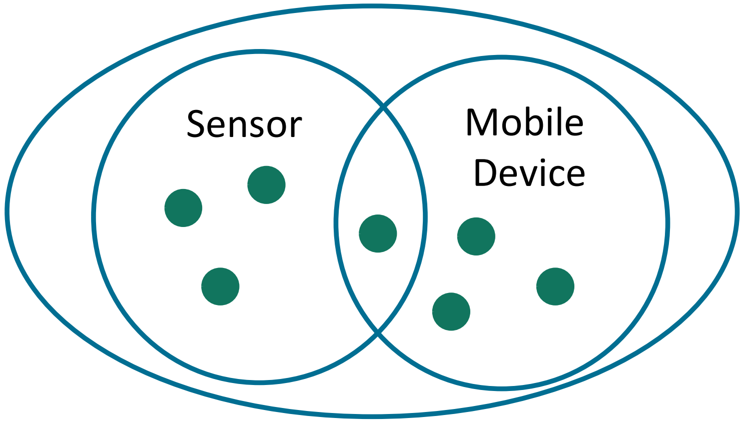
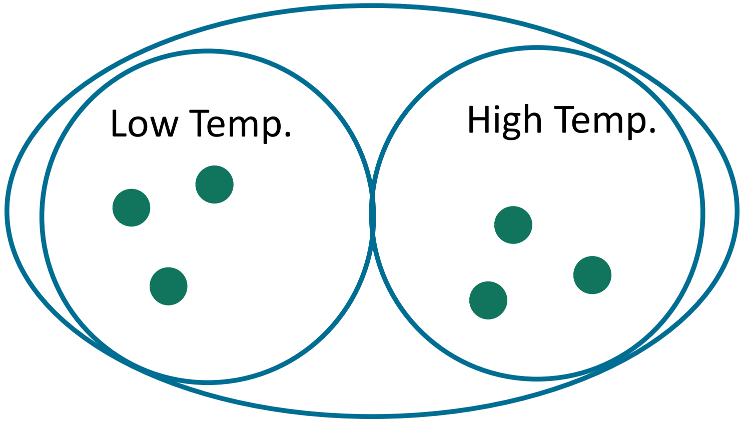
Building an Ontology - Class

Class Hierarchy	Overlap Classes	Disjoint Classe





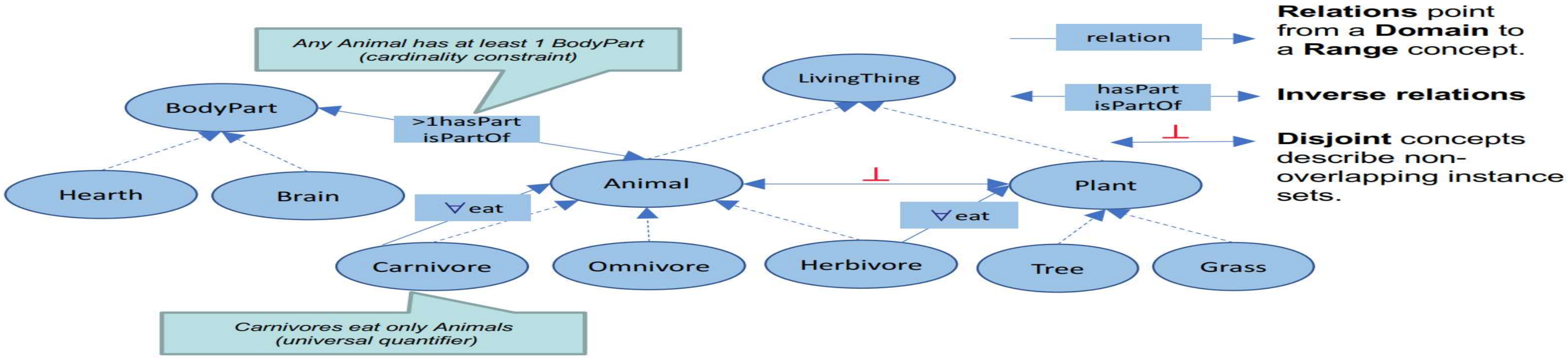


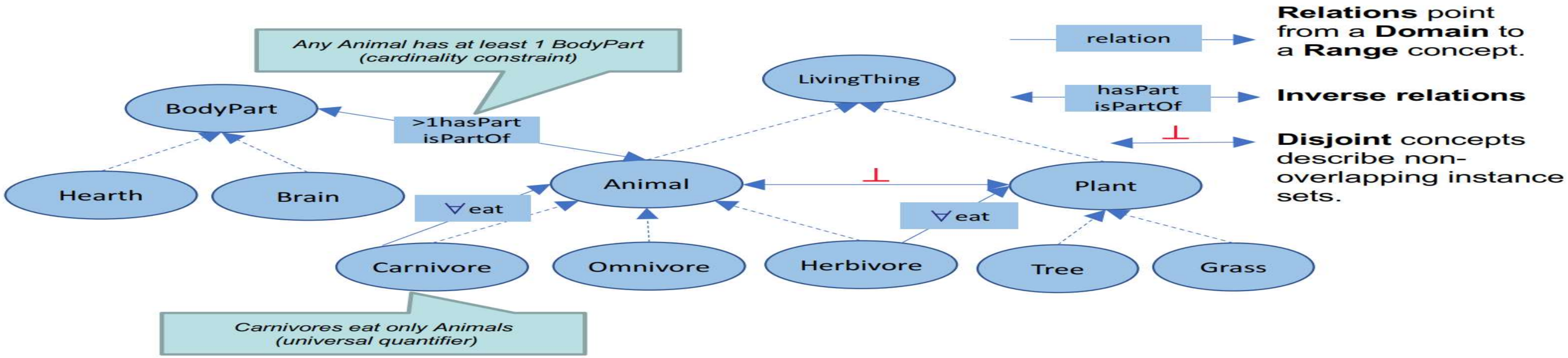
- Classes are disjoint if they **cannot have common instances**
- Disjoint classes **cannot have any common sub-classes** either

Knowledge Representation & Ontology Development

Building an Ontology - Class

Class Hi





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Knowledge Representation & Ontology Development

Building an Ontology - Relationships

- Typical **candidates** for relations are **VERBS**
  - verbal phrases and things that could have been verbs
    - → Example: “Oil leakage **is a** type of Leakage”
  - Recap: Knowledge Acquisition in METHONTOLOGY
- **How to define relationships:**
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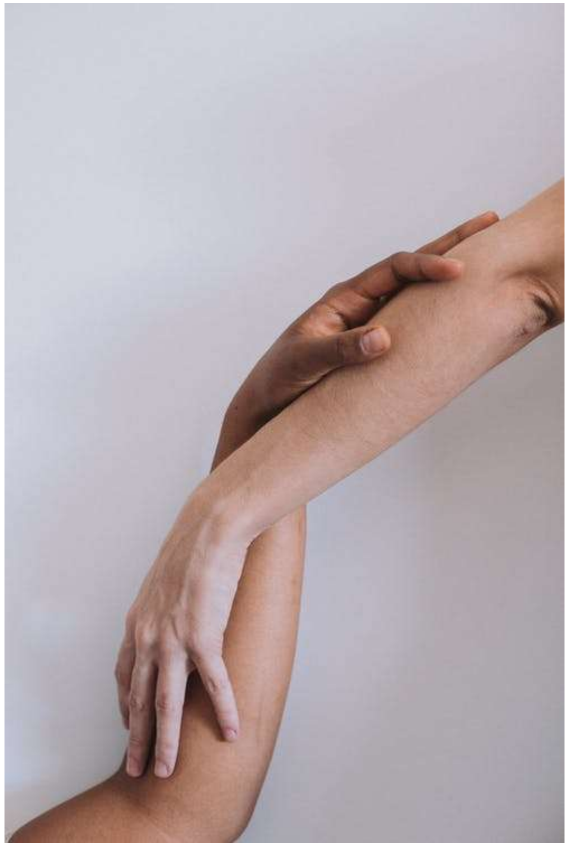
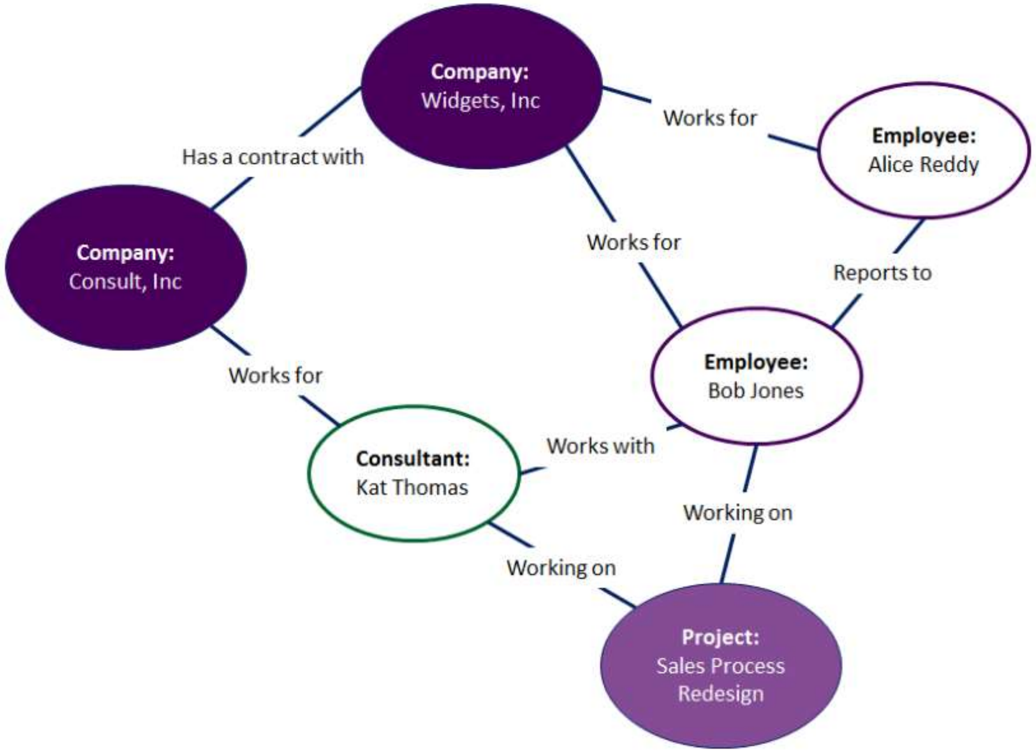
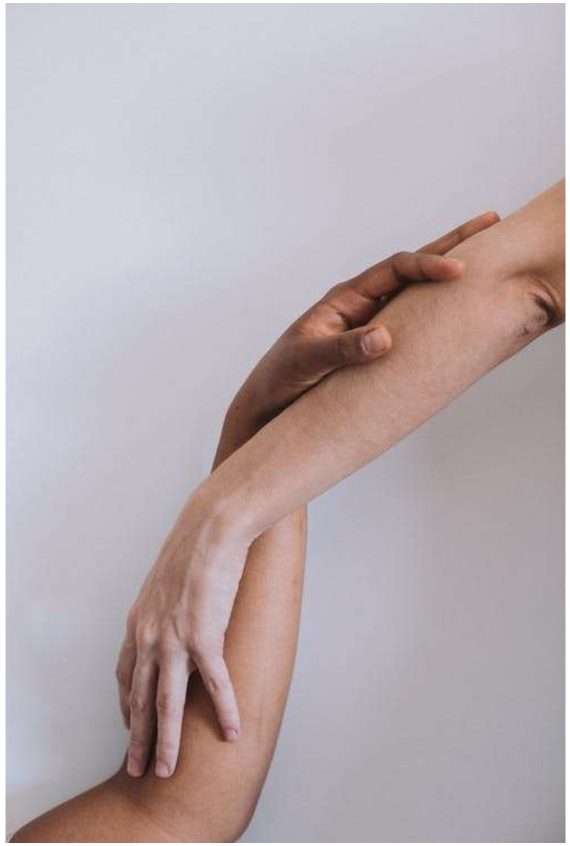


Knowledge Representation & Ontology Development
Building an Ontology - Relationships

- Typical
  - verb
  - Reca
- **How tc**
  - **Inter**
  - **Docu** subje prop
  - **Obse**
  - **Refle**



https://www.linkedin.com/pulse/ontology-data-science-favio-v%C3%A1zquez/



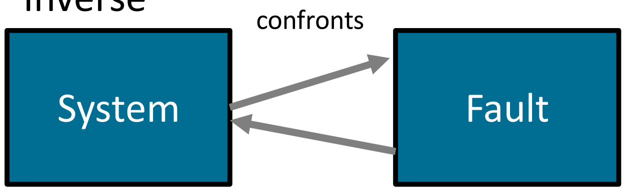
Knowledge Representation & Ontology Development

Building an Ontology – Relationship Characteristics 1/2

Inverse

- If relation ***p*** has inverse relation ***q***, and ***p*** links ***A*** to ***B***, then it can be inferred that ***q*** links ***B*** to ***A***

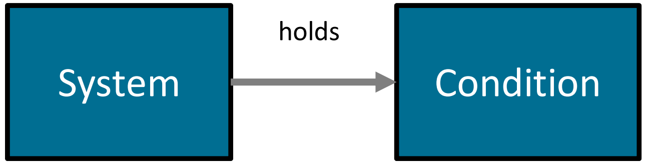
Inverse



Functional

- For a given individual, the relation takes only one value

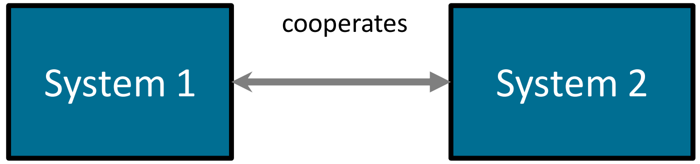
Functional



Symmetric

- If a relation links ***A*** to ***B*** then it can be inferred that it links ***B*** to ***A***

Symmetric



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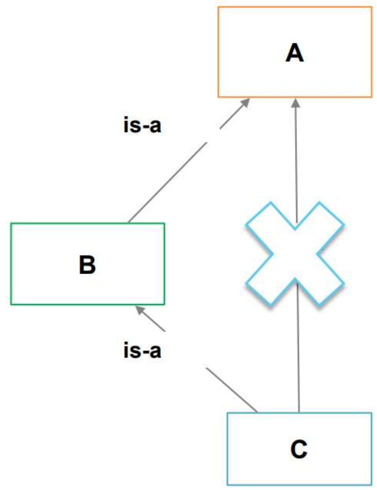
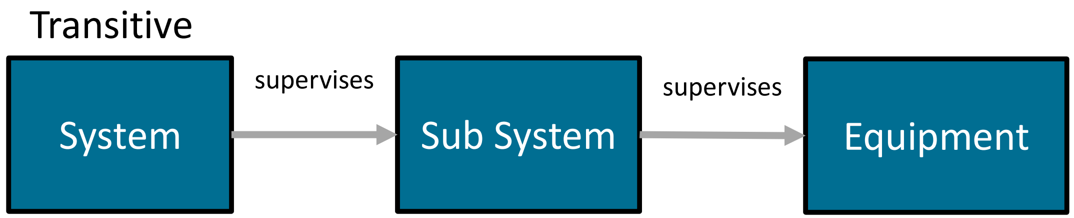
Knowledge Representation & Ontology Development

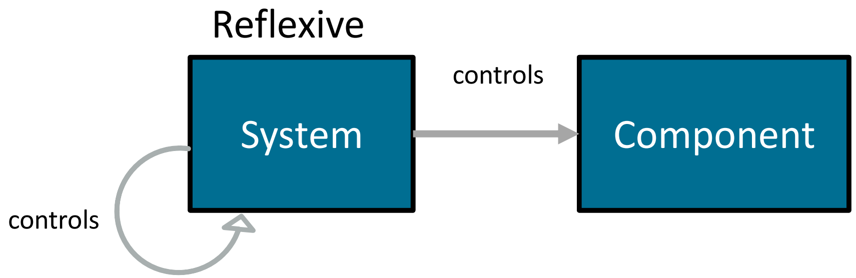
Building an Ontology – Relationship Characteristics 2/2

- **Transitive**: if a relation links ***A*** to ***B***, and ***B*** to ***C*** then it can be inferred that it links ***A*** to ***C***
  - **Danger** of multiple inheritance: cycles in the class hierarchy





- **Reflexive**: if a relation links one node back to itself



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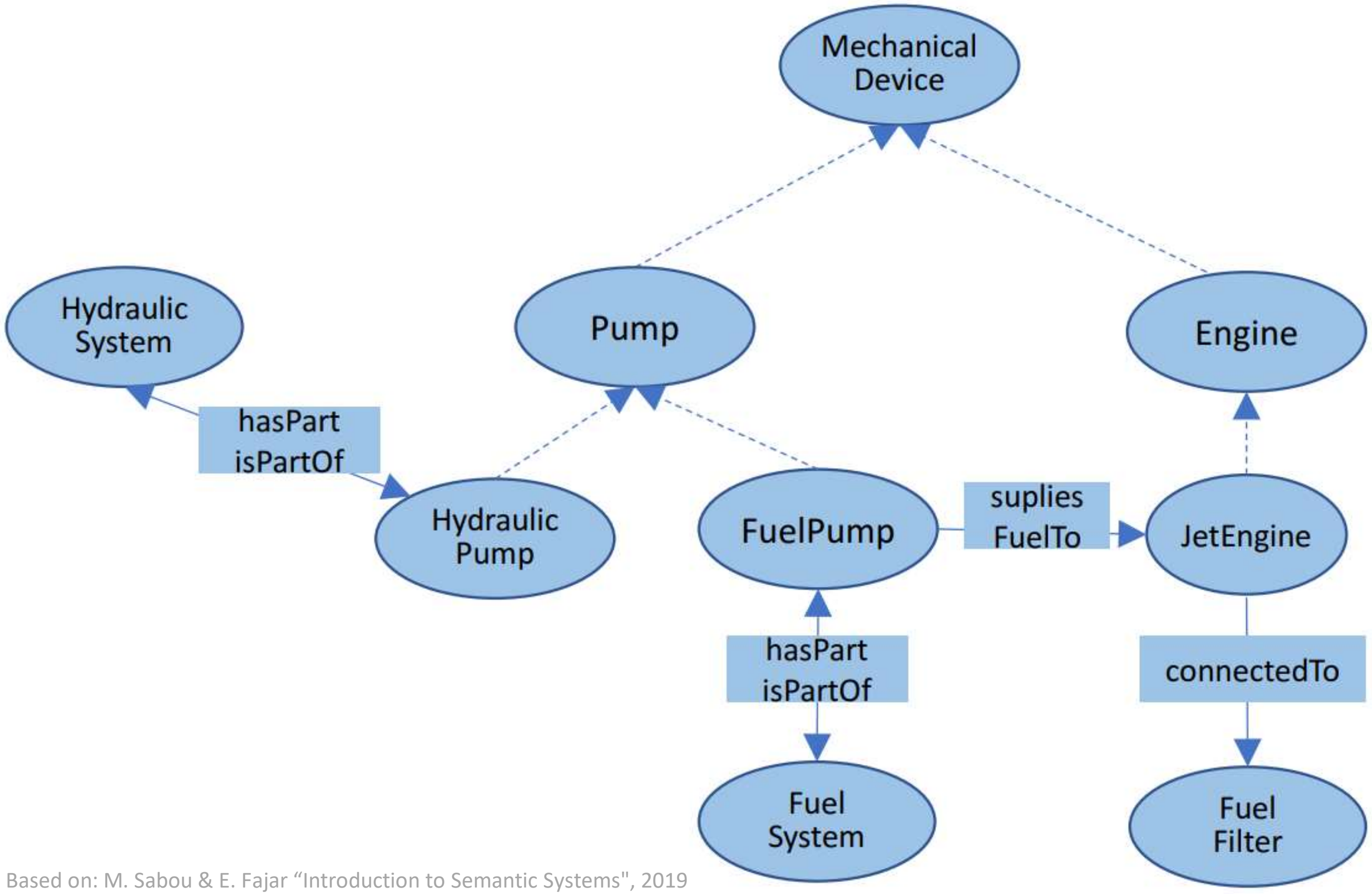
Knowledge Representation & Ontology Development

Building an Ontology – Relationship part-of

- Describes the r
- Existence depe
  - Component



Based on: M. Sabou & E. Fajar "Introduction to Semantic Systems", 2019

Knowledge Representation & Ontology Development

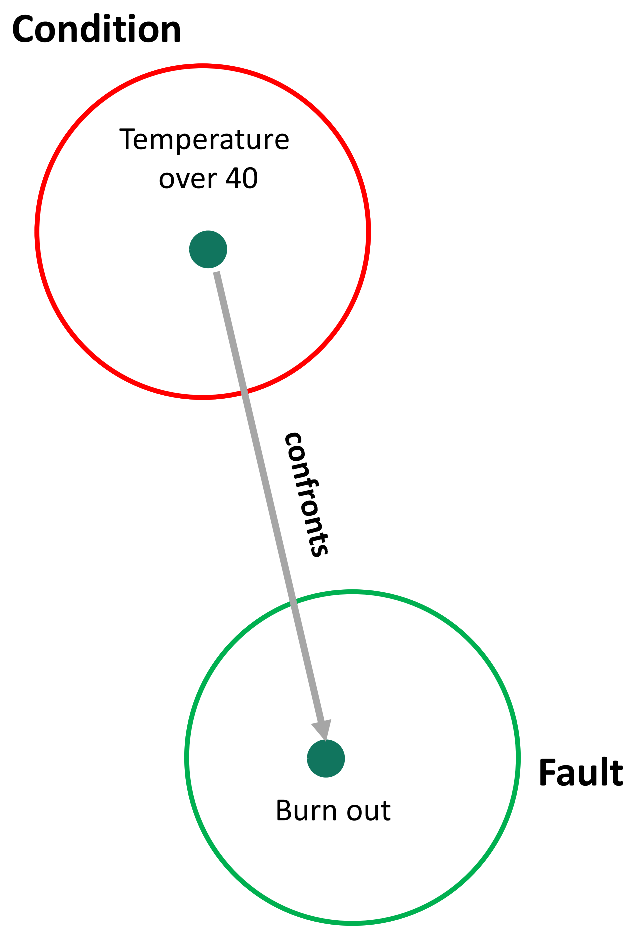
Building an Ontology – Individuals

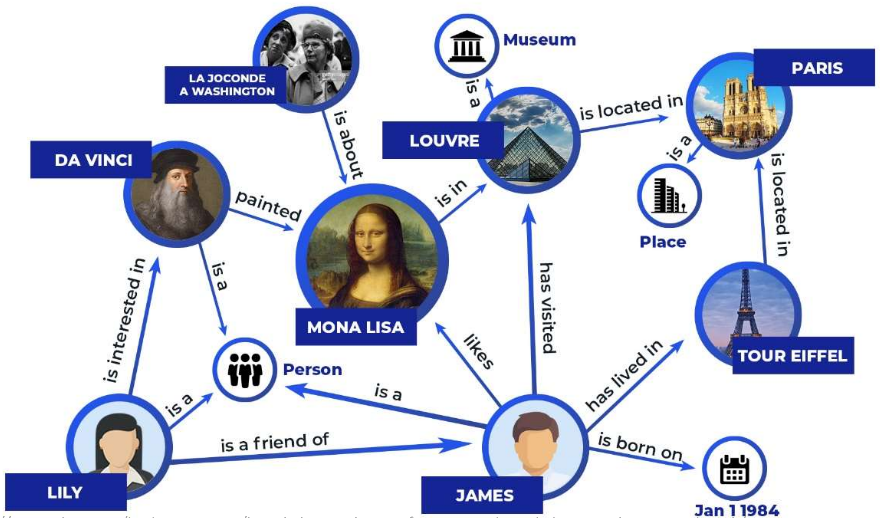
- **Define** an **individual**/instance of a class **requires**…
  - choose a class
  - create an individual instance of that class
  - filling in the values of the properties/relations

- If a relation is:

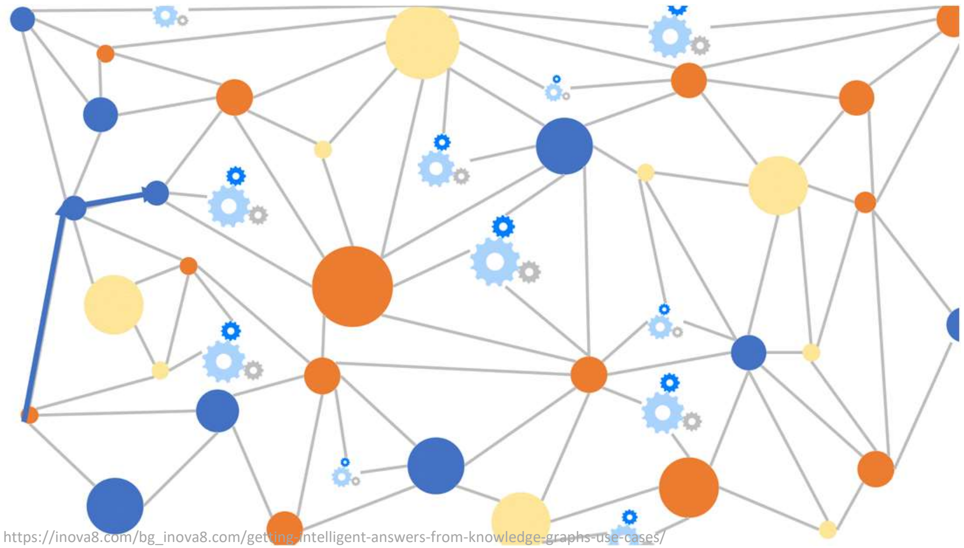
  subject_individual → hasProperty → object_individual

- The **domain** is the class of the **subject** individual
- The **range** is the class of the **object** individual





https://www.wipro.com/business-process/knowledge-graphs-transform-semantic-analytics-towards-a-semantic-web/

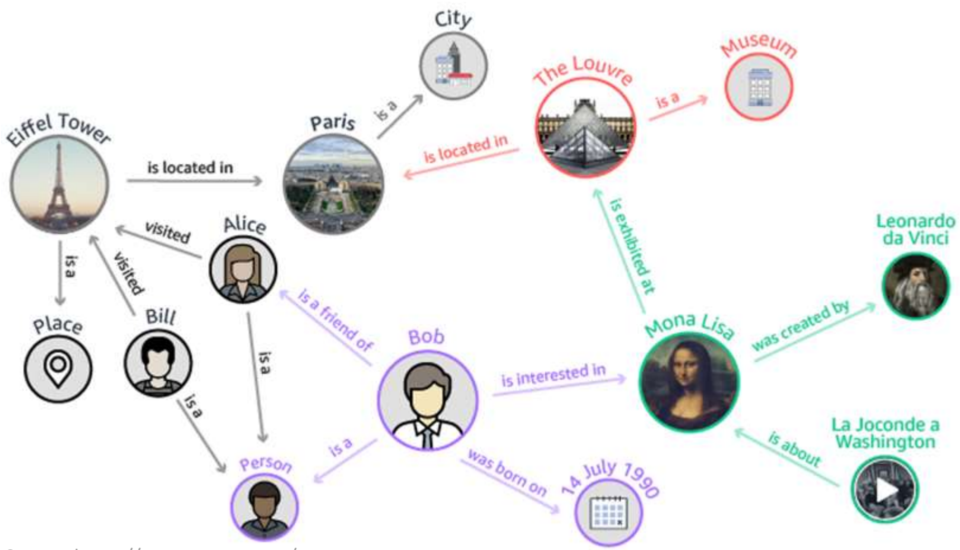

https://inova8.com/bg_inova8.com/getting-intelligent-answers-from-knowledge-graphs-use-cases/

KNOWLEDGE GRAPHS

Knowledge Graphs (KG)

Motivation

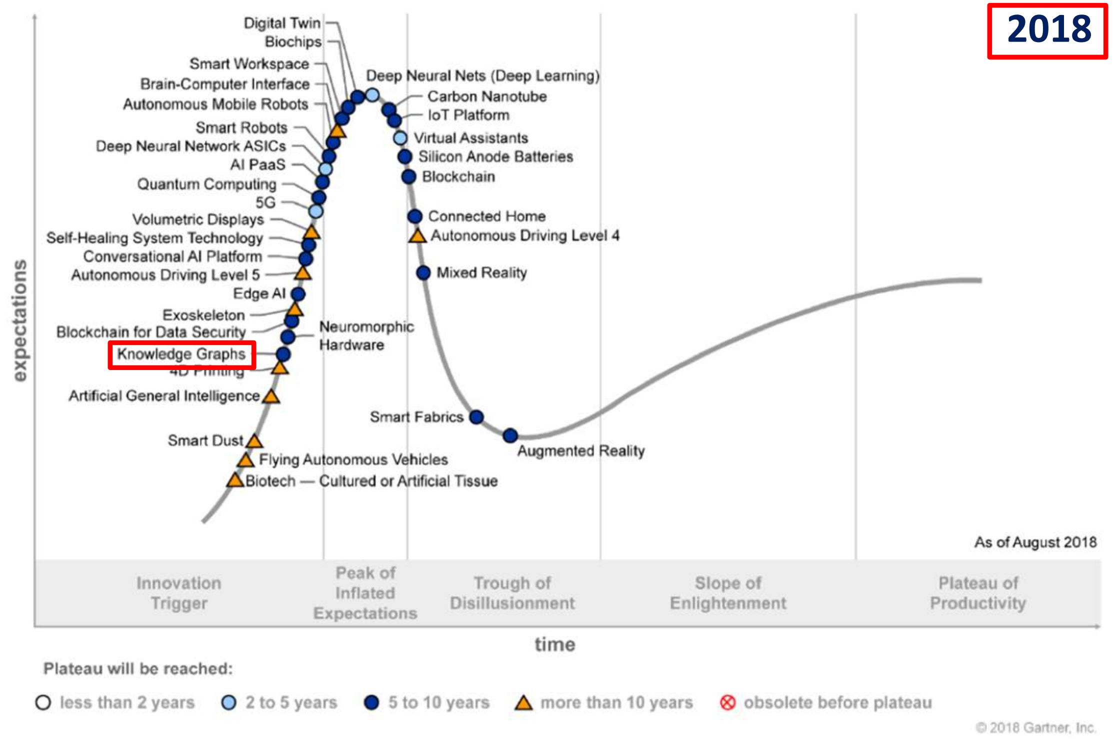
- Knowledge Graphs enable a compelling abstraction for organizing the world's structured knowledge
- Enable a way of integration information extracted form multiple data sources
- Central role in representing information extracted from
  - Natural Language Processing
  - Computer Vision
- A Knowledge Graph is a direct labeled graph where domain specific meaning is associated with nodes and edges
  - Friendships
  - Customer Relationships
  - Supply Chains
  - Manufacturing Processes

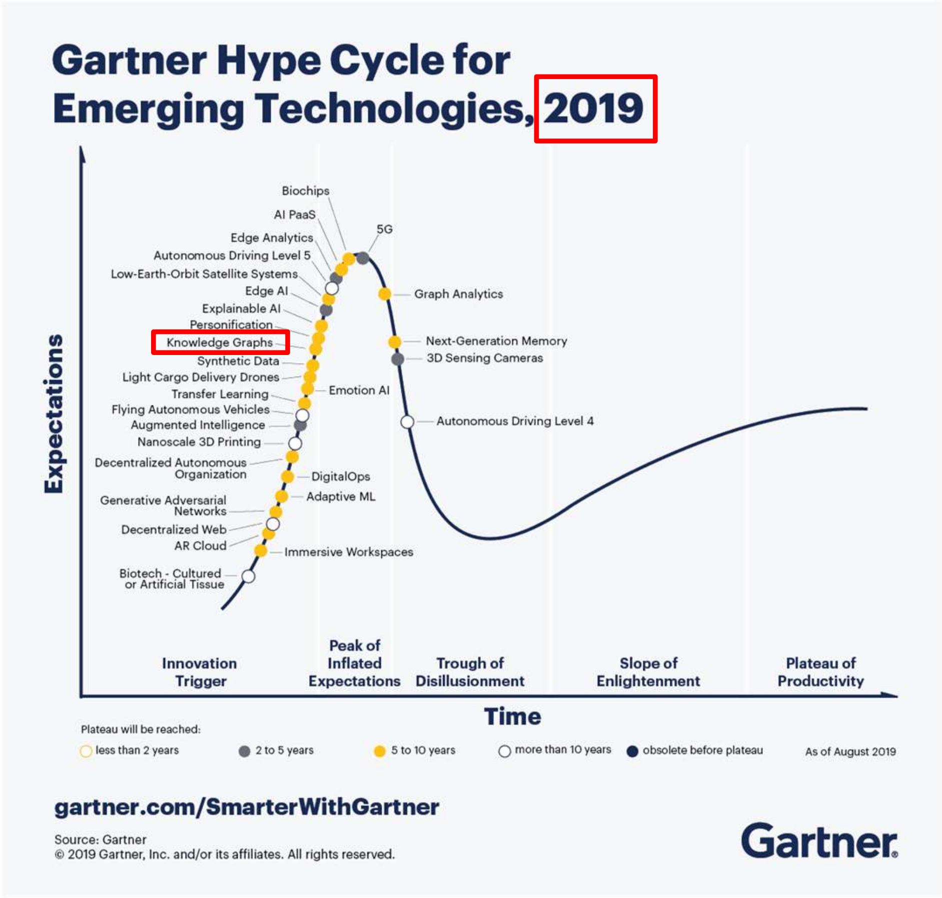


Source: https://aws.amazon.com/

Knowledge Graphs (KG)

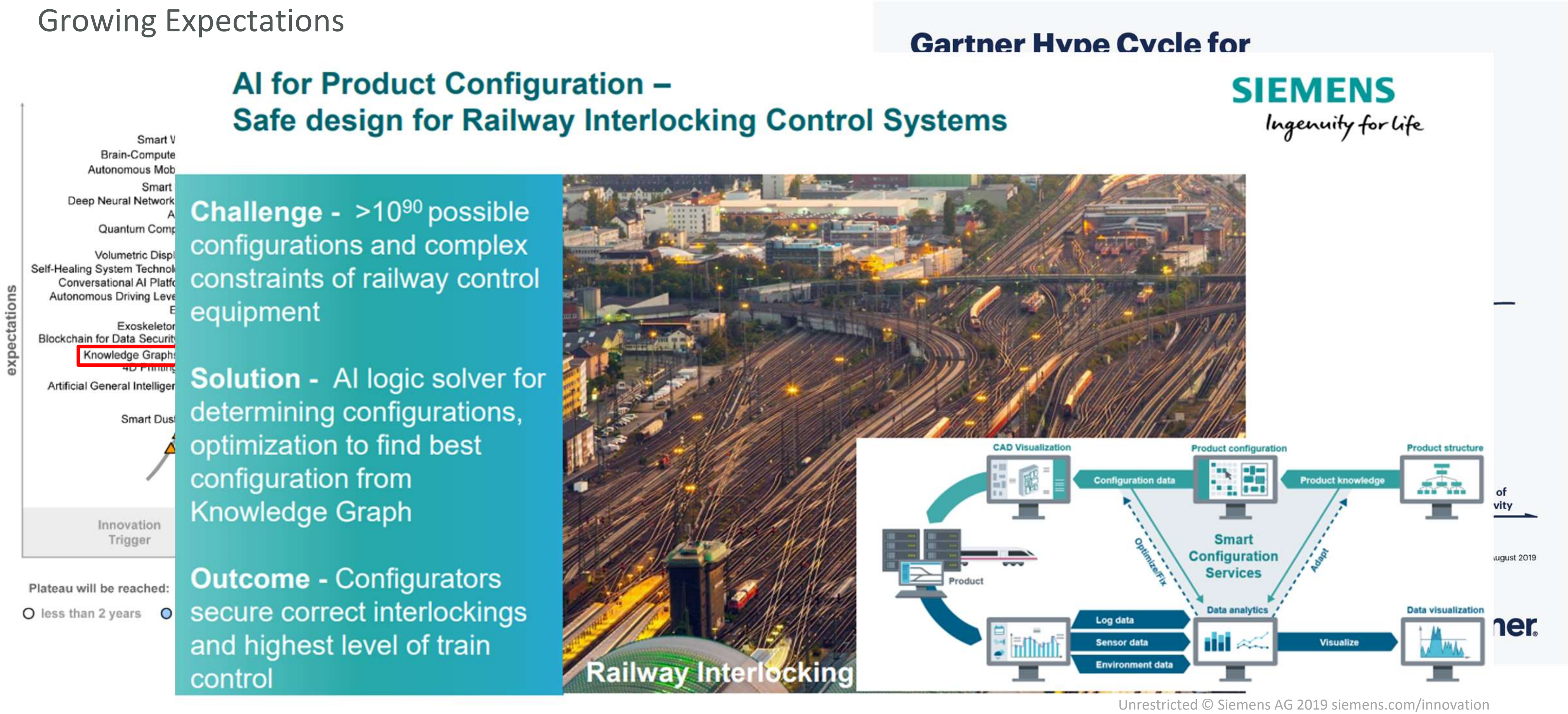
Growing Expectations





Knowledge Graphs (KG)

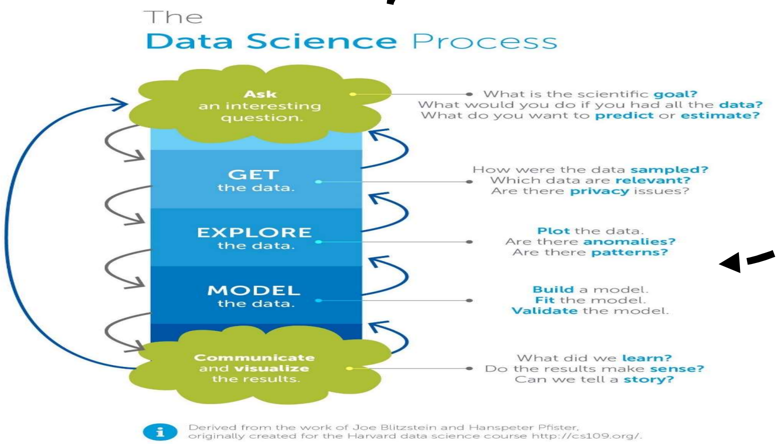
Growing Expectations



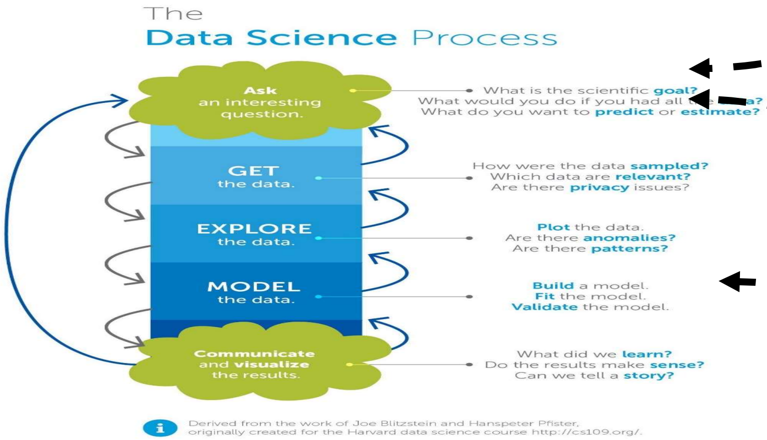
Knowledge Graphs

Technical Value

KG support the data science process



- As data sources for Data Science tasks
- Data integration from heterogeneous sources
- “Knowledge layer” over various data sources
- Representing new types of (graph) data



- Data Scientists have a better understanding of the available data

- Semantic features simplify model building
- Richer knowledge gained from richer data

- Improved transparency of results for end-users (explainable AI)

Knowledge Graphs

Technical Value

KG support the data science process

- As data sources for Data Science tasks

users (explainable AI)

Knowledge Graphs

Technical Value

KG enable high-level applications

- **Search Applications**

https://www.found.co.uk/blog/googles-knowledge-graph/#.Yn4_nuhByUk

- **Knowledge Discovery**

- **Discovery** implicit links and patterns in knowledge graphs
- **Gartner**: *“graph analysis is possibly the single most effective competitive differentiator for organizations pursuing data-driven operations and decisions”*

Knowledge Graphs

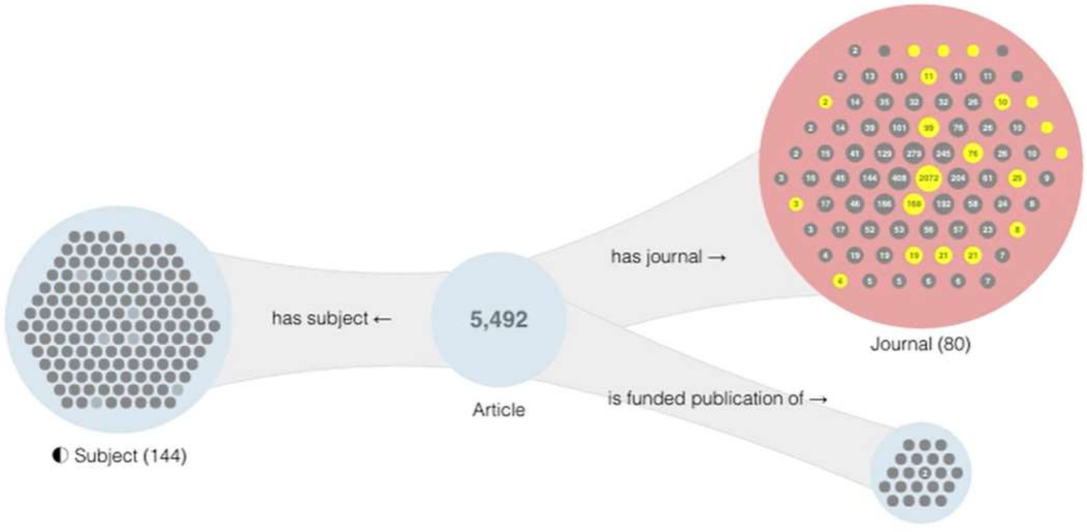
Technical Value

KG enable high-level applications

- **Search Applications**

https://www.semspect.de/

- **Knowledge Discovery**



https://www.semspect.de/

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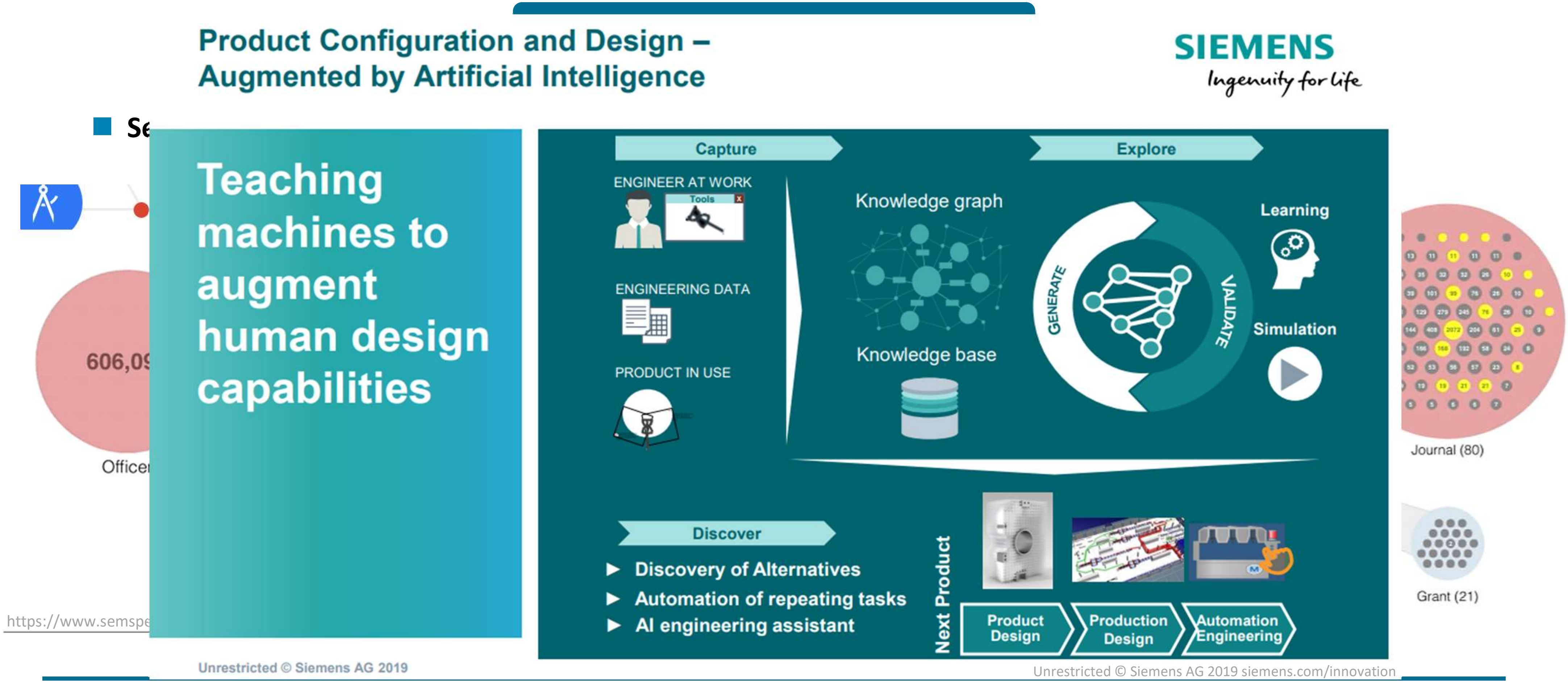
Knowledge Graphs

Technical Value

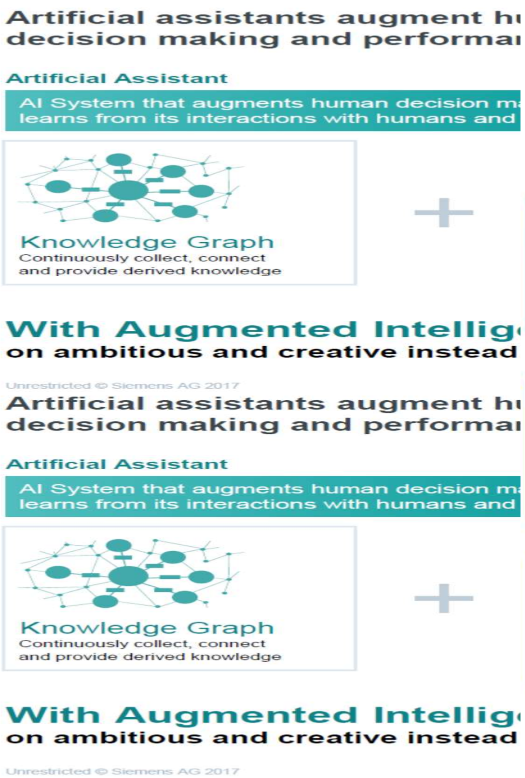


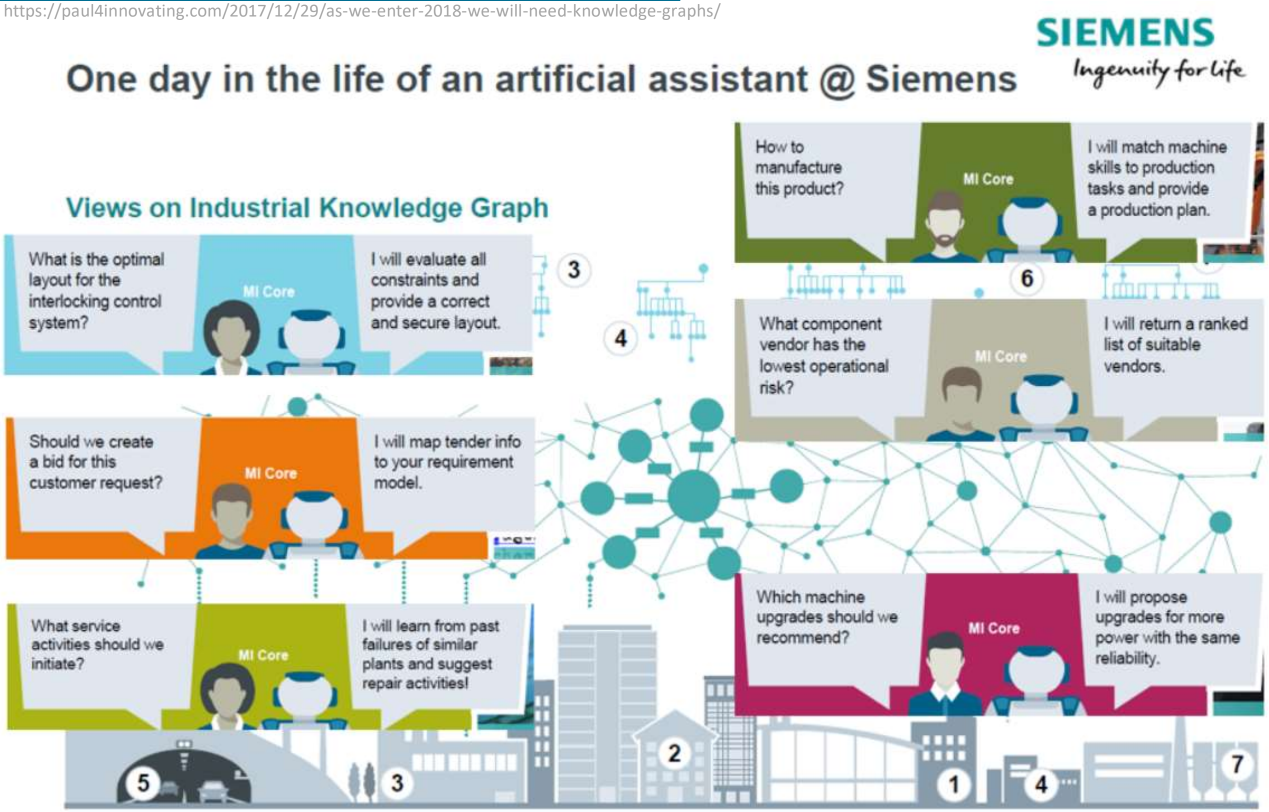
Knowledge Graphs

Technical Value

KG are key to industrial AI applications

https://paul4innovating.com/2017/12/29/as-we-enter-2018-we-will-need-knowledge-graphs/

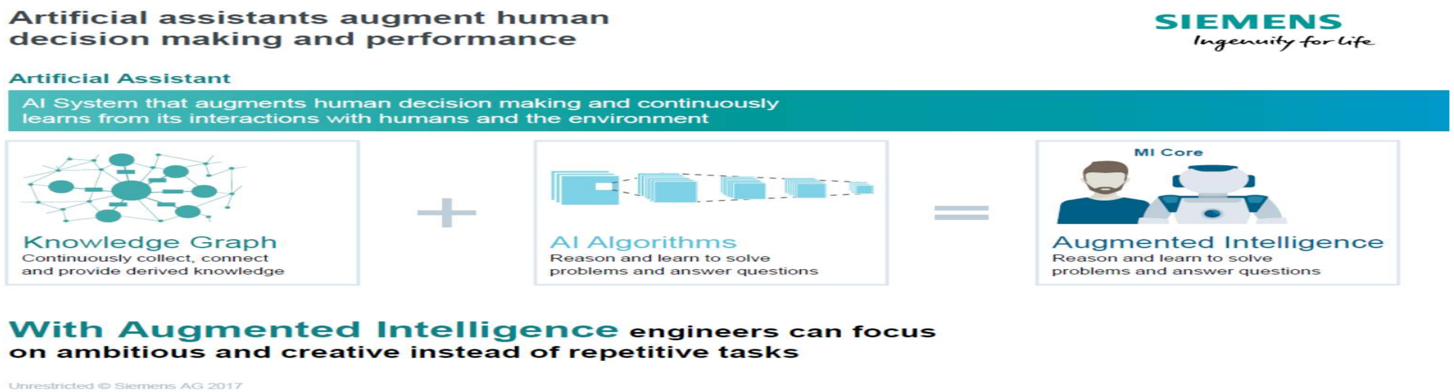


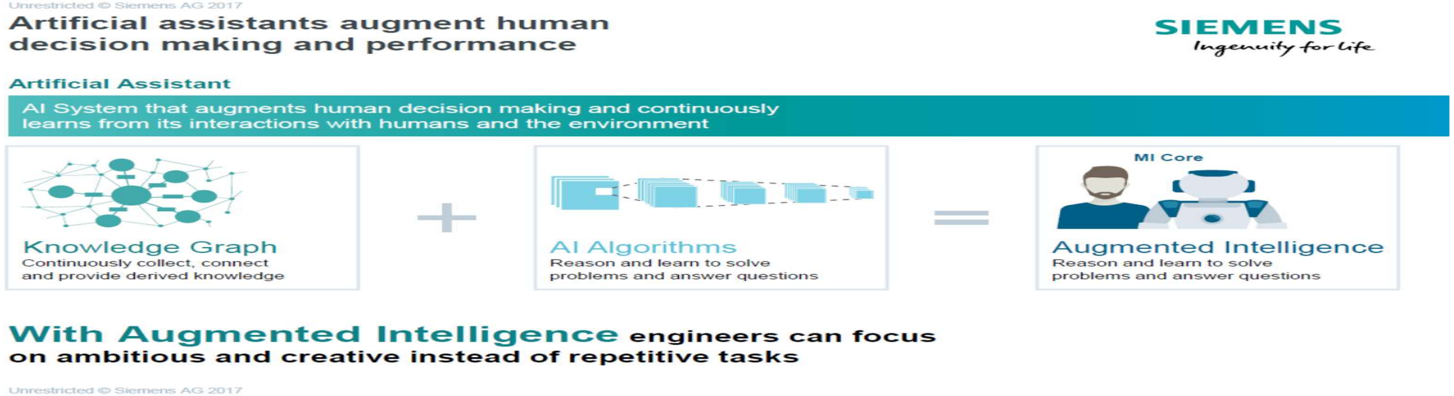


Knowledge Graphs

Technical Value

KG are key to industrial AI applications

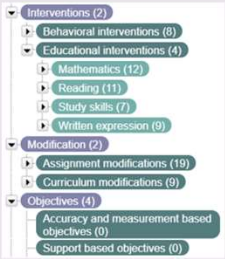




Knowledge Graphs

Technical Value

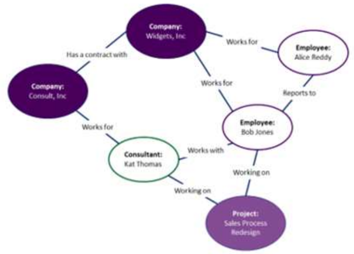
Business Taxonomy



Content Sources

salesforce
SharePoint
Drupal
Excel
MediaBeacon An ESKO Company
twitter
Microsoft Dynamics
WebDAM web-based digital asset management

Business Ontology

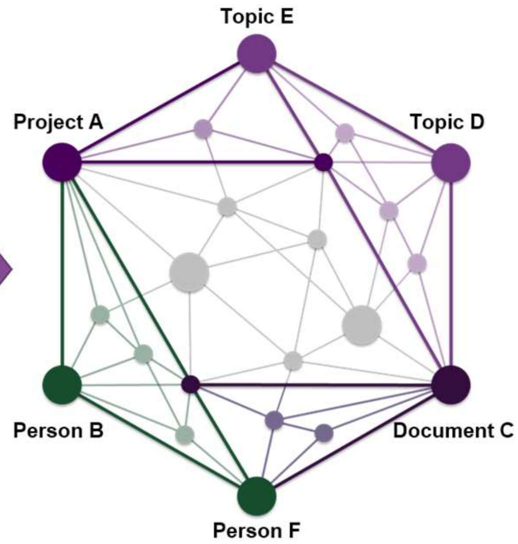


+

Graph Database

Subject	Predicate	Object
Project A	hasTitle	Title A
Person B	isPMOn	Project A
Document C	isAbout	Topic D
Document C	isAbout	Topic F
Person B	IsExpertIn	Topic D
…	…	…

Enterprise Knowledge Graph



https://enterprise-knowledge.com/what-is-an-enterprise-knowledge-graph-and-why-do-i-want-one/

Knowledge Graphs

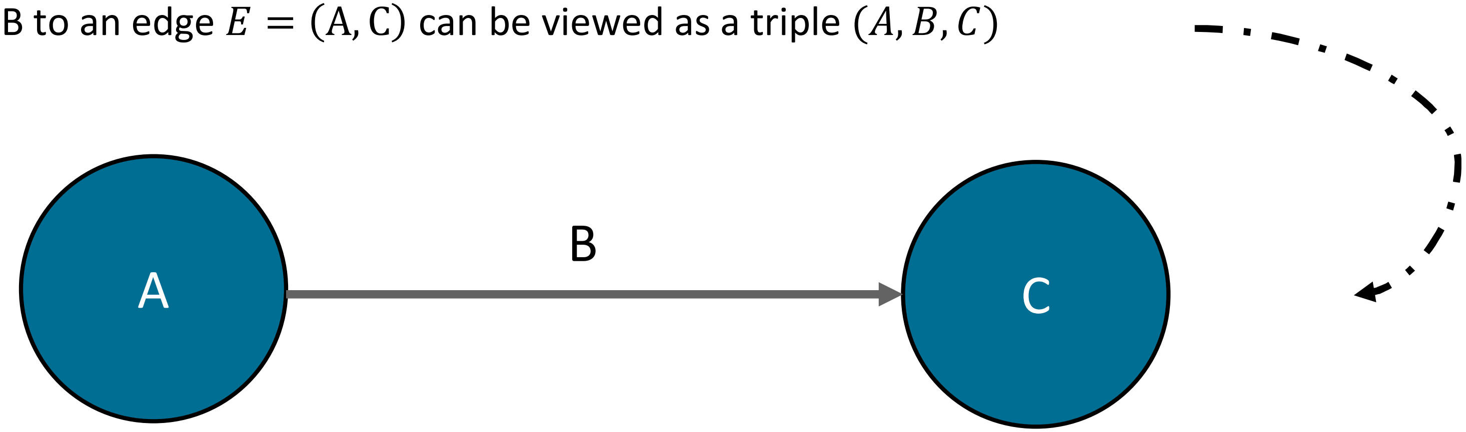
Definitions

Definition	Source
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**.	H. Paulheim. Knowledge Graph Refinement: A Survey of Approaches and Evaluation Methods. Semantic Web Journal, 2016.
Knowledge graphs are large **networks of entities**, their **semantic types**, properties, and **relationships** between entities.	M. Kroetsch, G. Weikum. Journal of Web Semantics: Special Issue on KGs, 2016.
Knowledge graphs could be envisaged as a **network of all kind things** which are relevant to a specific domain or to an organization. They are not limited to abstract concepts and relations but can also contain instances of things like **documents** and **datasets**.	A. Blumauer. From Taxonomies over Ontologies to Knowledge Graphs, 2014.
We define a Knowledge Graph as **an RDF graph**. An RDF graph consists of a set of RDF triples where each RDF triple (s,p,o) is an ordered set of the following RDF terms: a subject **s∈U⋃B**, a predicate **p∈U**, and an object **U⋃B⋃L**. An RDF term is either a URI **u∈U**, a blank node **b∈B**, or a literal **l∈L**.	M. Färber, B. Ell, C. Menne, A. Rettinger, and F. Bartscherer. Linked Data Quality of DBpedia, Freebase, OpenCyc, Wikidata, and YAGO. Semantic Web Journal, 2016.
[...] systems exist, [...], which use a variety of techniques to extract new knowledge, in the form of **facts**, from the web. These **facts are interrelated**, and hence, recently this extracted knowledge has been referred to as a knowledge graph.	J. Pujara, H. Miao, L. Getoor, and W. Cohen. Knowledge Graph Identification. In 12th Int. Semantic Web Conf., 2013.
A knowledge graph acquires and integrates information into an **ontology** and applies a reasoner to **derive new knowledge**.	L. Ehrlinger, W. Wöß: Towards a Definition of Knowledge Graphs. SEMANTiCS 2016

Knowledge Graphs

Mathematical - Definition

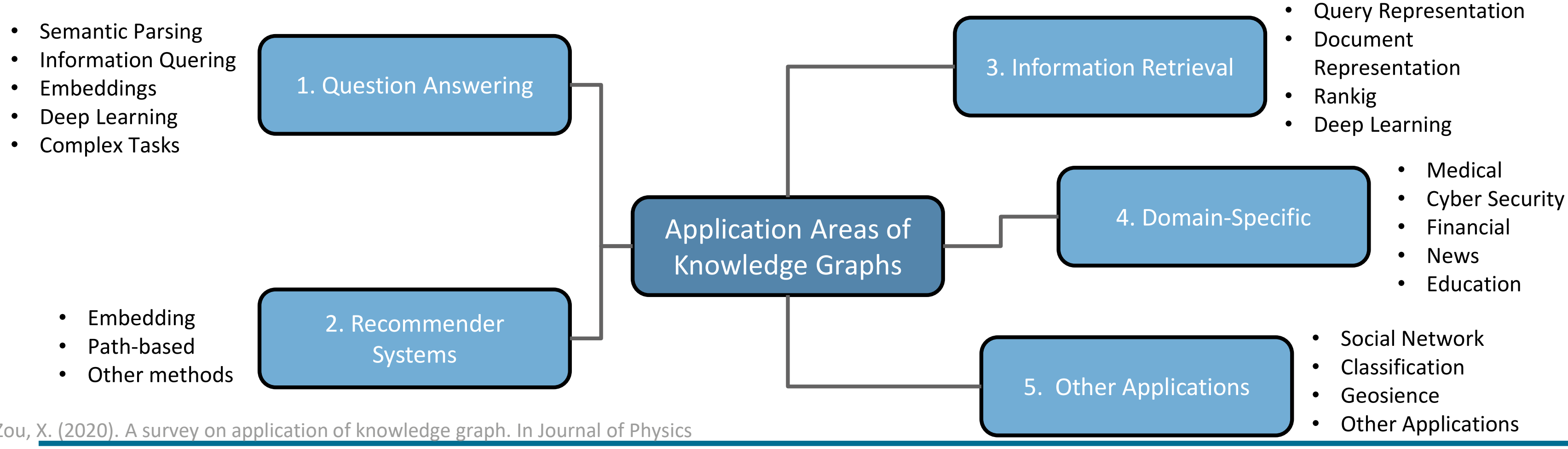
- A directed labeled graph is a 4-tuple $G = (N, E, L, f)$
- N is a set of nodes
- $E \subseteq N \times N$ is a set of edges
- L is a set of labels
- $f : E \rightarrow L$ is the assignment function from edges to labels
- For Example: The label B to an edge $E = (\mathrm{A}, \mathrm{C})$ can be viewed as a triple (A, B, C)

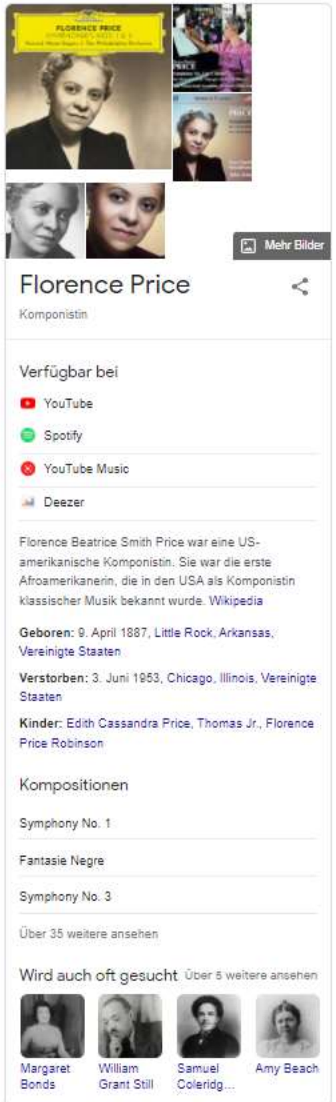


Knowledge Applications

State-of-the-Art

- Probably best-known application: Google-KG
- Over 500 billion facts and 5 billion entities
- Improves Google search results using information collected from various sources
- Presented in the form of an info box (see figure)
- Other applications: Amazon Product Graph, DBPedia, Geonames, etc. - Link
- Application areas of KGs: Question answering, Recommendation systems, Information retrieval, Domain specific, Other applications (Zou, 2020)



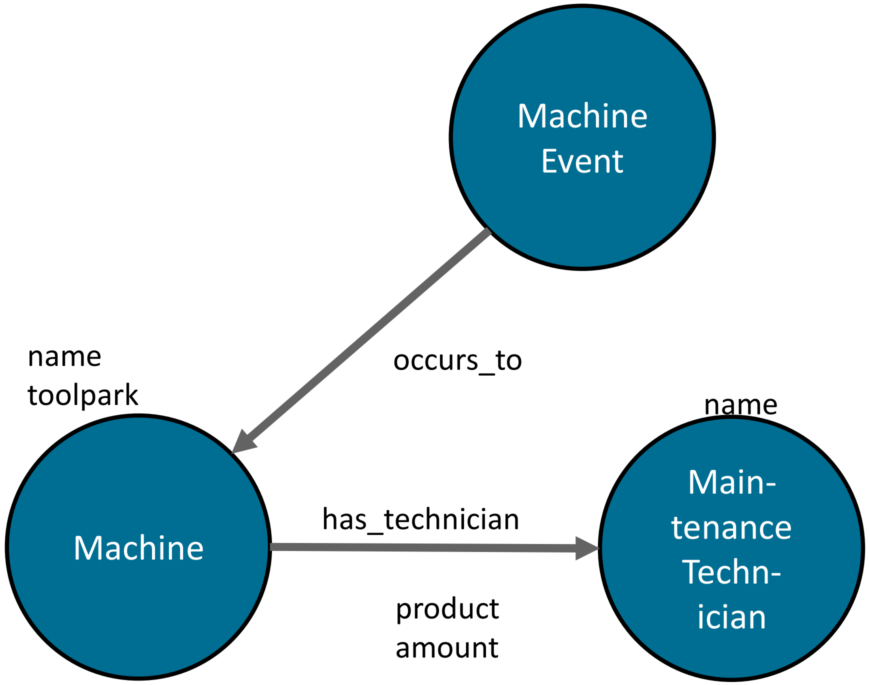


Zou, X. (2020). A survey on application of knowledge graph. In Journal of Physics

Knowledge Graphs

Knowledge Graphs Data Integration

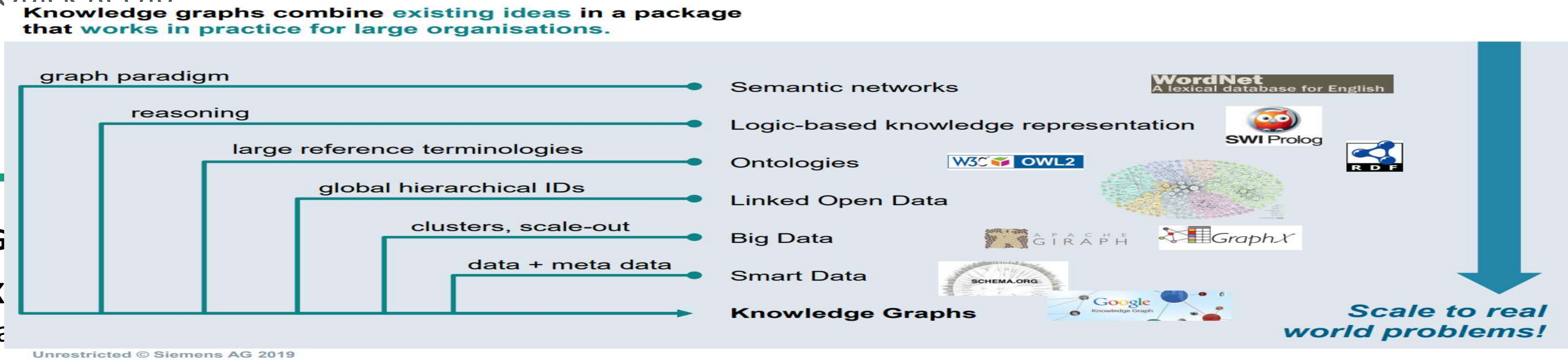
- Knowledge Graphs offer a 360-degree view of a topic
- Manufacturing companies can use Knowledge Graphs for machine failure documentation
- Methodology (Chaudhri et al., 2021)
  - Data Analyst sketching out schema with key entities, events and relations
  - Specification through business experts, enabled through visual nature
  - Loading individual data sources into the knowledge graph engine
  - Linking of data sources through vocabulary
  - Use of triple format to allow analyzing of relations of immediate relevance
  - Easy adoptable requirements of the analysis process due to generic tipple schema



Chaudri, Vinay K. et al. (2021) An Introduction to Knowledge Graphs http://ai.stanford.edu/

Knowledge Graphs

Quick Recap



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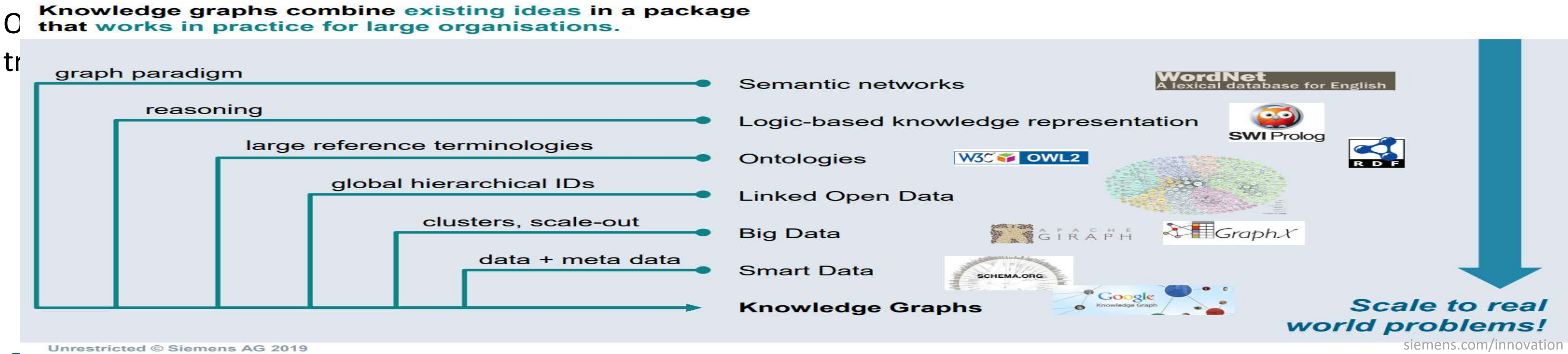
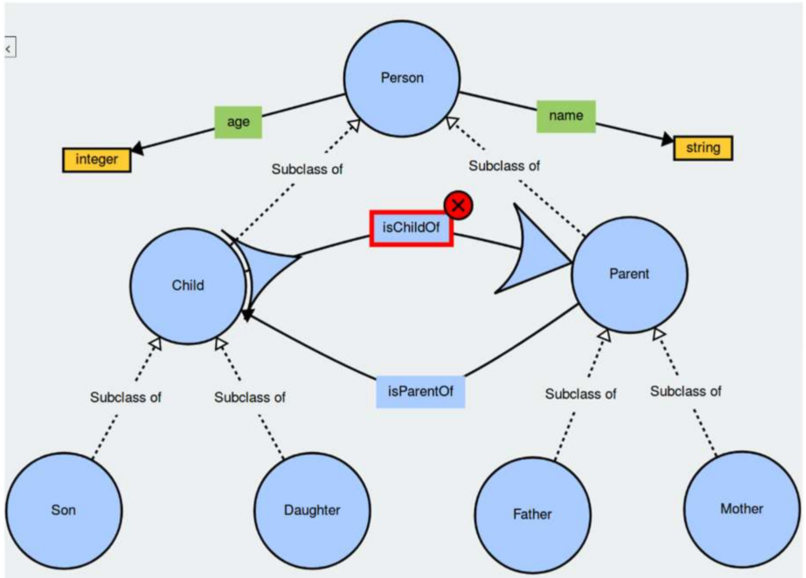


siemens.com/innovation

```
<owl:ObjectProperty rdf:ID=”located_In”/>

<owl:Class rdf:ID=”City”>
   <rdfs:subClassOf>

         <owl:restriction>

            <owl:onProperty rdf:resouce=”located_In”/>

            <owl:someValuesFrom rdf:resource=”State”/>

         </owl:restriction>
   </rdfs:subClassOf>

</owl:Class>
```

https://tdan.com/data-modeling-rdf-owl-part-one-an-introduction-to-ontologies/5025



http://editor.visualdataweb.org/

… BACK ON BUILDING AN ONTOLOGY - IMPLEMENTATION

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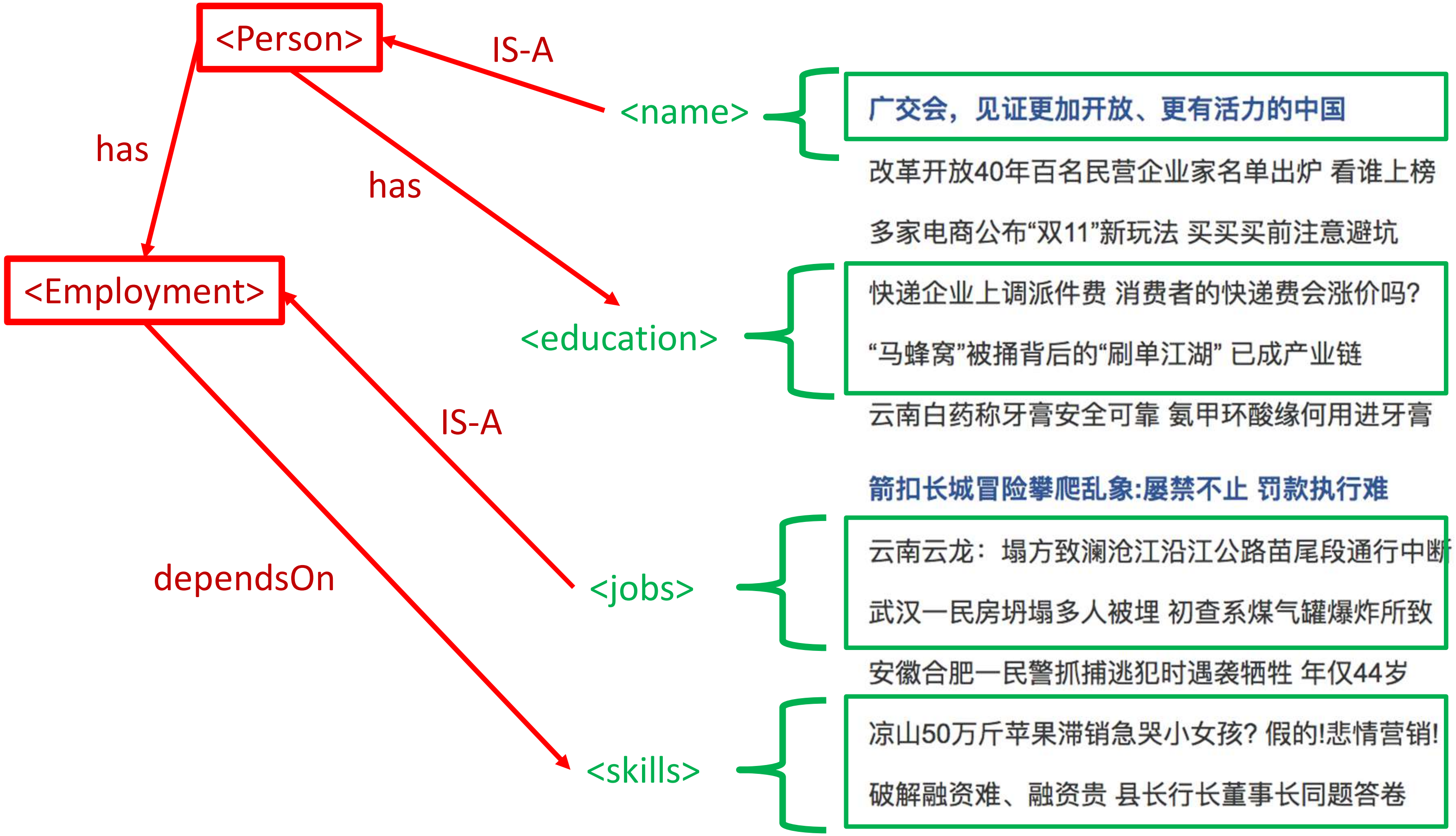
Knowledge Representation & Ontology Development

"Machine-Understandable Form"



Knowledge Representation & Ontology Development

Enabling Technologies

- One or more **standard vocabularies** (**ontologies**) capturing the semantics

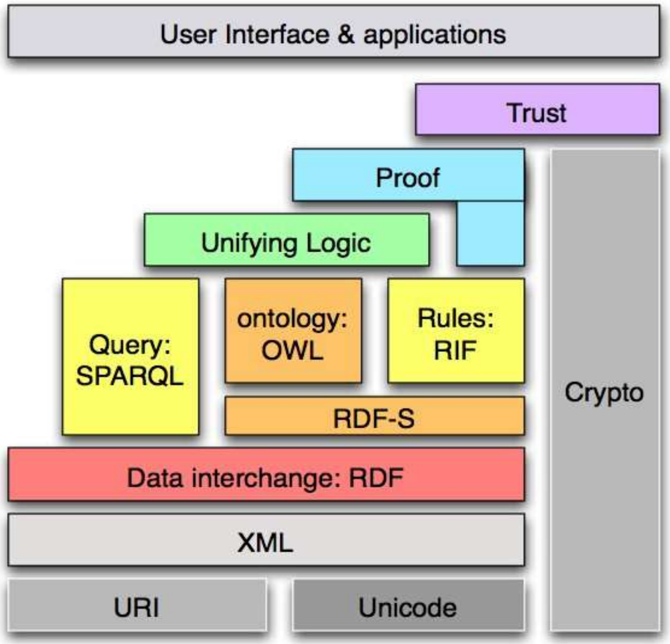
  → so search engines, producers and consumers **all speak the same language**
- A standard syntax

  → so meta-data can be recognized as such
- Examples are
  - XML, RDF, RDF Schema, OWL

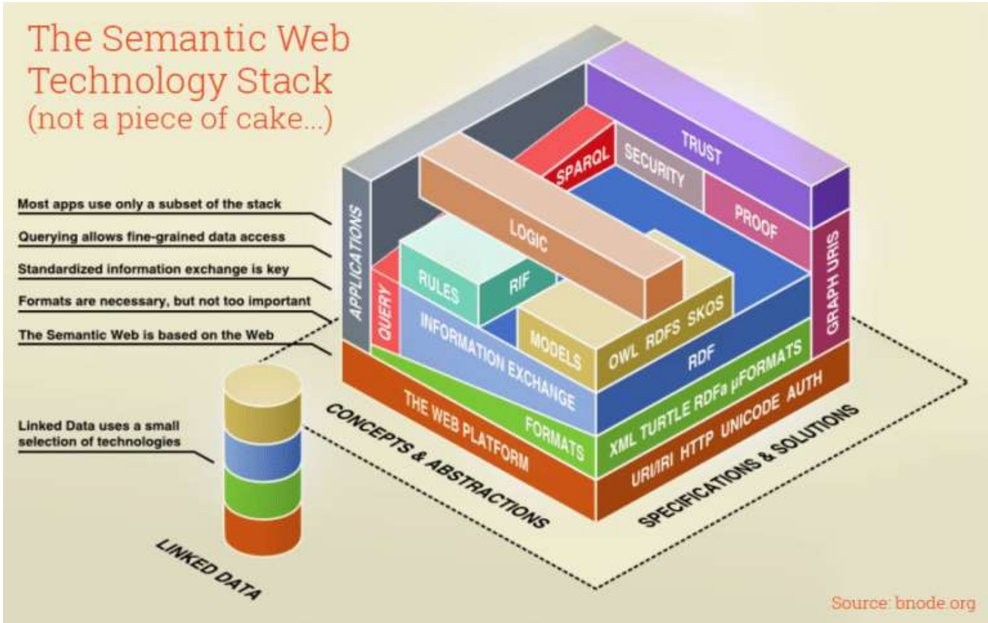
Knowledge Representation & Ontology Development

Enabling Technologies

Standard Syntax, Knowledge Representation Languages



Increased semantic expressivity



Podgorelec, V., & Grasic, B. (2010). Implementing Innovative IT Solutions with Semantic Web Technologies. In Products and Services; from R&D to Final Solutions. Sciyo.

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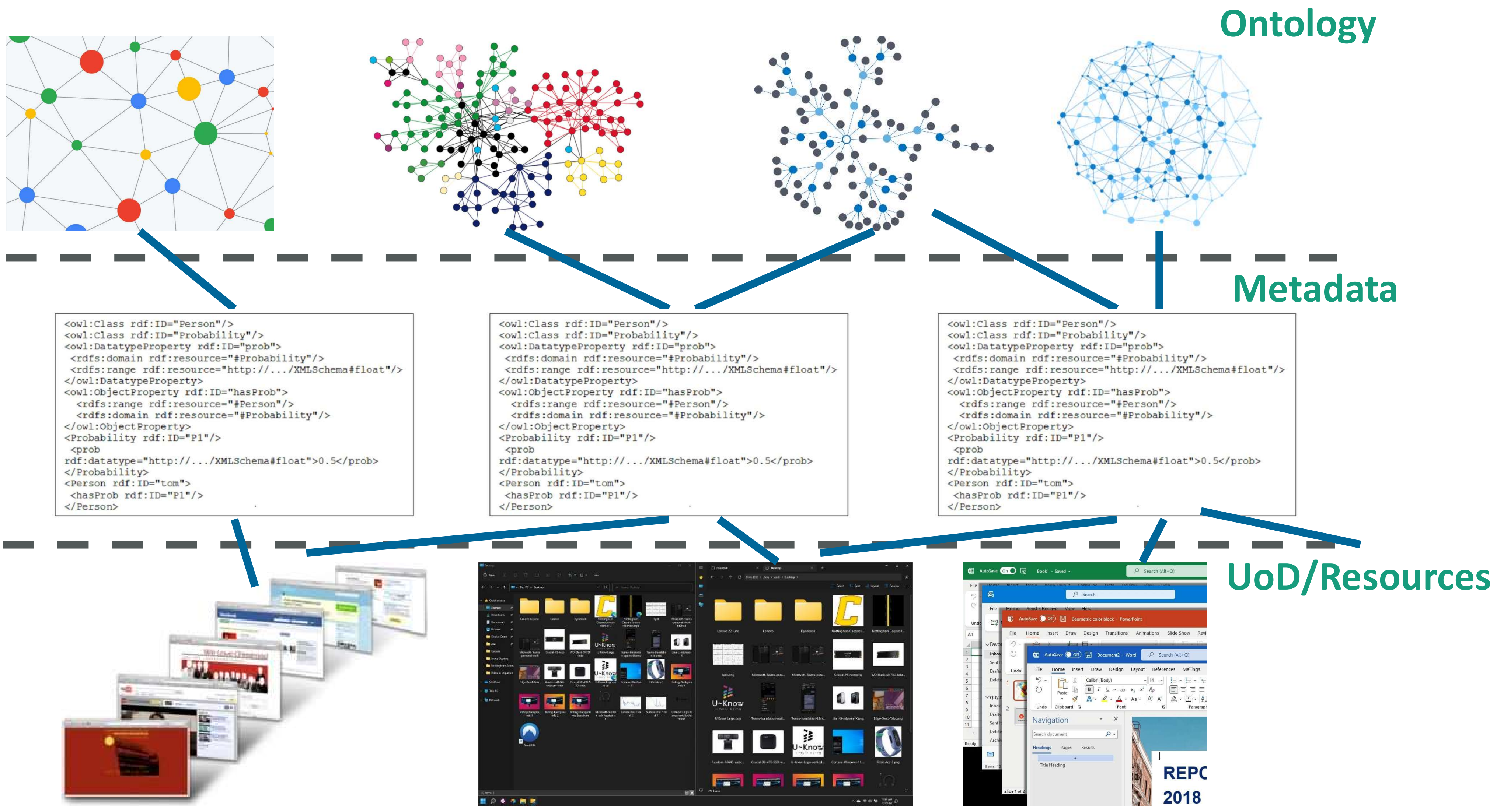
Ontology
Metadata
UoD/Resources
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<owl:Class rdf:ID="Probability"/>
<owl:DatatypeProperty rdf:ID="prob">
<rdfs:domain rdf:resource="#Probability"/>
<rdfs:range rdf:resource="http://.../XMLSchema#float"/>
</owl:DatatypeProperty>
<owl:ObjectProperty rdf:ID="hasProb">
<rdfs:range rdf:resource="#Person"/>
<rdfs:domain rdf:resource="#Probability"/>
</owl:ObjectProperty>
<Probability rdf:ID="P1"/>
<prob
rdf:datatype="http://.../XMLSchema#float">0.5</prob>
</Probability>
<Person rdf:ID="tom">
<hasProb rdf:ID="P1"/>
</Person>
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<owl:Class rdf:ID="Probability"/>
<owl:DatatypeProperty rdf:ID="prob">
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rdf:datatype="http://.../XMLSchema#float">0.5</prob>
</Probability>
<Person rdf:ID="tom">
<hasProb rdf:ID="P1"/>
</Person>
REPC
2018

Resource Description Framework - RDF

Building an Ontology - RDF

What is RDF?

- RDF – the Resource Description Framework – is a framework for representing **interconnected data** on the web
- RDF statements are used for **describing** and **exchanging metadata**, which enables standardized exchange of data based on relationships
- RDF is used to **integrate** data from **multiple sources**

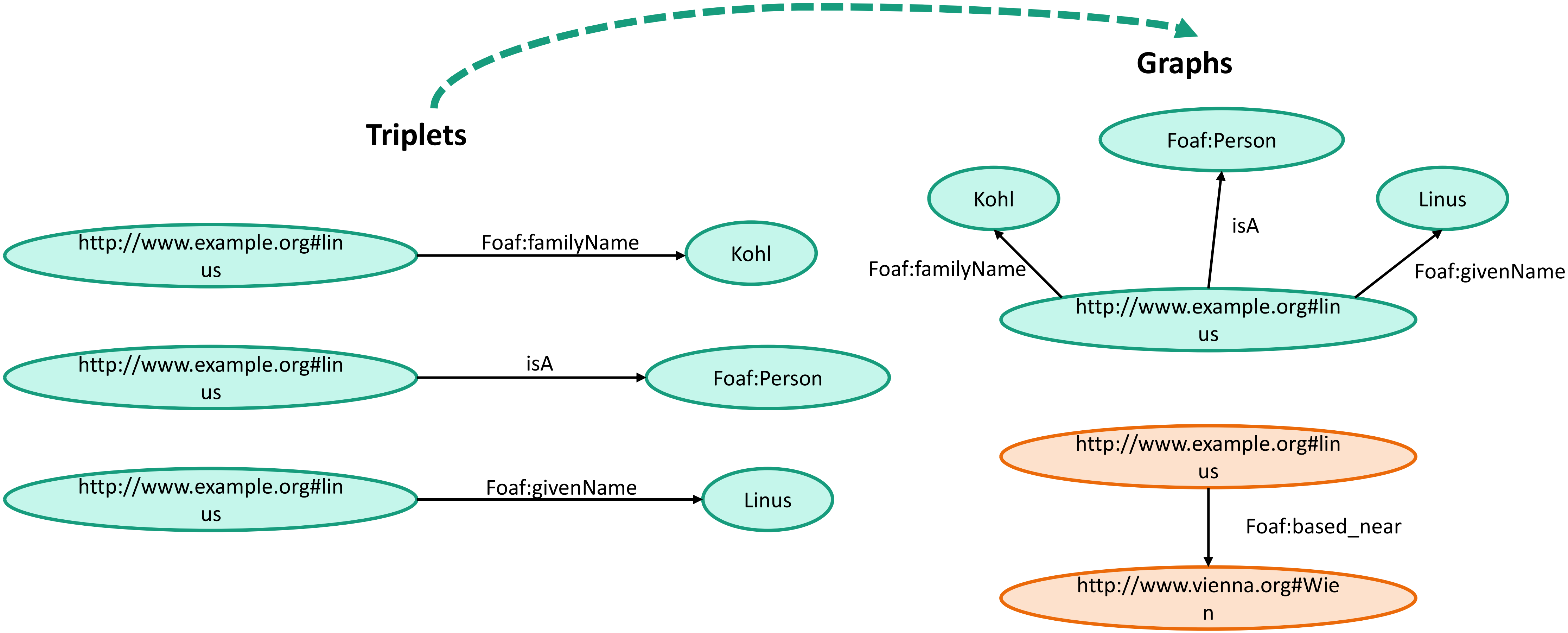
```
<rdf:RDF
        xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
        xmlns:foaf=http://xmlns.com/foaf/0.1/

        <foaf:Person rdf:about= "http://www.example.org#linus">
                        <foaf :familyName>Kohl</foaf:familyName>
                        <foaf :givenName>Linus</foaf:givenName>
        </foaf:Person>

</rdf:RDF>
```

Ontologies

Metadata

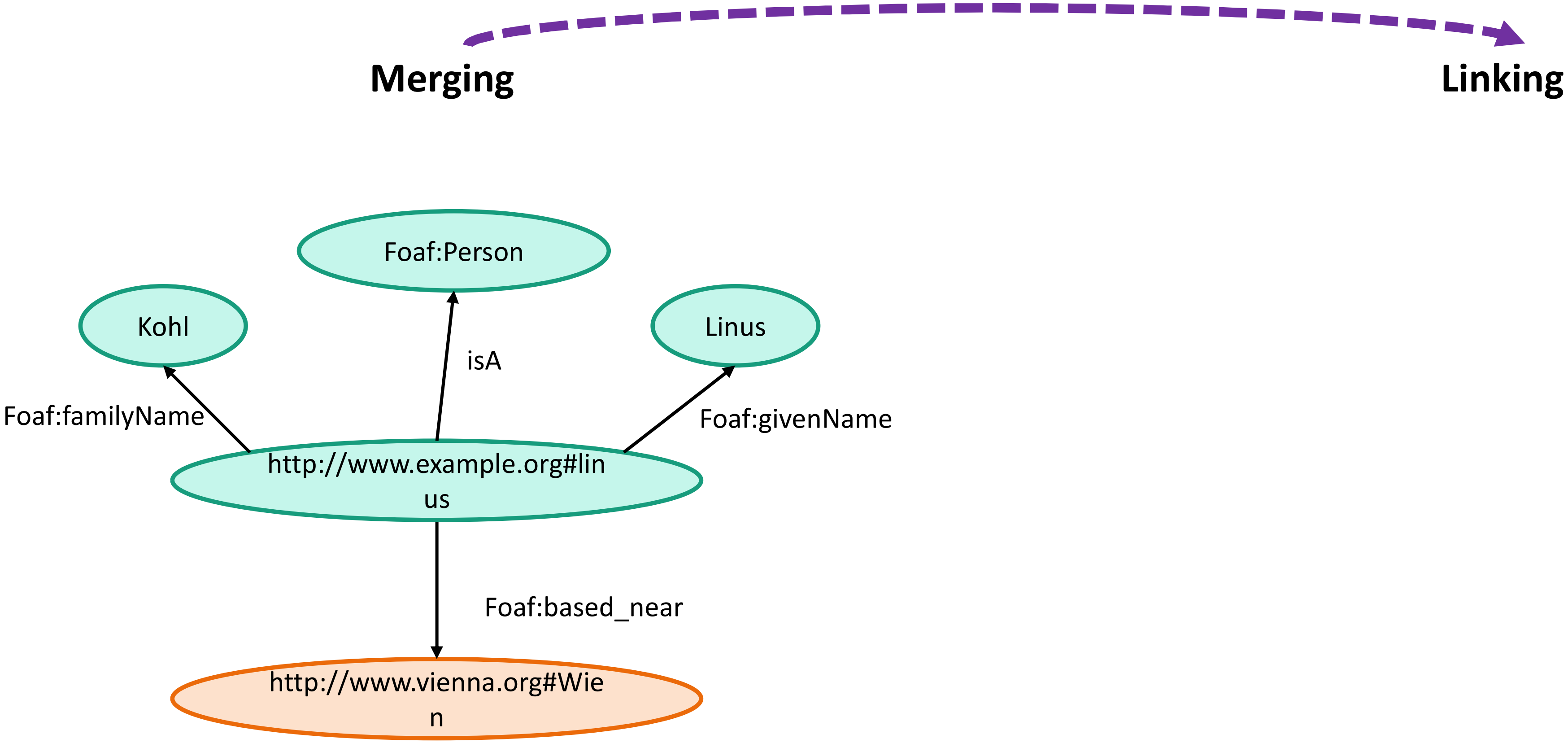
Resource Description Framework - RDF

RDF Basics



Resource Description Framework - RDF

Linking RDF



Resource Description Framework - RDF

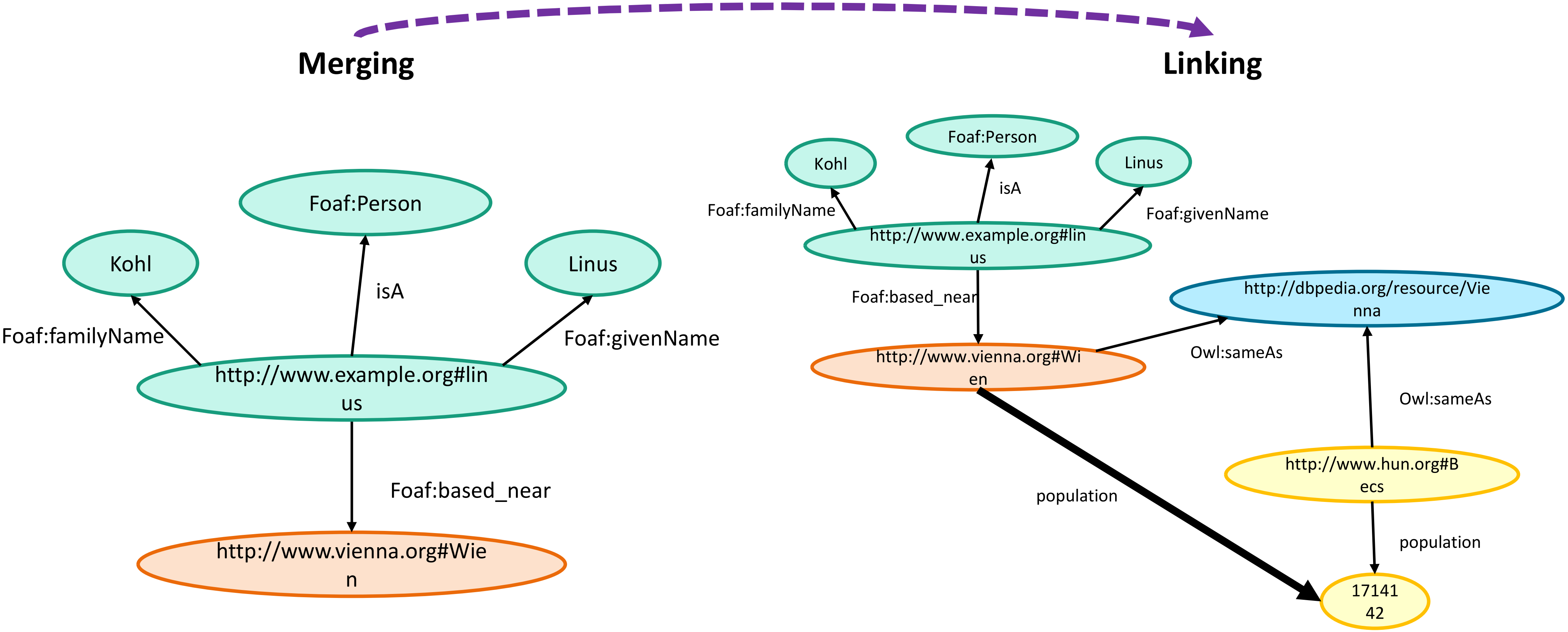
Linking RDF

Merging **Linking**

Ontology
(359 classes, 1.7K properties)

Resource Description Framework - RDF

Linking RDF



Knowledge Representation & Ontology Development

Building an Ontology – SPARQL

```
PREFIX x:<…>

SELECT ?subject ?property ?object
WHERE
{
?subject ?property ?object.
#this is comment
}
```

Declare prefix shortcuts

The **SELECT** clause lists variables that you want returned

The **WHERE** clause contains restrictions on them, mostly in the form of triples

(note: everything after a '#' is a comment)

SPARQL Editors:

- Apache Jena Fuseki
- SPARQL Tab in Protégé

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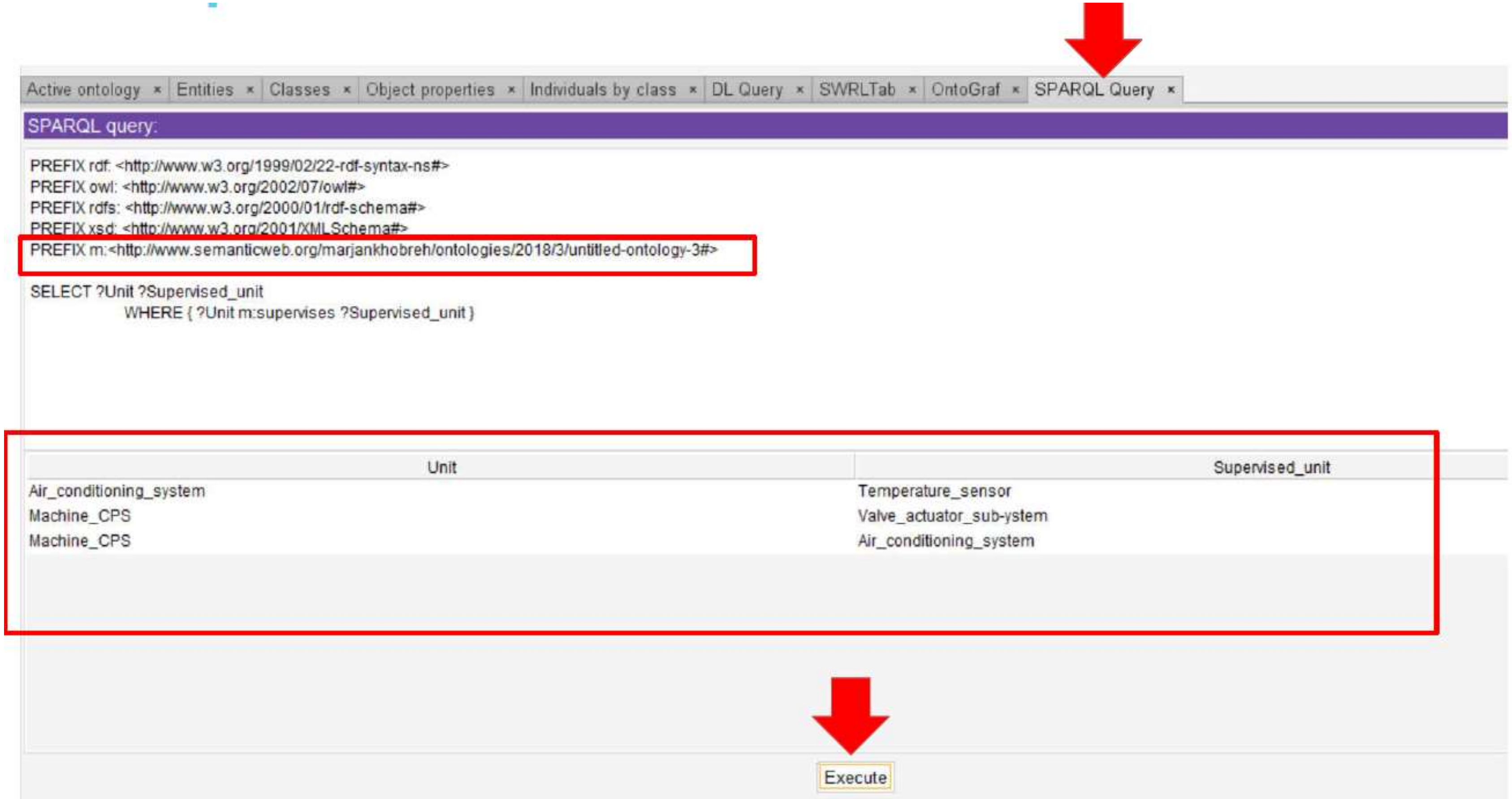
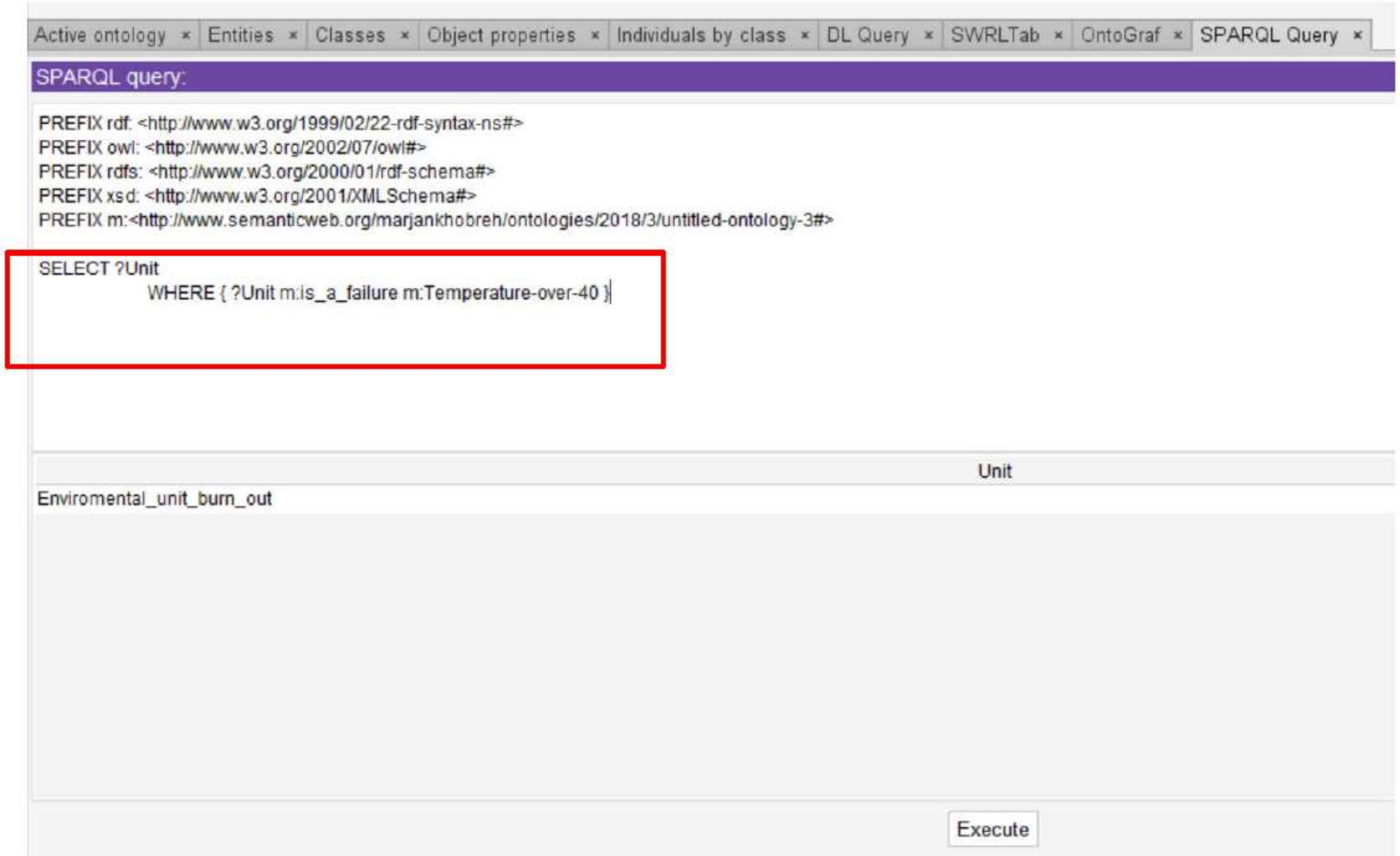
Knowledge Representation & Ontology Development

Building an Ontology – SPARQL Example 1/3



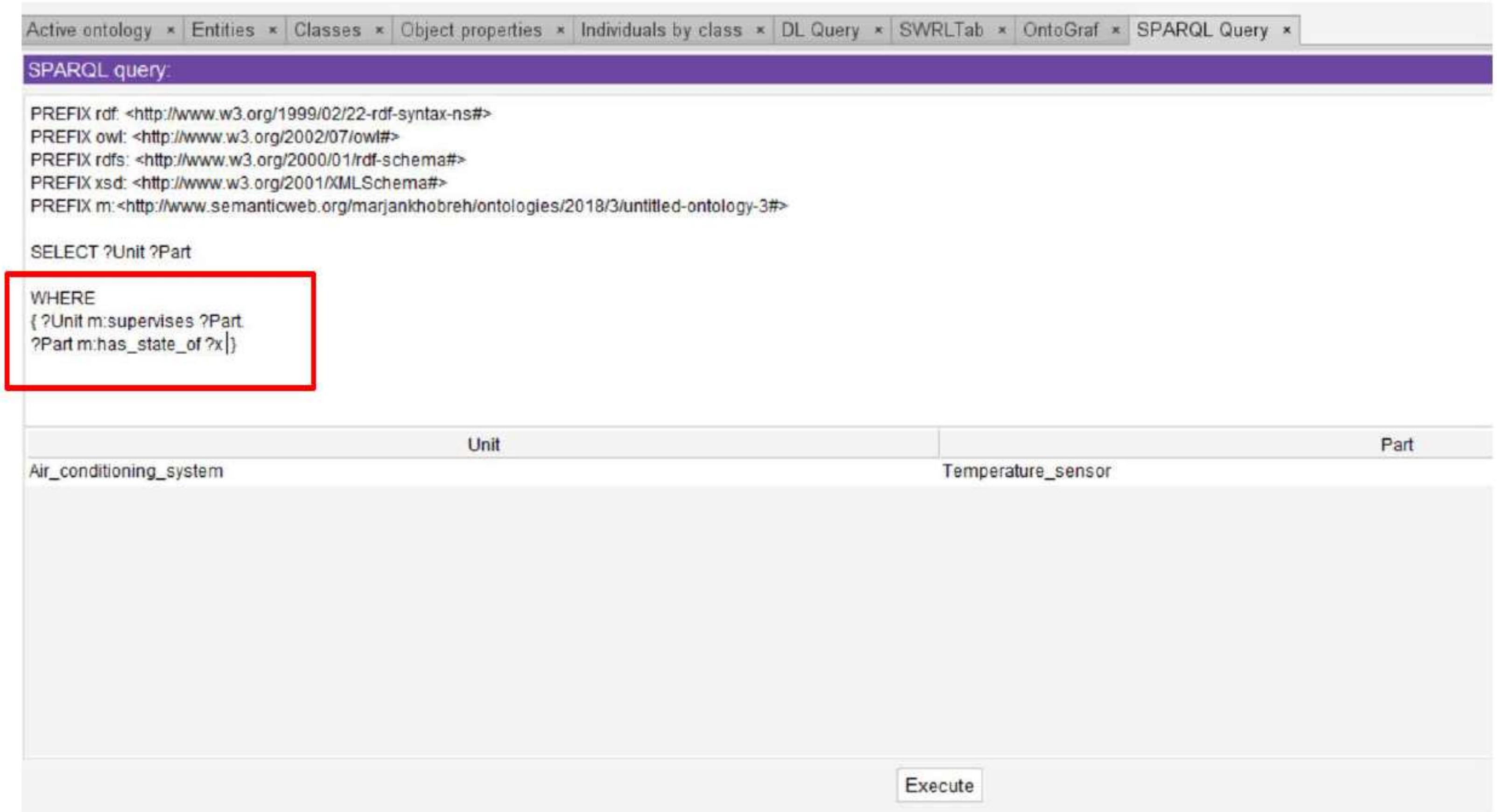
Knowledge Representation & Ontology Development

Building an Ontology – SPARQL Example 2/3



Knowledge Representation & Ontology Development

Building an Ontology – SPARQL Example 3/3



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