Course: Intelligent Systems

Unit 3: Ontology Engineering

Introduction: Knowledge Graphs

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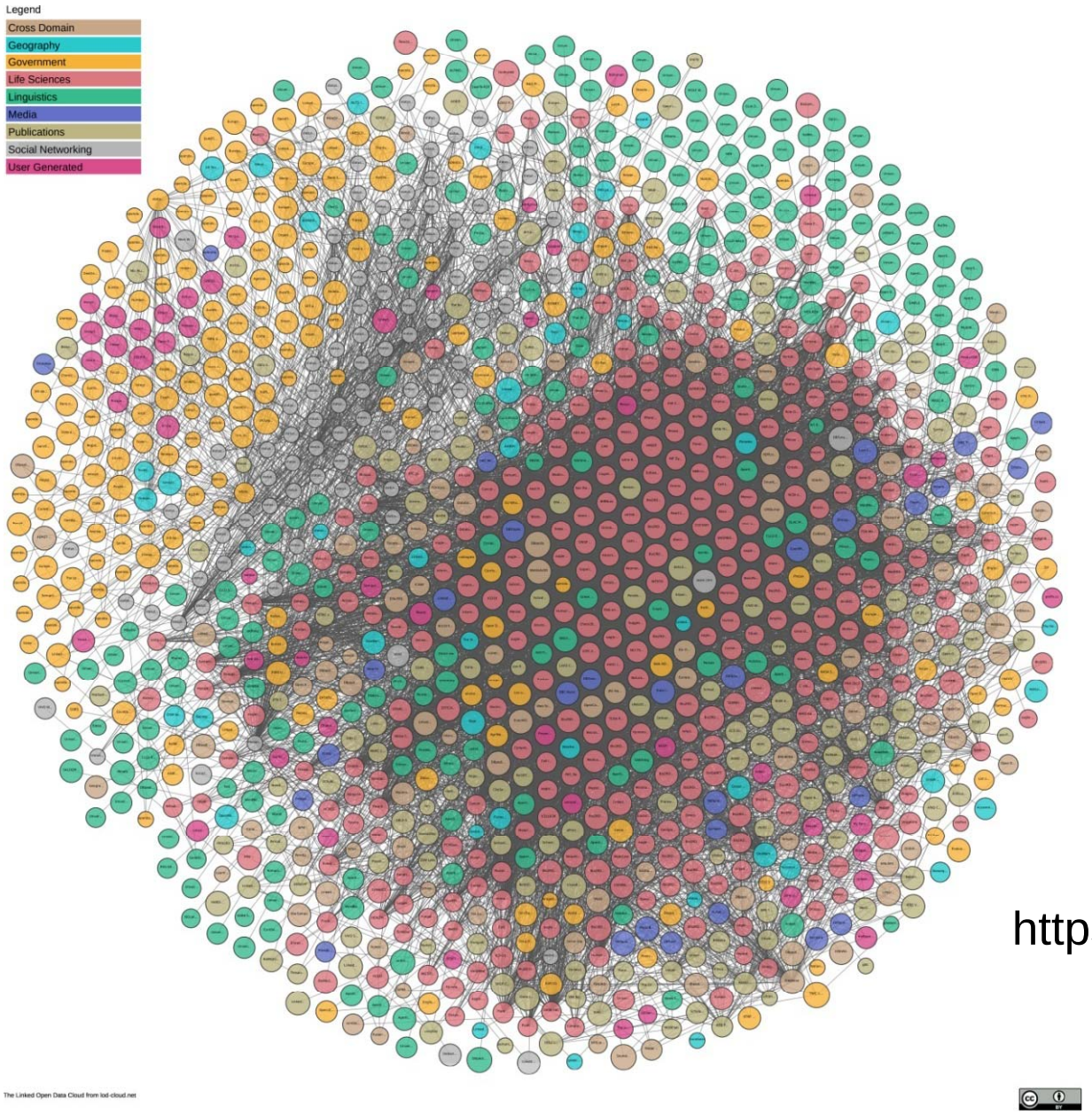
Introduction



https://lod-cloud.net/

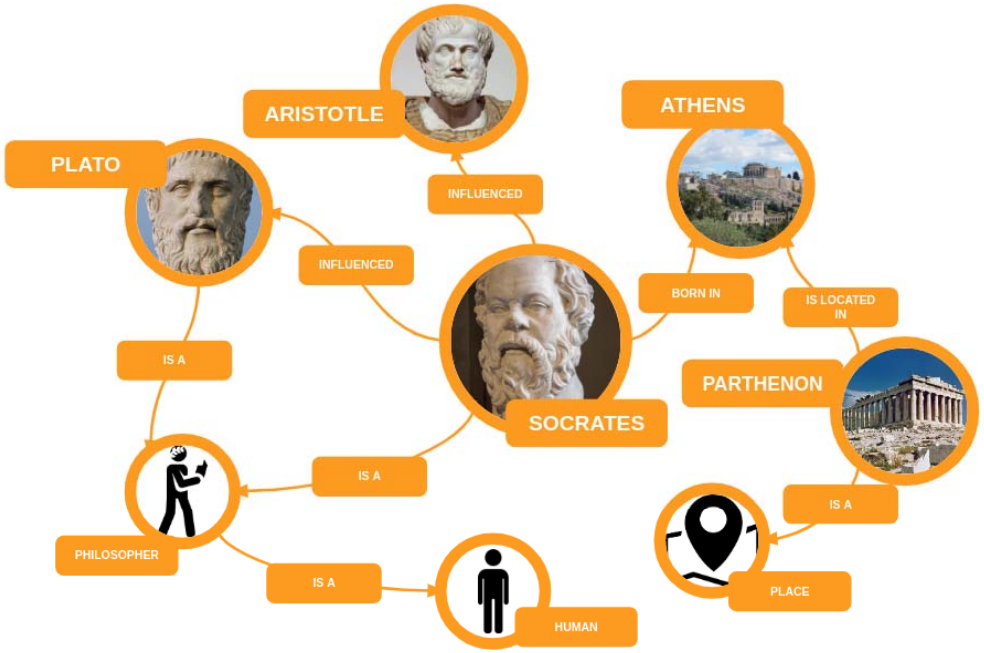
Introduction

- The term "**Knowledge Graph**" (KG) is becoming increasingly popular in the field of Artificial Intelligence (AI)

- The term itself is relatively new, but knowledge graphs (with other names) have been around for decades
  - Although Google were the ones to popularise the term a few years ago, it has been around also before that, and can even be traced back to ancient times

Introduction

- **Knowledge Graphs** (KGs) have emerged as a core abstraction for incorporating human knowledge into **intelligent systems**.



https://towardsdatascience.com/knowledge-graphs-at-a-glance-c9119130a9f0

Introduction: Examples of Use

- **Google uses a KG** to power its search engine results with information collected from varied sources.
  - The information from KG is presented to users in the form of a knowledge panel next to the search results.
  - When you perform a search, Google combines previous results from your query with what other people might have found, using KG, to better serve your query.

Amit Sheth, Swati Padhee, Amelie Gyrard, 'Knowledge Graphs and Knowledge Networks - The Story in Brief," IEEE Internet Computing, July-Aug 2019.

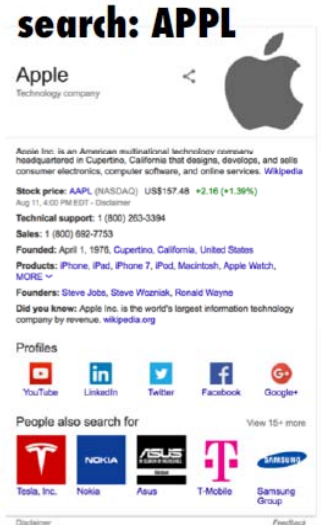
Introduction: Google Case

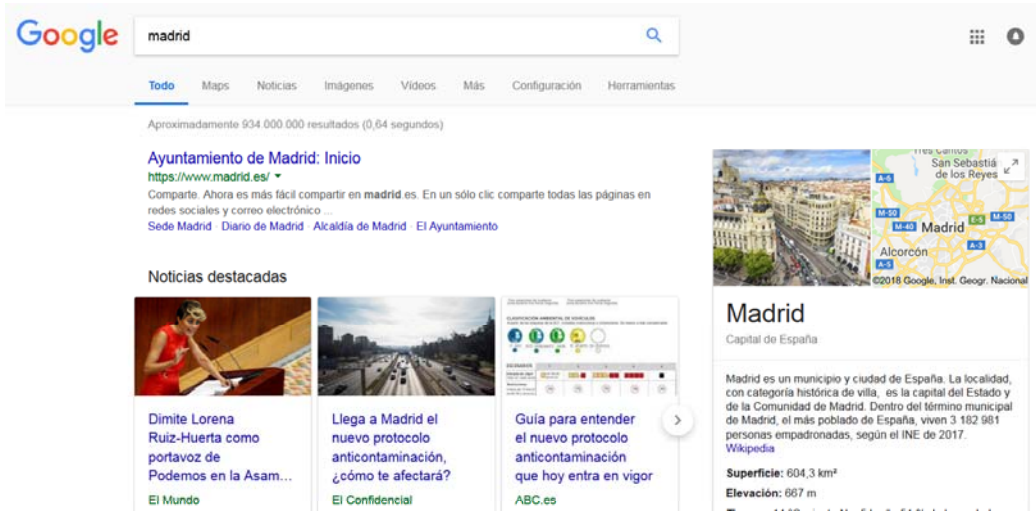
https://developers.google.com/knowledge-graph/how-tos/search-widget-example

derived from many sources, including the CIA World Factbook, Wikidata, and Wikipedia

powers a "knowledge panel"

the Knowledge Graph now holds 70 billion facts





Amit Sheth, Swati Padhee, Amelie Gyrard, 'Knowledge Graphs and Knowledge Networks - The Story in Brief," IEEE Internet Computing, July-Aug 2019.

Introduction: Examples of Use

- **Facebook uses KG** to monitor networks of people and links between socially relevant entities such as the things most chatted about by its users.
  - Besides using KGs to discover social connections among users and give users recommendations about social interests, Facebook's graph search feature uses KG to give answer to user's natural language queries.
  - An important reason that KGs have become so vital is the realization that the relations between data points are as valuable as the data points themselves, especially when we want to build social networks.

Amit Sheth, Swati Padhee, Amelie Gyrard, 'Knowledge Graphs and Knowledge Networks - The Story in Brief," IEEE Internet Computing, July-Aug 2019.

Introduction: Examples of Use

- **Netflix uses KG** to arrange information on its huge catalog of content, inferring links between TV shows, movies and the directors, producers and actors, or who link them.
  - The KG then helps infer what users might like to watch next, and nurture the "binge-watch" business model.

Amit Sheth, Swati Padhee, Amelie Gyrard, 'Knowledge Graphs and Knowledge Networks - The Story in Brief," IEEE Internet Computing, July-Aug 2019.

Introduction: Examples of Use

- **Siemens uses KG** to construct models of the data it produces and stores; and employ it for risk management and process monitoring applications.
  - They also use KG to build “digital twins” which is a simulated form of real-world systems and use the graph to design, prototype and train.

- KG are also being used in financial sectors for monitoring fraudulent transactions and for tasks such as investment analytics and marketing.

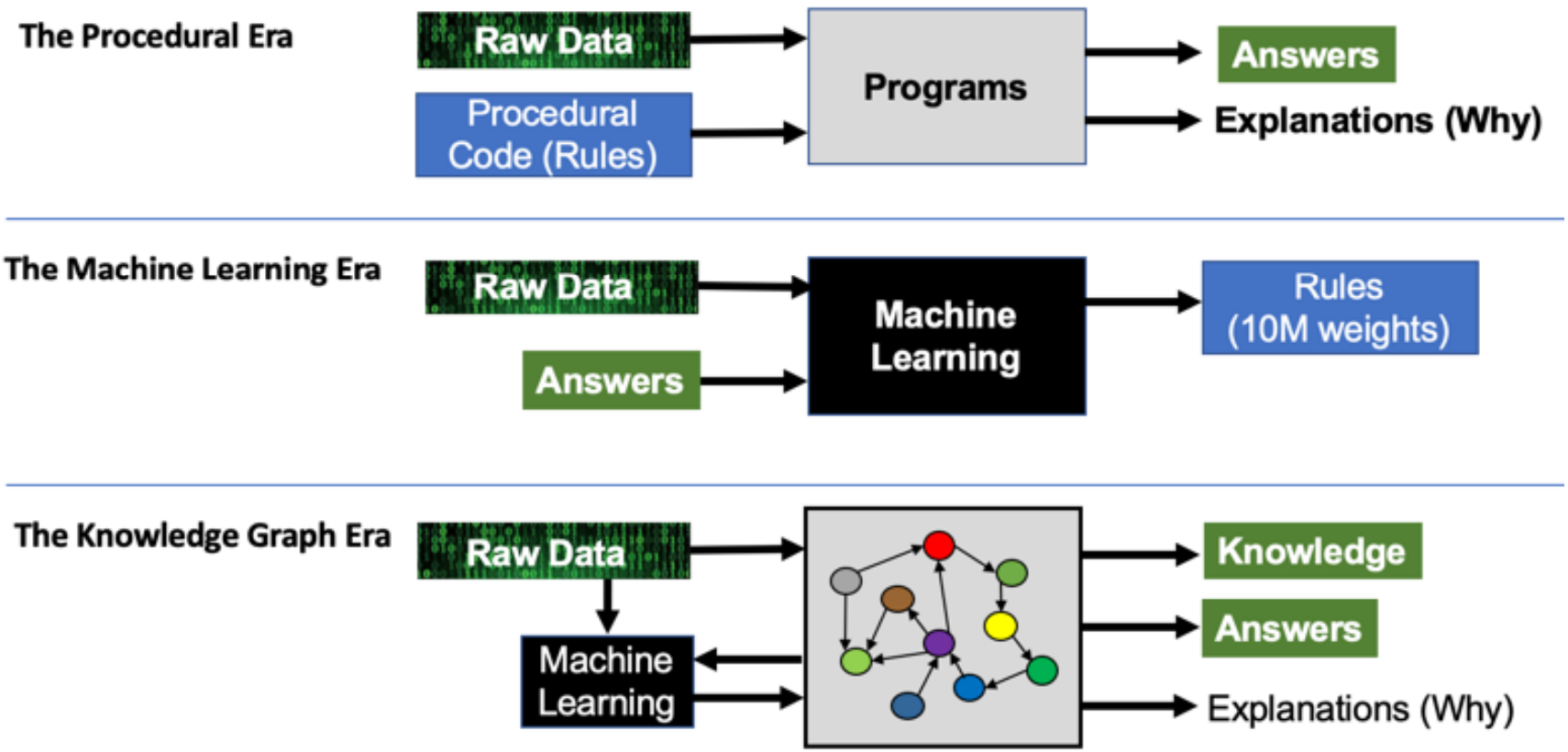
Amit Sheth, Swati Padhee, Amelie Gyrard, 'Knowledge Graphs and Knowledge Networks - The Story in Brief," IEEE Internet Computing, July-Aug 2019.

Introduction: Current Situation

- **Tech giants** including Microsoft, Siemens, LinkedIn, Airbnb, eBay, and Apple, as well
- **Smaller companies** (e.g. ezDI, Fraanz, Metaphactory/Metaphacts GmbH, Semantic Web Company GmbH, Mondeca, Stardog, Diffbot, Siren)
- **are using Enterprise KGs** (which are often proprietary but may incorporate public knowledge such as DBPedia) **and KG-enabled technologies** for critical products and services for its customers (e.g., Maana).

Amit Sheth, Swati Padhee, Amelie Gyrard, 'Knowledge Graphs and Knowledge Networks - The Story in Brief," IEEE Internet Computing, July-Aug 2019.

Knowledge Graphs: The Third Era of Computing



https://dmccreary.medium.com/knowledge-graphs-the-third-era-of-computing-a8106f343450

KG Definition

- What is a **Knowledge Graph**?
  - https://en.wikipedia.org/wiki/Knowledge_graph
- An informal definition:
  - A KG defines concepts, instances and relations in a graph
  - “a graph of data with the intention to encode knowledge” (Aidan Hogan and Antoine Zimmermann)
- A KG refers
  - Knowledge represented using a graph-based formalism
  - Knowledge that can be used as an information/data sources in different applications

KG (Informal) Definition

- A **Knowledge Graph**?
  - Mainly describes instances and their relations in a graph
  - Defines possible classes and relations in a schema or ontology
  - Allows for interlinking arbitrary entities with each other
  - Covers various domains

Slide adapted from Heiko Paulheim's presentattion (September 2018)

KG Components

- A **Knowledge Graph** can be seen as a set of semantic descriptions of entities and their relationships
  - Uses a knowledge representation formalism (e.g., RDF, OWL, etc.)
- **Entities**: Real world objects (things, places, people) and abstract concepts (genres, religions, professions)
- **Relationships**: Graph-based data model where relations are first-class
- **Semantic Descriptions**: Types and properties with a well-defined meaning (e.g., ontologies)

Slide adapted from Metaphacts' presentations

KG: Components

- KGs model **entities** and **relationships** between these entities
  - Nodes correspond to entities
  - Directed labeled edges between entities keep track of relationships
- A knowledge graph is (in the most simple vision)
  - a set of entities (SergioRamos, Spain)
  - a set of relations between those entities (<plays_for>, <was_born_in>), and
  - a set of facts
    - Facts are the combination of entities and relations (<SergioRamos, plays_for, Spain>)

Knowledge Graphs: Components

- **Entities** can be persons, organizations, locations or products
  - These are usually called named entities because they refer to real world objects (physical or abstract) that bear a name
    - Examples: Barack Obama, Hawaii, Greece, Batman, or iPhone 8
  - Since named entities are ambiguous (multiple named entities share the same name), each named entity in the knowledge graph must be uniquely identified

Knowledge Graphs: Components

- **Relations** join entities together
  - Relations are verbs or verbal phrases like <was_born_in>, <graduated_from>, <plays_for> or <acted_in>
  - Each relation must be unique, have a precise meaning, and a given scope, in the sense that they can only join specific classes of entities
    - <was_born_in> only involves persons and locations
    - <acted_in> only relates actors with movies, series or stage plays

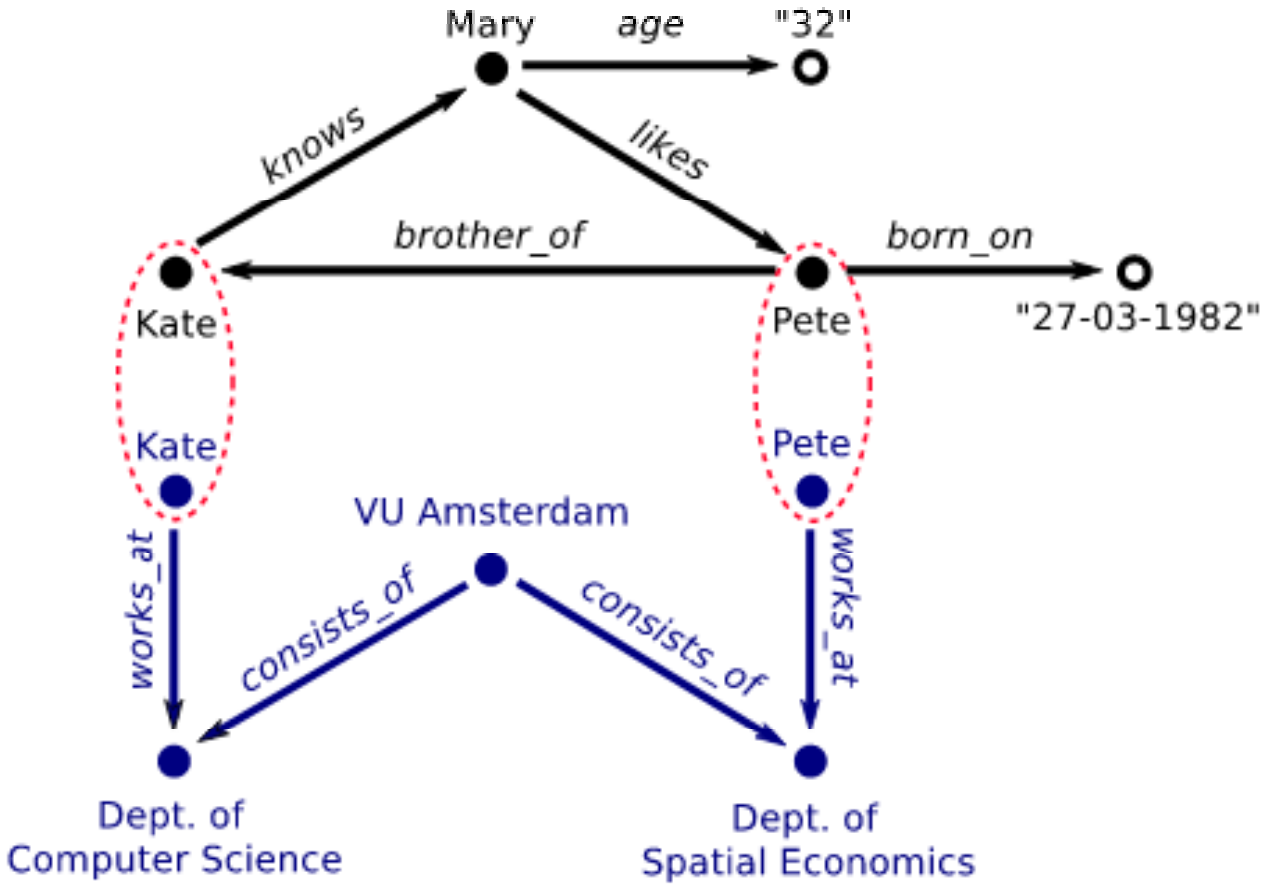
Knowledge Graphs: Components

- A **fact** is formed by joining entities through relations
  - For instance, <Obama, was_born_in, Hawaii> is a fact about entities Barack Obama and Hawaii, joined by the relation <was_born_in>, describing that the US president was born in the US state of Hawaii

Knowledge Graphs: Components

- Named entities can be categorized
  - Barack Obama is a president, a Nobel Prize Laureate, and a lawyer
  - Scarlet Johansson is an American actress and director
- **Classes/Concepts** are part of the **model** (together with relationships among them)
- The knowledge contained in a knowledge graph is represented by
  - the **set of facts** it contains, and
  - the **model** (general entities and relations)

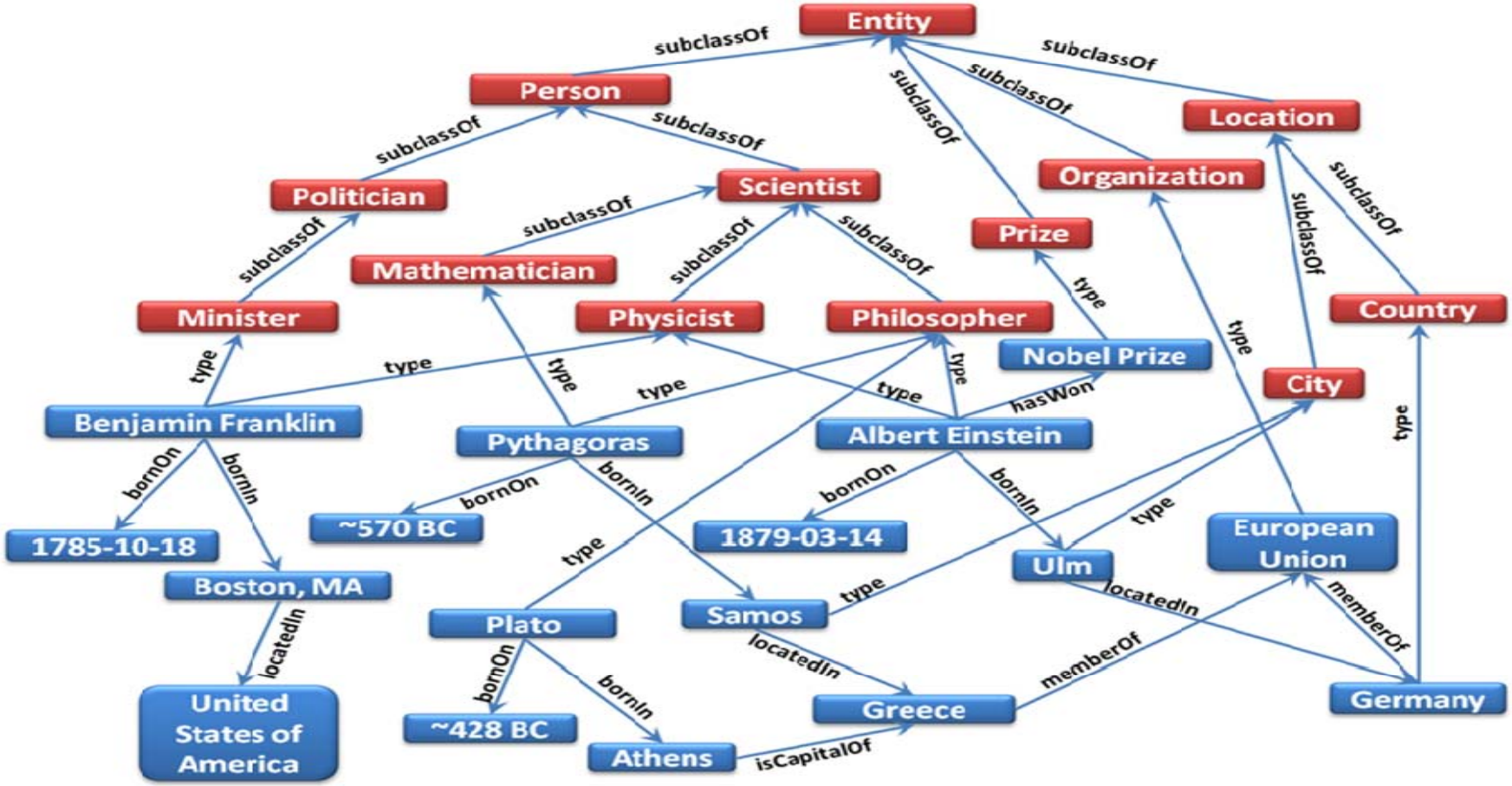
Knowledge Graph: Example



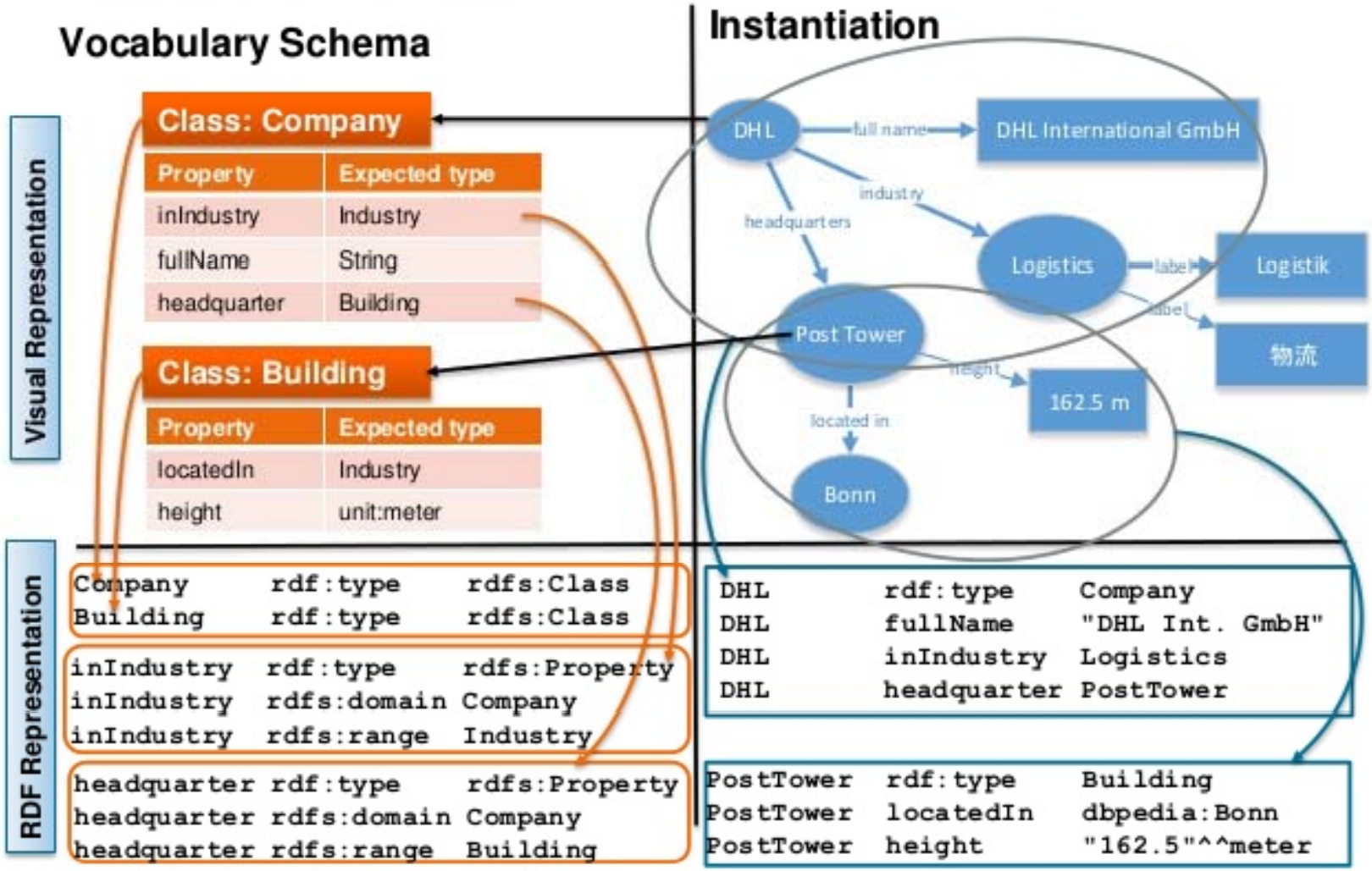
https://content.iospress.com/download/data-science/ds007?id=data-science%2Fds007

Knowledge Graph: Example

- Model (Concept/Classes)
- Data (Individuals/Instances)



Knowledge Graph: Data and Model



Knowledge Graphs: Representation

- KGs should be represented using a machine readable format and in a language with some formal semantics
  - RDF is an obvious candidate for representing Knowledge Graphs on the web
  - Graph Databases

Knowledge Graphs: Representation

- Serializing Knowledge Graphs
  - Resource Description Framework (RDF)
  - Database (triple store): AllegroGraph, Virtuoso,
  - Query: SPARQL (SQL-like)
- Graph Databases
  - Data model: Graph
  - Databases: Neo4J, Cayley, MarkLogic, GraphDB, Titan, OrientDB, Oracle, …
  - Query: GraphQL, Gremlin, Cypher
- Key-Value, Document Stores
  - Data model: Node-centric
  - Databases: Hbase, MongoDB, Elastic Search, …
  - Query: filters, keywords, aggregation (no joins)

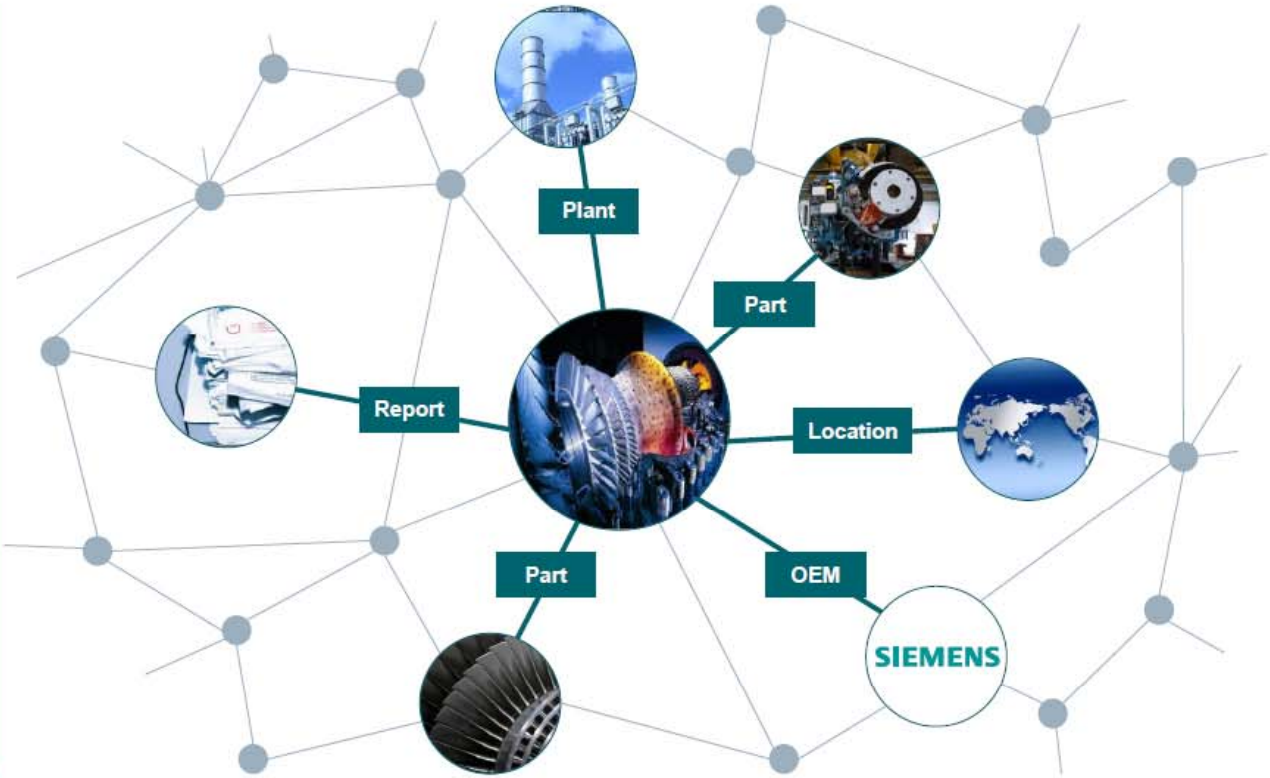
Benefits of using KGs

Why (Knowledge) Graphs?

SIEMENS
Ingenuity for life

Benefits of using knowledge graphs for data representation

- The world is entities and relations!
- Intelligible domain model instead of complex (physical) data model
- Schema-on-read instead of complex schema migration for extensions
- Easy integration of multiple data sources (schemas) and types (structured, unstructured, …)
- Formal semantic representation enables inference and machine processing



KGs and other (AI) areas

- Semantic Web, **Ontologies**, and Linked Data
  - Knowlege Graphs is a generalisation
- Property graphs and graph databases and the web
- Machine learning models with graph formats and methods for symbolic knowledge representation, e.g., to create explainable AI

References

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