
Ontology Languages

Knowledge Graph

Objectives



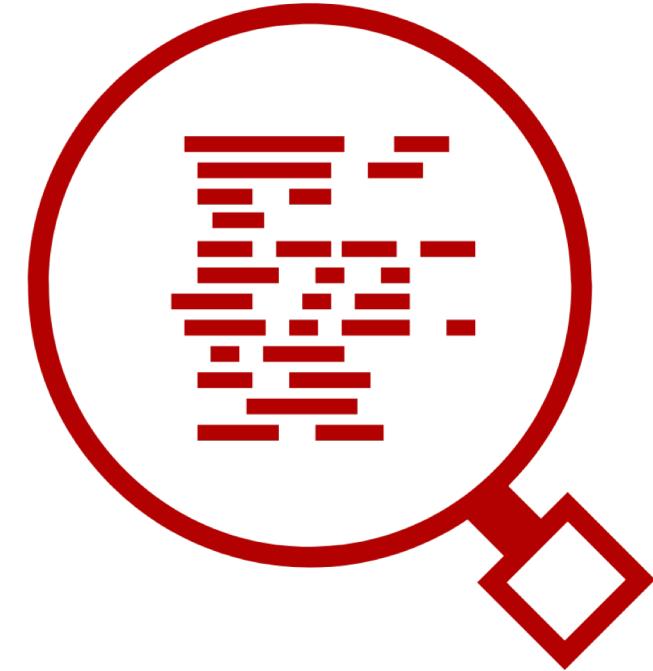
Objective

Explain the use of
ontologies in industrial
applications

Very Large Ontologies

| Recently there has been a lot of work on developing very large ontologies that capture various areas of human knowledge and deploying this knowledge in applications such as search engines or question answering.

| **Ex:** Watson, IBM's question answering system that beat humans in the quiz show Jeopardy



Examples of Very Large Ontologies



| Cyc

| Wordnet

| DBpedia

| YAGO

| Freebase

| Google's Knowledge Graph

| TextRunner

Towards a Definition of Knowledge Graph

| A knowledge graph acquires and integrates information into an ontology and applies a reasoner to derive new knowledge.

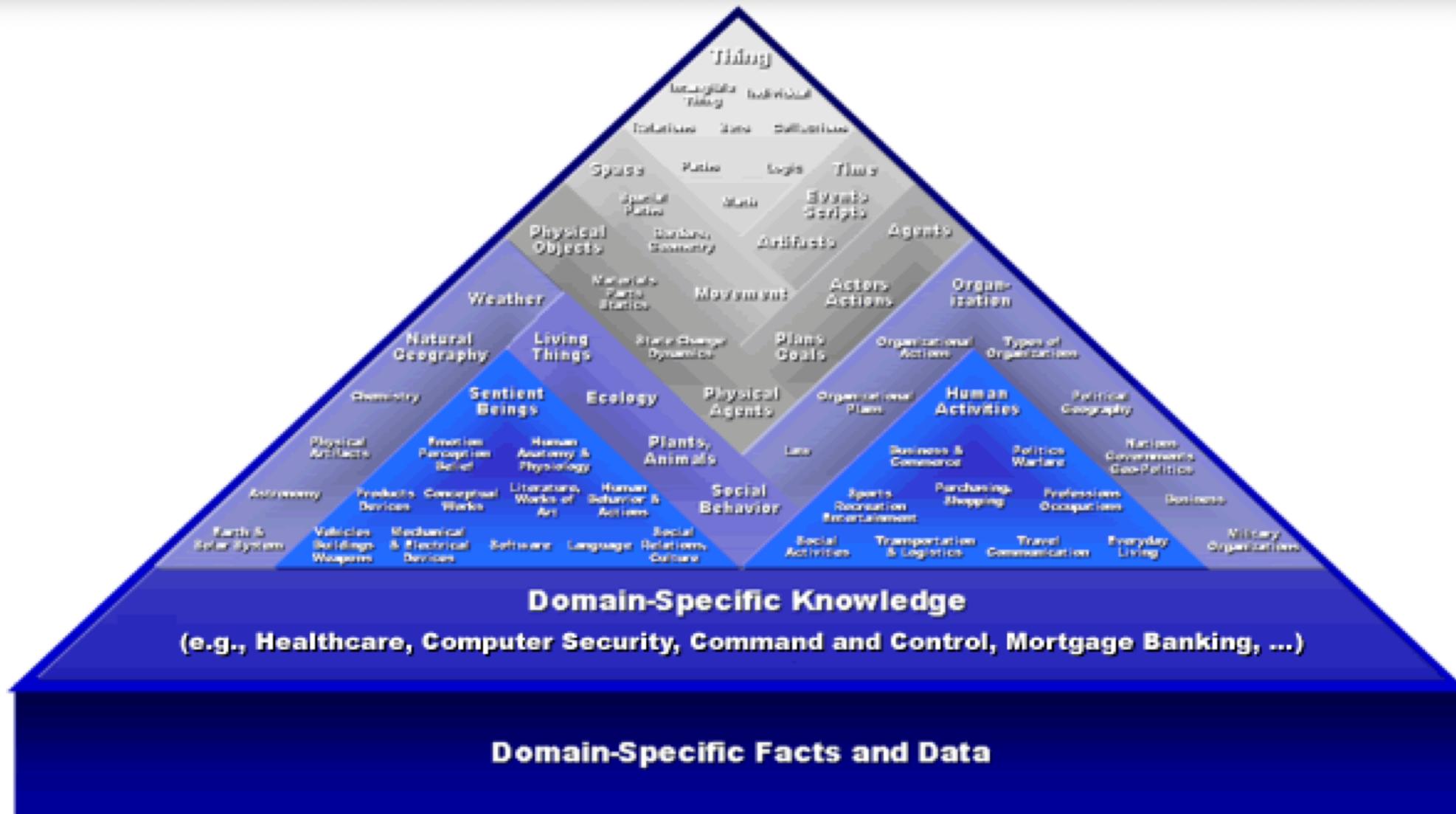
"A knowledge graph (i) mainly describes real world entities and their interrelations, organized in a graph, (ii) defines possible classes and relations of entities in a schema, (iii) allows for potentially interrelating arbitrary entities with each other and (iv) covers various topical domains."	H. Paulheim. Knowledge Graph Refinement: A Survey of Approaches and Evaluation Methods. Semantic Web Journal, (Preprint):1–20, 2016.
"Knowledge graphs are large networks of entities, their semantic types, properties, and relationships between entities."	M. Kroetsch and G. Weikum. Journal of Web Semantics: Special Issue on Knowledge Graphs. http://www.websemanticsjournal.org/index.php/ps/announcement/view/19 [August, 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, July 2014. https://blog.semantic-web.at/2014/07/15/from-taxonomies-over-ontologies- to-knowledge-graphs [August, 2016].
"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 $\in U_{UB}$, a predicate $p \in U$, and an object $\in U_{BUL}$. An RDF term is either a URI $u \in U$, a blank node $b \in B$, or a literal $l \in L$."	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. http://www.semantic-web-journal.net/content/linked-data-quality-dbpedia-freebase- opencyc-wikidata-and-yago [August, 2016] (revised version, under review)
"[...] 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 Proceedings of the 12th International Semantic Web Conference - Part I, ISWC '13, pages 542–557, New York, USA, 2013.

Cyc

- | A formalized representation of a vast quantity of **human common sense knowledge**
- | Currently contains nearly **500,000 terms**, including about **15,000 types of relations**, and about **5,000,000 facts** (assertions) relating these terms
- | New assertions continually added to the KB through a **combination of automated and manual means**



What does Cyc know?



SOURCE: ???

Cyc, cont'd

| Written in **Cycl**, an extension of FOL

- with equality, default reasoning, skolemization, and some second-order features

| Reasoning engine of Cyc uses around **1000 specialized reasoners**

| An **open source version** called OpenCyc is available



WordNet



- | Large lexical database of English (around 200,000 of words)
- | Nouns, verbs, adjectives and adverbs grouped into sets of cognitive **synonyms (synsets)**
- | Each synset expresses a distinct concept
- | Synsets are **interlinked** by means of **conceptual-semantic** (hyponym, hypernym, meronym etc.) and **lexical relations**
- | Not really an ontology but parts of it can be made into an ontology containing taxonomic information

WordNet Example

WordNet Search - 3.1

- [WordNet home page](#) - [Glossary](#) - [Help](#)

Word to search for:

Display Options:

Key: "S:" = Show Synset (semantic) relations, "W:" = Show Word (lexical) relations

Display options for sense: (gloss) "an example sentence"

Noun

- S: (n) **actor**, [histrion](#), [player](#), [thespian](#), [role player](#) (a theatrical performer)
 - [direct hyponym](#) / [full hyponym](#)
 - [has instance](#)
 - [direct hypernym](#) / [inherited hypernym](#) / [sister term](#)
 - S: (n) [performer](#), [performing artist](#) (an entertainer who performs a dramatic or musical work for an audience)
 - [derivationally related form](#)
- S: (n) **actor**, [doer](#), [worker](#) (a person who acts and gets things done) "*he's a principal actor in this affair*"; "*when you want something done get a doer*"; "*he's a miracle worker*"

DBpedia

- | A community effort to extract structured information from **Wikipedia** and to make the information available on the web in a knowledge base
- | Currently describes more than **3.5 million things**, out of which 1.67 million are classified in a consistent ontology
- | Has **several advantages over other knowledge bases**: it covers many domains; it represents real community agreement; it automatically evolves as Wikipedia changes, and it is truly multilingual



DBpedia, cont'd

- | Emphasis is on individuals, not general knowledge about various domains: different from Cyc
- | Written in RDF



DBpedia: Angelia Jolie



About: Angelina Jolie

An Entity of Type : [person](#), from Named Graph : <http://dbpedia.org>, within Data Space : [dbpedia.org](#)

Angelina Jolie Pitt (/dʒoʊ̯li:/ joh-LEE; née Voight; June 4, 1975) is an American actress, filmmaker, and humanitarian. She has received an Academy Award, two Screen Actors Guild Awards, and three Golden Globe Awards, and has been cited as Hollywood's highest-paid actress. Jolie made her screen debut as a child alongside her father, Jon Voight, in *Lookin' to Get Out* (1982). Her film career began in earnest a decade later with the low-budget production *Cyborg 2* (1993), followed by her first leading role in a major film, *Hackers* (1995). She starred in the critically acclaimed biographical television films *George Wallace* (1997) and *Gia* (1998), and won an Academy Award for Best Supporting Actress for her performance in the drama *Girl, Interrupted* (1999).

Property	Value
dbo:abstract	<ul style="list-style-type: none">Angelina Jolie Pitt (/dʒoʊ̯li:/ joh-LEE; née Voight; June 4, 1975) is an American actress, filmmaker, and humanitarian. She has received an Academy Award, two Screen Actors Guild Awards, and three Golden Globe Awards, and has been cited as Hollywood's highest-paid actress. Jolie made her screen debut as a child alongside her father, Jon Voight, in <i>Lookin' to Get Out</i> (1982). Her film career began in earnest a decade later with the low-budget production <i>Cyborg 2</i> (1993), followed by her first leading role in a major film, <i>Hackers</i> (1995). She starred in the critically acclaimed biographical television films <i>George Wallace</i> (1997) and <i>Gia</i> (1998), and won an Academy Award for Best Supporting Actress for her performance in the drama <i>Girl, Interrupted</i> (1999). Jolie's starring role as the video game heroine Lara Croft in <i>Lara Croft: Tomb Raider</i> (2001) established her as a leading Hollywood actress. She continued her successful action-star career with <i>Mr. & Mrs. Smith</i> (2005), <i>Wanted</i> (2008), and <i>Salt</i> (2010), and received critical acclaim for her performances in the dramas <i>A Mighty Heart</i> (2007) and <i>Changeling</i> (2008), which earned her a nomination for an Academy Award for Best Actress. Beginning in the 2010s, she expanded her career into directing, screenwriting, and producing, starting with the wartime dramas <i>In the Land of Blood and Honey</i> (2011) and <i>Unbroken</i> (2014). Her biggest commercial success came with the fantasy picture <i>Maleficent</i> (2014). In addition to her film career, Jolie is noted for her humanitarian efforts, for which she has received a Jean Hersholt Humanitarian Award and an honorary damehood of the Order of St Michael and St George (DCMG), among other honors. She promotes various causes, including conservation, education, and women's rights, and is most noted for her advocacy on behalf of refugees as a Special Envoy for the United Nations High Commissioner for Refugees (UNHCR). As a public figure, Jolie has been cited as one of the most influential and powerful people in the American entertainment industry, as well as the world's most beautiful woman, by various media outlets. Her personal life is the subject of wide publicity. Divorced from actors Jonny Lee Miller and Billy Bob Thornton, she has been married to actor Brad Pitt since 2014. They have six children together, three of whom were adopted internationally. (en)

DBpedia: Angelia Jolie, cont'd

dbo:activeYearsEndYear	▪ 1982-01-01 (xsd:date)
dbo:activeYearsStartYear	▪ 1982-01-01 (xsd:date)
dbo:birthDate	▪ 1975-06-04 (xsd:date)
dbo:birthName	▪ Angelina Jolie Voight (en)
dbo:birthYear	▪ 1975-01-01 (xsd:date)
dbo:citizenship	▪ dbr:Cambodia
dbo:occupation	▪ dbr:Angelina_Jolie_1
dbo:parent	▪ dbr:Jon_Voight ▪ dbr:Marcheline_Bertrand
dbo:relative	▪ dbr:Chip_Taylor ▪ dbr:Barry_Voight ▪ dbr:James_Haven
dbo:spouse	▪ dbr:Billy_Bob_Thornton ▪ dbr:Jonny_Lee_Miller ▪ dbr:Brad_Pitt
dbo:thumbnail	▪ wiki-commons:Special:FilePath/Angelina_Jolie_2_June_2014_(cropped).jpg?width=300

SOURCE: DBpedia Website (http://dbpedia.org/page/Angelina_Jolie)

YAGO

- | A huge semantic knowledge base, derived from Wikipedia, WordNet, and GeoNames
- | Currently has knowledge of more than **10 million entities** and contains more than **120 million facts** about these entities
- | In YAGO2, efforts were made to treat **time and location data as first-class citizens**, extending the basic triple model by special fields for time and location for querying.
 - Also to attach temporal and spatial data (when it can be derived) to all facts where it is semantically meaningful



Freebase

- | An open, Creative Commons licensed repository of structured data of almost **20 million entities**
- | An **entity** is a single person, place, or thing. Freebase connects entities together as a **graph**
- | Now owned by Google and its **Knowledge Graph** technology builds on it.
- | **Data Dumps** are a downloadable version of the data in Freebase.



Freebase: Angelia Jolie

Freebase Data Schema Apps Docs Sign In or Sign Up

Angelina Jolie

Scroll to:

- People
- Film
- Author
- Celebrity
- Awards
- Collector
- TV Actor
- More...

 Angelina Jolie (born Angelina Jolie Voight on June 4, 1975) is an American film actor and a Goodwill Ambassador for the UN Refugee Agency. She has been cited as one of the world's most beautiful women and her off-screen life is widely reported. Jolie has received three Golden Globe Awards, two Screen Actors Guild

Angelina Jolie cards, and an Academy Award. Though she made her screen debut as a child alongside her father Jon Voight in the 1982 film *Lookin' to Ge...* [More](#)

Date of birth: Jun 4, 1975 (age 36 years)

Place of birth: [Los Angeles, United States of America](#)

Height: 1.695 m (5.561 ft)

Religion: [Buddhism](#)

Also known as: Angelina Jolie Voight

People

Place of birth: [Los Angeles, United States of America](#)

Country of nationality: [United States of America](#)

Gender: Female

Profession: Writer
Actor
Film Producer
Model

Ethnicity: Slovak American

Parents: Jon Voight
Marcheline Bertrand

Children: Maddox Jolie-Pitt
Pax Thien Jolie-Pitt
Zahara Jolie-Pitt
Shiloh Jolie-Pitt

Related Topics

 Gwyneth Paltrow

 Gwen Stefani

 Jennifer Aniston

 Jerry Seinfeld

Angelina Jolie elsewhere on the web

 [Wikipedia](#)

 [New York Times](#)

 [IMDb profile](#)

 [NNDB](#)

 [Netflix](#)

 [MySpace Page](#)

 [Daylife Topic Page](#)

 [Chickpedia](#)

SOURCE: Freebase Website (http://www.freebase.com/view/en/angelina_jolie)

Google's Knowledge Graph

Google

<https://www.google.com/> ▾

Even more from Google · Sign in. Google. x. x. SEND FEEDBACK. CANCEL. OK. DELETE. Location unavailable --. SettingsSearch settingsAdvanced ...

[Google Account](#)

Personal info - Data & personalization - Security - ...

[Google Accounts](#)

Not your computer? Use Guest mode to sign in privately. Learn ...

[Google News](#)

Comprehensive up-to-date news coverage, aggregated from ...

[More results from google.com »](#)

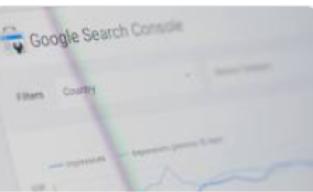
Top stories



Google warns its employees that Pride protests are against the company's code of...

The Verge

22 hours ago



Google Search Console's Testing Tools Gain Two New Features

Search Engine Journal

17 hours ago



Google accused of political bias in online video and by some lawmakers

WJLA

11 mins ago

Google

Technology company



google.com

Google LLC is an American multinational technology company that specializes in Internet-related services and products, which include online advertising technologies, search engine, cloud computing, software, and hardware. It is considered one of the Big Four technology companies, alongside Amazon, Apple and Facebook. [Wikipedia](#)

Founded: September 4, 1998, Menlo Park, CA

CEO: Sundar Pichai (Oct 2, 2015–)

Headquarters: Mountain View, CA

Subsidiaries: YouTube, Google.org, Dialogflow, Google Nest, MORE

Founders: Larry Page, Sergey Brin

Did you know: Google is the world's largest internet company by revenue. [wikipedia.org](#)

Profiles



Twitter



Instagram



LinkedIn



Pinterest



YouTube

People also search for



Amazon.c...



Apple



Yahoo!

View 15+ more



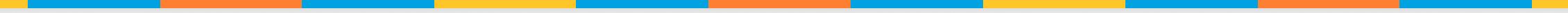
Microsoft Corporation



Huawei

SOURCE: Google

Building Ontologies



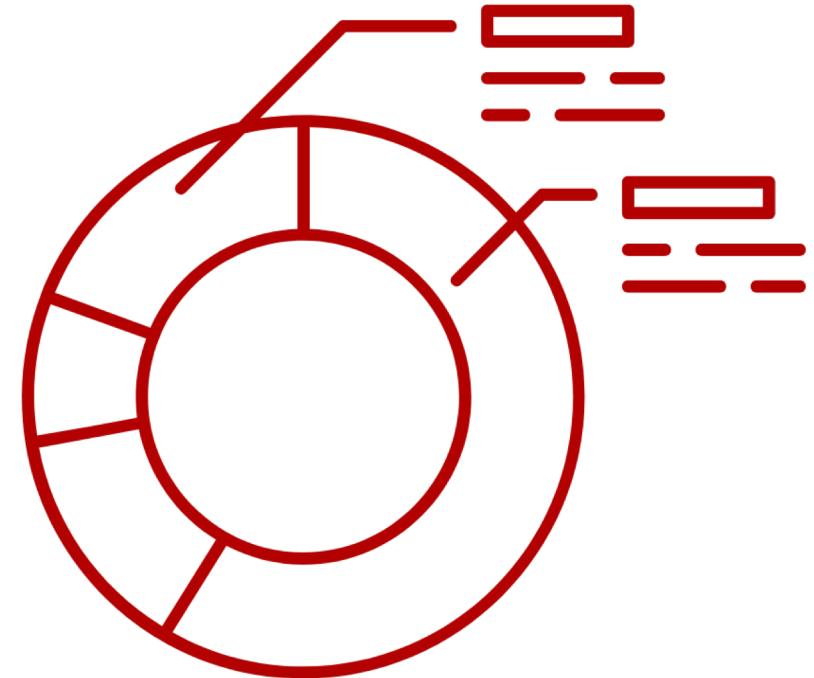
| The example ontologies we saw have been created using different means:

- Getting **a team of trained ontology engineers** to organize the ontology and write the axioms (CYC). WordNet was also built by trained experts (lexicographers).
- **Importing structured facts** from various Web sources possibly with some inference (DBpedia, FreeBase, YAGO2). Manual curation is also possible here (FreeBase, DBpedia).
- Parsing **text documents** and extracting information from them (TextRunner).

| The availability of open sources of knowledge on the Web has fueled the development of efforts such as DBpedia, FreeBase and YAGO2

What is a Knowledge Graph? (1 of 2)

- | Knowledge in graph form!
- | Captures entities, attributes, and relationships
- | Nodes are entities
- | Nodes are labeled with attributes (e.g., *types*)
- | Typed edges between two nodes capture a relationship between entities



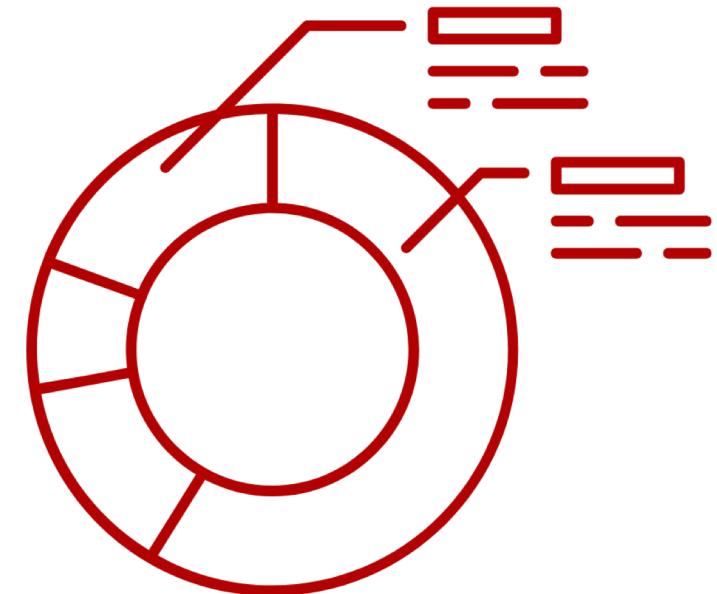
What is a Knowledge Graph? (2 of 2)

| Most knowledge graph implementations use RDF triples

- <rdf:subject, rdf:predicate, rdf:object> : r(s,p,o)
- Temporal scoping, reification, and skolemization...

| Common ontological primitives

- rdfs:domain, rdfs:range, rdf:type, rdfs:subClassOf, rdfs:subPropertyOf, ...
- owl:inverseOf, owl:TransitiveProperty, owl:FunctionalProperty, ...



Wrap-Up

