Turning a Taxonomy into an Ontology

KM World Connect: Taxonomy Boot Camp
November 17, 2021

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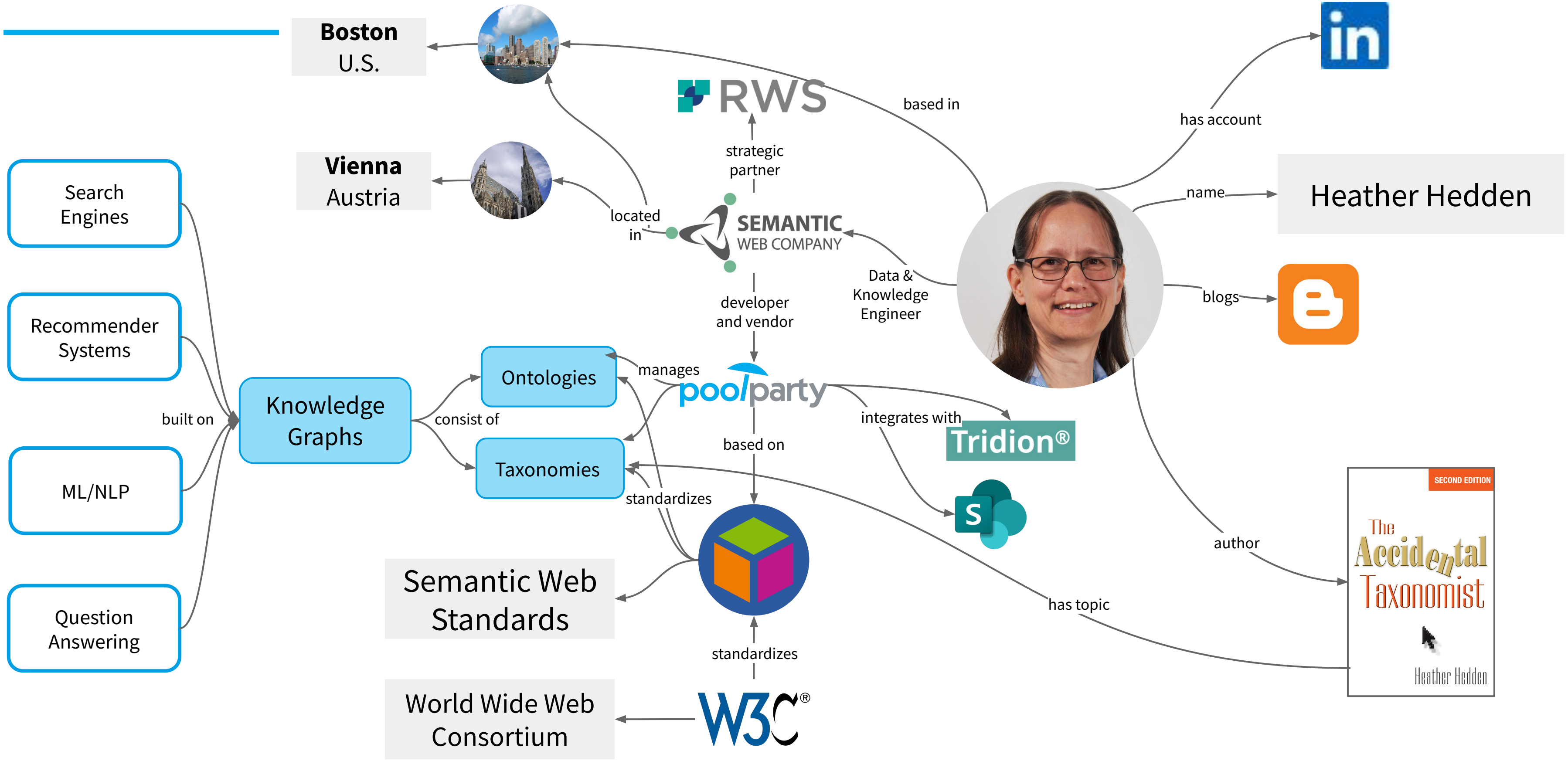


Background

- Experience as vocabulary editor at Gale (1995 - 2004, 2014 - 2019) involved managing vocabularies with customized "cross-object" relationships and "extended attributes" on terms.

- Use of different thesaurus management tools with capabilities to customize relationships and attributes.

- At Taxonomy Boot Camp November 2012, presented "From Accidental Taxonomist to Accidental Ontologist," a 10-minute, 10-slide "pecha kucha" talk.

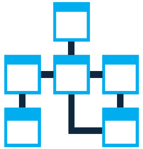
Outline

- Why extend a taxonomy
- Knowledge organization system types
- What is an ontology
- Standards for taxonomies and ontologies
- Extending a taxonomy: different approaches to creating an ontology
- Applying an ontology as a semantic layer to a taxonomy/thesaurus
- Example implementation of ontology-based facets

Why Extend a Taxonomy

What you can do with a taxonomy

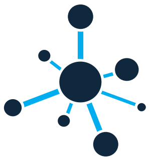
- Tagging: index content consistently so that retrieval is comprehensive and accurate
- Normalization: Bring together different names, localizations, languages for concepts
- Standard search: find content about…. (search string matches taxonomy concepts)
- Topic browse: explore subjects arranged in a hierarchy and then content on the subject
- Faceted (filtering/refining) search: find content meeting a combination of basic criteria
- Discovery: find other content tagged with same concepts as tagged to found content; explore broader, narrower, and (sometimes) related taxonomy topics
- Content curation: create feeds or alerts based on pre-set search terms
- Metadata management: for retrieval, identification, comparison, analysis, etc.



Why Extend a Taxonomy

What you cannot do with a taxonomy alone, but can with an added ontology

- Modeling complex interrelationships (e.g. in product approval or supply chain processes) and also connect to content
- Complex multi-part searches: e.g. find contacts in a specific location, who are employed by companies which belong to certain industries
- Exploring explicit relationships between concepts (not just broader, narrower, related)
- Search across datasets, not just search for content
- Search on more specific criteria that vary based on category (class)
- Visualization of concepts and semantic relationships
- Reasoning and inferencing
- Build a knowledge graph...

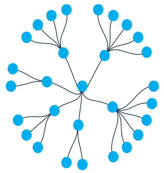


Why Extend a Taxonomy

Knowledge graphs: taxonomy + ontology + instance data in a graph database

What you can do with a knowledge graph

- Search expanded to data in different repositories, platforms, applications, etc.
- Search and discovery across heterogeneous content and data, both structured and unstructured
- Better personalization and recommendation systems
- Visualizations of curated data



Enterprise knowledge graphs are becoming the dominant implementation for business ontologies.

Knowledge Organization System Types

Knowledge Organization system (KOS)

- Any system of terms, terminology, classification, etc.
- To organize, define, manage, and/or retrieve information.
- Broader, includes more than just "controlled vocabularies."

KOS types:

- term lists
- synonym rings
- name authorities
- taxonomies
- thesauri
- glossaries
- dictionaries
- gazetteers
- terminologies
- categorization schemes
- classification systems
- subject heading schemes
- semantic networks
- ontologies

(term lists, synonym rings, name authorities, taxonomies, thesauri:) Controlled Vocabularies for tagging and information retrieval

Knowledge Organization System Types

Controlled vocabularies

- Term lists/Pick lists
- Synonym rings
- Authority files
  - Name authorities
- Taxonomies
- Subject heading schemes
- Thesauri

Defined vocabularies

- Dictionaries
- Glossaries
- Gazetteers
- Terminologies

Classification systems

- Cataloging systems
- Categorization schemes
- Classification schemes

Semantic models

- Mind maps
- Topic maps
- Semantic networks
- Ontologies

Knowledge Organization System Types

Less Complexity/Expressiveness *More*

Term List	Name Authority	Taxonomy	Thesaurus	Ontology
Ambiguity control	Ambiguity control Synonym control (Attributes)	Ambiguity control (Synonym control) Hierarchical relationships	Ambiguity control Synonym control Hierarchical relationship Associative relationships	Ambiguity control Semantic relationships Classes Attributes

Knowledge Organization System Types

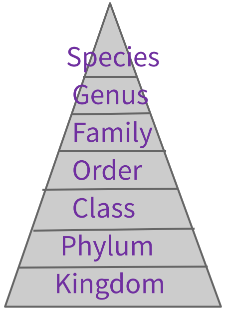
Less Complexity/Expressiveness *More*

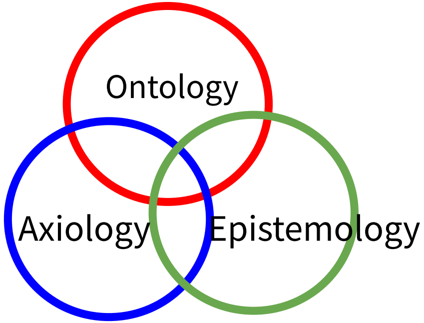
Ontology (model/layer)			
Term List	**Name Authority**	**Taxonomy**	**Thesaurus**
Ambiguity control	Ambiguity control Synonym control (Attributes)	Ambiguity control (Synonym control) Hierarchical relationships	Ambiguity control Synonym control Hierarchical relationship Associative relationships

What is an Ontology

Traditional meanings

- Taxonomy - an ordered naming system or classification system (especially in biology)
- Ontology - branch of metaphysics concerned with the nature and relations of being





Information and knowledge management usage:

- Taxonomy - a structured set of terms/concepts in a subject domain, used for tagging content to support information findability and retrieval
- Ontology - a structured set of entities, relationships and attributes in a subject domain, with semantic expressiveness, used for information exploration and analysis, in addition to findability and retrieval

What is an Ontology

Definition by Tom Gruber:

An ontology defines a set of representational primitives with which to model a domain of knowledge or discourse.

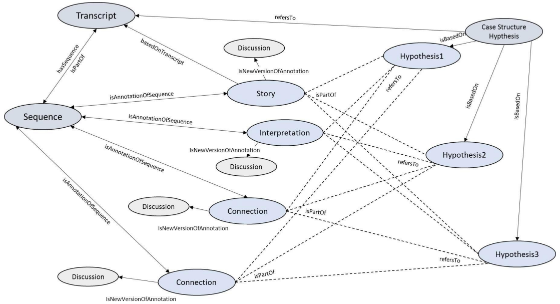
The representational primitives are typically classes (or sets), attributes (or properties), and relationships (or relations among class members).

The definitions of the representational primitives include information about their meaning and constraints on their logically consistent application.

In the context of database systems, ontology can be viewed as a level of abstraction of data models, analogous to hierarchical and relational models, but intended for modeling knowledge about individuals, their attributes, and their relationships to other individuals.

https://tomgruber.org/writing/definition-of-ontology.pdf
Gruber T. (2016) Ontology. In: Liu L., Özsu M. (eds) *Encyclopedia of Database Systems*. Springer, New York, NY, based on his original definition in 1993.

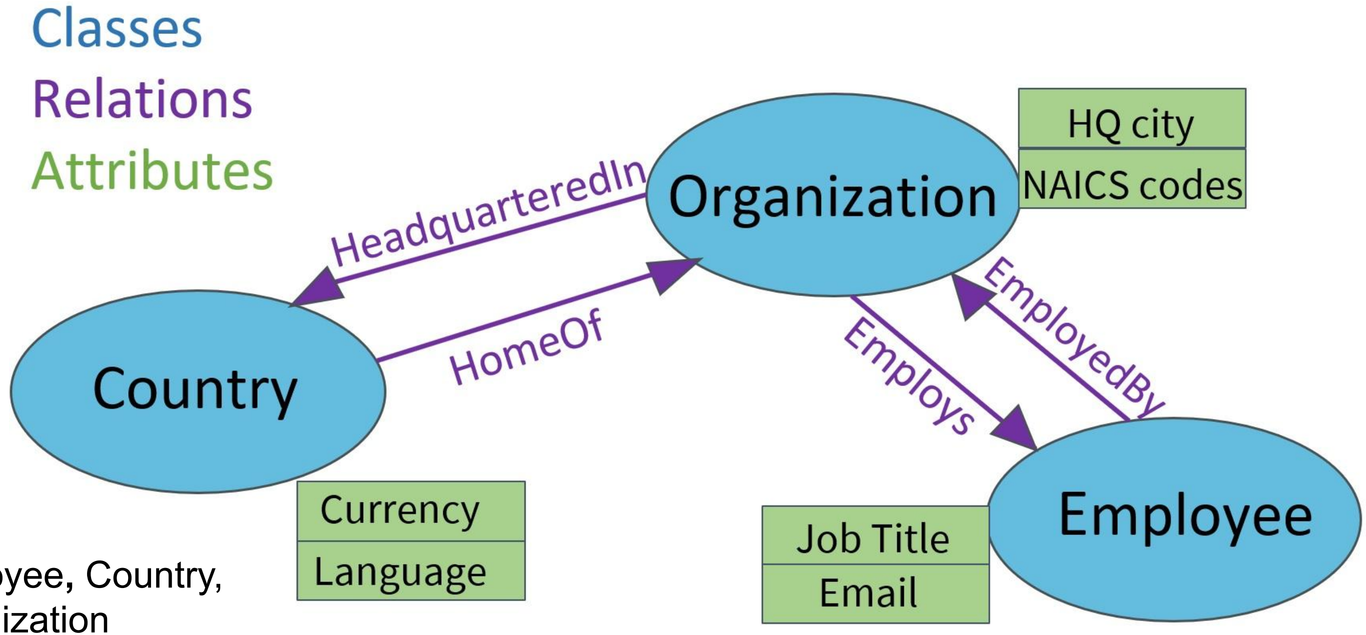
What is an Ontology



Other definition components of an ontology

- A form of knowledge representation
  - Not just knowledge organization
- A set of precise descriptive statements about a particular domain.
  - Statements as subject-predicate-object are expressed as triples.
- A formal naming and definition of the types, properties and interrelationships of entities in a particular domain.
  - Classes, custom attributes, and semantic relationships
- A more abstract layer in describing a knowledge organization system
  - Overlays and connects to a taxonomy or other controlled vocabulary to add semantics

What is an Ontology: Example



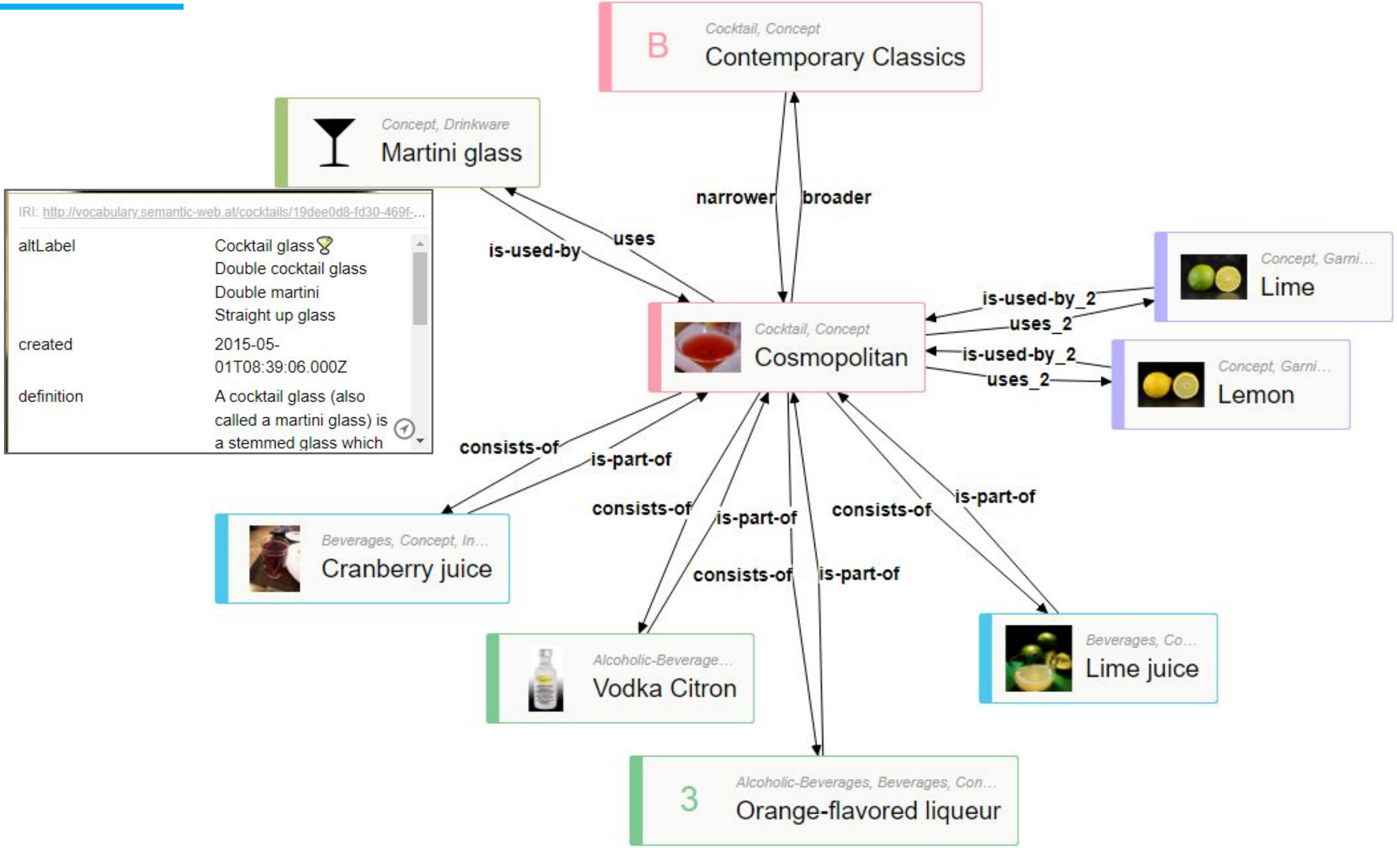
Classes

Employee, Country, Organization

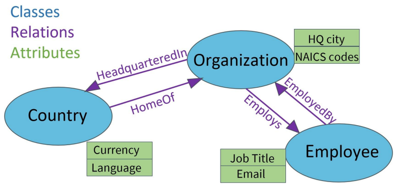
Relations: HeadquarteredIn < > HomeOf
EmployedBy < > Employs

Attributes: Email address, Job title, HQ city, NAICS codes, Currency, Language

What is an Ontology: Example



What is an Ontology



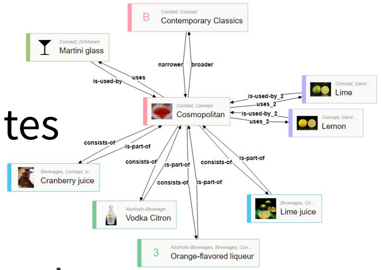
Ontology definition questions

Is it:

- A knowledge model, a semantic layer, a form of knowledge representation, that describes the classes, relationship types, and attribute types in a domain,

or:

- A knowledge organization system, that includes both: the classes, relationship types, and attribute types *and* the specific concepts, entities/individuals, and their specific attributes



Both definitions exist.
Turning a taxonomy into an ontology, refers to the latter definition of ontology.

An ontology can also be defined as a semantic model that conforms to OWL standards.

Standards for taxonomies and ontologies

Standards and Specifications

Taxonomy standards

- ANSI/NISO Z39.19 or ISO 25964
  Standards or design best practices, especially for thesauri
  - *preferred term, nonpreferred term, broader term, narrower term, and related term relationships; scope notes*
- W3C: SKOS (Simple Knowledge Organization System)
  Standard for machine-readability and interoperability
  - *concept schemes, concepts; labels, relationships, etc.*

Ontology standards

- W3C: RDF-S (Resource Description Framework - Schema)
- W3C: OWL (Web Ontology Language)

Both are languages for representing ontologies on the web - for machine readability and interoperability

Standards: RDF

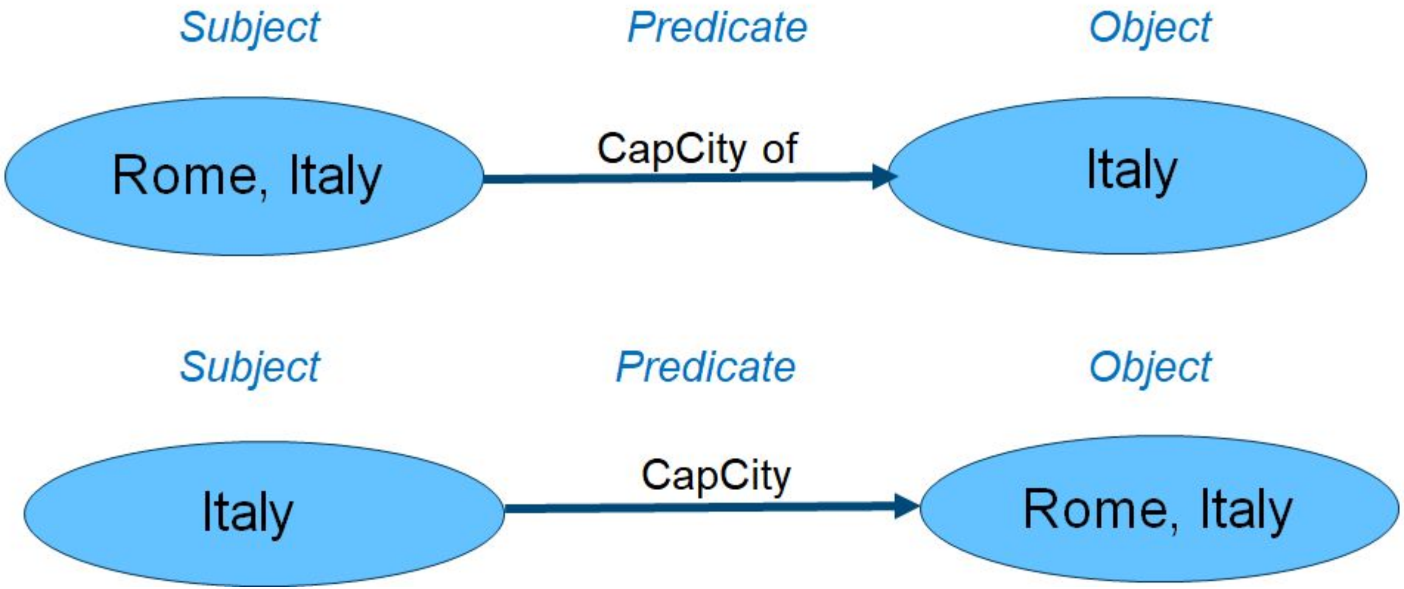
RDF (Resource Description Framework)

- A World Wide Web (W3C) recommendation https://www.w3.org/TR/rdf11-concepts
- Started in 1997, adopted by the W3C as a recommendation in 1999, RDF 1.1 specification in 2014.
- "A standard model for data interchange on the Web."
- Requires the use of URIs (uniform resource identifiers) to specify things and to specify relationships.
- Models information as triples: subject – predicate – object
- Models information on a graph-based model (as nodes and edges).
- Facilitates data merging even if the underlying schemas differ.
- More fundamental, basic, and generic than SKOS or OWL.
  RDF serves as a basic standard for *both* taxonomies (in SKOS) and ontologies.

Standards: RDF

RDF triple: (1) Subject – (2) Predicate – (3) Object

Example



Standards: SKOS

SKOS (Simple Knowledge Organization System) elements

Concept Scheme & Collection	Concepts	Labels & Notation	Documentation	Semantic Relations	Mapping Relations
ConceptScheme	Concept	prefLabel	scopeNote	broader	exactMatch
inScheme	hasTopConcept	altLabel	definition	narrower	closeMatch
Collection	topConceptOf	hiddenLabel	example	related	broaderMatch
orderedCollection		notation	changeNote		narrowerMatch
member			editorialNote		relatedMatch
memberList			historyNote		

https://www.w3.org/TR/skos-reference

Ontology Standards: RDF Schema

RDF Schema - RDFS or RDF/S or RDF(S)

- Also called: RDF Vocabulary Description Language 1.0
- A World Wide Web (W3C) recommendation https://www.w3.org/2001/sw/wiki/RDFS
- Published as part of the RDF Specification Suite Recommendations in 2004.
- “A general-purpose language for representing simple RDF vocabularies on the Web.”
- A flexible data model adaptable to specific needs.
- Goes beyond RDF to designate **classes** and **properties.**
- RDFS serves as a standard for ontologies.

Ontology Standards: OWL

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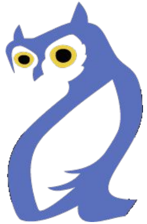
OWL - Web Ontology Language

- A World Wide Web (W3C) specification https://www.w3.org/OWL
- First published in 2004; OWL 2 (with extended features), published in 2009 https://www.w3.org/TR/owl2-overview
- “A Semantic Web language designed to represent rich and complex knowledge about things, groups of things, and relations between things”
- To provide a common way to process the content of web Information.
- A computer-readable language, usually written in XML,
- A declarative language (not a programming or schema language)
- Enables knowledge linking on the web/Semantic Web
- Based on RDF and RDFS. OWL is W3Cs attempt to extend RDFS.
- The Semantic Web led to a requirement for a “web ontology language.”



W3C OWL

Ontology Standards: OWL

OWL-Defined Ontology Components

Entities – subjects (domains) or objects (ranges) of properties, within RDF triples

- Classes (in SKOS: concepts)
  - Named sets of concepts that share characteristics and relations
  - May contain subclasses or individuals (instances of the class)
- Individuals (in SKOS: concepts)
  - Members or instances of a class. Unique named entities.

Properties – predicates about individuals (instances)

- Object properties (in SKOS: relations)
  - Relations between individuals
  - May be directed (single direction), symmetric, or with an inverse (different in each direction)
- Datatype properties
  - Attributes or characteristics of individuals
  - The object of a datatype property is a *value*.

Literals – values of attributes, with just a *lexical form* and a *datatype.*

https://www.w3.org/TR/2012/REC-owl2-primer-20121211/

Ontology Standards: OWL

- Names in OWL are international resource identifiers (IRIs).
- Syntaxes used in OWL: RDF/XML, OWL XML, and Manchester syntax.
- OWL modeling features also include:
  - Class disjointness
  - Complex classes
  - Property hierarchies
  - Property characteristics
  - Property restrictions
  - Property cardinality restrictions
  - Domain and range restrictions
  - Equality and inequality of individuals
  - Enumeration of individuals
  - Datatypes

Semantically enriching a taxonomy to become an ontology

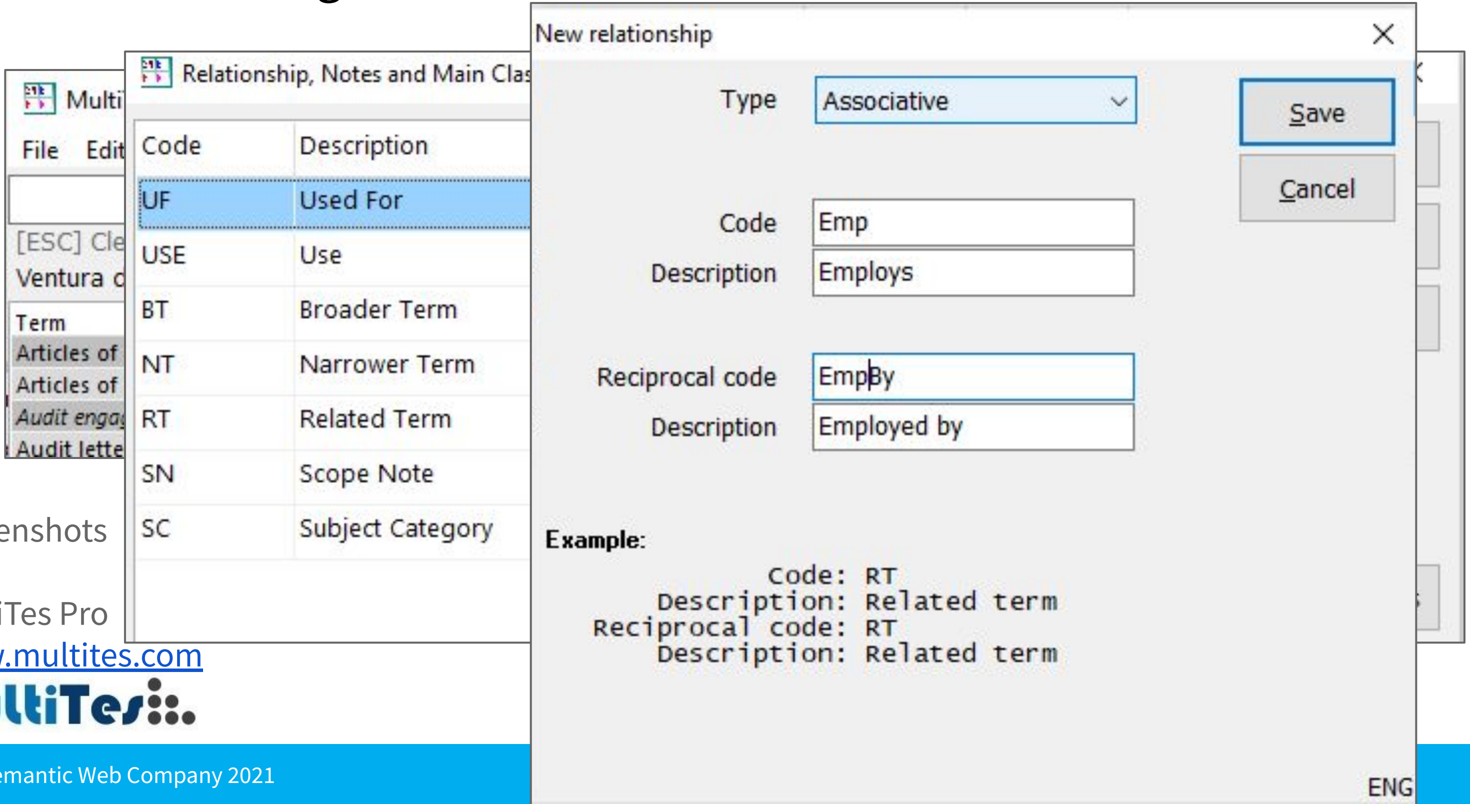
Ontology Creation Approaches

Different options for creating the semantic model + individual instances definition of an ontology:

1. Use a feature in thesaurus management tool to customize relationships, attributes, and categories to make an ontology-*like* semantic thesaurus
   - Follows thesaurus standards, but not ontology standards
2. Use a dedicated ontology tool or hand-coding OWL to build out the detailed taxonomic hierarchy (of subclasses and instances) within the ontology
   - Follows ontology standards, but not thesaurus standards
3. Use taxonomy/ontology combined tool to create taxonomy and an ontology and link them, with the ontology functioning as a semantic layer
   - Follows thesaurus/taxonomy and ontology standards

Ontology Creation Approaches

1. Customizing a thesaurus



Screenshots from MultiTes Pro www.multites.com

Ontology Creation Approaches

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1. Cust

Relationship, Notes and Main Classification codes

Code	Description	Reciprocal	Type	Usage
UF	Used For	USE	Equivalence	Preferred UF: NonPref
USE	Use	UF	Equivalence	NonPref USE: Preferred
BT	Broader Term	NT	Hierarchical	poodle BT: dog breeds
NT	Narrower Term	BT	Hierarchical	dog breeds NT: poodle
Emp	Employs	EmpBy	Associative	(A Emp: B) ~ (B EmpBy: A)
EmpBy	Employed by	Emp	Associative	(A EmpBy: B) ~ (B Emp: A)
RT	Related Term	RT		
Email	Email	-		
SN	Scope Note	-		
Co	Company	-		
Employee	Employee	-		
SC	Subject Category	-		

New

Edit

Delete

Problems with creating an “ontology” by customizing a thesaurus:

- Not interoperable/exchangeable.
  Cannot import, export, share.
- Limited governance/quality standards for internal validation. May have quality errors.
- No restrictions, constraints, reasoning, inferencing.

Ontology Creation Approaches

2. Using a dedicated ontology tool

- The ontology comprises all entities: classes, subclasses, and instances/individuals.
- The ontology is as detailed as any taxonomy or thesaurus, but has the addition of semantic relations and attributes.
- Classes have multiple levels of of subclasses.
- The ontology supports all OWL features: constraints, reasoning, inference, etc.

A method of building an ontology, but not by extending an existing taxonomy.

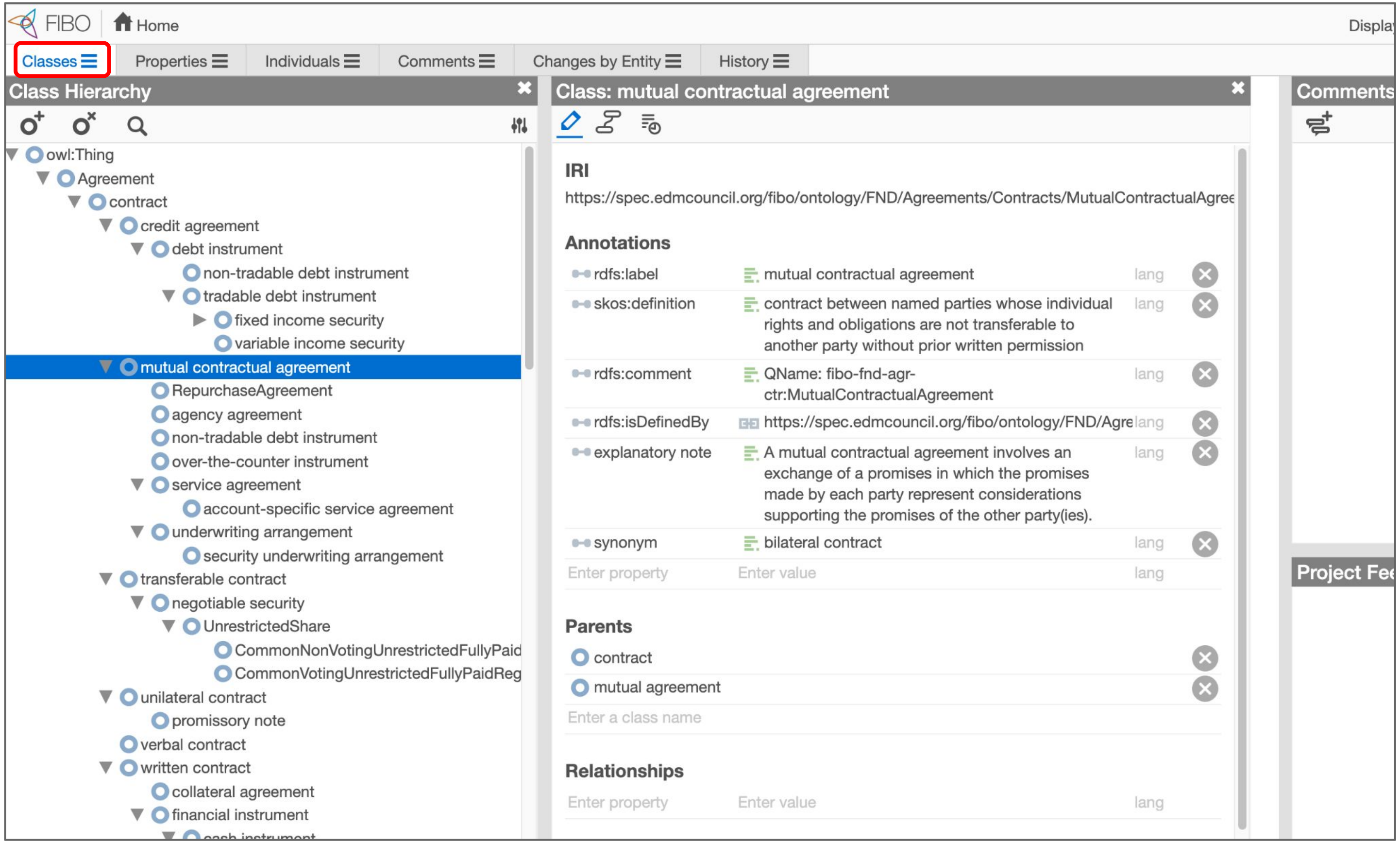
Screenshots from Protégé, free open-source ontology editor
https://protege.stanford.edu

Ontology Creation Approaches

2. Using a dedicated ontology tool: Protégé

Example of FIBO Financial Industry Business Ontology

Classes

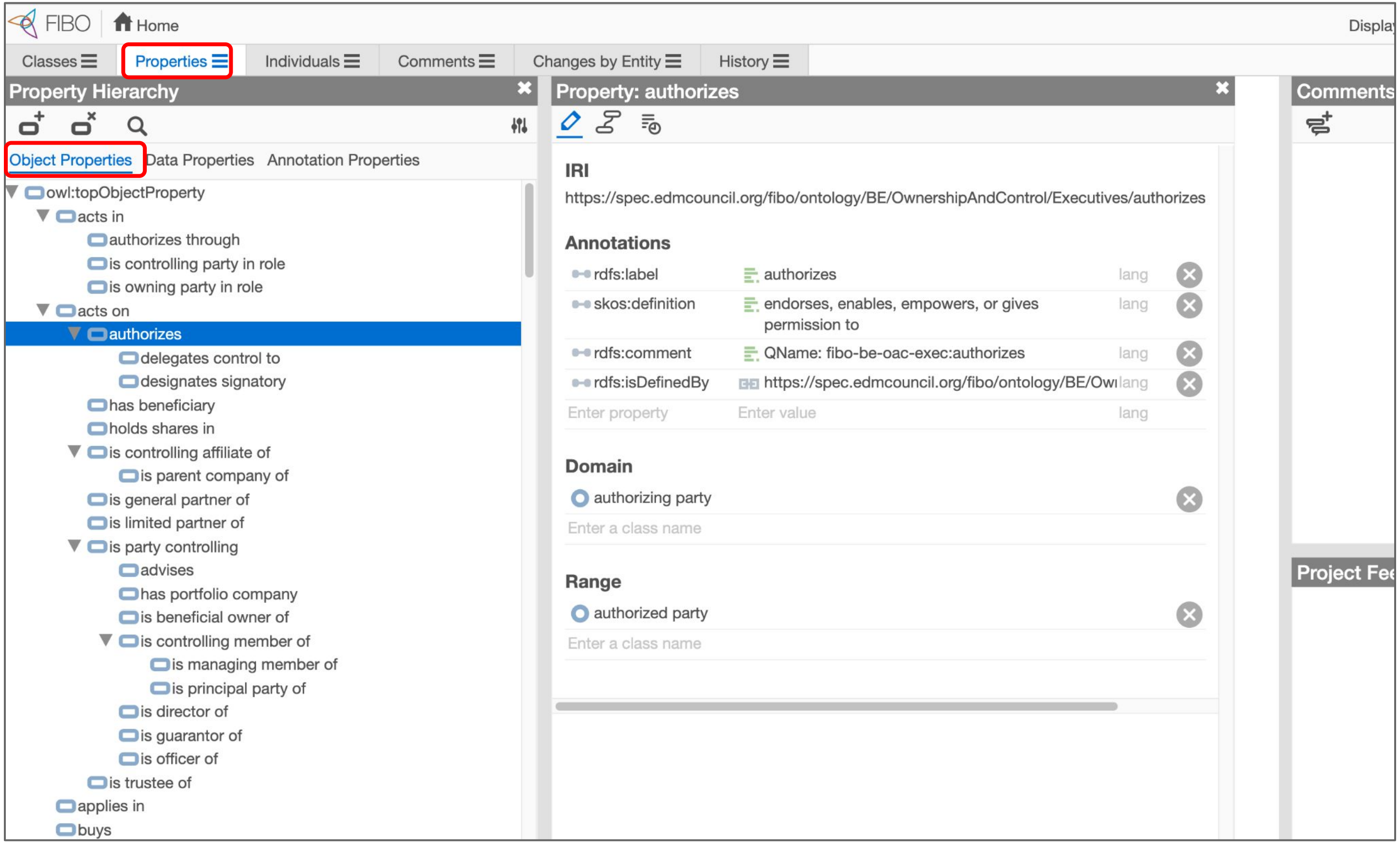


Ontology Creation Approaches

2. Using a dedicated ontology tool: Protégé

Example of FIBO Financial Industry Business Ontology

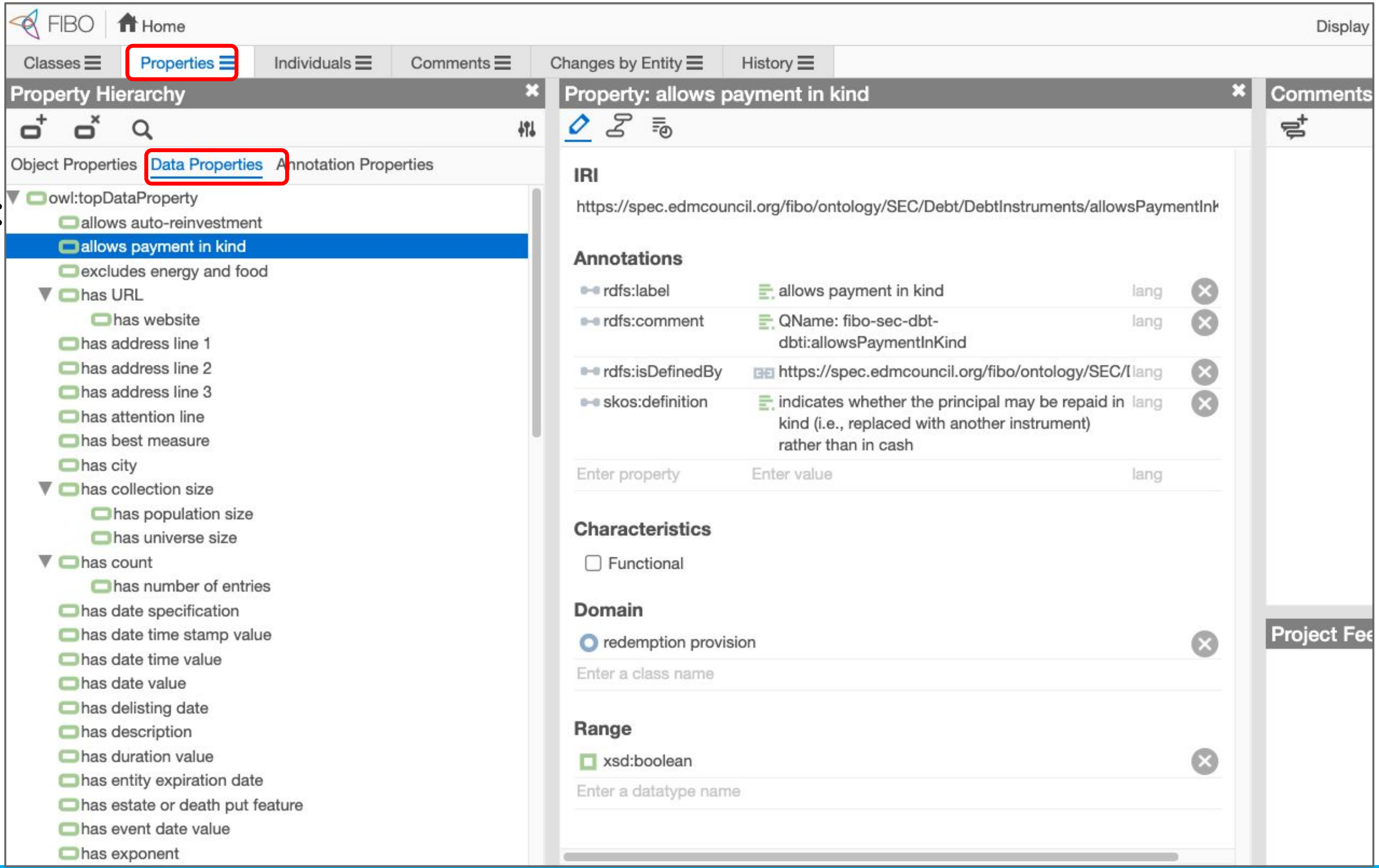
Relations



2. Using a dedicated ontology tool: Protégé

Example of FIBO Financial Industry Business Ontology

Attributes

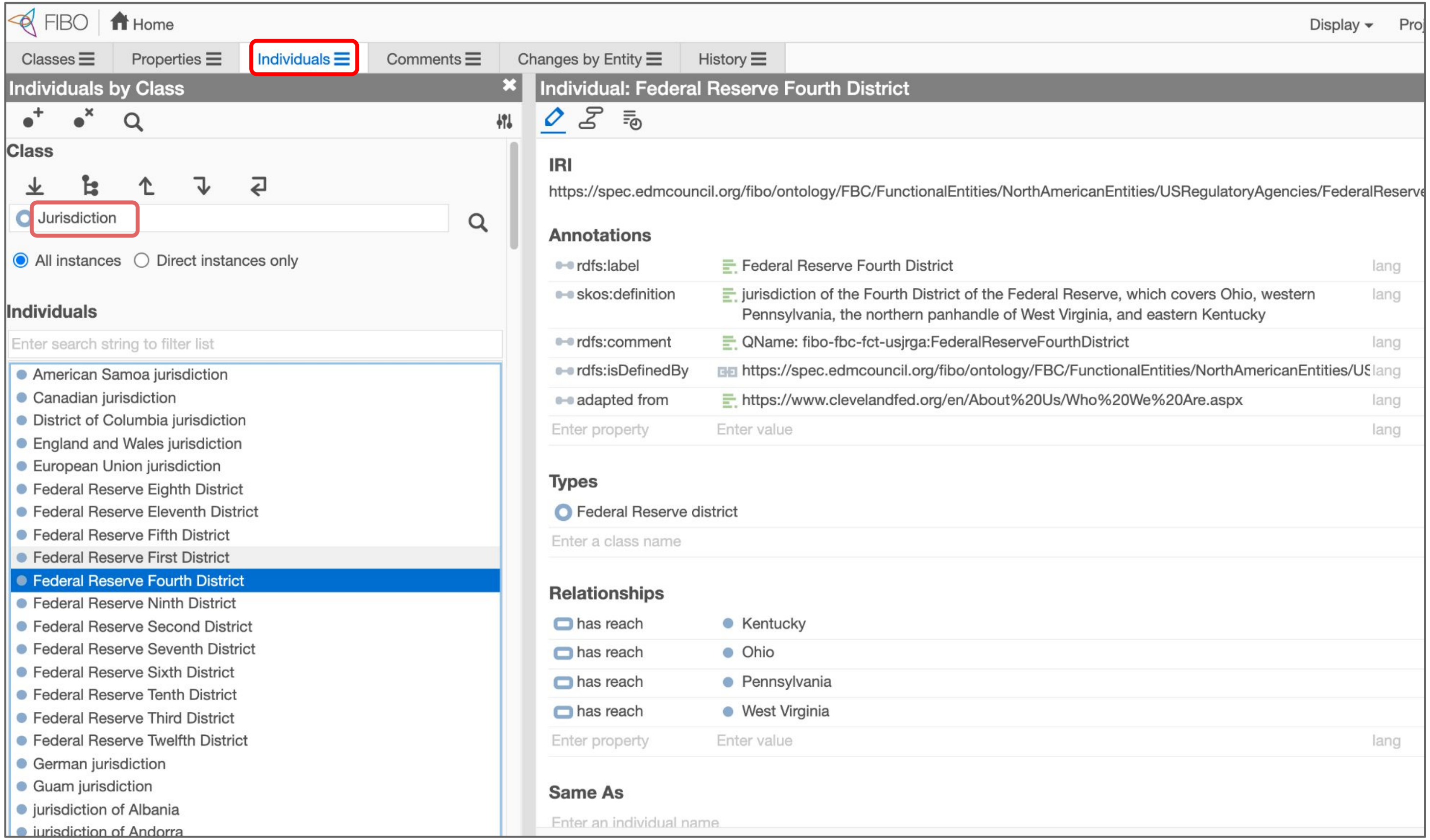


Ontology Creation Approaches

2. Using a dedicated ontology tool: Protégé

Example of FIBO Financial Industry Business Ontology

Individuals of a class



Ontology Creation Approaches

Importing taxonomies into an OWL-based ontology or dedicated ontology tool.
Not recommended approach to extending a taxonomy into an ontology:

Why not?

- All taxonomy hierarchies get converted to class-subclass hierarchies.
  - The class-subclass hierarchy in ontologies is of the hierarchical type generic-specific ("is a kind of") only.
  - Importing taxonomies into ontologies will incorrectly treat:
    - whole-part taxonomy relations (e.g. geographic) as class-subclass relations
    - generic-instance taxonomy relations as class-subclass relations, not class-instance affiliations
- Alternative labels can import, but as "Annotation" properties, and do not function as alternative labels for tagging and search.

Ontology Creation Approaches

3. In a combined taxonomy/ontology tool, create a taxonomy and an ontology and link them, with the ontology functioning as a semantic layer.

- The ontology comprises classes and subclasses to the extent needed to describe the generic characteristics of the semantic model.
- The ontology does not include all possible levels of hierarchy, nor any instances; More of the hierarchy and the instances reside in the SKOS taxonomy.

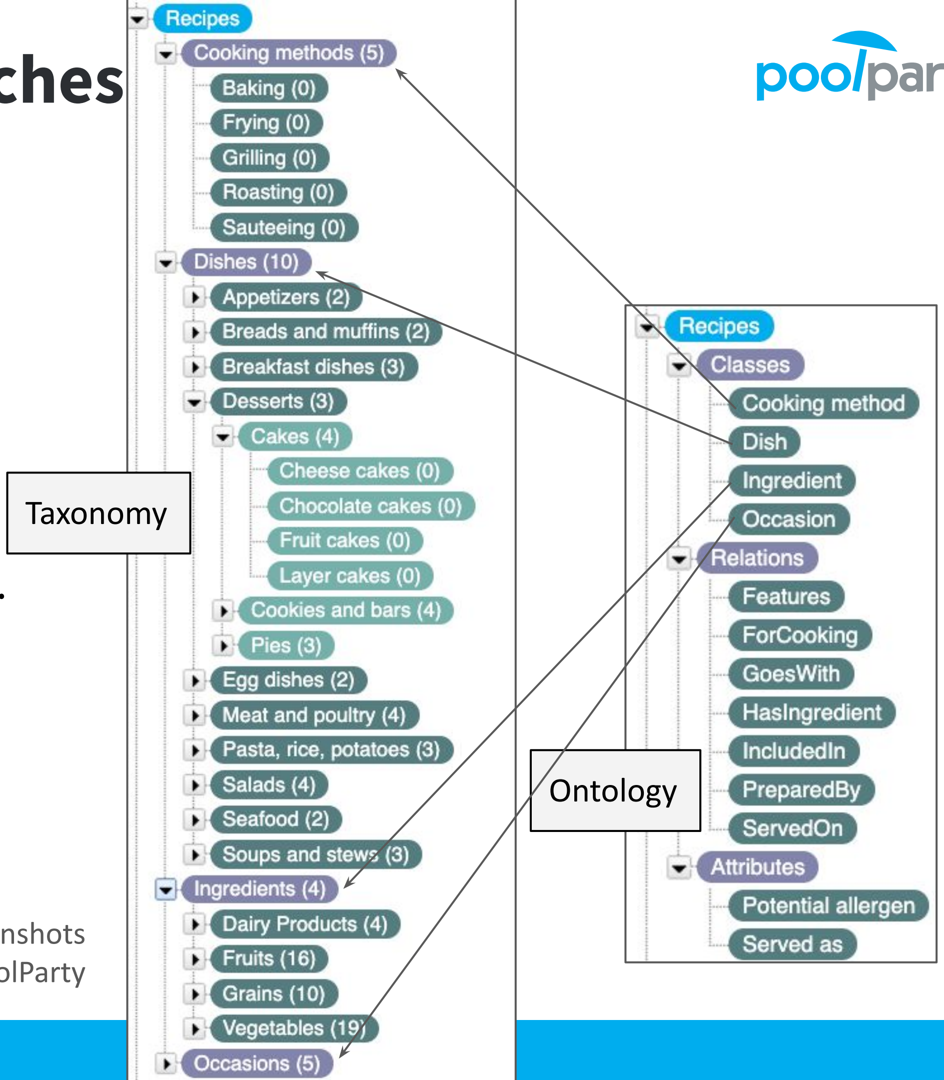
Ontology Creation Approaches

3. In a combined taxonomy/ontology tool, create a taxonomy and an ontology and link them, with the ontology functioning as a semantic layer.

Taxonomy + ontology layer

The ontology tends to be smaller and simpler.

Taxonomy may be based on SKOS, whereas ontology is based on OWL,
But they are compatible, based on RDF.



Screenshots from PoolParty

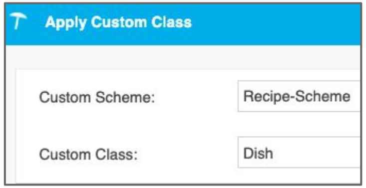
Applying Ontologies to Taxonomies

Extending SKOS taxonomy concepts to be part of an ontology

- Ontology class labels correspond/match the SKOS concept scheme or concept labels to which they will be applied
  - The ontology "layer" is not an upper hierarchical layer, but an **overlay** to the higher levels of the SKOS project.
  - Tip: consider using singular for ontology class names and plural for SKOS concept labels
- There is no dilemma in determining if an entity is an individual/instance or a class, since the ontology layer comprises only classes.

Applying Ontologies to Taxonomies

Extending SKOS taxonomy concepts to be part of an ontology



1. An ontology or custom scheme is applied/linked to the taxonomy project or to a specific concept scheme of a project.
2. Classes are applied to the levels of concept schemes, top concepts, or broad-level concepts, as appropriate. (Most often to concept schemes.)
3. Class properties (relations and attribute types) are then inherited by all narrower concepts.
4. Relevant relations and attributes are available for all concepts in the taxonomy, based on their class assigned to their broader concept or concept scheme.
5. Instantiating a relation between a pair of specific concepts or adding values to attributes may done manually or in a batch mode through importing spreadsheet tables.

Applying Ontologies to Taxonomies

Extending SKOS taxonomy concepts to be part of an ontology

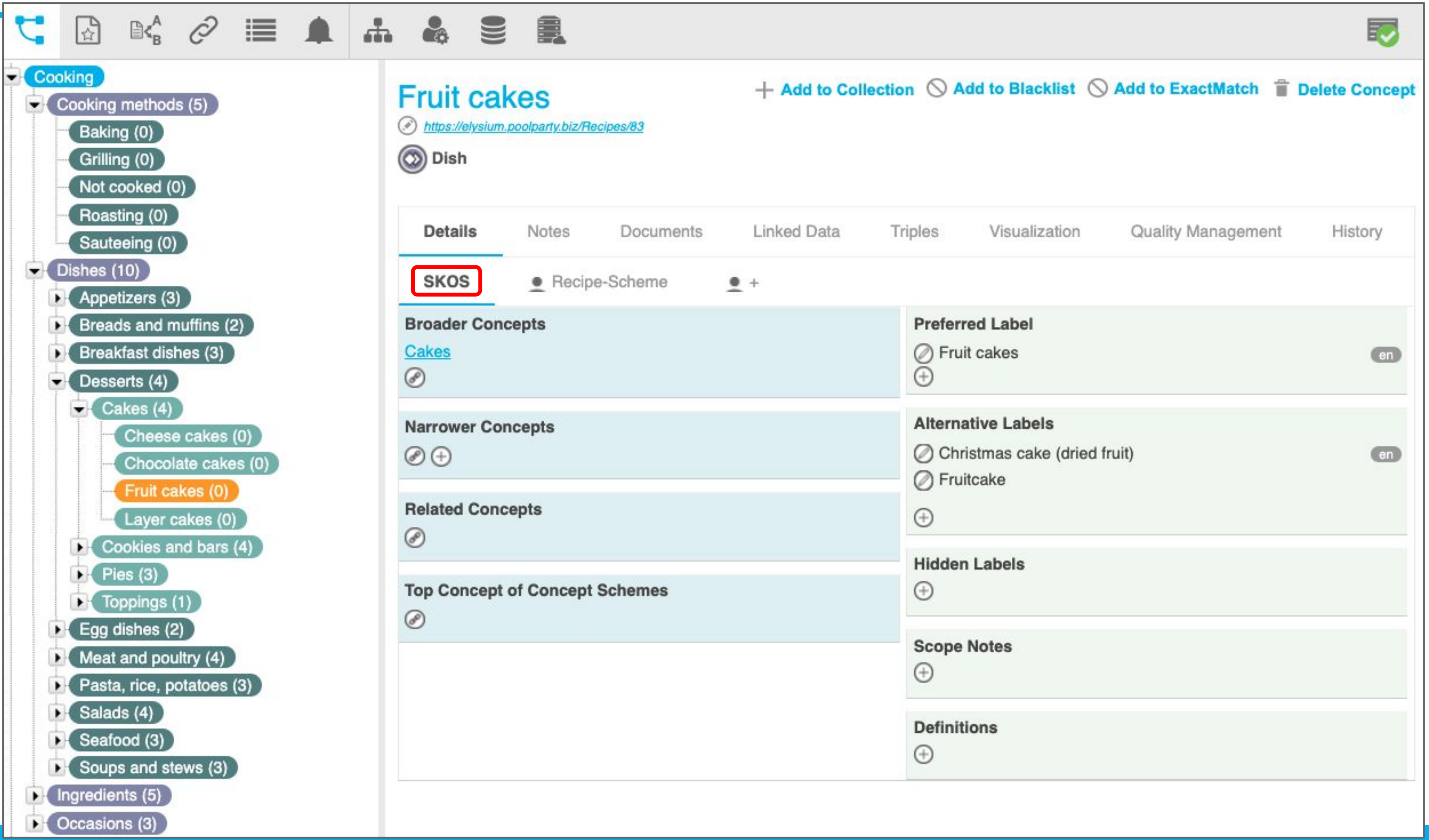
Instantiating relations between specific concepts and adding values to attributes done in a batch mode through importing a spreadsheet table

Concept	Class (URI)	Relation (URI)	Relation (URI)	Attribute (URI)	Attribute (URI)
A	B	C	D	E	F
concept	type	https://k2.poolparty.biz/Jobs/belongsTo	https://k2.poolparty.biz/Jobs/has-HQ-in	https://k2.poolparty.biz/Jobs/Address	https://k2.poolparty.biz/Jobs/Phone-number
Volkswagen	https://k2.poolparty.biz/Jobs/Employer	Automotive	Germany	Dieselstraße 28, 38446 Wolfsburg, Germany	49-5361-90
Accenture	https://k2.poolparty.biz/Jobs/Employer	Information technology and services	Ireland	Unit 1, Grand Canal Square, Grand Canal Quay,	353 1 407 6000
BASF	https://k2.poolparty.biz/Jobs/Employer	Chemicals	Germany	Carl-Bosch-Straße 38, 67056 Ludwigshafen/Rh	49 621 600
Tata Consultancy Services	https://k2.poolparty.biz/Jobs/Employer	Information technology and services	India	TCS House, Raveline Street, Mumbai 400001, M	91-22-6778 9999
Nestlé	https://k2.poolparty.biz/Jobs/Employer	Food and beverages	Switzerland	Av. Nestlé 55, 1800 Vevey, Switzerland	41 21 924 1111
Royal Dutch Shell	https://k2.poolparty.biz/Jobs/Employer	Oil and gas	Netherlands	Carel van Bylandtlaan 16, 2596 HR The Hague,	31 70 3779111
Toyota Motor	https://k2.poolparty.biz/Jobs/Employer	Automotive	Japan	1 Toyota-Cho, Toyota City, Aichi Prefecture, Jap	81 565 282121
Apple Inc	https://k2.poolparty.biz/Jobs/Employer	Computer hardware	United States	1 Infinite Loop Cupertino, CA 95014	1 408 996-1010
Samsung Electronics	https://k2.poolparty.biz/Jobs/Employer	Consumer electronics	South Korea	416, Maetan 3-Dong, Yeongtong-Gu, Suwon, G	82 31 2001114

Applying Ontologies to Taxonomies

Concepts have both:

SKOS relationships and properties



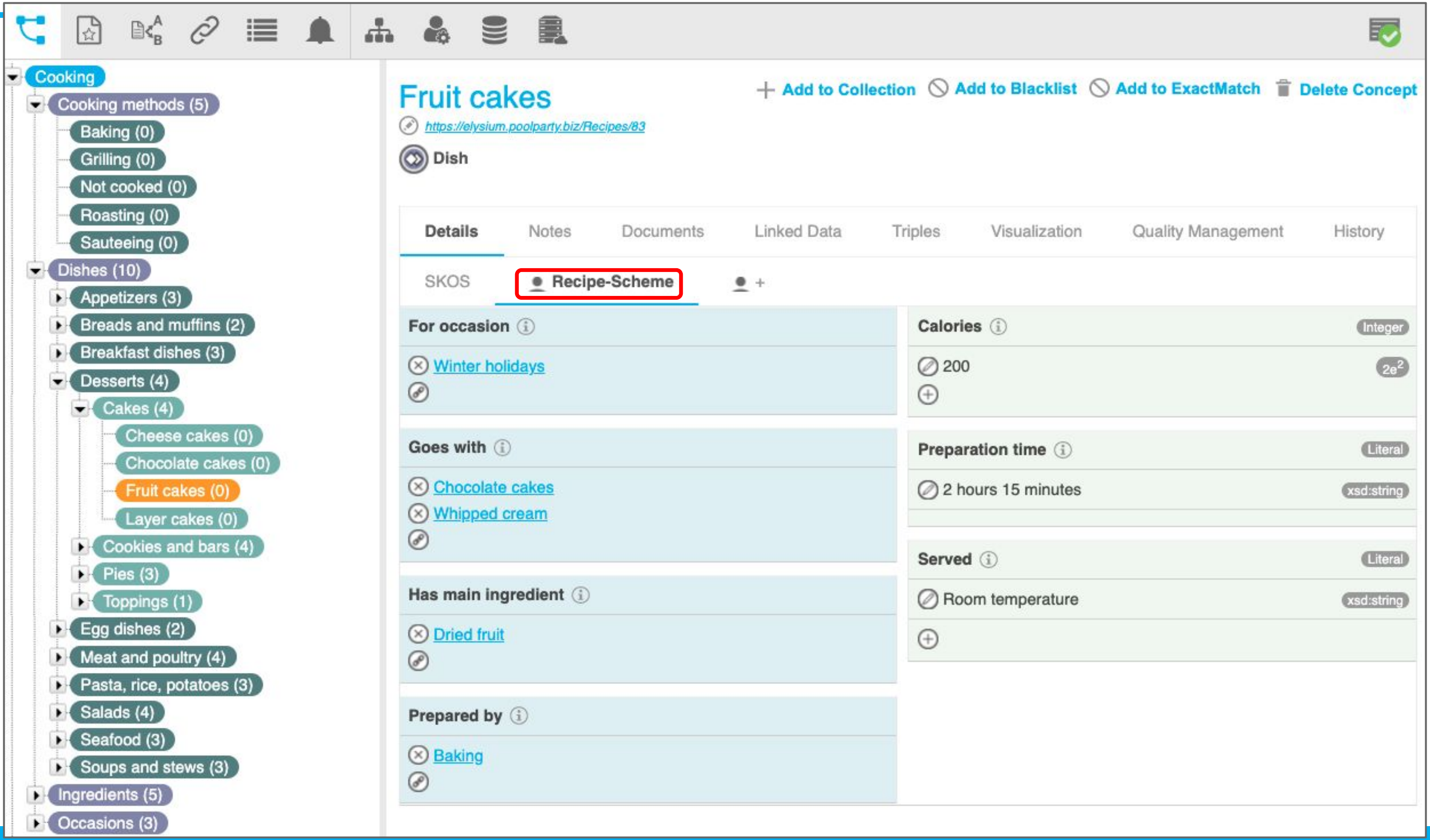
Screenshots from Poolparty

Applying Ontologies to Taxonomies

Concepts have both:

SKOS relationships and properties *and*

OWL-based semantic relationships and attributes from an ontology-based custom scheme.



Screenshots from Poolparty

Ontology Approaches

Benefits of combining a high-level ontology as a semantic layer with a taxonomy

- Makes use of existing taxonomies, even multiple taxonomies
- Easier to model the ontology
  - Existing taxonomies provide a basis for knowledge modeling.
  - No need to distinguish between sub-classes and individuals.
- Supports expert specialization
  - Taxonomists develop and maintain taxonomies.
  - Ontologists develop and maintain the ontology.
- More flexible and adaptable
  - The taxonomy changes more frequently than does the ontology.
  - Taxonomies can easily be added.
- Different purposes served
  - The ontology is for modeling, reasoning, and analysis.
  - The taxonomy is for tagging and information/data retrieval.

Taxonomy + Ontology Implementation Example

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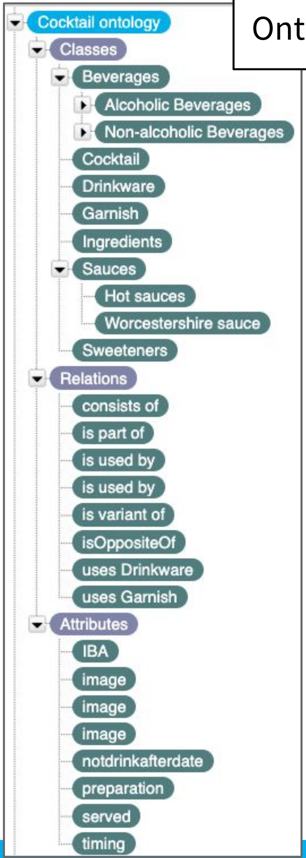
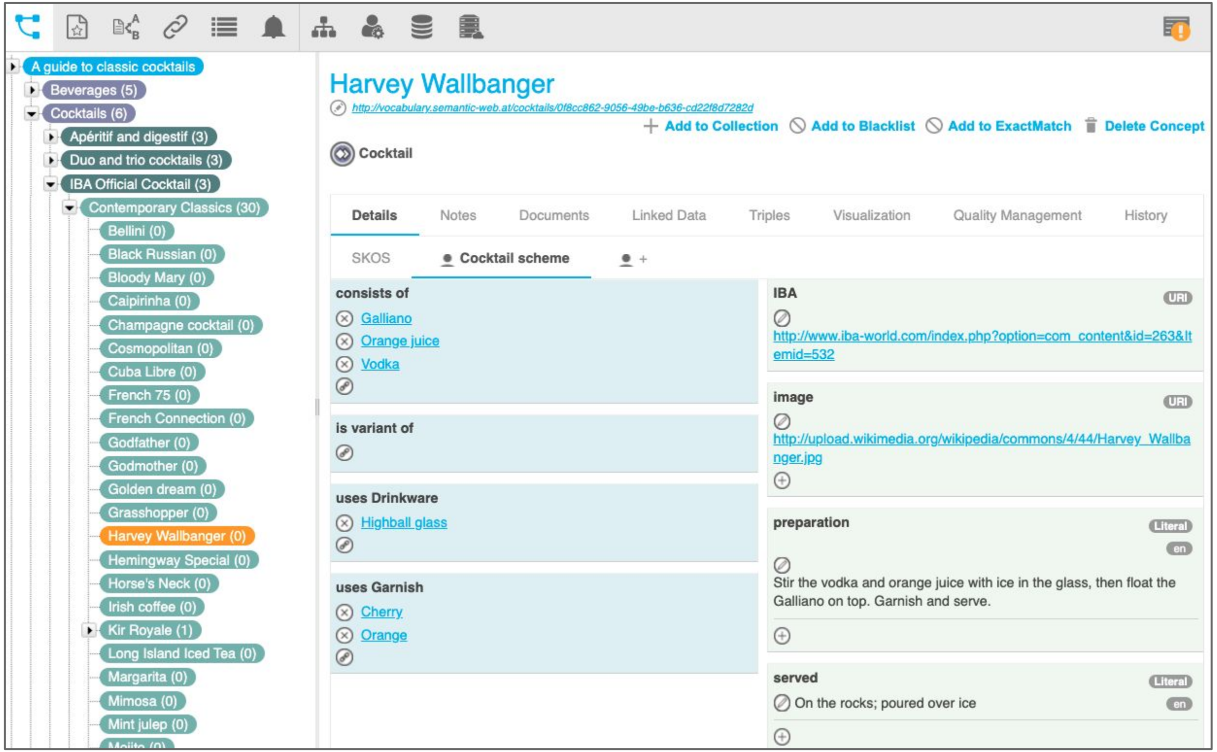
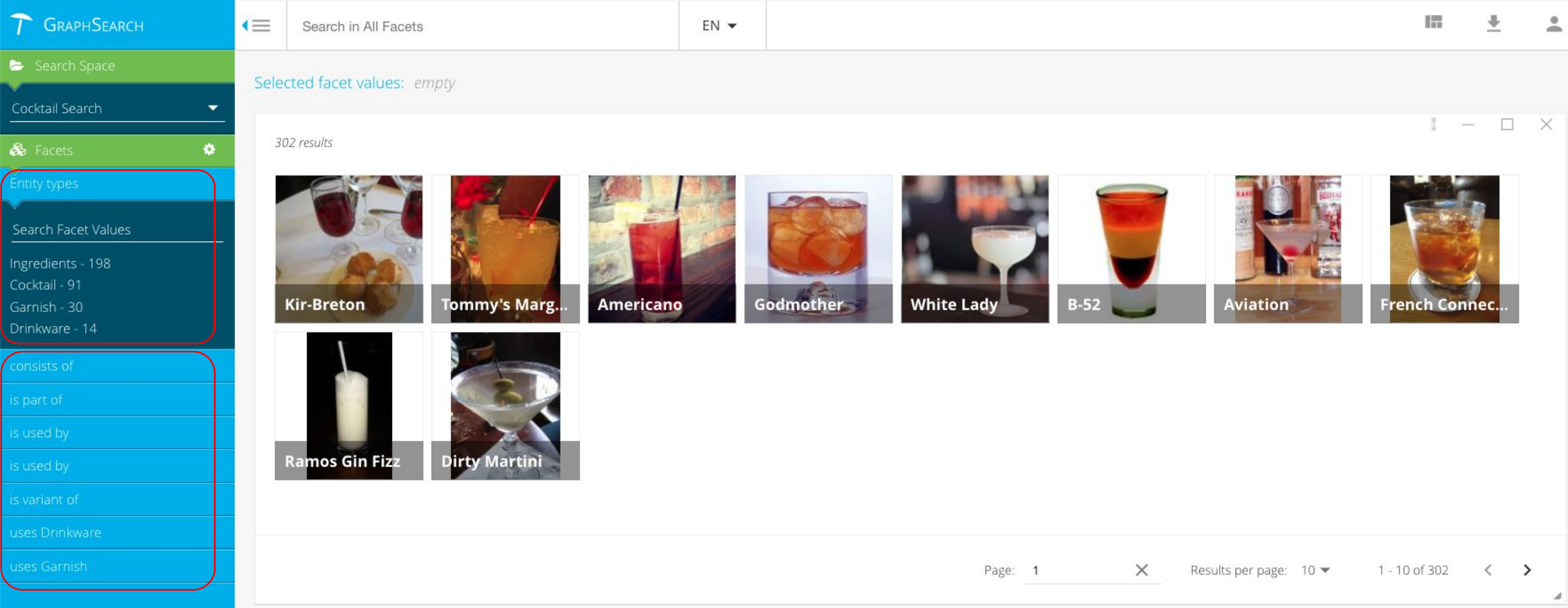
Taxonomy

Ontology



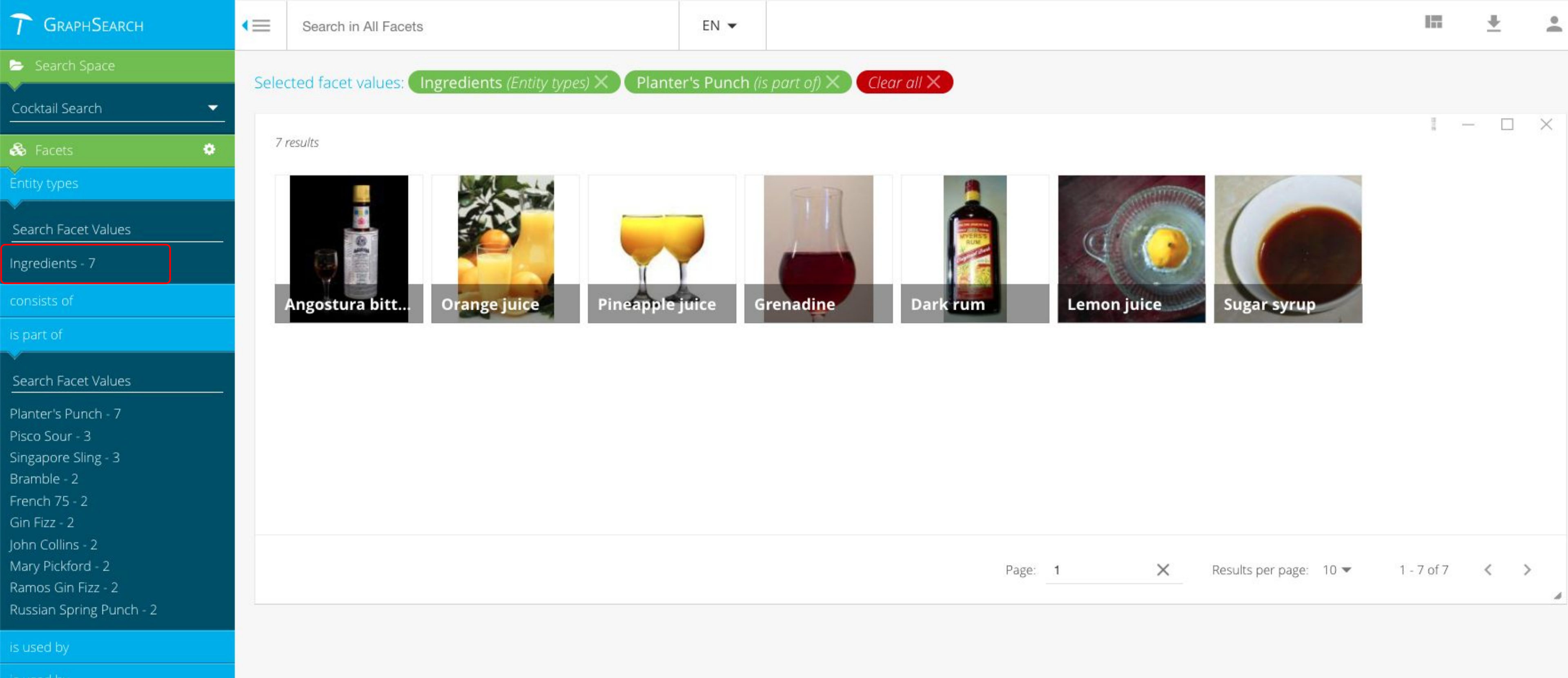
Taxonomy enriched with an ontology in PoolParty





Semantic relations as facets in PoolParty GraphSearch

https://vocabulary.semantic-web.at/GraphSearch/



Semantic relations as facets in PoolParty GraphSearch

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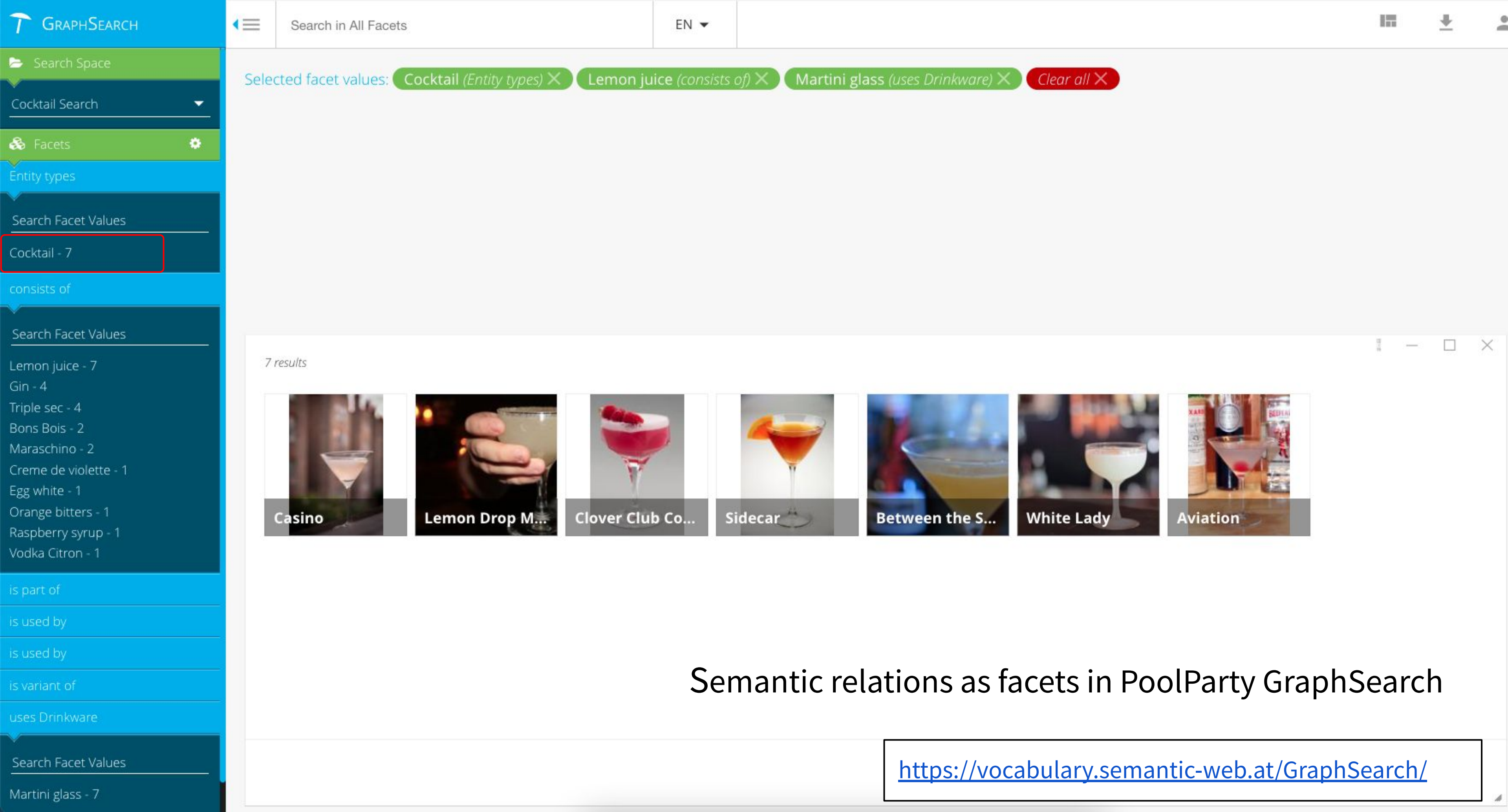

Semantic relations as facets in PoolParty GraphSearch

https://vocabulary.semantic-web.at/GraphSearch/

Conclusions

Extending a taxonomy to be an ontology

- Provides more uses than a taxonomy alone or an ontology alone
- Makes use of existing taxonomies
- Can conform to both taxonomy and ontology standards for interoperability
    - Start with a taxonomy in SKOS
- Is best done in a combined taxonomy/ontology tool based on W3C/ Semantic Web standards

Questions/Contact

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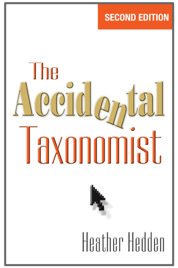

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