KDI : **Knowledge and Data Integration**

Evaluation

iTelos Formal Modeling & Data integration

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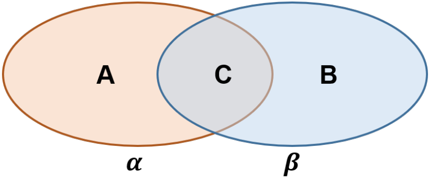
Metrics Definitions



- Coverage (*Cov*)
- Extensiveness (*Ext*)
- Sparsity (*Spr*)
- Cue Validity (*Cue*)

Metric definitions: Cue validity

Cue is a set of metrics to measure the quality of the Etype/ETG. By applying Cue, we focus on:

- Shareability and unity [1], we measure if the Etype/ETG is well-described by its features.
- Property richness [2], since we calculate the average number of properties that assigned to different Etypes.

[1] Giunchiglia, F. and Fumagalli, M., 2020, July. Entity type recognition–dealing with the diversity of knowledge. In Proceedings of the International Conference on Principles of Knowledge Representation and Reasoning (Vol. 17, No. 1, pp. 414-423).

[2] Tartir, S., Arpinar, I.B., Moore, M., Sheth, A.P. and Aleman-Meza, B., 2005. OntoQA: Metric-based ontology quality analysis.

Metric definitions: Cue validity

Cue is a set of metrics to measure the quality of the Etype/ETG.

Cue for Etype: $$Cue_e(e) = \sum_{i=1}^{|prop(e)|} Cue_p(p_i, e) \in [0, |prop(e)|]$$

Cue for ETG: $$Cue_k(K) = \sum_{i=1}^{|E_K|} Cue_e(e_i) \in [0, |prop(K)|]$$

Metric definitions: Cue validity

Cue for Etype: $$Cue_e(e) = \sum_{i=1}^{|prop(e)|} Cue_p(p_i, e) \in [0, |prop(e)|]$$

$$Cue_p(p, e) = \frac{PoE(p, e)}{|dom(p)|} \in [0, 1] \qquad PoE(p, e) = \begin{cases} 1, if e \in dom(p) \\ 0, if e \notin dom(p) \end{cases}$$

- e represents an Etype. $Cue_e(e)$ represents the *cue* validity of the Etype e.
- $|prop(e)|$ is the number of properties associated with the specific entity type e.
- $Cue_p(p, e)$ returns 0 if p is not associated with e. Otherwise returns *1/n*, where n is the number of entity types in the domain of p. Cue_p takes the maximum value 1 if p has only one entity type.
- $|dom(p)|$ presents the cardinality of entity types that are the domain of the specific property p.
- $PoE(p, e)$ determines if the Etype e is in the domain of property p.

Metric definitions: Cue validity

Cue for ETG: $$Cue_k(K) = \sum_{i=1}^{|E_K|} Cue_e(e_i) \in [0, |prop(K)|]$$

- The $Cue_k(K)$ is calculated as a summation of the cue validity $Cue_e(e)$ of all the entity types e_i in a given ETG K,
- E_K presents the number of Etypes in a given ETG K.
- $|prop(K)|$ refers to the number of the properties in the ETG, as the maximization of $Cue_k(K)$.

Metric definitions: Cue validity

About $Cue_e(e)$ and $Cue_k(K)$:

- Values are always within the interval [0,1].
- It captures the idea, that is Etypes are properly described by more specific properties.
- High values of *Cue* mean that there are enough number of properties for specifically describing the target Etype/ETG, which makes the target Etype more likely belongs to contextual category.
- Low values of Cue mean that the target Etype/ETG is describe by few general properties, which makes the target Etype more likely belongs to common category.

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Evaluation purpose on Formal Modeling phase

During Formal modeling phase, we evaluate the on schema level. We have the formal ETG and several reference ontologies. We aim to measure:

- If the formal ETG and its Etypes are properly defined by their properties, using metric $Cue_k(ETG)$ and $Cue_e(Etype)$
- If the proposed ETG is different from the reference ontologies, using metric $Sparsity$.
- If the ETG is well-designed, and information in the ETG is correct. By sampling from ETG and then **checking manually**.

Examples: Formal ETG vs Reference Ontology

To calculate Cue validity, we should first generate a FCA lattice for the target ETG.

Here we select an example from DBpedia:

FCA Context		Properties						
		name	date	citizenship	settlement	academy award	gold medalist	race track
Etypes	Person	O	X	O	X	X	X	X
	Event	X	O	X	X	X	X	X
	Place	O	X	X	O	X	X	X
	Artist	O	X	O	X	O	X	X
	Athlete	O	X	O	X	X	O	X
	Sports Event	X	O	X	X	X	X	O

Examples: Formal ETG vs Reference Ontology

According to the FCA lattice, we further calculate *Cue*(*ETG*), *Cue*(*Etypes*) by the Cue metrics.

Cue for Etype: $$Cue_e(e) = \sum_{i=1}^{|prop(e)|} Cue_p(p_i, e) \in [0, |prop(e)|]$$

Cue for ETG: $$Cue_k(K) = \sum_{i=1}^{|E_K|} Cue_e(e_i) \in [0, |prop(K)|]$$

	Cue_p Map	Properties							$Cue_e(E)$
		name	date	citizenship	settlement	academy award	gold medalist	race track	
Etypes	Person	0.25	0	0.33	0	0	0	0	0.29
	Event	0	0.5	0	0	0	0	0	0.5
	Place	0.25	0	0	1	0	0	0	0.625
	Artist	0.25	0	0.33	0	1	0	0	0.79
	Athlete	0.25	0	0.33	0	0	1	0	0.79
	Sports Event	0	0.5	0	0	0	0	1	0.75
								$Cue_k(K)$=	3.745

Cue calculation service can be found at: http:// liveschema.eu/ service/ cue_generator

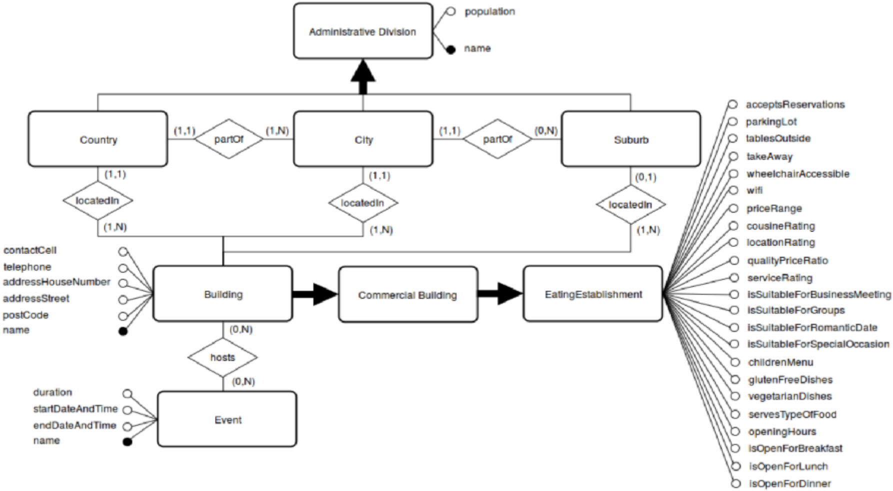
Generating Cue by LiveSchema service

Cue calculation service can be found at LiveSchema:
http://liveschema.eu/service/cue_generator

eType	Cue_e	Cue_er	Cue_ec	Cue_c	Cue_cr	Cue_cc
1.1	0.0	0.0	1.0	0.0	0.0	1.0
1.8	0.0	0.0	1.0	0.0	0.0	1.0
1.9	0.0	0.0	1.0	0.0	0.0	1.0
4.0	0.0	0.0	1.0	0.0	0.0	1.0
Class	1.25	0.3125	0.6875	1.3333...	0.2666...	0.7333...
DatatypeProperty	3.0	0.25	0.75	3.0	0.25	0.75
Graph	3.4166...	0.2628...	0.7371...	3.3333...	0.2564...	0.7435...
ObjectProperty	0.8333...	0.2777...	0.7222...	0.75	0.25	0.75
Ontology	0.8333...	0.2777...	0.7222...	0.75	0.25	0.75
Product	0.25	0.25	0.75	0.25	0.25	0.75
Property	0.3333...	0.3333...	0.6666...	0.5	0.25	0.75
System	0.25	0.25	0.75	0.25	0.25	0.75
Thing	0.5	0.25	0.75	0.5	0.25	0.75
ThingGraph	0.25	0.25	0.75	0.25	0.25	0.75
anyURI	0.5	0.25	0.75	0.5	0.25	0.75
bbc	0.0	0.0	1.0	0.0	0.0	1.0
boolean	0.5	0.25	0.75	0.5	0.25	0.75
dateTime	0.5	0.25	0.75	0.5	0.25	0.75
provenance	5.0833...	0.2675...	0.7324...	5.0833...	0.2541...	0.7458...
provenance.ttl	0.0	0.0	1.0	0.0	0.0	1.0
string	1.5	0.25	0.75	1.5	0.25	0.75
terms	0.0	0.0	1.0	0.0	0.0	1.0
KNOWLEDGE	19.0	0.2638...	0.7361...	19.0	0.2533...	0.7466...

*Notice, the Column in red refers to $Cue_e(E)$, and the value box in blue refers to $Cue_k(K)$

Examples: Formal ETG



Examples: Formal ETG

Classes/Etypes in ontology:

C_c={AdministrativeDivision, Country, City, Suburb, Building, CommercialBuilding, EatingEstablishment, Event}
(Num class = 8)

Properties in ontology:

C_p = {rating, suitableForGroup, childrenMenu, Vegetarians, contact, reservation, parkingLot,. . . .. OpenForlunch}
(Num property = 38)

Examples: Reference Ontologies

Reference ontology have similar structure with Formal ETG, which contains a set of Etypes and a set of properties.

Classes/Etypes in ontology:

C_c={Region, City, Suburb, Building, Customer, EatingEstablishment, ..., Event, FestivalEvent}
(Num class = 21, 5 of them aligned with formal ETG)

Properties in ontology:

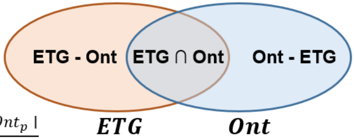
C_p = {rating, suitableForGroup, childrenMenu, Vegetarians, contact, reservation, parkingLot,duration, menu, ..., parkingArea}
(Num property = 50, 17 of them aligned with formal ETG)

Examples: Formal ETG vs Reference Ontology

Given the reference ontology (*Ont*) , the sparsity (*Spr*) of the Formal ETG (*ETG*) is:

Etype sparsity $Spr(ETG_c) = \dfrac{|ETG_c - Ont_c| + |Ont_c - ETG_c|}{|ETG_c \cup Ont_c|} = 1 - \dfrac{|ETG_c \cap Ont_c|}{|ETG_c \cup Ont_c|}$

$Spr = 1$ *Full Sparsity*
$Spr \simeq 0.5$ *Ideal*
$Spr = 0$ *No Sparsity*



Property sparsity $Spr(ETG_p) = \dfrac{|ETG_p - Ont_p| + |Ont_p - ETG_p|}{|ETG_p \cup Ont_p|} = 1 - \dfrac{|ETG_p \cap Ont_p|}{|ETG_p \cup Ont_p|}$

$Spr = 1$ *Full Sparsity*
$Spr \simeq 0.5$ *Ideal*
$Spr = 0$ *No Sparsity*

Examples: Formal ETG model vs Reference Ontology

Given the example ETG , and the example reference ontology, we have sparsity (*Spr*) as:

Etype Sparsity $$Spr(ETG_c) = 1 - \frac{|\, ETG_c \cap Ont_c \,|\ (5)}{|\, ETG_c \cup Ont_c \,|\ (24)} = 0.79$$

Property Sparsity $$Spr(ETG_p) = 1 - \frac{|\, ETG_p \cap Ont_p \,|\ (17)}{|\, ETG_p \cup Ont_p \,|\ (71)} = 0.76$$

**Notice that different (sparsity) information should be core or contextual information.*

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Evaluation purpose on Data Integration phase

During Data Integration phase, we evaluate on data level. We have the proposed final EG. We aim to measure:

- If the CQs in inception phase can be answered by our constructed EG. We can do evaluation based on practial applications, like SQL.

- If our collected dataset is sufficiently used. By using **Sparsity** to check if the dataset schema is aligned to ETG properties. Otherwise, there will be a loss of dataset information.

Examples: EG vs CQs

One of the reasons for constructing a new EG is to answer the CQs we proposed. Thus, answering CQs is the key aspect for EG evaluation.

We apply our EG on applications to search/reason the results for CQs. In the current situation, we reorganize CQs into SQL commands to straightforwardly search the results from EG.

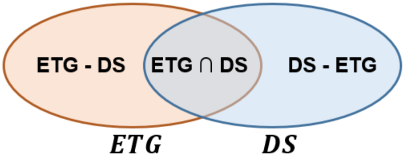
During the evaluation, we record the **accuracy** and **running time** to test if our constructed EG can effectively solve the CQs.

Examples: Formal ETG vs Dataset Schema

Given the Formal ETG (*ETG*), the sparsity (*Spr*) of the Dataset Schema (*DS*) is:

Property sparsity $$Spr(DS_p) = \frac{|\, DS_p - Ont_p \,| + |\, Ont_p - DS_p \,|}{|\, DS_p \cup Ont_p \,|} = 1 - \frac{|\, DS_p \cap Ont_p \,|}{|\, DS_p \cup Ont_p \,|}$$

$Spr = 1$ *Full Sparsity*
$Spr \simeq 0$ *Ideal*
$Spr = 0$ *No Sparsity*



*The calculation of the *Sparsity* in data integration phase is similar to the Formal ETG modelling phase.

Non-quantitative evaluation

Rather than the quantitative evaluation we introduced above, we also need to check in the schema-level and data-level of the EG:

Checklist

- Consistency Dimension
- Accuracy Dimension
- Completeness Dimension

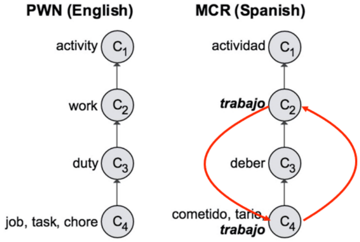
[1] Mc Gurk, S., Abela, C. and Debattista, J., 2017. Towards Ontology Quality Assessment. In MEPDaW/LDQ@ ESWC (pp. 94-106).

Consistency Dimension

Problem: Including Cycles in a class Hierarchy. Circulatory errors typically occurs, for example, when a class X1 is defined as a superclass of class X2, and X2 is defined as a superclass of X1 at the same time.

Solution: Do not use cycles in a class hierarchy.

Example:



Consistency Dimension

Problem: Number of Polysemous Elements. Number of properties, objects or datatypes that are referred by the same identifier. For example, ’contact’ might refer to different but related concept, such as referring to ’contact information’ or ’address’.

Solution: Avoid polysemous term.

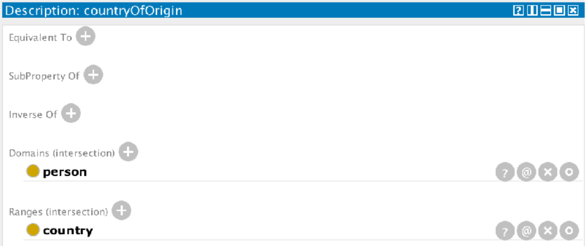
Example:

Consistency Dimension

Problem: Multiple Domains/Ranges. Multiple domains and ranges are allowed, however, these should not be in conflict with each other (that is, no two domains or ranges should contradict each other).

Solution: Use only one domain and range for each property.

Example:

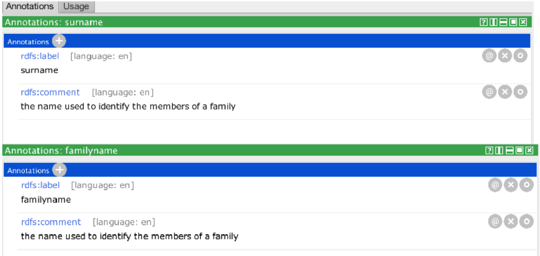


Consistency Dimension

Problem: Semantically Identical Classes. This anomaly occurs when an ontology includes multiple classes with the same semantics. For example, creating a two classes such as ’airport’ and ’airdrome’ for representing an airfield those are equipped with control tower and hangars.

Solution: Do not use different term to refer same element.

Example:

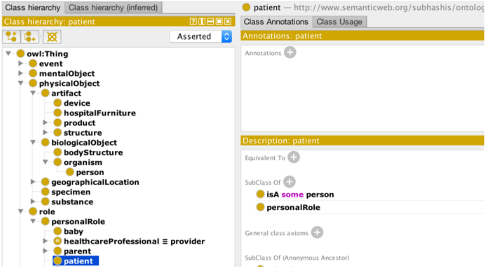


Accuracy Dimension

Problem: Incorrect Relationship. An incorrect relationship typically occurs with the vague use of ‘is’, instead of ‘subClassOf’, ‘type’ or ‘sameAs’. For example, student isA person, uses isA as a relation (i.e. object property in Protégé).

Solution: Avoid using relation name like isA or type.

Example:

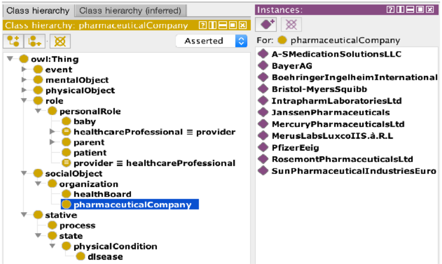


Accuracy Dimension

Problem: Hierarchy Over specification. Over specialisation occurs when a leaf class of a model does not have any instances associated with it. For example, having a class 'Mountain' in the model but did not have data for it.

Solution: Discard any leaf class for which there is no instances.

Example:

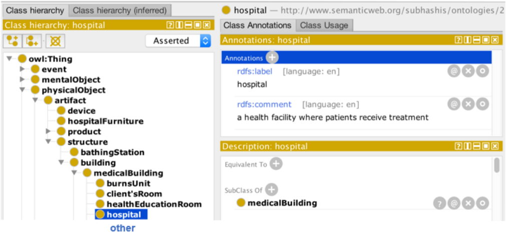


Accuracy Dimension

Problem: Using a Miscellaneous Class. A class within the hierarchy of the ontology which is simply used to represent instances that do not belong to any of its siblings. For example, having the class 'Building' with subclasses 'Hospital, 'Hotel', 'Library' 'Commercial building' and Miscellaneous.

Solution: Do not use miscellaneous or other as a class name.

Example:

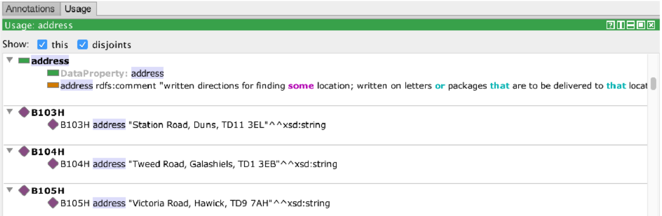


Completeness Dimension

Problem: Number of Isolated Elements. Elements, including classes, properties and datatypes are considered isolated if they do not have any relation to the rest of the ontology (declared but not used).

Solution: Avoid to keep isolated elements.

Example:

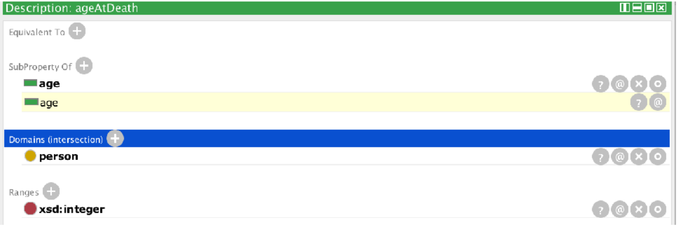


Completeness Dimension

Problem: Missing Domain or Range in Properties. Properties should be accompanied by their domain and range. Missing information about the properties may cause lack of completeness and may result in less accuracy and more inconsistencies.

Solution: Define domain and range for all properties.

Example:



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