Evaluating the Quality of Authoritative Linked Data Models

Hanan Muhajab
School of Computer Science and Informatics,
Cardiff University, Cardiff, UK, and
Jazan University, Saudi Arabia
email: muhajabh@cardiff.ac.uk

Alia Abdelmoty
School of Computer Science and Informatics,
Cardiff University
Cardiff, UK
email: abdelmotyai@cardiff.ac.uk

***Abstract*—Currently, there is a shortage of studies focusing on analyzing existing authoritative geographic ontologies to promote their reuse. This work attempts to fill this gap by reviewing and evaluating four authoritative geographic ontologies on the web. Evaluation is carried out using a set of quantitative quality metrics. Results provide insight into the accuracy, complexity, and completeness of the ontologies and highlight the need for further studies in the heterogeneity of their underlying models.**

***Index Terms*—Geographic Ontology; Linked Data; Metrics.**

I. INTRODUCTION

Semantic Web and Linked Data technologies have been considered for the representation and sharing of authoritative geographic data sets. For example, the Ordnance Survey, the mapping agency of Great Britain [1], has five defined ontologies, and provide open data sets of approximately 64,342,201 triples. Similarly, several spatial linked data sets for the Netherlands, Norway, Germany, Ireland, and Spain are published, and presented at the Knowledge Graph in Action conference (KGiA) [2]. The different providers propose different ontologies for the representation of their data. The heterogeneity of the ontologies is a limitation of their reuse. Evaluation of an ontology refers to measuring its quality to determine its fitness for purpose. The evaluation process involves two perspectives: the provider's perspective, that focus on the accuracy of presentation, error, and quality of naming, and the consumer's perspective, which focuses on the data level and ease of understanding the model. Several studies have been conducted to assess authoritative geographical linked data from the developer's perspective. For example, Debattista et al. [3] evaluated Ordnance Survey Ireland (OSI) using the Luzzu and OOPS platforms [4]. There is a need to assess the authoritative geographic ontologies from the user's perspective to better facilitate their understanding and reuse, as recommended in KGiA [2]. This work analyses a sample of established authoritative geographic ontologies available on the web to examine the complexity of their representation and their completeness of representation. Results show how spatial completeness is limited in most of the studied ontologies and thus further work needs to examine this factor in the future.

The remainder of this paper is organized as follows: section II explains the methodology used in the study. The evaluation results are discussed in section III, and the paper is concluded in section IV.

II. METHOD

Four ontologies were downloaded. These are the administrative units for the UK (O_1), Ireland (O_2), Greece (O_3), and France (O_4), as shown in Table I. A metric-based evaluation method was used as it provides a quantitative and objective way of comparison. Figure 1 shows the metrics used in the evaluation process. The schema metrics, graph metrics, and knowledge base metrics are derived from OntoMetrics [5].

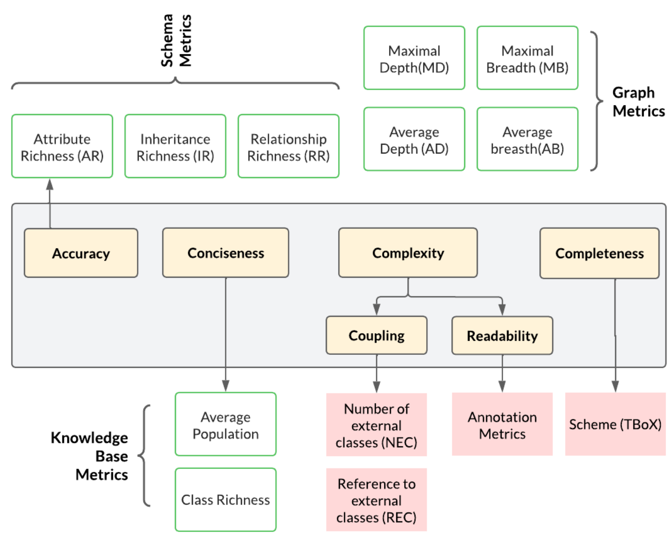

Fig. 1: The metrics used in the evaluation process.

Four criteria are considered: accuracy, conciseness, complexity, and completeness. The accuracy criterion measures the extent to which an ontology models its real-world domain. The schema metrics include Attribute Richness (AR), Inheritance Richness (IR), and Relationship Richness (RR), and graph metrics include Average Depth (AD), Average Breadth (AB), Maximal Depth (MD), and Maximal Breadth (MB). RR indicates the diversity of ontology relationships.

AR indicates the number of attributes (slots) defined for each class, which can be used to infer the quality of the

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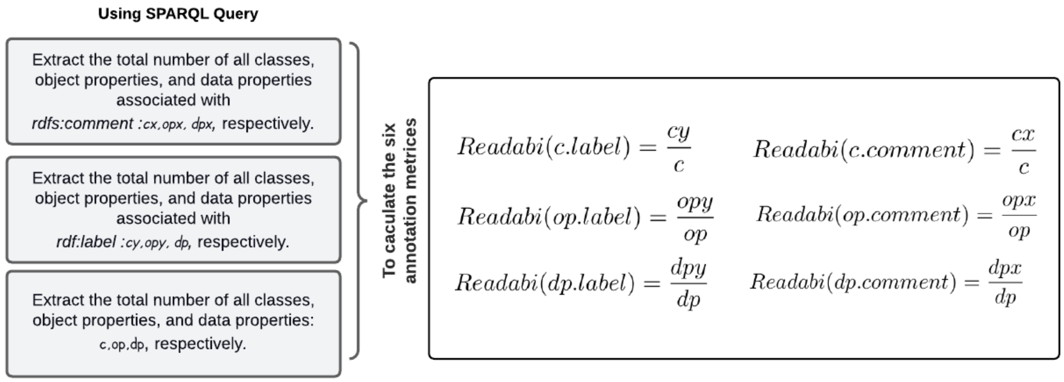


Fig. 2: Steps used to calculate the Annotation Metrics.

ontology design. IR shows the distribution of information across different levels of ontology. The conciseness criterion measures the degree of usefulness of the ontology knowledge. This quality criterion correlates with Average Population (AP) and Class Richness (CR). AP represents the average distribution of instances across all classes. CR is a measure of how instances are distributed among classes. Therefore, it indicates how many instances are related to the classes defined in the schema.

By understanding the complexity of the ontology, developers can better understand, reuse, and reduce maintenance requirements. The coupling and readability of the ontology determined the degree of complexity. Coupling reveals the number of external classes from imported ontologies referenced in the local ontology. It measures the relatedness between the local ontology and other existing ontologies or vocabularies used to construct the ontology [7]. It is defined as:

$$Coupling(O) = REC/NEC \quad (1)$$

Where NEC is the distinct number of external classes, and REC is the number of references to external classes. The stronger the coupling, the more difficult it is to understand and manipulate. By parsing the OWL file, we calculated the number of distinct external classes defined in the ontology and the number of references to external classes. The code is available online [8].

A measure of readability is the average number of names (labels) and descriptions (comments) per ontology entity, such as classes and properties. We utilize six annotation metrics to evaluate readability. As shown in Figure 2, $c.comment$, $op.comment$, and $dp.comment$ represent the average number of rdfs:comment statements per class, object property, and data property in the ontology, respectively. The average number of rdf:label statements per class, object property, and data property in the ontology is represented by $c.label$, $op.label$, and $dp.label$. GraphDB [6] was used to upload the data sets and to run the SPARQL queries to compute the annotation metrics.

Assessment of completeness considered the schema level and not the instance level of representation. Spatial completeness of the ontologies was done by considering the standard set of possible spatial relationships between data types. For example, there are five possible relationships between two regions, namely, inside, contain, overlap, touch and equal. A completeness score for the ontology is computed in terms of the completeness score of its spatial classes as presented in equation (2), where $Comp$ is the sum of the completeness score of all the spatial classes and C is the total number of spatial classes in the ontology.

$$Completeness = Comp/C \quad (2)$$

III. RESULT

Inheritance Richness (IR) shows the distribution of information across different levels of ontology. This metric can distinguish horizontal ontology (where classes have a large number of direct subclasses) from vertical ontology (where classes have a small number of direct subclasses). In Table I, O_2, O_3, and O_4 cover more specific details (depth), while O_1 defines the domain broadly. Relationship Richness (RR) is a measure of diversity of the type of relationships in the ontology. Ontologies O_1, O_2 and O_3 have a low RR score, as they represent mostly one type of relationship; namely the subclass relationship. Result shows that the low value of RR corresponds to higher Maximal Depth (MD) and Maximal Breadth (MB) values. In addition, Attribute Richness (AR) values indicate that the ontologies O_1, O_3 and O_4 contain more attribute information about the classes than O_2.

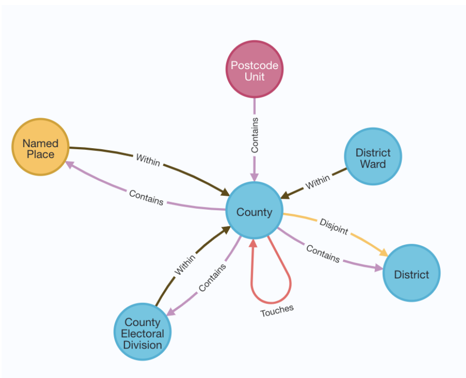
Average Population (AP) indicates how well the data extraction process was conducted to populate the knowledge base. Results show that O_1, O_2 have a large number of instance per class, indicating a good fit for the class representation in the ontology. CR is related to how instances are distributed across classes. As a result, it displays a percentage indicating the number of instances in each class in the Knowledge Base. The results indicate that O_1, O_2, and O_4 have more instances than O_3. As shown in Table II, O_2 and O_3 have high complexity due to the coupling and readability values. The result indicates

TABLE I: Results of evaluating the ontologies with the graph, knowledge base and schema metrics

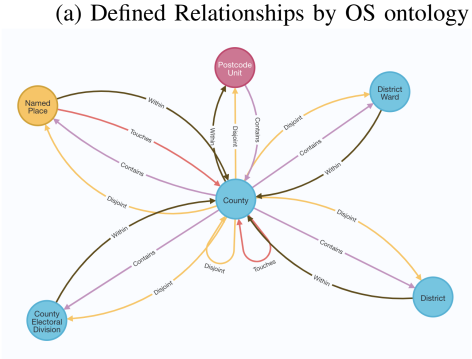
Index	Weblink	Classes	Individuals	AR	IR	RR	AD	MD	AB	MB	AP	CR
O_1	https://data.ordnancesurvey.co.uk/ontology/ [accessed: 2023-03-03]	53	2021346	0.321	5.35	0.11	2.38	3	4.33	8	38138.60	0.339
O_2	https://triplydb.com/osi/adminitrative-units [accessed: 2023-03-03]	18	659333	0	0.93	0.166	1.93	2	8	15	36629.61	0.777
O_3	http://linkedopendata.gr/dataset. [accessed: 2023-03-03]	9	2914	0.444	0.88	0.272	1.88	2	4.5	8	323.77	0
O_4	http://data.ign.fr/def/geofla/20190212.en.htm [accessed: 2023-03-03]	8	132567	0.409	0.5	0.56	1.54	3	5.5	15	6025.77	0.409

TABLE II: Evaluation results for the coupling, readability, and completeness criteria.

Index	Coupling	Readability						Completeness
		c.comment	*c.label*	*op.comment*	*op.label*	*dp.comment*	*dp.label*	
O_1	0	0.75	1	0.84	0.84	0.6	0.8	0.56
O_2	15	0.93	1	1	1	0	0	0.3
O_3	8	0	1	0	0	0	1	0.3
O_4	0	0.75	1	0.85	0.85	1	1	0.3



(a) Defined Relationships by OS ontology



(b) Completed Relationships

Fig. 3: Incompleteness Relationships

that O_2 has a strong coupling, which makes it more difficult to understand and maintain than O_1.

Each class in ontology is checked for completeness, and then equation (1) is used to compute the result.

As an example of incompleteness in the OS is shown in Figure 3, all possible relationships that can be defined between the two polygons, County and District, are $disjoint, contains, within$ as shown in 3b, graph 3a shows the defined relationship between the same two polygons is $within$; thus, the incomplete relationship is disjoint, contains. Results show that O_1 is 56% complete, O_2, O_3, and O_4 are 30%, making O_1 more capable of reasoning and retrieving the geographic information.

IV. CONCLUSION

In this paper, we evaluated authoritative geographic ontologies using metrics-based methods. Analysis of metrics result indicates that geographic ontologies contain enough data to facilitate knowledge usage. Results confirm that UK ontology covers a wide range of information and show that the ontologies have a good hierarchy. A high score for incomplete spatial relationships leads to fewer inferred geographical details in France, Greece, and Ireland. The UK ontology has very low complexity, which indicates that the model is easy to understand by the user. The future research direction would be to develop a unified data model to integrate the authoritative ontologies.

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