The Role of Community and Social Metrics in Ontology Evaluation: An Interview Study of Ontology Reuse

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Abstract: Finding a "good" or the "right" ontology for reuse is an ongoing challenge in the field of ontology engineering, where the main aim is to share and reuse existing semantics. This paper reports on a qualitative study with interviews of ontologists and knowledge engineers in different domains, ranging from biomedical field to manufacturing industry, and investigates the challenges they face while searching, evaluating, and selecting an ontology for reuse. Analysis of the interviews reveals diverse sets of quality metrics that are used when evaluating the quality of an ontology. While some of the metrics have already been mentioned in the literature, the findings from our study identify new sets of quality metrics such as community and social related metrics. We believe that this work represents a noteworthy contribution to the field of ontology engineering, with the hope that the research community can further draw on these initial findings in developing relevant quality metrics and ontology search and selection.

1 INTRODUCTION

Ontologies play a very important role in the field of knowledge and information management by furnishing the semantics to the semantic web (Shadbolt et al., 2006) and are used in different domains for various purposes. Ontologies have many benefits, no matter in which domain they are used. They facilitate communication and knowledge transfer between systems, between humans, and between humans and systems (Bürger and Simperl, 2008) by uniquely identifying the meaning of different concepts in any domain. They can also avoid the costs associated with new developments of knowledge models.

Despite the significant role that ontologies play in the semantic web, there is still little understanding about the way they should be developed and built (Ding and Foo, 2002). Some believe that the cost of building and maintaining ontologies in certain domains can outweigh the potential benefits gained by using them (Shadbolt et al., 2006). To deal with this concern, some have suggested reusing previously built ontologies, since this will help in achieving one of the main goals of ontology construction, that is to share and reuse semantics (Simperl, 2009), and will also save significant amount of time and financial resources. Uschold et al. (1998) believe that the future of construction of large-scale knowledge-based systems is highly dependent on reusing the components built by others.

Regardless of all the advantages of reusing ontologies and the availability of different ontologies, ontology reuse has always been a challenging task (Uschold et al., 1998). Methods for building ontologies are usually blamed for lack of reuse strategy and some argue that these methodologies are not explicitly concerned with ontology reuse (Annamalai and Sterling, 2003). Others consider the first steps of ontology reuse, which is identification and evaluation of the knowledge sources that can be useful for the application domain (Bontas et al., 2005), as the hardest step in ontology reuse. Researchers not only have to find the most appropriate ontologies for any search query, but they should also be able to evaluate those ontologies according to different implicit or explicit criteria.

This study aims to address some of the challenges that are faced in the first steps of the general process of reusing ontologies, which is to evaluate and then select a good ontology for reuse. This study contributes with qualitative data and findings to this ongoing challenge by documenting

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the process of selecting an ontology for reuse. It differs from previous studies, which focused purely on evaluating pre-selected metrics. In this study, our focus was to qualitatively understand the process and reasoning behind ontology selection and reuse, with a particular interest in the under-researched social and community aspects of ontology quality. Interviews were used to understand how ontologists and knowledge engineers in different domains search for, evaluate and select an ontology for reuse. This research asks:

1. What are the main characteristics of a reusable ontology?
2. What are the main metrics used to evaluate the quality of an ontology before selecting it for reuse?
3. Do knowledge and ontology engineers consider community related metrics e.g. who has built the ontology, who has used the ontology, etc. before selecting an ontology for reuse?

2 BACKGROUND

The main goal of ontology evaluation is to asses an ontology for the following purposes:1) to detect faults in an ontology and to measure its correctness (Hlomani and Stacey, 2014), 2) to evaluate its quality and to help in the selection process (Hlomani and Stacey, 2014), and 3) to track the process in ontology development (Yu et al.,2009). Ontology evaluation can also be done in different stages of ontology development namely while building an ontology, for checking inconsistencies in those ontologies that were built automatically and last but not least, while selecting an ontology for reuse (Tartir et al.,2010).

There are various ontology evaluation methods and several ways of classifying them in the literature. According to Brank et al. (2005) ontology evaluation can be done in four major ways: evaluating an ontology by comparing it to a "golden standard" 2) evaluating an ontology by comparing it to a source of data 3) evaluating an ontology by running it in an application as part of a system and evaluating the resulting performance, 4) asking human experts to evaluate an ontology against a set of predefined quality criteria.

From all the aforementioned methods, metric-based approaches (4) are very popular and different researchers have attempted to introduce various metrics that can be used to evaluate ontologies and help in the decision making process for ontology selection. The aim of this method, that is also called featured-based approach, is to offer a quantitative perspective of evaluating ontologies by gathering data and meta-data on different aspect of the ontology (Arpinar et al.,2006). Ontometric (Lozano-Tello and Gómez-Pérez, 2004) for example consists of a detailed set of 117 criteria to examine different dimensions of ontologies namely content, language, ontology construction methodologies, tools, and costs. While many of the criteria in metric-based evaluation approaches aim to measure different components of an ontology e.g. content, structure, coverage, etc., some of these have focused on non-ontological and social aspects (McDaniel et al., 2016) of ontologies like popularity (Martínez-Romero et al., 2014; Fernández et al., 2009; Wang et al., 2008).

Despite the widespread use of the terms popularity or acceptance in the literature, there is still no consensus on the definition of these terms. Popularity and acceptance tend to be mostly used to refer to the number of times an ontology has been viewed or used in a specific repository. NCBO Ontology recommender for example, calculates the popularity of an ontology by checking the presence of the ontology in well-known repositories as well as looking into the number of visits or pageviews to an ontology in ontology repositories in a recent specific period (Martínez-Romero et al., 2017). In the paper by Burton-Jones et al. (2005) the authors also refer to the term history to indicate the number of times an ontology has been used.

The second definition of popularity is based on applying the PageRank algorithm (Page et al.,1999) to ontology engineering field and focuses on the import feature of ontologies. Fernández et al. (2009) for example has defined the term "direct popularity" as the number of ontologies importing a given ontology. Wang et al. (2008) used the same definition to define what they call popularity, that for them is measured by considering how much an ontology is referenced by others. As a part of the authority metric in Supekar et al. (2004), authors have mentioned a metric called citation and have defined it as the number of occurrence of daml:sameClassAs, rdfs:seeAlso, owl:imports in a given ontology.

3 METHODS

Semi-structured interviews with ontologists and knowledge engineers were conducted to investigate the thinking behind and the processes commonly

involved in evaluating ontologies for their reuse. Purposive sampling was used to find the experts in the field of ontology engineering. Different sampling strategy namely intensity sampling was applied to find the ontologies that have been reused and then to interview the individuals who had built or had reused those ontologies. Moreover, homogenous sampling was used to find different ontology related research groups in different organisations and universities working in different domains.

We interviewed 15 researchers with different levels of expertise and knowledge engineering backgrounds. As it is seen in the table 1, four out of the fifteen interviewees had only worked in the biomedical field, five had some biomedical experience but had also worked in other fields such as computer science, and the rest of the interviewees were mostly involved in manufacturing, smart cities, etc. The semi-structured interview protocol focused on how each individual (i) built, (ii) searched for, (iii) evaluated and (iv) reused ontologies. Interviews ranged from 20 to 60 minutes, all of which were conducted via Skype. Interviews were recorded, and the interviewer took field notes during the interview. Field notes and transcriptions were coded using NVivo.

Interviews were conducted until no new information or theme was found (Guest et al.,2006) and the conceptual saturation was reached. The sample size can also be justified by some of the previous similar research on ontology evaluation for example the survey that was conducted by Tello (2002), which had 10 participants. Based upon the research questions, we began by coding for 1) building a reusable ontology, 2) characteristics of a reusable ontology, 3) finding a reusable ontology, 4) evaluating/trusting/selecting ontologies, and 5) the importance of community.

4 FINDINGS

According to the interview findings, metrics for evaluating the quality of an ontology for reuse can be classified into the following categories:

- metrics based on the ontology components including content, structure, coverage, etc.
- metrics related to the metadata about an ontology such as methodology, documentation, language, etc.
- metrics related to community, popularity, and ontology developer team

The main focus of this paper is on the community and social aspects of ontologies. The following parts of this paper moves on to describe in detail how participants in the interviews intended to refer to the community to search for, find and evaluate an ontology for reuse.

Table 1: Domain Expertise of Ontologists and Knowledge Engineers Interviewed.

Name/Code	Role / Domain, organisation, or project
BI1	Group leader / Bioinformatics, Gene ontology
BI2	Researcher / BioPortal
BI3	Ontology Developer / Bioinformatics, Gene ontology
BI4	Researcher / Biomedical Informatics
SB1	Ontology developer / Industry, W3C, NHS
SB2	Researcher / BioPortal
SB3	CEO and ontology developer / Bioinformatics
SB4	Lecturer / Computing Science and Biology
SB5	Research scientist / Protégé group
NBI1	Ontologist / IBM, Smarter Planet Project
NBI2	Professor, Manufacturing Informatics
NBI3	Ontology engineer / Semantic Web
NBI4	Researcher / Laboratory for Applied Ontology
NBI5	Researcher / Smart Cities, Geo Ontologies
NBI6	Researcher / Industrial ontologies

4.1 Community and Ontology Search

One of the fundamental objectives of the interviews was to explore the search process for reusable ontologies. Consequently, the question “how do you find the ontology you want to reuse?” was asked and while the researcher was expecting to hear about some popular search engines in ontology engineering domain like Swoogle, BioPortal, etc., literature and published papers were mentioned by many of the interviewees as one of their main sources of finding the ontologies they need.

Interviewee NBI4 for example, blamed his domain for lack of good and well-established repositories for ontologies and said that “I go to the literature”. Another interviewee, SB3, also

emphasised the significant role of literature in the process of searching for ontologies and mentioned that "reading publications around the ontology" is a very good method to help find the ontology, especially if someone is new to the field.

Besides helping to find a reusable ontology, some of the other interviewees stated that they use the literature and research papers as a tool to evaluate the quality of an ontology. Respondent NBI4 pointed out:

> If an ontology is good and is used, you find a cite in the literature.

Being based on published research papers will not only affect the quality of an ontology, but according to some of the respondents, will also affect the popularity of an ontology; BI4 for example stated:

> Popular ontologies are better ontologies, people are just familiar with popular ontologies so whenever you go to any ontology related conference, you will always have a workshop or a paper that talks about the ontology

4.2 Community and Ontology Evaluation

As was highlighted in section 2, various work has looked at the quality and evaluation of ontologies, however while some of the papers have attempted to cover the social aspects of ontology evaluation, none have gone further than measuring popularity, authority, and history of ontologies and almost all of them have neglected the other interactions in the community that can affect the way ontologies are evaluated, selected, and reused. Hence to explore the role of community in ontology sharing and reuse, participants were asked how interactions with people in their domain may affect the way they tend to evaluate an ontology for reuse. According to the interviews, participants not only use the community to evaluate an ontology before selecting it for reuse, but some of them also evaluate the ontologies they are building by the feedback they receive from the community.

4.2.1 Build Related Information

Several researchers mentioned the importance of different types of build related information such as who/which organisation has built the ontology, what the ontology has been built for e.g. the use case, who are the different stakeholders of the ontology, how the ontology was built (e.g. in collaboration), etc. Interestingly, one of the first things interviewees would say was that to evaluate an ontology, they will ask themselves if they know the developer of the ontology?

Interviewee BI3 for example emphasised the importance of knowing the developer team and its effect on the reuse process:

> I have to say, in reusing thing, there is often politics and connections are as important as anything else. So, it is not always the best one that wins.

He also added, quality of an ontology may sometimes come second:

> You know there might be constraint in terms of I may not like a particular ontology but because a bunch of other people are using it and I want to standardize with them, I might use it anyway.

Respondent SB4 also brought up the issue of trusting the developer team:

> Science is a social enterprise, I mean this is how everything works in science, you know if you look at a paper, do you trust the paper? you look at the authors first and then you read the paper and then you pick about what they have done but yes I mean it is a major criteria, major quality criteria, it may or may not right; it is a bit of old boys club but yes that is how people make decision. I normally read the definitions and then go to other things; do I trust the people who are making it?

Besides the information about the developer team or organisation, some of the respondents would consider the reasons that ontology was built and used for before selecting an ontology. They were also interested in having some information about the stakeholders of the ontologies. Interviewee SB3 said:

> Completely separated from the people developing it, are there other people who uses this ontology beyond just that group, that tells you something about it. I think also finding out how they are using it, is also important, you know what data is being annotated with those ontology is also important question, but I have some data and I know I want to integrate with something done in another institute, what is the ontology there they are using, that is also important, so I think there is a list of the things you want to check!

4.2.2 Regular Updates and Maintenance

Ontology maintainability is one of the significant metrics while evaluating the quality of an ontology and before selecting it for reuse. In the interviews, there were numerous examples of linking the quality of an ontology to how regularly it is updated and maintained. For some participants like NBI3, regularity of updates was the first thing that they would look at when evaluating a particular ontology:

> Somebody build ontology during his research in 1998 and he stored it on the web and then he left it, it is available but not updated, things will get obsolete very soon so we make sure to use the ontologies which are regularly updated, it is the first thing.

Some of the respondents like SB3 compared maintenance with some of the very popular quality metrics in the literature like coverage and said:

> Does it have my terms? I think is important but there are many others that you need to consider when you are picking an ontology beyond just does it have the words in ontology, about maintenance, do they update regularly, do they release regularly? do they have a record of doing that? How responsive they are to updates when you need new terms? all that sort of stuff. If they are publishing it once every two years it is probably not a good ontology.

Other participants like BI1 firmly believed that updates and maintenance play a very important role in their domain and said:

> No way that an ontology is keeping on in biology not getting updated, biology is changing too fast so all the relevant ontologies in biology are getting updated.

Interviewee NBI2 also made a link between the nature of the domain that he is working in and the necessity of regular updates:

> It is about flexibility, if you want to, in manufacturing business [towns] things are changing all the time so you need solutions that are easy and flexible to stay in, to stay relevant to what you are doing tomorrow as well as what you are trying to do today.

Interviewee BI3 compared the ontology engineering with software engineering and said:

> If you are going to reuse a piece of open source software you will do the same thing, you will open the GitHub website and say you know if you looked in it and nobody updated it or anything in three years, you might think no; whereas if it looks like there is an active ongoing community, you will think yes, if I have problems I can ask people and I can get bugs fixed.

BI4 believed that there is a link between the popularity of an ontology and the regularity of updating it and said:

> It might be useful to use popular ones because there are the ones that are mostly updated so gene ontology has a release I think every day or every 12 hours so the popular ontologies are the ones that are most updated.

Not only the regularity of updates is important, but also how people deal with it is the other important issue. Respondent SB3 talked about the importance of having an update mechanism and said:

> I think in the field that I am working, there are other challenges, one of which is how you deal with update mechanism of ontologies, if you annotate data to ontology which is typically use case for how you keep up-to-date with the fact that ontologies change reasonably often, you might have a big database of data, that you used the data in, new ontologies come along, the effect the way the data has been represented in your database, gotta have a update mechanisms for dealing with that and that can be tricky actually, it is not as simple often as swapping things out when something gets made obsolete, it is replaced with other things, you have to deal with.

4.2.3 Responsiveness

Responsiveness of the ontology developer/ maintenance team was among one of the other widely mentioned criteria when considering the quality of ontologies for reuse. Some of the respondents argued that not only knowing the developer team or organization is important, but also having an active ongoing community and their willingness to collaborate, evolve and develop the ontology further is an important factor when assessing an ontology. Interviewee BI3 put it in this way when he was asked about the importance of responsiveness:

> I would say it is definitely high up; I mean having someone at the other end of line that you feel that you can trust is definitely very important. If it looks like there is an active ongoing community, you will think yes if I

have problems I can ask people and I can get bugs fixed.

Another respondent, SB5, used one of the popular ontologies in her field as an example and said:

> For example, the fact that the Gene ontology has a huge community behind it is important because it means that they have a curation process in place and quality assurance and so on; so that kind of gives more confidence that the ontology is as good as it can be, it is not perfect for sure but I mean that it is vetted by the community.

Respondent BI1 chose responsiveness as the first quality metric he would consider for evaluating an ontology and compared it with one of the very popular ontology evaluation metrics, that is availability of documentation:

> I would say the responsive of the team obviously is the top-quality metric for me, because nothing is perfect but if something gets improved then it will get good like if you have a question, you need to add a term, something does not make sense, you contact them, they answer and they answer in a constructive way; this is good because all the ontologies are work in progress, there is no finished ontology in my domain.

4.2.4 Popularity

When asked about the popularity of an ontology and its effect on quality evaluation, participants had interesting thoughts and responses. As it was seen, most of the interviewees defined popularity as the number of times an ontology has been viewed or used in a repository. The responses fall into three different categories: those that were against the metric, those who supported it and those who while liking the popularity metric, did not agree with the way it was being computed.

The first group of respondents thought the popularity of an ontology considering the number of times it has been used is not that important for them. As interviewee BI1 would put it:

> To me it would not be very important except if two ontologies are really very equal in everything else, I will take the most used one but I do not think, it is not really relevant to me, if it is the right tool for the job, it is the right tool!

They also believed that the number of times an ontology is used depends on its size, level of specialization and the domain that it is built in and cannot be considered as a metric to measure quality. According to interviewee BI1:

> Some ontologies are more specialized so less people use them because it corresponds to a very special need, but may this people, are the right people and are using it well.

Interviewee SB3 also linked the use of an ontology to its size and added:

> If there is a small ontology but really focused on representing an area that has not been done before but it is correct, it is absolutely correct, I think that is perfectly reasonable, even if it is not widely used.

Some other interviewees like NBI5 found popularity a helpful metric, but believed that it is highly dependent on the domain that the ontology is used in:

> It depends on the domain that it has been reused in, if it is just medical domain, it is difficult to say that it is a reusable ontology!

The second group agreed on the necessity of having such a metric to identify the more popular ontologies in different domains but were not sure about the usefulness of the current methods that are used to measure the popularity. As interviewee NBI3 would put it:

> How many times an ontology is viewed will not help you, I may click just for exploration, and I will say it is not my thing and I don't want it; it shows how catchy the term is or how important, how regularly, how often this term is chosen, but it does not mean the use of the ontology; so, I think there should be some other way.

BI4 used a very interesting personal experience to prove the inaccuracy of the current techniques of measuring the popularity:

> When we were visualizing all the user exploration on ontologies on BioPortal, and we found that gene ontology is not accessed that much using BioPortal and I thought that it was very surprising because the gene ontology is very famous and then I found out because there is a gene ontology browser called AmiGo, and their visualizer tool is much better than BioPortal visualisation of gene ontology, so people generally go to gene ontology website and lunch the AmiGo browser and go to gene ontology there, so you can say that gene ontology is much more accepted but if you just look at the clicks (in

> BioPortal) and you might say that gene ontology is not that much famous.

Interviewee SB3 also thought that having a quality metric like popularity is a step in the right direction but believed that it might be misleading by causing a snowball effect; according to him:

> I can see that you can also putting a little metric for usage or browsing or how many people read these things, that is a kind of useful but it does not tell you the whole picture, you know you can end up with a false signal there; you recommended an ontology because it is useful because someone uses it and then you recommend it so someone else uses it and so on and so on, what I mean, so you are getting in that cycle of, it grows and grows!

The last and also the minority group were those who thought it worth having a metric like popularity and highlighted the importance of community acceptance. According to interviewee NBI4:

> If a community is using the ontology and is happy with it I take thing to account so I try to reuse or to do something to extend it or maybe very careful on changing it. I need to have motivations because after all ontologies should have people working in the domain and so if they are happy with that one and I see things that are no good, I point it out and I may suggest an extension, whatever but I try to reuse what I have.

Some of the respondents brought up the other definition that focuses on the link between popularity and the number of imported ontologies. NBI5 for example, made a link between the quality of an ontology and the fact that the ontology has reused other ontologies and said:

> The quality of an ontology depends on the relation between the ontology to upper level ontologies; the more “same-as”, “equivalent-as” links I can find in an ontology. It also can be seen as a sign or a feature of the ontology that can be reused because if it is "same -as" a concept that we already know, then it can be replaced.

NBI6 also believed that reusing some of the ontologies are inevitable and not importing will seem as a negative impression:

> Whenever I have an ontology where there is a person, I will never ever create my own person class, I will always reuse FOAF. I think it would be ridiculous to create my own class and some of those are very very strong class definition so it will always worth reusing and I think it will be even mistake by ontology engineer to develop their own class and for me, if I see an ontology doing that, I will get a negative impression.

5 DISCUSSION

This paper set out to assess the process of evaluating and selecting an ontology for reuse. Despite the various evaluation methods and approaches available in the literature, there is still no accepted approach or a set of metrics that can be used to evaluate ontologies effectively (Hlomani and Stacey, 2014) and most of the methods suffer from some serious limitations (Lewen et al.,2006). When respondents were asked how they evaluate an ontology for reuse, they mentioned some of the very well-known quality metrics based around content, structure, and metadata of an ontology, but their main focus was on the social and community aspects around an ontology. The scope of this study has particularly focused on the ways communities can help the process of ontology selection and evaluation.

As it was shown, most of the respondents highlighted community related factors such as reputation of the developer team or organisation in the domain and regularity of updates as some very important characteristics to be considered when selecting an ontology for reuse. The study has also found that the quality of ontologies is generally considered to be limited and some have pointed out that either way there isn’t such a thing as a complete or finished ontology, hence ontologists often need to count on the responsiveness of the ontology developer team and organization as well as their attitude toward the requests for changes. However, this has not previously been described and most of the existing studies have failed to cover and analyse the interactions in the community that can help in evaluating and selecting ontologies.

One unanticipated finding was that interviewees suspected the usefulness of one of the most commonly defined and used social quality metrics in the literature, ‘popularity’. According to the interviews, respondents care more about the projects that the ontology has been or is being used in, compared to the number of times it was used. Regarding the second definition of popularity, that is more about the linkage and the citation between ontologies (Supekar et al.,2004), it seems that further research should be undertaken to investigate

the importance of this factor and the way it can be employed to calculate popularity of an ontology.

Overall, the evidence from this exploratory study suggests that there is a clear interest for community based ontology evaluation and the need for relevant metrics. Further research is needed to confirm the quality metrics suggested in these research interviews and what their relative importance may be, whether there are differences in ontology engineering domains, or other important idiosyncrasies deserving further attention. To provide more generalizable findings for this research, the next stage of our research agenda will be to conduct large scale data collection via a survey targeting ontology engineers from heterogeneous domains. The expected outcome would be to introduce a community based quality metrics as well as to design and implement suggestions and guidelines that will help in designing and implementing ontologies that can be more easily found and reused, based on community measures identified through this ongoing research work.

6 CONCLUSIONS

This research study explored the set of steps ontologists and knowledge engineers tend to take when selecting an ontology for reuse. According to the presented interview study, the process of evaluating and selecting an ontology for reuse not only depends on the ontology content and structure, but it also depends on various non-ontological and community related metrics, from how it was built to how it has been maintained. Knowing about the organisation and the developer team involved in building and maintaining an ontology and their responsiveness also seems to play an important role in selecting and trusting an ontology. These findings enhance extant understanding of the evaluation metrics and it is hoped that they can be used to help in the selection process. A natural progression of this work is to design a framework based on non-ontological and community based quality metrics for ontology evaluation.

REFERENCES

Annamalai, M. and Sterling, L., 2003, July. Guidelines for Constructing Reusable Domain Ontologies. In *OAS* (pp. 71-74).

Arpinar, I.B., Giriloganathan, K. and Aleman-Meza, B., 2006, May. Ontology quality by detection of conflicts in metadata. In *Proceedings of the 4th International EON Workshop*.

Bontas, E.P., Mochol, M. and Tolksdorf, R., 2005, June. Case studies on ontology reuse. In *Proceedings of the IKNOW05 International Conference on Knowledge Management* (Vol. 74).

Brank, J., Grobelnik, M. and Mladenić, D., 2005. A survey of ontology evaluation techniques.

Bürger, T. and Simperl, E., 2008. Measuring the benefits of ontologies. In *On the Move to Meaningful Internet Systems: OTM 2008 Workshops* (pp. 584-594). Springer Berlin/Heidelberg.

Burton-Jones, A., Storey, V.C., Sugumaran, V. and Ahluwalia, P., 2005. A semiotic metrics suite for assessing the quality of ontologies. Data & Knowledge Engineering, 55(1), pp.84-102.

Ding, Y. and Foo, S., 2002. Ontology research and development. part 2-a review of ontology mapping and evolving. Journal of information science, 28(5), pp.375-388.

Fernández, M., Overbeeke, C., Sabou, M. and Motta, E., 2009, December. What makes a good ontology? A case-study in fine-grained knowledge reuse. In *Asian Semantic Web Conference* (pp. 61-75). Springer Berlin Heidelberg.

Guest, G., Bunce, A. and Johnson, L., 2006. How many interviews are enough? An experiment with data saturation and variability. Field methods, 18(1), pp.59-82.

Hlomani, H. and Stacey, D., 2014. Approaches, methods, metrics, measures, and subjectivity in ontology evaluation: A survey. Semantic Web Journal, pp.1-5.

Lewen, H., Supekar, K., Noy, N.F. and Musen, M.A., 2006, May. Topic-specific trust and open rating systems: An approach for ontology evaluation. *In Workshop on Evaluation of Ontologies for the Web*.

Lozano-Tello, A. and Gómez-Pérez, A., 2004. Ontometric: A method to choose the appropriate ontology. Journal of database management, 2(15), pp.1-18.

Martínez-Romero, M., Jonquet, C., O'Connor, M.J., Graybeal, J., Pazos, A. and Musen, M.A., 2017. NCBO Ontology Recommender 2.0: an enhanced approach for biomedical ontology recommendation. Journal of biomedical semantics, 8(1), p.21.

McDaniel, M., Storey, V.C. and Sugumaran, V., 2016, June. The Role of Community Acceptance in Assessing Ontology Quality. In *International Conference on Applications of Natural Language to Information Systems* (pp. 24-36). Springer International Publishing.

Page, L., Brin, S., Motwani, R. and Winograd, T., 1999. The PageRank citation ranking: Bringing order to the web. Stanford InfoLab.

Shadbolt, N., Berners-Lee, T. and Hall, W., 2006. The semantic web revisited.IEEE intelligent systems, 21(3), pp.96-101.

Simperl, E., 2009. Reusing ontologies on the Semantic Web: A feasibility study. Data & Knowledge Engineering, vol. 68, no. 10, pp.905-925.

Supekar, K., Patel, C. and Lee, Y., 2004, May. Characterizing Quality of Knowledge on Semantic Web. In *FLAIRS Conference* (pp. 472-478).

Tartir, S., Arpinar, I.B. and Sheth, A.P., 2010. Ontological evaluation and validation. In Theory and applications of ontology: Computer applications (pp. 115-130). Springer Netherlands.

Tello, A.J.L., 2002. Métrica de idoneidad de ontologías (Doctoral dissertation, Universidad de Extremadura).

Uschold, M., Healy, M., Williamson, K., Clark, P. and Woods, S., 1998, June. Ontology reuse and application. In *Formal ontology in information systems*, vol. 179, p. 192.

Wang, X., Guo, L. and Fang, J., 2008, April. Automated ontology selection based on description logic. In *Computer Supported Cooperative Work in Design*, 2008. CSCWD 2008. 12th International Conference on (pp. 482-487). IEEE.

Yu, J., Thom, J.A. and Tam, A., 2009. Requirements-oriented methodology for evaluating ontologies. Information Systems, 34(8), pp.766-791.