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Norris Syed Abdullah
The University of Queensland, norris@itee.uq.edu.au

Shazia Sadiq
University of Queensland, shazia@itee.uq.edu.au

Marta Indulska
University of Queensland, m.indulska@business.uq.edu.au

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Norris Syed Abdullah[1], Shazia Sadiq[2]
School of Information Technology and Electrical Engineering[1, 2]
The University of Queensland
Queensland, Australia
Faculty of Computer Science and Information Systems[1]
Universiti Teknologi Malaysia
Johor, Malaysia
Email: norris@itee.uq.edu.au[1], norris@utm.my[1], shazia@itee.uq.edu.au[2]

Marta Indulska
UQ Business School
The University of Queensland
Queensland, Australia
Email: m.indulska@business.uq.edu.au

Abstract

Ontology has been widely used to represent many real world aspects and is prominently used as tool to facilitate shared understanding (and knowledge sharing) in a particular domain. Ensuring that such an ontology is relevant to a particular domain, however, remains a challenging task to the ontology developer. This paper introduces a framework that guides industry-relevant ontology development. The framework follows a typical ontology development cycle and details incremental steps that need to be taken to assure industry-relevance of the ontology. To provide a thorough discussion of the framework, we utilise a previously completed ontology development project that followed the developed framework. The project was specifically aimed at developing an industry-relevant ontology for the compliance management domain and was based on three main inputs, namely, scholarly articles, industry expert/practitioner input and industry reports. Our experience indicates that the application of the developed framework promotes ontology development that utilises industry and academic inputs to assure the developed ontology is relevant to its domain.

Keywords

ontology development, ontology methodology, industry's inputs, industry case studies

INTRODUCTION

Ontology is defined as a set of representational primitives with which to model a domain of knowledge or discourse (Gruber 2009). Ontology has been widely used to represent many real world cases (Blomqvist and Öhgren 2008; Moreira et al. 2008) and is acknowledged to be beneficial to an organization (Grüninger and Lee 2002). First, it serves as a communication medium between computational systems and humans. Second, it is useful as a computational reference. Third, it facilitates the reuse of knowledge for structuring or organizing libraries or repositories of plans.

However, developing an ontology is a difficult and time-consuming process (Navigli and Velardi 2004). Although there are a number of methodologies available from the field of ontological engineering (Fernández et al. 1997; Grüninger and Fox 1995; Grüninger and Lee 2002; Sarraipa et al. 2008), many researchers tend to only loosely couple their ontology development with these methodologies. Considering the ontology building process is a craft rather than an engineering activity, each development team usually follows its own set of principles, design criteria and phases in the ontology development process (Fernández-López and Gómez-Pérez 2002). The first step in the development of an ontology requires the developer to have necessary domain expertise in order to ensure that the ontology elements, as well as the element relationships, are precisely defined and capable of being mapped to an end user's needs (Nawoj and Goniak 2004). Therefore, the development of an ontology that accurately represents the targeted domain requires a holistic approach; one that is able to guide the ontology developer in ensuring the quality and completeness of the ontology as well as the relevance of the ontology to the domain. Motivated by the lack of consistent holistic guidelines to assist ontology developers in industry-relevant domain ontology development, in this paper we introduce a framework for industry-relevant ontology development. This framework is based on two design principles. First, it emphasizes the need for a wide range and multiple sources of input, through which the ontology elements can be defined. We argue that these sources should span and balance the input from research literature as well as industry reports and experts. Second, it ensures a rigorous and reproducible approach for ontology development. Accordingly, the framework can simultaneously provide confidence in the depth and quality of the ontology as well as in the generalizability of the framework.

In the sections that follow, we present the details of the framework positioned within our experience with developing an ontology for the compliance management domain. This previous development project provides concrete examples of various stages of the framework, and demonstrates the feasibility of the proposed framework. The rest of this paper is organized as follows: Section 2 describes the related works on ontology development methodologies. Following this, Section 3 describes the details of our framework for industry-relevant ontology development. Finally, we present a discussion on lessons learnt and outlook for the framework.

RELATED WORK

The growth of ontology usage has prompted the emergence of research that focuses on providing methodologies, guidelines, frameworks etc. to serve as guidance for ontology developers. Existing methodologies – to name a few, include Cyc (Knight 1993), TOVE (Grüninger and Fox 1995), ENTERPRISE (Uschold 1996; Uschold and King 1995), METHONTOLOGY (Fernández et al. 1997), ontology integration methodology (Pinto and Martins 2001), OntoClean (Guarino and Welty 2009), and semantic interoperability methodology (Paredes-Moreno et al. 2010).

A number of researchers have also reviewed and analysed the features and applicability of ontology development methodologies. Fernández-López and Gómez-Pérez (2002), for example, discussed ontology development methodologies by categorising them into three different development approaches namely ontology building from scratch, ontology re-engineering, and cooperative ontology construction. In their work, Fernández-López and Gómez-Pérez (2002) analysed in detail the ontology development methodologies and compared their compliance with IEEE Standard for Developing Software Life Cycle Processes, 1074-1995. Their work includes a list of methodologies namely Cyc (Knight 1993), ENTERPRISE (Uschold 1996; Uschold and King 1995), TOVE (Grüninger and Fox 1995), KACTUS (Schreiber et al. 1995), METHONTOLOGY (Fernández et al. 1997), SENSUS (Knight and Luk 1994), CO4 (Euzenat 1995), and $(KA)^2$ (Benjamins et al. 1999).

Pinto and Martins (2004), on the other hand, discussed three most representative methodologies for building ontology from scratch i.e. TOVE (Gruninger and Fox 1995; Gruninger 1996), ENTERPRISE (Uschold and King 1995; Uschold 1996b), and METHONTOLOGY (Fernandez et al. 1997; Fernandez et al. 1999). Pinto and Martins (2004) reviewed the three methodologies by focusing on their activities and simultaneously mapping them to corresponding ontological engineering terminologies *viz.* specification, conceptualization, formalization, implementation, maintenance, knowledge acquisition, evaluation and documentation.

Focusing on the integration aspect, (Pinto and Martins 2001) proposed a methodology for ontology integration. They proposed a set of activities for ontology integration that include: identifying integration possibility, identifying modules, identifying assumptions and ontological commitments, identifying knowledge to be represented in each module, identifying candidate ontologies, obtaining candidate ontologies, studying and analysing candidate ontologies, choosing source ontologies, applying integration operations, and analyzing the resulting ontology.

A more recent methodology by Paredes-Moreno et al. (2010) proposed a semi-automatic approach in creating a data-driven business ontology that involves six stages of ontology development. These stages include: requirement analysis, metadata collection, construction, refinement, testing, and feedback. Paredes-Moreno et al. (2010) claimed that an ontology produced by using this methodology has a series of characteristics that make it highly appropriate for solving current problems of homogenization and integration in data-driven ontology development.

While comparisons of methodologies exist, as do proposals of new methodologies, our experience with ontology development indicates that there is limited academic guidance within existing ontology development methodologies on how to identify, gather, and use input in ontology development. One of the few works to touch on this topic is that of Velardi et al. (2001), who described a text mining technique that aids an ontology engineer in identifying the important concepts in a domain ontology. On a related topic, Brusa et al. (2006) discuss their experience in developing a government budgetary ontology based on inputs from the provincial budgetary application, its related documentations, and a group of experts within an organisation. While both works utilize inputs from a particular domain, they do not discuss how the relevant inputs were identified and prepared prior to concepts capturing process, and how the concepts were coded. Considering that industry relevance is an important factor that contributes to the usability and acceptability of a particular ontology, we address this need directly through our framework.

FRAMEWORK FOR ONTOLOGY DEVELOPMENT

Our framework for ontology development consists of five main phases, viz. Strategy Design and Data Preparation, Ontology Building, Ontology Validation, Ontology Refinement, and Ontology Documentation. Figure 1 shows our framework for Industry-Relevant Ontology Development including the sources of data associated with ontology development phases.

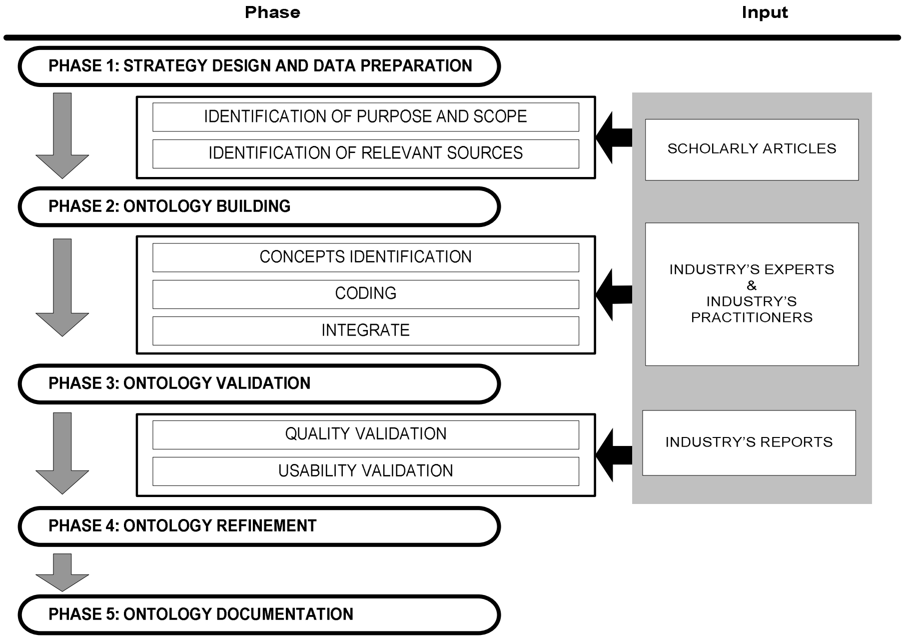

Figure 1: Framework for Industry-Relevant Ontology Development

Strategy Design and Data Preparation

We design the first phase of the ontology development framework specifically to provide a well versed theoretical background of a particular domain that the ontology is planned to serve. Hence, we suggest that review of literature is needed to investigate the principles and state-of-art in a particular domain. This review includes literature sourced from conferences, journals and industry white papers and reports. Furthermore, this phase also serves as foundation for the ontology developer prior to proceeding with ontology building.

<u>Identification of Purpose and Scope</u>

This phase starts with identification of the purpose and scope for the ontology that is planned to be developed. This identification is critical to ensure that the developer has a clear understanding of the ontology and its intended use(s) and users (Uschold and King 1995). Noy and Deborah (2001) highlighted that identifying the purpose and scope of the ontology will help limit the scope of the model (ontology). In order to clearly identify the purpose and scope for the ontology, the ontology developer needs to have sufficient knowledge of the targeted domain. Here, we suggest the best way to get essential knowledge on the domain of interest is through an exploratory study. We argue that the exploratory study must involve input from domain related scholarly articles but also industry input from domain experts and practitioners. In the case of our compliance management ontology project and its academic input, we utilised scholarly articles gathered through exhaustive filtration performed on high quality journals and conferences in the Information Systems discipline (Syed Abdullah et al. 2009). Balancing the need to understand the domain and its current state of the art, we considered all articles published in these outlets in 2001-2009. The list of considered outlets includes Business Process Management Journal (BPMJ), Communication of the Association for Information Systems (CAIS), Communication of the Association for Computing Machinery (CACM), European Journal of Information Systems (EJIS), Journal of Information and Management (JI&M), Journal of Information Systems Research (JISR), Journal of the Association for Information Systems (JAIS), MIS Quarterly (MISQ), Journal of Information Systems – Sarasota (JIS), Information Systems Frontier (ISF), Information Systems Journal - Blackwell (ISJ), Information Systems – Elsevier (IS), Journal of Management Information Systems (JMIS), and Journal of Database Management. Adding to these journals, the list of considered conferences includes Australasian Conference on Information Systems (ACIS), Americas Conference on Information Systems (AMCIS), Business Process Management Conference (BPMC), Conference on Advanced Information Systems Engineering (CAiSE), European Conference on Information Systems (ECIS), Conceptual Modelling Conference (ER), Hawaiian International Conference on Systems Science (HICSS), and International Conference on Information Systems (ICIS).

Each article was prepared and included in a full text search for the purposes of identifying relevance to the compliance management domain. The filtration of the articles was conducted in two stages. In the first stage, full text searches were conducted on the data set, using a keyword of “compliance”, “compliant” and “conformance”. As a step to assess article relevance to the domain of compliance management, we inspected the occurrence of the search terms in the article text, and included only those that had three or more hits. This step reduced and focused the data set to 774 papers. This second stage of the analysis and careful reading of each article resulted in a further reduction of the data set. Despite the articles having more than three references to “compliance” or being “compliant”, many were determined not to present a main contribution to the domain of compliance management. Instead, they mentioned compliance in various parts of the discussion and future works, however did not focus on the topic, or the notion of compliance was significantly different, e.g. compliance to a network protocol, or XML format, etc. Accordingly, the analysis reduced the set of articles from 774 to 304. These 304 articles serve as references in our ontology development that facilitate us in understanding compliance management domain and its state of the art. Thorough exploration on these 304 articles provide us with further details including the nature of the articles (solution article or exploratory article), type of compliance solution offered by the article (preventative, detective, or corrective), and the associated industries focused by the solution or study (e.g. financial, health, environment).

Balancing the understanding provided by the scholarly articles, we chose to gather the inputs from industry to further strengthen our understanding of compliance management in practice in our ontology development project. To obtain sufficient input, we use two sets of industry input (as reported in (Syed Abdullah et al. 2010a; Syed Abdullah et al. 2010b)) to provide industry’s perceptions of compliance management. The first set includes feedback through interviews performed of eleven compliance management experts, while the second set includes feedback through surveys of fifty-three compliance management practitioners. This feedback provides input that is based on real world experiences in managing compliance as perceived by compliance management experts and practitioners. We believe that by combining the industry input with relevant research literature further strengthens the developer’s understanding of compliance management domain.

Supported by our understanding of compliance management context, we proceed with formulating the purpose of the ontology as well as the scope that the ontology will cover. Referring to the same stage proposed by ENTERPRISE (Uschold 1996; Uschold and King 1995), we outline the purpose of the ontology, its intended uses, and a range of intended users of compliance management ontology. The purpose of compliance management ontology is stated as: “to provide practitioners, as well as the research community, with a shared vocabulary of compliance management concepts”. The use of compliance management ontology aims at providing a common understanding of compliance management concepts in practice to the intended compliance management users. The intended users for this ontology include compliance management professionals, businesses (regulatees), regulators, and researchers.

Identification of Relevant Sources

Following this, we proceed with identifying the relevant sources for ontology construction. Given that the sources for ontology construction are the essence for the overall ontology, gathering the sources that are relevant and providing balanced perception from theoretical and practice viewpoints is essential. Hence, in our case, we extend the utilisation of compliance related scholarly articles gathered in (Syed Abdullah et al. 2009) and industry’s feedback gathered in (Syed Abdullah et al. 2010a; Syed Abdullah et al. 2010b) as our sources for ontology development. We argue that by relying on multiple sources, will keep the ontology well-informed and industry-relevant. At the same time, this collection of sources also reduces the risk of omitting required concepts in ontology building. To further support the industry input in ontology building, we also added a collection of relevant industry articles from Gartner Research, KPMG, and Open Compliance and Ethics Group (OCEG).

Ontology Building

Based on the challenges encountered in this phase, we assumed this phase as the most critical and exhaustive phase in ontology development. In our framework, we utilise the ENTERPRISE ontology building approach proposed by (Uschold and King 1995), which includes the following activities: capture, prepare, and integration. In the following, we describe the details of the approach in capturing concepts for the ontology based on a synthesised analysis of industry’s data and scholarly articles. This is an effort to ensure that industry-relevance is consistently addressed throughout our framework.

Capture

Ontology capture includes identifying key concepts and relationships in the domain, producing precise and unambiguous text definitions for such concepts and relationships, and identifying terms to refer to such concepts and relationships (Uschold and King 1995). In our framework, we began the capture stage by coding and analysis of all main sources of data, facilitated by a qualitative analysis tool (NVivo). The process started with an exhaustive analysis of interview transcripts by the researchers. The researchers marked a fragment in data sources when it represented a concept related to compliance management (a node was created in NVivo). The identification and selection of the fragment was based on whether the concept was directly mentioned in the fragment, or whether the fragment contained a phrase or statement that implied the concept. For example, Figure 2 shows three different fragments that imply the same concept, (compliance) requirements management activity. First - FRAGMENT 1 shows the need to manage the continuously changing compliance requirements (regulations). Second - FRAGMENT 2 shows the difficulties in tracing compliance requirement (contracts) changes. Third – FRAGMENT 3 shows the situation involving multiple compliance requirements (regulations) faced by an organization. Although there is no single fragment that explicitly mentions the term 'requirements management', all the statements imply the need to manage compliance requirements.

This process continued until all data was coded, including data from practitioner surveys (which contained open ended questions).

FRAGMENT 1
…to satisfactorily identify & manage obligations to meet regulations & client needs that continuously change.

FRAGMENT 3
…if you take the big end of town where they have become conglomerates, you find that there are various regulators that are dealing with the same entity because it is in a number of lines of business.

FRAGMENT 3
The contract was in sort of a number of folders like shelves and shelves of a bookcase and yeah, with the geographical dispersion in main cities, that was really difficult to know when the contract changes…

Figure 2: Example of Similar Concept Implied by Different Fragments.

During coding of the transcripts, the researchers also marked fragments indicating a relationship between concepts. A fragment is considered as indicating a relationship if the fragment stated the association between a single concept to any other concept(s). These relationships were also organized in the form of NVivo nodes and later referred to as relationship nodes. The process resulted in 254 initial concept nodes and 38 relationship nodes. The initial capture process was followed by two further activities *viz.* concepts identification and relationships identification.

Concept Identification. After the initial capture of the 254 concept nodes, concept identification proceeded through a review process with the view to remove redundancy. We compared the 254 concepts and terms used to represent them. Where synonyms were found, either one of the terms was selected due to its wider usage, or a new, more accurate, term was defined to represent the concept. This resulted in a duplicate free, and more generic, list of concepts in the first draft of the ontology. Both stages of review reduced the number of concepts to 54. The data was then recoded using the 54 concepts to ensure that no concepts were lost in the refinement process. A total of 6 additional concepts resulted from this second coding process. Therefore, in total, 60 compliance management concepts were identified. Another important consideration in ontology development is maintaining the semantic capability of the ontology. To this end, we re-examine the remainder of the concepts that were not included in the list of the final 60. Following this examination, 23 concepts were categorised and linked with the final concepts as synonyms. Figure 3 shows the first and second level concepts from the overall compliance management ontology.

Relationship Identification. We began this process by using the 38 relationship nodes as a basis. It was clear that the initial nodes were not a sufficient representation of all relationships between the concepts. Accordingly, using related literature and the knowledge gained from data analysis as a basis, we proceeded to identify additional relationships to complement the linkage of the concepts. Various forms of relationships were observed, and resulted in the creation of a hierarchy of concepts with super- and sub-classes of concepts. Some concepts were positioned as part of a particular concept, and others as a variance of a particular concept. For example, we considered compliance activities and compliance structure to be child concepts of the compliance program concept that are needed to represent components that make up a compliance program. In another instance, we placed regulation, standard, policy and contract concepts as child nodes of the compliance requirement concept. This placement is based on the investigation of the types of compliance requirements that a particular organization may face. Therefore, this relationship depicts that regulation, standard, policy and contract are variations of compliance requirement concept. In ensuring that all concepts and relationships are defined in a precise and unambiguous manner, we also make direct reference to well-established definitions in compliance related research and practitioner publications (where applicable). In the circumstances where no suitable definition could be found, we then formulate our own definition based on the understanding we gathered in earlier stage (Strategy Design and Data Preparation). Therefore, we emphasise that all efforts have been taken to ensure that all concepts are presented with unambiguous definition and care has also been taken to ensure that a particular concept is well recognizable in the compliance management context.

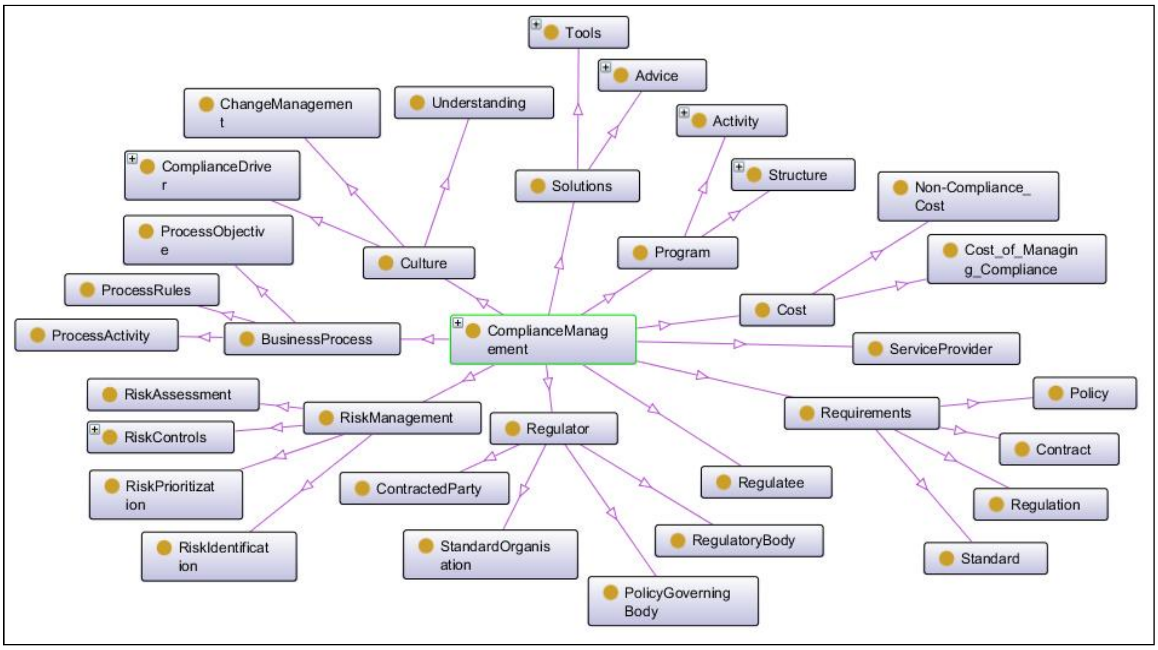

Figure 3: First and Second Tier Concepts of Compliance Management Ontology

Coding

Coding requires an explicit formal representation of the conceptualisation captured in the earlier stage. During this stage, choosing the suitable ontology representation language is essential to properly model the domain ontology to the right level of expressiveness. The languages that ontology developer may consider for ontology formal representation include OWL[1] (Web Ontology Language), MOF (Meta Object Facility), and UML (Unified Modeling Language). In our work, we employed the use of OWL-DL[2] (a sub language of OWL) to provide a formal representation of compliance management ontology. The result is a formal representation of the concepts and their associated relationships in OWL-DL. Figure 4 provides an example of concepts formalized by using OWL representation.

```
<owl:Class>
  <owl:oneOf rdf:parseType="Regulators">
    <owl:Thing
rdf:about="#Regulatory_Body"/>
    <owl:Thing
rdf:about="#Standard_Organisation"/>
    <owl:Thing
rdf:about="#Policy_Governing_Body"/>
    <owl:Thing
rdf:about="#Contracted_Party"/>
  </owl:oneOf>
</owl:Class>Class
```

Figure 4: Examples of Concepts Formalization presented in OWL.

Integrating with Existing Ontologies

Integration is also another activity in ontology development that could improve the richness and applicability of an ontology. Although included in many ontology development methodologies, integration with another existing ontology is not always applicable – it is considered only when an ontology is identified that fits the specific domain. Therefore, prior to integration, ontology developers need to identify and assess an existing ontology for its fit with their developed ontology. For this purpose, we suggest the use of guidance provided by Pinto and Martins (2001) to accommodate and facilitate ontology integration. In particular, they identify several important activities, *viz.* identifying integration possibilities, identifying modules, identifying assumptions and ontological commitments, identifying knowledge to be represented in each module, identifying candidate ontologies, obtaining candidate ontologies, studying and analysing candidate ontologies, selecting source ontologies, applying integration operations, and analysing the resulting ontology.

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[1] A de facto standard for ontology representation on the web (www. http://www.w3.org/TR/owl-features).

[2] OWL sublanguage that supports those users who want the maximum expressiveness while retaining computational completeness.

In the case of our compliance management ontology development, there is no existing ontology that fits for the purposes of integration with this ontology. Accordingly, we did not consider integration with existing ontologies. This may change in future as other relevant ontologies emerge.

Ontology Validation

All methodologies for building ontologies recognize the importance of evaluation (Uschold and King 1995). Evaluating ontology is vital in order to ensure the developed ontology is applicable and well suited to the domain it serves. There are a number of approaches studied in literature for evaluating a domain specific ontology (Brewster et al. 2004; Burton-Jones et al. 2005; Guo et al. 2009; Porzel and Malaka 2004). A review of ontology evaluation techniques by Brank et al. (2005) suggests that ontology evaluation approaches fall into one of the following categories: (1) those based on comparing the ontology to a “golden standard” (which may itself be an ontology); (2) those based on using the ontology in an application and evaluating the results; (3) those involving comparisons with a source of data (e.g. a collection of documents) about the domain to be covered by the ontology; (4) those where evaluation is done by humans who try to assess how well the ontology meets a set of predefined criteria, standards, requirements, etc. We have designed the evaluation strategy as a combination of (2) and (4) and formulated two validation tests: namely an ontology quality test and an ontology usability test. Quality validation involves expert assessment done on the ontology in term of its quality including syntactic quality, semantic quality, pragmatic quality and social quality (Burton-Jones et al. 2005). On the other hand, Usability validation involves examining the user perception on how the ontology is meeting their usage requirements in an application setting. Further, the ontology construction was based on large bodies of knowledge (source data) and thus (3) was somewhat embedded as part of the design process. Backed by human involvement (domain’s practitioners and experts) in the evaluation, and the extensive criteria from both tests, we found that the current evaluation strategy has provided us with sufficient feedback to improve the quality and usability of the ontology.

In our case of the compliance management ontology, our evaluation includes participants that have good background and knowledge on compliance management. We argue that to sufficiently evaluate the ontology for a particular domain, the evaluation should involve that particular domain’s practitioners and experts. Therefore, we chose to include compliance management experts and compliance management practitioners in the evaluation.

We present below as an example, a summary of results obtained from a pilot validation conducted for the compliance management ontology. This study included five Information Technology professionals, however, it is important to point out that the results below are presented to provide guidelines for the conduct of ontology validation, and not as a validation of the compliance management ontology.

Quality Evaluation

In order to evaluate the compliance management ontology quality, we utilise the metrics of (Burton-Jones et al. 2005) who introduce four metrics to evaluate the quality of ontology; namely, Syntactic Quality, Semantic Quality, Pragmatic Quality and Social Quality (refer to Table 1). However, as our ontology is a new ontology, we excluded Social Quality in this study. We argue that the ontology can only be evaluated on its social quality after it has been in use for some justified duration.

For the purpose of the study, we developed a questionnaire aimed at capturing participant feedback on the quality of the ontology with respect to clarity, interpretability, comprehensiveness, accuracy, and relevance of an individual concept in ontology. Questions relating to consistency, richness, and lawfulness are included separately to address the overall ontology evaluation. Furthermore relevance is captured by requiring participants to state whether a particular concept is relevant or not, whereas the remaining criteria are structured on a 7 level Likert scale. In the following we provide an excerpt of overall quality evaluation for compliance management ontology. This includes the mean scores for part of individual concepts as in Table 2.

Table 1. Metrics for Ontological Auditing (Burton-Jones et al. 2005)

Metrics suite	Attributes	Description
Syntactic quality	Lawfulness	Correctness of syntax
	Richness	Breadth of syntax used
Semantic quality	Interpretability	Meaningfulness of terms
	Consistency	Consistency of meaning of terms
	Clarity	Average number of word senses
Pragmatic quality	Comprehensiveness	Number of classes and properties

	Accuracy	Accuracy of information
	Relevance	Relevance of information for a task
Social quality	Authority	Extent to which other ontologies rely on it
	History	Number of times ontology has been used

Table 2. Excerpt from Quality Evaluation for Ontology Concepts

Concepts	Clarity	Interpretability	Accuracy	Comprehensiveness	Relevance
Business Process	6.4	6.6	6.2	6.4	1
Cost	6.6	6.4	5.8	5.8	1
Culture	6.2	5.2	5	5	1
Program	5.4	6.2	6.2	5.8	0.8
Regulator	6.8	6.4	6.4	6.4	1
Regulatee	6	6.4	6.2	6.2	1
Requirements	6.8	6.4	6.6	5.4	1
Risk Management	6.6	6.4	6.4	6.6	1
Solutions	5.8	5	5.8	5.4	1
Service Provider	6.8	6.6	6.2	6.2	0.4

These scores are useful to indicate the concepts that may need further improvement in relation to the above mentioned criteria. For example, low score for *culture* concept in terms of its accuracy may suggest that the definition provided for *culture* concept needs a review to improve its accuracy to represent culture existence in compliance management context. On the other hand, feedback received on *service provider* concept suggests that this concept although found as acceptable in other criteria, the participants remain doubtful on its relevance to compliance management context.

Usability Evaluation

We conducted the usability evaluation for compliance management ontology by using Technology Acceptance Model (TAM) criteria introduced in (Venkatesh and Bala 2008). We formulated a set of 28 questions to represent the multiple constructs presented in TAM (using the same level of Likert scale as described in quality evaluation section). Although there are 16 constructs in the recently revised TAM (Venkatesh and Bala 2008), in this survey we only use six of those. We argue that only criteria which are applicable to a particular ontology evaluation circumstances should be included for this evaluation purpose. For example, the use of Image construct is only applicable if the ontology has already been in use for some time in an organization. The list of constructs used in the usability evaluation includes Ontology Anxiety (ANX) – refers to Computer Anxiety in TAM (renamed to tailor with ontology evaluation), Behavioural Intention (BI), Perception of External Control (PEC), Perceived of Usefulness (PU), Perceived Ease of Use (PEOU), and Job Relevance (REL). The questions' distributions per construct are as follows: Ontology Anxiety (7 questions), Behavioural Intention (3 questions), Perception of External Control (5 questions), Perceived of Usefulness (3 questions), Perceived Ease of Use (7 questions), and Job Relevance (3 questions). The distributions of responses received for the constructs are listed in Table 3.

Table 3. Usability Evaluation Results (% per Likert level)

	LEVEL: (1) Strongly Disagree - (7) Strongly Agree						
Construct	**1**	**2**	**3**	**4**	**5**	**6**	**7**
ANX	0	28	8	0	24	36	4
BI	0	0	0	16	32	48	4
PEC	0	0	0	10	40	50	0
PU	0	6.7	13.3	20	6.7	40	13.3
PEOU	4	8	4	12	26	36	10
REL	0	6.7	6.7	13.3	20	40	13.3

Based on Table 3, we aggregate the percentage of responses that favors agreement i.e. somewhat agree, agree, and strongly agree to derive the ranking of constructs. The aggregation provides us with the highest agreement on responses found on PEC with a total of 90 percent responses favoring towards agreement. This follows with BI with a total of 84 percent responses, REL with 73.3 percent responses, and PEOU with a total of 72 percent responses. Completing the list, ANX received a total of 64 percent responses and PU with a total of 60 percent responses. The results from this survey suggest that more effort needs to be taken to improve the usability of the ontology and to reduce the participants' anxiety towards compliance management ontology. In terms of Job Relevance and Perceived Ease of Use, some improvements in labels of concepts, and graphical representation could offer better clarity and promote encouraging conditions to relate the ontology with real practice of compliance management.

Ontology Refinement

Upon completion of validation, the ontology requires refinement that manifests how the ontology developer addressed the feedback from ontology validation stage. To this end, we suggest that each individual concept be inspected and reviewed for its weaknesses *wrt.* clarity, interpretability, accuracy, comprehensiveness, and relevance. During this stage changes may include (but are not limited to) introduction of new concepts, refined definitions, refined relations, and concepts replacement.

Ontology Documentation

To facilitate future utility of the ontology, the developed ontology needs to be documented in a way that it can be easily referred by the target users. In addition to the formal OWL representation, a user friendly 'manual' can be prepared to facilitate the pilot and future validation case studies. Upon completion of the ontology evaluation and refinement, the document should be revised and made available as a reference document to the intended users e.g. in our example case, compliance management professionals, businesses (regulatees), and regulators.

DISCUSSION AND CONCLUSION

Based on our experience with ontology development, we have presented a framework for the development of an industry-relevant ontology that is well informed by both research literature and industry input. The framework includes five main phases namely Strategy Design and Data Preparation, Ontology Building, Ontology Validation, Ontology Refinement, and Ontology Documentation. The framework is motivated by the lack of consistent holistic guidelines to assist ontology developers in industry-relevant domain ontology development. The application of this framework is beneficial to promote ontology development that utilises industry inputs to assure the developed ontology's relevance to its domain.

In the paper, we have also emphasised that the framework is based on two design principles, namely, emphasis and utilisation of wide range and multiple sources for ontology development and a rigorous and reproducible approach for the ontology development. To facilitate the understanding of the framework, we have also demonstrated how this framework can be deployed in a particular ontology development activity. We used compliance management as a domain to demonstrate the above. Details of our experience in deploying this framework were discussed in detail in ontology building and ontology validation stages.

Despite our extensive coverage on industry-relevance of the ontology to be produced, we welcome any future extension of this framework. From our viewpoint, we anticipate that future refinement and extension of the framework may include: (1) development of a tool that accommodates and provides proper linkages between the developed ontology and its sources of inputs and is beneficial in accommodating future extension and integration of the ontology, with ease; (2) a documentation tool that is able to segment, filter and visualize the ontology formalisation for case specific ontology presentations and (3) exploration of other methods for evaluation that could strengthen the framework towards assuring its methodological rigour and improving its applicability.

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