Ontology based Knowledge Transferability and Complexity Measurement for Knowledge Sharing

Pornpit Wongthongtham and Behrang Zadjabbari
Curtin University, GPO Box U1987, Perth, WA 6845, Australia

Keywords: Ontology based Knowledge Transferability Measurement, Ontology based Knowledge Complexity Measurement, Knowledge Sharing.

Abstract: Importance of knowledge sharing raises the issue of how organizations can effectively encourage individual knowledge sharing behaviour and what factors enable promote or hinder sharing of knowledge. It is important to explore the factors affecting knowledge sharing and remove barriers to participation in knowledge sharing. Willingness and ability to share knowledge and willingness and ability of receiver to achieve knowledge are one of key issues in knowledge sharing. Knowledge sharing also depends on knowledge context including the nature, definition, and properties of knowledge which influence the ease with which knowledge can be shared. In this research the context of knowledge is defined by two key variables i.e. transferability and complexity which are subject of this paper. Ontologies are used mainly to provide a shared semantically domain knowledge in a declarative formalism. Ontology specifies consensual knowledge. In this paper, ontology is applied to explore knowledge context. It is then used to measure transferability of knowledge between individuals from different backgrounds by comparing the similarity of their ontologies. Then the difference of the ontologies is measured its complexity in order to determine how complicated of new knowledge being shared.

1 INTRODUCTION

Knowledge sharing is one of the most critical elements of effective knowledge processing and organizations often face difficulties when trying to encourage knowledge sharing behaviour (Saraydar et al., 2002). It has been estimated that at least $31.5 billion are lost per year by Fortune 500 companies as a result of failing to share knowledge (Babcock, 2004). Knowledge sharing refers to the provision of task information and know-how to help and collaborate with others to solve problems, share ideas, or implement policies or procedures (Cummings, 2004). Davenport and Prusak define knowledge sharing as equivalent to knowledge transfer and sharing amongst members of the organization (Davenport and Prusak, 2003). Knowledge sharing can occur in different forms such as written correspondence, face-to-face communications or through networking with other experts, documenting, organizing and capturing knowledge for others (Cummings, 2004). Knowledge sharing is important for companies to be able to develop skills and competence, increase value, and sustain competitive advantages due to innovation that occurs when people share and combine their personal knowledge with others (Matzler et al., 2008). The importance of knowledge sharing raises the issue of how organizations can effectively encourage individual knowledge sharing behaviour and what factors enable, promote or hinder sharing of knowledge. It is important to explore the factors affecting knowledge sharing and remove barriers to participation in knowledge sharing within and between communities. Researchers have found that organizational culture affects knowledge sharing and the benefits of a new technology were limited if long-standing organizational values and practice were not supportive of knowledge sharing across units (DeLong and Fahey, 2000). Among the many cultural dimensions that influence knowledge sharing, trust is the important dimension and a culture that emphasizes trust can help to alleviate the negative effect of perceived cost on sharing (Kankanhalli et al., 2005). Trust provides conduits for the knowledge exchange and learning needed to solve problems and achieve shared goals (Preece,

Wongthongtham P. and Zadjabbari B..
Ontology based Knowledge Transferability and Complexity Measurement for Knowledge Sharing.
DOI: 10.5220/0004103600050014
In *Proceedings of the International Conference on Knowledge Management and Information Sharing* (KMIS-2012), pages 5-14
ISBN: 978-989-8565-31-0

2004). Trust has been recognized as the gateway to successful relationships (Wilson and Jantrania, 1993). High levels of trust are the key to effective communications as trust improves the quality of dialogue and discussions (Dodgson, 1993). The willingness to share knowledge is a key issue in knowledge sharing (Connelly and Kelloway, 2003). Willingness trust is considered as one of the key variables in knowledge sharing measurement. Some of the researches show that management support affects both the level and quality of knowledge sharing through influencing employee willingness to make a commitment. Moreover, in an organizational context, willingness to share knowledge can be improved by management support, rewards and incentives and organizational structure (Wang and Noe, 2009). In interpersonal and team contexts, willingness to share knowledge depends more on the level of team cohesiveness (Bakker et al., 2006) and the diversity of team members (Ojha, 2005). It is understood by different researchers that the ability and competency to share knowledge and to send or receive knowledge is the most critical issue in knowledge sharing (Jap, 2001). Competency trust is considered as the next key variable in knowledge sharing measurement and it is one of the key issues. The reason is that competency trust refers to how the partner is expected to perform, or does perform, in relation to the underlining functions of the relationship (Heffernan, 2004). Competency trust is defined as whether a partner has the capability and expertise to undertake the purpose of relationship and meet the obligations of the relationship (Doney and Cannon, 1997). In overall, willingness and ability to share knowledge and willingness and ability of receiver to achieve knowledge are key issues in knowledge sharing.

Knowledge sharing also depends on knowledge context including the nature, definition, and properties of knowledge which influence the ease with which knowledge can be shared and accumulated (Argote et al., 2003). The context of knowledge has been recognized by a number of knowledge management researchers as being crucial to improving the understanding and sharing of knowledge. In this research the context of knowledge is defined by two key variables i.e. transferability and complexity which are subject of this paper. Firstly, transferability of knowledge is used to measure the nature of knowledge. It is based on the fact that, in most cases, knowledge senders and receivers are from different backgrounds such as engineering, business, medicine etc. and when individuals from different backgrounds start to share knowledge, the meaning of this knowledge for each party may differ. Complexity of knowledge is the next variable used to measure the ease with which particular knowledge can be shared. It is obvious that explicit knowledge and routine or day-to-day knowledge that people share in their daily conversation is less complex, while technical knowledge is more complex.

Ontology is an explicit specification of a conceptualisation (Gruber, 1993) enabling underlying knowledge representation. Ontologies are used in widespread application areas e.g. semantic web, medical informatics, e-commerce, etc. Mainly ontologies are used to provide a shared semantically domain knowledge in a declarative formalism. Ontology specifies consensual knowledge accepted by a community. In this paper, ontology is applied to explore knowledge context. It is then used to measure transferability of knowledge between individuals from different backgrounds by comparing the similarity of their ontologies. Then the difference of the ontologies is measured its complexity in order to determine how complicated of new knowledge being shared. The rest of paper is organized as follows. We discuss the related works about ontology comparison and complexity in the next section. Then we discuss ontology transferability and its metrics in section 3. Ontology complexity and its metric are presented in section 4. Experiment is given in section 5 followed by discussion in section 6. We conclude our work in section 7.

2 EXISTING APPROACHES

There are many studies in semantic web applications emphasizing on measuring ontology similarity and difference know as ontology matching and mapping. A number of approaches have been proposed to deal with the heterogeneity of ontologies (Wang and Ali, 2005). Ontology integration approach maps different ontologies into a generic ontology using vocabulary heterogeneity resolution on various ontologies (Kashyap and Sheth, 1998); (Weinstein and Birmingham, 1999); (Mena et al., 2000); (Stuckenschmidt and Timm, 2002). In this method, the semantic transferability has not been measured before merging into the generic ontology. Measuring the semantic transferability is important in the integrated ontology whether the ontologies should be merged. Suggested Upper Merged Ontology (SUMO) is developed to merge ontologies by sharing ideas from all available ontologies and mapping the entries of merged ontologies with WordNet entries (Pease et al., 2002). However this approach does not address the requirement of transferability of two ontologies. One approach creates a computational model to assess semantic similarity among entity classes from different and independent ontologies without having to form a shared ontology (Rodriguez and Egenhofer, 2003). This approach is not practical to measure semantic transferability of two ontologies due to the complexity of matching process. Another approach proposes ontology-based information retrieval model by using domain ontology to extend the original keywords input by users and calculates the concept similarity. Yet this approach does not address the requirement of transferability of two ontologies.

In regard to existing work on ontology complexity, there are existing metrics for analysing ontology quality but only few of them focus on complexity of ontology. Burton-Jones et al. (Andrew et al. 2005) measure elements of quality i.e. syntactic quality, semantic quality, pragmatic quality, and social quality using a number of attributes. Dazhou et al. (Dazhou et al., 2004) present complexity measurement for ontology based on UML. However UML cannot entirely represent semantic richness like ontology does. UML is not a suitable modeling language to represent an ontology, thus, the method cannot measure the structure complexity of ontology objectively. Chris Mungall (Mungall, 2005) researched the increased complexity of Gene Ontology which is similar to Dalu et al. method (Zhang et al., 2006). Anthony et al. (Anthony et al., 2007) also proposed a metric suite to measure the increased complexity of tourism ontologies throughout ontology evolution. However, the metrics in (Mungall, 2005), (Zhang et al., 2006), and (Anthony et al., 2007) are evaluating ontology in ontology evolution. Idris (His, 2004) proposed conceptual coherence and conceptual complexity metrics based on graph theory. Orme et al. (Anthony, Haining et al. 2006) examined coupling between ontologies. Nevertheless, in (Mungall, 2005); (Zhang et al., 2006); (Anthony et al., 2007); (His, 2004); and (Anthony et al., 2006), complexity is analysed by the concept structure and does not consider the number of restrictions.

In this paper we address the ontology transferability and complexity as two key variables for knowledge sharing.

3 ONTOLOGY BASED KNOWLEDGE TRANSFERABILITY AND ITS MEASUREMENT

Knowledge is a combination of the data and information being produced by human thought processes. Knowledge can be distinguished into general knowledge and specific knowledge. General knowledge is explicit and is easily understood by locals and neighbours since both their ontologies are similar. Specific knowledge is more technical and difficult to understand and depends on an individual's background and knowledge level (ontologies are different). It is necessary to understand the nature of knowledge in order to analyse the process of knowledge sharing between and within organizations or individuals. The characteristics of knowledge influence the outcome of knowledge sharing (Nonaka and Takeuchi, 1995). The impact of the nature of knowledge on knowledge sharing is part of this research's objective. The nature of the knowledge also affects the importance of trust in knowledge sharing. When the knowledge seems simple, competence-based trust is not necessarily important and in this case, people care more about benevolence-based trust. On the other hand, when the knowledge is complex and professional, people care more about competency-based trust.

We divide knowledge type into easy or hard transferable knowledge (transferability). Metrics to measure the complexity of knowledge by using ontology are presented. We develop a proposed model and measure the transferability of knowledge by comparing the two ontologies (sender and receiver of the knowledge) and ascertaining whether or not there are similarities.

Transferability of the knowledge is more related to the members' backgrounds and their domain ontology. We use the similarity of ontologies to measure the level of transformability between two members. Transferability of the knowledge for both transmitter and receiver will be given a value between 0 and 1.

To measure the transformability of two knowledge backgrounds, ontology similarity is considered and calculated. In the means of obtaining the senses and hyponyms of the each concept in the ontologies and based on the structure of the ontologies, the similarity of two ontologies can be calculated. Precisely said knowledge transferability is signified by ontology similarity. Nevertheless, there may be more than one sense for each concept. The senses of subclasses of ontology can be determined by their ancestors. To which sense from the root of the ontology it is determined by users.

In this paper, our formulas give a numeric measurement of ontology transferability. Assume we measure transferability of two ontologies which can be calculated by using ontology similarity formulas. Wang and Ali (Wang and Ali, 2005)defined the difference of set of concepts, S1, captured in ontology 1, O1, from set of concepts, S2, captured in ontology 2, O2 as shown in equation (1).

$$S1 - S2 = \{x | x \in S1 \wedge x \notin S2\} \quad (1)$$

The semantic difference between O1 and O2 can be defined by function Dif(S1, S2) in equation (2) (Wang and Ali, 2005).

$$\text{Dif}(S1, S2) = \frac{|S1 - S2|}{|S1|} \quad (2)$$

Based on the above formula, if the two ontologies are totally different, the difference value is given 1 or the similarity value is given 0. On the contrary, if the two ontologies are the same, the difference value is given 0 or the similarity value is given 1. Therefore, the similarity of set S1 from set S2 is defined as $\{x | x \in S1 \wedge x \in S2\}$

The semantic similarity between O1 and O2 or the transferability can be defined by function Trans(S1, S2) in equation (3).

$$\text{Trans}(S1, S2) = 1 - \frac{|S1 - S2|}{|S1|} \quad (3)$$

We compare in both directions i.e. Trans(S1, S2) and Trans(S2, S1) which may be given different value.

In domain ontology that two individuals (receiver and sender) are sharing their knowledge (a class in ontology), they first need to agree on a sense of shared knowledge. Sense sets will be provided to summarize the semantics of the shared knowledge (the class in ontology). Basically the sense set is a set of synonym words denoting the concept of the class in ontology. A sense set is extracted from the electronic lexical database WordNet which is available online as Java WordNet Library (JWNL). JWNL is used to obtain the semantic meanings of concepts confined in ontologies.

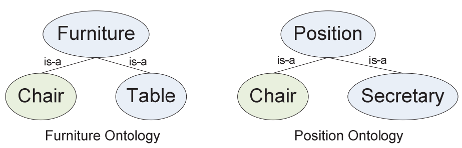

Figure 1: Chair concept in two different ontologies.

The simple ontology transferability algorithm is shown below:

```
OntologySenseSet(O)
begin
R = resultSet;
for all node n in Ontology O
p = parent node of n;
senseSetP = all senses of p;
senseSet = all WordNet senses of n;
if n = root
select related sense used in Ontology O;
else
relateFlag = false;
  for each sense S in senseSet
  hyperSet = hypernyms of each sense S of n;
    for each h in hyperSet
      if h is in senseSetP
      relateFlag = true;
        for each s in S
          if s == n
          R.add(s + "_is-a_" + p);
          else
          R.add(s);
          endif
        endfor
      endif
    endfor
  endfor
  if relateFlag == false
  R.add(n);
  endif
endif
endfor
return R;
end

OntologyTransferability(O1, O2)
begin
difference = 0;
for each r1 in OntoSenseSet(O1)
   if r1 is not in OntoSenseSet(O2)
   difference ++;
   endif
endfor
Trans = 1-difference/size of
OntoSenseSet(O1);
return Trans;
end
```

Quantifying the transferability of knowledge is intersection between two different ontologies and for this purpose it is important to assess the semantic similarity of difference between two ontologies. To demonstrate the above algorithm we use simple ontologies and show its transferability as example.

Assume we have two ontologies i.e. Furniture Ontology and Position Ontology as shown in Figure 1.

Furniture Ontology represents concepts of chair and table as furniture while Position Ontology represents concepts of secretary and chair as position. We assess transferability between these two ontologies. To assess transferability from Furniture Ontology to Position Ontology, we need to get the sense set of the two ontologies. In other words, we get the concepts and their senses with hypernyms for both Furniture Ontology and Position Ontology. In process of getting sense set, users initially choose which sense s/he means at the root concept if there is more than one sense. Senses and its hypernyms are obtained from WordNet. Among those retrieve from WordNet, we also include is-a relationship to differentiate concept from others if there is more than one senses in that particular concept.

Tables below show senses and hypernyms from WordNet for Furniture Ontology and Position Ontology. The highlighted senses are ones in sense set or are ones that have meaning within the meant content.

Table 1: Senses and hypernyms retrieved from WordNet for Furniture Ontology.

Concept	Senses	Hypernyms
Furniture	furniture, piece of furniture, article of furniture	furnishing
Chair	chair	seat
	Professorship, chair	position, post, berth, office, spot, billet, place, situation
	president, chairman, chairwoman, chair, chairperson	presiding officer
	electric chair, chair, death chair, hot seat	instrument of execution
Table	table, tabular array	array
	table	furniture, piece of furniture, article of furniture
	table	furniture, piece of furniture, article of furniture
	mesa, table	tableland, plateau
	table	gathering, assemblage
	board, table	fare

As can be seen in Table 2, there are 16 senses for Position concept. Since Position concept is the root concept, it need user to initially select which sense(s) s/he means. In this example sixth sense (position, post, berth, office, spot, billet, place, situation) is what the user chosen and is what s/he means by Position concept. The sixth sense will be included in sense set for the Position Ontology. There are 4 senses for Chair concept in Position Ontology, shown in Table 2, the second sense (professorship, chair) are selected and to be included in the sense set because its hypernyms are matched with selected root sense. We also need to differentiate 'chair' from other 'chair' in other senses by incorporating is-a relationship. To identify the is-a relationship, we add '_is-a_' follow with parent concept to 'chair' becoming 'chair_is-a_position'. For Secretary concept, there is no matched sense with parent (root) sense, we simply include it into sense set.

Table 2: Senses and hypernyms retrieved from WordNet for Position Ontology.

Concept	Senses	Hypernyms
Position	position, place	point
	military position, position	point
	position, view, perspective	orientation
	position, posture, attitude	bodily property
	status, position	state
	position, post, berth, office, spot, billet, place, situation	occupation, business, job, line of work, line
	position, spatial relation	relation
	position	point
	position	role
	placement, location, locating, position, positioning, emplacement	activity
	situation, position	condition ,status
	place, position	Item, point
	stance, posture	attitude, mental attitude
	side, position	opinion, view
	stead, position, place, lieu	function, office, part, role
	position	assumption
Secretary	secretary	head, chief, top dog
	secretary, secretarial assistant	assistant, helper, help, supporter
	repository, secretary	confidant, intimate
	secretary ,writing table, escritoire, secretaire	desk
Chair	chair	seat
	professorship, chair	position, post, berth, office, spot, billet, place, situation
	president, chairman, chairwoman, chair, chairperson	presiding officer
	electric chair, chair, death chair, hot seat	instrument of execution

From Table 1, the senses set for Furniture

Ontology is {furniture, piece of furniture, article of furniture, chair, table_is-a_furniture, table_is-a_furniture}. From Table 2, the senses set for Position Ontology is {position, post, berth, office, spot, billet, place, situation, secretary, professorship, chair_is-a_position}. To find transferability value from Furniture Ontology to Position Ontology, firstly we need to find sense(s) that appear in the Furniture sense set but do not appear in the Position sense set as follow:

Furniture sense set – Position sense set $= \{x \mid x \in$ *Furniture sense set* $\wedge\, x \notin$ *Position sense set*$\} = 6$

The transferability can be defined by function Trans(Furniture Ontology, Position Ontology) as follow:

Trans(Furniture Ontology, Position Ontology) $= 1 - \frac{6}{6} = 0$

The value of transferability 0 means that knowledge is not transferable. Concept chair is used in both ontologies but means differently.

4 ONTOLOGY BASED KNOWLEDGE COMPLEXITY AND ITS MEASUREMENT

Ontology complexity is related to the complexity of conceptualization of the domain of interest. It is measured to reflect how easy any ontology is to understand. Definition of ontology complexity is clarified in features that characterize complexity of ontology i.e. (i) usability and usefulness and (ii) maintainability. For example, a more complicated ontology indicates a more specified knowledge. However, it is difficult to comprehend and requires a high value of competence-based trust. Usability and usefulness of the knowledge may be then decreasing which implies a major impact on knowledge sharing. Additionally complicated ontology is hard to maintain.

In order to measure the complexity of ontology, number of ontology classes, number of datatype properties, object properties, constraints, and hierarchical paths are considered. Number of Ontology Classes (NoOC) is needed to obtain average value. Number of Datatype Properties (NoDP) illustrates how well concepts are being defined. In OWL the datatype properties are indicated as owl:dataTypeProperty. Number of Object Properties (NoOP) illustrates how well spread of concepts within the ontology. In OWL the object properties are indicated as owl:objectProperty. Number of Constraints (NoC) illustrates how well relations being restricted. In OWL the constraints are indicated as owl:allValuesFrom, owl:someValueFrom, owl:hasValue, owl:cardinality, owl:minCardinality, and owl:maxCardinality. Lastly Number of Hierarchical Paths (NoHP) illustrates how fine concepts being presented. In OWL the hierarchical paths are represented as owl:subClassOf.

To calculate complexity of an ontology O, a numeric measurement is defined by function Complex(O) using above parameters in following formula:

$$Complex(O) = \left(\frac{\sum(\mathrm{NoDP}+\mathrm{NoOP}+\mathrm{NoC}+\mathrm{NoHP})}{\mathrm{Max(NoDP)}+\mathrm{Max(NoOP)}+\mathrm{Max(NoC)}+\mathrm{Max(NoHP)}}\right)/\mathrm{NoOC}$$

Where Max(NoDP) is maximum number of datatype property, Max(NoOP) is maximum number of object property, Max(NoC) is maximum number of constraint, and Max(NoHP) is maximum number of hierarchical path. The complexity value is ranged between 0 and 1 which 0 means the ontology is not very complicated while 1 means the ontology is very complicated.

5 EXPERIMENT

We experiment pizza domain. We take Pizza Ontology developed by CO-ODE team at Manchester University (Drummond et al., 2007). We have modified the Pizza Ontology and created another 2 different Pizza ontologies namely Vegetable Pizza and Meat Pizza for experiment studies. The prototype is implemented using JAVA. We use OWL2.0 API to load and manipulate ontologies which are related to the domains of people who are going to share the knowledge. JWNL is the main API which is used to obtain the semantic meanings of each concept captured in ontologies.

Assuming people want to share knowledge about pizza. Ones who are vegetarian have idea of vegetable pizza which will be different from ones who have idea of meat pizza and from others who have idea of pizza in general. In other words, when people start to share pizza knowledge, vegetarian people will be thinking of vegetable pizza, meat lover people will be thinking of meat pizza, and other people will be thinking of pizza in general. We assess how well they share the pizza knowledge. We have modified Pizza Ontology and create Vegetable Pizza Ontology and Meat Pizza Ontology. In experimental studies, we firstly measure the

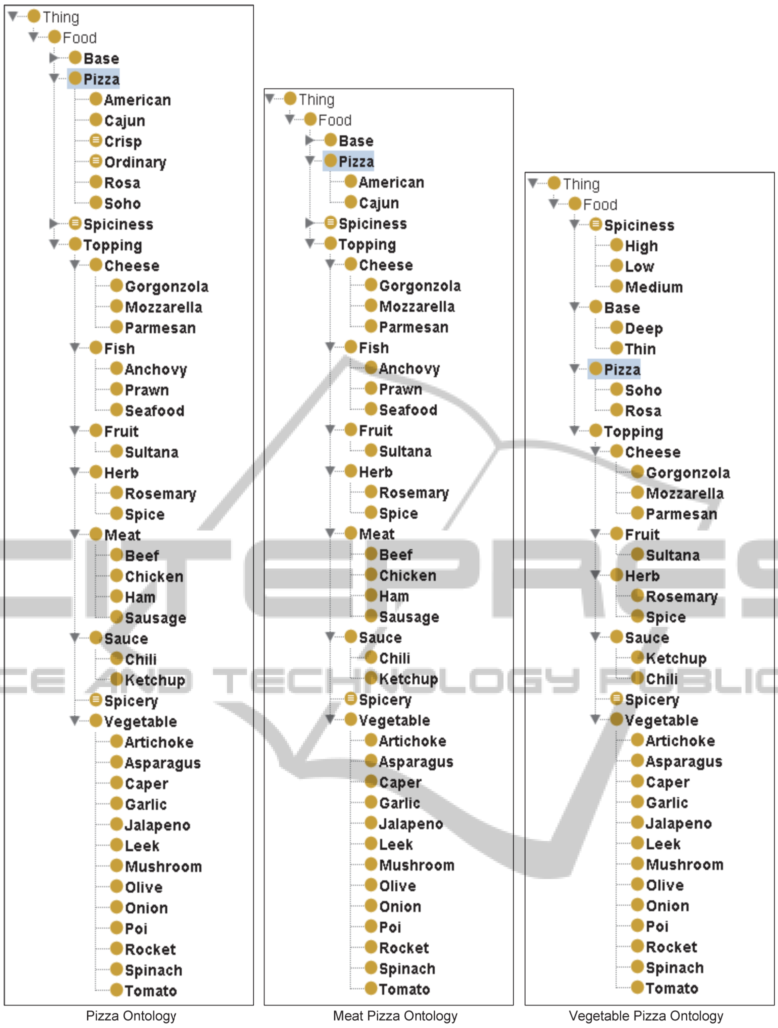

Figure 2: Relation hierarchy of different ontologies.

transferability of pizza knowledge in different ontologies. Figure 2 shows relation hierarchy of Pizza Ontology, Meat Pizza Ontology, and Vegetable Pizza Ontology.

Considering transferability between Vegetable Pizza Ontology and Meat Pizza Ontology, it is as follow. From Word Net 2.1, the number of senses (|S1|) found in Vegetable Pizza Ontology is 56. The number of senses (|S2|) for Meat Pizza Ontology is 72. After comparing,

$$S1 - S2 = \{x | x \in S1 \wedge x \notin S2\} = 2$$

There are 2 distinct senses existing in Vegetable Pizza sense set and are not in Meat Pizza sense set. The two senses are “rosa and soho”. The transferability from Vegetable Pizza Ontology to Meat Pizza Ontology is as follow:

$$Trans(S1, S2) = 1 - \frac{|S1 - S2|}{|S1|} = 1 - \frac{2}{56} = 0.9642858$$

In opposite direction, the transferability from Meat Pizza Ontology to Vegetable Pizza Ontology is as follow:

$$Trans(S2, S1) = 1 - \frac{|S2 - S1|}{|S2|} = 1 - \frac{18}{72} = 0.75$$

There are 18 distinct senses existing in Meat Pizza sense set and are not in Vegetable Pizza sense set. The 18 senses are “american, cajun, fish_is-a_topping, anchovy_is-a_fish, anchovy_is-a_fish, prawn_is-a_fish, shrimp, seafood_is-a_fish, meat_is-a_topping, beef_is-a_meat, boeuf, chicken_is-a_meat, poulet, volaille, ham_is-a_meat, jambon, gammon, and sausage_is-a_meat”.

Table 3 shows other results of different transferability in different ontologies.

Next we calculate complexity of new knowledge or complexity of the different part of ontology. If one who has Vegetable Pizza ontology shares his/her knowledge to one who has Meat Pizza ontology, complexity of new knowledge of one who has Vegetable Pizza has to give to one who has Meat Pizza ontology is measured. Figure 3 shows properties and restrictions of classes rosa and soho which are different parts in Vegetable Pizza ontology.

Table 3: Transferability of different ontologies.

Ontology target	Ontology source	Transferability
Pizza	Meat Pizza	$1 - \frac{7}{79} = 0.9113925$
Pizza	Vegetable Pizza	$1 - \frac{7}{79} = 0.9113925$
Meat Pizza	Vegetable Pizza	$1 - \frac{18}{72} = 0.75$
Meat Pizza	Pizza	$1 - \frac{0}{72} = 1$
Vegetable Pizza	Pizza	$1 - \frac{0}{56} = 1$
Vegetable Pizza	Meat Pizza	$1 - \frac{2}{56} = 0.9642858$

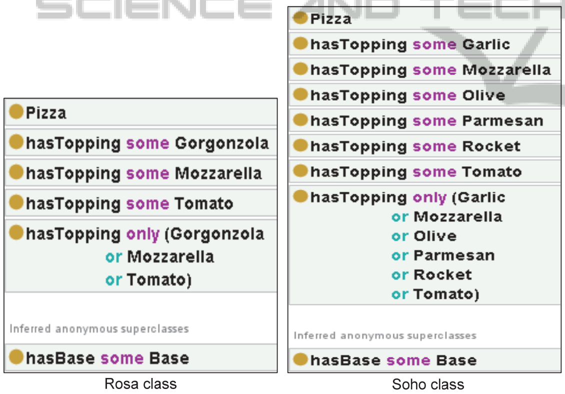

Figure 3: Properties and restrictions of Rosa class and Soho class in Vegetable Pizza ontology.

In order to measure complexity value of different path in the Vegetable Pizza ontology, we need to find number of classes, datatype properties, object properties, constraints, and hierarchical paths that have in Vegetable Pizza ontology but not appear in Meat Pizza ontology. There are 2 classes i.e. Rosa and Soho. As in Figure 3, class Rosa has 2 object properties (i.e. hasTopping and hasBase) and has 5 constraints. As in Figure 3, class Soho has 2 object properties (i.e. hasTopping and hasBase) and has 8 constraints. There is no hierarchical path in classes Rosa and Soho. Therefore complexity value of the different path in the Vegetable Pizza ontology is as follow:

$$Complex(O) = \left(\frac{\sum(NoDP+NoOP+NoC+NoHP)}{Max(NoDP)+Max(NoOP)+Max(NoC)+Max(NoHP)}\right)/NoOC = \left(\frac{0+4+13+0}{0+2+8+0}\right)/2 = 0.85$$

Table 4 shows other results of different complexity in different ontologies.

Table 4: Complexity of different ontologies.

Ontology target	Ontology source	Complexity
Pizza	Meat Pizza	$(\frac{0+7+17+0}{0+2+8+0})/4 = 0.6$
Pizza	Vegetable Pizza	$(\frac{0+7+16+0}{0+2+6+0})/4 = 0.71875$
Meat Pizza	Vegetable Pizza	$(\frac{0+11+19+2}{0+2+6+1})/11 = 0.3232323$
Meat Pizza	Pizza	**0**
Vegetable Pizza	Pizza	**0**
Vegetable Pizza	Meat Pizza	$(\frac{0+4+13+0}{0+2+8+0})/2 = 0.85$

Value of the new knowledge complexity is 1 which means the new knowledge is more complicated. In contrarily, value of the new knowledge complexity is 0 which means the new knowledge is less complicated. Meat Pizza and Vegetable Pizza are subset of Pizza so there is no new knowledge to share between Meat Pizza to Pizza or Vegetable Pizza to Pizza. Therefore the complexity value is 0.

6 DISCUSSION

In this study we define two key variables for knowledge sharing measurement i.e. knowledge transferability and knowledge complexity. Since we utilise ontology as knowledge representation in this paper we propose procedure of measurement of ontology transferability and ontology complexity. In the experiment we numerically measure how well ones share the particular knowledge given that they have different background or have different information domains. The process is simple by measuring their knowledge background similarity and then finding the difference of knowledge background. Below is some of result summary from the experiment:

- People have same background knowledge resulting in best knowledge sharing.
- People have similar background knowledge and the new knowledge is not complicated resulting some value of knowledge sharing.
- People have similar background knowledge and the new knowledge is complicated. It results some value of knowledge sharing.
- People have different background knowledge and the new knowledge is very complicated

resulting low vale of knowledge sharing. This can result people will not be able to share knowledge.

The value of knowledge transferability and knowledge complexity can be put in fuzzy logic system to explain in high, medium, or low levels. There are some limitations in our prototype as follow. In the process of finding transferability and complexity value we implement sense set which is extracted from the electronic lexical database WordNet. By using WordNet, we can only define ontology concept as a single word which mean it can only be noun and cannot be adjective, verb, or adverb. In transferability measurement process, we only in this paper consider is-a relationship omitting properties (i.e. object property and datatype property), constraints, and concept relations e.g. siblings. Nevertheless, we assess the new knowledge complexity after finding its transferability considered above mentioned ontology attributes.

7 CONCLUSIONS AND FUTURE WORK

We have addressed knowledge complexity and knowledge transferability as key variables for knowledge sharing. We then proposed the ontology based approach which measures ontology complexity and transferability to correspond to knowledge complexity and knowledge transferability respectively. Experimental studies were given taking Pizza domain and a prototype has been developed for proof of concept.

For future work a key variable of trust especially in form of competency trust and benevolence trust will be incorporated to measure knowledge sharing in business intelligent applications. Our approach can be applied to other domains for example e-commerce and health domains. Future work also includes a better complexity measurement which will incorporate depth of concepts i.e. properties (object property and datatype property) and constraints, and breadth of concepts i.e. concept relations e.g. siblings. Comparative evaluation will also be needed in future work in order to compare result with other researches in areas of knowledge sharing measurement and alike.

REFERENCES

Andrew, B.-J., C. S. Veda, et al. (2005). "A semiotic metrics suite for assessing the quality of ontologies." *Data Knowl. Eng.* 55(1): 84-102.

Anthony, M. O., Y. Haining, et al. (2006). "Coupling Metrics for Ontology-Based Systems." *IEEE Softw.* 23(2): 102-108.

Anthony, M. O., Y. Haining, et al. (2007). "Indicating ontology data quality, stability, and completeness throughout ontology evolution: Research Articles." *J. Softw. Maint. Evol.* 19(1): 49-75.

Argote, L., B. Mcevily, et al. (2003). "Managing knowledge in organizations:An integrative framework and review of emerging themes." *Management Science* 49(4): 571-582.

Babcock, P. (2004). Shedding light on knowledge management. *HR Magazine* 49: 46-50.

Bakker, M., R. T. A. J. Leenders, et al. (2006). "Is trust really social capital? Knowledge sharing in product development projects." *The Learning Organization* 13: 594−605.

Connelly, C. E. and E. K. Kelloway (2003). "Predictors of employees' perceptions of knowledge sharing cultures." *Leadership & Organization Development Journal* 24: 294−301.

Cummings, J. N. (2004). "Work groups, structural diversity, and knowledge sharing in a global organization." *Management Science* 50(3): 352−364.

Davenport, T. H. and L. Prusak (2003). *Working knowledge: How organization manage what they know*, Harvard Business School Press.

Dazhou, K., X. Baowen, et al. (2004). A complexity measure for ontology based on UML. Distributed Computing Systems, 2004. *FTDCS 2004. Proceedings. 10th IEEE International Workshop on Future Trends of.*

DeLong, D. W. and L. Fahey (2000). "Diagnosing cultural barriers to knowledge management." *Academy of Management Executive* 14(4): 113−127.

Dodgson, M. (1993). "Learning, trust and technological collaboration." *Human Relations* 46(1): 77-95.

Doney, P. M. and J. P. Cannon (1997). "An examination of the nature of trust in Buyer-Seller relationships." *Journal of Marketing* 61: 35-51.

Drummond, N., M. Horridge, et al. (2007). "*Pizza Ontologyv1.5"* Retrieved May 31, 2010, from http://www.co-ode.org/ontologies/pizza/2007/02/12/.

Gruber, T. R. (1993). Toward principles for the design of ontologies used for knowledge sharing. *International Workshop on Formal Ontology in Conceptual Analysis and Knowledge Representation*, Padova, Italy, Kluwer Academic Publishers, Deventer, The Netherlands.

Heffernan, T. (2004). "Trust formation in cross-cultural business to business relationships." *Qualitative research-An international Journal* 7: 114-125.

His, I. (2004). Analyzing the Conceptual Coherence of Computing Applications through Ontological *Excavation PhD Thesis Proposal.*

Jap, S. D. (2001). "The strategic role of the saleforce in developing customer satisfaction across the relationship." *The Journal of Personal Selling and Sales Management* 21: 95-109.

Kankanhalli, A., B. C. Y. Tan, et al. (2005). "Contributing knowledge to electronic knowledge repositories: An empirical investigation." *MIS Quarterly* 29(1): 113−143.

Kashyap, V. and A. Sheth (1998). *Semantic Heterogeneity in Global Information Systems: The Role of Metadata, Context, and Ontologies*. London, UK, Academic Press.

Matzler, K., B. Renzl, et al. (2008). "Personality traits and knowledge sharing." *Journal of economic pcychology* 29: 301-313.

Mena, E., A. Illarramendi, et al. (2000). "OBSERVER: An Approach for Query Processing in Global Information Systems Based on Interoperation across Preexisting Ontologies." *Distributed and Parallel Databases* 8(2): 223-271.

Mungall, C. (2005). *Increased complexity in the GO*, BDGP / GO Consortium.

Nonaka, I. and H. Takeuchi (1995). *The knowledge creation company: How Japanese companies create the dynamics of innovation*, New York: Oxford University Press.

Ojha, A. K. (2005). "Impact of team demography on knowledge sharing in software project teams." *South Asian Journal of Management* 12: 67−78.

Pease, A., I. Niles, et al. (2002). The Suggested Upper Merged Ontology: A Large Ontology for the Semantic Web and its Applications. *the AAAI-2002 Workshop on Ontologies and the Semantic Web*, Edmonton, Canada.

Preece, J. (2004). "Etiquette, Empathy and Trust in Communities of Practice: Stepping-Stones to Social Capital." *Journal of Universal Computer Science* 10(3): 294-302.

Rodriguez, M. A. and M. J. Egenhofer (2003). "Determining semantic similarity among entity classes from different ontologies." *IEEE Transactions on Knowledge and Data Engineering*.

Saraydar, C., N. B. Mandayam, et al. (2002). "Efficient power control via pricing in wireless data networks." *IEEE Trans. Commun.* 50(2): 291-303.

Stuckenschmidt, H. and I. J. Timm (2002). Adapting communication vocabularies using shared ontologies. *the Second International Workshop on Ontologies in Agent Systems*, Bologna, Italy.

Wang, J. Z. and F. Ali (2005). An efficient ontology comparison tool for semantic web applications. t*he 2005 IEEE/WIC/ACM International Conference on Web Intelligence (WI'05), IEEE*.

Wang, S. and R. A. Noe (2009). "Knowledge sharing: A review and directions for future research." *Human Resource Management Review.*

Weinstein, P. and P. Birmingham, (1999). Comparing Concepts in Differentiated Ontologies. *12th Workshop on Knowledge Acquisition, Modeling, and Management*., Banff, Canada.

Wilson, T. and S. A. Jantrania (1993). Measuring value in relationship development. *9th IMP conference*, Bath.

Zhang, D., C. Ye, et al. (2006). An evaluation method for ontology complexity analysis in ontology evolution. *Managing Knowledge in a World of Networks, 15th International Conference, EKAW 2006*, Podebrady, Czech Republic.