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Ontology based Approach in Knowledge Sharing Measurement

Behrang ZadJabbari
(Curtin University of Technology, Perth, Australia
behrang.zadjabba@postgrad.curtin.edu.au)

Pornpit Wongthongtham
(Curtin University of Technology, Perth, Australia
P.Wongthongtham@cbs.curtin.edu.au)

Farookh Khadeer Hussain
(Curtin University of Technology, Perth, Australia
Farookh.Hussain@cbs.curtin.edu.au)

Abstract: For many years, physical asset indicators were the main evidence of an organization's successful performance. However, the situation has changed following the revolution of information technology in the knowledge-based economy and in the new ideas in economy; knowledge assets are a critical strategic resource in economy. Knowledge management [KM] tools have become very important and in order to gain a competitive advantage, it is necessary to create, store, share and apply knowledge. Knowledge sharing is one of the key issues in knowledge management. One of the main challenges facing pioneer firms is to provide an effective strategy to exchange knowledge formally or informally. In this paper, we will discuss the effectiveness of knowledge sharing and our proposal for an effective knowledge sharing strategy. Based on a review of knowledge sharing literature, we will focus more on the trust and knowledge contexts as key issues in knowledge sharing. Trust is the most important issue when creating a relationship, knowledge sharing and partnership. Moreover, there are a number of forms that trust can take in these relationships and the most regularly cited forms are competence and benevolence trust. In this paper, we will explore these two forms of trust and will examine their role in knowledge sharing and how they can be defined and measured. On the other hand, we will apply ontologies to explore the knowledge context. Ontologies are used in widespread application areas particularly to provide a semantically shared domain knowledge in a declarative formalism for intelligent reasoning. Even ontology enables knowledge sharing; however, the complexity of knowledge being conceptualized in the ontology is critical to the success of knowledge sharing efforts. Other factors like trust in the source of knowledge can also affect knowledge transfer. In this paper, we propose metrics to measure the complexity of ontology for knowledge sharing. Finally, the effectiveness of our proposed knowledge sharing methodology is presented both using a fuzzy-inference engine and a crisp system.

Keywords: Knowledge sharing, Trust measurement, ontology, competency trust, willingness trust, tacit knowledge, knowledge transformability, knowledge complexity
Categories: I.2.4, I.2.8

1 Introduction

Knowledge, in its different forms, is increasingly recognized as a crucial asset in modern organizations [Bonifacio, 2002]. Over the past two decades, knowledge management has become most important in the knowledge-based economy. Dustdar [2005] defines knowledge Management [KM] as "processes, culture, and ways of communicating" and argues that knowledge management (KM) represents the processes that enable an organization to act "in response to the changing internal and external environments in which they operate"[p.591]. Although knowledge management has been investigated in the context of decision-making support systems [DSS] for over a decade, interest in and attention to, this topic has exploded recently [Nissen, 1999]. Knowledge asset is now explored as a factor of no less importance than the traditional business inputs of labor and finance [Forbes, 1997]. There are many definitions of knowledge management. Swan [1999] defines KM as "any processes or practice of creating, acquiring, capturing, sharing, and using knowledge, wherever it resides, to enhance learning and performance in organizations". Perrot explains that Knowledge management is the identification, storage, protection of knowledge for future operational and strategic benefit of the organization; this may be implicit or explicit [Perrott, 2006]. In most of the knowledge management definitions, knowledge sharing is one of the key elements. Now, it is going to become more common for scholars and practitioners in various fields to turn their attention to knowledge management systems [KMS] as a means of sharing knowledge in organizations. [Alavi, M., 1999] posits that knowledge sharing is the fundamental means through which employees can contribute to knowledge application, innovation, and ultimately the competitive advantage of the organization [Jackson, 2006]. Research has shown that trust is one of the key issues in knowledge sharing between individuals. Trust, a mutual expectation that partners will not exploit the vulnerabilities created by cooperation [Sako, 1998], has been recognized as an important factor affecting knowledge sharing [Ridings, 2002]. Moreover, there are a number of forms that trust can take in knowledge sharing and the most regularly cited forms are competence, benevolence and contractual trust. Willingness and competency trust are considered as the most critical forms [Ahmed, 1999] and in this paper, we will explore these two forms of trust and will examine their role in knowledge sharing and how they can be defined and measured. On the other hand, knowledge context is also a key issue in knowledge sharing. Context has been recognized by many KM researchers as being crucial to improving the understanding and sharing of knowledge [Goldkuhl, 2001]. We will apply ontologies to explore knowledge context. Ontologies are developed in common application domains such as the semantic web, medical informatics, e-commerce, etc. Mainly, ontologies are developed to provide a semantically shared domain knowledge in a declarative formalism for intelligent reasoning. Besides, complexity of knowledge is critical to the success of knowledge sharing efforts. Presumably, the knowledge is conceptualized in declarative formalism i.e. Ontology having quality data, stability, and completeness. When the ontology is less complex, we may not need a high value of competence-based trust. In contrast, if the ontology is rather complicated, a high value of competence-based trust is required. Yet, some knowledge is difficult to codify in ontology which is not the concern of this paper.

In this paper, we propose metrics to measure the complexity of ontology for knowledge sharing. Then, we propose metrics to measure the transformability of specific knowledge within different ontologies and based on different values of trust [competency and willingness trust], we propose metrics to measure the effectiveness of knowledge sharing between sender and receiver of the specific knowledge.

2 Background

2.1 Knowledge Sharing

Knowledge sharing is one of the most critical elements of effective knowledge processing and organizations often face difficulties when trying to encourage knowledge sharing behavior [Saraydar, 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, 1998]. 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, 2007]. The importance of knowledge sharing raises the issue of how organizations can effectively encourage individual knowledge sharing behavior 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. [De Long, 2000]. Among the many cultural dimensions that influence knowledge sharing, trust is the most important dimension and a culture that emphasizes trust can help to alleviate the negative effect of perceived cost on sharing [Kankanhalli, 2005]. Trust provides conduits for the knowledge exchange and learning needed to solve problems and achieve shared goals [Preece, 2004]. “Trust” has been recognized as being “at the heart of knowledge sharing” [Davenport, 1998] and “the gateway to successful relationships” [Wilson, 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, 2003] and, in this paper, we consider willingness trust 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, 2009]. In interpersonal and team contexts, willingness to share knowledge depends more on the level of team cohesiveness [Bakker, 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].We consider competency trust in our paper as the next key variable in knowledge sharing measurement and again 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, 1997]. In overall, willingness and ability to share knowledge and willingness and ability of receiver to achieve knowledge are key issues in knowledge sharing and in the proposed method to share effectiveness of knowledge sharing in this paper; these two variables are considered to be key variables.

Knowledge sharing also depends on the nature, definition and properties of knowledge, which influence the ease with which knowledge can be shared and accumulated [Argote, 2003]. In general, knowledge can be classified as explicit or tacit knowledge according to the degree to which people can share easily with others [Nonaka, 1994; Nonaka& Takeuchi 1995]. Explicit knowledge consists of facts, rules, and policies that can be expressed and codified in writing or symbols and can be easily shared [Zander, 1995]. However, most knowledge is tacit and cannot be codified. Tacit knowledge is often ambiguous, difficult to interpret scientifically and cannot easily be reduced to formal grammars and records in a database [Preece, 2004]. According to the economic value of knowledge, knowledge can be classified into general and specific knowledge [Becella-Fernandez, 2004]. General knowledge is held by a large number of individuals and can easily be shared but, specific knowledge is possessed by a very limited number of individuals and is not easily shared [Yang, 2008]. Specific knowledge may be technical or contextual and includes the knowledge of tools and techniques for addressing problems in that area by people such as physicians or engineers [Yang, 2008]. In this paper, the nature of knowledge is defined by two key variables. "Complexity" of knowledge is 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. We propose an ontology-based model to measure complexity of knowledge. Each individual has his/her own ontology [personal] and based on this personal ontology, the complexity of knowledge can be measured. In relative terms, explicit knowledge can be easily modelled and represented in personal ontology. As a result, these two kinds of knowledge are easy to share. "Transformability" of knowledge is the next variable used to measure the nature of knowledge in this paper. 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. In this paper, ontologies are used to measure transformability of knowledge between individuals from different backgrounds by comparing the similarity of their ontologies.

In the next section, trust is discussed in detail and key issues such as trust definition, trust building and trust measurement are reviewed. Then, knowledge definition and complexity and transformability of knowledge are discussed as the key issues in knowledge sharing measurement.

2.2 Trust

Trust is an essential ingredient in any successful society [Alesina, 2002]. Mayer defines trust as "the willingness of a party [trusting agent] to be vulnerable to the actions of another party [trusted agent] based on the expectation that the other [trusted] will perform a particular action important to the trusting, irrespective of the ability to monitor or control that other party [Mayer, 1995]. Williams defines trust as "one's willingness to rely on another's actions in a situation involving the risk of opportunism" [Williams, 2001]. Trust can be viewed as an attitude [derived from trustor's perceptions, beliefs, and attributions about the trustee based upon trustee's behavior] held by one individual toward another [Whitener, 1998]. Trust is necessary for the exchange of knowledge, goods and services, and any organization/team or community has to build and sustain a mutual level of trust in the other party's actions [Kugler, 2007].

Trust consists of different components and dimensions. McKnight defines trust components as trusting intention and trusting beliefs. Trusting intention describes one's willingness to depend on the other party in a given situation, and trusting belief is defined as one's belief that the other person is benevolent, honest, or predictable in situation [McKnight,1998]. Moreover, Bhattacherjee [2002] defines different dimensions of trust as the "ability [expertise, information, competence, expertness, dynamism], integrity [fairness in transaction, fairness in data usage, fairness in service, morality, credibility, reliability, dependability], and benevolence [empathy, resolving concerns, goodwill, responsiveness]". Similarly, Mayer suggested that trust evaluations are composed of perceptions of the ability, benevolence and integrity of the target [Mayer, 1995]. Ability is the group of skills, competencies, and characteristics that enable a party to have influence within some specific domain; benevolence is the extent to which a trustee is believed to want to do good to the trustor, aside from an egocentric profit motive; and integrity involves the trustor's perception that the trustee adheres to a set of principles that the trustor finds acceptable [Ammeter, 2004]. The concept of competence trust refers to "reliability" and "integrity" as two important dimensions of trust [Caniels, 2004]. Reliability refers to the extent to which an exchange partner has the required expertise to perform the job successfully [Ganesam, 1994]. Integrity refers to the expectancy that the partner's word or statement can be relied on [Doney, 1997].

In this paper, we focus on competence and willingness trust as two key issues in knowledge sharing measurement. In the next section, we discuss ways to build competence and willingness trust and how to measure them for use in our model.

2.3 Trust Building and Trust Level Measurement [TL]

Trust value changes according to positive and negative experiences in a specific context [Campo, 2006]. Our research will focus on the two most important dimensions of trust by considering benevolence and competency as the two dimensions of trust. Competence trust refers to trust that is created by ability, contracts, laws, governance mechanisms, and structural assurances, while benevolence trust refers to trust due to goodwill intentions [Pavlou, 2006]. Competence and willingness trust are viewed as independent constructs. It has been empirically proven that they are distinct variables that usually have different relationships with other variables [Pavlou, 2006]. The proposed distinction between competence and benevolence trust is consistent with the economic literature wherein benevolent sellers are committed to acting in a goodwill fashion, while competent sellers are committed to fulfilment [Dellarocas, 2003].

Benevolence is related to willingness within a community and is based on the idea that individuals will not intentionally harm another when given the opportunity to do so. This kind of trust would be positive in scenarios where agents within a community may believe in others' willingness to share knowledge. On the other hand, they may refuse to accept others' willingness, and in such scenarios willingness trust would be negative. We assign 1 for the highest level of willingness trust (benevolence trust) within a community, and -1 for the lowest level of trust within a community. All the values for willingness trust will be within a closed interval [-1, 1]. A benevolence trust relationship between two entities A and B is represented as Tb[A,B] which signifies agent A's willingness attitude towards agent B.

The second dimension of trust is competency. This kind of trust refers to the trusting agent's belief in the trusted agent's capability. It describes a relationship in which an individual believes that another person is knowledgeable about a given subject area. Competence-based trust can also be negative or positive and agents can believe in others' ability or they completely reject others' ability in a given subject area. Again, we assign 1 for the highest level of competence-based trust within community and -1 for the lowest level of competence-based trust within the community. All the values for competence trust will be within a closed interval [-1,1]. Competence trust relationship is defined by Tc[A,B] which signifies agent A's competence attitude towards agent B. An illustration of trust change over time is shown below in Fig.1.

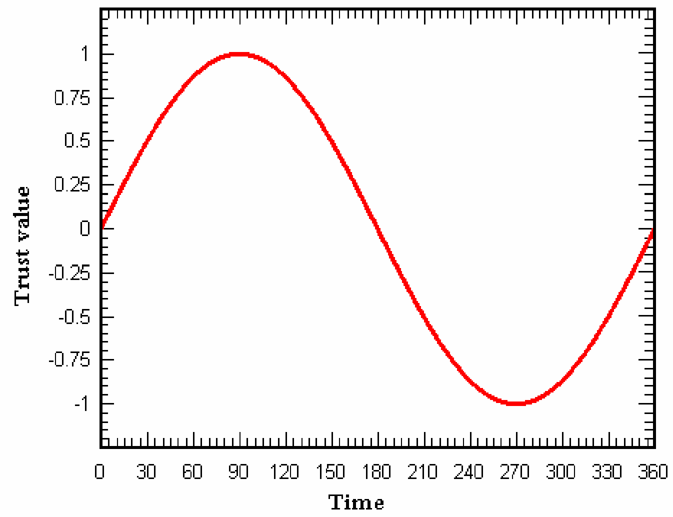

Figure 1: Trust level changes in different time

Two important variables in the trust network of a specific knowledge domain are: 1] the number of members in the network; and 2] the level of trust between that member and other members in the network. The system is defined by having N members T={$\alpha_1,\alpha_2,\alpha_3,\alpha_4,\alpha_5....,\alpha_n$} n= 1,2,3,…,N and 3 trust levels O={Distrust[-1], unknown[0], high trust[1]}.

Some basic rules must be followed in order to establish a trust matrix within a community in a specific knowledge domain. The most important rules are:

1. Everyone trusts him/herself when s/he wants to share the specific knowledge.
2. If A's trust in B is t1, we cannot assume B's trust in A is the same and equal to t1.
3. If A's trust in B is t1 [for example high trust] and B's trust in C is t1 [high trust], we cannot assume A's trust is C is t1. [Although another's trust affects member's trust of each other, the transitive rule is not considered in trust].

Based on the trust rules, a trust matrix can be developed as:

$$\text{T[benevolence]} = \text{Tb} = \begin{array}{cc} & \begin{array}{ccccc} \alpha1 & \alpha2 & \alpha3 & \ldots\ldots & \alpha n \end{array} \\ \begin{array}{c} \alpha1 \\ \alpha2 \\ \alpha3 \\ \ldots\ldots \\ \alpha n \end{array} & \begin{pmatrix} 1 & tb12 & tb13 & \ldots. & tb1n \\ tb21 & 1 & tb23 & \ldots.. & tb2n \\ tb31 & tb32 & 1 & \ldots\ldots & tb3n \\ \ldots. & \ldots.. & \ldots.. & 1 & \ldots.. \\ tbn1 & tbn2 & tbn3 & \ldots.. & 1 \end{pmatrix} \end{array}$$

Matrix 1: benevolence trust

$$\text{T[competency]} = \text{Tc} = \begin{array}{cc} & \begin{array}{ccccc} \alpha1 & \alpha2 & \alpha3 & \ldots\ldots & \alpha n \end{array} \\ \begin{array}{c} \alpha1 \\ \alpha2 \\ \alpha3 \\ \ldots\ldots \\ \alpha n \end{array} & \begin{pmatrix} 1 & tc12 & tc13 & \ldots. & tc1n \\ tc21 & 1 & tc23 & \ldots.. & tc2n \\ tc31 & tc32 & 1 & \ldots\ldots & tc3n \\ \ldots. & \ldots.. & \ldots.. & 1 & \ldots.. \\ tcn1 & tcn2 & tcn3 & \ldots.. & 1 \end{pmatrix} \end{array}$$

Matrix 2: competency trust

In a crisp system, the value of the variables in the two matrices would be between -1 and 1. In a fuzzy logic based system, the value of the variables would be one of the following linguistic variable: Distrust, unknown, high trust. In a simple model, we assume that all members have the same weight and are equal 1. However, in a developed model, each member can be assigned a different weight.

There is no need to normalize the matrices because all the variables are between -1 and 1. But, if we assign different weights to the different members, we will need to normalize the matrices. Based on the matrices, the value of benevolence trust and competency trust for each member of the community can be calculated using the following formulas:

Benevolence trust of member n to other members in community = $\sum_{m=1}^{N} tbnm$

Competency trust of member n to other members in community = $\sum_{m=1}^{N} tcnm$

Benevolence trust of all members in community to member n = $\sum_{m=1}^{N} tbmn$

Competency trust of all members in community to member n = $\sum_{m=1}^{N} tcmn$

Average of benevolence trust within community= $\sum_{m,n=1}^{N} tbnm$ /N

Average of competency trust within community= $\sum_{m,n=1}^{N} tcnm$ /N

2.4 Knowledge

There is no universal definition of knowledge and knowledge management. Knowledge is a combination of the data and information being produced by human thought processes. Knowledge management is the process by which organizations generate value from their intellectual and knowledge-based assets [Smith, 1995]. Drucker defines knowledge as an input resource that will have a greater impact than will physical capital in the future [Drucker, 1993]. Knowledge can be categorized in two different classes: explicit and tacit knowledge. Explicit knowledge can relatively easily be formulated by means of symbols and can be transferred to others easily [Nonaka, 1995]. Tacit knowledge is defined as non-codified, disembodied know-how that is acquired via the informal take-up of learned behavior and procedures [Howells, 1996]. Also, as we discussed earlier, knowledge can be distinguished into general knowledge and specific knowledge. General knowledge is explicit and is easily understood by locals and neighbors [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 analyze the process of knowledge sharing between and within organizations or individuals. The characteristics of knowledge influence the outcome of knowledge sharing [Nonaka, 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.

In this paper, we divide knowledge type into easy or complex knowledge [complexity of knowledge], and easy or hard transformable knowledge [transformability]. We propose metrics to measure the complexity of knowledge by using ontology, choosing personal ontology. Ontologies have to be created explicitly by hand and require a process of explicit community negotiation to achieve a consensus on the shared understanding that is to be expressed [Novak 2004]. Also, we will develop a proposed model and measure the transformability of knowledge by comparing the two ontologies [sender and receiver of the knowledge] and ascertaining whether or not there are similarities. Numerically, we will represent the complexity and transformability of knowledge to be between 0 and 1. Fig. 2 shows the complexity/transferability functions of the knowledge.

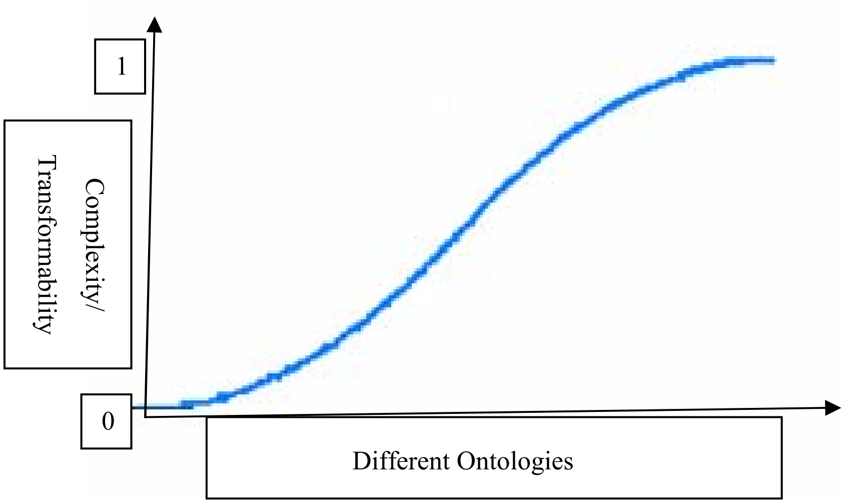

Figure 2: Complexity/ transferability of the knowledge

Ontologies have widespread application in areas such as semantic web, medical informatics, e-commerce, etc. Mainly ontologies are used to provide a semantically shared domain knowledge in a declarative formalism for intelligent reasoning. Besides, complexity of knowledge is critical to the success of knowledge sharing efforts. Presumably, the knowledge is conceptualized in declarative formalism, i.e. with an ontology having quality data, stability, and completeness. When the ontology is less complex, we may not need a high value of competence-based trust. In contrast, if the ontology is rather complicated, a high value of competence-based trust is required. Ontology complexity is related to the complexity of conceptualization of the domain of interest. It is measured to reflect the ease with which any ontology is to be understood. Definition of ontology complexity is clarified in features that characterize complexity of ontology i.e. [i] usability and usefulness and [ii] maintainability. There is no unified metric to date that reflects the complexity of ontotology. In this section, we present our metrics: Total Number of Datatype Properties [TNoDP], Average Datatype Properties per Class [ADP/C], Total Number of Object Properties [TNoOP], Total Number of Constraints [TNoC], Average Constraints per Object Property [AC/OP], Total Number of Hierarchical Paths [TNoHP], and Average Hierarchical Paths per Class [AHP/C]. The metrics give an indication of how well and how finely concepts are being defined. A detailed presentation and discussion of these metrics, along with their definition can be found in Zadjabbari et al. [Zadjabbari, 2010]. A high numerical value for these metrics shows that concepts are being well presented within an ontology. We assume that the complexity of the ontology being evaluated is written in Web Ontology Language [OWL]. Fig. 3 shows the complexity measurement of the knowledge.

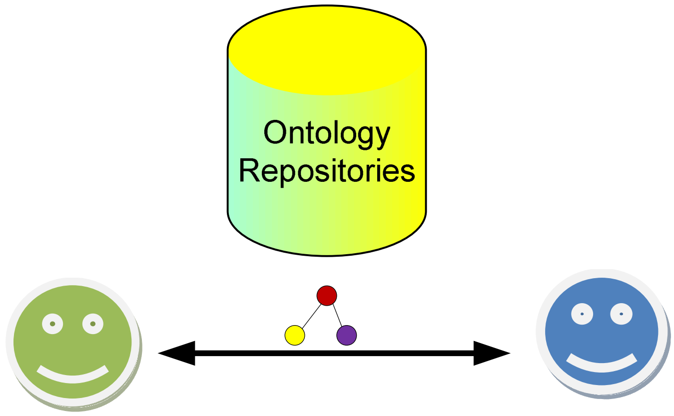

Figure 3: complexity measurement of the knowledge

As shown in Fig. 3, all the shared knowledge can be evaluated against the knowledge in the ontology repositories to calculate complexity of the knowledge. We will show complexity of the knowledge for the knowledge transmitter by Kc and for knowledge receiver by K'c. Both Kc and K'c will be given value between 0 and 1.

Transformability of the knowledge is more related to the members' backgrounds and their domain ontology. We will use the similarity of ontologies to measure the level of transformability between two members. Fig. 4 shows the transformability measurement of the knowledge.

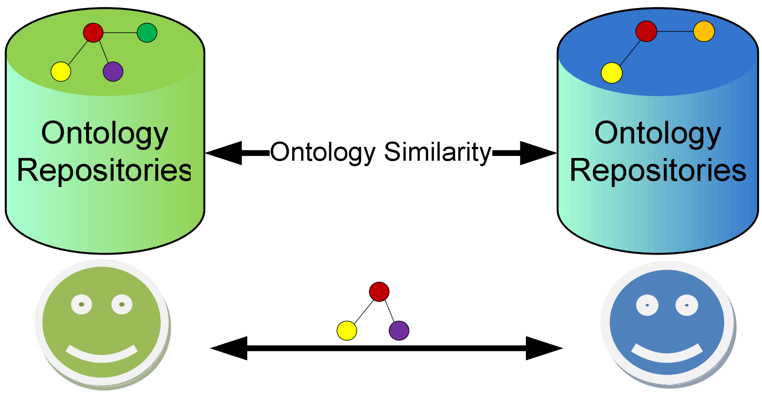

Figure 4: Transformability measurement of the knowledge

We will show transformability of the knowledge for the knowledge transmitter by Kt and for knowledge receiver by K't. Both Kt and K't will be given a value between 0 and 1.

3 New Proposed Model in Knowledge Sharing

Overall, two main factors related to knowledge sharing efforts are trust and knowledge context. Two specific types of trust in the knowledge sharing process are benevolence-based trust and competence-based trust. Besides, complexity and transformability of knowledge is critical to the success of knowledge sharing efforts. In contrast, if the ontology is rather complicated, a high value of competence-based trust is required. It is important to note that some knowledge is difficult to codify in ontology which is not the concern of this paper.

Based on these variables, a knowledge sharing measurement model is proposed in Fig. 5.

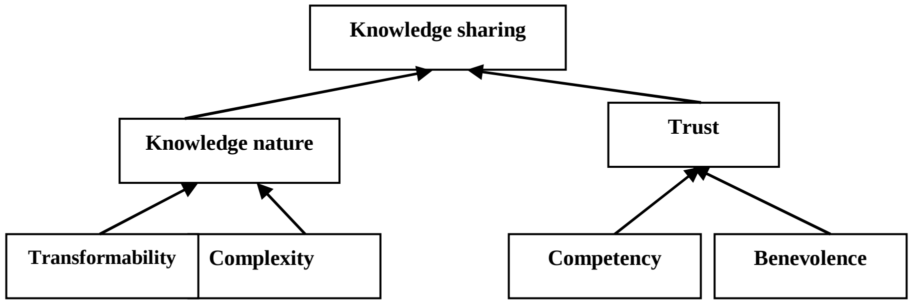

Figure 5: Knowledge sharing measurement model

Based on Fig. 5, the equations below are proposed to measure knowledge sharing:

$$\text{Knowledge sharing} = F\ [\text{knowledge nature, trust}] \qquad 0 \le \text{Knowledge sharing} \le 1 \qquad \text{.......... (1)}$$

$$\text{Trust} = F\ [\text{competence, benevolence}] = T\ [A, B] = F\ (\ Tb\ [A, B]\ ,\ Tc\ [A, B]\ ) \qquad 0 \le Tb\ [A, B],\ Tc\ [A, B] \le 1 \qquad \text{.......... (2)}$$

$$[3]\text{Knowledge nature} = F\ [\text{transformability, complexity}] \qquad 0 \le \text{ transformability, complexity} \le 1 \qquad \text{.......... (3)}$$

In knowledge sharing, both knowledge sender and knowledge receiver have to be evaluated and both parts are important. As seen in Fig. 6, if the knowledge sharing level for sender be Ks and knowledge sharing level for receiver be K's, the final knowledge sharing level will be the minimum of Ks and K's.

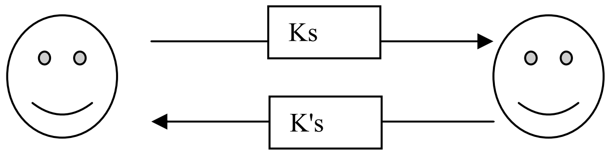

Figure 6: Knowledge sharing between two parties

$$\text{Knowledge sharing} = \min(\text{Ks}, \text{K's}) \quad 0 \le \text{Knowledge sharing} \le 1 \qquad (4)$$

Due to the fuzzy nature of variables, we can use fuzzy logic to measure knowledge sharing. In this paper, we have validated our model in both Crisp and Fuzzy systems. In the next section, the fuzzy system is used to measure the knowledge sharing level between two parties.

3.1 Knowledge Sharing Measurement in Fuzzy Systems

Fig. 7 shows a Fuzzy Inference System used to measure knowledge sharing level in specific knowledge and in defined trust level.

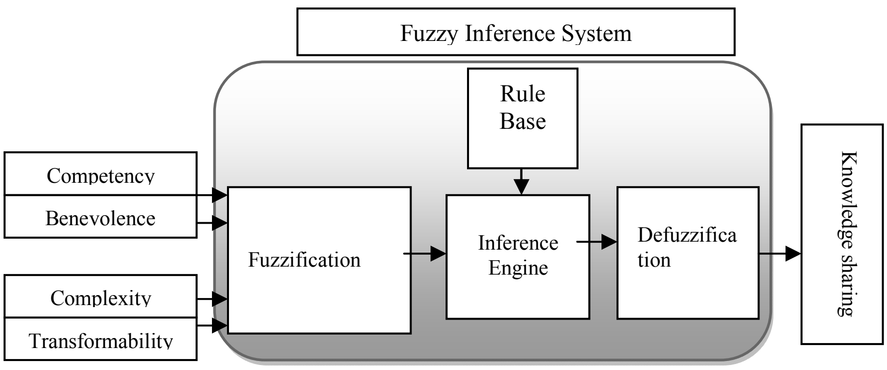

Figure 7: Fuzzy Inference system to measure knowledge sharing

Fuzzy Inference Systems [FIS] can efficiently handle the situations that cannot be characterized by a simple and well-defined deterministic mathematical model. This method utilizes simple rules and a number of simple membership functions to derive the correct result. The subjective and heuristic FIS is particularly efficient for various aspects of uncertain knowledge. The FIS structure is composed of three basic elements: fuzzification, fuzzy reasoning, and defuzzification.

3.1.1 Fuzzification

Crisp input variables are first transformed into fuzzy values based on input membership functions [MF]. These fuzzy variables will then be used to apply rules formulated by linguistic expressions of the fuzzy rule base. The membership function [MF] essentially embodies all fuzziness for a particular fuzzy set. The shape of the membership function [triangular, trapezoidal, Gaussian, etc.] is chosen based on the work that need to be conducted. In this work, four crisp input variables are transformed into fuzzy sets as shown in Fig. 7. It is clear from Fig. 7 that for the two first two input variables [competency and willingness], the crisp universe of discourse is considered to be between -1 and 1. The fuzzy membership functions include the linguistic fuzzy sets of Negative, Zero, and Positive. Other two crisp input variables [Complex and Structure] are laid in the universe of discourse [0 1], which are transformed to fuzzy linguistic variables of Low, Medium, and High. All fuzzy sets are a Generalized Bell shape.

3.1.2 Fuzzy Reasoning

As shown in Fig 7, information flows from four-input variables to a single-output. Though there are various ways to represent human knowledge using the fuzzy rule base, the most common way is to form it into natural language expressions of the if–then type. An expression in such a form is commonly called the if–then rule based form. It typically expresses an inference such that, if we know a fact [premise], then we can infer, or derive, another fact called a conclusion. This form of knowledge representation can express human empirical and heuristic knowledge in our language of communication. In the inference engine, the truth value for the premise [If part] of each fuzzy logic rule is computed and applied to compute the conclusion part of the rule [Then part]. The output fuzzy sets of all rules are then combined to form a single fuzzy set for the output variable.

3.1.3 Defuzzification

As shown in Fig 7, defuzzification is the last stage of a Fuzzy Inference System, which converts the conclusion made by the fuzzy inference into a crisp output value. The output linguistic variables are Absolutely Unsatisfactory, Unsatisfactory, Satisfactory, and Ideal. Of the different available methods of defuzzification, this paper implements the most popular defuzzification method, centre of gravity, formulated as:

$$P = \frac{\int_{p} \mu_c(p) \times p dp}{\int_{p} \mu_c(p) dp}$$

Where p is the fuzzy output value of each rule and P is the crisp output value of the Fuzzy Inference System.

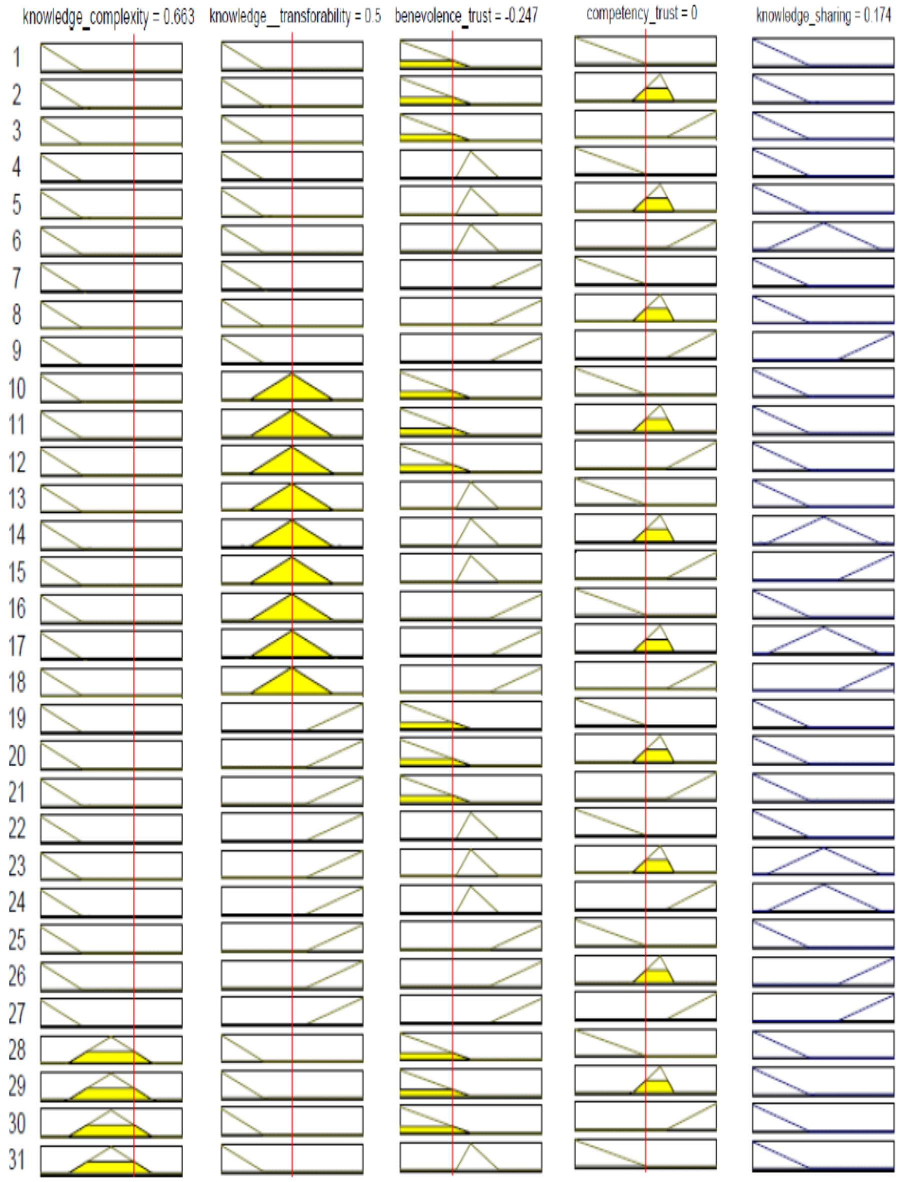

Figure 8: Results in fuzzy systems

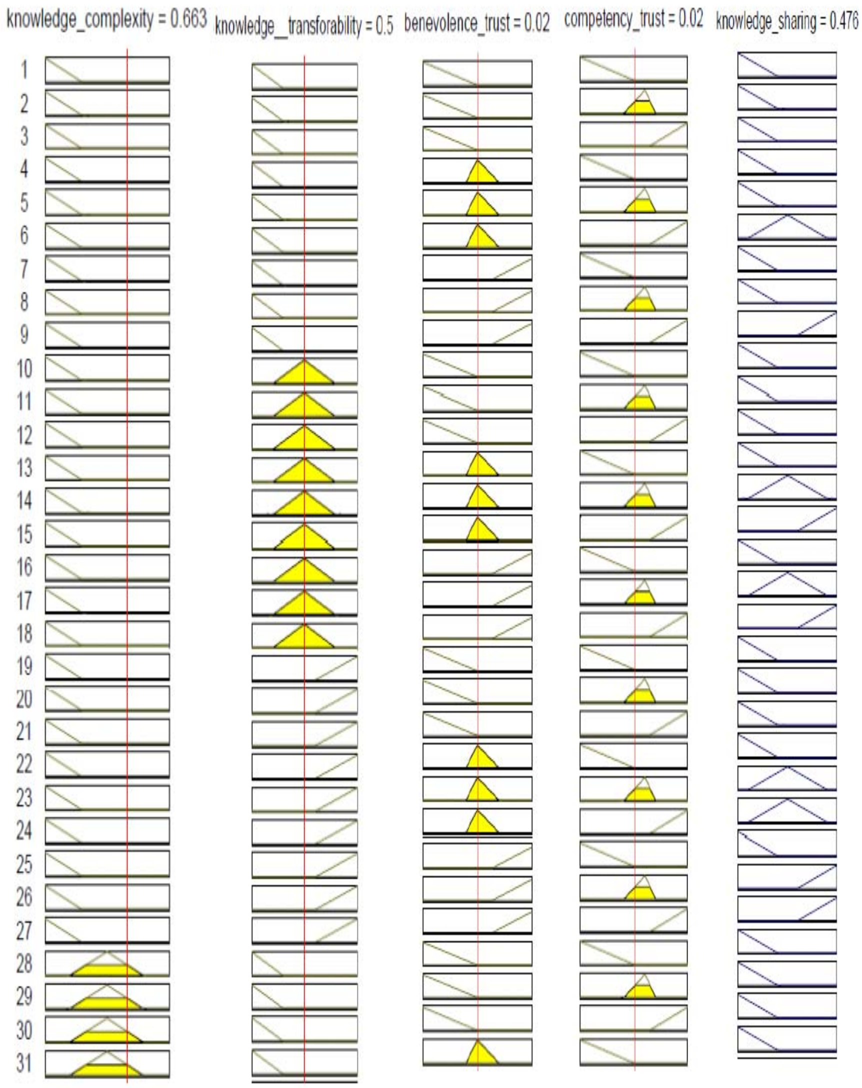

Figure 9: Knowledge sharing for different values of benevolence trust

4 Results

4.1 Result in Fuzzy Systems

Matlab software is used to simulate and test our model in Mamdani Fuzzy systems. As is seen in Fig. 7, input variables are knowledge complexity, knowledge transformability, trust competency and trust benevolence and output variable is knowledge sharing. Based on the literature review and the effect of input variables on knowledge sharing, fuzzy rules are used to measure knowledge sharing level. Input variables have a fuzzy value in the model. Knowledge complexity and knowledge transformability could be low, medium or high. Willingness and competency trust could be distrust, no idea [when one party does not has any idea for another party or the other party is new] and high trust. Knowledge sharing as an output variable could be low, medium or high. A dynamic model is designed in Matlab and it can measure knowledge sharing based on input variables changes and the model is dynamic.

Fig. 8 shows that the model is dynamic and, based on changes in input variables, the knowledge sharing level fluctuates. For example, in the first sample, the knowledge complexity is .663 and knowledge transformability is 0.5 and benevolence trust and competency trust are -0.247 and 0. The knowledge sharing level in this position is calculated as 0.174. In the next figure the value of all variables is the same but we have increased the value of benevolence trust to 0. As a result, as seen in Fig. 9, the value of knowledge sharing is increased to 0.476.

This dynamic model measures knowledge sharing from one party to another party and as discussed previously, in the mathematical formula real knowledge sharing between two parties is the minimum of two values [knowledge sharing from party A to B and knowledge sharing from party B to A.

4.2 Result in CRISP System

We engineered a system to measure the complexity and transformability of specific knowledge in different ontologies. As a sample, we have chosen two knowledge exchangers one of which uses vegetarian pizza ontology and the other uses meat pizza ontology and they want to share knowledge about “topping”.

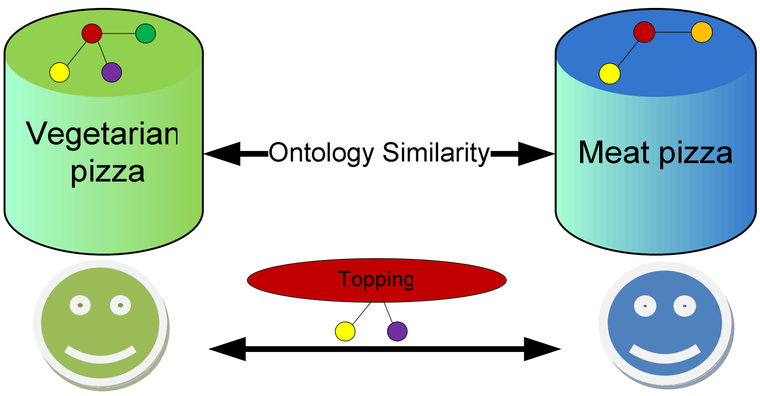

Figure 10: Knowledge sharing between two different ontologies

As can be seen in Fig. 10, two different ontologies are used between two knowledge exchangers in this case. We modified two different ontologies as meatyPizza.owl ontology and vegetarianPizza.owl ontology. We used open online sources to define these two different ontologies. Some of the main sources used in our program are:

- ✓ www.owl-ontologies.com
- ✓ www.w3.org
- ✓ www.protege.stanford.edu
- ✓ www.co-ode.org/ontologies
- ✓ www.daml.org
- ✓ www.purl.org
- ✓ www.co-ode.org

The main classes in these ontologies are defined as :

- ✓ Meat
- ✓ Fruit
- ✓ Herb
- ✓ Nut
- ✓ Sauce
- ✓ Fish
- ✓ Vegetable
- ✓ Topping

Also, sub classes and properties are defined for each class as shown in Fig. 11.

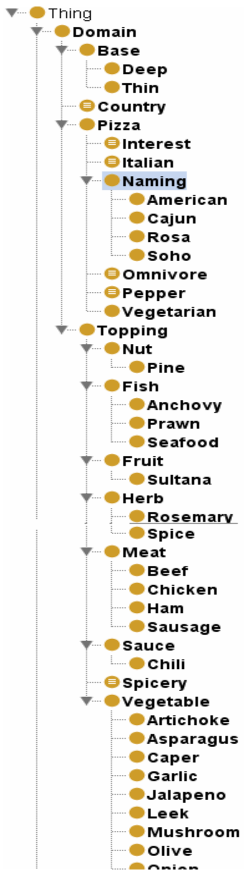

Figure 11: Classes, subclasses and properties

Based on different values of trust between knowledge exchangers, the result for this specific knowledge (topping) is shown in the table below:

Kc	Kt	Tb	Tc	K'c	K't	T'b	T'c	KS1	KS2	KS
0.857143	0.944444	0.8	0.8	0.857143	1	0.8	0.8	0.720635	0.742857	0.720635
0.857143	0.944444	0.8	0.8	0.857143	1	0.8	0.2	0.720635	0.453357	0.453357
0.857143	0.944444	0.8	0.8	0.857143	1	0.8	-0.8	0.720635	0.741371	0.720635
0.857143	0.944444	0.8	0.8	0.857143	1	0.2	0.8	0.720635	0.491286	0.491286
0.857143	0.944444	0.8	0.8	0.857143	1	0.2	0.2	0.720635	0.185714	0.185714
0.857143	0.944444	0.8	0.8	0.857143	1	0.2	-0.8	0.720635	0.184786	0.184786
0.857143	0.944444	0.8	0.8	0.857143	1	-0.8	0.8	0.720635	0.072	0.072
0.857143	0.944444	0.8	0.8	0.857143	1	-0.8	0.2	0.720635	0	0

0	0.435718	0.435718	0.435718	0.435718	0.185714	0.184786	0.072	0	0.719194	0.453357
0	0.742857	0.453357	0.741371	0.491286	0.185714	0.184786	0.072	0	0.742857	0.453357
0.720635	0.435718	0.435718	0.435718	0.435718	0.435718	0.435718	0.435718	0.435718	0.719194	0.719194
-0.8	0.8	0.2	-0.8	0.8	0.2	-0.8	0.8	-0.8	0.8	0.2
-0.8	0.8	0.8	0.8	0.2	0.2	0.2	-0.8	-0.8	0.8	0.8
1	1	1	1	1	1	1	1	1	1	1
0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143
0.8	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	-0.8	-0.8
0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444
0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143

0.719194	0.491286	0.185714	0.184786	0.072	0	0	0.482397	0.453357	0.482397	0.482397
0.741371	0.491286	0.185714	0.184786	0.072	0	0	0.742857	0.453357	0.741371	0.491286
0.719194	0.719194	0.719194	0.719194	0.719194	0.719194	0.719194	0.482397	0.482397	0.482397	0.482397
-0.8	0.8	0.2	-0.8	0.8	0.2	-0.8	0.8	0.2	-0.8	0.8
0.8	0.2	0.2	0.2	-0.8	-0.8	-0.8	0.8	0.8	0.8	0.2
1	1	1	1	1	1	1	1	1	1	1
0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143
-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	0.8	0.8	0.8	0.8
0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.2	0.2	0.2	0.2
0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444
0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143

0.185714	0.184786	0.072	0	0	0.180159	0.180159	0.180159	0.180159	0.180159	0.180159
0.185714	0.184786	0.072	0	0	0.742857	0.453357	0.741371	0.491286	0.185714	0.184786
0.482397	0.482397	0.482397	0.482397	0.482397	0.180159	0.180159	0.180159	0.180159	0.180159	0.180159
0.2	-0.8	0.8	0.2	-0.8	0.8	0.2	-0.8	0.8	0.2	-0.8
0.2	0.2	-0.8	-0.8	-0.8	0.8	0.8	0.8	0.2	0.2	0.2
1	1	1	1	1	1	1	1	1	1	1
0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143
0.8	0.8	0.8	0.8	0.8	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444
0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143

0.072	0	0	0.179258	0.179258	0.179258	0.179258	0.179258
0.072	0	0	0.742857	0.453357	0.741371	0.491286	0.185714
0.180159	0.180159	0.180159	0.179258	0.179258	0.179258	0.179258	0.179258
0.8	0.2	-0.8	0.8	0.2	-0.8	0.8	0.2
-0.8	-0.8	-0.8	0.8	0.8	0.8	0.2	0.2
1	1	1	1	1	1	1	1
0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143
0.2	0.2	0.2	-0.8	-0.8	-0.8	-0.8	-0.8
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444
0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143

Table 1: Result in Crisp model

5 Conclusion and Future Works

Billions of dollars every year are spent on improving knowledge sharing within and between organizations. Governments spend huge amounts of money to share knowledge between citizens in order to increase the knowledge level of society. Knowledge sharing is not easy and no-one can force others to share their knowledge. On the other hand, it is not easy to measure the level of knowledge sharing in order to improve it. Decision makers need some metric variables to make decisions about ways to improve knowledge sharing. We have proposed a new model in knowledge sharing measurement. This model is dynamic and is based on the nature of trust and knowledge. We have defined knowledge in two dimensions including complexity of the knowledge and transformability of the knowledge. We have applied ontologies to represent complexity and transferability of knowledge. Also, we applied fuzzy logic to measure the trust level within the community and to define benevolence and competency as two main dimensions of trust. Then, mathematical formulas were proposed to measure each part of knowledge sharing. We are going to develop the model as a new business intelligence application to provide real and on-time information about knowledge sharing so that decision makers have a better view of a community's ability to share knowledge. Further studies can be done to develop the model for unstructured knowledge and apply text mining techniques to measure the effectiveness of knowledge sharing in different domains such as business, politics [such as election speeches effectiveness], medicine etc. From a leadership perspective, leaders' speeches and behavior are very important in creating motivated employees and improving business performance and this model can be developed to measure the effectiveness of speech in sharing knowledge.

References

[Ahmed, 1999] Ahmed, F., Patterson, P., Styles, C. The Determinants of Successful Relationships in International Business. Australian Marketing Journal 7: 5-21, 1999.

[Alavi, 1999] Alavi, M.L.D. Knowledge management systems: issues, challenges, and benefits. CAIS 1: 2-36, 1999.

[Alesina, 2002] Alesina, A., La Ferrara, E. Who trusts others? Journal of Public Economics 85: 207–234., 2002.

[Ammeter, 2004] Ammeter, A.P., Douglas, C., Ferris, G.R., Goka, H. A social relationship conceptualization of trust and accountability in organizations. Human Resource Management Review 14: 47-65, 2004.

[Argote, 2003] Argote, L., Mcevily, B., Reagans,R. Managing knowledge in organizations:An integrative framework and review of emerging themes. Management Science 49: 571-582, 2003.

[Babcock, 2004] Babcock, P. Shedding light on knowledge management. HR Magazine 49: 46-50, 2004.

[Bakker, 2006] Bakker, M., Leenders, R. T. A. J., Gabbay, S. M., Kratzer, J., Van Engelen, J. M. L. Is trust really social capital? Knowledge sharing in product development projects. The Learning Organization 13: 594−605, 2006.

[Becella-Fernandez, 2004] Becella-Fernandez, I., Gonzalez, A., Sabherwal, R. Knowledge management challanges, solusion, and technologies. Pearson Prentice Hall, 2004.

[Bhattacherjee, 2002] Bhattacherjee, A. Individual Trust in Online Firms: Scale Development and Initial Test. Journal of Management Information Systems 19: 211-241, 2002.

[Bonifacio, 2002] Bonifacio, M., Bouquet, P., Cuel, R. Knowledge Nodes: the Building Blocks of a Distributed Approach to Knowledge Management Journal of Universal Computer Science 8: 652-661, 2002.

[Campo, 2006] Campo, C., Almenárez, F., Díaz, D., García-Rubio, C., Marín López, A. Secure Service Discovery based on Trust Management for ad-hoc Networks. Journal of Universal Computer Science 12: 340-356, 2006.

[Caniels, 2004] Caniels, M.C.J., Gelderman, C.J. Buyer-supplier relationship development-Empirical identification and quantification. 2004.

[Connelly, 2003] Connelly, C.E., & Kelloway, E. K. Predictors of employees' perceptions of knowledge sharing cultures. Leadership & Organization Development Journal 24: 294−301., 2003.

[Cummings, 2004] Cummings, J.N. Work groups, structural diversity, and knowledge sharing in a global organization. Management Science 50: 352−364, 2004.

[Davenport, 1998] Davenport, T.H., Prusak, L. Working knowledge: How organization manage what they know. Harvard Business School Press, 1998.

[De Long, 2000] De Long DW, Fahey, L. Diagnosing cultural barriers to knowledge management. Academy of Management Executive 14: 113−127, 2000.

[Dellarocas, 2003] Dellarocas C. The digitization of word of mouth: Promise and challenges of online feedback mechanism. Management Science 49: 1407-1424, 2003.

[Dodgson, 1993] Dodgson, M. Lerning, trust and technological collaboration. Human Relations 46: 77-95, 1993.

[Doney, 1997] Doney, P.M., Cannon, J.P. An examination of the nature of trust in Buyer-Seller relationships. Journal of Marketing 61: 35-51, 1997.

[Drucker, 1993] Drucker, P.F. Post-capitalist society. New York: Butterworth Heineman, 1993.

[Dustdar 2005] Dustdar, S. Reconciling Knowledge Management and Workflow Management Systems: The Activity-Based Knowledge Management Approach Journal of Universal Computer Science 11: 589-604, 2005.

[Forbes, 1997] Forbes. Special Focus on Intellectual Capital. In: Forbes ASAP1997.

[Ganesam, 1994] Ganesam, S. Determinants of long-term orientation in buyer-seller relationships. Journal of Marketing 58: 1-19, 1994.

[Goldkuhl, 2001] Goldkuhl, G., Braf, E. Contextual knowledge analysis—understanding knowledge and its relations to action and communication,. In: Proceedings of 2nd European Conference on Knowledge Management, IEDC-Bled School of Management,. Slovenia: 2001.

[Heffernan, 2004] Heffernan, T. Trust formation in cross-cultural business to business relationships. Qualitative research-An international Journal 7: 114-125, 2004.

[Howells, 1996] Howells, J. Tacit knowledge, innovation and technology transfer. Technology Analysis & Strategic Management, 8: 91-105, 1996.

[Jackson, 2006] Jackson, S.E., Chuang, C. H., Harden, E. E., Jiang, Y., Joseph, J. M. Toward developing human resource management systems for knowledge-intensive teamwork. Research in personnel and human resources management 25: 27-70, 2006.

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

[Kankanhalli, 2005] Kankanhalli A., Tan, B. C. Y., Wei, K. -K. Contributing knowledge to electronic knowledge repositories: An empirical investigation. MIS Quarterly 29: 113−143., 2005.

[Kugler, 2007] Kugler, T., Bornstain, G., Kocher, M.G., Sutter, M. Trust between individuals and groups: Groups are less trusting than individuals but just as trustworthy. Journal of Economic Psychology 28: 646–657, 2007.

[Matzler, 2007] Matzler K, Renzl, B., Muller, J., Herting, S., Mooradian,T. A. Personality traits and knowledge sharing Journal of economic pcychology 29: 301-313, 2007.

[Mayer, 1995] Mayer RC, Davis, D. J. ,Shoorman, F. D. . An Integrative Model of Organizational Trust. Academy of Management Review 20: 709-734, 1995.

[McKnight, 1998] McKnight, D.H., Cummings, L. L., Chervany, N. L. . Initial trust formation in new organizational relationships. Academy of Management Executive 23: 473−490., 1998.

[Nissen, 1999] Nissen, M.E. Knowledge-based knowledge management in the reengineering domain. Decision Support Systems 27: 47-65, 1999.

[Nonaka, 1995] Nonaka, I. The knowledge creating company-How Japanese companies create the dynamics of Innovation. New York: Oxford University Press, 1995.

[Nonaka, 1994] Nonaka, I. A Dynamic theory of organizational knowledge creation. Organ Sci 5: 14-37, 1994.

[Nonaka& Takeuchi 1995] Nonaka, I., Takeuchi, H. The knowledge creation company: How Japanese companies create the dynamics of innovation. New York: Oxford University Press, 1995.

[Novak 2004] Novak, J., Wurst, M. Supporting Knowledge Creation and Sharing in Communities based on Mapping Implicit Knowledge. Journal of Universal Computer Science 10: 2004.

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

[Pavlou, 2006] Pavlou, P.A., Dimoka, A. The Nature and Role of Feedback Text Comments in Online Marketplaces: Implications for Trust Building, Price Premiums, and Seller Differentiation. INFORMATION SYSTEMS RESEARCH 17: 392-414, 2006.

[Perrott, 2006] Perrott, B.E., Knowledge management in health:an evolution? In: Proceedings of knowledge management: The Key to Innovative Health Programs. Sydney, Australia: 2006.

[Preece, 2004] Preece, J. Etiquette, Empathy and Trust in Communities of Practice: Stepping-Stones to Social Capital. Journal of Universal Computer Science 10: 294-302, 2004.

[Ridings, 2002] Ridings, C.M., Gefen, D., Arinze, B. Some antecedents and effects of trust in virtual communities. Strategic Information Systems 11: 271–295, 2002.

[Sako, 1998] Sako, M. The informational requirements of trust in supplier relations: evidence from Japan, Europe and the United States. In: Trust and Economic Learning, edited by Lorenz E. Cheltenham: Edward Elgar, 1998, p. 23–47.

[Saraydar, 2002] Saraydar, C. Efficioent power control via pricing in wireless data network. transactions on communication 50: 291-303, 2002.

[Smith, 1995] Smith, M. Design and natural science research on information technology. Decision Support Systems 15: 251-266, 1995.

[Swan, 1999] Swan, J., Scarborough, H., Preston, J. Knowledge management: the next fad to forget people? In: Proceedings of the 7th European Conference on Information Systems,Copenhagen1999.

[Wang, 2009] Wang, S., Noe, R.A., Knowledge sharing: A review and directions for future research Human Resource Management Review doi:10.1016/j.hrmr.2009.10.001: 2009.

[Whitener, 1998] Whitener EM, Brodt, S. E., Korsgaard, M. A., Werner, J. M. Managers as initiators of trust: an exchange relationship framework for understandign managerial trustworthy behavior. Academy of Management Review 23: 513–530, 1998.

[Williams, 2001] Williams M. In whom we trust: group membership as an affective context for trust development. Academy of Management Review 26: 377–396, 2001.

[Wilson, 1993]Wilson TD, Jantrania,S.A., Measuring value in relationship development. In: Proceeding of the 9th IMP conference. Bath:, 23-25,1993.

[Yang, 2008] Yang, H.L., Wu, T.C.T. Knowledge Sharing in an Organization. Technological Forecasting&Social Change 75: 1128-1156, 2008.

[Zadjabbari, 2010] Zadjabbari, B., Wongthongtham, W., Hussain, F., Metrics to measure the complexity of knowledge for business intelligence, International Journal of Business Intelligence and Data Mining (Accepted Paper, Under Press)

[Zander, 1995] Zander, U., Kogut, B. Knowledge and the speed of the transfer and imitation of organizational capabilities: An empirical test. Organization Science 6: 76-92, 1995.