Disjoint-Knowledge Analysis and Preservation in Ontology Merging Process

Muhammad Fahad[1,2], Nejib Moalla[1], Abdelaziz Bouras[1]
Muhammad Abdul Qadir[2], Muhammad Farukh[2]
[1]University of Lyon2 - CERRAL / IUT-Lumiere Lyon II, Bron, France
[2]Center for distributed and Semantic Computing, M.A.J.U., Islamabad, Pakistan
{muhammad.fahad, nejib.moalla, abdelaziz.bouras}@univ-lyon2.fr
aqadir@jinnah.edu.pk, mhd.farukh@gmail.com

***Abstract*—Ontology mapping and merging systems play a vital role that aim at promoting automatic interoperability among different heterogeneous systems, agents, web services or groups in open environments such as Semantic Web. These systems help ontologists to resolve different types of conflicts among local ontologies to produce global merged ontology. This paper provides three contributions to the study and design of ontology merging systems that provides complete, consistent and coherent merged global ontology. First, we analyze that one of the important merge requirements is ignored yet by state-of-the-art ontology mapping and merging systems, i.e., Disjoint-knowledge Preservation between concepts. Second, we introduce another type of semantic conflict, which needs attention for consistent and coherent merged ontology, i.e., Alignment Conflict among disjoint relations. Third, we present an overview of our semantic-based ontology merger, DKP-OM, as a solution for the generation of global merged ontology that is consistent, coherent and complete with respect to local ontologies. We conclude that disjoint knowledge analysis for ontology merging is very much helpful for the detection of inconsistent initial mappings that originate from concept name or instance matching strategies, reduce search space for concept matching, and promote consistent computation by exploiting reliable logical inference on facts by axiomatization.**

Keywords-Disjoint knowledge; Ontology Mapping and Merging; Ontology Errors; Consistent Global Merged Ontology.

I. INTRODUCTION

The goal of Semantic Web is to bring current web into its full potential by using ontology as a key technology to annotate the data [1]. Ontologies, as they explicitly identify objects and relationships between objects, are regarded as the best means for describing the semantics and background information of data and promote explicit context of knowledge about them. But, as they are being developed for multiple purposes by many enterprise and consortiums according to their desired needs, tasks, and requirements, same ontologies can model overlapping domain knowledge and can be used for annotation of multiple data sources such as web pages, relational databases, xml repositories, multi-media data, etc. [2]. The use of such shared knowledge in ontologies enables a certain degree of interoperation between these data sources. Hence, promoting interoperability with ontology alignment, mapping and merging is one of core tasks of current landscape of ontology-based research. They benefit many tasks for enterprise and web such as solving queries to support e-commerce, building collaborations that involve sharing of data, knowledge, or resources among modern companies, multi-agents, autonomous individuals, web services or groups in open environments [10]. They are also playing significant roles for development of ontologies by reusing existing open ontologies and integration of ontology based web data sources, that reduces the cost of ontology engineering and promote use of standard tested modules of ontologies.

Ontology mapping and merging systems achieve the desirable task of automatic interoperability by using different aids such as common vocabulary, reference ontology, basic initial alignments by human, etc., each of which might be the most appropriate in tasks with given set of circumstances [4]. In recent years, many systems and approaches have been developed that use similarity computation mechanisms based on linguistic and synonym based strategies for proposing correspondences between source ontologies. These correspondences serve the basic unit for the integration of multiple ontologies. Cui et al. highlights several issues in ontology-based information integration and suggest development of three types of ontologies. Resource ontologies that use specific resource terminology of a domain, Personal ontologies that use terminology understandable by the users or group of users, and Shared ontologies that use common terminology between a number of different systems [15]. In research literature, there are three precise meaning of INTEGRATION of ontologies for specific task and usage with its particular meaning. INTEGRATION - to build new ontology by reusing other ontologies that assemble, extend, and specialize each other. MERGE - to build ontology by merging source ontologies having semantic heterogeneity into one ontology, and USE - to build an application that incorporates and utilizes several local ontologies [16]. But all these tasks require machine to interpret semantics hidden within the local ontologies to detect reliable mappings and avoid inconsistencies for the generation of global complete, consistent, and coherent ontology. The problems that arise are the mismatches between source ontologies, as they are totally created by the conceptualization and explication of domain knowledge by ontologists with different views of knowledge, tasks and requirements of applications and heterogeneity of several types in syntactic, structural and semantic representations as discussed by several authors [12, 18]. Syntactic heterogeneity includes the usage of different languages (e.g., OWL [26], RDFS [27], DAML+OIL [28], etc.) for ontology development, and data representations (e.g., synonym, homonym, hyponym, hypernym, etc.) [1]. Structural differences occur when same information is modeled differently when classification of knowledge in terms of concepts and properties in the ontology hierarchies due to different pragmatics of ontologist and level of knowledge granularity in scope. Ontology merging systems should be capable enough to find these mismatches and resolve them with or minimum user intervention.

The ontology merging process is still semi-automatic and needs higher level of user intervention for validation of mappings and resolving conflict. Current merging systems only produce suggestions that aid ontologists to produce merged ontology. Resolution of conflicts and validation of suggestions are totally depending on human users. Moreover, all existing approaches suffer from serious limitations and they need a higher level of user intervention to prevent inconsistencies in merged ontology. The reason for their inaccuracy is that merging systems do not exploit semantics embedded within ontologies, and they require user intervention to resolve conflicts with their intelligence. Before OWL, ontology languages provide very limited constructs for knowledge representation and thus integration of ontologies becomes difficult and suffers with various dilemmas. OWL with its expressive power and decidability gave opportunity to reason about the concepts, properties and individuals to the degree permitted by the formal semantics of the OWL language [9]. By exploiting the whole breath of semantic knowledge about concepts and their properties, ontology merging process can be made more accurate that requires less dependability on human experts. One of such semantic description is depicted by disjoint axioms in ontologies. In recent ontology-based research, disjoint knowledge axioms gained much popularity as they separate the domains and builds boundaries of concepts so that machine can reason in semantically sound manner. Volker et al. proposed the learning mechanisms about the disjoint knowledge within the hierarchies of concepts to automatically enrich single ontology with disjoint axioms [22]. Qadir et al. proved that omission of disjoint knowledge in ontology that serves as a backbone in critical system may lead to erroneous and catastrophic situations, and proposed a criterion to generate alarms for disjoint knowledge omission between concepts in ontologies [9]. There are several intra-ontology errors that occur due to disjoint knowledge omission and wrong placement of disjoint axioms that cause inconsistency and in-conciseness in ontology [17]. However, these works only discuss the intra-ontology issues about disjoint knowledge within a single ontology.

In this paper, we discuss inter-ontology issues about disjoint knowledge with respect to several local ontologies that merge to produce a global ontology. We present disjoint knowledge preservation as one of ontology merge requirement for ontology merging systems. Disjoint knowledge analysis helps proposing the accurate matches and point-out the erroneous initial mappings during the first stages of merging. We emphasis that merging process should exploit and preserve such a important knowledge for building complete, consistent and coherent merged global ontology. Without exploiting such knowledge, mapping systems produce many inaccurate suggestions that lead toward inaccurate, inconsistent and incomplete merged ontology. Following, we present certain cases that may produce new conflicts among disjoint relations in local ontologies to resolve during preserving of disjoint knowledge in merged ontology.

The rest of paper is organized as follows. Section 2 discusses extension in ontology merge requirements and throws a light on alignment conflict among disjoint relations in local ontologies that may arise during disjoint knowledge preservation in building global merged ontology. In addition, it presents significance of disjoint knowledge analysis during merging of local ontologies and describes how inconsistent mappings can be identified by exploiting the disjoint descriptions of concepts of local ontologies. Section 3 discusses state-of-the-art ontology mapping and merging approaches and their abnormal behaviors while tackling with severe semantic heterogeneity. The same section discusses the overview of our *Disjoint Knowledge Preservation based Ontology Merger* (*DKP-OM*). Section 4 concludes the paper and draws lessons about the adequacy of disjoint knowledge usage in ontology merging.

II. Our Contributions To The Design And Study Of Ontology Merging System

This section shows our contributions to the study and design of ontology merging system that provides complete, consistent and coherent merged global ontology.

A. *Extension in Ontology Merge Requirements*

The merge function, "$Merge(A, Map_{AB}, B) \rightarrow G$", that merges ontologies A and B based on mapping Map_{AB} to generate a global merged ontology G is formally defined by Pottinger and Bernstein [11]. They described that the merge function should satisfy Generic Merge Requirements to cope with the diverse nature of semantic heterogeneity in local ontologies to produce global merged ontology. While analyzing existing merging approaches, we observed that these approaches fulfill those requirements at some extent and specifically they do not preserve the disjoint knowledge in merged global ontology. Disjoint knowledge in ontologies plays a vital role in describing the semantics of data and separate the domains into distinct classes. Realizing its significance within ontology and its omission as catastrophic, we propose one more merge requirement, i.e., Disjoint-Knowledge preservation in merged ontology as shown in dotted box in Figure 1. Disjoint knowledge preservation means that the disjointness information about the concepts in local ontologies O_1 and O_2 is preserved in global merged ontology O_3 and none of mappings violate the description of disjointness to produce accurate global merged ontology.

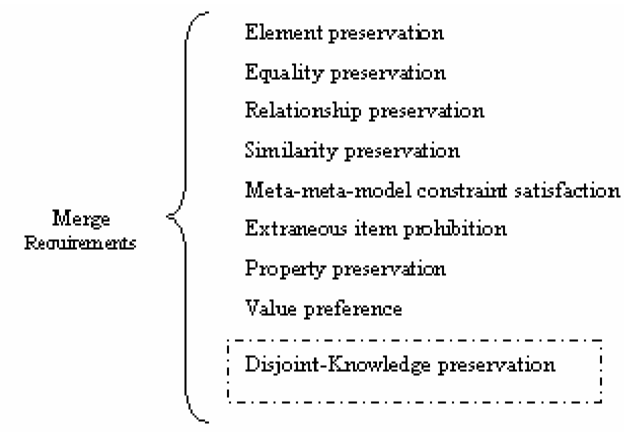

Figure 1. Extension in Ontology Merge Requirements.

The concepts in hierarchies of merged ontology O_3 remain complete, consistent, and coherent with respect to all the knowledge hidden in local ontologies O_1 and O_2. A common example of disjoint-knowledge preservation in merged ontology is depicted in Figure 2. The disjoint axioms between concepts *C*, *D*, and *B* in O_1, and disjoint axioms between (*G*, *D*), (*G*, *B*), (*D*, *B*) in O_2 are preserved in merged ontology O_3 that is complete, consistent and coherent with respect to all the knowledge hidden in local ontologies. But during the preservation of disjoint knowledge in ontologies, one has to be careful and avoid redundancy of *disjoint-of* relations that compromise with the conciseness of merged ontology. Redundancy of *disjoint-of* relations means that the concepts in hierarchies that are implicitly disjoint due to disjoint axioms between their parents are again specified as disjoint but this can be deduce from disjoint descriptions of their parent concepts [20]. For example, specifying disjoint axiom between concept *G* and any (*Z*, *Y*, *X*) makes redundancy of *disjoint-of* relation, because this can be deduced by disjoint description of Concepts *G* and *B*.

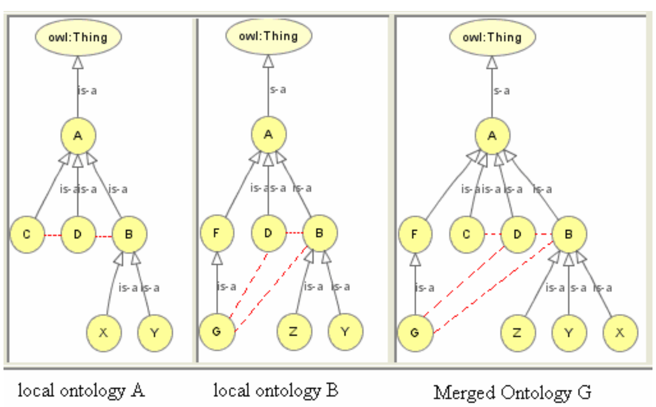

Figure 2. Disjoint knowledge preservation in merged global ontology O_3. (dotted lines show the disjoint-of axioms)

B. *Conflict among Disjoint Relations*

Conflicts are the natural because of the fact that ontologists made ontologies according to their own conceptualization, scope, pragmatics and requirements of their domain. There are many types of conflicts which may occur during ontology mapping and merging proposed in research literature. While preserving disjoint knowledge in merged ontology, we identified a new conflict, i.e., alignment conflict among disjoint relations that may occur. This type of conflict arises when same concepts within the source ontologies contradict with respect to their mutual agreement. For example, consider local ontologies O_1 and O_2 in Figure 3. In ontology O_1, concept *Employee* and *Student* are disjoint with each other and have no instance in common. But, in ontology O_2, a *PhD* researcher, as a funded student and employee of the university forms overlapping between the concepts *Employee* and *Student*. In addition, concepts *Lecturer* and *Lab_instructor* form alignment conflict between disjoint descriptions. Such conflicts among disjoint relations at top level nodes of practical ontologies that have thousand of concepts make huge troubles for interoperability. Thus, disjoint knowledge axiom analysis is highly significant because if not paid attention, then all the merging process leads to inconsistent global ontology. By analyzing existing approaches for ontology merging, we observed that no existing merging approaches pay attention to this conflict and thus, they produce many inaccurate suggestions. By considering this type of information highlights the erroneous situations, gives more accurate mappings and less error-prone merged ontology.

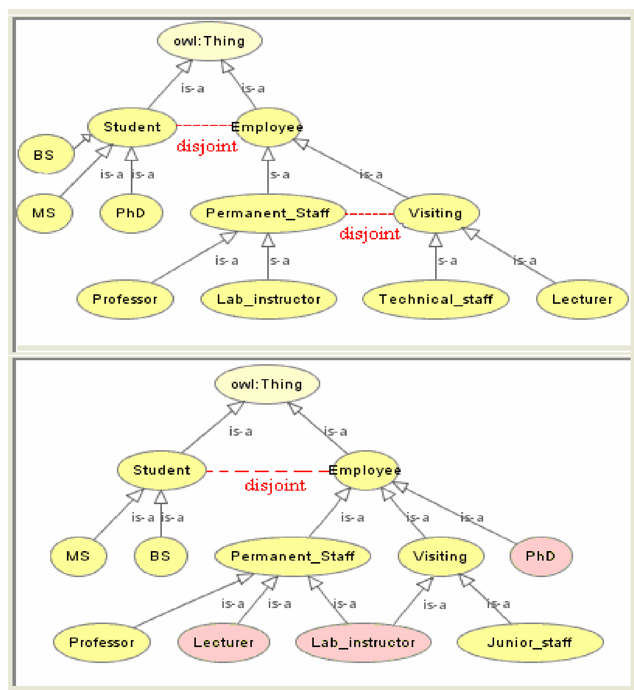

Figure 3. Alignment Conflict among disjoint relations

C. *Benefits of Disjoint knowledge Analysis and Preservati -on in Ontology Merging Process*

There are several benefits of disjoint knowledge analysis and preservation in ontology merging, as elaborated below.

1) Incompleteness in Merged Ontology: According to Ontological Error's Taxonomy, disjoint knowledge omission among concepts in ontology is categorized as Incomplete Partition Error [17]. During ontology merging process, if we ignore disjoint knowledge axioms then the merged ontology would be incomplete with respect to all type of knowledge hidden in local ontologies leading to catastrophic complications in practice.

2) Inconsistency in Merged Ontology: Disjoint knowledge analysis avoids chances of inconsistencies in merged ontology. When disjoint knowledge is not considered in ontology merging process, initial mappings lead toward inconsistent merged ontology with respect to local ontologies. For example, let O_1 and O_2 be two local ontologies as shown in Figure 4. In ontology O_1, concepts *Student* and *Employee* are taken as disjoint which means that there is no instance student that is also an instance of employee. But, in ontology O_2, *Student* can be an *Employee*, e.g., *PhD Researcher*, *Erasmus Mundus Scholar*, etc, and hence represented as overlapping concepts. When these local ontologies are merged then a common class (i.e., *PhD_Researcher*) between disjoint classes (*Employee* and *Student*) which creates inconsistency in the global ontology.

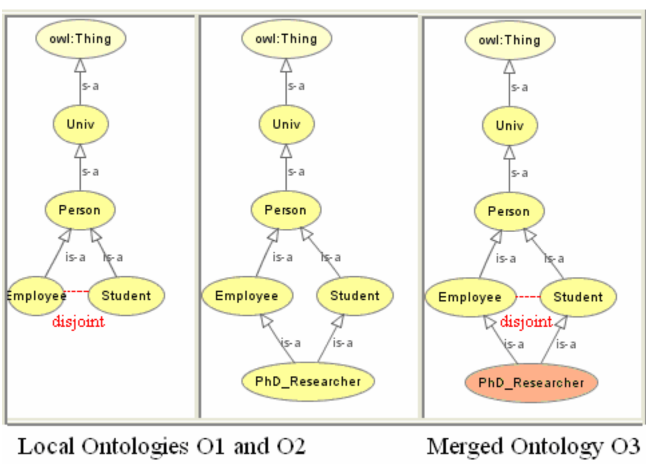

Figure 4. Inconsistency in merged ontology O3

3) Reduce Search Space and Runtime Complexity: For finding the best match of any concept of ontology O_1 need exhaustive analysis with entire concepts of O_2, resulting n_1xn_2 comparisons where n represents the number of concept of ontology. Disjoint axioms seperate the knowledge in distinct chucks and enable concept matching within boundaries of sub-hierarchies of entire ontology concept hierarchy. While finding matches between concepts of ontologies, domain specific heuristics about disjoint knowledge about concepts in source ontologies minimize the search space and thus reduce the runtime complexity of ontology merging. However domain specific heuristics can only be applied on well-known ontologies where we do not expect any alignment conflict within the sub-hierarchies of disjoint concepts. For example, consider family ontology O_1 where *Male* concept is disjoint with *Female* concept, and ontology O_2 where *Men* concept is disjoint with *Women* concept. Here, If we get a top level mapping of concept (*Male AND Person*) on *Men* and (*Female AND Person*) on *Women*, then search space would be reduced by only seeking mapping of sub-children concept of (*Male AND Person*) into sub-children concept of *Men* only and vice versa rather than in all the taxonomy of concepts.

4) Detecting Inaccurate Mappings by Concept name matching strategy: Disjoint knowledge axioms help identifing initial inaccurate mappings and remove ambiguity when concept with same symbolic identifier means differently in different local ontologies in the process of ontology merging. For example, consider ontologies O_1 and O_2 as shown in Figure 4. In ontology O_1, *Course* concept is further classified as *BS* and *MS* courses, and in ontology O_2 concept *Student* is categorized according to his qualification as *BS*, *MS* and *PhD* students. If mapping and merging based on concept label maps *BS* of O_1 to *BS* of O_2, based by linguistic (or synonym) matches, then this would lead towards inconsistent global merged ontology. By exploiting disjoint knowledge in ontology O_1, which restricts concept *Course* as disjoint with *Person*, ontology mapping and merging systems should reject such initial mappings to avoid inconsistencies in merged ontology. Moreover, disjoint axioms togather with equivalence axioms help validation of initial alignments and mappings found in first stages of ontology merging. For example, explicit descriptions about the disjointness of two concepts (*C* and *D*) in ontology O_1 and equivalence of concepts (*D'* and *F*) in ontology O_2 help to detect semantically inaccurate mapping between concepts (*D* and *F*).

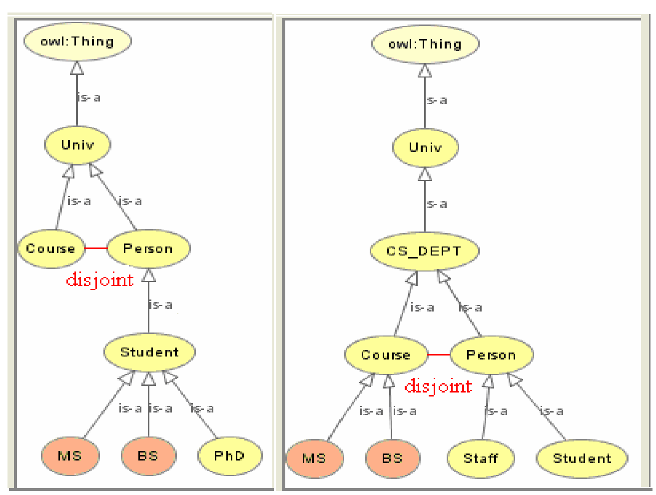

Figure 5. Detecting inaccurate mappings based on concept name strategy by disjoint axiom analysis

5) Detecting Inaccurate Mappings by Instance matching strategy: Disjoint knowledge axioms help identifying initial inaccurate instance based mappings that originate when same instance propose semantically distinct concept as merge candidate in the process of ontology merging. For example, consider ontologies O_1 and O_2 as shown in Figure 5 where instance based matching technique identify concept *Professor* of ontology O_1 as candidate of merge with the concept *Researcher* of ontology concept O_2 based on Identical Instance *JOHN*. These mappings could be rejected if merging system considers disjoint knowledge axioms in local ontologies that separate the domain of concepts *Student* and *Staff (Faculty)* while calculating similarities to produce mappings of semantically distinct concepts.

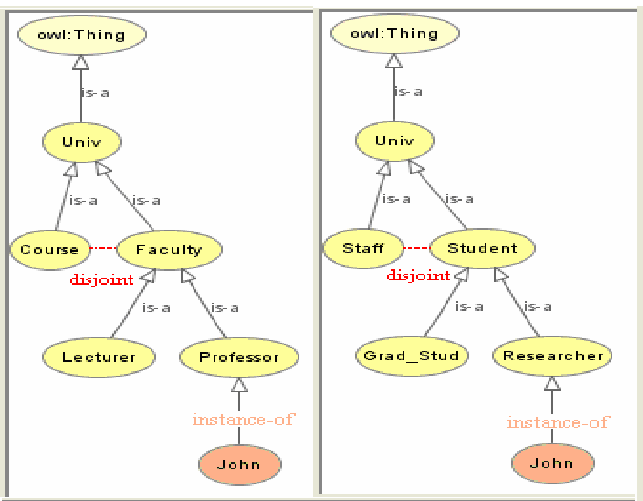

Figure 6. Detecting inaccurate mappings based on instance matching by disjoint axiom analysis

6) Better reasoning and inference mechanisms with disjoint-of axioms among properties: Due to significance of *disjoint-of* axioms, W3C has included the construct *disjoint-of* to specify disjointness between properties and their hierarchies in new specie of OWL, i.e., OWL 2 that serves as current recommendation (2009) for building ontologies [26]. During evaluation of current description logic reasoners, we observed that they do not fulfill the existing demands of enriched expressive ontologies with constraints of disjointness and lack reasoning when used in real applications [30]. Reasoning and inference with disjoint axioms between concepts and properties furnish more semantic power, spark the inference machanism and provide better automatic reasoning capability to ontology merging process, and help to build more well formed ontologies, which fulfill their purposes when used in applications. This requires that ontology merging systems should avoid all type of errors especially disjoint knowledge omission, common class or property in disjoint decomposition, redundancy of *disjoint-of* relations among concepts and properties during construction of merged global ontology from local ontologies.

III. State-of-the-Art And Our System DKP-OM

Developing efficient ontology merging systems has been a core issue of recent ontology research to answer the question of combined use of independently developed ontology and interoperability in heterogeneous systems. As a result, many approaches and systems have been proposed in research literature for alignment, mapping, and merging of local ontologies like *Glue* [3], *Prompt* [4], *Chimaera* [5], *OLA* [6,7], *Cupid* [8], *Anchor-Prompt* [13], , *Observer* [14], *IF-Map* [19], *Hcone Match and Merge* [23], *S-Match* [24], *FCA-Merge* [25]. According to the detailed discussion and analysis in [1], these approaches use lexical database WordNet [29], taxonomy analysis, string matching algorithms, formal concept analysis, extensional comparisons and many more heuristics to produce initial mappings between source ontologies to aid user. User with his intelligence observes and validates those mappings to avoid inconsistencies during construction of global merged ontology. Many of these systems assume semantically distinct concepts to be the same as they are using only some specific methods such as concept label matching, attribute matching, structure matching, instances matching, etc., to find correspondences between concepts and hence produce inaccurate suggestions for ontology merging. The concept label matching approach suffers when semantically same concepts are modeled with different names (i.e., synonym). Attribute matching produces inaccurate mappings when different concepts have same attributes, For example concept *Person* and *Company* are proposed to be the same on the basis of identical attribute labels such as name, address, phone, etc. The major drawback by instance matching approach is seen when semantically distinct concepts having the common instance are considered to be the same. Moreover existing approaches that make use of common vocabulary, reference ontology, articulation rules, etc., are specific to the particular domain for which they are built for and produce efficient results while used for merging of same specific domain and subject ontologies, but they compromise accuracy when applied to more generalized domain ontologies. In addition, they do not validate the suggestions before showing initial suggestion list to users whether they lead to inconsistent merged ontology. They do not exploit the full knowledge (e.g., disjoint knowledge) embedded within the ontology. However, single or domain specific strategy appeared to be unsuccessful due to diverse nature of semantic heterogeneities. Therefore, hybrid techniques that make combined use of different methods propose semantic mappings to some more extend, and achieve higher level of accuracy.

Our system *Disjoint Knowledge Preserver* (*DKP*) based *Ontology Merger* (*OM*) [21], *DKP-OM*, follows a hybrid strategy for ontology merging by exploiting all the semantic knowledge available in the ontologies especially the disjointness of the concepts. Multi-strategies including linguistic matching, synonym matching by using wordnet, structural similarities between hierarchies, and description logic analysis make it capable to find all types of matches between the local ontologies to build the global ontology. The use of whole breadth of available knowledge hidden in local ontologies about concept, properties, formal semantics of concepts' definitions, disjoint knowledge axioms and validation of initial mappings by considering disjoint relations between concepts make it suitable for merging different available ontologies from different domains and subjects, lessens users' dependability for validating the consistency of the generated mappings and distinguishes it from rest of the existing systems.

IV. Conclusion

This paper presents disjoint knowledge preservation as one of the ontology merge requirement. Preserving such knowledge within the merged ontology brings out two major important points. First, by exploiting such knowledge in ontology mapping phase promote reliable inference-ability and brings out more accurate and reliable suggestions. Those suggestions that are based on linguistic match or instance match by assuming two semantically different concepts are rejected that lead to inconsistent merged ontology. Second, many other mismatches such as alignment conflicts among disjoint relations in hierarchies of local ontologies could be identified that need to be resolved for consistent and coherent merged ontology. It presents how analysis of disjoint knowledge axioms in local ontologies is helpful for identification of reliable correspondences between concepts, and detection of inconsistent mappings that lead to inconsistent, incomplete and non-coherent global merged ontology with respect to local ontologies. Ignoring disjoint knowledge in merged process would lead to various erroneous situations in global merged ontology such as incomplete partition error, i.e., disjoint knowledge omission among concepts error, common class in disjoint decomposition of concepts, and redundancy of *disjoint-of* relations between concepts and properties. Finally, we discuss our system, *DKP-OM*, which exploits disjoint knowledge between concepts and properties during merging of local ontologies with different subjects, domains and contexts, and avoids erroneous situations in global merged ontology. By this, ontology mapping and merging system promote more reliable interoperability among heterogeneous autonomous software systems and agents by enabling them to communicate, share, and exchange information in semantically sound and consistent way in presence of several types of semantic heterogeneities.

Acknowledgment

This work is done under the eLink (east-west Link for Innovation, Networking and Knowledge exchange) Erasmus Mundus program with collaboration between the University of Lyon 2 – CERRAL Laboratory and Mohammad Ali Jinnah University – CDSC Laboratory.

References

[1] J. Euzenat and P. Shvaiko, Ontology Matching, 2007, ISBN: 978-3-540-49611-3, Springer Berlin Heidelberg, New York

[2] A. Gomez-Perez, M. Fernández-López, and O. Corcho, Ontological Engineering: With examples from the Areas of Knowledge Management, E-Commerce and the Semantic Web, 2004, ISBN:1-85253-55j-3, Springer

[3] A. Doan, J., Madhaven, P., Domingos, and A, Halevy,"Ontology matching: A machine learning approach. Handbook on Ontologies in Information Systems," Springer-Verlag 2004, pp. 397-416.

[4] N. F. Noy and M. A. Musen, "The PROMPT suite: interactive tools for ontology merging and mapping", IJHCS, Elsevier, vol. 59-6, 2003, pp. 983–1024.

[5] D. L. McGuinness, R. Fikes, J. Rice, and S. Wilder, "An environment for merging and testing large ontologies," Proc. 7th Intl. Conf. On Principles of Knowledge Representation and Reasoning, USA, April 2000, pp. 483–493.

[6] J. Euzenat and P. Valtchev, "An integrative proximity measure for ontology alignment", In Proc. ISWC-2003 workshop on semantic information integration, Sanibel Island, 2003, pp. 33–38.

[7] J. Euzenat and P. Valtchev, "Similarity-based ontology alignment in OWL-lite", In Proc. 16th ECAI, Valencia, Spain, 2004, pp. 333–337.

[8] J. Madhavan, P. Bernstein, and E. Rahm, "Generic schema matching using Cupid". In Proc. 27th VLDB, Roma, Italy, 2001, pp. 48–58.

[9] M. A. Qadir and W. Noshairwan, "Warnings for Disjoint Knowledge Omission in Ontologies," Proc. International Conference on Internet and Web Applications and Services, 2007, IEEE CS, pp. 45-50.

[10] M. Klein, "Combining and relating ontologies: an analysis of problems and solution," In Gomez-Perez, A. et al., editors, Proceedings of Workshop on Ontologies and Information Sharing at the 17th International Joint Conference on Artificial Intelligence 2001, Seattle, WA, USA, pp. 53-62.

[11] R.A. Pottinger and P.A. Bernstein, "Merging Models Based on Given Correspondences", Proceedings of the 29th VLDB Conference, Berlin, Germany, 2003, pp. 862-873.

[12] P. Mitra and Gio Wiederhold, "Resolving terminological heterogeneity in ontologies." In Workshop on Ontologies and Semantic Interoperability at the 15th European Conference on Artificial Intelligence, France, 2002, pp. 45-50.

[13] N. Noy and M. Musen,"Anchor-PROMPT: Using non-local context for semantic matching," Proc. IJCAI 2001 workshop on ontology and information sharing, Seattle, USA, 2001, pp. 63–70.

[14] E. Mena, A. Illarramendi, V. Kashyap, and A. P. Sheth, "OBSERVER: An approach for query processing in global information systems based on interoperation across pre-existing ontologies," Distributed and Parallel Databases, vol. 8-2, 2000, pp. 223-271.

[15] Z. Cui, D. Jones, and P. O'Brien, "Issues in Ontology-based Information Integration," Proc. of the IJCAI, Seattle, USA, August 2001, pp. 141-146.

[16] H. S. Pinto, A. Gomez-Perez, and J. P. Martins, "Some issues on ontology integration," In proceedings of the workshop on ontologies and Problem Solving Methods during IJCAI, Sweden, August 1999, vol. 18-7, pp. 1-12

[17] M. Fahad and M. A. Qadir "A Framework for Ontology Evaluation," Proceedings International Conference on Conceptual Structures, Toulouse, France, July 7-11, pp. 149-158.

[18] P. R. S. Visser, D. M. Jones, T. J. M. Bench-Capon, and M. J. R. Shave, "An analysis of ontological mismatches: Heterogeneity versus interoperability," In AAAI Spring Symposium on Ontological Engineering, Stanford, USA, 1997, pp. 164-172.

[19] Y. Kalfoglou and M. Schorlemmer, "If-map: an ontology mapping method based on information flow theory," Journal of Data Semantics I, vol. 2800, 2003, pp. 98–127.

[20] W. Noshairwan, M.A.Qadir, and M. Fahad, "Sufficient Knowledge Omission error and Redundant Disjoint Relation in Ontology," Proc.

5th Atlantic Web Intelligence Conference, Adv. in Intel. Web, ASC 43, France, Springer-Verlag, June 2007, pp. 260–265.

[21] M. Fahad, M.A. Qadir, W. Noshairwan, and N. Iftikhar, “DKP-OM: A Semantic Based Ontology Merger,” Proc. 3rd International conference on Semantic Technologies, I-Semantics 5-7 September 2007, (special issue) J.UCS. pp. 313-322.

[22] J. Volker, D. Vrandecic, Y. Sure, and A. Hotho, “Learning Disjointness,” LNCS Springer, vol. 4519, 2007, pp. 175-189.

[23] S. Castano, A. Ferrara, and S. Montanelli, “Matching Ontologies in Open Networked Systems: Techniques and Applications,” Journal on Data Semantics, JoDS 3870, Springer Berlin, 2006, pp. 25-63.

[24] F. Giunchiglia, P. Shvaiko, and M.Yatskevich, “S-Match: an algorithm and an implementation of semantic matching,” Proceedings of the European Semantic Web Symposium, LNCS Springer, Vol. 3053, pp 61-75.

[25] G. Stumme and A. Mädche, “FCA-merge: bottom-up merging of ontologies,” In Proc. 17th IJCAI, Seattle, USA, 2001, pp. 225–230.

[26] OWL 2 Web Ontology Language, Last accessed on 17 May 2010, http://www.w3.org/TR/2009/REC owl2-new-features-20091027/

[27] RDF Vocabulary Description Language 1.0: RDF Schema, Last accessed on 17 May 2010, http://www.w3.org/TR/rdf-schema/

[28] DAML+OIL (March 2001) Reference Description, Last accessed on 17 May 2010, http://www.w3.org/TR/daml+oil-reference

[29] G. A. Miller, “WordNet: A lexical database for English,” Commun. ACM journal. Vol. 38-11, 1995, pp. 39-41.

[30] M. Fahad, M. A. Qadir, and S.A. HussainShah, “Evaluation of Ontologies and DL Reasoners,” Intelligent Information Processing IV, Vol. 288/2008, Springer Boston, pp. 17-27.