Foundations on Multi-Viewpoints Ontology Alignment

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Abstract. In the last few years, a lot of effort has been paid to support both consensus and heterogeneity in the same ontology. As a result, multi-viewpoints ontologies have become essential for heterogeneous organizations and for diverse user communities that need to share and exchange information in an application domain. The development of multi-viewpoints ontologies by different communities makes distributed and heterogeneous knowledge resources not accessible. So, to solve this problem and in order to support users in sharing and reusing vocabularies and knowledge, we need for techniques for solving heterogeneity problems between different multi-viewpoints ontologies. In this case, multi-viewpoints ontology alignment is required to provide a consensual understanding of that domain represented by these ontologies. In the literature, there are much alignment systems, but existing systems are not capable to support multiple viewpoints. So, our challenge is to introduce the notion of multiple viewpoints in the alignment process. Therefore, in order to align multi-viewpoints ontologies, we present in this paper first, the definition of multi-viewpoints ontology in description logics extended by a stamping mechanism, and then we deal with their alignment problems and definitions.

Keywords: multi-viewpoints ontology, ontologies alignement, description logics, stamping mechanism.

1 Introduction

Ontologies can apprehend, capitalize, represent, operate and share semantically knowledge and information. However in reality, there are usually several ways to capture the knowledge of a given domain, that is to say different viewpoints (or perceptions) by which this knowledge can be represented. Thus, the same domain may have more than one ontology, where each one is described according to a viewpoint or a particular perception. Indeed, in a large organization, there may be several communities or groups of individuals with their own viewpoints. These viewpoints depend on the type of person (occupation, age, educational level, experience …) or use (the same person may have different views depending on the task which he is trying to accomplish) [1].

The two concepts ontology and viewpoint are complementary [2], indeed the ontology represents the knowledge shared by multiple users and the viewpoint represents the domain of knowledge that is relevant at a given viewpoint. With the coupling of these tow notions we are talking about multi-viewpoints ontology. The latter gives the same universe of discourse several partial descriptions such that each one is on a particular viewpoint.

The exploration of multi-viewpoints ontologies [1], [3-4] could be an efficient way for heterogeneous organizations to share knowledge. The development of these ontologies by different communities makes distributed and heterogeneous knowledge resources not accessible. So, to solve this problem and in order to support users in sharing and reusing vocabularies and knowledge, we need for techniques for solving heterogeneity problems between different multi-viewpoints ontologies. In this case, multi-viewpoints ontology alignment is required to provide a consensual understanding of that domain represented by these ontologies.

An ontology alignment is defined as a set of correspondences between ontological entities, i.e. classes, properties, and individuals, of two ontologies [5]. In the literature, there are much alignment systems presented in [6] and [7]. However, existing systems are not capable to support the notion of multiple viewpoints. So, our challenge is to introduce this notion in alignment process to align multi-viewpoints ontologies.

Therefore, the objective of this work is to find an alignment definition of the multi-viewpoints ontologies described in description logics extended by a stamping mechanism, and to find a definition of the semantics of these alignments. The aim of these definitions is to be able to align multi-viewpoints ontologies.

The rest of the paper is organized as follows. Section 2 presents a multi-viewpoints ontology. In section 3 we detail syntax and semantics of multi-viewpoints ontology described in description logics extended by stamping mechanism. Section 4 looks at the problems of the multi-viewpoints ontology alignment. In section 5 we present a set of definitions for the multi-viewpoints ontology alignment, and Section 6 concludes with the future directions of work.

2 Definition of Multi-Viewpoints Ontology (MVp Ontology)

2.1 Viewpoint Approach

For a given domain of knowledge, several criteria can be used to observe an object. These different perceptions of the world are called viewpoints or perspectives. In computer science, most of data modeling systems don't deal with the variety of perceptions related to the same universe of discourse, and develop tools to create a single model for a single vision of the observed world. The viewpoint approach is opposed to this monolithic approach and makes it possible to model the same reality according to different points of view [8].

The viewpoint approach is constructed on the conjunction actor/information. Therefore, it is necessary to include the actor in the action. In [9] viewpoint is defined as "*a conceptual manner binding, on the one hand an actor who observes and, on the other hand, a universe of discourse which is observed*".

2.2 Multi-Viewpoints Ontology

A multi-viewpoints ontology is defined as an ontology in which a concept can have multiple definitions, each definition corresponding to a particular viewpoint on the concept [1], [3].

In [4], a multi-representation ontology is seen as an ontology that characterizes an ontological concept by a variable set of properties (static and dynamic) or attributes in several contexts and granularities.

The accepted definition in our work is that mentioned in [2] and [8], where a multi-viewpoints ontology is defined as an ontology that gives the same universe of discourse, several partial descriptions, in a way that, each one is on one viewpoint. These partial descriptions share on a global level the ontological elements (concepts and global roles) and semantic links constitute a consensus between the different viewpoints.

3 A Multi-Viewpoints Ontology in Description Logics Extended by a Stamping Mechanism

Description logics (DL) [10-11] are a family of knowledge representation languages that can be used to represent the knowledge of an application domain in a structured and formally well-understood way. A stamping mechanism allows multiple representations of concepts. In [2] and [8], description logics extended by a stamping mechanism have a signature, which is based on the following types: global concepts, local concepts, global roles, local roles, individuals and bridge rules. This language allows the use of constructors to create complex elements.

Definition 1 (Multi-viewpoints Ontology in Description Logics Extended by a Stamping Mechanism). A multi-viewpoints ontology described in description logics extended by a stamping mechanism is a multiple descriptions of the same universe of discourse according to different viewpoints. It is defined as the quadruple $O_{mpv} = \langle C^G, R^G, V_p, M \rangle$ where: C^G : is a set of global concepts, R^G : is a set of global roles, M : is a set of bridge rules and V_p : is a set of viewpoints, where a viewpoint is a partial description of a universe of discourse in a particular perception. It is defined by the triplet $\langle C^L, R^L, A^L \rangle$, where: C^L : is a set of local concepts, R^L: is a set of local roles and A^L : is a set of local individuals.

Definition 2 (Syntax of a Global Concept). Given $\boldsymbol{V_p} = \{\boldsymbol{vp_i}, \dots, \boldsymbol{vp_k}, \dots, \boldsymbol{vp_m}\}$ a set of viewpoints. A global concept $\boldsymbol{C^G}$ can be formed using the Boolean manufacturers (conjunction, disjunction) and the following global restrictions manufacturers:

- $\forall_{vp_1,\dots,vp_k} R.C, \exists_{vp_1,\dots,vp_k} R.C$: defines a new concept that all their instances are connected by the role R,
- $\leq_{vp_1,\dots,vp_k} R.C, \geq_{vp_1,\dots,vp_k} R.C$: specifies the minimum or maximum cardinality of the role R in the viewpoints $vp_i\ to\ vp_k$.

Definition 3 (Syntax of a Local Concept). Given $\boldsymbol{vp_i} \in \boldsymbol{V_p}$. A local concept $\boldsymbol{vp_i}: C^L$ is either a primitive local concept or a defined local concept:
vp_i: $C^G \rightarrow (Gocal\ Concept\ ) \mid (\neg C^L) \mid (C^L \sqcap D^L) \mid (\exists R^L.C^L) \mid (\forall R^L.C^L) \mid$
$(\geq n\ R^L.C^L) \mid (\leq n\ R^L.C^L) \mid (a_1, a_2, \dots)$, where C^L and D^L are local concepts, R^L is a local Role, $a_1, a_2, \dots$ are individuals, and n is a natural number.

Definition 4 (Syntax of a Local Role). A given local role $\boldsymbol{vp_i}: R^L$ is defined as: $\boldsymbol{vp_i}: R^L(C^L, D^L)$, where R^L is the name of the local role defined in the viewpoint $\boldsymbol{vp_i}$, C^L **and** D^L are two local concepts defined in this viewpoint $\boldsymbol{vp_i}$. As well, a local role R^L can be a primitive local role or a defined local role: $(R^L \sqcap S^L)$, $R^L \sqcup S^L$, $\neg R^L$, $R^L \circ S^L$ and R^{L^-}, R^{L^+}, where R^L **and** S^L are given local roles.

Definition 5 (Syntax of a Global Role). A global role $\boldsymbol{R^G}$ is defined as: $\boldsymbol{R^G}(\boldsymbol{vp_i}: C^L, \boldsymbol{vp_j}: D^L)$, where $\boldsymbol{R^G}$ is the name of the global role, C^L **and** D^L are two local concepts defined in two different viewpoints. As well as a local role, a global role can be a primitive or a defined global role.

Definition 6 (Syntax of a Subsumption Relation). Below a viewpoint $\boldsymbol{vp_i}$, a local hierarchy $\boldsymbol{vp_i/H}$, is defined as a triplet $(\boldsymbol{C^L}, \boldsymbol{\partial}, \sqsubseteq)$ where: $\boldsymbol{C^L}$ is a set of local concepts, $\boldsymbol{\partial}$ is a function of $\boldsymbol{C^L}$ in $\boldsymbol{C^G}$, witch associated for all root concept denoted $\boldsymbol{C_S^L}$ of $\boldsymbol{C^L}$a global concept of $\boldsymbol{C^G}$, and $\sqsubseteq$ is the subsumption relation used to express explicitly a direct order relationships as follows:

- $vp_i: \boldsymbol{C^L} \sqsubseteq vp_i: \boldsymbol{D^L}$, where $\boldsymbol{C^L}$ and $\boldsymbol{D^L}$ are two local concepts defined in the same viewpoint vp_i.
- $vp_i: \boldsymbol{C_S^L} \sqsubseteq C^G$, where $\boldsymbol{C_S^L}$ is the most general concept defined in the viewpoint vp_i, and C^G is a global concept.

Definition 7 (syntax of a Bridge Rule). We distinguish:

- *Inclusion.* $vp_i: X \xrightarrow{\sqsubseteq} vp_j: Y$. It expresses the set inclusion between a local concept extension of a viewpoint and another concept of another viewpoint.

- *Inclusion with Multiple Sources.* $vp_i: X \sqcap \dots \sqcap vp_k \overset{\sqsubseteq}{\rightarrow} vp_j: Y$. It expresses an inclusion relation between a list of local concepts belonging to several viewpoints and another destination concept belonging to another viewpoint.
- *Bidirectional Inclusion.* $vp_i: X \overset{=}{\leftrightarrow} vp_j: Y$. It expresses equality between two local concepts belonging to two different viewpoints.
- *Bidirectional Exclusion.* $vp_i: X \overset{\perp}{\leftrightarrow} vp_j: Y$. It expresses a relationship between two local concepts belonging to two different viewpoints.

3.1 Semantics of Multi-Viewpoints Ontology

In [2] and [8], the semantics of description logics extended by the stamping mechanism is defined by a global interpretation, a set of local interpretations, and a set of domain relations:

Definition 8 (Local Interpretation). A local interpretation $(\Delta^{I_k}, \cdot^{I_k})$, is associated for each local element, where Δ^{I_k} is a domain of local interpretation and $\cdot^{I_k}$ I is a local interpretation function such that for all local concepts of $\boldsymbol{C^L}$, $\boldsymbol{C}^{L^{I_k}} \subseteq \Delta^{L^{I_k}}$, for all local roles $\boldsymbol{R^L}$, $\boldsymbol{R}^{L^{I_k}} \subseteq \Delta^{L^{I_k}} \times \Delta^{L^{I_k}}$, and for all individuals $\boldsymbol{a}$, $\boldsymbol{a}^{I_k} \subseteq \Delta^{I_k}$.

Definition 9 (Global Interpretation). A global interpretation $(\Delta^{I}, \cdot^{I})$ is associated for each global element, where $\Delta^{I} = \Delta^{I_1} \cup \dots \Delta^{I_k} \dots \cup \Delta^{I_m}$ is a domain of global interpretation and $\cdot^{I}$ is a global interpretation function such that for all global concepts $\boldsymbol{C^G}$, $\boldsymbol{C}^{G^{I}} \subseteq \Delta^{I}$, for all global role $\boldsymbol{R^G}$, $\boldsymbol{R}^{G^{I}} \subseteq \Delta^{I} \times \Delta^{I}$.

Definition 10 (Domain Relation). A relation domain defines how two different viewpoints interact.

4 The problems of Multi-Viewpoints Ontology Alignment

In this work, we will take into consideration the notion of viewpoint in the alignment process. Thus, the multi-viewpoints ontologies alignment is the task to find the relationships that hold between the entities belonging to these ontologies.

Multi-viewpoints ontologies cover different domains that can be modeled differently and can represent several viewpoints. They can support both heterogeneity (at a local level) and consensus (at a global level). In the multi-viewpoints ontologies alignment, there is a great heterogeneity resides in the variations present in the semantic coverage of comparable concepts, especially local concepts that are defined according to different viewpoints and that can be semantically very similar. Indeed, the mapping task or alignment task between multi-viewpoints ontologies is more difficult than that between classical ontologies, because there is much specificity for this process. Among the specificities of multi-viewpoints ontologies alignment, we may find:

4.1 *Elements to Align*

In the alignment process between classical ontologies, the task is to discover correspondences between concepts, properties and individuals. In our context of multi-viewpoints ontologies described in description logic extended by stamping mechanism, it is necessary to take into account the different types of concepts (global and local), the different types of roles (global and local), individuals.

4.2 *Localization of Local Elements According to the Different Viewpoints*

In our context, there are two description types: a global description and other partial descriptions defined according to different viewpoints. So, taking into account the localization of the local concept (local role) in the alignment process influenced on the remaining correspondences that can be discovered.

4.3 *Bridge Rules*

The consideration of bridges rules between elements of different viewpoints impact on the set of correspondences found.

5 Multi-Viewpoints Ontologies Alignment

We adopt the definitions of classical ontology alignment presented in [12] and [13], to define the MVp ontology alignment.

Definition 11 (MVp Ontology Alignment). Given $\boldsymbol{O_{mvp}}$, $\boldsymbol{O'_{mvp}}$ two multi-viewpoints ontologies in description logics extended by a stamping mechanism. An alignment between $\boldsymbol{O_{mvp}}$, $\boldsymbol{O'_{mvp}}$ is defined as the task to find the *best subset of the correspondences* between multi-viewpoints ontology elements belonging to $\boldsymbol{O_{mvp}}$and $\boldsymbol{O'_{mvp}}$.

Definition 12 (MVp Ontology Element). A multi-viewpoints ontology element is a term of the multi-viewpoints ontology (e.g., global concept, local concept, global role, local role or individual).

Definition 13 (Correspondences). Given$\boldsymbol{O_{mvp}}$, $\boldsymbol{O'_{mvp}}$ two multi-viewpoints ontologies in description logics extended by a stamping mechanism, a correspondence between $\boldsymbol{O_{mvp}}$, $\boldsymbol{O'_{mvp}}$ is defined as a triple $\langle e_{mvp}, e'_{mvp}, A_{mvp}\rangle$ where: e_{mvp} and e'_{mvp} are multi-viewpoints ontology elements from the two multi-viewpoints ontologies to align, and A_{mvp} is a relation that is asserted to hold tween e_{mvp} *and* e'_{mvp}

Multi-viewpoints ontologies alignment contains correspondences between global concepts, local concepts, global roles, local roles or between individuals belonging to these ontologies. These correspondences are similar to the bridge rules in a same multi-viewpoints ontology. We can identify the different types of correspondences between two multi-viewpoints ontologies i and j as follows: $i{:}\,C^G \overset{\sqsubseteq}{\leftrightarrow} j{:}\,D^G$, $i{:}\,C^L \overset{\sqsubseteq}{\leftrightarrow} j{:}\,D^L$, $i{:}\,C^L \overset{\sqsubseteq}{\leftrightarrow} j{:}\,D^G$, $i{:}\,R^G \overset{\sqsubseteq}{\leftrightarrow} j{:}\,S^G$, $i{:}\,R^L \overset{\sqsubseteq}{\leftrightarrow} j{:}\,S^L$, $i{:}\,R^L \overset{\sqsubseteq}{\leftrightarrow} j{:}\,S^G$, $i{:}\,C^G \overset{\perp}{\leftrightarrow} j{:}\,D^G$, $i{:}\,C^L \overset{\perp}{\leftrightarrow} j{:}\,D^L$, $i{:}\,C^L \overset{\perp}{\leftrightarrow} j{:}\,D^G$, $i{:}\,R^G \overset{=}{\leftrightarrow} j{:}\,S^G$, $i{:}\,R^L \overset{=}{\leftrightarrow} j{:}\,S^L$, $i{:}\,R^L \overset{=}{\leftrightarrow} j{:}\,S^G$, $i{:}\,a \overset{\in}{\leftrightarrow} j{:}\,C^G$, $i{:}\,a \overset{\in}{\leftrightarrow} j{:}\,C^L$, $i{:}\,a \overset{=}{\leftrightarrow} j{:}\,b$, where C^G and D^G are global concepts, C^L and D^L are local concepts, R^G and S^G are global roles, R^L and S^L are local roles, a and b are individuals, $\overset{\sqsubseteq}{\leftrightarrow}$ is a subsumption relation , $\overset{\perp}{\leftrightarrow}$ is a disjunction relation , $\overset{\in}{\leftrightarrow}$ is a membership relation, and $\overset{=}{\leftrightarrow}$ is a identity relation.

Consequently, a multi-viewpoints ontology alignment involves a set of entities connected by symbols of relations. It is seen as a pair (E_{mvp}, A_{mvp}), where E_{mvp} is a set of entities described in description logics extended by a stamping mechanism. And A_{mvp} is a set of symbol of relationships between these entities. So, it is necessary to interpret the pair (E_{mvp}, A_{mvp}) before interpreting a multi-viewpoints ontology alignment.

Definition 14 (Entities Interpretation). Interpretation of entities is a pair $(\Delta^{\boldsymbol{I}}, \cdot^{\boldsymbol{I}})$, where $\Delta^{\boldsymbol{I}}$is a domain of interpretation and $\cdot^{\boldsymbol{I}}$ is an interpretation function such that for all local concepts $\boldsymbol{C^L}$, $\boldsymbol{C^{L^I}} \subseteq \Delta^{\boldsymbol{L^I}}$, for all global concepts $\boldsymbol{C^G}$, $\boldsymbol{C^{G^I}} \subseteq \Delta^{\boldsymbol{I}}$, for all local roles$\boldsymbol{R^L}$, $\boldsymbol{R^{L^I}} \subseteq \Delta^{\boldsymbol{L^I}} \times \Delta^{\boldsymbol{L^I}}$, for all global roles $\boldsymbol{R^G}$, $\boldsymbol{R^{G^I}} \subseteq \Delta^{\boldsymbol{I}} \times \Delta^{\boldsymbol{I}}$, and for all individuals $\boldsymbol{a}$, $\boldsymbol{a^I} \subseteq \Delta^{\boldsymbol{I}}$, where$\Delta^{\boldsymbol{L^I}}$ is a local domain of interpretation and it is a subset of $\Delta^{\boldsymbol{I}}$.

Definition 15 (Multi-Viewpoints Ontologies Alignment Interpretation). In our context, all entities are coming from the same description language. An interpretation of an alignment relation between two multi-viewpoints ontologies $i \text{ and } j$ is a pair $(\Delta^{\boldsymbol{I}}., \cdot^{\mathbf{I}})$, where $\Delta^{\mathbf{I}}$ is a global domain of interpretation and $\cdot^{\mathbf{I}}$ is a binary relation of interpretation such that for all relations $A_{mvp}, A_{mvp}{}^{\mathbf{I}} \subseteq \Delta^{\mathbf{I_i}} \times \Delta^{\mathbf{I_j}}$, where $\Delta^{\mathbf{I_i}}$ and $\Delta^{\mathbf{I_j}}$ are domain of interpretation of the multi-viewpoints ontologies $\mathbf{i \text{ and } j}$ respectively, and are subsets from$\Delta^{\mathbf{I}}$. Each multi-viewpoints ontology has its own domain of interpretation.

6 Conclusion

In this paper, we specified the basic concepts that constitute a starting point for multi-viewpoints ontology alignment.

Several research directions are considered to carry out this work. We will use these definitions to propose a method of multi-viewpoints ontology alignment. We, also, plan to include bridge rules between multi-viewpoints ontologies elements for the reasoning on the multi-viewpoints ontologies and alignments in order to obtain the best set of alignments between these ontologies.

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