Context-awareness in Semantic Web: Local vs. Global Knowledge in Healthcare

Ratnesh Sahay
Digital Enterprise Research Institute
National University of Ireland, Galway, Ireland
ratnesh.sahay@deri.org

Abstract. This paper proposes a framework to see context-awareness as a key concept to deal/solve interoperability issues in current Semantic Web as well as in future (which will possibly lack the globally consistent view of ontologies in presence of heterogeneity). Currently major research efforts in the area of context-awareness (Pervasive/Ubiquitous computing) is to capture, model, or process the local settings (e.g. Mobile, sensors, etc.) but focus of this paper is to highlight the need of a comprehensive framework to capture, represent, model, or process a particular domain in Semantic Web from the user’s perspective. This framework can play a major role in dealing with interoperability issues in Semantic Web. This framework suggests, as a core part, a semantically-enabled coordination space through which context information can be communicated between applications. Though this paper presents such context communication between applications in healthcare domain, the proposed framework can be easily adapted or extended for any other application domains where context communication is needed.

1 Introduction

An overwhelming amount of healthcare knowledge is represented in natural language, information models, clinical repositories (databases), ontologies for terminologies, vocabularies, etc. The grand challenge in information technology is ensuring reliable and effective integration or management of this knowledge. Processing information faster or more efficiently—which today’s technology can easily accomplish—is not sufficient. More intelligent processing, logical aggregation of information, synthesis and analysis, and the development of knowledge systems that can serve purposeful ends are needed. Figure 1 summarizes the relationship between medical ontologies (e.g., Galen, Snomed-CT, etc.), information models (e.g., HL7 (RIM), openEHR, etc.), languages (e.g., UML, Owl, WSML, etc.) and our proposal of Context which can make overall knowledge integration meaningful.

The scope of ontologies and information models are categorised in global and local views. Galen and Snomed-CT, for example, are ontologies which define medical terminologies and keep global view among health care institutes, on
other side information models offered by various medial standards are local in their scope and they have their own vocabularies, concepts, etc. In short, medical knowledge is a part of clinical information systems in standard compliant healthcare institutes.

1.1 Ontologising healthcare standards . . . is a good solution?

In past few years various research efforts were involved for ontological representation of information models of various healthcare standards (HL7, DICOM, CEN13606, etc.) to make them global and integrate with other globally available ontologies (Galen, Snomed-CT, etc.) but this approach is still facing the core issues of integration problems such as ontological heterogeneity, ambiguous separation between global and local knowledge, etc. Figure 2 shows various levels (abstract to concrete) of information models within HL7 (version 3). Due to special local requirements, three different hospitals (say A, B, and C) can have three different set of ontologies defining a concept “PLACE” as shown in Figure 3.

It’s obvious from Figure 2 and Figure 3 that actual message may change at concrete level even if the healthcare institutes follow the same standard, situation can be worse if information models of different healthcare standards (DICOM, CEN 13606 etc...) are considered for interoperability to realize the global EHR (Electronic Healthcare Record). As we mentioned before, few research efforts were initiated to ontologise HL7 (version 3) [RIM: Reference Information Model, see Figure 2] using OWL, therefore HL7 (RIM) has shifted from local to
global view. This migration may cause several problems if we try to integrate ontologized HL7 (RIM) with other information models of HL7 (version 3) such as DMIM, RMIM and HMD as they have their own local views. In traditional ontology integration approaches, it is assumed that everything is global and users’ perspective of the local domain is largely ignored. It is necessary to distinguish between the scope and responsibilities, in terms of local and global knowledge, of both the reference model and ontologies. Therefore, we feel that there is a need of a comprehensive framework that allow capturing, representing, modeling, and processing information without losing the user’s perspective of a domain. The user’s perspective of a domain is taken as context in the scope of
1.2 Ontology languages and Contextualization

Ontology languages, in its current form, suffer from several serious drawbacks in terms of contextualization [1, 2] as listed below:

No support for localized semantics: Inference is usually performed on the integrated centralized ontology therefore it directly introduces both terms and axioms of the imported ontologies into the referring ontology, which results in a global interpretation of all imported ontologies (everything becomes global).

No support for local point of view: Ontologies are required to adopt completely the same semantic perspective, e.g. if the “Place” ontology in Hospital A [Figure 3] asserts “city and county are disjoint”, the “Place” ontology in Hospital B cannot adopt another point of view asserting that “city” is similar to “county”.

No support for directional semantic relations: Since a global model is used, the semantic constraints specified in a referring ontology will be completely transferred over the imported ontologies. If the “Place” ontology in Hospital B adds “city” is similar to “county”, the consistency of the “Place” ontology in Hospital A that asserts “city and county are disjoint” is violated.

Two broad classes of approaches are of our interest to assert and use semantic relations between contextual ontologies, because at the architectural level, the crucial difference between the notions of contextual ontology and global ontology is on how mappings between them are constructed:

Importing approach: In this approach, the ability of combining ontologies is restricted to the import of complete ontology and to the use of the imported elements by direct reference. With the import mechanism, a set of local models is globalized in a unique shared model. It is often assumed that references to external statements are made only for statements from imported ontology. Current ontology languages are mainly inspired from family of description logics, and to overcome this limitation of considering everything global (shared), these languages need to provide support for richer expressiveness.

Linking approach: A limited and completely controlled form of globalization is obtained by using explicit mappings (linking). In this approach, mappings are regarded as projections of a local representation onto another, and are first class modelling elements with a unique identity. In other words, mappings are viewed as part of a local representation. Linking approach inspires from DDL (Distributed Description Logics) [3, 4], where DDL assumes that contextual ontologies are nonoverlapping or disjoint, which initiates first step toward considering contextual ontologies as of distributed nature.
2 Context in Semantic Web

There are various definitions of context influenced by particular domain or application. From the Semantic Web perspective context can play a major role to capture, represent, model, or process the “user’s view of a domain” and make the overall (Global, Local) integration process meaningful. The goal of this paper is not to establish the universal definition of “Context” but to identify its role in Semantic Web through problem definition in medical domain. In the scope of this paper, context is defined as a “modifier of semantics”, that is context should be seen as entity that changes the semantics of information.

In order to define context aware framework, we need to categories two types of ontologies (global & local) with different set of scopes and responsibilities while complementing each other in their entirety. The original idea of this categorization is described in [1, 3] and our approach of categorization (Global & Contextual ontology) and features identification of contextual ontologies are defined with formal definition in [2, 4, 5]:

**Fig. 4.** Ontology space (global (G) & contextual ontologies (L1, L2))

**Ontology (Global semantics (G))** is shared model of some domain that encodes a view which is common to a set of different parties. Current Semantic Web works on this model.

**Contextualized Ontologies (local semantics (L1, L2))** are local (where local is intended to imply not shared) ontologies that encode a user’s view of a domain.

Figure 4 represents both forms of ontologies (global, contextual) that should be integrated in the representational infrastructure of the Semantic Web. Thus, on the one hand, the intended meaning of terms provided by parties which are willing to share information can be captured with global ontology (G) (“importing approach”). On the other hand, information that should not be shared should be contextualized (L1, L2) i.e. perceived as local ontologies. Therefore, as shown in Figure 4, a global ontology G is used and extended with local ontologies L1 and L2 to construct two different ontologies O1 and O2. The local ontologies L1 and L2 do not necessarily reflect a common conceptual view as they are constructed
taking into account the user’s perspective on local domain. However, these local ontologies can be related with each other via explicit mappings (“linking approach”) [2, 5].

3 Context-aware Framework

Figure 5 below represents a framework that is semantically-enabled, where two clinical information systems (A, B) exchange the contextual information between applications. This framework is based on the concept of Triple Space Computing (TSC) where Triple Spaces embody a communication paradigm for anonymous, asynchronous context exchange through publication and reading. Each published semantic data (Context) is persistent and uniquely identified by unique identification (URI) particularly tailored to machine-machine interaction patterns. The main parts of the context-aware framework as shown in Figure 5 are:

![Fig. 5. Context-aware Framework](http://tsc.deri.at)

**Ontology Parser:** It takes ontology from its user i.e. a Clinical Information System and parse it such that local and global view of the ontology can be obtained. When the parsing process is complete, it uses Rule generator component.
in order to create an association rule between the local and global ontologies and stores both the ontologies to the ontology space.

**Rule Generator**: Rule generator together with Ontology Parser creates the association rule between the local and global ontology and stores them in the Rule Space.

**Ontology space**: Described in Figure 4:

**Query Processor**: The query processor is responsible for decomposing a query to parts that are defined by using local ontology and to parts that are defined by global ontology in order to fill the query in its entirety. This is achieved by working together with Triple Space.

**Triple Space**: Triple Space is a virtual global space where applications can share information [6]. It consists of multiple non-overlapping spaces, which are structured into hierarchical trees of sub-spaces. It can be used both as an underlying storage system and as a communication channel [7]. Communication support provided by Triple Space is associative in nature. That is, it does not require explicit addressing of the communicating partners. Partners publish their information to the space and retrieve required information by supplying a template. The template provides the structure of the required message but not the explicit address of the partner who supplied this message.

**Context Space**: Context Space is a Triple Space which is capable of handling context information. That is a Triple Space together with Ontology Parser and Rule Generator forms a Context Space. In Context Space, Triple Space allows storage of linked data (e.g. both global and local ontologies, rules and instances) and asynchronous communication between different clinical information systems.

### 4 Related Works

Research works relevant to our approach are categorized in two dimensions:

**Logical framework**: A recent initiate from research community to accommodate distributed nature of systems in Semantic Web, Distributed Description Logics (DDL) [3] has been proposed, and refined form of approach based on DDL is C-OWL [2], Other approaches similar to DDL also been proposed recently, like E-connections and Package-extended Description Logics (P-DL) [4]. Our approach is inspired from these initiatives and we are working on improving the logical framework according to our above proposed framework.

**Application framework**: EU projects like SemanticHealth and Artemis [8] are providing the semantic interoperability solution using owl (web ontology language), their approach incorporates importing mechanism and contextualization is achieved by design time ontology engineering e.g. Artemis uses Archetype to process contextual information that is based on owl importing mechanism.

---


5 Conclusion and Future Works

Currently most of the research on context-awareness focuses on capturing local settings (time, location, etc.) with the help of sensors or applications but our approach towards context is to see it as a key entity that can solve major integration and interoperability problems in Semantic Web. As most of the current information systems (especially based on standards) bind the knowledge, information and data together, framework described above can deal with global and local knowledge semantically because Semantic Web based solution for integration and interoperability must be capable of managing shared (global) and local knowledge. Our work on logical framework is inspired from [1, 2] and we are working on further improvements in the direction of Distributed Description Logic (DLL). DDL connects two contextual ontologies via explicit mapping (a.k.a bridge rules) but when the number of involved contextual ontologies may increase, the explicit declaration of such bridge rules may become tedious. This limitation demands an efficient representation of mapping between contextual ontologies and corresponding reasoner.

Acknowledgement

The work presented in this paper was supported (in part) by the L’ion project supported by Science Foundation Ireland under Grant No. SFI/02/CE1/I131 and (in part) by SAOR project No. CFTD 2005 INF 224 supported by Enterprise Ireland and (in part) by the EU projects TripCom No. IST-4-027324-STP, RIDE No. IST-27065-CA.

References