Ontology Generation from XML Documents

[LAMARA Aymen, MOSTFAI Sihem]

***Abstract*—[1]XML has become the de facto standard for data exchange in the Internet. It allows different parties to exchange data by providing common understanding of the basic concepts in a domain. XML covers the syntactic level, but lacks support for expressing semantics. Ontologies provide a promising technology for domain knowledge representation and sharing using classes, properties and instances; they support efficient reasoning and convey domain semantics by their expressive power. In this paper we survey the most relevant strategies for ontology generation from XML documents.**

***Keywords*—*component*, XML, Ontology generation, Semantic.**

I. Introduction

Nowadays, the web is the world's largest source of information; it has brought interoperability to a wide range of applications. Hence, managing large data collections becomes very tedious with the increasing number of data sources, and their varying and heterogeneous formats. To avoid these proprietary formats and facilitate their return, the markup languages were proposed and the notion of structured document has emerged. Thanks to formalism languages [1] and especially XML based technology; it is now possible to provide a means of information interchange on the World Wide Web, as well as a semi structured data model for integrating information and knowledge.

Today, XML has reached a wide acceptance; it has become the de facto standard for data exchange via Internet. It allows representing not only structured data but also irregular or poorly structured information (semi-structured documents) via XML explicit tags.

Indeed, XML covers the syntactic level of a document, but lacks support for efficient sharing of conceptualizations. In other words, it lacks support for expressing semantics of domain knowledge.

Ontologies provide a promising technology for domain knowledge representation using classes, properties and instances to describe information in various and distributed environments, especially the World Wide Web. Ontology could be defined as an *"explicit specification of conceptualization"* [9], it plays a key role in describing the "semantics" of data. By means of ontologies, web documents are given well defined meaning, better enabling web-based agents to perform automatic tasks such as information retrieving and inference drawing.

The semantic representation of data as ontology, allows extracting knowledge by applying ontology definitions and axioms to XML data, in order to infer knowledge, which is not explicitly represented in the source. In addition, ontologies play a central role in realizing the burgeoning vision of the semantic Web: data should be more sharable and understandable by humans as well as software agents because their semantics will be represented in Web-accessible ways[2].

In order to bring the vision of the semantic web to its full potential, tremendous efforts are being made and several methods are investigated. Deriving ontologies from XML documents in order to understand their semantic is one such approach. The objective of this paper is to present a survey on existing studies of mapping XML documents to ontologies. We evaluate and compare these methods in order to show their main characteristics, strengths and weaknesses.

The rest of this paper is organized as follows: In section 2, we present essential mapping strategies developed in this domain. In section 3, a comparative study is provided together with a discussion of results and also open challenges for XML to Ontology Mapping. Finally, the paper is ended by some important conclusions and prospects, suggested in ontology generation from XML Documents.

II. Mapping XML to Ontology

A. *XML Based MArkup*

From its early days and its adoption by the W3C as a standard for data exchange, XML went thru distinct development phases, giving birth to a variety of "dialects", depending on growing requirements and improvements. Hence, we have self-contained XML documents, XML-DTD, XML Schema, RDF and so forth. Giving a comprehensive description of all XML varieties is out of the scope of this paper; however, we will report herein, XML constructs that are mentioned in the presented mapping schemes.

XML is a markup language used for describing structured (i.e. databases …) or unstructured (i.e. web pages ...) document content, it is considered as a platform for data storage and exchange over the web. An XML document is said validated, if it is conforms to the rules of Document Type Definition ([2]DTD) or XML Schema. They both define XML document structure with a list of legal elements and blocks; except that XML Schema is richer and more powerful than DTD for describing XML document content. However, XML

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[1]XML: eXtensible Markup Language
[2]DTD: Document Type Définition
[3] RDF: Resource Description Framework.

is luck for expressing data semantics. For this case RDF model and OWL language have emerged.

[3]RDF [29] is the first piece of semantic web for presenting web metadata as triples (subjects->predicates->objects). Which allows their automatic treatments. Hence, RDF Schema allows defining meta-data schema and enriches description of RDF documents.

[4]OWL [13] ontology language extends RDFS vocabulary and adds axioms (description logic), to express more complex relations of classes and properties. It allows Knowledge representation, exchange, combination (inference of new knowledge). In addition, RDF/RDFS and OWL are W3C recommendation since 2004, and both are based XML syntax.

B. *XML to ontology mapping*

Extracting ontology from XML document can be done in different ways; as indicated in **Figure1**.

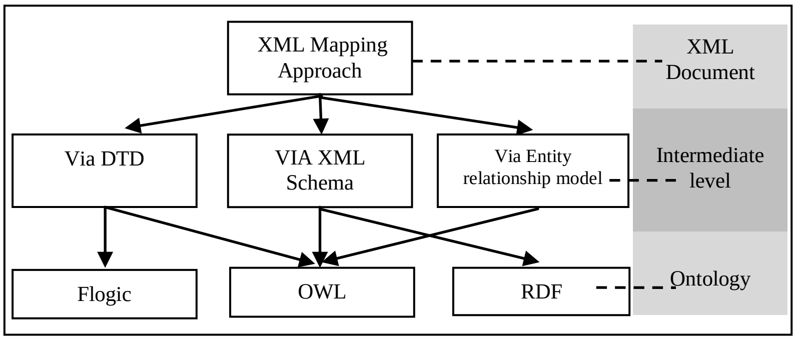

Figure1: XML to ontology mapping schemes.

Depending on the XML document type handled as input, and the ontology language produced as output, we can classify the mapping schemes, into the following broad categories, as shown in **Figure1**:

- *Mapping with DTD, to produce ontologies in Flogic language or OWL,*
- *Mapping with XML Schema , to produce ontologies in OWL or RDF,*
- *Mapping with entity relationship model to produce ontologies in OWL.*

1) Mapping with DTD

DTD is the basic schema mechanism for XML Documents. It is used in this case as a way to generate ontology. Depending on the ontology format/language produced, we can distinguish the following schemes:

a) Mapping to Flogic

- ***Ronaldo dos Santos and al*** [3] [4], proposed a ***DTD Conversion*** process for XML sources integration. The later generates ontology for concepts presented in XML sources through the execution of three conversion rule classes: ***Transformation rules***, ***Restructuring rules***, ***Cardinality rules***. The generated ontology acts as a global schema for user queries. The mapping process is preceded by a user intervention step to provide ontology semantic adjustment.

b) Mapping to OWL:

- *Lu Xiao and al* [6] proposed an automatic process for XML to OWL mapping, by using elements and attributes of DTD. They constructed a table of synonyms, in which XML elements and attributes correspond to the same semantic concepts of ontologies. The proposed method describes the given ontology with a [5]DAG and checks the structural validity against the DAG to constructs the mapping rules.

2) Mapping with XML Schema

a) Mapping to OWL

- ***Bedini and al*** [7] proposed a tool called ***JANUS*** for XML schema to OWL mapping, this tool can generate ontologies from a large source of XML Schemas corpus automatically. The proposed approach makes it possible to mine XML Schema sources to extract enough knowledge to build semantically correct and expressive OWL ontologies.
- **Thomas Bosch and al** [8] used a generic multilevel approach to generate OWL Ontologies from any XML Schema automatically, by using XSLT Transformation. It is based on XML Schema Meta-model of XML Schemas, which is transformed directly to a generic ontology consisting of *class hierarchies, data-type properties, and object properties*. They represent classes that correspond to elements information items located in XML Schemas. These ontologies are connected to domain ontology(ies) by means of *class equivalence relationship*, and they are enriched with semantic domain information with experts help.

However, there is still an important link missing in these approaches [7] [8]: *the connection between existing XML data sources and ontology instances.* The next approaches answer this question:

- ***H. Bohring and al*** [19] designed ***XML2OWL***, an automatic OWL ontology instances generator from XML Data. The ontology creation has an XML schema as input and uses [6]XSLT. If no XML schema exists, The ***XML2OWL*** tool generates it automatically from existing XML data sources. The transformation rules are summarized as follows: *OWL classes are derived from complex types or complex contents. OWL datatype-Properties are merged from simple types and XML attributes. When an XML element contains another element, an Object-Property is created between their corresponding classes*.
- ***Rodrigues and al*** [20] proposed a java framework called ***JXML2OWL*** that uses manual mapping between XML Schema and an existing OWL model to generate XSLT mapping rules. Once made, the tool uses these rules to automatically convert XML data sources to a semantic model defined in OWL.
- ***Damien Lacoste and al*** [21] developed ***EXCO*** approach that helps automating model extraction and

[4]OWL: Ontology Web Language.
[5]DAG: Directed Acyclic Graph.
[6]XSLT: Extensible Stylesheet Language Transformation.

instance generation. The conversion process is done in two steps that can be parallelized: *1) OWL model extraction from XML schema files, and 2) XML instances association to their corresponding OWL model to obtain the ontology instances*. It is based on simple and commonly available technologies like XSLT or [7]Perl and it is able to process multiple XML instances in a single round.

- ***Yuan An et al*** [22] defined a generic and formal approach for translating XML documents into an OWL-DL ontology instances. It is based on a semantic mapping between XML Schema and an Ontology discovered by their prototype tool [14].The developed algorithm, used for computing a *canonical solution* enables the resulting ontology to answer queries by using data in the XML documents.
- ***Nora Yahia et al*** [23] proposed a **java** tool to automatically generate OWL ontology instances from XML data sources. This approach is based on XML schema which is automatically constructed from a given XML Data source. The process follows mapping rules such as: *OWL Classes emerge from complex types, and element group declarations. Object-properties emerge from element/sub-element relationships. Datatype-properties emerge from attributes and simple types.*
- ***TAN Jieping and al*** [25] proposed a general solution for bootstrapping ontology development from XML documents that conform to XML Schemas. It firstly defines an OWL model for each XML Schema, then it generates the ontology instances. Based on XPath expressions, it selects XML element/attribute and maps them to the corresponding position in the ontology.
- ***R. Ghawi and al*** [26] proposed ***X2OWL*** framework to automatically translate XML data sources to local ontology. It generates the ontology structure from XML schema, which can be generated automatically from XML document instance. The translation is based on a set of bridging correspondences between XML entities and OWL terms. ***X2OWL*** copes with all possible design patterns of XML Schemas: simple and complex cases that arise from the reuse of global types and elements. Expert adjustments on generated ontology and mapping bridges are required as a finalization step.
- ***Patrick Lehti and al*** [27] proposed an approach for XML data integration with OWL by mapping heterogeneous data sources to a common global schema. The first step consists of mapping XML Schema to OWL model, then XML Schema instances are mapped to OWL instances in the second step. These constructs are mapped as follows: *Complex type definitions correspond to OWL classes. Simple type definitions are mapped to OWL data-types and Element and attribute declarations are mapped to OWL properties.*

b) Mapping to RDF:

According to proposed approaches, we can distinguish two major categories [11] for this conversion:

1- Fixed XML to RDF Mapping

It applies fixed mapping rules the same way to all XML documents, as exemplified by the following systems:

- ***Steve Battle*** [10] developed ***GLOZE,*** a tool that works with Jena framework, for a bidirectional mapping between XML documents and RDF (XML→RDF and RDF→XML) based on XML Schema. The mapping rules could be summarized in: *Complex types are mapped to RDF classes. Elements and attributes are mapped to either RDF object or data-type-properties. If element content is defined by a complex type, it is mapped to an object-Property; otherwise, it is defined by a data-Type property (content is defined by a simple type).*
- ***Roberto García and al*** [12] proposed an approach that is complemented by a transparent mapping of metadata from XML documents to Semantic Web domain (RDF). Therefore, a structure-mapping approach has been selected [14], and it is also possible to take a model-mapping approach [27].

2- Ontology dependent XML to RDF mapping

The fixed XML/RDF mapping lacks extracting correct semantic from XML documents. To avoid this, the ontology based mapping is proposed, to ensure more robust conversion. This categories is illustrated by:

- ***C.Cruz et al*** [15] proposed an ontology-based approach to integrate XML data (modeled by XML Schema). It aims to make two XML documents interoperable at the semantic level while retaining their nesting structure [24]. This method uses the fixed mapping described previously, to translate XML documents to RDF local ontologies. Then these ontologies are merged into a global one, in a semi-automatic process. Hence, the later mentioned encodes mapping information between each local ontology concept and the corresponding XML element. Furthermore, the global ontology unifies the query access and establishes semantic connections among the underlying individual databases. The process produces a *mapping information table* that links the global ontology and concepts in the local ontologies.
- ***Davy Ven Deursen*** [11] proposed a generic approach for XML data to RDF conversion with an ability to handle complicated cases. The process is ontology-dependent by means of a mapping document that describes the link between an XML Schema and OWL ontology. The developed tool ***XMLtoRDF*** translates the XML data to RDF instances of the given ontology. It is possible to combine multiple XML Schemas to be mapped to a single ontology or multiple ontologies.

[7]Perl: http://www.perl.org/

- ***Matthias Ferdinand and al*** [17] proposed a general solution for automated binding of XML structured data to Semantic Web languages. They have defined a direct mapping from XML Schema to [8]OWL as well as mapping from XML to RDF graphs. These two steps are interdependent, and Once XML Schema/OWL links are established, it is possible to generate RDF instances for the corresponding ontology. In terms of engineering concepts, they have incorporated the RACER DL reasoner [16] and used its inference services to realize a real-world e-business Web application.
- ***Gerald Reif Vienna*** [18] proposed an approach called ***WEESA*** related to Semantic Web applications, based on established Web Engineering methodologies. It manually defines mapping bridges from XML Schema to ontology. Once constructed, it is used to automatically generate RDF meta-data from XML Document content. According to ***Gerald Reif Vienna,*** "The ***WEESA*** system provides also a way to generate (X)HTML web pages as RDF annotations with regard to constructs defined in the ontology".

3) Mapping with Entity-Relationship Model

It is based essentially on two main steps: a first mapping between XML documents to entity-relationship models, followed by entity-relationship model to ontology transformation. In this category, we can mention the work of **J. Xu and W. Li** [28], who proposed a way to transform XML documents to OWL ontology with the help of entity-relationship model. The extracted OWL ontology is expressed using ad-hoc vocabularies for describing relational database, therefore it cannot be considered as domain ontology.

III. wrap-up and Discussion

In order to have a better idea about the stated mapping methods, they are presented in a chart structure to exhibit their main features and show more clearly their "pros and cons". This will help in comparing the methods in a more consistent way and ultimately to draw important remarks regarding the open issues that need to be addressed further in this field.

A. *Synthetic recap chart*

The described mappings are summarized in table1. From the previous study, we can derive many criteria that can help to classify and compare the stated methods, namely:

- *The automation level*: to indicate whether a mapping scheme is fully automatic (FA) or semi-automatic (SA).
- *The input/output type*: several methods are aimed at creating ontology from single XML document [4] [5] [8] [25]. Others aim to generate ontologies from heterogeneous XML data sources [15] [21] [23] [26].
- The *generalization ability*: to indicate whether a mapping scheme generalizes well to more complex XML document types [17] [22] ("imports", "include" and internal references), or is only restricted to simple cases [5] [6].

TABLE I. XML TO ONTOLOGY RECAP

Mapping approach		**Output format**	**Automation level***	**Generalization Ability/ Special features**
1: Mapping with DTD	R.dos Santos et al. [3] [4]	Flogic	SM, to provide semantic Adjustment	- uses a DTD to connect XML documents to ontology.
	L.Xiao et al. [6]	OWL	SM, to define synonyms table.	-Automatic generation of the mapping rules.
2: Mapping with XML Schema	Bédin et al. [7]	OWL	FA	-XML Schema contains complex cases
	T. Bosch, et al. [8]	OWL	FA	-Based on XML Schema meta-model of XML Schemas. XML Schemas contain complex cases
	H.Bohring et al. [19]	OWL	SM, only when no XML Schema is available, a manual mapping is used	- Able to handle "include" in XML Schema files. - Able to handle internal references. - uses XSLT files.
	Rodrigues et al. [20]	OWL	SM, to define bridges between XML Schema and existing ontology	- does not handle "imports" in XML schema files. - Able to handle internal references.
	D.Lacoste et al. [21]	OWL	FA	- Able to handle "imports", "include", "internal references" cases. -parallelism of conversion. -Based on taxonomy and data extracted from XML tags.
	Yuan An et al. [22]	OWL	FA	-the resulting ontology is able to answer user queries using information in XML documents
	N. Yahia et al. [23]	OWL	FA	-The XML Schema is generated automatically from XML Data Sources.
	T. Jipeng et al. [25]	OWL	FA	-Input XML Documents conform to predefined XML Schema.
	R.Ghawi et al. [26]	OWL	SM, for a refinement step if necessary.	- If no XML Schema exists it will be generated automatically
	S. Battle [10]	RDF	Not mentioned	-the mapping approach is reversible.
	R. Garcia et al. [12]	RDF	Not mentioned	-This approach is better when XML metadata is semantically exploited for concrete purposes.
	C.Cruz et al. [15]	RDF	SM, only to merge local ontologies to get a global one	-simple mapping is defined -heterogeneous XML document can be mapped
	D. ven dersen [11]	RDF	FA	-Uses another input: a mapping document.
	M. Ferdinand et al. [17]	RDF	FA	-incorporated the RACER DL reasoner [16] and used its inference services
	G. Vienna et al. [18]	RDF	SM, to map XML Schema model to ontology model	-Based on predefined XML Schema
3: Mapping with Entity-Relationship Model	J.XU et al. [28]	OWL	Not mentioned	-Two main steps: 1/ XML->Entity relation model, 2/then relation model->OWL ontology

*FA= Fully

From table 1, we can draw some important remarks.

The automatic ontology generation methods [11] [5] [7] [21] [23] [25] from XML documents use a predefined schema such as (DTD's, XML Schema …). If it does not exist, the schema is constructed from XML Data sources [23] [26]. However, these approaches in most cases [12] [23] apply the same predefined mapping rules for heterogeneous XML documents. Indeed, if the user has no control over the newly generated ontology, the automatic process might not capture the right implicit semantics existing in XML documents, and the process is only about changing the XML syntax level to a higher one (from XML to OWL or RDF …), Thus, the generated ontologies are quite primitive, and are not semantically richer than the initial XML document. Furthermore, the automatic nature of mapping generation causes some invalid mapping bridges which requires a refinement step in some systems [26] [3][4].

The semi-automatic methods [3] [4] [18] [19] [20] [26] allow expert interventions to modify the ontology structure manually in different ways: For refining and correcting the invalid mapping bridges [3] [4] [26], or to describe the correspondence between Schemas and the predefined ontologies [20], or even, to express the mapping rules according to a specific type of XML Documents [6] [18]. Furthermore, the incorporation of human intervention is sometimes necessary to guide the system in extracting the relevant semantics of XML documents. However, the generated ontologies are richer than the initial XML document, and the mapping process is more meaningful than automatic one; because it focuses on extracting semantics from XML Documents and generating new domain knowledge.

As a result, the previous study indicates that the mapping process considers only XML tags as significant semantic units. XML Documents can be either data centric or text centric. For the former, XML tags could be sufficient to derive the document semantic, whereas for the later, they represent only the general structure in terms of: section titles, paragraphs … The biggest semantic content is generally contained in the text surrounded by these tags. Thus, relying on structural tags only does not convey truly document semantic.

In order to solve this issue, we suggest to extend the previous techniques to be able to handle the text included between tags, using natural language processing (NLP) tools. Furthermore, NLP Tools (taggers namely) can help in capturing text semantic. Therefore, exploiting both semantic sources: structure tags and plain text, may yield deeper semantic content in the resulting ontology.

Moreover, if we add information about the document context (domain) this could lead to better results in terms of semantic description.

B. Open challenges for XML to Ontology Mapping

Based on recent research literature, and on previous mentioned mapping goals, we can distinguish two major levels of challenges:

1) Syntactic level mapping

- Developing more powerful and efficient tools to deal with complex mapping cases, as most mapping schemes are based on simple XML document examples which potentially requires extra efforts to be generalized (imports, external references ….)
- Designing a fully automated mapping tools, because intensive user involvement is still needed in some approaches, which reduces the efficiency of such systems
- We could also suggest to minimize the number of steps to get the resulting ontology, by means of optimization techniques for example.

2) Semantic level mapping

- Extracting all domain knowledge from XML document (concepts, relations, properties …)
- Exploiting the information presented in XML documents to answer the user queries.
- Supporting inferences and extract new domain knowledge from existing ones.

IV. Conclusion

Ontology generation from XML Document is a valuable mechanism that should be integrated to World Wide Web in order to make semantic web tangible.

The main objective of this study is to present an overview of ontology generation from XML document strategies. We suggest that an efficient generation method should take into account several aspects, especially:

- *It should be based on XML schemas instead of documents.*
- *Rely on XML schema's type declarations (instead of element declarations) in order to benefit from the reusability of types by several elements within the schema.*
- *It should provide mapping bridges that specify the correspondences between XML entities and ontology terms (defined by expert).*
- *Refine the generated ontology and mapping bridges.*
- *The resulting ontology should be expressed in OWL for reasoning purposes.*
- *Consider the document types variety.*

Regarding all these aspects, there's still room for wide investigations in this field for the near future.

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