MATCHING OF ENHANCED XML SCHEMAS WITH A MEASURE OF STRUCTURAL-CONTEXT SIMILARITY

Amar Zerdazi and Myriam Lamolle
LINC – University of Paris VIII, IUT of Montreuil – 140, rue de la Nouvelle France, 93100 – Montreuil, France

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Abstract: Schema matching is a critical step in integration of heterogeneous data sources. Recent integration work has mainly focused on developing matching techniques to find equivalent elements among the different XML sources. In this paper we propose a new approach to structural similarity measure based on the notion of context, between entities of the Enhanced XML Schemas, called EXS. In our approach, the set of the EXS schemas, are considered like a federation of XML schemas descended of different heterogeneous sources schemas (relational, object, XML, etc.) and enriched by the semantic metaknowledge. We present here the major problems bound to this crucial task, notably with regard to the semantic of schemas. So, we propose a structural matching algorithm. The algorithm takes two schema graphs as input, and produces as output a mapping between corresponding nodes of the schema graphs. After our algorithm runs, we expect a human to check and adjust the results.

1 INTRODUCTION

Schema matching is a schema manipulation process that takes as input two heterogeneous schemas and possibly some auxiliary information, and returns a set of dependencies, so called mappings that identify semantically related schema elements (Rahm et Bernstein, 2001). In practice, schema matching is done manually by domain experts (Miller and al., 2000), and it is time consuming and error prone. As a result, much effort has been done toward automating schema matching process. This is challenging for many fundamental reasons. According to (Drew et al., 1993), schema elements are matched based on their semantics. Semantics can be embodied within few information sources including designers, schemas, and data instances. Hence schema matching process typically relies on purely structure in schema and data instances (Doan and al., 2001). Schemas developed for different applications are heterogeneous in nature i.e. although the data they describe are semantically similar, the structure and the employed syntax may differ significantly (Abiteboul et al., 1997). To resolve schematic and semantic conflicts, schema matching often relies on element names, element datatypes, structure definitions, integrity constraints, and data values. However, such clues are often unreliable and incomplete. Schema matching cannot be fully automated and thus requires user intervention, it is important that the matching process not only do as much as possible automatically but also identify when user input is necessary and maximally used (Boukottaya et al., 2004).

Consequently, a lot of work on schema matching tried to automate this process. The main goal of this paper is to propose a novel approach for structural matching based on the notion of structural node context. We propose a structural algorithm that can be used for matching of Enhanced XML Schema, called EXS. The EXS schemas, are considered like a federation of XML schemas descended of different heterogeneous schema sources (relational, object, XML, etc.) and enriched by the set of semantic metaknowledge. The algorithm that we suggest to

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perform structural matching is based on the following idea. The first step assigns for each node in source and target schema a context. After what, such context is compared to produce a node similarity coefficient that reflects structural similarity between schema nodes. The second one uses produced node similarity to derive a set of mappings.

The rest of paper is organized as follows. In section 2, we summarize some examples of recent schema matching algorithms that incorporate XML structural matching. Section 3 gives a brief overview of the Enhanced XML Schema (EXS), with his schema graph (EXS graph). This graph is used in the matching process for the measure of node context similarity. Section 4 presents and discuses our algorithms for structural contexts. Section 5 concludes the paper.

2 RELATED WORK

Schema matching is not a recent problem for the community of databases. (Castano and De Antonellis, 1999) developed the ARTEMIS system employ rules that compute the similarity between schemas as a weighted sum of similarities of elements names, data types, and structural position. With the growing use of XML, several matching tools take into consideration the hierarchical and deal essentially with DTDs. In the following, we present some examples of recent schema matching algorithms that incorporate XML structural matching.

We do not present here of exhaustive manner all existing systems for schema matching, but those that appeared us interesting for the problematic that they raise or for the considered solutions.

2.1 Cupid

Cupid is a hybrid matcher combining several matching methods (Madhavan et al., 2001). It is intended to be generic across data models and has been applied to XML and relational data sources. Cupid is based on schema comparison without the use of instances. Despite these extensions, Cupid does not exploit all XML schema features such as substitution groups, abstract types, etc that could give a significant clue in solving XML schema matching problem.

2.2 LSD

The LSD (Learning Source Description) system (Doan et al., 2001) uses machine-learning techniques to match a new data source against a previously defined global schema. LSD is based on the combination of several match result obtained by independent learners. This approach presents several limitations since it does not fully exploit XML structure. Besides, the only structural relationship considered within the LSD system is the parent-child relationship, which is not sufficient to describe the context of elements to matcher.

2.3 Similarity Flooding

In (Melnik et al., 2002), authors present a structure matching algorithm called Similarity Flooding (SF). The SF algorithm is implemented as part of a generic schema manipulation tool that supports, in addition to structural SF matcher, a name matcher, schema converters and a number of filters of choosing the best match candidates from the list of ranked map pairs returned by the SF algorithm. SF ignores all type of constraints while performing structural matching. Constraints like typing and integrity constraints are used at the end of the process to filter mapping pairs with the help of user.

2.4 SemInt

SemInt (Li and Clifton, 1994), (Li and Clifton, 2000) represents a hybrid approach exploiting both schema and instance information to identify corresponding attributes between relational schemas. The schema-level constraints, such as data type and key constraints are derived from the DBMS catalog. Instance data are exploited to obtain further information, such as actual value distributions, numerical averages, etc. For each attribute, SemInt determines a signature consisting of values in the interval [0,1] for all involved matching criteria. The signatures are used first to cluster similar attributes from the first schema and then to find the best matching cluster for attributes from the second schema. The clustering and classification process is performed using neural networks with an automatic training, hereby limiting pre-match effort. The match result consists of clusters of similar attributes from both input schemas, leading to m:n local and global match cardinality.

3 OUR SCHEMA

3.1 Enhanced XML Schema

The objective of our approach is to provide a flexible integration model, capable to federate different heterogeneous data sources while holding in account the structural and semantic dimensions of schema sources. For it, the definition of our model must include a minimal number of entities to manipulate but sufficient to translate schemas (Lamolle and Mellouli, 2003), (Lamolle and Zerdazi, 2005). We defined rules of extraction that homogenise the representation of the different schema sources to integrate while expressing them under shape of XML-Schemas (XML-Schema, 2001). This phase is called structural modelling. Once this transformation made, the semantic part of the XSDi created is refined by the addition of metaknowledge (Semantic modelling) (Zerdazi and Lamolle, 2005), which are deducted (for instance, the catalogue of data in the case of relational databases), or are specified by the expert of the domain.

3.1.1 Structural Modelling

The enhanced XML schema (noted EXS) as it is modelled at the time of the first phase (structural modelling) is composed of three types of entity.

Concept: a concept in the EXS schema is equivalent to the notion of entity in an ER diagram, a class in an object-oriented diagram or an element in the semi-structured data model. He can generate properties and/or include other concepts and having relations with some concepts.

Relation: two concepts are connected via a relationship. A relationship in EXS schema represents a nesting relationship. Each relationship has a degree and some constraints, and possesses also a predefined category and other metaknowledge.

Property: a property in the EXS schema is equivalent to the notion of attribute in the relational, object-oriented or the semi-structured data model. A property can be a property of a concept or property of a relationship.

3.1.2 Semantic Modelling

The semantic enrichment phase follows the phase of structural modelling of the EXS schemas. The semantic dimension of entities (concepts, relations, and properties) is enriched by the contribution of metaknowledge at the time of a survey more deepened of the entity state (structure, completeness, level of encapsulation, type of association, constraints on properties, cardinality, etc.). These metaknowledge are used at the time of the integration phase in order to get more precise correspondences between EXS schema. The semantic enrichment consists in spreading the structure of entities (concepts, relations, properties) via attributes and facets.

3.2 EXS Schema Graph

We model an EXS schema as a directed labelled graph with constraint sets. An EXS schema graph consists of series of nodes that are connected to each other through directed labelled links. In addition, constraints can be defined over nodes and links (Zerdazi and Lamolle, 2006). Figure 1 illustrates a schema graph example.

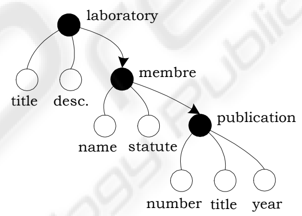


Figure 1: An EXS schema graph example.

4 STRUCTURAL MATCHING ALGORITHMS

In this paper, we focus on understanding, modelling and formalizing the problem of structural XML schema matching. The scope of this paper, in the context of our research, is indicated in figure 2.

The first phase of our matching process concerns the **terminological matching (T.M)**. The aim of this phase is to compute the similarity between schema nodes based on the similarity of their labels. The proposed matching method takes as input a matrix of terminological similarity coefficients (ranging in [0,1]) between source and target nodes as well as semantic relationships. Terminological similarity uses WordNet (Miller, 1995), (Miller et al., 2000) as auxiliary information.

Techniques of terminological matching compare only nodes between a source schema and target schema. These matching techniques may provide incorrect match candidates. Structural matching is used to correct such match candidates based on their **structural context**. For example, assume that we let the schema graph in figure 3 be the source schema

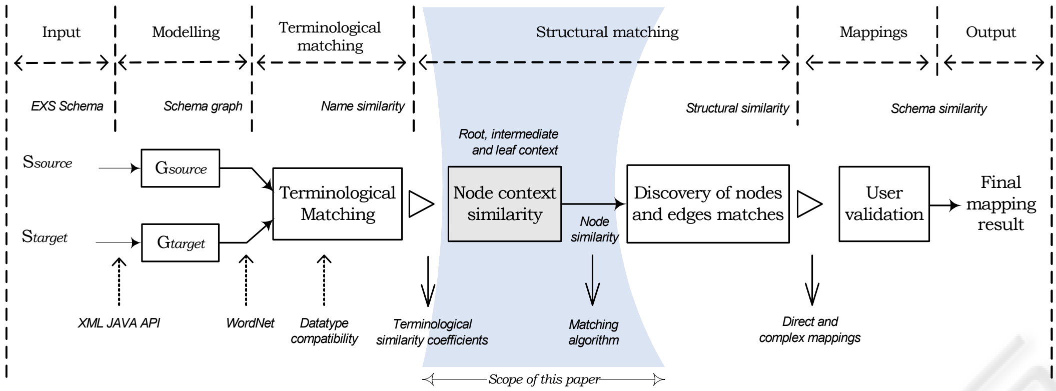


Figure 2: The matching process.

graph, denoted G_{source} and the target schema graph, denoted G_{target}.

Based on the two terminological matching and datatype compatibility techniques, we obtain a match between node *laboratory/address* (of G_{source}) and node *Author/Address* (of G_{target}), while the first is a laboratory address and the second is an author address. The structural matching (following phase in the matching process) compares the contexts in which nodes appear and can deduce that the two nodes *address* do not match, instead the node *address* in the source schema match the node *location* in the target schema and source relationship between *laboratory* and *address* match target relationship between *laboratory* and *location*. In this paper we only present our structural matching relies on the notion of *node context*.

4.1 Node Context Definition

The aim of structural matching is the comparison of the structural contexts in which nodes in the schema graph appear. Thus, we need a precise definition on what we mean by node context. We distinguish three kinds of node contexts depending on its position in the schema graph.

The root-context: A root context of a node n_i is defined by the *root path* having n_i as its ending node and the root of the schema tree as its starting node. For instance, the root-context of node *publication* in figure 3(a) is given by the path *laboratory/member/publication* which describes the publications of a member belonging to a laboratory. If the root-context of the root node is empty, it is assigned a *null* value.

The intermediate-context: An intermediate-context of node n_i includes its immediate subnodes. The intermediate-context of node reflects its basic structure and its local composition. For instance, the intermediate-context of node *Laboratory* of figure 3(a) is given by *(name, address, and member)*. The intermediate-context of an atomic node is assigned a *null* value.

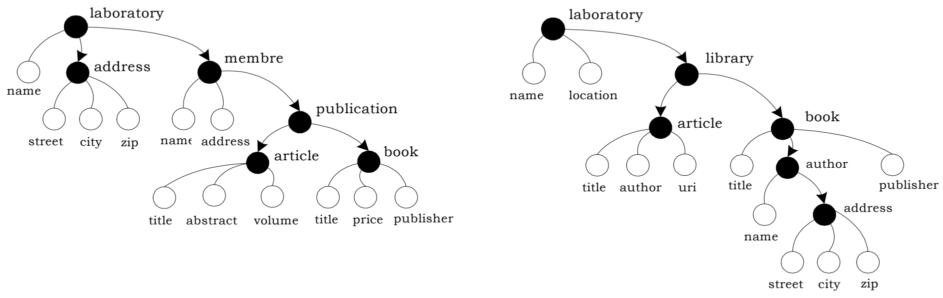
The leaf-context: Leaves in the XML tree represent the atomic data that the schema describes. The leaf-context of node n_i includes the leaves of the subtree rooted at n_i. For instance, the leaf-context of node *Publication* in the schema graph of figure 3(a) is given by the set *(title, abstract, volume, title, price, and publisher)*. The leaf-context of an atomic node is assigned a *null* value.

Finally, the context of a node is defined as theunion of its root-context, its intermediate-context and its leaf-context. Two nodes are structurally similar if they have similar contexts. The notion of context similarity has been used in Cupid and SF; however none of them relies on the three kinds of contexts. To measure the structural similarity between two nodes, we compute respectively the similarity of their root, intermediate and leaf contexts. In the following we describe the basis needed to compute such similarity.

4.2 Node Context Similarity

4.2.1 Root-Context Similarity

The root context similarity, *root_ctxSim* captures the similarity between two nodes based on their root context. Since the root context of a given node n_i is described by the root path (the path from the root to n_i), computing root contexts similarity is equivalent to comparing two paths. The *root_ctxSim* between



(a) A schema graph source *(Gsource)* (b) A schema graph target *(Gcible)*

Figure 3: An EXS schema graph (source and target).

two nodes n_1 and n_2 is given by the path resemblance measure between the two paths *(root$_1$, n$_1$)* and *(root$_2$, n$_2$)* weighted by the terminological similarity *(TSim)* between n_1 and n_2.

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root_ctxSim (n1, n2)← pathSim
((root1, n1),(root2, n2))× TSim(n1, n2)
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4.2.2 Intermediate-Context Similarity

The intermediate-context similarity *(inter_ctxSim)* is obtained by comparing nodes immediate descendents (children) sets including subtree. Given a node n_1 having *m* immediate children represented by the set $(n_{11},\ldots n_{1m})$ and node n_2 having *k* immediate children represented by $(n_{21}, \ldots n_{2k})$. To compute the similarity between these two sets, we (i) compute the terminological similarity between each pair of children in the two sets, (ii) select the matching pairs with maximum similarity values and (iii) take the average of best similarity values. Algorithm 1 illustrates how we compute the intermediate-context similarity.

Algorithm 1 – INTERMEDIATE-CONTEXT SIMILARITY

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1. ***Input***: n_1, n_2, TSimMat *// having respectively // m and k children*
2. ***Output***: Inter_ctxSim
3. ***Begin***
4. inter_sim $\leftarrow \text{MAX}_{i\in[1,m], j\in[1,k]} \{(n_{1i}, n_{2j}, \text{TSim}) \in \text{TSimMat}\}$
5. sim_pairs $\leftarrow (n_{1i}, n_{2j}, \text{Sim\_Inter})$
6. inter_ctxSim $\leftarrow \dfrac{\sum_{(n1i,\, n2j,\, inter\_sim)\in sim\text{-}pairs} (\text{inter\_sim})}{\text{MAX}\,(m, k)}$
7. return inter_ctxSim
8. ***End.***

4.2.3 Leaf-Context Similarity

Since the effective content of a node is often captured by the leaf nodes of the subtree rooted at that node, we compute leaf context similarity of two nodes n_1 and n_2 by comparing their respective leaves sets, *n_1\{leaves\}* and *n_2\{leaves\}*. Thus to compute the similarity between two leaves $l_1 \in n_1\{leaves\}$ and $l_2 \in n_2\{leaves\}$, we propose to compare the contexts in which these leaves appear. If a leaf node $l \in n_1\{leaves\}$, then the context of *l* is given by the path from n_1 to *l*. The context similarity of two leaves is then obtained by comparing such paths, and the similarity between two leaf nodes is obtained by comparing their context similarities and their terminological similarity. Algorithm 2 illustrates how we compute the leaf-context similarity.

Algorithm 2 – LEAF-CONTEXT SIMILARITY

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1. ***Input:*** n_1, n_2 *// having respectively m and k leaves*
2. ***Output:*** leaf_ctxSim
3. ***Begin***
4. for each $l_{1i} \in n_1\{\text{leaves}\}$
5. for each $l_{2j} \in n_2\{\text{leaves}\}$
6. leaf_sim $(l_{1i}, l_{2j}) \leftarrow \text{pathSim}((n_1, l_{1i}), (n_2, l_{2j})) \times \text{TSim}(l_{1i}, l_{2j})$
7. temp_sim $\leftarrow \text{MAX}_{i\in[1,m], j\in[1,k]} (l_{1i}, l_{2j}, \text{leaf\_sim}\}$
8. sim_pairs $\leftarrow (n_{fk}, n_{fh}, \text{temp\_Sim})$
9. leaf_ctxSim $\leftarrow \dfrac{\sum_{(l1i,\, l2j,\, leaf\_sim)\in sim\text{-}pairs} (\text{leaf\_sim})}{\text{MAX}\,(m, k)}$
10. return leaf_ctxSim
11. ***End.***

The goal of this measure of structural-context similarity, it easier to optimize and to automatically generate transformation scripts expressed in XSL language between EXS schemas.

5 CONCLUSION

In this paper we have interested on schema matching, and focused on structural context matching for enhanced XML schemas. We began by an analysis of problems involved in the matching, and we proposed a new solution taking into account of heterogeneity of the schema sources. For the structural similarity measure, we recovered a matrix of terminological similarity coefficients between schema nodes based on the similarity of their labels. We outlined the limitations of current solutions through the study of Cupid and Similarity Flooding systems. Then we proposed a structural matching technique that considers the context of schemas nodes (defined by their roots, intermediates and leafs contexts in schema graph). By the way, we suggest a simple structural algorithm based on the previous ideas and exploit the three types of contexts. We refer to the result produced by the algorithm as a mapping. The user validates this mapping in order to produce a final mapping result that serves to generate transformation scripts.

For future work, we would like to improve the matching process, while taking into account the optimisation of the process in order to determine a set of semantic equivalences between schemas (source and target). That will facilitate the generation of operators based on the primitive of transformations between entities of EXS schemas. The second axis to land concerns the efficiency and the time of human interaction. The key is then to discover how to minimize ser interaction but maximizing the impact of the feedback.

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