Semantic Technologies Applying to Data Warehouses Federation

Mouhni Naoual  
University Cady Ayyad  
Faculty of sciences and technology  
Marrakesh-Morocco  
nmouhni@gmail.com

Elkalay Abderrafiaa  
University Cady Ayyad  
Faculty of sciences and technology  
Marrakesh-Morocco  
elkalay@hotmail.fr

Abstract—Business intelligence is based on the existence of main components including: data warehouses. The data warehouse is a specialized database which main task is to provide quick access to data in analysis objective. But in some cases it is necessary to use a set of data warehouses to provide a complete information. This structure is what we call federation, and even if the components are physically separated, they are logically seen as a single component. Generally, these items are heterogeneous which make it difficult to create the logical federation schema and the execution of user queries a complicated mission. In this paper, we will fill this gap by proposing a model for logical federation schema creation based on ontology, in order to treat different schema types (star, snow flack) including the treatment of hierarchies dimension too.

General Terms—Data warehousing, Database systems, Information systems, Algorithm

Index Terms—Data warehouse Federation, Ontology, Hierarchical dimension, Schema Integration

I. INTRODUCTION

A Data Warehouse represents the enterprise-wide "single source of truth" and corporate memory of all business process data [3], it is "a subject oriented, non-volatile, integrated, time variant collection of data in support of management's decisions." as defined by Bill Inmon in 1990, the father of data warehouses.

In some cases, one data warehouse is not sufficient to provide a complete information about a fact, which makes grouping multiple data warehouses the only solution. e.g. in the context of a hotel chain that is geographically distributed in many countries, it may have several heterogeneous warehouses to store and analyse data about customers reservations. this set of warehouses is what we call "a data warehouse federation".

Federated data warehouses are different than distributed Data warehouses, in order that distributed data warehouses can refer different subjects and there is a strict rule in data distribution (horizontal, vertical...) which make it easy to integrate the query results by using join or sum operations [7].

In federated system, the user send his query without having an idea about the location of data or its structure, the set of data warehouses is seen as a whole and the result is the combination of data warehouses components results.

The components in FDWS (Federated data warehouse system) can differ in aspects such as: data model, query language and data semantic [9].

So, a FDWS must contains the following elements [8] :

- An integration procedure of the schemas of the component warehouses giving the logical schema of the federation.
- A query language for user who does not need to know the schemas of the component warehouses.
- A procedure which enables decomposition of user queries to the federation into sub-queries which are sent to the component warehouses

The warehouse federation system management is first based on a logical schema called the federation schema, which integrates all the components schemas. to create this schema, we must integrate all the other local schemas, without loosing information. During this integration, it may be difficult to decide keeping or not an information by using the procedure shows in [8], which compare every measure to the one in the existing federation schema, if it exists only the location of this measure which is characterized by the couple \( (D_0', b'\_name) \) is added, where :

\[ D_0': \text{represents the fact table in the data warehouse } i. \]
In all domain research, it is always worth considering the others work, discuss it and check if we can refine and extend it for our particular purpose. In computer sciences, reusing existing sources is one of the reasons that made the development of this domain possible.

Warehouses federation according to Sheth and Larson [9], and that appears in [7] and [4], is a set of data warehouses that are heterogeneous, autonomous and dispersed. Every component can continue its local operations and at the same time participate in federation. It's for the better that all the integration operations be done without interrupting the process of component data warehouses.

There are no many studies on the data warehouse federation, however, R. Kern, K. Ryk, and Ngoc Thanh Nguyen, proposed a framework for building logical schema and query decomposition in data warehouse federations [7], they developed an algorithm to integrate component schemas into one global logical federation schema.

But this algorithm presents some limits in order to treat the case of warehouses with star schema only, and it doesn't consider the hierarchical dimensions and all the heterogeneity types, which are described in [9] as the difference in structure, where different data models provides two different structural primitives, then , differences in constraints ,differences in query languages and semantic heterogeneity.

Semantic heterogeneity, is one of the biggest problem that faces information integration nowadays, it occurs when two synonym terms from two different sources describe the same subject [1] ( e.g: schedule and timetable are synonyms but we have to show it to the system).

One of the solutions to fill this gap is using ontology, which is according to [6]" ontology is a formal explicit description of concepts in a domain of discourse (classes (sometimes called concepts)), properties of each concept describing various features and attributes of the concept (slots (sometimes called roles or properties)), and restrictions on slots (facets (sometimes called role restrictions)). An ontology together with a set of individual instances of classes constitutes a knowledge base. In reality, there is a fine line where the ontology ends and the knowledge base begins."

According to their use, we distinguish many types of ontologies, Generic Ontology, Domain ontology, Application ontology, Representation ontology, The ontology of methods, tasks and resolution of problems, Light ontology and rich ontology [2].

Even if using ontology may resolve the heterogeneity problem in federated data warehouses, it is not yet used in this context, and all the solutions proposed are based on Meta data repositories, which solve the problem of structure definition but not the semantic issues.

II RELATED WORKS

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III OUR CONTRIBUTION

III.1 Presentation of the Solution

Our work is an extension to [7] algorithm to create the global logical federation schema.

R. Kern, K. Ryk, and N. Nguyen, proposed an algorithm of integration of component schemas into a federated logical schema. They assume that all warehouses are with star schema, so they do not deal with hierarchies in dimensions.

In fact, even with a star schema the hierarchy for dimension are stored are stored in the dimensional table itself.

Whereas, in a snow flack schema, a dimension table have more or more parent tables, and hierarchies are broken into separate tables in snow flake schema . These hierarchies helps to drill down the data from topmost hierarchies to the lowermost hierarchies [5].

Our objective is an improvement of this integration algorithm to cover heterogeneous schemas (snow flack or star schema). And use ontology as a tool to solve the semantic heterogeneity problem instead of using meta data only.

We propose a federation data warehouse management system (FDWS), which cover :

- Improved algorithm for schemas integration using application ontology
- A query analysis and decomposition tool
- An ontology-based integration Algorithm for query results.
1. Every federation component may or not have its own local application ontology, which is written in OWL language describing the semantic of every attribute and measure, and describe the relationship between items and hierarchies of dimensions by using is_a and parentOf relations.

2. This local ontologies are exported to the logical layer ontology repository, besides that a meta data xml file is loaded into the federation system to describe data structure.

3. The user query is analyzed by the FDWS, decomposed, executed on the selected components

4. The query results are integrated using ontology to solve the heterogeneity problem.

III.2 Equations

In our case, the input can be with different schemas types (star, snow flack), so to treat the dimension hierarchies we propose the following algorithm:

**Annotation:**

We use the same notation as [7].

**Input.**

\( P_i \)

as the set of parents of a dimension defined by

\[ P_i = \{ D_1, \ldots, D_n \} \]

\( H \)

a Data warehouse schema defined as

\[ H = (D_0, D_1', \ldots, D_m') \]

\( F \)

an existing federation schema defined by

\[ F = (D_0, D_1, \ldots, D_n) \]

**Output.**

\( F \) the federation after integration with \( H \) .

Other notations are used:

\( a \text{-name} \)

: name of attribute \( a \)

\( b \text{-name} \)

: name of measure \( b \)

\( D_x \sim D_y \), \( D_x \) is similar to \( D_y \) (based on ontology and meta data OR expert's decision)

\( a_x \equiv a_y \)

: \( a_x \) is similar to \( a_y \) (based on ontology and meta data OR expert's decision)

\( b_x \Leftrightarrow b_y \)

: similar measures (based on ontology and meta data OR expert's decision)

**Recall of the Measure integration algorithm.**

R. Kern, K. Ryk, and N. Nguyen in [7], defined a measure integration algorithm as follow:

For each measure from input data warehouse try to find corresponding measure in federation schema. If such a measure exists in federation schema add a mapping between them. If none of the federation measures corresponds to the current one add it to the federation and make a mapping between new measure and the current one.

**Dimension Integration**

In every iteration of the algorithm, the global schema is being updated by integrating parents of dimensions, then integrating the dimension it self.

1. For each dimension from a component schema, using ontology, we extract the set of this dimension parents , this set can be equal to \( \emptyset \) or contains one or many items.

a. For each parents item, we look for similarity in \( F \), if it contains a similar structure, we compare its attributes with the existing one, in case two attributes are similar, we add a new location to the attributes inventory represented by the couple \( (D_y, a' \text{-name}) \), else, we add the attribute as a new one to the dimension. In case that the attribute doesn't exist in the target dimension, we add a new attribute.

b. After integrating all the dimension parents, we integrate using the same operations the dimension it self.

\[
\text{foreach } D_y^p \text{ in } H_y, y = 1, 2, \ldots, \alpha p
\]

\[
\text{if } P_y^p \neq \emptyset
\]

\[
\text{foreach dimension } D_i \text{ in } P_y^p
\]

\[
\text{if } \exists D_i \in F : D_i \sim D_i
\]

\[
\text{foreach attribute } a' \text{in } D_i
\]

\[
\text{if } \exists a \in D_i : a \equiv a' \wedge a \text{ is characterized by } (a' \text{-name}, \text{list})
\]

\[
\text{list} = \text{list} \cup \{(D_i, a' \text{-name})\}
\]

\[
\text{else}
\]

\[
D_i = D_i \cup \{(a' \text{-name}, \{(D_i, a' \text{-name})\})\}
\]

\[
\text{endforeach}
\]

\[
D_i = \emptyset
\]

\[
\text{foreach } a' \text{in } D_i
\]

\[
\text{endforeach}
\]

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\[ D_i = D_i \cup \{(a'\_name, \{(D_j, a''\_name)\})\} \]
endforeach
\[ F = F \cup \{D_i\} \]
endif
if \( \exists D_i \in F : D_i \neq D_y \)
foreach attribute \( a' \) in \( D_y \)
if \( \exists a \in D_i : a \equiv a' \land a \) is characterized
by \( (a\_name, list) \)
\[ list = list \cup \{(D_y, a'\_name)\} \]
else
\[ D_i = D_i \cup \{(a'\_name, \{(D_j, a''\_name)\})\} \]
endfor
 endforeach
else
\[ D_i = \emptyset \]
foreach \( a'' \) in \( D_y \)
\[ D_i = D_i \cup \{(a''\_name, \{(D_j, a''\_name)\})\} \]
endforeach
\[ F = F \cup \{D_i\} \]
endif
endforeach

III.3 Comparison and Discussion

The aim of our work, is to propose an improvement of an existing algorithm presented in [8]; in order to take by consideration multiple schema types and less human intervention during the integration process.

<table>
<thead>
<tr>
<th>Type of schemas covered</th>
<th>Existing work</th>
<th>Our solution using ontology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Star schemas only</td>
<td>Star, Snow flack, constellation schemas</td>
<td></td>
</tr>
<tr>
<td>Hierarchical dimensions integration</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Human intervention in the integration process</td>
<td>Important: in every integration step</td>
<td>Only when preparing Component's ontologies</td>
</tr>
</tbody>
</table>

As we can see from the table above (table 1.), which situates our solution among the related works, we can conclude that the existing solution does not treat other schemas types such as snowflack or constellation, which makes it limited as a solution for federated heterogeneous data warehouses that may not always have a star schema type.

Otherwise, the related work used a simple stored taxonomy created manually over all the data warehouses, which could be a complicated mission if the number of components increases, also by using a manually created shared taxonomy that treat only synonyms, the problem of hierarchical dimension persists, that's why we proposed to exploit local ontologies which expresses all types of relations between attributes (parent/child, synonyms, ...) and improve the schema integration algorithm by comparing every two attributes before the integration in the global logical federation schema. the integration in the global logical federation schema is an automated process with less human intervention since the human control is already done during the global ontology creation. this ontology will be used also in other steps of the federation management process such as the query results integration.

IV. Example

We consider that we have two data warehouses which represent the sources of our federation system. The first component is with start schema, so hierarchies dimension are represented in dimension itself. e.g. the hierarchy Country \( \rightarrow \) Region \( \rightarrow \) City.

Fig. 2. A star schema of hotel reservations

The second component , is a snow flack schema representing Hotel reservations. this schema contains some hierarchies of dimensions.

Fig. 3. A snow flack schema for hotel reservations

After applying the proposed integration algorithm we get the global schema as follow:
Let consider two data ware houses, the first one (Fig2) with a star schema and the second one (Fig3) is a snow flack schema related to a reservation management in a hotel chain.

1. We first extract ontologies and metadata files from different nodes, in the integration layer of the FDWS, then include new entries into the global ontology repository.
2. Then we integrate fact tables by testing the existence of this table in the global federation schema, if it exists, we compare its measures to the existing ones referring to the ontology repository.
3. Next step is to integrate dimensions and hierarchies dimension, e.g: we first integrate the client dimension from DW1 into the global schema, then when we try to include Customer dimension, which is a synonym of client dimension, so referring to the ontology repository we don't add it as a new dimension, and we compare its attributes with clients attributes. Based on parentof relationship mentioned in ontology files, between Customer/client and Category and sub_Category we integrate this hierarchy.

V Implementation

The integration schema algorithm was implemented using Java API Jena, to manipulate RDF language from java application. We are using two data warehouses; the first one with a star schema and has an ontology written in OWL/RD, the second data warehouse with a snow flack schema and has no local ontology. Metadata files and OWL/RDF files are mapped into xml file and transferred into the network to the Federated data warehouses management system.

VI Conclusion

In this article, we have presented a part of our data warehouses federation management system. In particular the process of creating the federation schema based on the integration of local schemas using application ontology. Which makes possible to treat the hierarchies of dimensions by analyzing the parent of relationships, and make the it easy to automate the integration process in federation context.

REFERENCES