COMPARATIVE ANALYSIS OF ONTOLOGY EXTRACTION TECHNIQUES FROM RELATIONAL DATABASE

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ABSTRACT: *Today semantic web perform an imperative role in every field of life. Semantic web is based on creation of computer understandable data which is the key element of its success. Ontology performs an essential role in the creation of semantic data on web. Still many website uses Relational database on their backend as database, but for efficient and intelligent information retrieval ontology is utilize to print data on web. Nevertheless Relational database is a key source for ontology formation. Currently different mapping techniques and tools are being used to extract ontology from relational database. This paper presents an association among relational databases (RDB's) and ontologies by analysis of existing techniques and tools for ontology extraction from relational databases. Finally a comparative analysis is presented that shows different aspects of these techniques based on their methodology and performance.*

KEYWORDS: Relational Database, Mapping Techniques, Ontology, OWL, Ontology Extraction

1. INTRODUCTION

Currently many researchers are paying attention towards the development of ontology due to its importance in information retrieval. Ontology is used in numerous fields specifically it is more important element in semantic web [1]. Current web advances with the evolution of Semantic web which control the web components with the usage of ontologies and enable it to be machine understandable [2]. In semantic web applications the information is presented in the form of ontologies that are essential components of semantic web and used as knowledge base for a specific domain [3]. The main challenge in semantic web is the building of domain precise ontology for the retrieval of relevant information from databases. Different formats of data are available such as HTML, doc, Pdf etc. but Relational database (RDB) is an effective source for extraction and construction of web Ontology to build a domain specific knowledge [4].RDBs are useful source for information and provide data for web surface with high quality [5,6] represents an analysis report that is "It is evaluated that the database accesses through Internet encloses five hundred times more data than fixed web and approximately seventy percent of websites are linked with RDB's ". However RDB creates data integrity problem due to its dependency on autonomous software and hardware. To make the performance of information retrieval system effective relational database is used to construct ontology to resolves the data integration problem. Relational databases (RDBs) contain the knowledge about various domains so it can be used as an important source for ontology construction [7,8]. However, ontology formulates the knowledge that is not visible to the user as in RDB but it make precise knowledge by conceptualization [9].

It is more desirable to convert the relational databases into ontologies due to two causes: Firstly the data to be available on Web as Web Ontology Language OWL and secondly to attain data integration by merging data in a relational database with OWL. OWL is standardized as a ontology mapping language by World Wide Web Consortium (W3C) [10].OWL contains different logical operators like AND, OR and negation that are not found in other web languages. These operators built complex concepts from simpler ones by finding similarities in the user query terms and represent data in ontology that can be understandable by machine.

The main challenge in the process of mapping RDB into Ontology is accuracy in translation process [11]. The conversion of RDB into ontology is based on some mapping rules. Many researchers have presented different techniques to convert RDB into ontology [12-17]. Different techniques and tools use different language and mapping mechanism [18] making RDB to ontology mapping more difficult. To eliminate mapping issue, recently W3C standardize some mapping mechanisms and languages e.g R2RML [19] and Straight Mapping mechanism [20].

This paper presents a comparative analysis of ontology extraction techniques from relational database. As emphasized earlier on importance of ontology and its effective role in semantic web, this paper at first presents relationship between relational database and ontology. In next section different components of our analysis architecture is presented. Later we discusses the existing technologies which are being used by researchers for extraction of ontology from RDBs. Towards the end, an objective comparison of the existing techniques is presented and limitations of these techniques are discussed. Finally the discussion is concluded along with some future recommendations on explored limitations of the topic under discussion

2. RELATIONAL DATABASE AND ONTOLOGY

With the advancement and development in semantic web the techniques and tools to extract ontology from relational databases is the field of interest in current era [21]. Relational database is the major source of organized data. The majority of websites are linked with relational databases to take data on Web due to its optimized storage, efficient query execution, scalability, frequent access and reliability. In RDB, the relation is characterized as a table or entity which consists of set of records/tuples having number of attributes. The relational database is dependent on system hardware and software, therefore the organizations or companies running many systems at the same time in an organization could not shared the data due to different data schema in every system [22]. Whereas the ontology is considered as the main source of shared and integrated knowledge [23,24]. Ontology consists of Concepts, properties and Instances. The knowledge in ontologies is represented with universal language that overcomes the problem of data heterogeneity by giving semantics of data that is shared, formal and explicit definition of data.OWL is a semantic web language to create ontologies, standardized by W3C group that support different techniques to organize the data for solving the issues of data heterogeneity and semantic interoperability [25].

OWL Ontologies are constructed from Relational Database based of relational association and mapping rules. RDB is mapped to ontology by exploring the components of both; RDB and ontology. The relations between these components are the base for the improvement of mapping rules to automatically map RDB to ontology. Table 1 shows the association between components of RDB and ontology.

The association presented in table 1 between the components of relational database and ontology outcome in the improvement of mapping rules that automatically maps

Table 1. Association between RDB and Ontology

RDB	Ontology
Attributes	Properties
Tuples	Instances
Relations	Classes
Constraints	Functional Properties/Cardinalities

RDB into ontology. The mechanism of Ontology Extraction from relational database is presented in figure 1. Figure 1 demonstrates the process of transformation from RDB to ontology. The transformation process consists on schema and data transformation [26].

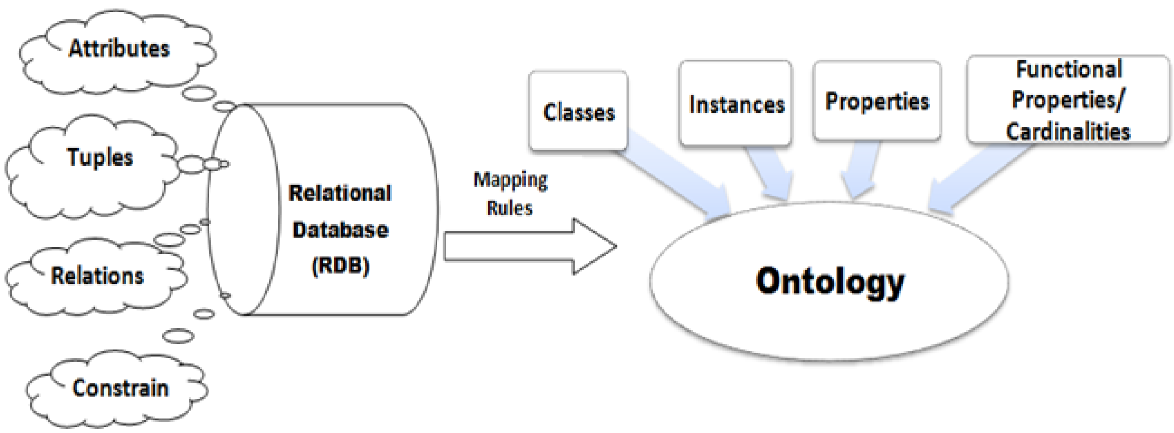

Figure 1: Mechanism of Ontology Extraction from Relational Database

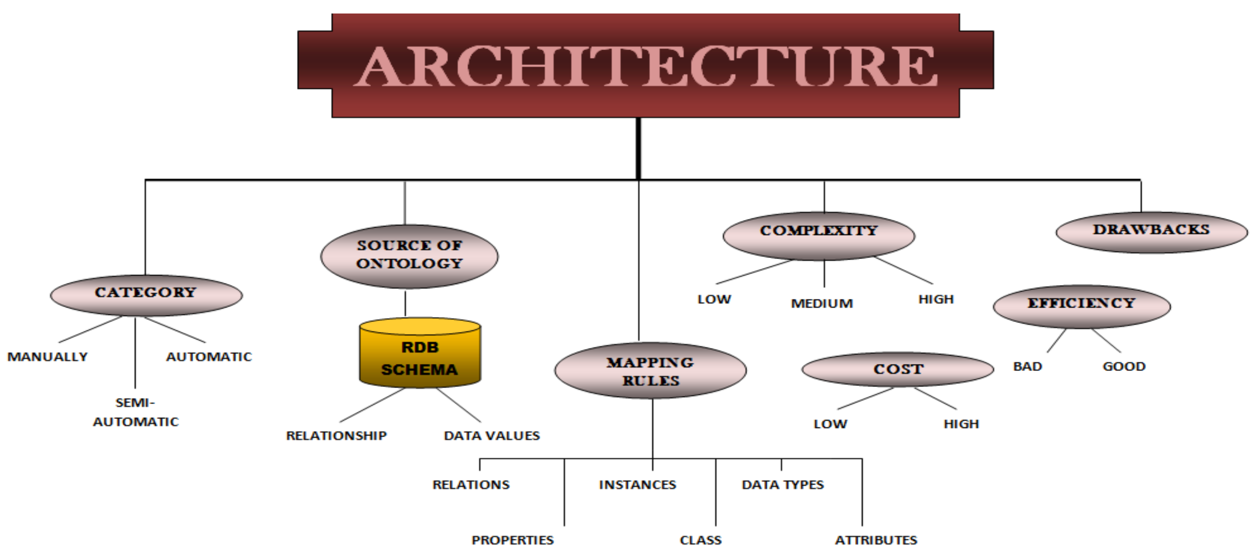

Figure 2: Architecture of Analysis

3. ARCHITECTURE OF ANALYSIS

This section contains the architecture of our analysis of different techniques for ontology extraction from relational databases. The architecture consists of seven components that are used to compare these techniques as shown in Figure 2.

3.1 Category

On the bases of analysis the ontology extraction techniques from relational databases can be classified in three categories.

A) Manually

Ontology extraction from RDB is based on domain expert knowledge. Ontology is constructed after examine the relations and the dataset schema between database and ontology.

B) Automatic

Ontology is automatically constructed from Relational database (RDB) after examining the relationships expression between database and Ontology

C) Semi-Automatic

In this technique both techniques; manual and automatic, are used to construct ontology.

3.2 Source of ontology

RDB schema is the main source for ontology construction.RDB schema further consists of relationships and data values that are mapped to ontology.

3.3 Mapping rules

The mapping rules are the constraints used to construct ontology from RDB. The mapping rules are applied on relations, attributes, data types, classes, properties and instances in RDB and Ontology.

3.4 Complexity

We compared different techniques and evaluate its complexity as low, medium and high on the bases of its execution, storage capacity and manufacturer technique.

3.5 Cost

On the bases of execution period of technique we categorize processing time as low and high. The technique that consist on complex mapping rules, expert knowledge and complex operations takes more time than simpler one.

3.6 Efficiency

On the bases of performance and results of presented technique, we categorized its efficiency as good or best.

3.7 Drawbacks

The limitations of different presented techniques are highlighted in terms of ambiguity, time requires, normalization and complexity.

4. ONTOLOGY EXTRACTION TECHNIQUES

This section describes various techniques for ontology extraction from relational databases.

4.1 Automapper

[10] has presented a tool named Automapper that build OWL ontology from RDB. The process of translation uses database schema and mapping ontology which is based on mapping rules used by [27] to construct OWL domain ontology and mapping instance data ontology. The proposed technique uses these ontologies in their semantic Distribution Query (SDQ) Architecture in which Semantic Decomposition Component decomposes a SPSRQL Query and Semantic Bridge for Relational Databases (SBRB) component translate sub SPARQL queries to SQL. Semantic Web Rule Language (SWRL) and mapping rules add more complexity to the proposed technique.

4.2 Automatic Local Ontology

[12] has presented a technique to automatically build ontology from RDB to solve the integration of heterogeneous data as in manual ontology construction which is more complicated and too time taking process. The main objective was to analyze mainstream database assuming it's in 3NF to extract a series of semantically rich transition rules to obtain OWL from relational schema .Finally ontology enrich with semantics is obtained using transition rules from RDB.

4.3 OWLFROMDB

[28] has proposed an ontology generator tool OWLFROMDB that automatically, construct ontology from RDB through examining the relationship expression between database and Ontology. Previous approaches were based on manual construction of ontology and required in such techniques the ontology is constructed by domain experts for knowledge acquisition from dataset schema. The main goal of the proposed technique is to utilize the existed RDB to build ontology automatically in less time with improved efficiency. After analyzing the relationship between RDB and ontology tables, fields and records in RDB are converted into classes, properties and instances respectively in OWL ontology. The proposed technique consists of 4 steps and two schema and data conversion mechanisms. First step involves extracting ER model from RDB through reverse engineering process. In the second step, after the brief evaluation of ER model, ontology is constructed from ER model through schema conversion methodology. The data in the database is converted to ontology instances through data conversion mechanism in the third step. At the last the resultant generated OWL file is analyzed through engineering tools and converted into OWL ontology. On the bases of above steps and conversion mechanisms; OWLFROMDB ontology generator is designed consisting of mainly four functional components; Database Analyzing Engine, Model Transformation Engine, Data Transformation Engine and OWL Document Parser. The OWLFROMDB development is based on OOP mechanism to make the above four components implementation as classes and objects. Objects of classes such as CDataBaseT, CSqlTable and CTabdAttribute are involved in Database analyzing Engine whereas Class CDataBaseT object is also involved in Model Transform Engine and Data Transform Engine. In OWL Document Parser component object of classes COWLElement, COWLClassElement, COWLProperytElement, OWLProperytPlus and COWLEntityElement are involved. To verify the effectiveness of proposed technique experiment was conducted by running OWLFROMDB on Books RDB using SQL Server 2000. OWLFROMDB automatically generate a Books.owl ontology which can be analyzed by any Editor tool.

4.4 AGOFRD

[29] has proposed a new technique named as "*Automatic Generation of Ontology from Relational Database*" (AGOFRD) which evaluate and extend ontology to achieve its effective use in a logical data model. The technique is distinct from previous technique as previous techniques do not construct ontology automatically with all necessary elements such as classes, attributes, attribute properties, instances cardinality. AGOFRD generates ontology in OWL with all necessary elements using collection of learning rules. A basic ontology is created manually after analyzing relations in terms of Primary key. Foreign Key and attributes. Manual ontology is then extended by introducing subclasses, constraints, loading data from database as instances using automated export program.

4.5 Ontology Construction from Relational Database with Updated mapping Rules

After analyzing the exiting proposed rules, [30] has presented updated mapping rules to generate ontology from database schema. The proposed updated rules accommodate the issues and limitations of existing techniques. To demonstrate the proposed technique, a relational database schema that consists of fee group and course registration is used. To implement the proposed technique firstly the data in database is converted into 3NF. The database contains all the constraints and types of relationships of relational databases. The conversion process involving ontology construction from relational database consists of seven steps: In first step the Primary keys(PK's) of all relations is identified. Foreign keys(FK's) of all relations are identified in second step. Third step involves construction of classes of ontology according to following four rules:

Rule1: involves creation of ontology class as presented in Table 2.

Rule 3: Map relation to ontology class if PK is composite and consists of FK and local attribute(s).

Rule 4: If a relation contains composite PK which consists of only FK, not map it as ontology class. Instead map this relation in ontology class named as associative entity for object properties knowledge.

In forth step, different properties of object is defined on the basis of FK's as following cases occurs:

Case 1: PK does not contain any relation with FK then ontology class 'P' property of object is mapped from FK. Whose P's realm will be similar class and range will be FK's home relation.

Table 2. Rule 1

Rule1	If relation contains:				
	FK	FK as Alternate Key	FK as PK	FK as part of PK	Action Taken
Case1	No	Yes	No	No	New Ontology Class for relation create
Case2	Yes	Yes	No	No	Create ontology class as subclass of Foreign Key's house class
Case3	Yes	No	No	No	New Ontology Class for relation create

Table 3. Rule 2

Rule 2	Could Relation Contains		
	FK as PK	Dignity Attributes	Action Taken
Case1	Yes	No	Merge Child and parent relation into single ontology class
Case2	Yes	No	Create subclass of parent ontology class from child relation
Case3	Yes	No	Create new Ontology class

Rule 2: If hierarchical association between relations exists, construct ontology as presented in Table 3.

Case 2: Two inverse properties of objects named as is-part-of and has-part are generated if FK is the part of PK. Further, for each FK, object property is generated which is not the part of PK in relation.

Case 3: If the relations represent many to many relationships with FK's as part of PK's and no additional attributes their two object properties of cardinality 0 or 1 are added, one for each class of relationship.

Case 4: If a relation representing many to many relationship and also have some additional attributes other than FK's which are part of PK's, move additional attributes to respective parent relations and follow case 3 actions for FK's of relation.

The data properties of ontology classes are generated from attributes other than FK's are mapped as properties of data corresponding to ontology classes. The fifth step consist of conversion process in which each data property range is mapped to XML data types equivalent to data type of attributes in relation.

Sixth step handles the Cardinalities in ontology. For PK min and max cardinality will be 1. For NOT NULL attributes min cardinality will be 1. For UNIQUE constraint the max cardinality will be 1.In the last step the Instances of ontology classes are created from tuples in relations of database. The proposed mapping rules generate ontology schema from complicated real world relational schema. The resultant ontology contains all essential properties of RDB model.

1.1. Semantic Enrichment Ontology

[31] has presented a new technique based on reverse engineering in which RDB schema is transform into ontology schema using external domain ontology. The major objective of proposed technique is to construct a comprehensive Ontology with additional domain semantics to provide better results against user needs. Existing reverse engineering techniques that transform RDB to Ontology can be grouped into three categories. First category analyzes the relational schema uses some mapping rules to map RDB to ontology. Techniques presented in [32-35] are examples of this category. The second category is based on user query analysis. The ontology is firstly created from RDB and then enriches by using user queries. This approach is used for a specific domain. [36] presented such a technique to construct new concepts for ontology. Third category is based on evaluation of HTML pages. The techniques discussed in [37, 38] are the examples of this category. In this category the HTML pages which communicate with database are analyzed to discover semantics.

The proposed technique is based on first category of reverse engineering of RDB to ontology and consists of three stages:

1. Conversion Process
2. Process of Enrichment
3. Data Immigration

The paper discusses first two stages and reserve third stage for future work. Stage 1 consists of eight rules.

Rule1: Suggests creating classes for each relation in database, if the primary key (PK) did not contain foreign key (FK). Next two rules create a generalization association between classes as described below:

Rule2: Participating classes have same PK's.

Rule3: K of our relation is part of candidate key of another relation.

Rule 4,5 and 6 involves creation of object property with cardinalities as represented in Table 4.

Table 4. Rules 4, 5, 6 Creation of object property with cardinalities

Rules	Description	Cardinality
4	FK is not part of PK	1 to Many
5	FK is part of PK	1 to 1
6	PK contains two or more FK	Many-to-Many

Rule 7 states that if two or more FK's participate in PK then create a functional property and represents it in OWL in the same way as presented in [34].

Last rule states that, except FK, make other fields of relation as attributes of related class.

Stage 2: The stage describes the enrichment process that consists of on additional set of rules and algorithm to add more classes. For this purpose domain ontology DOnto [39] and WordNet is used to get synonyms of the classes. The algorithm used in enrichment process is inspired from [40]. The algorithm consists of two steps: Local Ontology (LO) and Domain Ontology (DOnto). The algorithm calculates the similarities on the bases of properties of concepts. The resultant constructed ontology is enriched with semantic after these transformations. To verify this ontology Protégé editor is used. The proposed technique is semi automated because for enrichment process expert interaction is required.

5. RESULTS AND DISCUSSION

After literature survey Table 5 presents the comparison between different techniques.

Table 5. Comparative Analysis of Ontology Extraction Techniques

Techniques	Category	Source of Ontology	Mapping Rules	Complexity	Cost (Processing Time)	Performance	Drawbacks
Automapper	Automatic	– RDB Schema – Mapping Rules – Semantic Bridge Module	Classes, Data Type properties, Object properties,	High	High	Good	– Un-Normalized Database Source – Time Consuming
Automatic Local Ontology	Automatic	– RDB Schema – Transition Rules	Relations, Attributes, Data Type and Object properties	Low	Low	Good	-Use specific knowledge of relations -Ambiguous
OWLFROMDB	Automatic	– RDB Schema Relation And stored data	Classes, Properties and Instances	Low	Low	Good	-Use Specific Knowledge of Relations -Ambiguous
AGOFRD	Semi-Automatic	– Data in RDB Schema – Learning Rules	Classes, Instances Properties, Properties Characteristics, and Cardinality	High	Medium	Best	-Ambiguous -Resultant ontology has no distinction division between a schema and data
Ontology Construction from Relational Database With Updated Mapping Rules	Manual	– RDB Schema – Mapping Rules	Classes, Instances Properties, Properties Characteristics, and Cardinality	Medium	High	Good	-Time Consuming, -Complex Mapping Rules
Semantic Enrichment Ontology	Semi-Automatic	– RDB Schema – Mapping Rules	Classes, Data Type Properties, Object Properties,	High	Medium	Best	-Time Consuming -Expert Knowledge is needed

The table shows different aspects of the Ontology extraction technique from Relational Database. After analysis, we categorize the ontology extraction techniques in three categories: manual, automatic and semi-automatic. In manual Techniques domain expert knowledge is needed and it may be error prone due to complex manual operations. Automatic extraction techniques use different mapping rules and tools to construct ontology from relational databases. Semi-Automatic is a combination of above two categories that uses an automatic mechanism for ontology construction with domain expert facts. The key source of ontology building is RDB schema. Two important components of RDB other than schema are Relationships and Data sets. Different mapping rules are used to map these components to ontologies. The mapping rules involve Relations, Attributes, Data Type, Classes, Instances, Object properties, Properties Characteristics, and Cardinality. On the bases of these mapping rules and mechanism to construct ontology, the complexity of the technique can be categorized as low, medium and high. The time span for ontology construction is called processing time.

The technique that is based on manual work takes more time as compared to automatic techniques. Semi-Automatic techniques are hybrid techniques; their processing time is less than manual techniques, but high than automatic techniques due to complex operations and user interaction. The efficiency of these techniques is categorized as good and best on the bases of their complexity, processing time and accuracy and advantages.

With the passage of time more advance techniques are developed to construct ontologies, but still these techniques have some drawbacks such as un-normalized databases, ambiguity in concepts and inefficient accommodation of semantics due to mapping of specific relations of databases some techniques are efficient but take too much cost in terms of time for development.

After the brief comparison between these technique we analyzed Semantic Enrichment Ontology is the best technique for ontology construction with some modification.

6. CONCLUSION

Relational database is a major source of organized and useful data. Many web applications rely on RDB to retrieve information. But semantic web engines are unable to retrieve intelligent information through RDB. To retrieve effective, intelligent and semantically enrich information a source is needed that attain efficient interoperability of information systems and provide information with semantic reasoning. Ontology plays a key role towards the advancement of contextual web (semantic web) to enable user to share and communicate semantic

knowledge more easily. Ontology resolves the problem of heterogeneity meaning in data by providing a mutual resource of information about a particular domain. However, these are many web applications that still use RDB as their backend database. Schema mapping is the one of the way to establish interoperability between these relational databases and ontologies. Now a day different mapping techniques and tools are developed for efficient information retrieval based on semantic reasoning. The paper describes the importance of ontology in semantic web and also presents a review of ontology extraction techniques and tools from relational databases. After analysis of these techniques and tools a comparative analysis is presented in the form of table that highlights different aspects of these existing techniques.

In future the research directions would focus on developing an automatic ontology construction technique without any manual interaction that provides efficient performance in less time and cost. Our suggestion for future work is to use additional mapping rules with automatic mechanism and also find innovative methods that find more comparison parameters for more efficient comparison.

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