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Approaches for Loss-less Mapping from Relational Database to OWL Ontologies

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Abstract

As the semantic web is picking up fame, issues of incorporation of information from diverse sources to ontologies are likewise picking up investment of analysts. Social Databases are basically utilized for saving a lot of web information; in this way we mean to advance an immediate instrument or tool for Relational Databases to ontology transformation. Existing methodologies for RDB to ontology transformation have a few drawbacks. A portion of the methodologies are manual and require a ton of exertion for transformation. Some are programmed however they perform mappings at an extremely essential level. A percentage of the tools advanced thus are of exceptionally fundamental level, out-dated or not open. We give a study of some existing methodologies; assess them on some arrangement standard, and near the finale we infer future look into bearings in this area.

Keywords: Semantic-web, ontology, relational database.

Introduction

The web today is full of advantageous data. In any case concentrating the definite data is an exceptionally troublesome errand since; the information on the web is not composed in a formal manner. Accessible web search tools can furnish some data however client still needs to experience all the information physically to get the needed data. To solve this issue the information on the web ought to be machine clear. Here, comes the idea of semantic web. The semantic web points above issue, by forming the information in machine reasonable configuration which makes accumulation and synthesis of the Web data exceptionally simple. Ontology is the fundamental concept of semantic web. Ontology is utilized to catch the learning of a particular domain. It gives a normal comprehension of area information. Ontology formally characterizes an area; it contains classes and characterizes relationships between these classes. We have to arrange the information on web in a formal manner, to make it machine intelligible. Ontology arranges the information in a formal manner which is machine decipherable and furnishes a regular comprehension. The information set on web is for the most part stored in relational databases (Rdbs), as it can store a lot of information. Along these lines, we need to change over this information of Rdb's to ontologies. Rdbs are the most mainstream storage devices and are generally utilized within all fields. Now the issue of changing over Rdb to ontology comes. The most effective method to guide Rdb's tables, columns, primary key, foreign key and data-types and so forth to ontology's classes, attributes, properties, restrictions and axioms and so on is the inquiry of today's research. The database schema includes structure and semantic information of relational database. But extracting this information and afterward making the guidelines for mapping the data to ontology is an extremely difficult assignment. There exist issues with physically improving ontologies from Rdbs. It is time intensive procedure and need ontology experts. Ontologists are solicited to invest a lot of time in database to ontology construction. Comprehension the essentialness of Rdb to ontology mapping, a considerable measure of research is in advancement here. Latest research has demonstrated various approaches and proto-sort instruments, having a few pros and cons. Some of these methodologies are automatic and others are semi-automatic which require manual work.

In this paper, we attempt to survey existing approaches for database to ontology conversion. We have identified the problems with existing approaches. We have also identified the future work that need to be done in this domain. This paper will give clear future directions in this domain.

The paper is structured as follows: Section II explains the fundamentals of semantic-web and databases; Section III explains the applications utilization of our work; Section IV covers existing approaches and their draw-backs; comparison of approaches is given in Section V; conclusion and future work is given in the last section.

Fundamentals of Domain

In this section, we explain the basic concepts of semantic web, ontology and relational databases which will help in understanding the rest of the paper.

Relational Database: The relational databases are the most well-known storage devices and broadly utilized within all fields. It was conceived in 1970 by E.f. Codd. Information is archived and accessed in the form of tables; rows and columns. Information might be embedded, entered, redesigned and erased from the tables of Rdb. The table alludes to relation, row alludes to tuple and column alludes to attribute in relational database. Rdbs can store a lot of information that is the reason the greater part of the web information is saved in Rdbs. The structured query language (Sql) is utilized for saving and entering information from a relational database. Relational databases are not difficult to make access and extend. To guarantee that the information in Rdb is correct referential integrity rules are applied.

Semantic web: Semantic web is extended version of customary web. It gives a standardized method for explaining the relationships between web pages, to permit machines to comprehend the importance of hyperlinked data. Semantic Web alludes to W3c's vision of the Web of linked data. Ontology is the fundamental thought of semantic web. According to Gruber: "An ontology is an explicit and formal specification of a conceptualization"[1].

Ontology is utilized to catch the information of a particular domain. It provides a common understanding of domain knowledge. It holds classes, connection between these classes, properties and different restrictions. The important ontology languages for the Web are Xml, Xml schema, RDF, RDF schema and OWL.

Applications

As the semantic web is picking up popularity, the utilization of ontology is likewise increasing. Ontology refers to shared understanding of a domain of interest. In this section, we survey and expand the causes for making ontologies from relational databases.

Integration of heterogeneous databases points at accessing information from distinctive databases in a steady way. Ontology matching determines the issue of schema matching. Data base is utilized to store data as tables. The point when the data increments, it is instructed to store it in distinctive databases. These data bases are heterogeneous. For consistency these heterogeneous data bases need to be combined periodically. Data base schema matching is a challenging task, in any case it's simpler if these data bases are changed over to ontologies and afterward integrated as a lot of work is carried out in ontology integration.

As the world today is moving from only web to semantic web. The SPARQL is the Query Language prescribed by W3C. SPARQL could be applied on ontology for querying.

To administer the knowledge of an association successfully, ontology decreases conceptual and terminological confusion by providing a unifying frame-work. Ontology comprises of classes which represent the critical concepts of the domain. Other than this, ontology incorporates properties, restrictions, disjointness among classes and specification of logical relationships. This shared and detailed understanding serves to overcome terminological and conceptual differences.

Existing Approaches and their Classification

Researchers are aware of the significance of building ontology from relational database. A few methodologies have been displayed to solve the mentioned issue. Nadine *et al.* has created a tool named DB2OWL which can change over database schema to ontology[2]. Authors present diverse cases and apply defined rules on the database. At the same time the developed tool is restricted. Only tables from RDBs are mapped to concepts and the columns are mapped to properties.

Kavitha *et al.* talks over the issue of integrating heterogeneous databases[3]. For accomplishing the semantic relationship around the databases, idea of ontology is applied. It proposes a strategy that changes over databases to local ontologies, and after that these ontologies are consolidated into global ontology. Authors have proposed certain steps for mapping of RDB to Owl ontology however it needs discussion on constraints which ought to be acknowledged while mapping, e.g. referential integrity constraints.

Zhang and Li[4] propose a methodology to automatically produce ontology from relational database. The methodology is performed in three steps i.e. database metadata reading, ontology meta-model development, goal ontology generation. The primary part, extracts data from the relational database to develop relational database meta-model e.g. tables, columns, primary key foreign key and so on. The second part, changes over relational database meta-model to ontology meta-model. This transformation is carried out by applying particular mapping rules. The third part, at last changes over relational data to Owl ontology. But still at present there is a huge contrast between the ontology produced automatically and the one created manually.

Mostafa-e-Saleh[5] prescribes offline ontology extraction and online query issuing. In the first stage, ontology is created from relational database. For transformation two rules are shown. In second stage, client creates Sparql query, which is changed over to SQL query by applying the principles given by the authors. The proposed technique does not uphold all SPARQL syntax and proposed mappings are constrained.

Xu *et al.* proposes a semi-automatic strategy for changing over relational database schema to ontology, and uses Wordnet to extend the created ontology[6]. Seven ontology extraction rules are proposed. After ontology extraction, the ontology is expanded by Wordnet to uproot the redundancies and equivalent words. At last the ontology is checked and revised manually. But the issue in this approach is that it is not automatic.
The basic aim of the paper[7] is relocating relational database to

web semantics. The proposed strategy is isolated into three stages. In the first stage metadata of Rdb is extracted with the help of an algorithm. The metadata incorporates fields, relations and properties. The following stage is to develop a canonical data model (CDM). The CDM constitutes of class, relations and attributes. In the last stage, particular standards are applied on the CDMto map the CDM constructs to Owl classes. Again the proposed technique has restrictions.

Minyoung *et al.* proposes the strategy that is a mixture of two methodologies; subsequently the creators have named it Mixed Ontology Building Methodology (MOBM)[8]. In the first stage primary data from the database is extracted to structure fundamental concepts and relations of ontology. This is called kernel ontology. Six mapping runs for mapping kernel ontology are furnished. Second and third stage constitutes of gathering upper-level and lower-level terms. The upper-level and the lower-level terms are extracted from domain information and further used to assemble the concepts by applying top-down and bottom up systems individually. These upper and lower concepts are then combined with the kernel ontology in the fourth stage. The following three steps, manage inter-terms, restrictions and axioms which are recognized from domain information. The eighth stage contains incorporating ontology into an ontology language. However the issue with the methodology is that it is not automatic and requires a considerable measure of manual work to get data from domain information and business archives. Additionally MOBM don't work properly when the amounts of tables are less in number.

Astrova and Stantic's[9] approach utilizes the thought of changing over Html format directly to ontology. As per them relational schema, foreign key, primary key, relations and dependencies, might be extracted from Html structures. They reason that Html structures are an exceptionally prevalent interface for corresponding with RDBs and likewise for web showing. Some descriptive text is associated with HTML forms, which makes them user-friendly. Also the structure of RDBs is behind these structures; in front they just serve to correspond with the RDBs. Authors have divided their methodology in three steps: (1) extraction of structure model schema from Html. Domain masters can do it effectively as they have the area learning, however it makes this step manual.(2) Mapping administers are made. Essential concepts of classes are secured in these standards. (3) Data relocation; production of ontological instances.

Shufeng *et al.*[10] proposes a methodology of creating ontology from RDBs which is based upon Jena API. Eight Rdb to ontology rules are built. The ontology generator, RDB2ON, is an automatic method, to spare the time. RD2ON is created on the base of eight mapping rules. Ontology generator is partitioned into three modules: (1) Data base dissection: in this module, reverse engineering is applied to extract the schema of an RDB. The data like tables, columns, primary keys, foreign keys and so on is procured. This data is then assembled to apply the rules explained before. (2) Schema transformation: conversion of Rdb to owl ontology is carried out in this module. (3) Owl ontology generation: the last ontology report is created in the third module.

Cebrah[11] implemented tool named "RDBtoONTO". It is semi-automatic tool for generation of ontology. The methodology helps the client to get a populated ontology. Cebrah insists on normalization of RDB for ontology generation. Normalization guarantees disposal of information duplications. Mining concepts are likewise applied in RDBtoONTO tool. But mapping rules are not talked over, and the tool implementation is not discussed.

Hamid *et al.*[12] approach uses SQL DDL language. SQL DDL schema is automatically extracted for ontology generation. Authors discuss SQL to ontology conversion rules in detail. Six sets of rules are explained. It is stated that this proposed automated approach has short-comings. For an accurate ontology generator human interaction is important.

Martin *et al.*[13] point at converting data from spreadsheets to Owl ontology. A new mapping language, M2, has been introduced by the authors, for mapping from spreadsheets to ontology; M2 provides an easy and friendly interface. The methodology is implemented and the instrument is named as "mapping master". Mapping master is executed as a protégé module and the mapping system is performed in three steps.

Ayesha *et al.*[14] prescribe online query issuing while extraction of ontology is done offline. In first stage ontology is produced from relational database. For transformation two standards are established. In second stage, client produces SPARQL query, which is changed over to SQL inquiry by applying the tenets given by the creators. At the same time the rules examined are at an exceptionally fundamental level.

An alternate issue with few executed models like, mapping master, RDBtoONTO and "relational-owl" is that they are not effectively accessible[15].

Discussion

In this section, we have discussed different criteria's, in which the existing approaches are categorized.

Classification criteria: Approaches are categorized in the following classification criteria's: **Aim:** We consider about the fundamental reason for the methodology. What was the fundamental thought behind this research? RDB to ontology mapping is utilized within numerous situations, so understanding the point behind the exploration is exceptionally vital.

Table-1
Idea behind each approach and their drawbacks

Approach	**Concept**	**Draw-backs**
Tool for automatic data-base to ontology mapping[2]	New tool, DB2OWL implementation Automatic tool Limited mapping rules discussion and implementation Ontology is generated	Mapping is done at a basic level e.g. tables and columns are mapped.
Ontology based integration of heterogeneous data-bases[3]	Automatic Establishing mapping rules Conversion of data-bases to ontology Matching of Ontology Generation of Ontology	Approach does no discussion on constraints.
Automatic generation of ontology based on data-base[4]	An automatic method Detail discussion and implementation of mapping rules Ontology generation	The quality of ontology generated by this approach and the ontology generated manually has different results
Semantic-Based query in RDB using ontology[5]	Automatic approach Uses DB of a library Extraction of Offline ontology. Creation of wrapper ontology User will issue online SPARQL query SPARQL-SQL conversion Generating query	Only basic rules are discussed Third normal form of database is mandatory RDF is used
Ontology construction based on RDB[6]	Approach is semi-automatic Mapping rules are defined WordNet is used for checking synonyms and creation of sub-classes Data from domain knowledge is used for manual correction of ontology	Approach is Semi-automatic Lot of manual work is required No implementation is shown in the approach
Mapping relational data-base into OWL structure[7]	Methodology is automatic Process is divided into three parts Extraction of Mata-data is performed Implementation of rules for creating Canonical model OWL file is generated	Mapping discussed at basic level Data is lost
Mixed ontology building methodology using DB[8]	Kernel ontology is created using established mapping rules Domain knowledge and DB instances are used to create Class hierarchies In kernel ontology, hierarchies are integrated From domain knowledge axioms and restrictions are added. Ontology is generated	Approach is not automatic. Methodology is less efficient as the number of tables in database decreases
Reverse Engineering of Relational Databases to Ontologies[9]	HTML format is converted directly to ontology Method is semi-automatic From HTML, extraction of form model schema is done Schema transformation, from model to ontology Ontological instances are created	It is a semi-automatic method Just HTML form can’t be used for extracting RDB schema. There is no implementation

Approach	Concept	Draw-backs
Ontology Generator from Relational Database Based on Jena[10]	It is an automatic approach New tool, RDB2On is implemented For extraction of RDB schema, application of reverse engineering is introduced Application of mapping rules Creation of ontology document	Data is lost
Learning Highly Structured Semantic Repositories from Relational Databases[11]	A new tool RDBtoONTO is implemented Populated ontology is created with the help of this tool Data mining is also considered Normalization is discussed as an important aspect	Mapping rules are not defined Semi-automatic methodology
Translating SQL Applications to the Semantic Web[12]	SQL DDL is used For generation of ontology , they automatically extract SQL DDL schema Detail discussion on mapping rules	No implementation is shown
A Flexible Approach for Mapping Spreadsheets to OWL[13]	Spreadsheet data is converted to OWL ontology A new mapping language, M^2, has been introduced New tool Mapping Master has been developed.	Mapping rules are not even discussed.
Semantic – Based Querying Using Ontology in Relational Database of Library Management System[14]	It's an automatic approach Library management RDB is used Suggests offline extraction of ontology. Wrapper ontology is built, to avoid migration of data User issues online SPARQL query SPARQL is converted to SQL Generation of query	RDF is used Implementation not discussed
Mapping master, RDB to Onto and "relational-owl"[15]	Proto-types	Tools not accessible

Application: Applications of a methodology are exceptionally imperative. Here we talk about where the methodology is connected in actual living. As semantic web is picking up popularity, applications of ontology are likewise developing. Along these lines, we have to figure out which application is focused by the methodology.

Automation level: Some of the research tools give automatic result and others semi-automatic. Ontology could be developed physically, yet it is an extremely repetitive and drawn out and expensive task. Therefore, a mechanized methodology is needed.

Ontology language: Ontology could be communicated in numerous languages e.g. RDF/RDFS, OWL-DL, OWL-Lite or OWL-Full, etc. This order paradigm examines the distinctive ontology languages utilized by each methodology. It will help us understand pros and cons of these languages.

Implementation: Here we examine an exceptionally vital reality that if the creator has truly actualized his methodology or he has barely given suggestions.

Software availability: Here we examine that if the methodology gives free software access or not. At times devices are proposed yet not adequately implemented. With new discoveries and technologies a periodic updating of soft-wares is very important, so they can be compatible with the new technologies. , so they might be compatible with the new innovations. Then again some soft-wares are either not easily accessible or they are just not approachable. Without programming, it does not matter how exceptional a methodology is.

Use of existing resource: This parameter examines about utilization of any outside asset. These existing resources are helpful in ontology mapping. Usually it requires manual work-done by the ontology developer. But this re-using of resources helps creating a better and detailed ontology from RDBs.

Table-2
Categorization of Relational Databases to Ontology Approaches

Approach	Aim	Application	Automation level	Ontology language	Implement ation	Software availability	Use of existing resource
Tool for automatic data-base to ontology mapping[2]	DB2OWL tool implementatio n	Resolving the heterogeneity of semantics	Automatic	OWL-DL	Yes	Yes	None
Ontology based integration of heterogeneous data-bases[3]	Multiple database integration	Resolving the heterogeneity of semantics	Automatic	OWL	Yes	No	None
Automatic generation of ontology based on data-base[4]	Generation of ontology, automatically from RDB	Generation of ontology automatically	Automatic	OWL	Yes	No	None
Semantic-Based query in RDB using ontology[5]	Semantic query using RDB	World is moving from SQL to SPARQL	Automatic	RDF	Yes	No	None
Ontology construction based on RDB[6]	Ontology building from RDB	Ontology construction	Semi-automatic	Not Given	No	No	Word-net
Mapping relational data-base into OWL structure[7]	Migration of RDB to Web semantic	Web is moving to semantic web	Automatic	OWL	Yes	No	None
Mixed ontology building methodology using DB[8]	Managing knowledge of an organization using ontology	Shared understanding of domain knowledge is provided by ontology	Semi-automatic	OWL	Yes	No	Domain expert
Reverse Engineering of Relational Databases to Ontologies[9]	Ontology extraction from HTML forms	Moving on tosemantic web based on ontology	Semi-automatic	F-logic/ OWL-DL	No	No	None
Ontology Generator from Relational Database Based on Jena[10]	Improving ontology generation quality	Web is moving to semantic web	Automatic	OWL	Yes	Yes	None
Learning Highly Structured Semantic Repositories from Relational Databases[11]	Learning of ontology	Web is moving to semantic web	Semi-automatic	OWL	Yes	Yes	None
Translating SQL Applications to the Semantic Web[12]	Generation of OWL-DL ontology automaticallyf rom SQL DDL	Web is moving to semantic web	Automatic	OWL-DL	No	No	None
A Flexible	Data from	Web is moving	Automatic	OWL	Yes	Yes	None

Approach	Aim	Application	Automation level	Ontology language	Implementation	Software availability	Use of existing resource
Approach for Mapping Spreadsheets to OWL[13]	spread sheet is converted to OWL, and new OWL-centric mapping language is introduced	to semantic web					
Semantic – Based Querying Using Ontology in Relational Database of Library Management System[14]	Semantic query in RDB	SPARQL	Automatic	RDF	No	No	None

Mapping Rules: After the RDB schema has been extracted, stage of making mapping rules start. Generation of ontology mainly depends on these mapping rules. The greater part of the methodologies we talked above, have a few pros and cons. In most methodologies mapping rules are examined at an exceptionally fundamental level. A few methodologies examine rules in detail, yet then they either have no execution or are manual.

RDB and ontology has some semantic similarities. Relations in RDB are characterized as concepts/classes in ontology. Non-key attributes are known as data-type properties in ontology. Foreign key attributes are defined as object-properties. Tuples are converted to class instances and constraints on attributes in RDB are known as axioms in ontology.

Here we examine some mapping runs rules. At that point methodologies will be arranged as per these rules: A table is converted to class. If two tables have same primary keys, then they are merged. If attributes of table 1 are subset of attributes of table 2 then, class 1 is sub-class of class 2. Foreign key attributes are converted to object properties. If a table's foreign key is equal to primary key, then two object properties are created. Both are inverses of each-other. Non-key attributes are directly mapped to data-type properties. For a non-null able attribute of RDB, minimum cardinality is 1. For a unique attribute, maximum cardinality is 1. The tuples in RDB are converted to class instances. RDB constraints are converted to axioms.

Conclusion

As the semantic web is gaining popularity, problems of integration of data from different sources to ontologies is also gaining interest of researchers. Relational Data Bases are broadly utilized for archiving huge web information; in this way they are continuously changed over to ontologies. Ontologies have numerous other imperative applications like combination of heterogeneous databases and information administration.

Specialists have done a great deal of endeavors in this area and proposed distinctive methodology. In any case existing methodologies have issues which have been talked about in the above section. The major detriments in these methodologies are that they are semi-automatic, do mapping at an extremely essential level and are old fashioned or not approachable.

In existing methodologies, mappings are carried out at an extremely fundamental level on small databases. When existing devices are utilized for little databases transformation they indicate 90% outcomes however if same tools are utilized for a huge database, they don't perform proper changes and are not productive enough.
The vast majority of the devices recently advanced are out-dated or not receptive. We attempted utilizing some of these instruments like "mapping master", relational-owl, RDBtoONTO but failed due to many reasons given above.
In anticipated, it is remarkably prescribed to improve a tool that can automatically change over relational database to ontology and that can perform enhanced mappings from relational database to Owl ontologies. Moreover, these types of tools when implemented in true sense must be available to public for use.

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Table-3
Mapping Rules and their implementation in different approaches

Approach	**Rule1**	**Rule2**	**Rule3**	**Rule4**	**Rule5**	**Rule6**	**Rule7**	**Rule8**	**Rule9**	**Rule10**
Tool for automatic data-base to ontology mapping[2]	✓	×	✓	✓	✓	✓	×	×	×	×
Ontology based integration of heterogeneous data-bases[3]	✓	✓	×	✓	×	✓	×	×	✓	×
Automatic generation of ontology based on data-base[4]	✓	×	×	✓	✓	✓	×	×	✓	✓
Semantic-Based query in RDB using ontology[5]	✓	✓	×	✓	×	×	×	×	×	×
Ontology construction based on RDB[6]	✓	×	×	×	✓	✓	✓	✓	×	×
Mapping relational data-base into OWL structure[7]	✓	×	×	×	×	✓	×	×	×	×
Mixed ontology building methodology using DB[8]	✓	×	×	×	✓	✓	×	×	×	×
Reverse Engineering of Relational Databases to Ontologies[9]	✓	×	×	×	×	×	×	×	×	×
Ontology Generator from Relational Database Based on Jena[10]	✓	×	×	✓	✓	✓	✓	✓	×	×
Learning Highly Structured Semantic Repositories from Relational Databases[11]	×	×	×	×	×	×	×	×	×	×
Translating SQL Applications to the Semantic Web[12]	✓	×	×	✓	×	✓	✓	×	×	×
A Flexible Approach for Mapping Spreadsheets to OWL[13]	×	×	×	×	×	×	×	×	×	×
Semantic – Based Querying Using Ontology in Relational Database of Library Management System[14]	✓	✓	×	✓	×	×	×	×	×	×

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