



Groupe de recherche interdisciplinaire en informatique de la santé

Faculté des sciences et Faculté de médecine et des sciences de la santé
Université de Sherbrooke, Québec

Generating relational data models using an ontology a review RR2020-001

Authors : Christina Khnaisser, Luc Lavoie, Jean-François Ethier

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Plan

ABSTRACT	1
1 METHODS COMPARISON	2
1.1 Requirements.....	2
1.2 Criteria definition.....	2
1.3 Criteria and requirement correspondence	3
1.4 Criteria evaluation	4
1.5 Criteria applicability.....	4
REFERENCES	6

Abstract

This report presents an evaluation of 10 methods using 8 requirements and 23 criteria. Following this study, this paper shows that none of the methods are complete as well as the conversion process does not use the full expressivity of ontology to derive a complete relational schema including advanced constraints and modification procedures. Thus, more work must be done to decrease the gap between ontologies and relational data models.

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GRIIS (Groupe de recherche interdisciplinaire en informatique de la santé)
Faculté des sciences et Faculté de médecine et sciences de la santé
Université de Sherbrooke
Sherbrooke, QUÉBEC J1K 2R1.

1 Methods comparison

1.1 Requirements

The results of a literature review conducted to explore existing methods for generating an RDB from an ontology is published in [Khnaisser et al. 2018]. In this paper, comparison with OntoRel α is added to highlight the contributions. Moreover, an extended version of the comparison is added to reflect the quantitative evaluation of the methods with respect to the number of requirements covered.

Thus, the conversion process must [Khnaisser et al. 2018]:

- R1. Preserve property cardinalities
- R2. Handle missing information
- R3. Preserve axioms expressivity
- R4. Maintain Ontology-SQL type compatibility
- R5. Enable structural and tuple reversibility
- R6. Maintain schema documentation
- R7. Be automatable
- R8. Handle knowledge and schema evolution

1.2 Criteria definition

Based on the issues and challenges described above, criteria were defined and grouped into four categories : the ontology criteria, the relational schema criteria, the conversion process criteria and tool implementation criteria.

- Ontology language – the ontology language supported by the method: OWL-DL, OWL-QL, OWL-RL, OWL-EL, RDF(S), DAML, etc.
- Structure normalization – the relational schema normal form? : 3NF, BCNF, 5NF or 6NF. This criterion can be deduced from the conversion rules.
- Structure scope – the form of the predicate represented by the relvars of the generated relational: schema generic [G] (RDF generic style <predicate, subject, object>) or specific [S] (a specific predicate per class or association).
- Domains – does the method convert the ontology data types and their constraints into domains (e.g. CREATE DOMAIN in PostgreSQL)?
- Primary keys – does the method generates [G] or calculates [C] the primary keys? A generated key is an artificial key defined independently of the set of axioms. A calculated key is a key deduced from the set of axioms.
- Secondary keys – does the method generate the secondary key from the set of axioms?
- Foreign keys – does the method convert the appropriate axioms into foreign keys?
- Participation constraints – does the method convert cardinalities into constraints?
- General constraints – does the method convert datatype and disjoint constraints into general constraints?
- Modification procedures – does the method define the procedures for modifying the data (insert, delete, and update triggers)?
- Target RDBMS – such as PostgreSQL, MySQL, Oracle, MSSQL, etc.
- Axiom reduction – does the conversion process deals with complex axioms?
- Intermediate structure – the intermediate data structure used for the conversion of OWL into a relational schema: MOF (Meta-Object Facility) FOL (First order logic), RDF, Jena model, etc.

- Type conversion – does the conversion process specifies or configures the conversion rules between ontology types and SQL types?
- Restriction conversion – does the conversion process converts the restrictions to general constraints? If yes: is explicit conversion [E] or metadata (implicit conversion [I]).
- Annotation conversion – does the conversion process converts the annotations to document the relational schema?
- Structural reversibility – does the conversion process makes it possible to refer to the ontology construct? Structural reversibility algorithm – does the method describe the algorithm and suggest an implementation of structural reversibility?
- Tuples reversibility – does the conversion process makes it possible to import tuples stored in the DB in their full ontological expression? Tuples reversibility algorithm – does the method describe the algorithm and proposes an implementation of tuples reversibility?
- Implementation – has the method been implemented?
- Availability – is the tool publicly available?

1.3 Criteria and requirement correspondence

Table 1 presents the criteria used to identify if the requirement is covered, partially covered or not covered. For example, for R1, 11 criteria are used to evaluate the requirement coverage and the criteria “Ontology language” is used by 7 requirements.

	R1	R2	R3	R4	R5	R6	R7	R8	
Ontology									Total (X)
Ontology language	X	X	X	-	X	X	X	X	7
Schema									
Structure	X	X	X	-	X	X	X	X	7
Domains	-	-	X	X	-	-	-	X	5
Primary keys	X	X	X	-	-	-	-	X	7
Secondary keys	X	X	X	-	-	-	-	X	7
Foreign keys	X	X	X	-	-	-	-	X	7
Participation constraints	X	X	X	-	-	-	-	X	7
General constraints	X	X	X	X	-	-	-	X	8
Modification procedure	-	-	-	X	-	-	-	X	8
Target DBMS	-	-	-	X	-	X	-	X	4
Process									
Axiom reduction	X	X	X	-	X	-	X	X	7
Intermediate structure	X	X	X	X	-	X	X	X	8
Type conversion	-	-	X	X	X	-	X	X	5
Restriction conversion	X	X	X	-	X	-	X	X	6
Individual conversion	-	-	X	-	X	-	X	X	4
Annotation conversion	-	-	-	-	X	X	X	X	4
Structural reversibility Onto <-> REL	X	X	X	X	X	X	X	X	8
Tuples reversibility Tuple <-> RDF	-	-	-	-	X	X	X	X	4
Tool									
Implementation	-	-	-	-	-	-	X	X	2
Availability	-	-	-	-	-	-	X	X	2
Total (X)	11	11	14	7	9	7	12	20	

Table 1. Criterion and requirement correspondence [covered (X), not covered (-)].

1.4 Criteria evaluation

Table 2 presents the criteria evaluation as described in the papers. For example, for according to the paper A9 the generated SQL code is compatible with Microsoft server DBMS (MS-SQL). The symbol “?” means that the information cannot be found in the paper.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	OntoRel α
Ontology													
Ontology language	OWL ?	OWL ?	OWL ?	OWL ?	OWL DL	OWL DL	OWL QL, RL, EL	OWL ?	OWL DL	OWL DL	OWL ?	Onto-UML	OWL QL, RL, EL
Schema													
Structure	? S	BCNF S	3NF S	BCNF S	BCNF S	3NF S	BCNF S	? S	? S	? G	? S	3FN S	6NF S
Domains	No	No	No	No	No	No	No	No	No	No	No	No	Yes
Primary keys	G	C	G	G	C	G	C	G	G	G	?	C	G
Secondary keys	No	?	No	Yes	?	?	Yes	?	?	Yes	?	No	Yes
Foreign keys	?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Participation constraints	?	?	No	No	No	No	Yes	No	No	Yes	?	?	Yes
General constraints	?	?	Yes	Yes	?	Yes*	Yes	Yes*	No	Yes	?	Yes	Yes
Modification procedure	No	No	No	No	No	No	No	No	No	Yes	?	No	No*
Target DBMS	?	OntoDB	PgSQL	?	?	many	?	MySQL	MSSQL	?	?	?	PostgreSQL*
Process													
Axiom reduction	?	?	No	?	?	No	No	?	?	?	No	?	Yes
Intermediate structure	FOL	MOF	No	OWL	RDF	No	?	Jena	Jena	?	?	UML	μ Onto
Type conversion	?	?	No	?	?	?	Yes	Yes	Yes	?	?	?	Yes
Restriction conversion	?	I	No	I	No	No	E*	I	I	E	?	?	E
Individual conversion	Yes	No	No	No	Yes	No	Yes	Yes	No	Yes	Yes	?	No*
Annotation conversion	No	No	No	Yes	Yes	No	No	No	No	No	?	-	Yes
Structural reversibility Onto <-> REL	Yes Yes	Yes ?	No No	Yes ?	No No	? ?	No No	Yes No	Yes ?	? ?	No No	? ?	Yes No*
Tuples reversibility Tuple <-> RDF	Yes Yes	Yes ?	No No	Yes ?	Yes Yes	? ?	Yes Yes	? ?	? ?	? ?	No No	? ?	No* No*
Tool													
Existence	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	?	Yes	Yes	Yes
Availability	No	?	?	No*	Yes*	?	No	?	?	?	?	Yes	Yes

Table 2. Method comparison using criteria (extension of [Khnaisser et al. 2018])

Compared Papers:

- A1. [Dou et al. 2010]
- A2. [Bellatreche et al. 2010]
- A3. [Saccol et al. 2011]
- A4. [Vyšniauskas et al. 2012]
- A5. [Hornung and May 2013]
- A6. [Podsiadły-Marczykowska et al. 2014]
- A7. [Jiménez-Ruiz et al. 2015]
- A8. [Ho et al. 2015]
- A9. [Afzal et al. 2016]
- A10. [Achpal et al. 2016]
- A11 [Mahmudi et al. 2018]
- A12 [Guidoni et al. 2020]

1.5 Criteria applicability

Table 3 presents the criteria applicability per method a simplified version of Table 2 to facilitate requirements evaluation. A criterion is fulfilled by the method (X), not fulfilled (-) or unknown (?). For example, for A1, criterion

“Ontology language” is unknown, “Primary Keys” are fulfilled. Also, the count of fulfilled criteria is calculated for each method.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	OntoRel α
Ontology													
Ontology language	?	?	?	?	X	X	X	?	X	X	?	-	X
Schema													
Structure	?	X	-	X	X	-	X	?	?	?	?	X	X
Domains	-	-	-	-	-	-	-	-	-	-	-	-	X
Primary keys	X	X	X	X	X	X	X	X	X	X	?	X	X
Secondary keys	-	?	-	X	?	?	X	?	?	X	?	-	X
Foreign keys	?	X	X	X	X	X	X	X	X	X	X	X	X
General constraint	?	?	-	-	-	-	X	-	-	X	?	?	X
Participation constraint	?	?	X	-	?	X	-	X	-	X	?	X	X
Modification procedure	-	-	-	-	-	-	-	-	-	X	?	-	-
Target DBMS	?	?	X	?	?	X	?	X	X	?	?	?	X
Process													
Axiom reduction	?	?	-	?	?	-	-	?	?	?	-	?	X
Intermediate structure	-	X	-	X	-	-	?	X	X	?	?	X	X
Type conversion	?	?	-	?	?	?	X	X	X	?	?	?	X
Restriction conversion	?	X	-	X	-	-	X	X	X	X	?	?	X
Individual conversion	X	-	-	-	X	-	X	X	-	X	X	?	-
Annotation conversion	-	-	-	X	X	-	-	-	-	-	?	-	X
Structural reversibility	X	X	-	X	-	?	-	X	X	?	-	?	X
Tuples reversibility	X	X	-	X	X	?	X	?	?	?	-	?	-
Tool													
Implementation	X	X	X	X	-	X	X	X	X	?	X	X	X
Availability	-	?	?	-	X	?	-	?	?	?	?	X	X
Total (X)	5	7	5	10	8	6	12	9	8	9	9	7	17

Table 3. Criterion application by method [defined (X), not defined (-), unknown(?)].

Finally, for each method, requirement coverage for each compared method is evaluated (Table 7) according to the requirement-criterion correspondence and criterion application for each method. The requirement is covered by the method if all the associated criteria are fulfilled, the requirement is partially covered by the method if more than half of the criteria are fulfilled, the requirement is not covered by the method if half or less of the criteria is fulfilled, and the requirement coverage is unknown if more than half of the associated criteria cannot be evaluated based on publicly available information or through correspondence with the authors. For example, for A2, R1 coverage is partial : from the 11 criteria used to evaluate R1 coverage only 6/11 criteria are applicable, 5/11 are unknown. This comparison must be extended by adding weight to the criteria.

Paper	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	OntoRel α
Requirement													
R1. Cardinalities	?	P	-	P	-	-	P	P	P	?	?		P
R2. Missing information	?	P	-	P	-	-	P	P	P	?	?		P
R3. Axiom expressivity	?	-	-	P	-	-	P	P	P	?	?		P
R4. Type compatibility	?	-	-	-	?	?	?	P	P	?	?		P
R5. Reversibility	?	P	-	P	P	?	P	?	?	?	?		P
R6. Documentation	?	P	-	-	-	-	-	-	P	?	?		P
R7. Automation	?	P	-	P	-	?	P	P	P	P	?		P
R8. Evolution	?	-	-	-	-	-	P	-	-	-	?		P

Table 4. Requirements covered by method [covered (X), partially covered (P), not covered (-), unknown(?)].

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