Incremental Export of Relational Database Contents into RDF Graphs

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Outline

• Introduction
• Proposed Approach and Measurements
• Discussion and Conclusions
Introduction

• Information collection, maintenance and update is not always taking place directly at a triplestore, but at a RDBMS
• Triplestores are often kept as an alternative content delivery channel
• It can be difficult to change established methodologies and systems
• Newer technologies need to operate side-by-side to existing ones before migration
Mapping Relational Data to RDF

• No one-size-fits-all approach

• Synchronous Vs Asynchronous RDF Views
  • Real-time Vs Ad hoc RDF Views
  • Real-time SPARQL-to-SQL Vs Querying the RDF dump using SPARQL

• Queries on the RDF dump are faster in certain conditions, compared to round-trips to the database
  • Difference in the performance more visible when SPARQL queries involve numerous triple patterns (which translate to expensive JOIN statements)

• In this paper, we focus on the **asynchronous** approach
  • Exporting (dumping) relational database contents into an RDF graph
Incremental Export into RDF (1/2)

• Problem
  • Avoid dumping the whole database contents every time
  • In cases when few data change in the source database, it is not necessary to dump the entire database

• Approach
  • Every time the RDF export is materialized
    • Detect the changes in the source database or the mapping definition
    • Insert/delete/update only the necessary triples, in order to reflect these changes in the resulting RDF graph
Incremental Export into RDF (2/2)

• Incremental transformation
  • Each time the transformation is executed, not all of the initial information that lies in the database should be transformed into RDF, but only the one that changed

• Incremental storage
  • Storing (persisting) to the destination RDF graph only the triples that were modified and not the whole graph
  • Only when the resulting RDF graph is stored in a relational database or using Jena TDB
  • Regardless to whether the transformation took place fully or incrementally
R2RML and *Triples Maps*

- RDB to RDF Mapping Language
- A W3C Recommendation, as of 2012
- Triples Map: a reusable mapping definition
  - Specifies a rule for translating each row of a *logical table* to zero or more RDF triples
  - A *logical table* is a tabular SQL query result set that is to be mapped to RDF triples
  - *Execution* of a triples map generates the triples that originate from a specific result set (logical table)
The R2RML Parser

• An R2RML implementation
• Command-line tool that can export relational database contents as RDF graphs, based on an R2RML mapping document
• Open-source (CC BY-NC), written in Java
  • Publicly available at https://github.com/nkons/r2rml-parser
• Tested against MySQL and PostgreSQL
• Output can be written in RDF/OWL
  • N3, Turtle, N-Triple, TTL, RDF/XML notation, or Jena TDB backend
• Covers most (not all) of the R2RML constructs (see the wiki)
• Does not offer SPARQL-to-SQL translations
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Information Flow

- Parse the *source database* contents into result sets
- According to the R2RML *Mapping File*, the *Parser* generates a set of instructions to the *Generator*
- The *Generator* instantiates in-memory the resulting RDF graph
- Persist the generated *RDF graph* into
  - An RDF file in the Hard Disk, or
  - In Jena’s relational database, or
  - In Jena’s TDB (Tuple Data Base, a custom implementation of B+ Trees)
- Log the results
Incremental RDF Triple Generation

• Basic challenge
  • Discover, since the last time the incremental RDF generation took place
    • Which database tuples were modified
    • Which Triples Maps were modified
  • Then, perform the mapping only for this altered subset

• Ideally, we should detect the exact changed database cells and modify only the respectively generated elements in the RDF graph
  • However, using R2RML, the atom of the mapping definition becomes the Triples Map
Keeping Track

- **Reification**
  - Allows assertions about RDF statements
  - "Reified" model
    - A model that contains only reified statements
    - Stores the Triples Map URI that produced each triple

- **Logging**
  - Store MD5 hashes of
    - Triples Maps, SELECT queries, Result sets
  - A change in any of the hashes triggers execution of the Triples Map

```
<http://data.example.org/repository/person/1> foaf:name "John Smith" .

[] a rdf:Statement ;
  rdf:subject
  <http://data.example.org/repository/person/1> ;
  rdf:predicate foaf:name ;
  rdf:object "John Smith" ;
  dc:source map:persons .
```
Proposed Approach

• For each *Triples Map* in the *Mapping Document*
  • Decide whether we have to produce the resulting triples, based on the logged MD5 hashes

• Dumping to the Hard Disk
  • Initially, generate a number of RDF triples
  • RDF triples are logged as reified statements, followed by a provenance note
  • Incremental generation
    • In subsequent executions, modify the existing reified model, by reflecting only the changes in the source database

• Dumping to the Database or TDB
  • No log is needed, storage is incremental by default
Measurements Setup

• An Ubuntu server, 2GHz dual-core, 4GB RAM
• Oracle Java 1.7, Postgresql 9.1, Mysql 5.5.32
• 7 DSpace (dspace.org) repositories
  • 1k, 5k, 10k, 50k, 100k, 500k, 1m items, respectively
• A set of complicated, a set of simplified, and a set of simple queries
  • In order to deal with database caching effects, the queries were run several times, prior to performing the measurements
Query Sets

• Complicated
  • 3 expensive JOIN conditions among 4 tables
  • 4 WHERE clauses

• Simplified
  • 2 JOIN conditions among 3 tables
  • 2 WHERE clauses

• Simple
  • No JOIN or WHERE conditions

```sql
SELECT i.item_id AS item_id, mv.text_value AS text_value
FROM item AS i, metadatavalue AS mv,
metadataaschemaregistry AS msr, metadatafieldregistry AS mfr
WHERE msr.metadata_schema_id = mfr.metadata_schema_id AND
mfr.metadata_field_id = mv.metadata_field_id AND
mv.text_value is not null AND
i.item_id = mv.item_id AND
msr.namespace = 'http://dublincore.org/documents/dcmi-terms/
AND mfr.element = 'coverage'
AND mfr.qualifier = 'spatial'
```

```sql
SELECT i.item_id AS item_id, mv.text_value AS text_value
FROM item AS i, metadatavalue AS mv,
metadatafieldregistry AS mfr
WHERE mfr.metadata_field_id = mv.metadata_field_id AND
i.item_id = mv.item_id AND
mfr.element = 'coverage' AND
mfr.qualifier = 'spatial'
```

```sql
SELECT "language", "netid", "phone",
"sub_frequency", "last_active", "self_registered",
"require_certificate", "can_log_in", "lastname",
"firstname", "digest_algorithm", "salt", "password",
"email", "eperson_id"
FROM "eperson" ORDER BY "language"
```
Measurements (1/3)

• Export to the Hard Disk
• Simple and complicated queries, initial export
• Initial incremental dumps take more time than non-incremental, as the reified model also has to be created
Measurements (2/3)

• 12 Triples Maps
  a. non-incremental mapping transformation
  b. incremental, for the initial time
  c. 0/12
  d. 1/12
  e. 3/12
  f. 6/12
  g. 9/12
  h. 12/12

Data change
Measurements (3/3)

- Similar overall behavior in cases of up to 3 million triples
- Poor relational database performance
- Jena TDB is the optimal approach regarding scalability
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The approach is efficient when data freshness is not crucial and/or selection queries over the contents are more frequent than the updates.

The task of exposing database contents as RDF could be considered similar to the task of maintaining search indexes next to text content.

Third party software systems can operate completely based on the exported graph.
- E.g. using Fuseki, Sesame, Virtuoso

Updates can be pushed or pulled from the database.

TDB is the optimal solution regarding scaling.

Caution is still needed in producing de-referenceable URIs.
Discussion (2/2)

• On the efficiency of the approach for storing on the Hard Disk
  • Good results for mappings (or queries) that include (or lead to) expensive SQL queries
    • E.g. with numerous JOIN statements
  • For changes that can affect as much as \( \frac{3}{4} \) of the source data
• Limitations
  • By physical memory
  • Scales up to several millions of triples, does not qualify as “Big Data”
• Formatting of the logged reified model did affect performance
  • RDF/XML and TTL try to pretty-print the result, consuming extra resources, N-TRIPLES is the optimal
Room for Improvement

• Hashing Result sets is expensive
  • Requires re-run of the query, adds an “expensive” ORDER BY clause
• Further study the impact of SQL complexity on the performance
• Reification is currently being reconsidered in RDF 1.1 semantics
  • Named graphs being the successor
• Investigation of two-way updates
  • Send changes from the triplestore back to the database
Thank you for your attention!

Questions?