Towards distributed RDF querying

Citation for published version (APA):

Document status and date:
Published: 01/01/2004

Publisher Version:
Publisher’s PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:
• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher’s website.
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Towards Distributed RDF Querying

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Introduction / motivation
- Hera
- Integration model
- Query Processing
- Optimization

Introduction: Layout

Motivation
- Demand for combining distributed data on the Web
  - Comparative Shopping
  - Virtual Museums
  - Digital Libraries
  - Web Portals
- User:
  - formulate his query
  - split the query
  - assemble results

Introduction: motivation

The RDF data model
- statements are <subject, predicate, object> triples:
  - http://wwwis.win.tue.nl/~houben/
  - dc:creator, "Geert-Jan"

- statements describe properties of resources
- a resource is everything that has an identifier: URI
- Directed Labelled Multi-graph

Introduction: RDF (S)

Sem. Web / RDF(S) to the Rescue (?)
- RDF(S)
  - The Pivot Language of the Semantic Web
  - Solves the problem of syntactic heterogeneity of different sources
  - Provides basic modelling primitives and reasoning techniques for conceptual knowledge
  - Built on an extremely simple data model that avoids complications of other object oriented formalisms
  - And (most importantly): It is a standard!

Introduction: motivation

Sem. Web / RDF(S) to the Rescue (?)
- Benefits
  - Common Syntax
  - Formal (limited) Semantics
  - Flexible
    easy to express anything about anything
  - Our User?
    - formulate his query
    - split the query
    - assemble results
    ...
    (still unhappy)
**Possible Solution: Data Warehousing**

- Gather All Data Locally
- Watch for Updates
- Insert New Data
- Delete Old Data
- Evaluate (locally) User Query

**Data Warehousing: Problems**

- Performance
- Bottleneck
- Freshness
- Copyright / Data Ownership issues

**Another Solution: Virtual Repository**

- Split the User Query into Sub-Queries
- Translate Sub-Queries to Source Schemata
- Distribute Sub-Queries
- Assemble Results

**Challenges/ Requirements for Integration of RDF(S) Sources**

- Unified Interface to data sources
  - Usually only a part of a source is of interest
  - “Freshness” of data must be guaranteed
  - Sources are many, autonomous, and volatile
- Semantic Heterogeneity
  - Schema heterogeneity
  - Designation heterogeneity
- Distributed Query processing
  - Complex/Join queries (SelRQL language)
- Flexibility w.r.t. user needs/query
  - (the order of importance changes)
  - Correctness, Completeness
  - Performance

**Hera Design Methodology**

- Data retrieval is just a beginning
- Navigational Structure
- Presentation Rendering
- Adaptation / Adaptivity

**The Semantic Layer**

- Hera Back-end
- Hera Front-end
**Conceptual Model (CM)**
- Interface between data retrieval and presentation generation (via SeRQL)
- CM exists on its own (even without instances)
  - Made by a system designer
  - Top down approach
- Specifies the application’s semantics
  - What is the information system about
  - Expressed in RDF(S)
- Populated on demand with data from several heterogeneous information sources
- Challenge: Map the Sources to the defined CM

**Integration Model (IM)**
- A generic framework for describing, integrating and relating concepts from sources to their CM counterparts
  - View Definition/Translation Language +
  - Object reconciliation language +
  - Language for programming the mediator +
- Expressed in RDFS
- Instantiated by the integration designer into IMIs: program the mediator to overcome the semantic heterogeneity between the sources and the CM

**Integration Model in RDF(S)**

**Schema heterogeneity**
- Sources are autonomous and can therefore differ a lot from each other
- Mappings are formed through the notion of Path Expressions (PE) which form articulations
  - An articulation is a pair of two PEs, one in an external source, one in the CM
  - consists of a link between the start-classes and a link between the ending-edges
Schema heterogeneity

- Sometimes a value should be mapped to a list of values
- A transformer is needed for the necessary action
- Denoted in the IM as “obtained by list”

Integration Model: Expressive power

Designation heterogeneity

- Different sources may have different ways to uniquely identify instances
- Need to define the identifying properties “primary key” of objects in every source
- Consolidate them into the CM so that a join can be performed across multiple sources

Integration Model: Expressive power

Designation heterogeneity

- IM offers three kinds of data-identification:
  1. idByUri: every object has a unique URI
  2. idByValue: a value is unique for an object
  3. idByProperty: a “super resource” defines the uniqueness of an object

Examples:

Integration Model: Expressive power

Designation heterogeneity: idByUri

- An object is uniquely defined by its URI
- Can be used/imposed within closed communities, e.g. corporate IS
- Does not work World Wide

Integration Model: Expressive power

Designation heterogeneity: idByValue

- Value based (similarly to the relational model)
- A object is uniquely defined by one(or more) of its own properties

Integration Model: Expressive power

Designation heterogeneity: idByProperty

- idBy-information provided by a super-resource
- Recursive path until either idByUri or idByValue is encountered

Integration Model: Expressive power
Join Example
- If the primary key is the same data is joined
- The two idBy paths are different but joining is still possible if the end-values for the primary key are the same

Different sources - different qualities
- Sources can “get points” for certain qualities:
  - Data reliability
  - Data quality: e.g. picture quality for a Photo database
  - Reachability
  - Speed
- Sources can be consulted in different order based on the current user preferences
- Decorations
  - making background knowledge explicit
  - “exported” into the CM (extending the Schema)

Extra IM features
- Process Instructions:
  - (Need to compare (primary) keys
  - Transformers/Comparators
  - Conversion functions (date of birth -> Personal number)
  - Look-up table value translations
  - Unit conversions (km->mile)
  - Formal conversion (ft -> jg)
- Direct translation
  - In case of homogeneous Schemas/sources
  - Lists of classes with identical outgoing edges

CM Instance (CMI)
- The Hera presentation engine needs more data than that resulted from a “bare” user query
- The user query is extended to retrieve literal values (the real content)
- An RDF graph is constructed out of the “flat” SeRQL output
Initial Performance experiments
- Queries against small-size applications (e.g., the comics database or virtual museum) answered within ms
- Medium Test Set: RDF version of Wordnet
  - Naturally split in four parts: Nouns (10MB), Glossary (15MB), Similar To Definitions (2MB), Hyponyms (8MB)
- Test Setting:
  - Three local stores: Vrije Universiteit Amsterdam, CWI (Amsterdam) and Eindhoven Technical University, Mediator at Vrije Universiteit
- Results:
  - When installed locally Performance of distributed system is between 50 and 200% of the original Sesame (200-1000 msec.)
  - The performance drops with the size of the result set due to extensive joining and communication overhead

Optimization: Initial Performance

Where the Time Goes?
Depends on many factors
- Data Size / Source Processing Speed
- Query (complexity, result size ...)
- Connection Speed

Improving the Performance
- Large applications (hundreds of MB) require sophisticated optimization techniques:
  - Currently
    - Schema/path Indexing
    - Join ordering
    - Algebraic optimizations
  - Work in progress
    - Reducing the transferred data
    - requires an architecture change (similar to P2P)

Optimization: Approaches

Schema/Path Index Hierarchy
- Central place to store the translatable paths from the articulations
- The main idea: pushing long paths to sources is more efficient than joining many small paths at the mediator
  - fewer joins
  - smaller data traffic
- The index is constructed out of a pool of articulations
- Articulations can be added/deleted or modified on the fly: flexible source management
- Index is able to infer “new” paths of its own:
Schema/Path Index Hierarchy

- Key = path (sequence of properties)
- Value = list of sources to which this path can be translated

Optimization: Path Indexing

Performance Results: Full Index vs 1-path Index

From a RDF Path to Relational Tables

A Cost Model for RDF Querying

Join Ordering Heuristics

Optimization: Path Indexing

Optimization: Join Ordering

Optimization: Join ordering
Optimizing Communication: Collaborating Network of Mediators

- One coordinator + Set of cooperating nodes
- The coordinator generates the (global) query plan for other nodes
- instructions:
  - obtain data
  - use your local data
  - join obtained data in a given order
  - ship data to another node

Conclusions

- Virtual Repositories are a viable solution for building distributed WIS
- Challenges:
  - Semantic heterogeneity
    - Source schemas can differ
    - URI is not enough for joining
    - Flexible Evaluation
  - Performance / Scalability
    - Path Indexing
    - Join Ordering
    - Collaborating Mediators

Questions