Towards distributed RDF querying

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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

Sem. Web / RDF(S) to the Rescue (?)

- RDFS
  - 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

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 (?)

- 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 (SiROQ 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
- User Query
- Presentation
- Source Classes

**Hera Semantic Layer**
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

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

Hera: Conceptual Model

Layout

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

Integration Model in RDF(S)

Integration Model: Definition

Integration Model: RDFS syntax

Integration Model: Expressive power
**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”

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**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

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**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

---

**Designation heterogeneity:** idByValue

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

---

**Designation heterogeneity:** idByProperty

- idBy-information provided by a super-resource
- Recursive path until either idByUri or idByValue is encountered
Join Example
- If the primary key is the same data is joined

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)
  - Formatting conversion (lot -> fig)
- 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?

Where the Time Goes?

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: Path Indexing

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:

Optimization: Path Indexing

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Optimization: Path Indexing
**Schema/Path Index Hierarchy**

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

**Performance Results:**

Full Index vs 1-path Index

**From a RDF Path to Relational Tables**

**The Problem of Join Ordering**

- Determine the optimal order of join execution in a (chain) query
- Different strategies have different execution costs due to different selectivity of the join operations
- Problem is NP-hard: we consider heuristic solutions

**A Cost Model for RDF Querying**

- Data Access Costs
  - Initializing the transmission
  - Transferring the data
- Join Costs
  - Nested Loop Join
  - Hash Join (potentially faster but less flexible w.r.t. determining object identity)
- Costs of a Query Plan:
  - Transmission costs for all relations
  - Join costs for the chosen footprint

**Join Ordering Heuristics**

- Complexity of Task demands heuristic approaches, performance of heuristics depends on class of queries.
  - For chain queries the following performs best [Steinbrunn et al. 1997]
- 1) Iterative Improvement
  - Start with random solutions
  - Improve solution using a greedy heuristic
  - Result: local optima
- 2) Simulated Annealing
  - Further improve solutions allowing for increasing costs with a certain probability
  - Helps to get out of local optima and converge towards better solutions
**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
  - Receive a table
  - 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**