Querying Web Data in a Triple-Based Universal Storage with Application to Social Networks

Marcel Karnstedt

Digital Enterprise Research Institute (DERI)
National University of Ireland, Galway
Outline

Motivation & Applications

The Vision: A Universal Storage for Web Data

A Distributed Universal Storage
  - P2P & DHT
  - Data & Query Model
  - Operators
  - Query Engine
  - Mappings & Query Expansion

The Praxis: Implementation

Summary & Outlook
Outline

Motivation & Applications
The Vision: A Universal Storage for Web Data
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Summary & Outlook
“The Web needs to be *studied* and understood, and it needs to be *engineered*.” [Berners-Lee 2006]

**Web Science**

“... methods for *modelling, analysing and understanding* the Web at the various *micro- and macroscopic* levels. It is also about *engineering* protocols and ensuring that there is fit between infrastructure and the society that hosts it.” [Berners-Lee 2006]
Online social spaces (blogs, bulletin boards, forums, wikis) are one the fastest growing sectors of the Web.

Key objectives for DERI:
Provide new browsing opportunities by interlinking these social spaces.
To do that, we need
1: graph *analytical tools* to understand the social, information and structural dynamics of online communities.
2: to *Engineer* standard vocabularies, tools and applications that support communities and their members.
Key Questions

Clique: Graph & Network Analysis Cluster

Key questions (IBM, Idiro):
- What structures and behaviours influence information flow?
- What are the most useful generative models?
- What Web engineering innovations can we create to better enable information flow and prevent subversion?

We need data…!
- Anonymising data provided by partners, network sampling
- Integrated, data crawling, extraction, consolidation, structured storage
- Data pre-processing, integration, restructuring, indexing
- Data access API and query processor for complex queries
Huge heterogeneous data sets, collaboration, dynamic, structured, deep, linked, ...
Public Data Management

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- …Semantic & social Web, encyclopedias, recommender systems … “The world is a database“
- Datasets, which are
  - Maintained by large communities in a distributed way
  - Of public interest

- „Homogenized“ database, extensible and flexible, distributed, scalable, structured data and queries
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Main Challenges

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- Data management
- Scalability and robustness
- Security, trust, fairness
- Query expressiveness
  - DB-like queries with advanced functionality
  - Support of IR queries and similarity is mandatory
  - Schema-unaware queries and/or queries on schema
- Efficient processing
  - Efficient query operators
  - Cost awareness in changing situations
Approaches

Who pays the load?
Who owns the data?

Do we trust them?

views over 100,000 data sources?

Efficient query processing?

✓ Sindice, YARS
✓ Jena, Oracle
✓ SW-Store

✓ PIER, PeerDB
✓ RDFPeers
✓ UniStore

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Influences

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- Efficient lookups
- Robustness, self-organization, scalability
- Transparency, query processing

- Index structures
- DHTs & SDDS
- PDMS
- Distributed DBS
- Sensor networks
- Data streams
- P2P paradigm

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Who wrote an article for cool movies?

Wikipedia(article, author) "Pulp Fiction", "MK"

Del.icio.us(bookmark, tag, creator) "http://...pfiction", "cool", "MKa"

DBPedia(link, wikilink, category) "Pulp Fictoon", "Q. Tarantino", "movie"
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DHTs

- **Distributed Hash Table** offering two operations
  - `put(k, v)`: storing the pair `(k, v)`
  - `get(k) → v`: returning value `v` for `k`
- Partitioning the logical key space among peers
- „data centered“ routing without global knowledge
- Small number of neighbors (degree), low latency (diameter) → Small World networks
- Guarantees (usually log.), replication

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Layers of Processing

Routing

Query Operators

Scheduling, Adaptation, Costs

Processing Strategies

Similarity / Approximate Operators

Multicast, Aggregation, Range

Routing

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- Developed at EPFL Lausanne [Aberer et al. 05]
- Binary prefix tree as topology
- Lookup, range queries, prefix queries
P-Grid: Range Queries

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Range query message
n: Sequence in time
Result set

Initiator

A

B

C

D

E

F

Lower bound 0101
Higher bound 100

subtree 01
subtree 001
subtree 1

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Since the eighties: Model for simplified retrieval in (relational) databases

Universal relation containing all attributes

simplifies navigation over multiple relations during query formulation
Universal relation model
- Storing each tuple as a set of triples (oid, attribute, value)
- similar to RDF: subject, predicate, object

<table>
<thead>
<tr>
<th>OID</th>
<th>Car</th>
<th>Mileage</th>
<th>HP</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>232</td>
<td>Volvo V70</td>
<td>34.000</td>
<td>180</td>
<td>28.000</td>
</tr>
</tbody>
</table>

Extensible
Flexible
Self-descriptive
No need for representing null values

SW-Store
RDFPeers
Sindice, YARS
...
Indexing

- Indexing of attributes = key for Hashing
- Which attributes? All!
- For tuple (oid, v₁, v₂, ...) of R(OID, A₁, A₂, ...)

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- \( h(\text{oid}) \) for object lookup
- \( h(A₁ \parallel v₁) \)
- \( h(A₂ \parallel v₂) \)
- for \( A_i \geq v \)
- ... trade-off storage vs. performance

- YARS
- Hexastore
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Similarity Queries

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WHERE { ?o attrib ?value
FILTER (edist(?value, v) < 2) }

- Numerical similarity: value distance
- String similarity:
  - Edit distance using (positional) q-Grams
  - [Gravano et al. 2001, Schallehn et al. 2004]
- Requires additional key-value pairs in P-Grid
  - For each triple (oid, A, v)
    - h(q-gram_i(A)) → oid
    - h(q-gram_i(v)) → oid
- Approach for instance and schema level

SPARQL
LSH forest
SWAM
More Operators

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- Similarity joins [NetDB 06]

```sparql
WHERE { ?o attr1 ?v1 . ?o2 attr2 ?v2
  FILTER (edist(?v1, ?v2) < k) }
```

- Ranking queries: top-k, skyline [DBRank 07]

```sparql
WHERE { ?o attr ?v }
ORDER BY ?v LIMIT k
```

```sparql
WHERE { ?o attr ?v }
ORDER BY ?v NN "A String" LIMIT k
```
Similarity Joins

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Doubled sequential

Doubled parallel

Parallel and sequential

Sequential and parallel

Cloud services

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Skyline queries

- objects, which are not "dominated" by other objects
  - Scoring function on multiple attributes, no weighting

![Diagram](image-url)
Frame Skyline algorithm over 2 dimensions

- Minimum of first dimension defines maximum for second dimension
- Minima/Maxima provide a frame narrowing the search space
1. Find minimum in one *selective* dimension $x$
2. Use $y$ value of $\min(x)$ to limit search range
3. Use range query routing to build local skylines
4. Always ship current skyline with query
5. Determine global skyline at one peer
6. Optionally: distributed range querying “on the way“ to $\min(x)$
Skylines: More Dimensions

- All projections to 2d sub-spaces are skyline candidates
- Objects of the searched frame can dominate projections
- Projections cannot dominate objects of the searched frame
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Goal: stateless processing → „Push“ approach

- Messages containing both plan and intermediate results (based on Mutant Query Plans [Papadimos et al. 02])
- Receiver peer is identified by applying the hash function
- Multiple instances of the plan travel through the network
Cost-Based Planning

- [NetDB 06, P2P 06, DBRank07]
- Find all values of attribute A in max. distance d=1

Query all peers for A in parallel or sequence

$$\#\text{msgs} = m_1 + |A| - 1$$

Query d+1 q-grams in parallel

$$\#\text{msgs} = (d+1) \times m_1$$

- ObjectGlobe
- DARQ
Guarantees: Completeness

- Estimation on peer level
  - Based on routing graphs and routing methods
  - Probabilistic guarantees supported
- Accuracy improved by Milestone Messages
- [P2P 07, CIKM 08]

Query graph

Routing graph

Join(A=B)

Extract(A)\_sequ Extract(B)\_range

P_0 \rightarrow P_1^A \rightarrow P_2^A \rightarrow P_3^A \rightarrow ... \rightarrow P_n^A

P_1^B \rightarrow P_2^B \rightarrow P_3^B \rightarrow ... \rightarrow P_m^B

Routing level

Routing point

Seaweed
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[Ideas 08]

Simple kind of attribute correspondences

- Triple representation
  - \((A_4, \text{equiv}, A_5)\)
  - \((A_3, \text{subsumes}, A_6)\)

- Extendible to ontologies and views
Query Expansion

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Unexpanded query

Map operators added

First mapping

Expanded query

- GridVine
- PDMS

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UniStore

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[ICDE 07]
Evaluation: Similarity Joins

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- c1: seq & par/seq
- c2: par & par/seq
- c3: seq & par/par
- c4: par & par/par
- c5: par & local

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Evaluation: Completeness

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Min, max, avg 74 peers

Min, max, avg 50 peers

With MiMes

Without MiMes
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Web data is huge, heterogeneous, structured, linked
- Modern applications require a universal and flexible storage
- DB-like and RDF-liking

DHTs well-suited for large-scale data management

UniStore as one solution
- Robust and scalable, universal and light-weight
- Sophisticated query capabilities
- Adaptive, cost-based, stateless and parallel QP
- Guarantees, semantic Layer

Open issues
- Privacy & Trust
- ...

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Related Systems

**Clique: Graph & Network Analysis Cluster**

- **Sindice**: Sindice. The semantic web index. http://sindice.com/
- **SPARQL**: E. Prud'hommeaux and A. Seaborne. SPARQL Query Language for RDF, 2006. W3C Candidate Recommendation.
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- **DARQ**: B. Quilitz and U. Leser. Querying Distributed RDF Data Sources with SPARQL. In ESWC’08, pages 524–538, 2008.


Thank you!

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