PGX.ISO: Parallel and Efficient In-Memory Engine for Subgraph Isomorphism

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The Subgraph Isomorphism Problem

Q: Query Graph
G: Data Graph
A, B, C – Node Properties
X, Y, Z – Edge Properties

Problem: Find all subgraphs of G that are isomorphic to Q

Matching Criteria:
1. Topology of the graphs and
2. Properties on nodes and edges
Existing Solutions

- **Graph Databases**
  - RDF data Model
    - Oracle, Virtuoso, ...
    - SPARQL: standard query language
  - Property Graph (PG) data model
    - Neo4J, ...
    - No standard query language yet

  ➔ Disk-based solutions
    - [pro] Process very large graphs
    - [con] Disk latency becomes performance bottleneck

- **In-Memory Solutions**
  - Mostly from academia
    - VF2, QuickSI, TurboISO, etc...
  - Mostly sequential algorithms
  - Common approach:
    backtracking + filtering ➔ prune partial solutions

[ Issues and Lessons ]
- Parallelizing backtracking algorithms is challenging – esp. load balancing
- Poor spatial locality from depth-first approaches
- Matching Order is important
- Need efficient partial solutions handling
Our Approach (1) : PGX.ISO

• **Parallel, In-memory** engine for subgraph isomorphism
  – Use efficient data structure for graph and partial solutions
  – Considers load balancing and workload distribution

• **Breadth-first search**
  – Fixed order of query nodes for matching
  – Better for parallelization and more cache friendly

• **Other optimizations**
  – Different matching strategies for different graph patterns
  – Edge-first matching to improve performance

➡ Visit our poster for details
Our Approach (2) : GMQL

• GMQL: Graph Matching Query Language
  – A Query Language for Property Graph Data Model
  – First-class constructs for nodes, edges and properties
  – Compiles query into PGX.ISO

• Native SPARQL support
  – Automatic conversion: SPARQL → GMQL

• IDE and Visualization
  – Pluggable to Eclipse
  – Visualize query (and result)
  – Built from Spoofax language bench (TU DELFT)

⇒ Visit our poster for details
GMQL: Look and Feel

Graphical editor synchronizes with textual GMQL editor in real-time

SPARQL Query

GMQL Query can be automatically generated from SPARQL

Query results

Integrated with Eclipse
Performance Evaluation: PGX.ISO

• Dataset: LUBM Lubm datasets evaluated:
  – A standard benchmark for RDF/SPARQL
  – Lubm 8K – 173.8 million nodes, 701.8 million edges
  – Lubm 25K – 543 million nodes, 2.1 billion edges

• Environments (x86 and SPARC)
  – X86: 2 x 8-Core Intel(R) Xeon(R) CPU E5-2660 @ 2.2 GHz (X3-2)
  – SPARC: 8 x 16-Core SPARC T5 processor @ 3.6 GHz

• Comparisons
  – Oracle SPARQL SQL with Oracle RDBMS 12.1.0.1
  – SPARQL SQL queries run directly on the Oracle RDBMS
  – Graph is loaded into memory before running SPARQL queries in PGX
## Performance on LUBM Queries

<table>
<thead>
<tr>
<th>LUBM Query</th>
<th>LUBM 8K</th>
<th>Execution Time on x86 (s)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>#Solutions</td>
<td>SQL</td>
<td>PGX.ISO</td>
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<tr>
<td>Query 1</td>
<td>4</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Query 2</td>
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<td>21.26</td>
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<tr>
<td>Query 3</td>
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<tr>
<td>Query 4</td>
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<td>0</td>
<td>0</td>
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<td>Query 5</td>
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<td>0</td>
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<td>Query 7</td>
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<tr>
<td>Query 8</td>
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<tr>
<td><strong>Query 9</strong></td>
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<td><strong>58</strong></td>
<td><strong>0.58</strong></td>
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<tr>
<td>Query 10</td>
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<td>0</td>
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<tr>
<td>Query 11</td>
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<tr>
<td><strong>Query 14</strong></td>
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<td><strong>21.09</strong></td>
<td><strong>0.1</strong></td>
</tr>
</tbody>
</table>

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Comparison of PGX.ISO and Oracle-SQL
LUBM 8K and 25K on x86 and Sparc

100x improvement over SQL for all queries
Major gains from:
• Being in-memory
• Parallelization
Scalability of PGX.ISO

LUBM Query 2 Scalability on x86 and SPARC

PGX.ISO is well-parallelized (for x86 and SPARC)

*Best numbers for x86 and SPARC (with different optimizations and matching orders)
LUBM 8K, Query 2 on x86

- Node First
- Edge First

Plot shows the optimization is effective (vs. Node First)

Edge First: one of our optimization (See our poster for details)

[Observation] Performance depends on matching order

⇒ On-going research: finding best matching order
The whole PGX System

• PGX
  – In-memory, parallel graph analytic engine
  – Use database as persistence layer
  – Load graph into memory

• Two kinds of workloads
  – Graph query (this paper)
    ➔ Find patterns in graph
  – Computational analytics (OTN)
    ➔ Page rank, community detection, ...
  – We are merging these two engines

Check PGX engine at:
http://tinyurl.com/olabspgx
Summary

• PGX.ISO
  – Parallel, in-memory solution for subgraph isomorphism

• GMQL
  – a query language for property graph data
  – Provides RDF/SPARQL compatibility

• Evaluation with LUBM
  – With x86 and SPARC
  – Up to 300x faster than SQL-based Implementation
Hardware and Software
Engineered to Work Together
Backup Slides
GMQL: Graph-Matching Query Language