BENCHMARKING ESSENTIAL GRAPH QUERIES

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2. THE BENCHMARK

3. PRELIMINARY EXPERIMENTAL RESULTS

4. CONCLUSIONS
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Motivation

• Increasing amount of graph data (e.g., social networks)

• How to store graph data?
  • Graph (oriented) databases
  • RDF Triple stores (RDF databases)
  • NOSQL databases?

• What is the most suitable graph database?
  • Theoretical comparison (complexity and expressive power)
  • Empirical comparison (performance, usability, etc.)
  • Benchmarks for GDBs (there is not a standard one)
  • The application domain is very important
Our work

• Development of a benchmark for graph databases
  • Graph data based on a social network use case
  • Oriented to evaluate essential graph queries
  • Tools: data generator + test-driver + data converter

• Experiments
  • Small datasets: 1K, 100K, 500K, 1M nodes (done)
  • Very large datasets: > 10M nodes (current work)

• Experience on using several graph/RDF databases
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Benchmark Data Model

Social Network Data based on Facebook
Benchmark Query Mix

- Objective: real-life graph queries in a social network
- Approach: exploration of Facebook
- Selection: essential graph queries
- Result:
  - Attribute searching (Get people with a given name)
  - Node/edge adjacency (Get people that likes a given Web page)
  - Fixed-length paths (Get the friends of the friends of a given person)
  - Reachability (Is there a “friend” connection between two people?)
  - Pattern matching (Get the common friends between two people)
  - Aggregates (Get the number of friends of a given person)
Benchmark query mix

- (Q1) Get people having a given name
- (Q2) Get people that likes a given Web page W
- (Q3) Get the Web pages that a given person P likes
- (Q4) Get the name of a person with a given ID
- (Q5) Get the friends of the friends of a given person P
- (Q6) Get Web pages liked by the friends of a given person
- (Q7) Get people that likes a Web page which a person P likes
- (Q8) Is there a “friend” connection (path) between two people
- (Q9) Get the shortest path between two people
- (Q10) Get the common friends between two people
- (Q11) Get the common web pages that two people like
- (Q12) Get the number of friends of a given person P
## Expressing graph queries

<table>
<thead>
<tr>
<th></th>
<th>Get the friends of a person identified by id 10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dex</strong></td>
<td>long person_id = dex_graph.findObject(pid, dexvalue.setLong(10)); dex_graph.neighbors(person_id, friend, EdgesDirection.Outgoing);</td>
</tr>
</tbody>
</table>
| **InfiniteGraph** | Person person = this.findPersonByld(10); Iterator<
VertexHandle> it = person.getNeighbors().iterator(); while (it.hasNext) { … } |
| **Neo4j** | START p=node:peopleIdIndex(id=10) MATCH p-[:
friend]->f RETURN f |
| **OrientDB** | SELECT FROM ographvertex WHERE in[label='friend'].out in (select rid from index:personIdx where key = 10) |
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Datasets

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Nodes</th>
<th>Edges</th>
<th>RDF Triples</th>
<th>Tuples (SQL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>1000</td>
<td>5.874</td>
<td>8695</td>
<td>6.874</td>
</tr>
<tr>
<td>G2</td>
<td>100,000</td>
<td>1.002.216</td>
<td>1.283.727</td>
<td>1.102.216</td>
</tr>
<tr>
<td>G3</td>
<td>500,000</td>
<td>5.735.332</td>
<td>7.142.423</td>
<td>6.235.332</td>
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<tr>
<td>G4</td>
<td>1,000,000</td>
<td>12.094.498</td>
<td>14.909.745</td>
<td>13.094.498</td>
</tr>
</tbody>
</table>

Running on a HP Proliant, Intel Xeon X3430 2.40GHz, 8 GB RAM, Debian 64 bits
Data loading test

N=1,000 E=5,874

N=100,000 E=1,002,216

N=500,000 E=5,735,332

N=1,000,000 E=12,094,498
(Q1) Get people having a given name (attribute searching)

N=1,000     E=5,874

N=100,000     E=1,002,216

N=500,000     E=5,735,332

N=1,000,000     E=12,094,498
(Q2) Get people that likes a given Web page \( W \)
(Q3) Get the Web pages that a given person P likes (adjacency)

N=1.000  E=5.874

N=100.000  E=1.002.216

N=500.000  E=5.735.332

N=1.000.000  E=12.094.498
(Q4) Get the name of a person with a given ID

- N=1,000   E=5,874
- N=100,000  E=1,002,216
- N=500,000  E=5,735,332
- N=1,000,000  E=12,094,498
(Q5) Get the friends of the friends of a given person P (path)
(Q6) Get the Web pages likes by the friends of a given person

N=1,000  E=5.874

N=100,000  E=1,002.216

N=500,000  E=5.735.332

N=1,000,000  E=12.094.498
(Q7) Get people that likes a Web page which a person P likes

<table>
<thead>
<tr>
<th>Database</th>
<th>N=1.000</th>
<th>E=5.874</th>
</tr>
</thead>
<tbody>
<tr>
<td>4etore</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Allegro</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Bigdata</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Dex</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Infinite</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>Neo4j</td>
<td>150</td>
<td>180</td>
</tr>
<tr>
<td>OrientDB</td>
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<td>250</td>
</tr>
<tr>
<td>PostgreSQL</td>
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<td>350</td>
</tr>
<tr>
<td>Virtuoso</td>
<td>500</td>
<td>600</td>
</tr>
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</table>

<table>
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<tr>
<th>Database</th>
<th>N=100.000</th>
<th>E=1.002.216</th>
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<tr>
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<td>200</td>
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<tr>
<td>Dex</td>
<td>500</td>
<td>1000</td>
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<tr>
<td>OrientDB</td>
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<td>6000</td>
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<tr>
<td>PostgreSQL</td>
<td>5000</td>
<td>10000</td>
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<tr>
<td>Virtuoso</td>
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</table>

<table>
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<th>E=5.735.332</th>
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<tbody>
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<td>10</td>
</tr>
<tr>
<td>Allegro</td>
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<td>20</td>
</tr>
<tr>
<td>Bigdata</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Dex</td>
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<td>400</td>
</tr>
<tr>
<td>Neo4j</td>
<td>1000</td>
<td>2000</td>
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<tr>
<td>OrientDB</td>
<td>2000</td>
<td>4000</td>
</tr>
<tr>
<td>PostgreSQL</td>
<td>3000</td>
<td>6000</td>
</tr>
<tr>
<td>Virtuoso</td>
<td>5000</td>
<td>10000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Database</th>
<th>N=1.000.000</th>
<th>E=12.094.498</th>
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</thead>
<tbody>
<tr>
<td>4etore</td>
<td>100</td>
<td>200</td>
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<tr>
<td>Allegro</td>
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<td>Bigdata</td>
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<td>Dex</td>
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<td>OrientDB</td>
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<td>PostgreSQL</td>
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<td>100000</td>
</tr>
<tr>
<td>Virtuoso</td>
<td>60000</td>
<td>120000</td>
</tr>
</tbody>
</table>
(Q8) Is there a “friend” connection (path) between two people

- N=1.000, E=5.874
- N=100.000, E=1.002.216
- N=500.000, E=5.735.332
- N=1.000.000, E=12.094.498
(Q9) Get the shortest path between two people

- N=1,000, E=5,874
- N=100,000, E=1,002,216
- N=500,000, E=5,735,332
- N=1,000,000, E=12,094,498
(Q10) Get the common friends between two people (graph pattern)

N=1.000     E=5.874
N=100.000     E=1.002.216
N=500.000     E=5.735.332
N=1.000.000     E=12.094.498
(Q11) Get the common web pages that two people like

N=1.000     E=5.874

N=100.000     E=1.002.216

N=500.000     E=5.735.332

N=1.000.000     E=12.094.498
(Q12) Get the number of friends of a given person P (aggregation)

- For $N=1,000, E=5,874$
- For $N=100,000, E=1,002,216$
- For $N=500,000, E=5,735,332$
- For $N=1,000,000, E=12,094,498$
Total time for query mix (12 queries x 100 instances)

- N=1.000  E=5.874
- N=100.000  E=1.002.216
- N=500.000  E=5.735.332
- N=1.000.000  E=12.094.498
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Conclusions

• The comparison of current graph databases is not an easy task
  • There are several graph data models
  • There is not standard graph query language
  • Models and query languages are not formally defined
  • There is not a standard graph data format (to data export/import)

• We developed a benchmark for graph databases
  • Based on a social data network use-case
  • Oriented to evaluate essential graph queries
Conclusions

• Our experience
  • Most graph databases implement APIs for managing graph data
  • Several problems for installing and using the systems
  • Several problems during data loading (e.g., slow, codification)
  • Different query languages and/or query features (APIs)
  • Graph queries are well supported by graph databases
  • Most implementations fail by RAM use

• Current and future work:
  • Improvement of the benchmark
  • Evaluation of very large datasets: 10M, 100M, 1B ... nodes
  • Inclusion of other databases (e.g., column-store, key/value, etc.)
Acknowledgments

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Design and development of the graph data generator Sebastián Arancibia, graduated student, Department of Computer Science, Universidad de Talca, Chile

Execution and reporting of benchmarking tests Sergio Silva, undergraduate student, Department of Computer Science, Universidad de Talca, Chile