Advanced Data Management

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Assignment-1 due on Aug 15 23:59 IST. Submission instructions will be posted by tomorrow, Friday Aug 12 on the course webpage.

Project groups due on Aug 22, 18:00 IST. Emailing instructions will be given shortly before that.
Recap

- BitMat’s query processing algorithm.
- **Semi-joins**.
- Nice properties of *acyclic* query graphs.
- N-way multi-joins.
- Brief introduction to RDF-3X.
Contemporary Systems

- RDF-3X [Neumann2010]
- gStore [Zou2011]
- TripleBit [Yuan2013]
- Virtuoso
- MonetDB
- Neo4j
RDF-3X

- Assumes the graph as a 3-column table.
- Creates all 6-way indexes – PSO, POS, SPO, SOP, OPS, OSP.
- Index compression using *delta-encoding*.
- Indexes are created as compressed B+ trees.
- Creates a *pipelined left-deep* join operator tree.
- *Sideways-information-passing* during scans and merge-joins.
- Aggressive *selectivity estimation* for all possible single edge patterns.
Sideways-information-passing (SIP)

- Passes information of scanned values from one join to another scan, before executing that join.
- SIP has a strong similarity to the semi-joins.

Figure taken from RDF-3X, SIGMOD 2009 paper.
Sideways-information-passing (SIP)

Figure taken from RDF-3X, SIGMOD 2009 paper.
Create equivalence class of join variables across all the edges in the pattern – inherent to SPARQL, e.g., ?friend, ?sitcom. The equivalence class of ?friend in corresponding SQL query will be \{t1.o, t2.s\}.

Create a shared memory for SIP information passing between operators like scan and merge-joins.

Hash joins created using bloom filters.

Bloom filters are populated with a distance preserving hash function.
Query plan

Figure taken from RDF-3X, SIGMOD 2009 paper.
Selectivity estimation

- Creates *aggregation statistics* for *binary projections* and *unary projections*, e.g., for each pair of SP value values of O are indexed along with their frequencies. For each S value, number of edges (tuples) with that value are noted.
- Join selectivities of *pairs* of triple patterns pre-computed.
- The join selectivity estimation for the pairs of triple patterns has a flavor of computing *outgoing and incoming single-hop paths* for all the edges in the graph.

\[
\text{sel}(c_1, c_2, v) \bowtie_{v=s_2} (s_2, p_2, o_2) = \frac{\mid (c_1, c_2, v) \bowtie_{v=s_2} (s_2, p_2, o_2) \mid}{\mid (c_1, c_2, v) \mid \ast \mid (s_2, p_2, o_2) \mid} = \sum_{x \in \Pi_v(c_1, c_2, v) \bowtie (x, p_2, o_2)} \frac{x}{\mid (c_1, c_2, v) \mid \ast \mid (s_2, p_2, o_2) \mid}
\]
Evaluation Results

- Very fast n-way merge-joins through SIP strategy, when there are *star* shaped sub-patterns in the given query.
- Better *selectivity estimation* during query plan generation.
- Fast query evaluation when queries are highly selective and can make use of the optimization techniques of SIP by avoiding large index scans.
TripleBit

- Uses bitvector based indexing method.
- Compressed *dictionary* encoding.
- Mix of bitvector based indexing (like BitMat) and column-wise storage (like relational column-stores).
- ID-Chunk matrix and ID-Predicate bit matrix.
- ID-predicate index – for edges with wildcards in the query pattern.
- Aggregate indexes – for edges with two wildcards in the query.
- Use technique similar to Byte-aligned Bitmap Compression (BBC).
- Use the *same* query graph model as BitMat!
### Figure: Triple matrix

Figure taken from TripleBit, VLDB 2013 paper.
## ID-chunk bit matrix

![ID-chunk bit matrix diagram](image)

Figure taken from TripleBit, VLDB 2013 paper.
Byte-aligned Bitmap Compression style

<table>
<thead>
<tr>
<th>uncompressed (in 7-bit groups)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>compressed</th>
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<tbody>
<tr>
<td>A</td>
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<tr>
<td>B</td>
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</tbody>
</table>

Figure taken from TripleBit, VLDB 2013 paper.
Query Processing

- Uses dynamic query plan generation (DQPGA).
- Consists of bushy (star) join processing, similar to *clustered semi-joins* of BitMat, and pruning the data before final joins.
General recap of the three systems we learnt, brief overview of other graph related problems, and then moving on to the distributed management.
Questions?