An Out-of-Core GPU Accelerated Multi-Predicate Join Algorithm for Graph Processing
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Motivation
- Treat graphs as relations
- Empower domain users to use general declarative languages.
- Joint work with LogicBlox Inc.

A LogiQL Rule
\[ \text{triangle}(x,y,z) \leftarrow E(x,y), E(y,z), E(x,z), x < y < z. \]
\[ 4\text{cl}(x,y,z,w) \leftarrow E(x,y), E(x,z), E(x,w), E(y,z), E(y,w), E(z,w), x < y < z < w. \]

- Formulations as a multi-predicate join can
  - Reduce data movement between binary joins.
  - Reduce data reorganization (sorting or hash table construction).

Core Algorithm: LeapFrog TrieJoin (LFTJ) [1]
- A general multi-predicate join algorithm.
- Worst case optimal.

LFTJ on 3 Tries to find triangles
1. Find one intersection in the current layer
2. Down to the next layer

Operates similar to Depth First Search (DFS)

Performance: GPU-Optimized LFTJ [3]
- Change depth first to breadth first to exploit more parallelism.
- Optimized for load balance and memory access patterns.
- Evaluated over randomly generated graphs.
- Much faster than original LFTJ and binary join (Red Fox).
- Throughput is smaller than PCIe bandwidth.

Example: Clique Listing
- Key ingredients for many graph algorithms such as
  - Triangle clustering
  - Cohesive subgraph
  - Extensive attention from
    - Graph theory
    - Database
    - Network analysis

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Out-of-Core Management: Boxing LFTJ [2]
- The partition algorithm from the Logicblox Runtime.
- When the graph is out-of-core, the data space is partitioned into boxes that fit in memory and executed with in-memory LFTJ.
- The boxing algorithm is worst case optimal.
- The boxed LFTJ has the same complexity as in-memory LFTJ.
- The boxed LFTJ matches the state-of-art specialized algorithm when finding triangles.

Execute Large Graphs in GPUs ([1]+[2]+[3])
- Evaluate large real or synthesized graphs.
- Baseline is CPU boxed LFTJ.
- GPU is usually more efficient.
- SSD and PCIe are not the bottleneck.

References:
2. Zinn. General-purpose join algorithms for listing triangles in large graphs.
3. Wu. Multipredicate join algorithms for accelerating relational graph processing on GPUs.