Graphalytics: A Benchmark for Large-Scale Graph Analysis on Parallel and Distributed Platforms

Presentation developed jointly with Ana Lucia Varbanescu.
Several slides developed jointly with Yong Guo.

Co-authored by LDBC team:
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Prof. dr. ir. Alexandru Iosup
Massivizing Computer Systems
VU Amsterdam / TU Delft – the Netherlands – Europe

Amsterdam
- founded 10th century
- pop: 850,000

Delft
- founded 1880
- pop: 23,500

Walldorf, Germany
- founded 1842
- pop: 19,500

The Netherlands
- pop: 16.5 M

Europe
- pop: 100,000
GraphsComp in Academic Publications

Title Keywords in Computer Systems Conferences (CCGRID, CLOUD, Cluster, HPDC, ICPP, IPDPS, NSDI, OSDI, SC, SIGMETRICS, SoCC, SOSP, ) and Journals (CCPE, FGCS, JPDC, TPDS) and Journals (CCPE, FGCS, JPDC, TPDS)

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</table>
Graphs Are at the Core of Our Society: The LinkedIn Example

The State of LinkedIn

A very good resource for matchmaking workforce and prospective employers

Vital for your company’s life, as your Head of HR would tell you

Vital for the prospective employees

Tens of “specialized LinkedIns”: medical, mil, edu, science, ...

150,000,000 registered members (Q1 ’12)

LinkedIn’s Service Analysis

By processing the graph: opinion mining, hub detection, etc. Always new questions about whole dataset.
LinkedIn’s Service Analysis

Periodic and/or continuous full-graph analysis

Sources: Vincenzo Cosenza, The State of LinkedIn, http://vincos.it/the-state-of-linkedin/
How to do Graph Analysis? Graph Processing @large

Interactive processing not considered in this presentation.
Streaming not considered in this presentation.
Graph Processing Platforms

Which platforms perform well?

What to tune?

What to re-design?
Graph Processing Platforms

- Intel Graphmat
- IBM System G
- Benchmark!
What Is the Performance of Graph Processing Platforms?

- **Graph500**
  - Single application (BFS), Single class of synthetic datasets. @ISC16: future diversification.

- Few existing platform-centric comparative studies
  - Prove the superiority of a given system, limited set of metrics

- **GreenGraph500, GraphBench, XGDBench**
  - Issues with representativeness, systems covered, metrics, ...
What Is the Performance of Graph Processing Platforms?

Graphalytics = comprehensive benchmarking suite for graph processing across many platforms

http://ldbcouncil.org/ldbc-graphalytics
http://graphalytics.ewi.tudelft.nl/
Graphalytics, in a nutshell

- An LDBC benchmark
- Advanced benchmarking harness
- Many classes of algorithms used in practice
- Diverse real and synthetic datasets
- Diverse set of experiments representative for practice
- Renewal process to keep the workload relevant
- Extended toolset for manual choke-point analysis
- Enables comparison of many platforms, community-driven and industrial

http://ldbcouncil.org/ldbc-graphalytics
Graphalytics = Benchmarking Harness

Iosup et al. LDBC Graphalytics: A Benchmark for Large Scale Graph Analysis on Parallel and Distributed Platform, PVLDB’16.
Graphalytics = Representative Classes of Algorithms and Datasets

- 2-stage selection process of algorithms and datasets

<table>
<thead>
<tr>
<th>Class</th>
<th>Examples</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graph Statistics</td>
<td>Diameter, Local Clust. Coeff., PageRank</td>
<td>20</td>
</tr>
<tr>
<td>Graph Traversal</td>
<td>BFS, SSSP, DFS</td>
<td>50</td>
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<tr>
<td>Connected Comp.</td>
<td>Reachability, BiCC, Weakly CC</td>
<td>10</td>
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<tr>
<td>Community Detection</td>
<td>Clustering, Nearest Neighbor. Community Detection w Label Propagation</td>
<td>5</td>
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<tr>
<td>Other</td>
<td>Sampling, Partitioning</td>
<td>&lt;15</td>
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</tbody>
</table>

+ property/weighted graphs: Single-Source Shortest Paths (~35%)

Graphalytics = Distributed Graph Generation with DATAGEN

- Rich set of configurations
- More diverse degree distribution than Graph500
- Realistic clustering coefficient and assortativity

Graphalytics

- Person Generation
- Edge Generation
- “Knows” graph serialization
- Activity Generation
- Activity serialization

Level of Detail
### Graphalytics = Diverse Set of Automated Experiments

<table>
<thead>
<tr>
<th>Category</th>
<th>Experiment</th>
<th>Algo.</th>
<th>Data</th>
<th>Nodes/ Threads</th>
<th>Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
<td>Dataset variety</td>
<td>BFS,PR</td>
<td>All</td>
<td>1</td>
<td>Run, norm.</td>
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<tr>
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<td>Algorithm variety</td>
<td>All</td>
<td>R4(S), D300(L)</td>
<td>1</td>
<td>Runtime</td>
</tr>
<tr>
<td><strong>Scalability</strong></td>
<td>Vertical vs. horiz.</td>
<td>BFS, PR</td>
<td>D300(L), D1000(XL)</td>
<td>1—16/1—32</td>
<td>Runtime, S</td>
</tr>
<tr>
<td></td>
<td>Weak vs. strong</td>
<td>BFS, PR</td>
<td>G22(S)—G26(XL)</td>
<td>1—16/1—32</td>
<td>Runtime, S</td>
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<tr>
<td><strong>Robustness</strong></td>
<td>Stress test</td>
<td>BFS</td>
<td>All</td>
<td>1</td>
<td>SLA met</td>
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<tr>
<td></td>
<td>Variability</td>
<td>BFS</td>
<td>D300(L), D1000(L)</td>
<td>1/16</td>
<td>CV</td>
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<tr>
<td><strong>Self-Test</strong></td>
<td>Time to run/part</td>
<td>--</td>
<td>Datagen</td>
<td>1—16</td>
<td>Runtime</td>
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</table>
Graphalytics = Modern Software Engineering Process

Graphalytics code reviews
- Internal release to LDBC partners (first, Feb 2015; last, Feb 2016)
- Public release, announced first through LDBC (Apr 2015)
- First full benchmark specification, LDBC criteria (Q1 2016)

Jenkins continuous integration server
SonarQube software quality analyzer

https://github.com/ldbc/ldbc_graphalytics
Ongoing Activity in the Graphalytics Team (2016-2017)

1. A public, curated database of rated graph-processing platforms
   - Demo follows in next presentation

2. Grade10: systematic analysis of performance bottlenecks

3. Granula: process for modeling, modeling, archiving, and sharing performance results for graph-processing platforms

4. Release of full-fledged LDBC Graphalytics benchmark
Graphalytics = Portable Performance Analysis with Granula

Modeling

Granula Performance Model

Monitoring

Performance Analyzer

Logging Patch

Graph Processing System

Archiving

Granula Archiver

logs

rules

Sharing, Analysis
(based on online Visualization)

Minimal code invasion + automated data collection at runtime + portable archive (+ web UI) → portable bottleneck analysis
Incremental Performance Modelling with Granula

GiraphJob

Deployment
- AppStartup
- ContainerAssignment
- ContainerLoad

BspExecution
- BspSetup
- BspIteration
- BspCleanup

Decommission
- ContainerOffload
- AppTermination

GlobalStartup
- ContainerStartup

GlobalDataloader
- Dataloader
- PostDataloader

GlobalSuperstep
- PreSuperstep
- Computation
- MsgSend
- PostSuperstep

GlobalCleanup
- ZookeeperCleanup
- ClientCleanup
- ServerCleanup
- DataOffload
- ContainerCleanup

BSP Programming Model
Performance Monitoring, Archiving, Visualization with Granula

Giraph - CDLP on LDBC-1000, 8 nodes
Performance Visualization, Analysis with Granula

Computation imbalance!

Giraph - BFS on LDBC-1000, 5 nodes
Performance analysis is time-consuming and expertise-driven. Grade10 analyses Granula & resource utilization data for you.

Possible performance bottlenecks:

- 20% slowdown due to imbalance in ‘Computation’ phase
- HW resource bottlenecks of ‘GlobalSuperstep’: CPU 60%, network 30%, none 10%
Performance analysis is **time-consuming** and **expertise-driven**. Grade10 analyses Granula & resource utilization data for you.

**Possible performance bottlenecks:**

- 20% slowdown due to imbalance in 'Computation' phase
- HW resource bottlenecks of 'GlobalSuperstep':
  - CPU 60%, network 30%, none 10%

**Goal:** Aid users in understanding performance through automated analysis of performance data
Possible future directions:

1. Support **performance regression tests** by identifying shifts in bottlenecks

2. Identify **platform-wide bottlenecks** through systematic evaluation of Graphalytics results

3. Integrate **low-level performance data**, including HW performance counters, tracing data
Full Benchmark: 4 Types of Benchmarks

1. **Test benchmark / fire drill**

2. **Standard benchmark**
   - cost-efficiency*, performance

3. **Full benchmark**
   - scalability, robustness

4. **Custom benchmark**
   - specialized analysis, based on Granula and Grade10

*A public, curated DB of rated graph-processing platforms

* Cost-efficiency will be discussed by the LDBC BoD on Friday.
<table>
<thead>
<tr>
<th>Date</th>
<th>Release</th>
<th>Competition</th>
<th>Activities</th>
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<tbody>
<tr>
<td>2017-01-30</td>
<td>v0.2.8</td>
<td>Beta Competition: R2</td>
<td>Refine standard benchmark definition + cost-efficiency + performance</td>
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<td>2017-03-13</td>
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<td>Beta Competition: R3</td>
<td>Refine system specification, cost model</td>
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<td>Refine full benchmark definition + scalability + robustness</td>
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<td>Beta Competition: R3</td>
<td>Refine competition, auditing Rules</td>
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<td>2017-06-05</td>
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<td>2017-06-19</td>
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<td>2017, Edition 1: Completed</td>
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<tr>
<td>2017-06-26</td>
<td>v1.0.0</td>
<td>2017, Edition 2: Started</td>
<td>Global participation</td>
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Graphalytics, in the future

An LDBC benchmark
Advanced benchmarking harness
Diverse real and synthetic datasets
Many classes of algorithms
Granula, Grade10 for bottleneck analysis
Modern software engineering practices
Supports many platforms
Enables comparison of community-driven and industrial systems
Public, curated DB of rated systems

https://github.com/ldbc/ldbc_graphalytics