GRAPHALYTICS
A Big Data Benchmark for Graph-Processing Platforms

https://github.com/tudelft-atlarge/graphalytics/

Mihai Capotă, Yong Guo, Ana Lucia Varbanescu,
Tim Hegeman,
Wing Lung Ngai,
Alexandru Iosup,
Jose Larriba Pey, Arnau Prat, Peter Boncz, Hassan Chafi

GRAPHALYTICS was made possible by a generous contribution from Oracle.
(TU) Delft – the Netherlands – Europe

Delft
- founded 13th century
- pop: 100,000

Barcelona
- founded 1842
- pop: 15,000
- pop: 16.5 M
The Parallel and Distributed Systems Group at TU Delft

Alexandru Iosup
- Grids/Clouds
- P2P systems
- Big Data/Graphs
- Online gaming

Dick Epema
- Grids/Clouds
- P2P systems
- Video-on-demand
- e-Science

Ana Lucia Varbanescu (now UvA)
- HPC systems
- Multi-cores
- Big Data/Graphs

Henk Sips
- HPC systems
- Multi-cores
- P2P systems

Johan Pouwelse
- P2P systems
- File-sharing
- Video-on-demand

Home page
- www.pds.ewi.tudelft.nl

Publications
- see PDS publication database at publications.st.ewi.tudelft.nl

Winners IEEE TCSC Scale Challenge 2014
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, gov, ...

Sources: Vincenzo Cosenza, The State of LinkedIn, http://vincos.it/the-state-of-linkedln/
LinkedIn’s Service/Ops Analytics

3-4 new users every second

The State of LinkedIn

but fewer visitors (and page views)

By processing the graph: opinion mining, hub detection, etc.

100+ million questions of customer retention, of (lost) customer influence, of ...
LinkedIn Analytics

The State of LinkedIn

3-4 new users every second

but fewer visitors (and page views)

Periodic and/or continuous analytics at full scale

Sources: Vincenzo Cosenza, The State of LinkedIn, http://vincos.it/the-state-of-linkedin/
LinkedIn Is Not Unique: Data Deluge

LinkedIn:
- 400M users
- ??? edges

Twitter:
- 270M MAU
- 200+ avg followers
- >54B edges

Facebook:
- 1.2B MAU
- 0.8B DAU
- 200+ avg followers
- >240B edges
LinkedIn Is Not Unique: Data Deluge

IBM

IBM 280k employee-users, 2.6M followers
company/day:
100+ posts, 1,000+ comments

LinkedIn

270M MAU
200+ avg followers
>54B edges

Twitter

1.2B MAU 0.8B DAU
200+ avg followers
>240B edges

friendster

Facebook

TU Delft

Delft University of Technology
The Data Deluge of Large-Scale Graphs

Data-intensive workload

10x graph size → 100x—1,000x slower

270M MAU

1.2B MAU 0.8B DAU

200+ avg followers

>240B edges
The Data Deluge of Large-Scale Graphs

Linkedin

Data-intensive workload
10x graph size → 100x–1,000x slower

Compute-intensive workload
more complex analysis → ?x slower

Friendster

270M MAU
200+ avg followers
>54B edges

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Compute-intensive workload
10x graph size → 100x–1,000x slower

TU Delft
Delft University of Technology
The Data Deluge of Large-Scale Graphs

LinkedIn

Data-intensive workload
10x graph size $\rightarrow$ 100x–1,000x slower

Compute-intensive workload
more complex analysis $\rightarrow$ ?x slower

Dataset-dependent workload
unfriendly graphs $\rightarrow$ ??x slower
The “sorry, but…” moment

Supporting multiple users
10x number of users \( \rightarrow \) ????x slower
Interactive processing not considered in this presentation. Streaming not considered in this presentation.
Interactive processing not considered in this presentation. Streaming not considered in this presentation.
Graph-Processing Platforms

- Platform: the combined hardware, software, and programming system that is being used to complete a graph processing task

Which to choose? What to tune?
What is the performance of graph-processing platforms?

- **Metrics Diversity**
- **Graph Diversity**
- **Algorithm Diversity**

Graphalytics = comprehensive benchmarking suite for graph processing across all platforms
Graphalytics = A Challenging Benchmarking Process

- Methodological challenges
  - Challenge 1. Evaluation process
  - Challenge 2. Selection and design of performance metrics
  - Challenge 3. Dataset selection and analysis of coverage
  - Challenge 4. Algorithm selection and analysis of coverage

- Practical challenges
  - Challenge 5. Scalability of evaluation, selection processes
  - Challenge 6. Portability
  - Challenge 7. Result reporting

Graphalytics = Advanced Harness

Support of cloud-based platforms technically feasible, methodologically difficult

M. Capota et al., Graphalytics: A Big Data Benchmark for Graph-Processing Platforms. SIGMOD GRADES 2015
Graphalytics = Real & Synthetic Datasets

<table>
<thead>
<tr>
<th>Graphs</th>
<th>V</th>
<th>E</th>
<th>d</th>
<th>D</th>
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<tr>
<td>G7 Friendster</td>
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<td>18,323,558</td>
<td>2.719</td>
<td>1,663</td>
<td>undirected</td>
</tr>
</tbody>
</table>

- Interaction graphs (possible work)
- Property graphs (planned work)

The Game Trace Archive


Graphalytics = Graph Generation w DATAGEN

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

Graphalytics

Level of Detail
Graphalytics = Many Classes of Algorithms

- Literature survey of metrics, datasets, and algorithms
  - 2009–2013, 124 articles in 10 top conferences: SIGMOD, VLDB, HPDC, ...

<table>
<thead>
<tr>
<th>Class</th>
<th>Examples</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graph Statistics</td>
<td>Diameter, PageRank</td>
<td>16.1</td>
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<td>Graph Traversal</td>
<td>BFS, SSSP, DFS</td>
<td>46.3</td>
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<td>Connected Component</td>
<td>Reachability, BiCC</td>
<td>13.4</td>
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<td>Community Detection</td>
<td>Clustering, Nearest Neighbor</td>
<td>5.4</td>
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<tr>
<td>Graph Evolution</td>
<td>Forest Fire Model, PAM</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Future work: more diverse algorithms from application domains

Graphalytics = Choke-Point Analysis

• Choke points are crucial technological challenges that platforms are struggling with

• Examples
  • Network traffic
  • Access locality
  • Skewed execution (stragglers)

• Challenge: Select benchmark workload based on real-world scenarios, but make sure benchmark covers important choke points

Choke-point analysis often require fine-grained analysis of system operation, across many systems

ongoing work
Coarse-grained vs Fine-grained Evaluation (1)

Coarse-grained Method
system viewed as a black-box

Algorithms, Datasets, Resources

Graph processing system

Coarse-grained performance metrics
(Overall Execution Time)

Fine-grained Method
system viewed as a white-box

Algorithms, Datasets, Resources

IO operations
Processing operations
Overheads

Fine-grained performance metrics
(Stage 3 time, straggler tasks)

Fine-grained evaluation method is more comprehensive
Coarse-grained vs Fine-grained Evaluation (2)

**Abstract**

Coarse-grained Method
knowledge at conceptual level

- Graph Processing Systems
- Distributed Infrastructure

several performance results

**Granular**

Fine-grained Method
knowledge at technical level

- hadoop
- Giraph
- Oracle Labs
- PGX

many performance results

**Fine-grained evaluation method is more comprehensive**

... but more time-consuming, esp. to implement
Graphalytics: Granula Overview

Granular

Fine-grained Method

1. Modeling
   - Configuration
   - Dataset Generator
   - Benchmark Core
   - Platform-specific algorithm implementation

2. Archiving
   - Concepts
   - Feedback

3. Visualizing
   - Information

https://github.com/tudelft-atlarge/granula/
Granula Modeller

Job

Operation

Operation [Actor @ Mission]

Info [StartTime]

Info [EndTime]

Info [....................]

Visual

Visual

Visual

Time-consuming, expert-only, done only once
Granula Archiver

Modeling

Performance Model

Archiving

Performance Analyzer

Logging Patch

Graph Processing System

Granula Archiver

Time-consuming, minimal code invasion, automated data collection at runtime, portable archive
Granula Visualizer
Portabe choke-point analysis for everyone!
Graphalytics = Advanced Software Engineering Process

https://github.com/tudelft-atlarge/graphalytics/

- All significant modifications to Graphalytics are peer-reviewed by developers
  - Internal release to LDBC partners (Feb 2015)
  - Public release, announced first through LDBC (Apr 2015*)
- Jenkins continuous integration server
- SonarQube software quality analyzer
Graphalytics in Practice

Data ingestion not included here!

6 real-world datasets + 2 synthetic generators

Many more metrics supported

10 platforms tested w prototype implementation

5 classes of algorithms

• Missing results = failures of the respective systems

M. Capota et al., Graphalytics: A Big Data Benchmark for Graph-Processing Platforms. SIGMOD GRADES 2015
Graphalytics: Key Findings So Far

- Performance is function of (Dataset, Algorithm, Platform, Deployment)
  - Previous performance studies lead to tunnel vision

- Platforms have their specific drawbacks (crashes, long execution time, tuning, etc.)
  - Best-performing system depends on stakeholder needs

- Some platforms can scale up reasonably with cluster size (horizontally) or number of cores (vertically)
  - Strong vs weak scaling still a challenge—workload scaling tricky
  - Single-algorithm is not workflow/multi-tenancy

Guo et al., How Well do Graph-Processing Platforms Perform? IPDPS’14.
Graphalytics, in a nutshell

- Advanced benchmarking harness
- Diverse real and synthetic datasets
- Many classes of algorithms
- Many classes of algorithms
- Granula for manual choke-point analysis
- Modern software engineering practices
- Supports many platforms
- Ongoing development

http://graphalytics.ewi.tudelft.nl
https://github.com/tudelft-atlarge/graphalytics/
Thank you for your attention! Comments? Questions? Suggestions?

http://graphalytics.ewi.tudelft.nl
https://github.com/tudelft-atlarge/graphalytics/

Join us for the SC2015 tutorial, Nov 15 (tut149)

Alexandru Iosup
A.Iosup@tudelft.nl

GRAPHALYTICS was made possible by a generous contribution from Oracle.

PELGA 2015, May 15
http://sites.google.com/site/pelga2015/

+ many other contributors
A few extra slides
Discussion

• How much preprocessing should we allow in the ETL phase?
• How to choose a metric that captures the preprocessing phase?

http://graphalytics.ewi.tudelft.nl
Discussion

- How should we assess the correctness of algorithms that produce approximate results?
- Are sampling algorithms acceptable as trade-off time to benchmark vs benchmarking result?

http://graphalytics.ewi.tudelft.nl
Discussion

• How to setup the platforms? Should we allow algorithm-specific platform setups or should we require only one setup to be used for all algorithms?

http://graphalytics.ewi.tudelft.nl
Discussion

• Towards full use cases, full workflows, and inter-operation of big data processing systems
• How to benchmark the entire chain needed to produce useful results, perhaps even the human in the loop?

http://graphalytics.ewi.tudelft.nl

Graphs at the Core of Our Society: The LinkedIn Example → Data Deluge

The State of LinkedIn

We now have 300 million LinkedIn members, more than half of whom live outside of the U.S. That's enough to make LinkedIn the fourth largest country in the world. In celebration, we took a look back to see how much our membership has grown and diversified over the past five years. It's a helpful reminder of not only where we've been, but also where we're headed as we work to create economic opportunity for every professional in the world.

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