

Motivation and Goal

- graph processing becomes increasingly important in academic and industrial environments
 - many problems modeled with graphs, e. g., machine learning and data mining
 - many business models are based on graphs, e. g., viral marketing or Google's search engine
 - graph sizes increase to several billion edges
- performance, parallelism and distribution of graph algorithms becomes more important

*Main Goal: Comparison of five graph processing systems
in their performance on different graphs and algorithms.*

Overview

1. Preliminaries

- Basics
- Computation Styles
- Hugepages

2. Frameworks

3. Evaluation

- Research vs. Production Case
- Results
- Impact of Hugepages on Galois

4. Conclusion

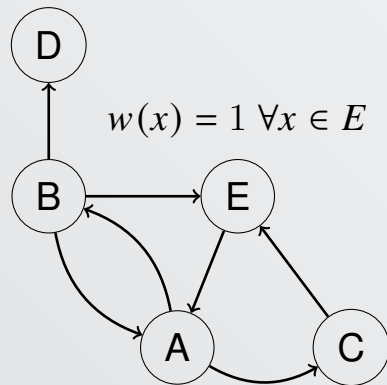
Preliminaries

Graphs

A *weighted, directed graph* is the tuple $G = (V, E, w)$ where the *vertex set* is $V \subseteq \mathbb{N}$ and the E is the *edge set* with

$$E \subseteq \{(x, y) \mid x, y \in V, x \neq y\}$$

and $w : E \rightarrow \mathbb{R}$ is a mapping of edge to a weight.



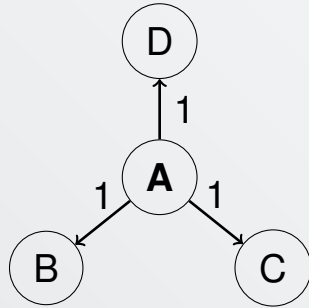
Algorithms

Single-Source Shortest-Paths (SSSP): find the shortest path from a starting vertex to every other vertex

Breadth-first search (BFS): find a node outgoing from a starting vertex, by increasing maximum hop count step-wise

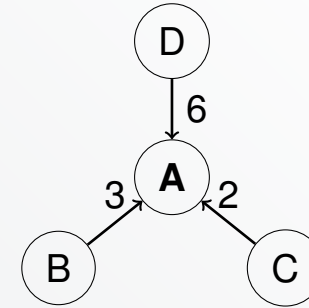
PageRank (PR): link analysis algorithm; weighs vertices, measuring their relative importance

Push Style



- reads active vertex, writes neighborhood
- more efficient, if only few active vertices at the same time
- more efficient, if neighborhoods of active vertices do not overlap

Pull Style



- reads neighborhood, writes active vertex
- only one write and many read operations
- less synchronization in parallel implementations needed
 - more efficient, if many vertices active at the same time

Hugepages

- most systems use virtual memory management
 - represents an abstraction to hardware memory
 - virtual memory is organized in pages
 - translations of virtual memory to physical memory are cached, because every translation takes time
- typically, memory pages are 4 KiB in size
- **hugepages** can be several MiB in size → reduce number of cache misses
- especially noticeable in very memory intensive applications

Frameworks

Framework	Version	NUMA	Dist.	Features	Notes
■ Galois	29.06.2020	✓	(✓)	general purpose library designed for parallel programming	Distributed using Gluon
■ Gemini	02.11.2016	✓	✓	distributed message-based approach from scratch	Version contains bugs that had to be fixed
■ Giraph	08.05.2020	X	✓	built on Apache Hadoop	BFS is not natively supported
■ Ligra	14.08.2019	✓	X	dynamically switches between push and pull style	
■ Polymer	28.08.2018	✓	X	optimizes data layout and memory access strategies	

Evaluation

Machines

vsflash1-5,

- 96 cores, of which 48 virtual
- 256 GB of RAM each¹
- Ubuntu 18.04.2 LTS

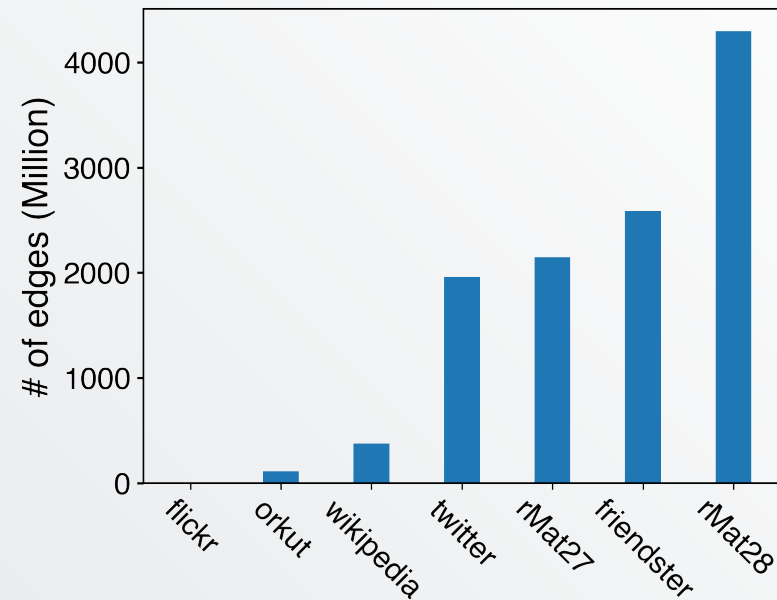
Measurements

- **execution time:** time from start to finish of the console command
- **calculation time:** time the framework actually executed the algorithm
- executed each test case 10 times

¹one machine only 128 GB

Graphs

Both rMat graphs are synthetic, others are real-world data sets; Flickr: 24MB, rMat28: 76GB



Production Case

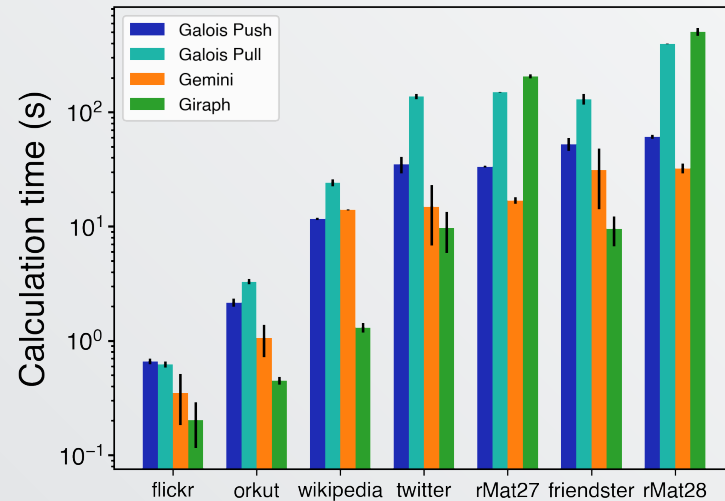
- running system: multiple calculations on a single graph
 - graph data stays loaded between calculations
- short calculation times should be preferred
- Not main focus of this presentation!²

Research Case

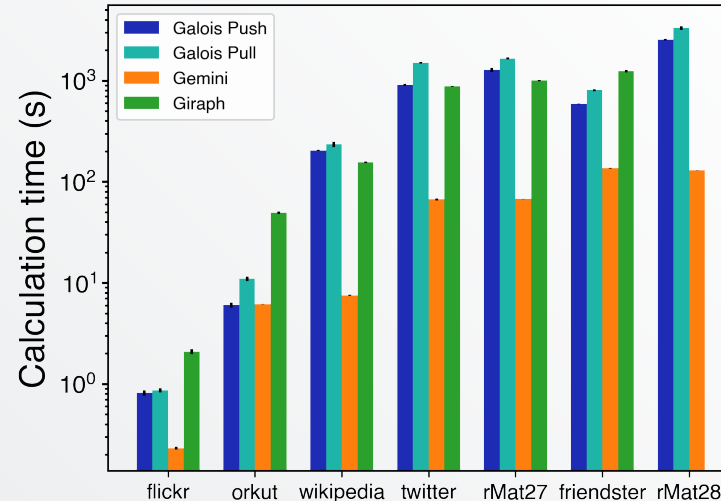
- individual calculation cases: possibly new graph for each calculation
 - frequently changing algorithm
- framework should be relatively fast on different algorithms
- overall small execution times should be preferred

²see paper for details

Production Case Distributed



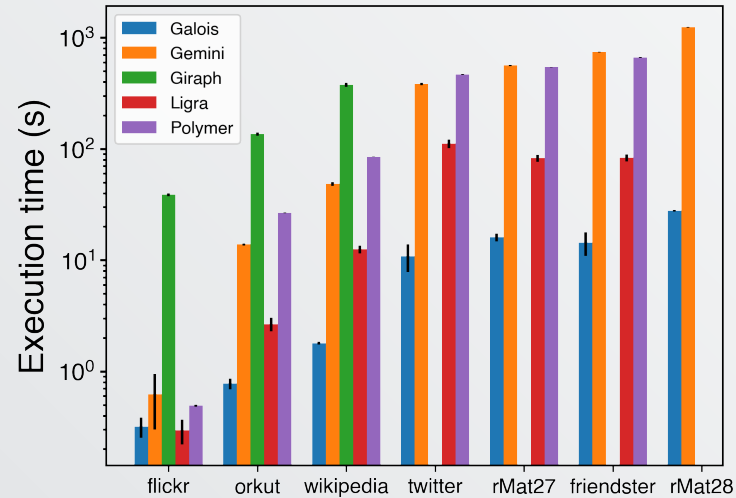
(a) SSSP



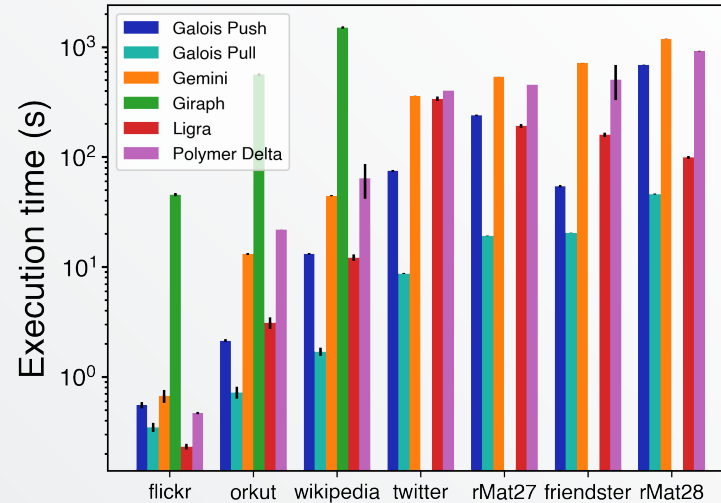
(b) PR

- Giraph is fastest on SSSP and BFS on the real world graphs
- Giraph has problems with synthetic graphs
- Gemini is fastest on PR, with Giraph on second place

Research Case Single Node



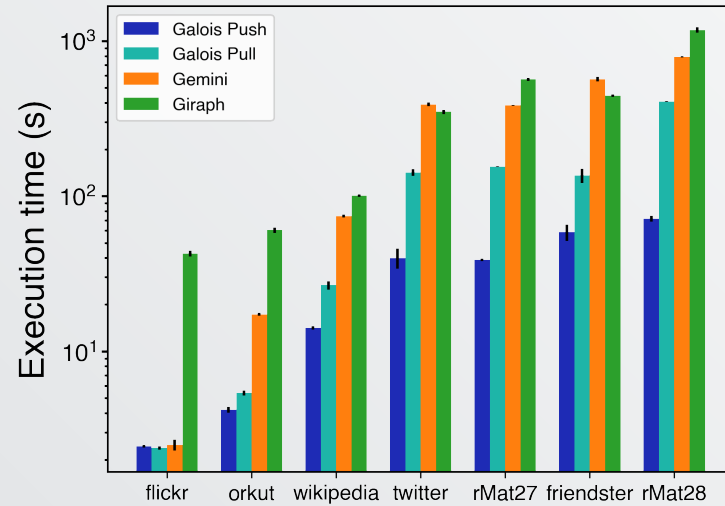
(a) SSSP



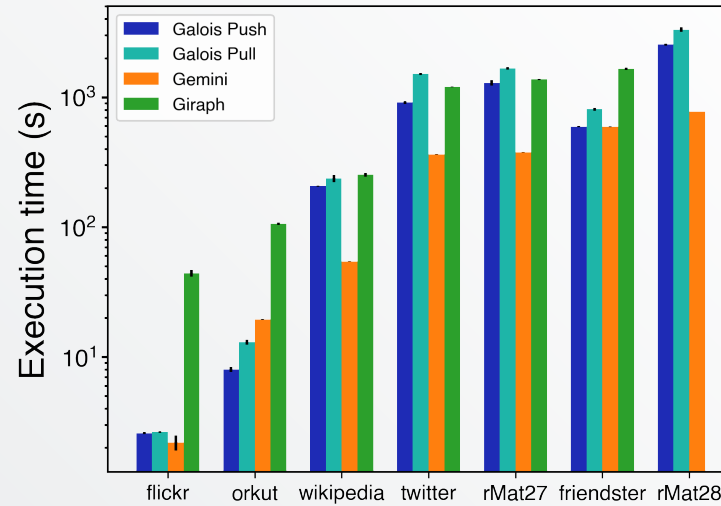
(b) PR

- Giraph is either slowest or requires too much RAM (>256 GB)
- Galois is fastest in almost all cases, second fastest is Ligra
- Gemini and Polymer are comparably slow

Research Case Distributed



(a) SSSP



(b) PR

- Galois Push is faster than Pull in all cases
- Both Galois implementations fastest on SSSP or BFS
- Gemini is fastest on PR in almost all cases

Galois With Hugepages

Graph	Calc Time (s)		Exec Time (s)	
	w/o	w/	w/o	w/
flickr	0.01	0.01	0.3	0.2
orkut	0.10	0.02	0.8	0.5
wikipedia	0.38	0.11	1.8	1.1
twitter	2.47	0.94	10.8	5.1
rMat27	4.50	1.39	16.0	6.4
friendster	4.70	1.78	14.4	7.5
rMat28	9.77	3.34	27.8	13.1

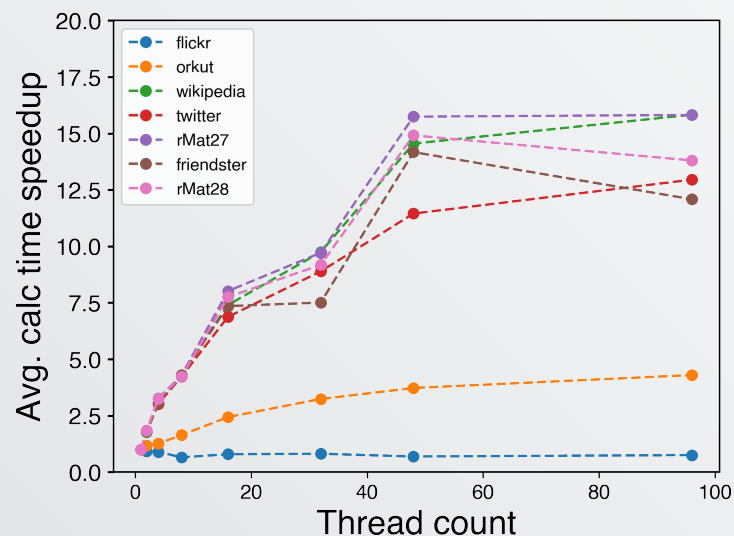
(a) SSSP

Graph	Calc Time (s)		Exec Time (s)	
	w/o	w/	w/o	w/
flickr	0.01	0.01	0.3	0.2
orkut	0.06	0.02	0.7	0.6
wikipedia	0.17	0.03	1.7	1.4
twitter	0.77	0.11	8.7	9.3
rMat27	0.65	0.13	19.2	8.1
friendster	1.01	0.14	20.4	13.1
rMat28	1.15	0.24	46.0	16.4

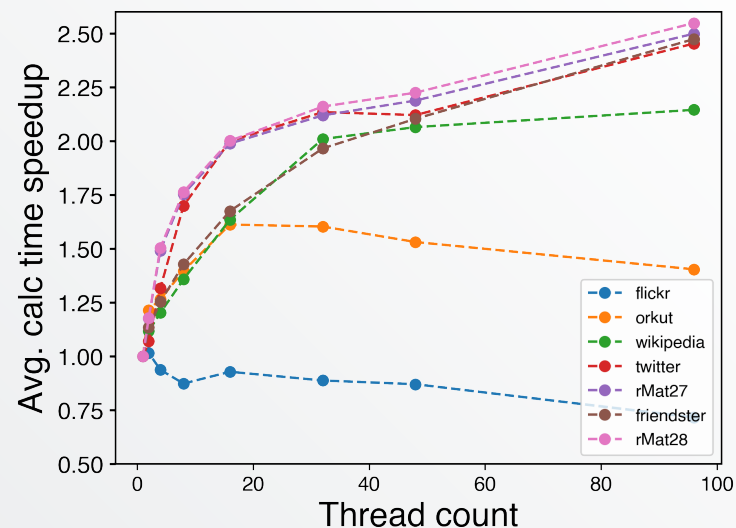
(b) PR Pull

- Hugepages reduce both calculation and execution time on all algorithms
- Execution times can be up to 3× shorter

Multithreaded Speedup of Galois



(a) SSSP with Hugepages



(b) PR Pull with Hugepages

- Speedups can be significant, with and without hugepages
- Speedup of PR not to the same degree as on SSSP (2.5× vs. 15×)

Conclusion and Outlook

Generally: 1) performance highly dependent on the framework, algorithm and data set
2) single node almost always preferable, as long as RAM is sufficient

Production Case

- Giraph is very fast on distributed systems (especially SSSP and BFS)
- Gemini and Ligra are good options for single node

Research Case

- Galois is fastest in almost all cases; further improvements with hugepages possible

Outlook

- incorporate new frameworks and new algorithms
- explore range of settings and other implementations
- repeat similar tests in the future: frameworks are updated and new ones are introduced