EmptyHeaded: A Relational Engine for Graph Processing

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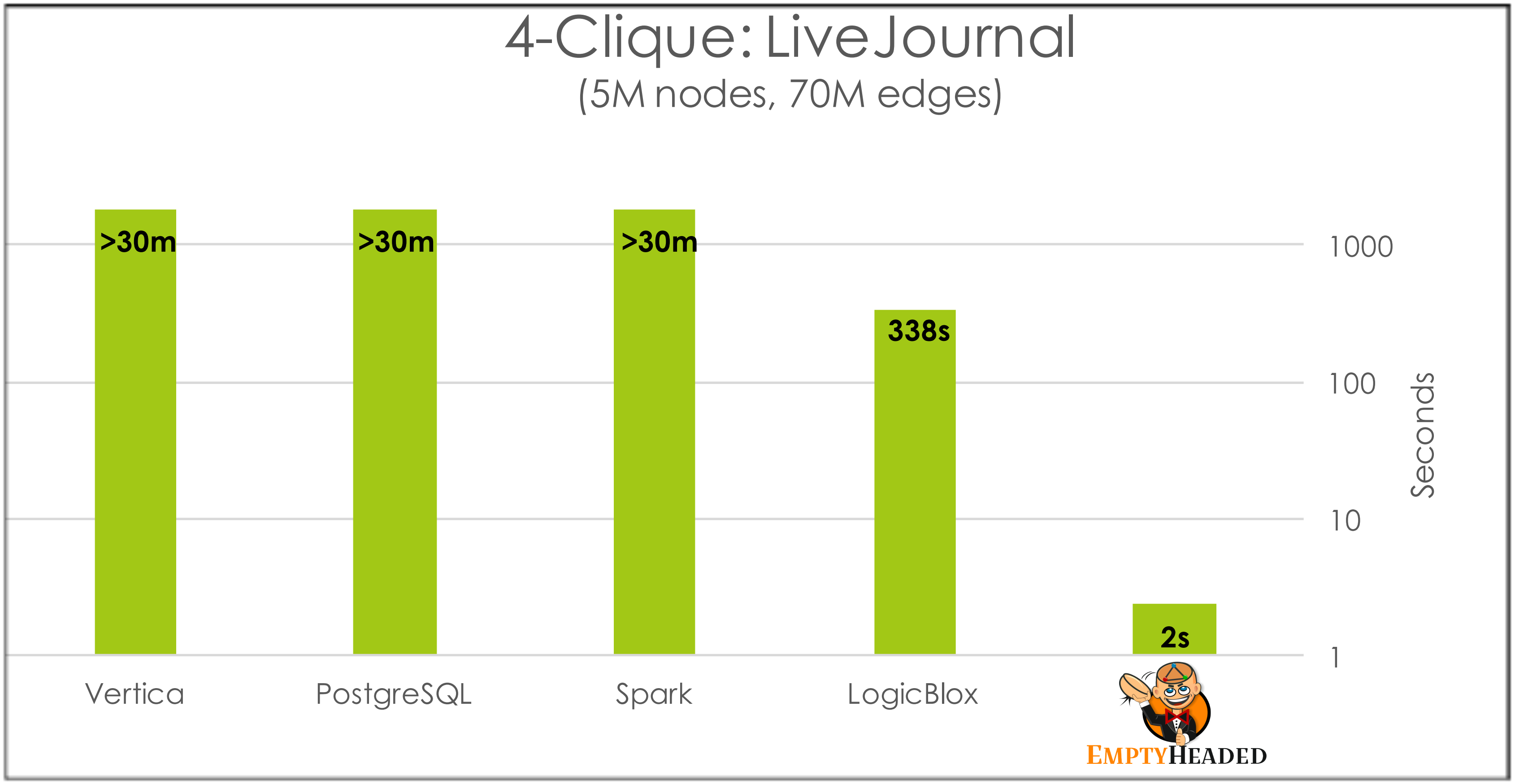
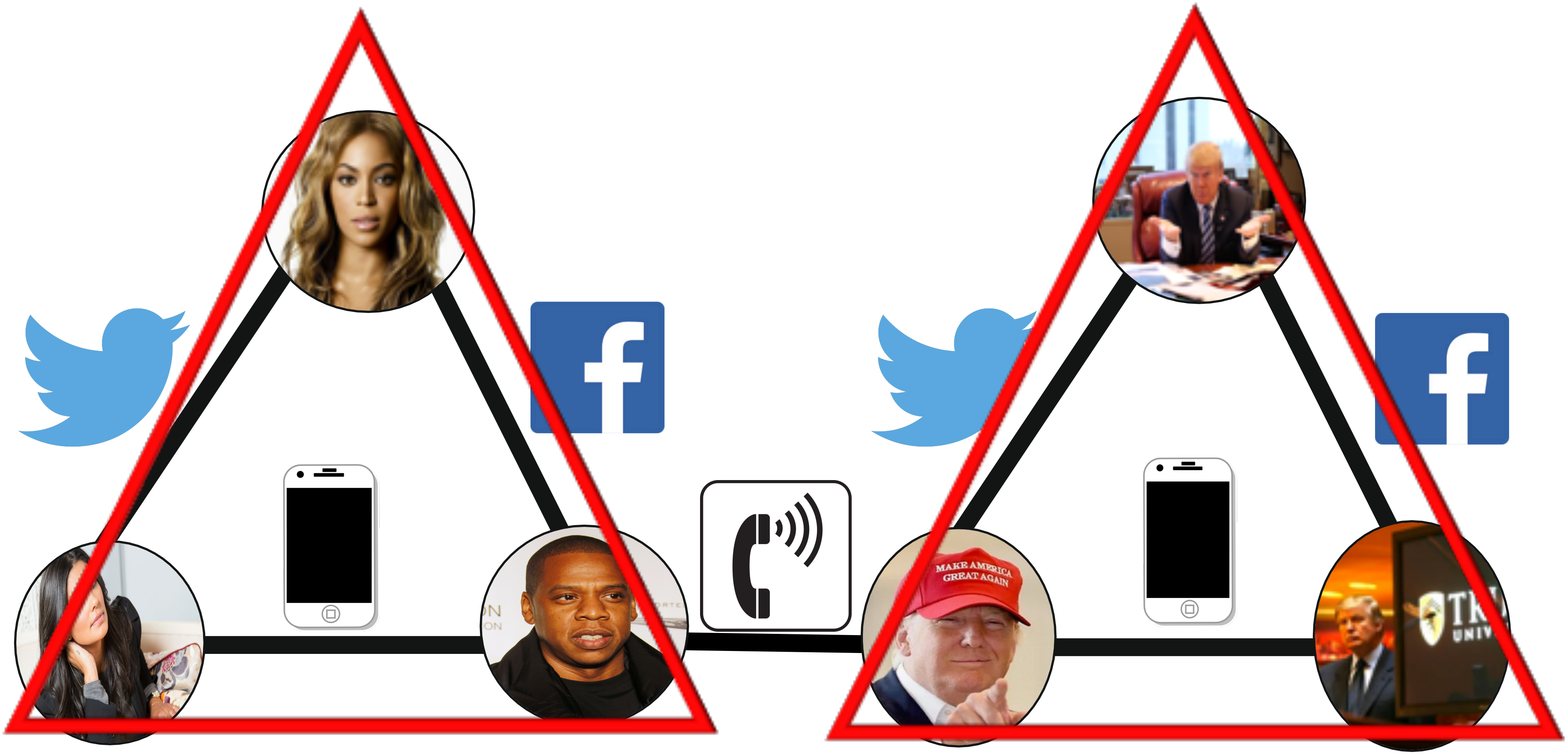
In theory, theory and practice are the same.

New join algorithms translate to big gains!



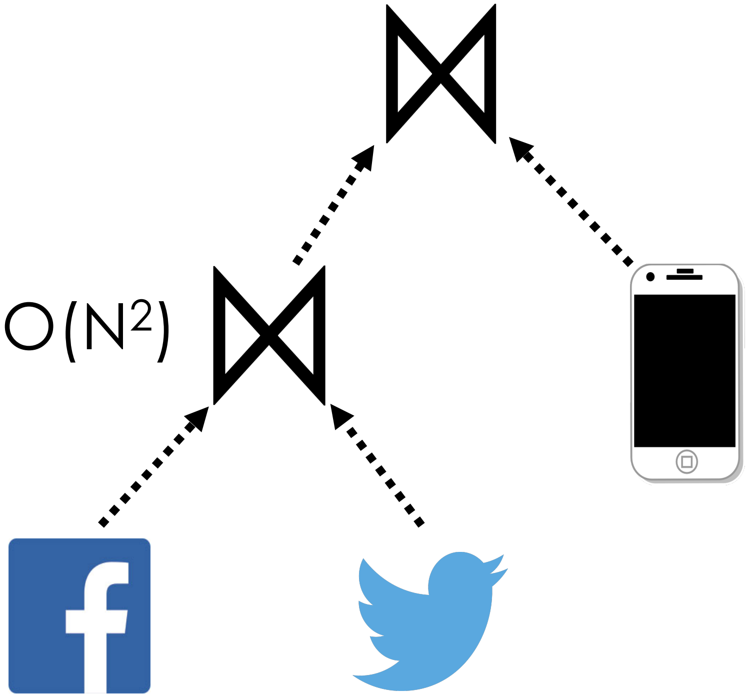
EmptyHeaded = (1) **Theory** -> Use GHDs
(2) **Systems** -> Exploit SIMD

The Cool Cliques



Pairwise joins are suboptimal

Facebook(x,y) ⋈ Twitter(y,z) ⋈Text(x,z)



Panic: Best known bound is $O(N^{3/2})$ and any pairwise join plan takes $\Omega(N^2)$.

Ngo, Porat, Ré, and Rudra *(PODS 2012)*

1st algorithm for joins with optimal worst-case runtime

Instead of computing joins over **relations** in a **pairwise** manner, compute them over **attributes** in a **multiway** fashion.

Algorithm: Only Foreach and Set Intersection.

Demystifying the WC-Optimal Algo.

$\text{Facebook}(x,y) \bowtie \text{Twitter}(y,z) \bowtie \text{Text}(x,z)$

```
for $x$ in $\mathit{Facebook}[] \cap \mathit{Twitter}[]$
  for $y$ in $\mathit{Facebook}[x] \cap \mathit{Twitter}[]$
    for $z$ in $\mathit{Twitter}[y] \cap \mathit{Text}[x]$
      $\text{out} \leftarrow \text{out} \cup (x,y,z)$
```

In EmptyHeaded, theory and practice are the same.

High-Level Engines

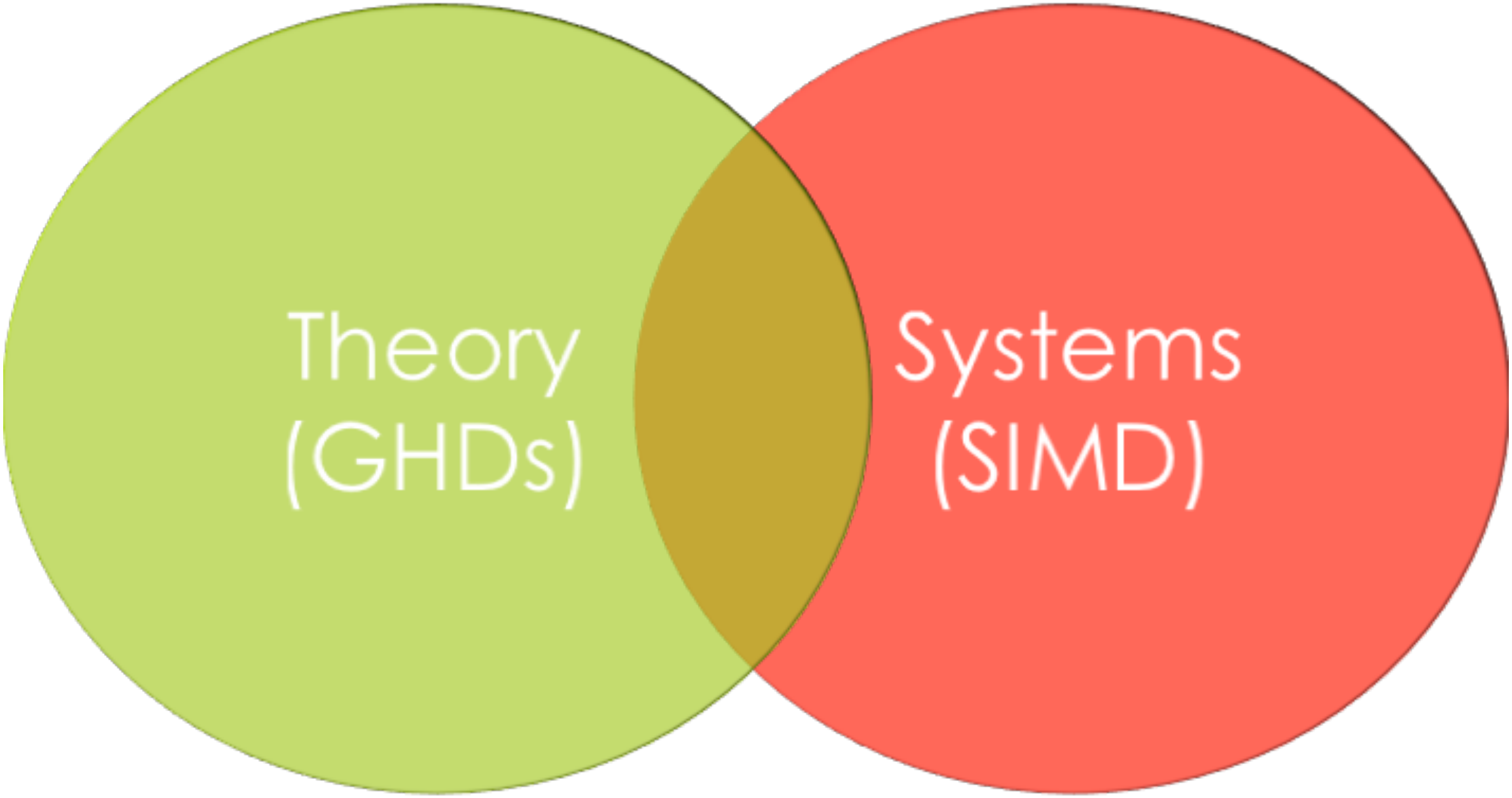
- **Outperforms** ***LogicBlox*** by **19x-3500x**
- **Outperforms** ***SociaLite*** by **8x-3500x**

Low-Level Graph Engines

- **Outperforms** ***PowerGraph*** by **3x-10x**
- **Outperforms** ***Snap-Ringo*** by **2x-11x**
- **Competes** within **0.98x-4x** of ***Galois***

Standard graph workloads (PageRank, Triangle, SSSP) and pattern queries

EmptyHeaded = Theory + Systems



Query Plans for WC-Optimal Joins

Generalized hypertree decompositions (GHDs) yield even better runtimes.

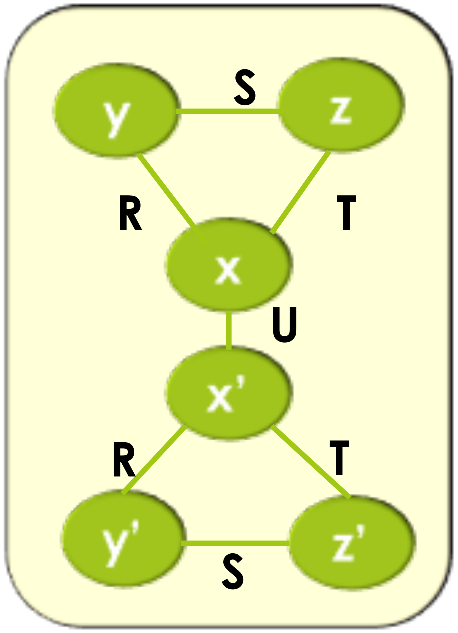
- Gottlob et al. & Puttagunta et al. [PODS '16]

Key Idea: This is our analog of relational algebra to represent logical query plans.

Enables: Classic query optimizations like early aggregation and pushing down selections

Key Insight: Creates an execution DAG.

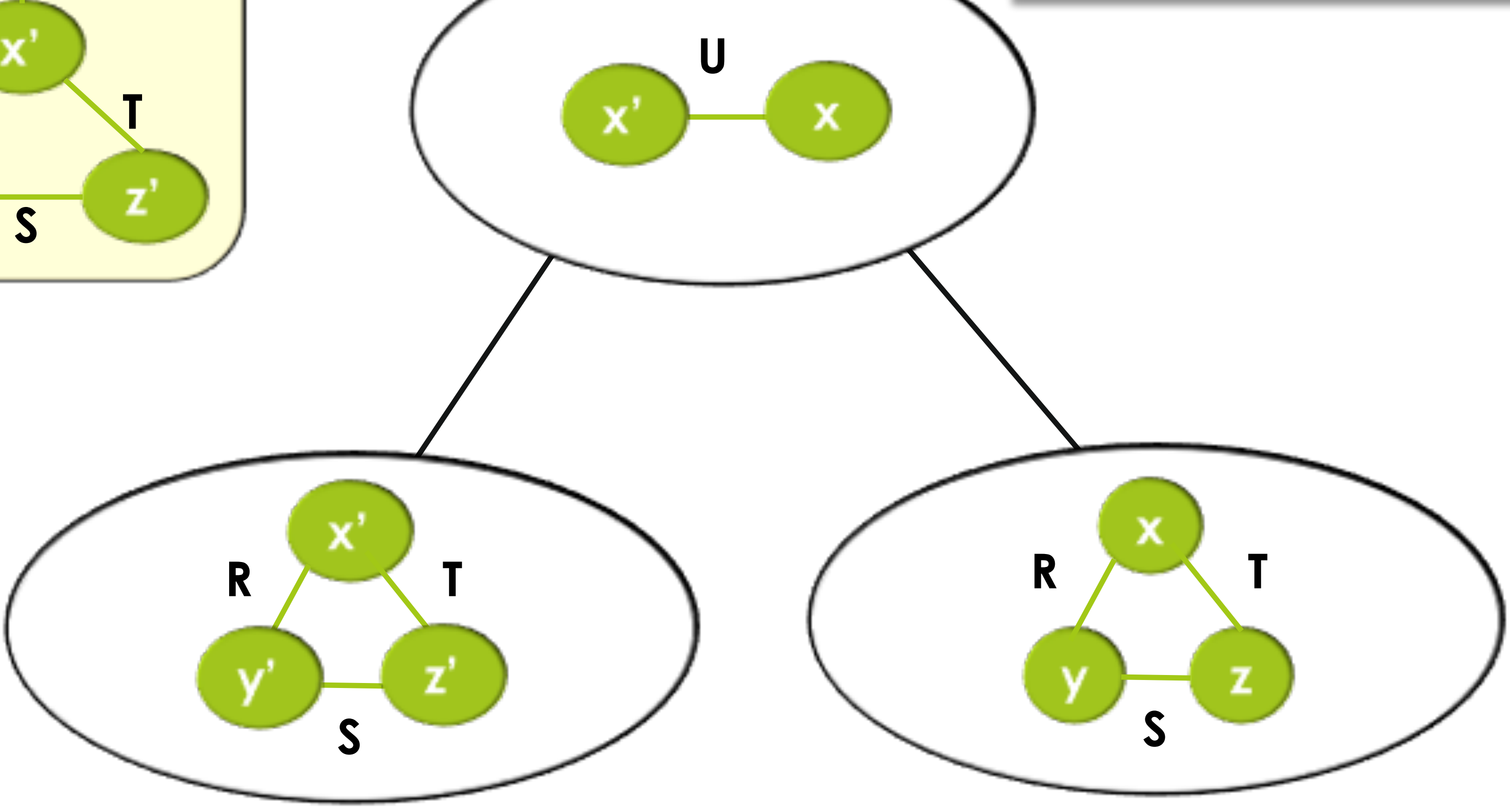
GHDs in 1 minute.



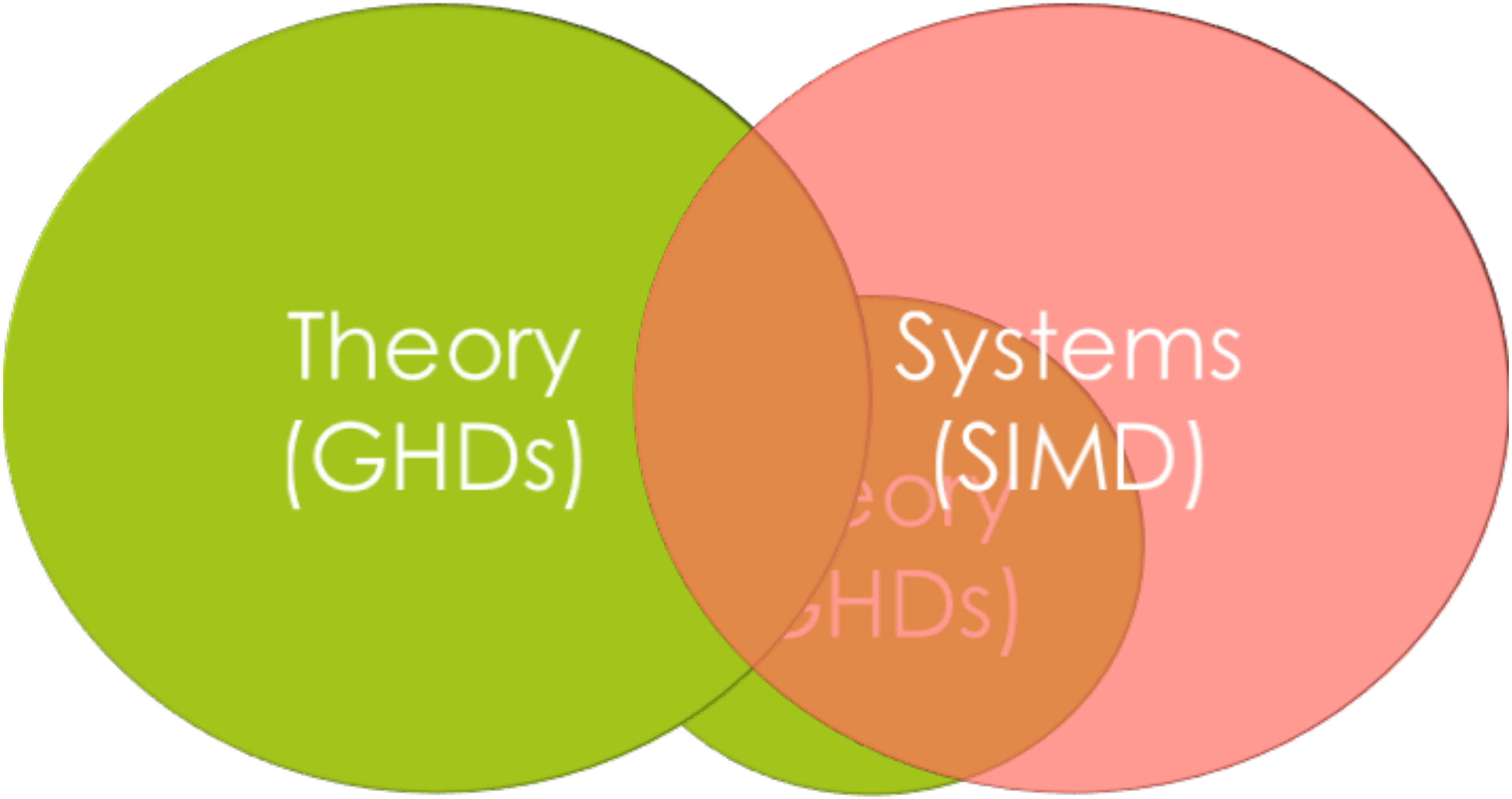
WC: **O(N^{3})**

GHD+WC: **O(N$^{3/2}$)+ | OUT |**

>3500x speedup



EmptyHeaded = Theory + Systems



Data Layout: Trie Representation

friends (or foes?)

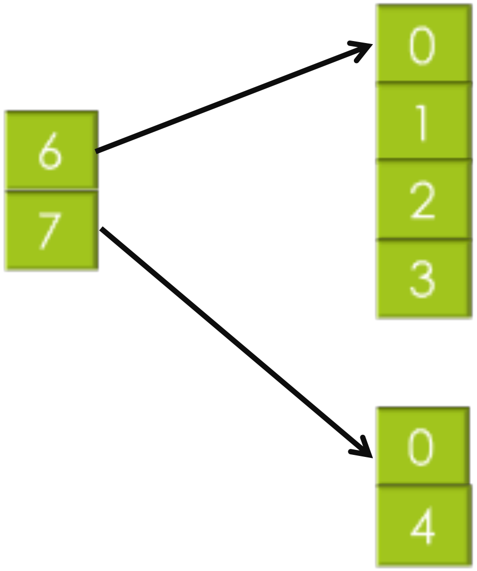
src	dst
C. Ré	M. Stonebraker
C. Ré	D. DeWitt
C. Ré	A. Pavlo
C. Ré	J. Hellerstein
K. Olukotun	M. Stonebraker
K. Olukotun	D. Patterson

friends

src	dst
6	0
6	1
6	2
6	3
7	0
7	4

Dictionary Encoded ID's for each node

Trie
friends(src,dst)



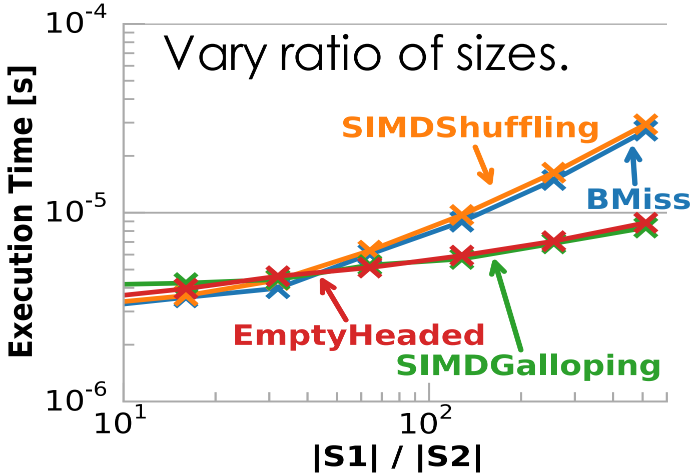
Panic: Sets are skewed in several different ways!

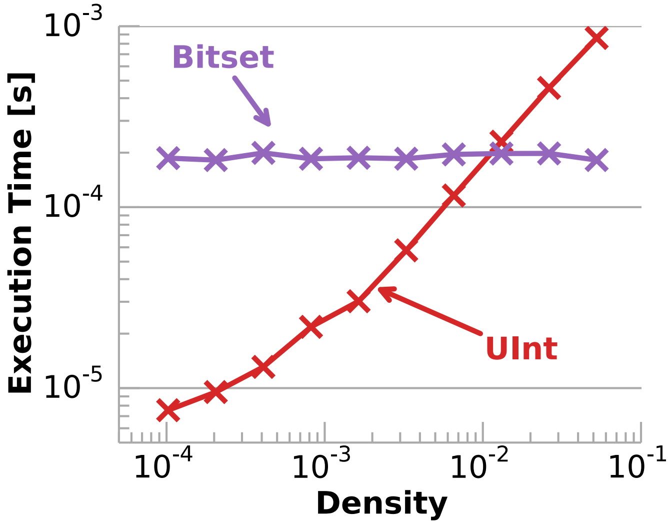
Exploiting SIMD: The battle with skew

Goal: Design an execution engine that **automatically** exploits SIMD parallelism.

Challenge: cope with **skew** in data

- *Cardinality Skew*
  - *Solution: Choose amongst SIMD **algorithms**!*
- *Density Skew*
  - *Can we do better than choosing amongst SIMD **algorithms**?*
  - *Solution: Use multiple **representations**!*





>400x speedup

Conclusion

- ***GHDs*** to represent **logical query plans** in addition to WC Optimal join algorithm result in **>3500x speedup**
- ***Multiple representations*** and ***set intersection algorithms*** optimized for **SIMD parallelism** result in **>400x speedup**
- Theory + Systems translates to promising results!
  - **Outperforms** LogicBlox, SociaLite, PowerGraph and Snap-Ringo by **2-3500x**
  - **Competes** within **0.98x-4x** of Galois

Thanks! Christopher Aberger
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EMPTYHEADED

Try me:
https://github.com/HazyResearch/EmptyHeaded