VENUS: Vertex-Centric Streamlined Graph Computation on a Single PC

Jiefeng Cheng[1], Qin Liu[2], Zhenguo Li[1], Wei Fan[1], John C.S. Lui[2], Cheng He[1]

[1]Huawei Noah's Ark Lab, [2] The Chinese University of Hong Kong

Why Single Machine System?

Motivations

We have **large graphs**:

- Web graph, Social graph, User-movie ratings graph, …

We need to do intensive **computation** on graphs:

- PageRank, community detection, alternating least squares for collaborative filtering, shortest path, …

Two Solutions

Systems for graph computation: **distributed** or **single-machine**?

Distributed systems: Pregel, GraphLab, GraphX, Giraph, …

- Expensive clusters
- Complex setup & configuration
- Writing buggy distributed programs

Single-machine systems: GraphChi[1], X-Stream[2], TurboGraph, FlashGraph, …

- Store graphs on disk or SSDs
- Graph computation on a **commodity PC** (**cheap**, **easy to program**)

We can achieve competitive results over distributed systems:
PageRank on a Twitter graph (41M nodes, 1.4B edges)

- Spark: 8.1min with 50 machines (each with 2 CPUs, 7.5G RAM)[3]
- **VENUS**: 8 min on a single machine with quad-core CPU, 16G RAM

Exiting Systems

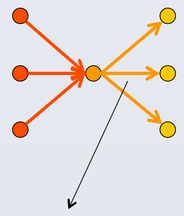
Vertex-centric programming model: used by Pregel, GraphLab, GraphChi, …

- Each vertex updates itself based on its neighborhood

A seminar work, **GraphChi**[1]

```
for each iteration
  for each vertex v
    update(v)

void update(v)
  fetch data from each in-edge
  update data on v
  spread data to each out-edge
```



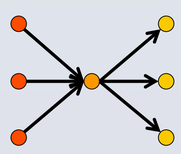
Duplicated data

- Updated data on each vertex must be propagated to its neighbors through disk
- Extensive disk I/O

Our new system, **VENUS**:

- Only store mutable values on vertices

```
void update(v)                    in-neighbor
  fetch data from each ~~in-edge~~
  update data on v
  ~~spread data to each out-edge~~
```



- Much less data access
- Enable streamlined processing
- Sacrifice little expressiveness

VENUS: Vertex-Centric Streamlined Graph Computation

Main Ideas

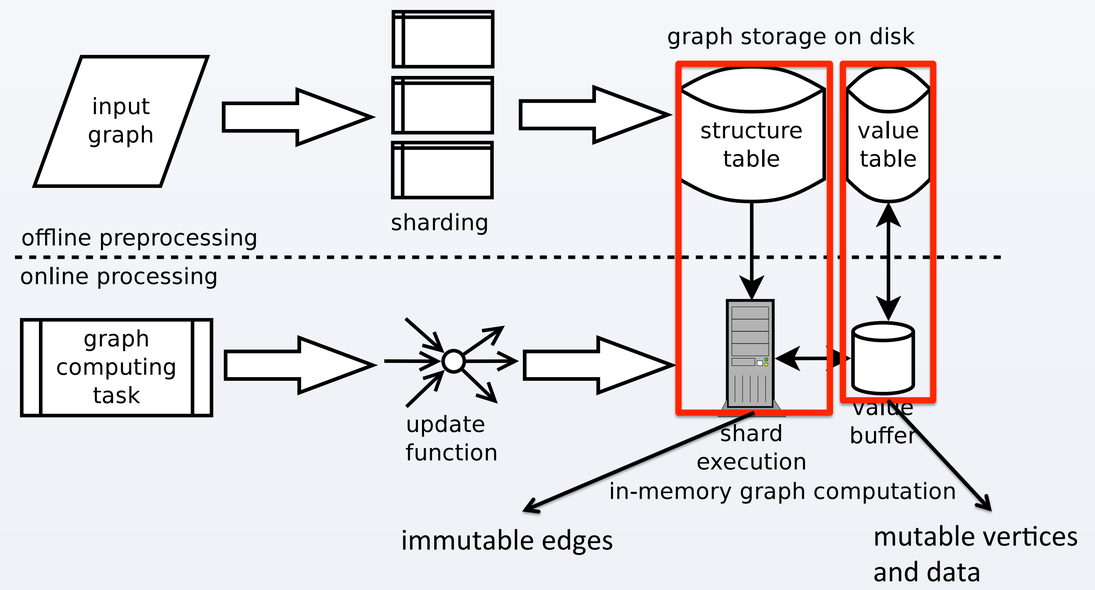
Disk storage (offline)

- Split graph into shards and execute each in memory
- Separate edge data and vertex data

Computing model (online)

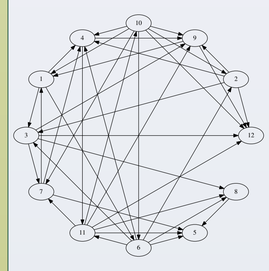
- Cache vertex data
- Load edge data sequentially
- Execute update functions in parallel

Architecture



Offline Storage

Each shard corresponds to an interval of vertices:
G-shard: in-edges of nodes in the interval (immutable)
V-shard: vertex values of all vertices in the shard (mutable)



Interval	I_1=[1,4]	I_2=[5,8]	I_3=[9,12]
G-shard	7,9,10 → 1 6,10 → 2 1,2,6 → 3 1,2,6,7,10 → 4	6,7,8,11 → 5 1,10 → 6 3,10,11 → 7 3,6,11 → 8	2,3,4,10,11 → 9 11 → 10 4,6 → 11 2,3,9,10,11 → 12
V-shard	$I_1 \cup$ {6,7,9,10}	$I_2 \cup$ {1,3,10,11}	$I_3 \cup$ {2,3,4,6}

Online Computing Model

Vertex-centric streamlined processing

- V-shards are cached
- G-shards **stream in**
- Execute `update(v)` in **parallel**

Load and Update v-shards

Two I/O efficient algorithms:

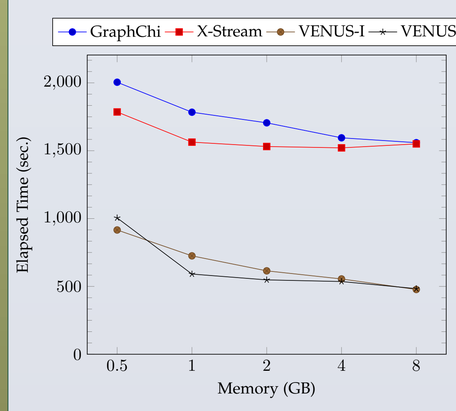
1. An extension of PSW[1];
2. A merge-join between value table and v-shard

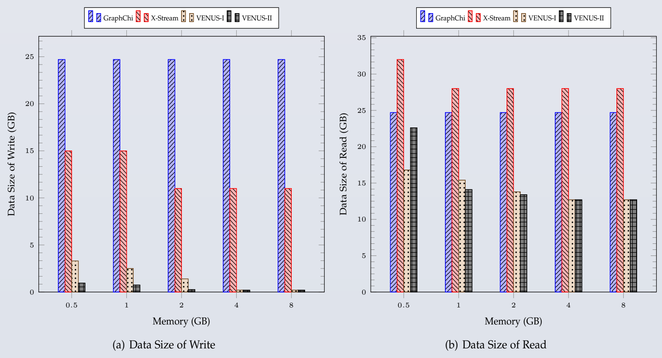
Detailed in our paper[4].

Experimental Results

Run PageRank on Twitter graph

- Faster due to less data access

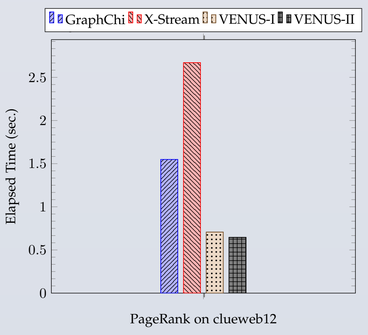




(a) Data Size of Write (b) Data Size of Read

Clueweb12: web scale graph

- 978 million nodes, 42.5 billion edges
- 402 GB on disk
- 2 iterations of PageRank



PageRank on clueweb12

References

[1] Kyrola, A., Blelloch, G., & Guestrin, C. (2012). GraphChi: Large-Scale Graph Computation on Just a PC. In *OSDI*.

[2] Roy, A., Mihailovic, I., & Zwaenepoel, W. (2013). X-Stream: Edge-centric Graph Processing using Streaming Partitions. In *SOSP*.

[3] Stanton, I., & Kliot, G. (2012). Streaming Graph Partitioning for Large Distributed Graphs. In *KDD*.

[4] Cheng, J., Liu, Q., Li, Z., Fan, W., Lui, J. C. S., & He, C. (2015). VENUS: Vertex-Centric Streamlined Graph Computation on a Single PC. In ICDE.

Contact: Qin Liu (qliu@cse.cuhk.edu.hk)