Distributed Frameworks for Alternating Least Squares

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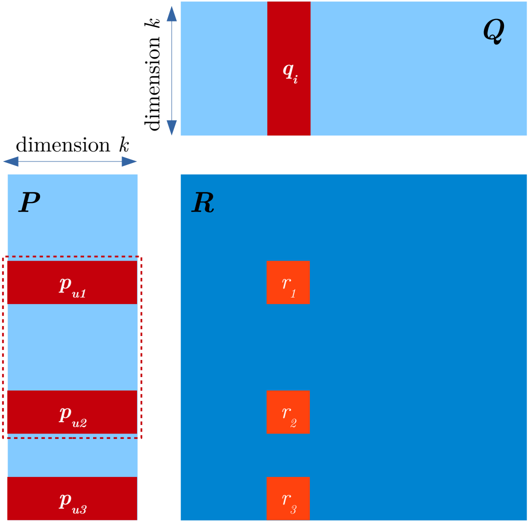
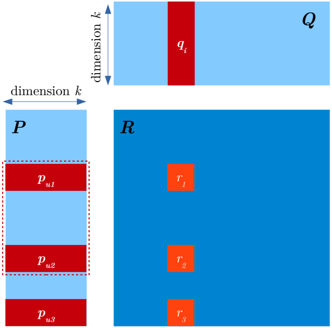
Alternating Least Squares



Alternating Least Squares

$$f_{RMSE}(P,Q) = \sum_{(u,i)\in\text{Training}} (R_{ui} - p_u \cdot q_i^T)^2 + \lambda \cdot (\|P\|_F^2 + \|Q\|_F^2)$$

- Update step for Q: $Q_i \leftarrow (P^TP)^{-1}P^TR_i$
- For each nonzero rating we communicate $(P^TP)^{-1}$ of dim k^2

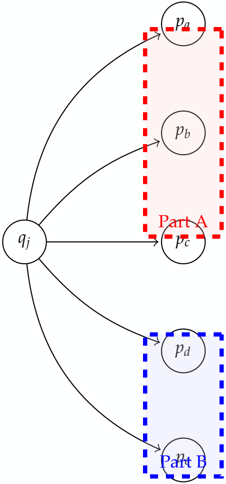


ALS MULTI-MACHINE NO SHARED MEMORY

- Goal: efficient ALS *and* models for other algorithms
- Problem: Large amount of communication alternating between rows and columns
  - ALS message size is quadratic in number of latent factors
- Drawback of "think as a node" philosophy
  - Repeat the same message for all graph nodes
  - Even if they reside on the same server

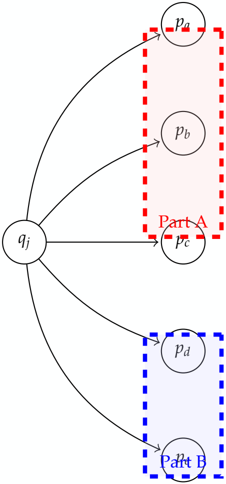
DISTRIBUTION OVERHEAD

- Partitioned graph or ratings matrix
- Naive approach: q_j communicates to each p_i individually
- In ALS, PageRank, $\ldots$, messages from q_j are identical
- **Network communication becomes the bottleneck.**



Proposed solution

- Efficient communication between partitions
- Translated to graph processing this is just a *multicast*.



Big Data Frameworks

- Big Data frameworks lack an operator for this job.
  - Hadoop (Mahout) Map, Reduce
  - Spark “Functional” operators on (memory) Resilient Distributed Datasets
  - Flink “Functional” operators and iteration
    Our experimental platform
- **Notion of the partition hidden from user when implementing ALS by vector-to-vector communication.**

Big Data Frameworks - Solution

- Mahout implementation: “CustomALS”.
- Algorithm provides an artificial partition ID
- Map-Reduce grouped by partition ID, expected one partition per reducer
- Partitioning to minimize the communication between partitions **not ensured** but left for the framework

Graph processing engines

- Bulk Synchronous Parallel (BSP)
  - Sends along ALL nonzero ratings
  - Even if the message is identical
  - This issue holds even for PageRank
- Example: Giraph
  - “Think like a vertex”, no partition notion
  - No multicast support in framework

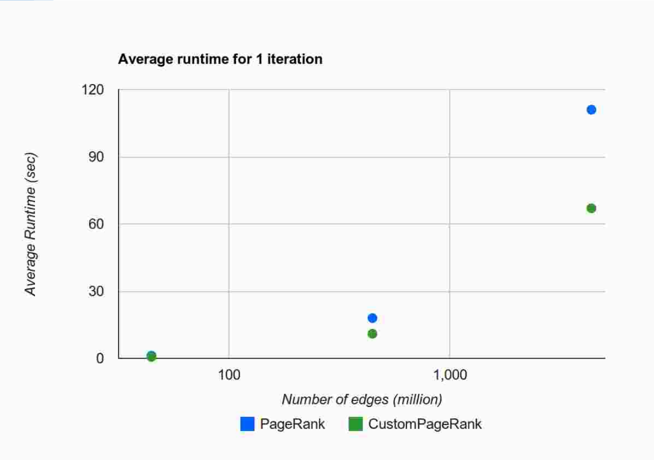
Distributed GraphLab

- Several optimization over plain BSP:
  - Framework support to distribute very high degree nodes: PowerGraph partitions scatters and gathers
  - Optimization: emit unchanged information by caching on gather side
  - Optimization: graph partitioning to reduce number of edges cut (hard to partition a real implicit ratings matrix)
- **But no handling for multiple identical messages**

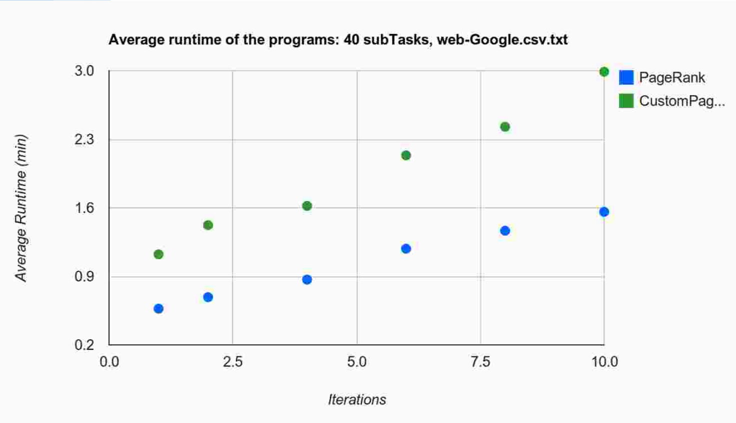
Experiments – distributed message passing in C++

- Proof of concept for a low communication task: PageRank
- We rely on direct control over partitions
- Each vertex sends the message to relevant partitions once
- Test on large Web crawl (`.pt`): 300M nodes, 1B edges
- Significant improvement

CUSTOM PAGERANK IN C++

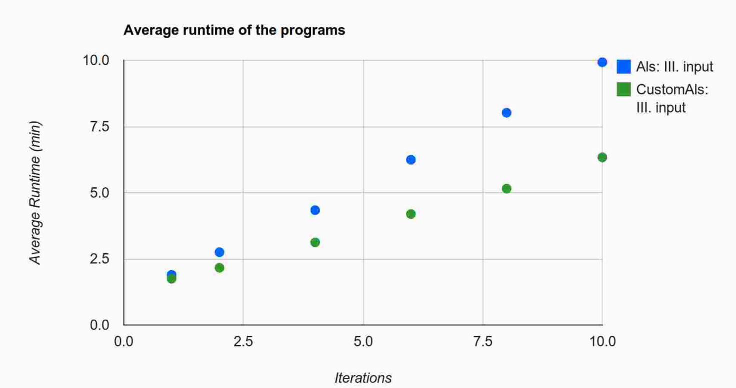


CustomPageRank in Apache Flink



- We define hypernodes – Mahout CustomALS style
- Insufficient for low communication tasks
- Web-Google graph from Stanford Large Network Dataset Collection, $9 \cdot 10^5$ nodes,

CustomALS in Apache Flink



- Generated test data 15 million ratings (courtesy: Gravity)
- Framework support already sufficient for ALS

Conclusions

- ALS multi-machine no shared memory
  - Heavy communication alternating between rows and columns
  - ALS message size is quadratic in number of latent factors
  - Affects MapReduce with no permanent storage (Mahout "CustomALS")
  - Graph parallel frameworks with nonzero ratings mapped to edges
- Ongoing experiments with Message Passing, Giraph, Apache Flink, and its Pregel implementation Spargel.
  - Communication primitives to bind identical messages - use multicast
  - Promising even for seemingly low communication intense algorithms such as PageRank.