Parallel Information Retrieval for Dense Vectors

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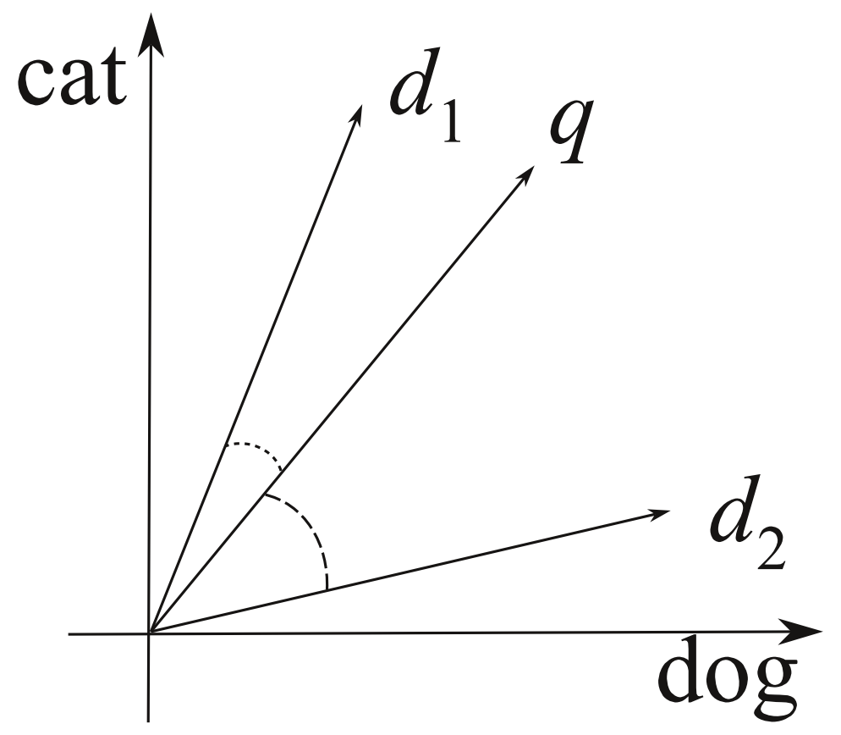
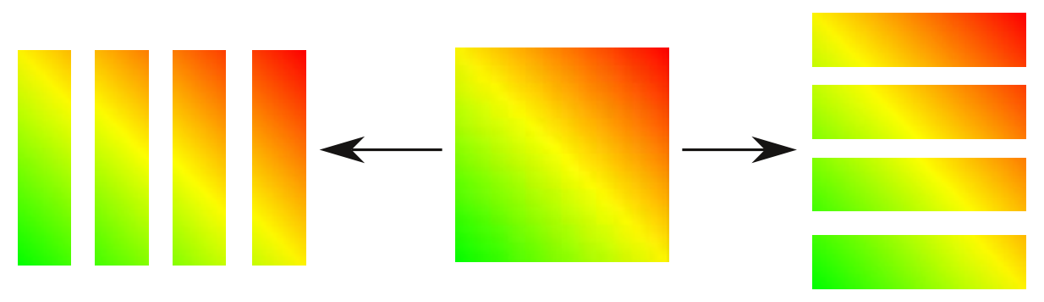
1. The Vector Space Model in a Nutshell



- Documents and queries: feature vectors,
- Similarity score: cosine of enclosed angle,
- Search: compute similarity and sort results,
- Corpus matrix C: contains all documents,
- Compute similarities: $s = C\,q$ for a given query q,
- Partition the corpus: split C row-wise or column-wise.

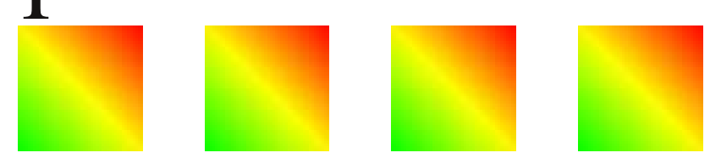
C	d_1	d_2
cat	0.19	0.8
dog	0.9	0.36

visually:



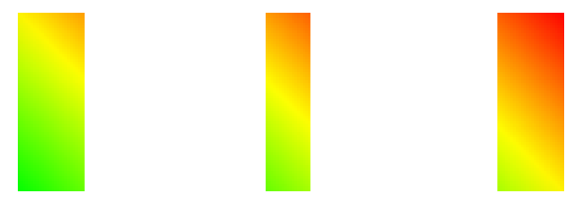
2. Forms of Parallelism

Index Replication



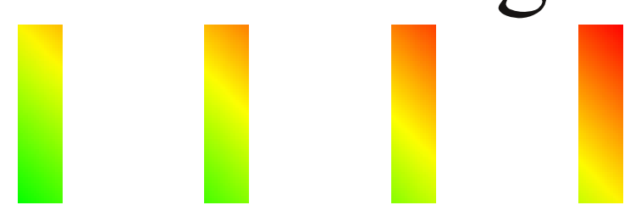
answer queries in parallel

Clustering



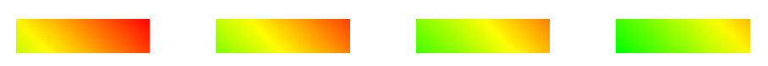
limit search to similar clusters

Document Partitioning



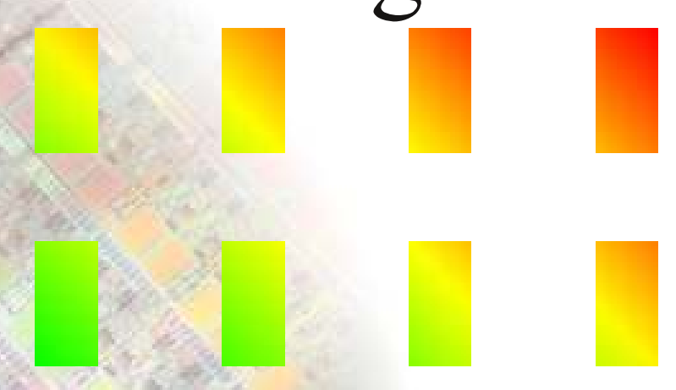
parallel merge-sort

Feature Partitioning



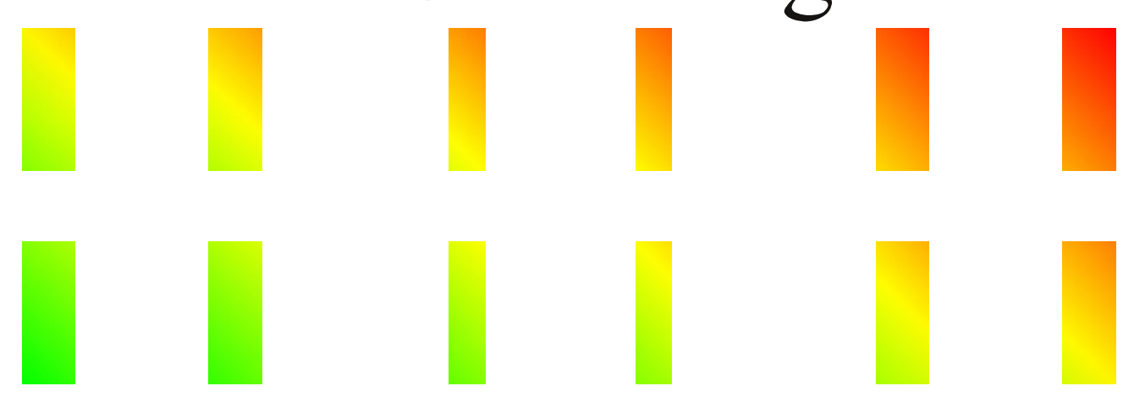
parallel matrix-vector product

Hybrid Partitioning



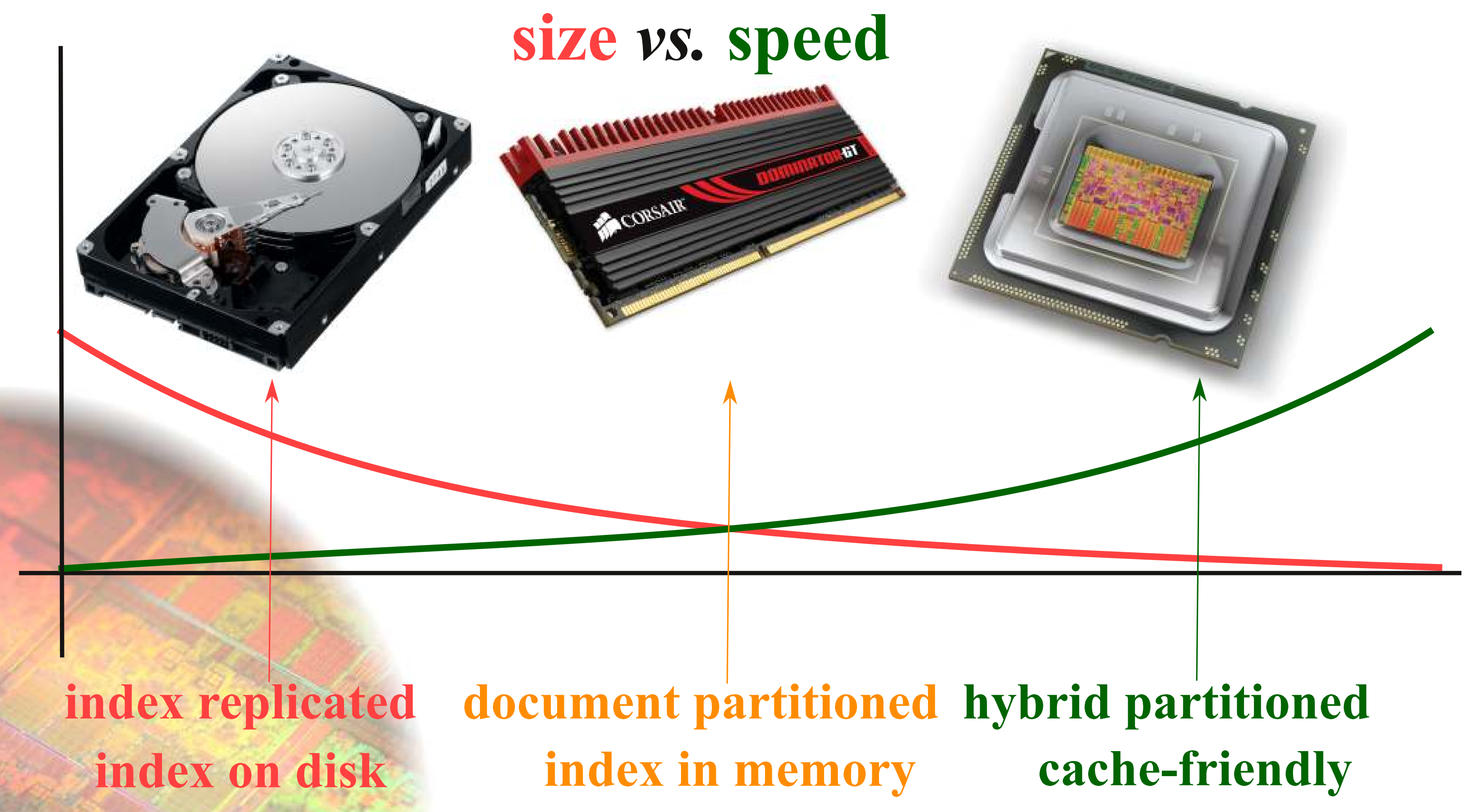
split both features and documents

Hybrid with Clustering



parallel search within clusters

3. The Memory Hierarchy



4. Our Parallel Retrieval System

- Hybrid partitioning: split into equal parts,
- Dense vectors/matrices: dimensionality reduction (LSI, COV),
- Implemented using MPI: supercomputer-grade middleware,
- In-memory system: avoids slow HDDs,
- Single-precision floating point: avoids the memory bottleneck,

5. Query Response Time

Test Environment

- 8 quad-core Xeon E5520 at 2.27 GHz with 48 GB RAM,
- InfiniBand network fabric, 10 Gbps,
- Random corpus: 1024 features, and D=10^5...10^6 documents.

Serial Base-Line

Document Partitioning

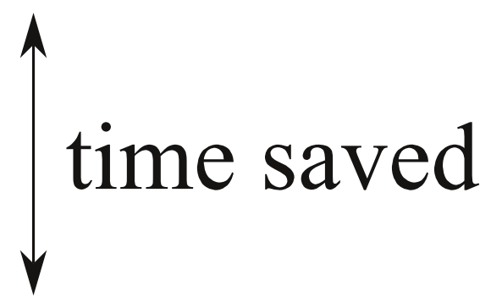
Hybrid Partitioning

6. Improved Response Time

- Hybrid partitioning exploits the memory hierarchy,
- Delivers super-linear speed-up over serial, in-memory system,
- Disk-based systems are not considered here.

7. Improved Throughput

- The standard for parallel search engines is index replication.
- Can a parallel program outperform multiple serial programs? Yes!
- Parallel queries/serial programs vs. serial queries/parallel program:



8. Summary

- Modern retrieval systems require dense matrix/vector algorithms,
- Exploiting the memory hierarchy is crucial for high speed-up,
- Hybrid partitioning delivers super-linear speed-up,
- Short query response time improves user satisfaction,
- Super-linear speed-up improves throughput over replication,
- MPI problematic as middleware for persistent parallel services.

9. Work in Progress

- Add clustering - conduct the parallel search within clusters,
- New middleware on top of MPI for persistent parallel services,
- Corpus analysis and feature weighting,
- Functional decomposition into components - pipelining parallelism,
- Thread-level parallelism for enhanced utilization,
- More components needed for a full search engine,
- GPGPU computing - CUDA or OpenCL numeric kernels.