Global Document Frequency Estimation in Peer-to-Peer Web Search

WebDB 2006

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June 30, 2006

Outline

Motivation

Peer-to-Peer

- Became famous through file-sharing applications like Gnutella, KaZAA, Napster
- Today: Applications like: Skype, pub/sub, Web search

Why P2P Web Search?

- Benefit from social networks for more powerfull IR models
- Break information monopolies
- Exploit mostly idle resources

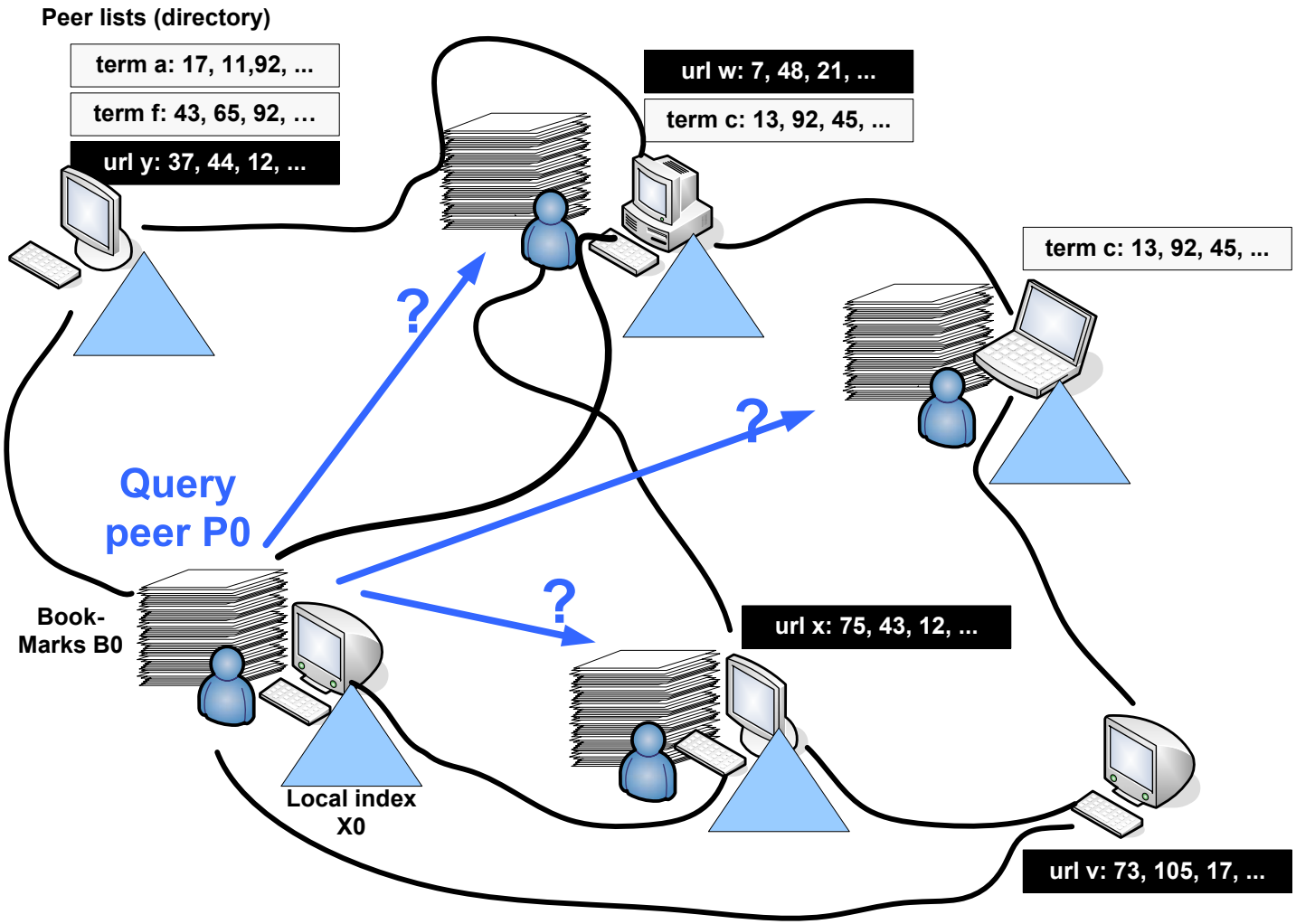
Related to distributed IR, but some additional aspects

- High dynamics
- Overlapping collections from autonomous peers

Minerva Design Fundamentals

- Peers with local collections, e.g., built by focused crawler. Tailored to the users' specific interest profiles.
- Peers share metadata about local indexes
- Form physically distributed *term* $\longrightarrow$ *peer* directory
- Layered on top of DHT
- Peers use directory to discover promising peers for query

Minerva System Architecture



Scoring in IR

Usually weighted sum

$$s(d) := \sum_{t \in Q} \frac{1}{DF(t)} * TF(t, d)$$

where DF = Document Frequency, and TF = Termfrequency.

Problem Statement

Lack of Global Statistics

- No global DF values available, peers use *local* DF
  $\longrightarrow$ document scores incompatible
- "Good" peers with many documents have *high* DF $\longrightarrow$ *low* local scores $\longrightarrow$ documents from bad peers boosted

Goal: Estimate global DF in the presence of

- overlapping collections (global DF $\neq$ sum of local DF's!!!)
- network dynamics

without additional messages
$\longrightarrow$ Scores compatible, result merging trivial

Global Counting

Example 1

How many distinct movies are available in the P2P system?

- high degree of replication (current top movies replicated probably a few hundred times)
- no global knowledge (no central manager like in Napster)

Example 2

Counting the number of persons at SIGMOD '06:

- everybody participates in counting
- cannot take max: nobody has seen all participants
- high overlap: summing up is not accurate

Hash Sketches [Flajolet and Durand]

Centralized setting: Hash sketches as multiset cardinality estimator.

- Pseudo-uniform hash function h
- Apply h to all documents and record the position of the least significant (leftmost) 1-bit in the binary representation in a bitmap vector $B[0 \ldots L-1]$.
- Idea: $B[0]$ will be set approximately $\frac{n}{2}$ times, $B[1]$ approximately $\frac{n}{4}$ times, ...
- More formally: The rightmost 1 bit at position provides an estimation of $log(n)$.
- Use multiple bitmap vectors to increase accuracy

Hash Sketches

Distributivity Theorem:

Let $\beta(S)$ be the set of bit positions $\rho(h(d))$ for all $d \in S$, and $\rho(y) = min_{k \geq 0}\, bit(y,k) \neq 0,\ y > 0$.
Then $\beta(S_1 \cup S_2) = \beta(S_1) \cup \beta(S_2)$.

Example

Let hs_A be the hash sketch describing set A, and hs_B the hash sketch of set B.
Then $hs_A OR_{bit-wise} hs_B = hs_{A \cup B}$.

Directory based DF Estimation

Directory Maintenance

- Include per-term hash sketch in term-specific post

→ No additional messages

- Retrieval combined hash sketch while retrieving Peerlists

→ No additional messages

Usage in Query Execution

- Send estimated DF as weights to queried peers
- Local QE, reweight on-the-fly with global DF

Evaluation

Experiment 1

General accuracy of hash-sketch based cardinality estimation.
omitted here for time reasons

Experiment 2

Accuracy of global df estimation in dynamic networks

Experiment 3

Impact of global df in P2P search

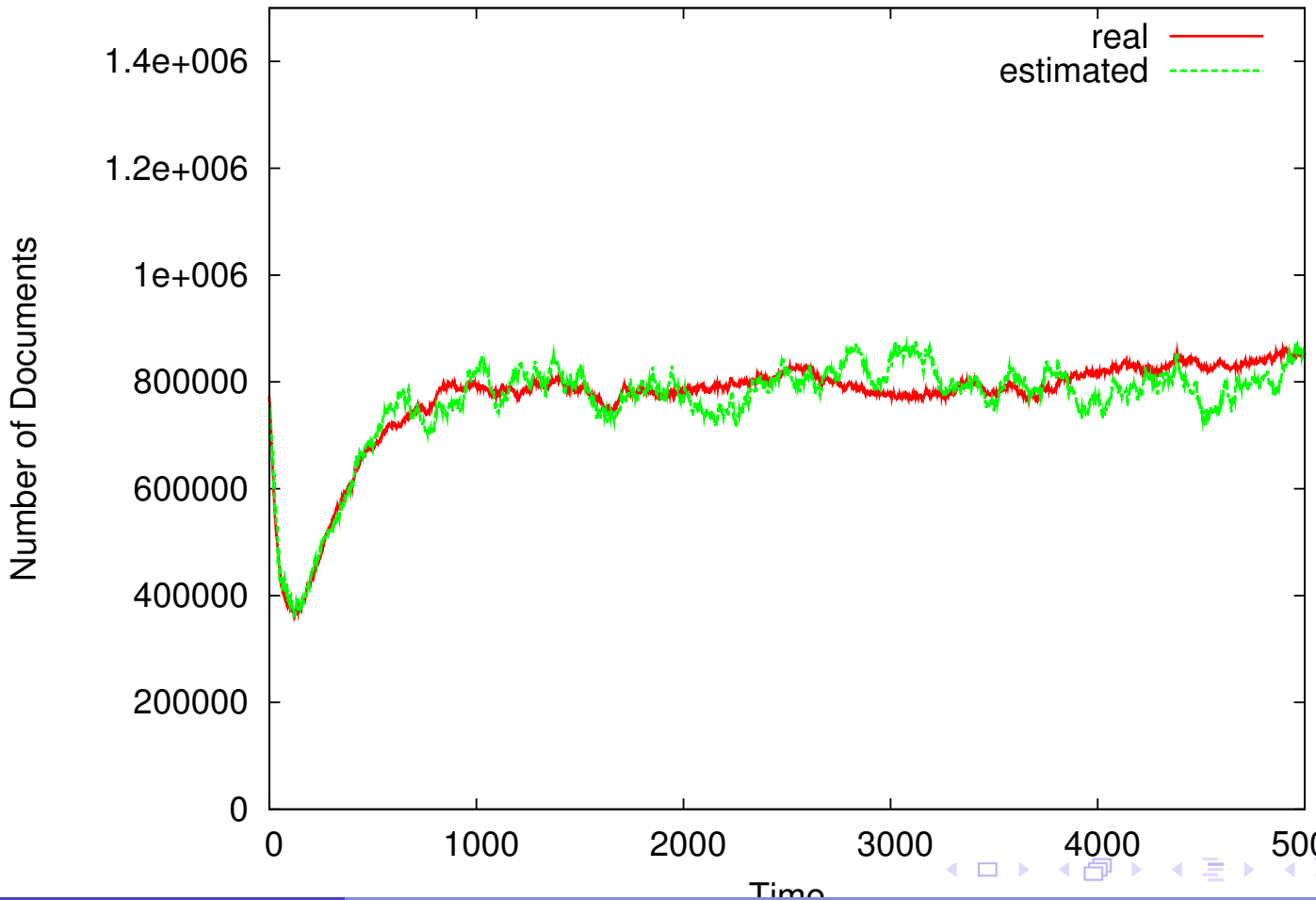
Experiment 2: Accuracy of DF Estimation under Churn

Data/Peers

- synthetic data (document ids)
- 256 bitmap hash-sketches
- Initially 1000 Peers + Entering/Leaving Peers

Experiment 2: Accuracy of DF Estimation in dynamic Networks

256 bitmap hashsketch, synthetic collections



Experiment 3: Impact on Result Quality

Dataset

- 10 thematic web collections, split into 4 fragments each
- Created 40 peers by creating all 3-subsets for each topic

Queries

- 30 popular Google queries (Zeitgeist)

Quality Measure

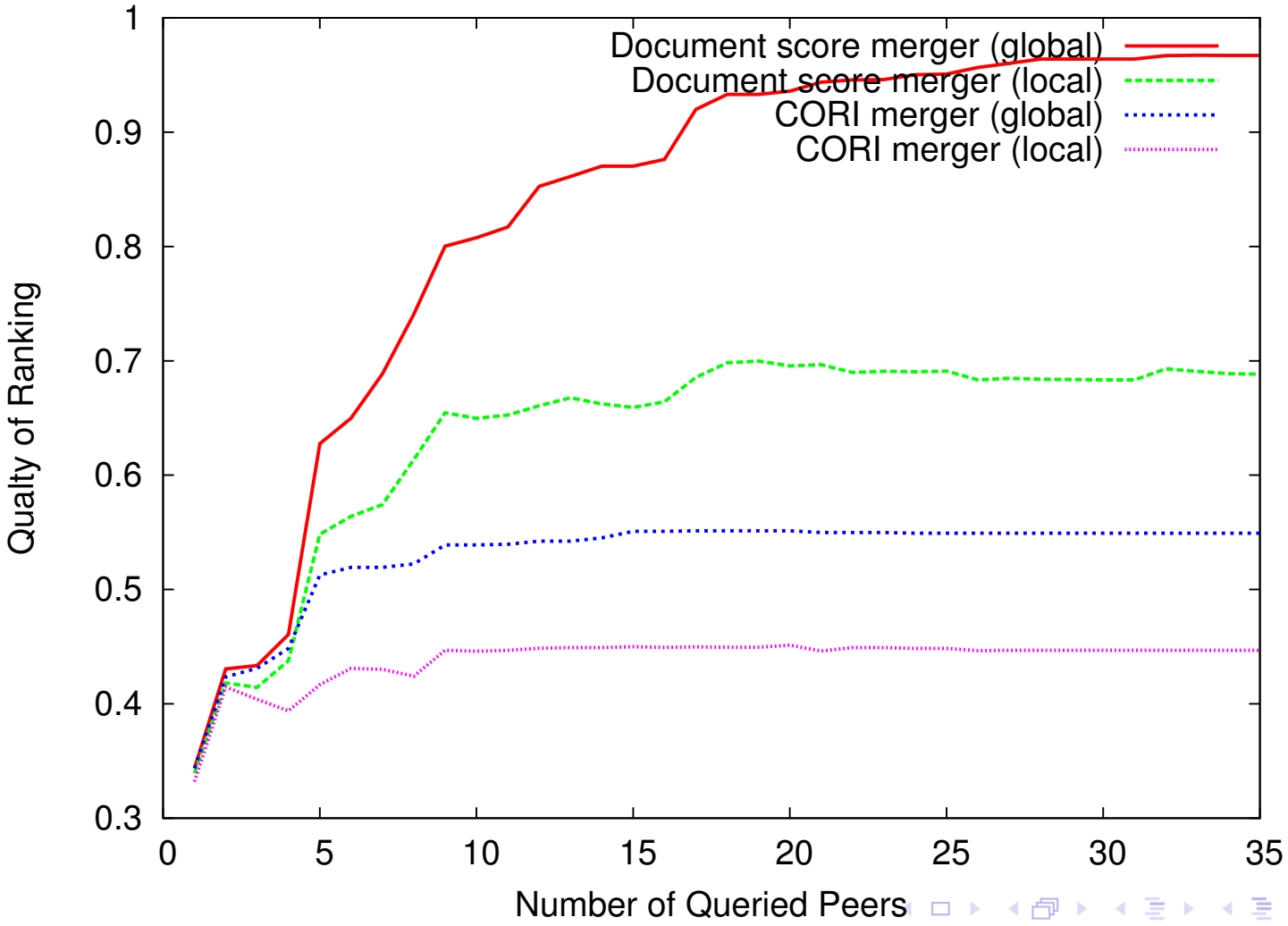
Distance of

- global DF based merging
- local DF based merging
- CORI [Callan et al.] based result merging (normalization)

to hypothetical centralized ranking

Experiment 3: Impact on Result Quality

40 peers



Conclusion and Outlook

Conclusion

- New method for global df estimation in large scale P2P networks
- Experiments in dynamic networks
- Experiments on real-web data

Future Work

- Evaluation of the impact using relevance assessments