Building Self-Organized Image Retrieval Network

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Motivation

- What we have:
  - *very* large collection of multimedia data, e.g. digital images
  - networks with volatile peers where data can change in time
  - peers organize their own data

- What we want:
  - large shared multimedia database (like KaZaA, Gnutella)
  - data searchable by content $\Rightarrow$ metric space
  - efficient approximative search $\Rightarrow$ self-organizing search system

Self-organizing Search Systems

Properties:

- Scalability – system finishes operations within acceptable performance even if amount of data or users in the networks increase
- Robustness – system is resistant against nodes' failures
- Self-organization – local knowledge is sufficient to find requested data
- Self-adaptation – system adapts to changes in users' tastes and data distribution

Image Retrieval Network

Image Retrieval Network =

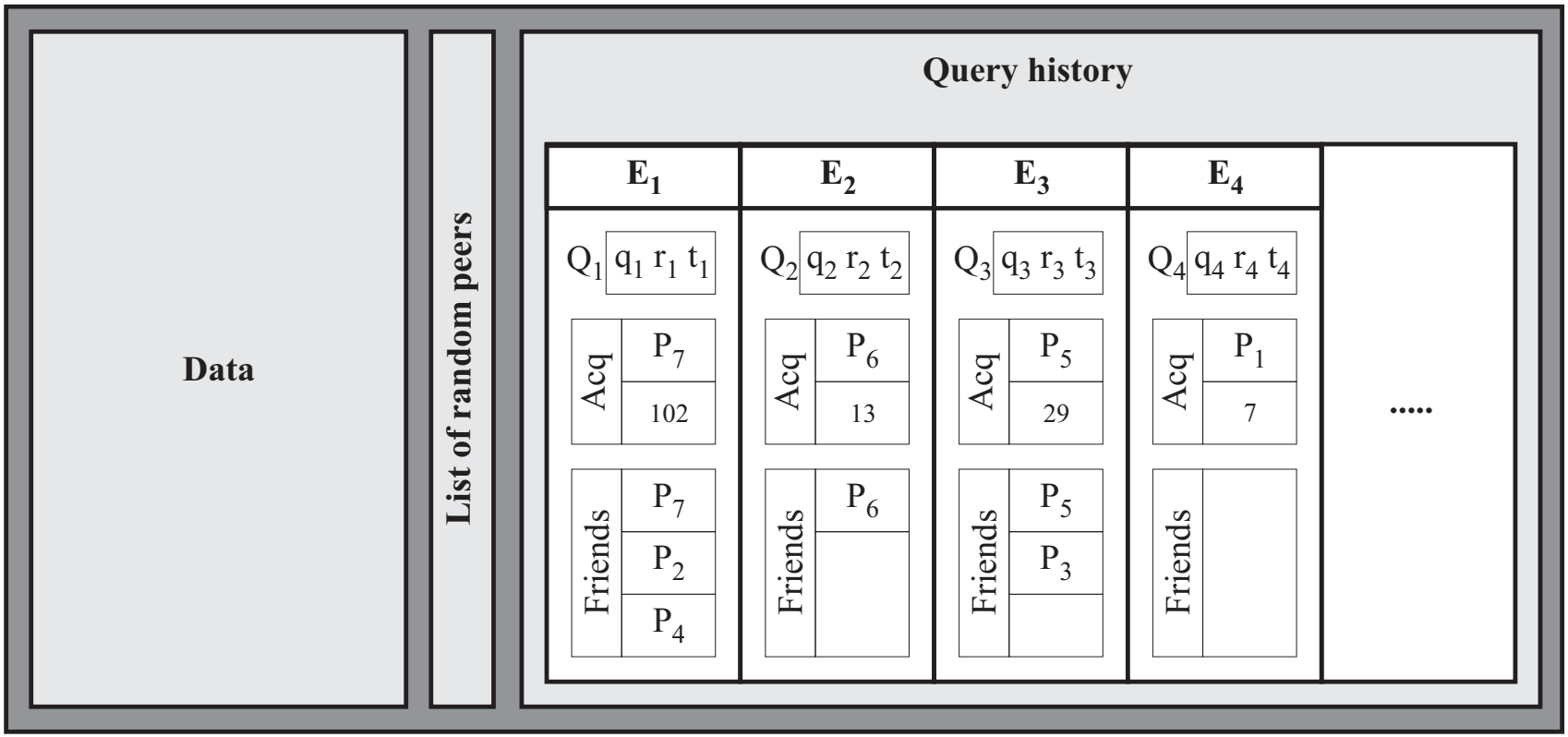
= Metric space + Self-organizing network + Social-network paradigm

- Self-organizing network for similarity searching
- Supports range queries

- Based on the social-network paradigm:
  - Entities – peers within the network
  - Relationships
    - *friends* – short ties, identify similar peers
    - *acquaintances* – long ties, navigation purposes
  - Small-world phenomenon

Architecture – Peer Anatomy

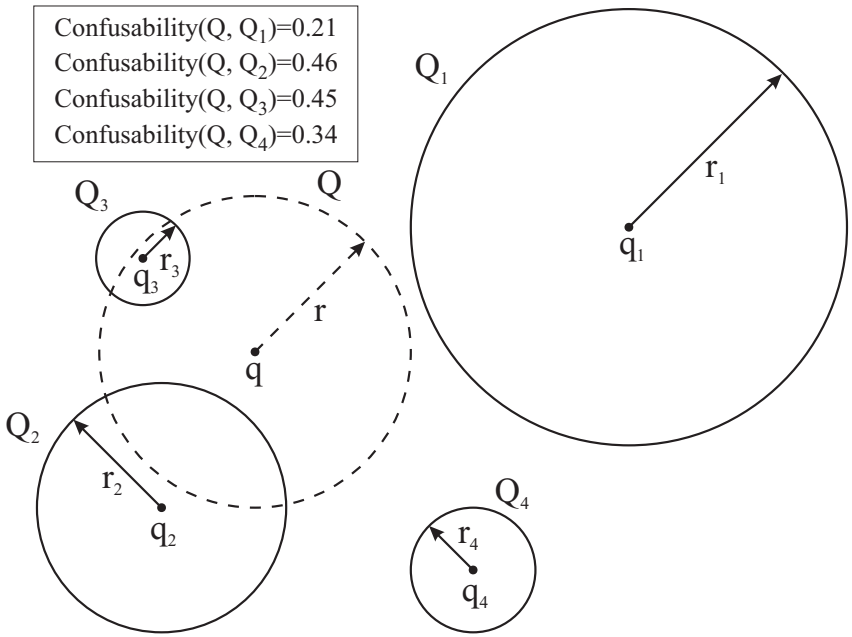
- Relationships among the peers are created according to peers' answers to processed query
- Relationships are exploited by query routing algorithm



Architecture – Confusability of Queries

- Confusability expresses the similarity between two range queries Q_1 and Q_2 with timestamps

$$Confusability(Q_1, Q_2) = w_D \cdot D(Q_1, Q_2) + w_I \cdot I(Q_1, Q_2) + w_T \cdot T(Q_1, Q_2)$$



- The size of query history is limited $\Rightarrow$ very similar and obsolete queries might be replaced by new ones

Architecture – Quality of Answer

- Quality of Answer makes answers to processed query comparable
- expressed as a number of retrieved objects
- partial answers of individual peers

$$A(Q) = |\bigcup_{i=1}^{n} A_{P_i}(Q)|$$

- also represents stop condition to the navigation algorithm
- query history entry - pointers to peers, their respective qualities

Architecture – Adaptive Navigating

- Each node estimates self-confidence to the processed query
- Exploitation
  - exploit the best knowledge so far
  - following most relevant acquaintance ties taken from peer's query history
  - spreading more with low certainty = average confusability of 5 most similar (confusable) template queries
  - looking for most suitable *community* of peers
  - stops when the quality associated with template query *maximal*
- Exploration
  - explore paths that have not been followed
  - each peer maintains a list of random peers
  - processed query is forwarded to a random peer when *certainty* is low

Data – CoPhIR

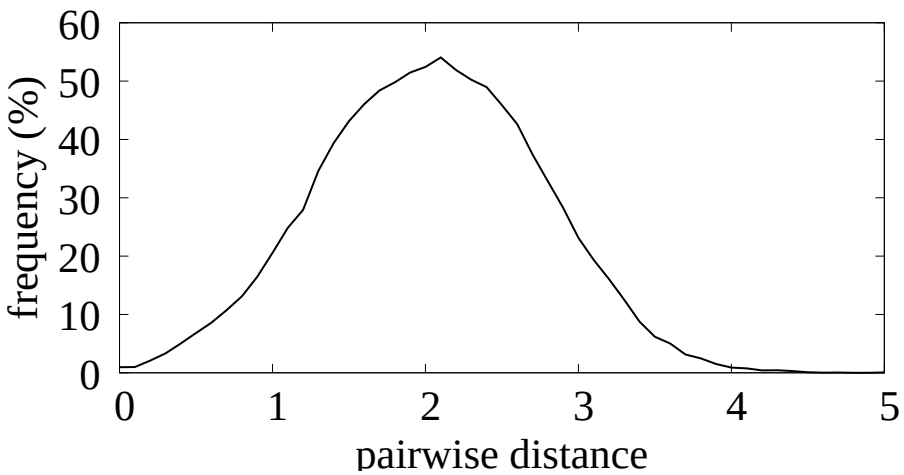
Content-based Photo Image Retrieval Test-Collection

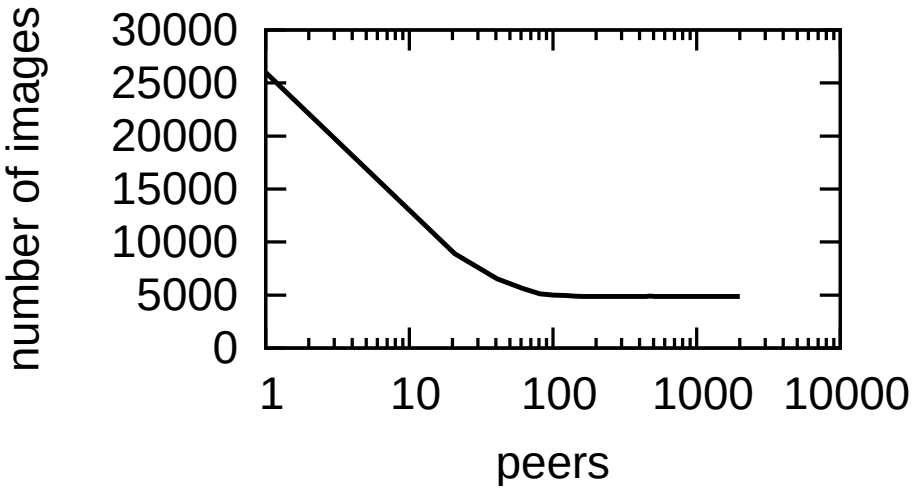
- descriptors taken from MPEG-7 standard
- 5 characteristic features are extracted from each digital image
- aggregated distance function

MPEG-7 Feature	**Metric**	**Weight**
Scalable Color	L_1 metric	2
Color Structure	L_1 metric	3
Color Layout	sum of L_2	2
Edge Histogram	special	4
Homogeneous Texture	special	0.5

Experimental Trials – Settings

- 2000 peers index 10,000,000 images
- each network peer represent a Flickr.com user and his contribution





Experimental Trials – Measures

EOPP is normalized error on peers' positions gaining values from the interval $[0, 1]$

$$EOPP = \frac{\sum_{i=1}^{|Approx|} Total[Peer_i] - Approx[Peer_i]}{|Approx| \cdot |Total|}$$

where *Approx* stands for the approximate answer and *Total* for the total answer.

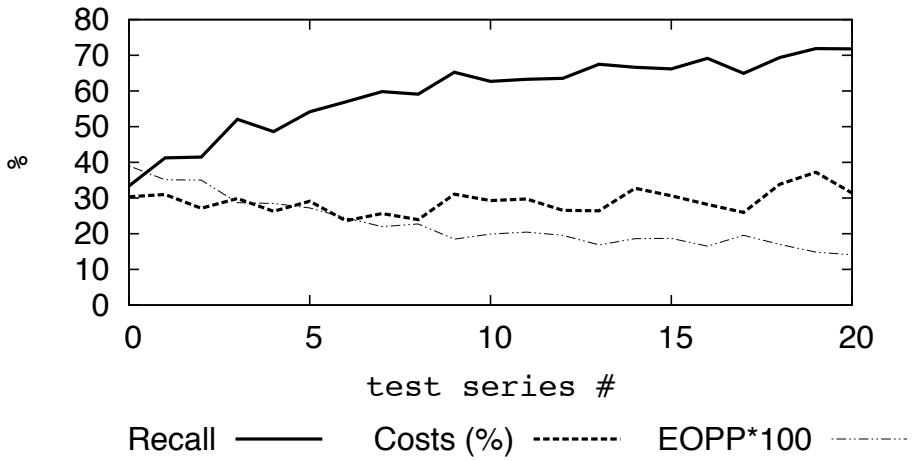
IRN-NER a number of peers that returned a Non-Empty Result (non empty peer's answer) to the processed query by IRN.

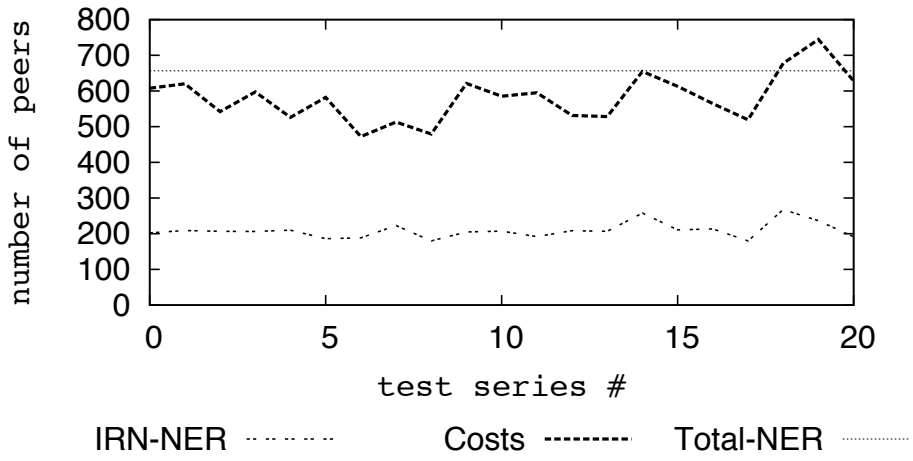
Total-NER a number of peers of the network that have non-empty answer to the processed query.

NER-ratio a ratio of *IRN-NER* and *Total-NER*.

Experimental Trials

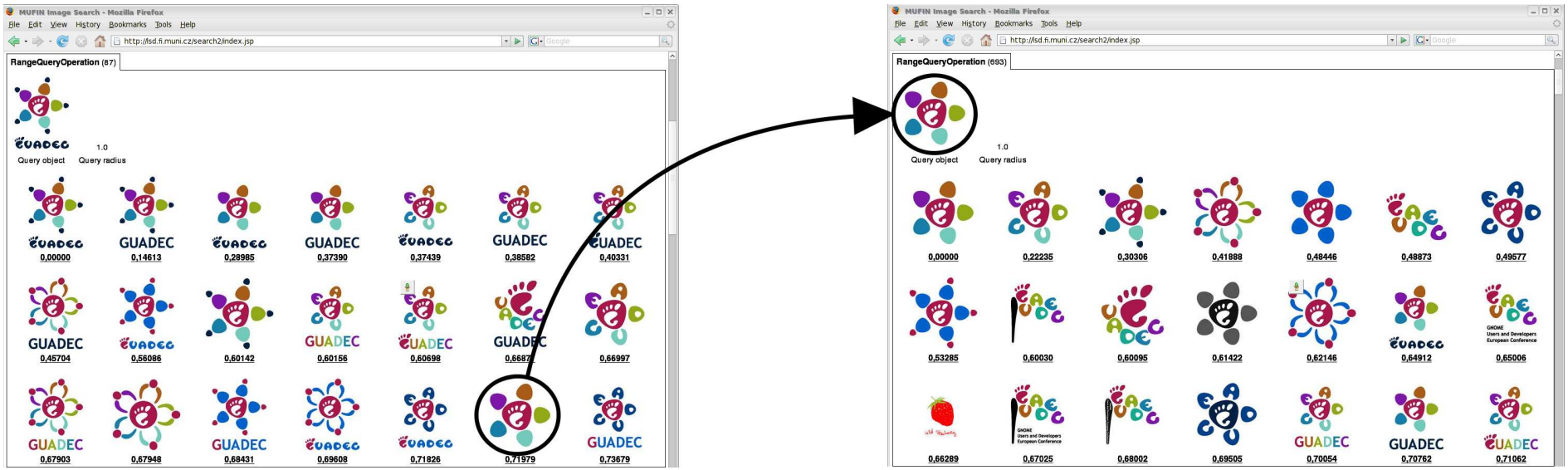
- set of 50 learning queries
- subset of 20 measuring queries
- series of 20 steps



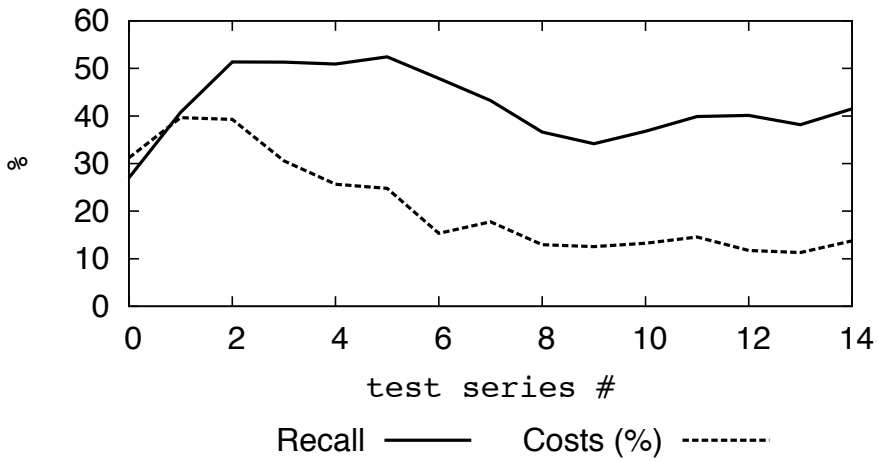


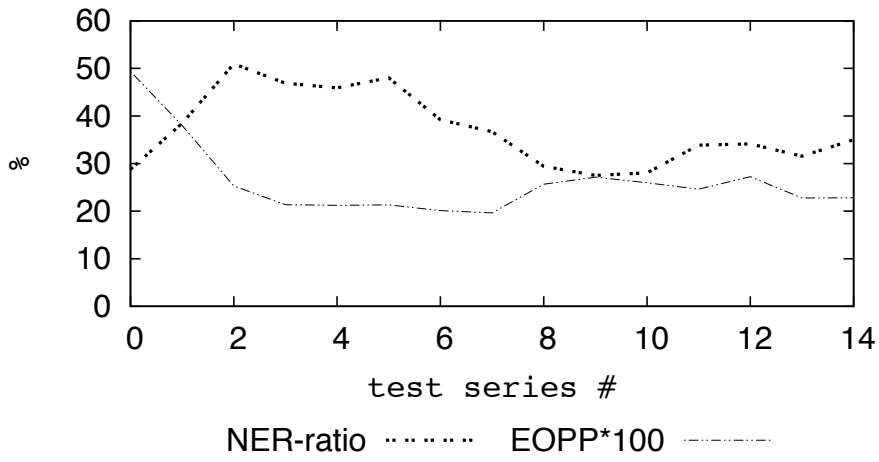
Experimental Trials – Image Browsing Scenario

- users browse the images
- query image is selected from the result of previous query



Experimental Trials – Image Browsing Scenario Results





- low-learned IRN
- 11 browsing sessions
- 15 browsing steps

Future Work

- enhance the architecture of the network to support also the nearest neighbor queries
- measure quality of answer by proximity of retrieved objects
- analyze how peer dynamism affect the IRN

- further study scalability of the system towards indexing hundreds millions of images
- study other self-organizing bio inspired approaches (ants, bio-networking, etc.)
- general wire-frame for self-organizing search systems

Questions?

Thank you for your attention.

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