Simrank++

Query Rewriting through Link Analysis of Click Graph

Alekh Jindal

Motivation

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Motivation

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Sponsored Search

- Ads relevant to user query shown above or alongside search results
- Each bid has query(q), ad(α) and price(p)

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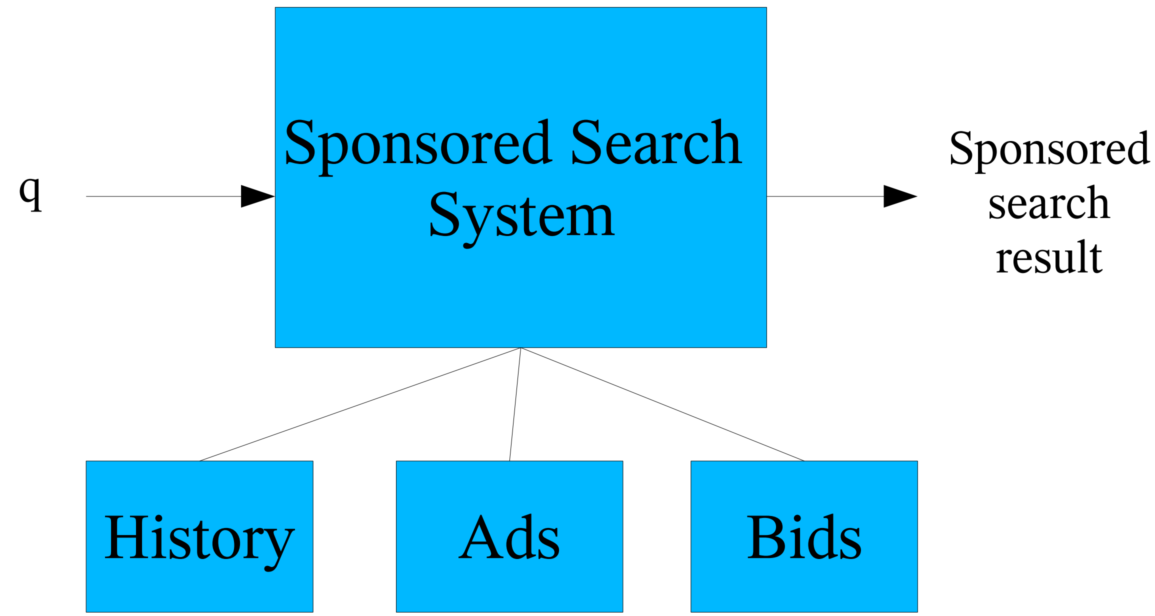

Query Rewrites

- Not direct bids for many queries
- Ads have little text; lesser information
- Rewrites: similar queries based on history of ads displayed and clicked

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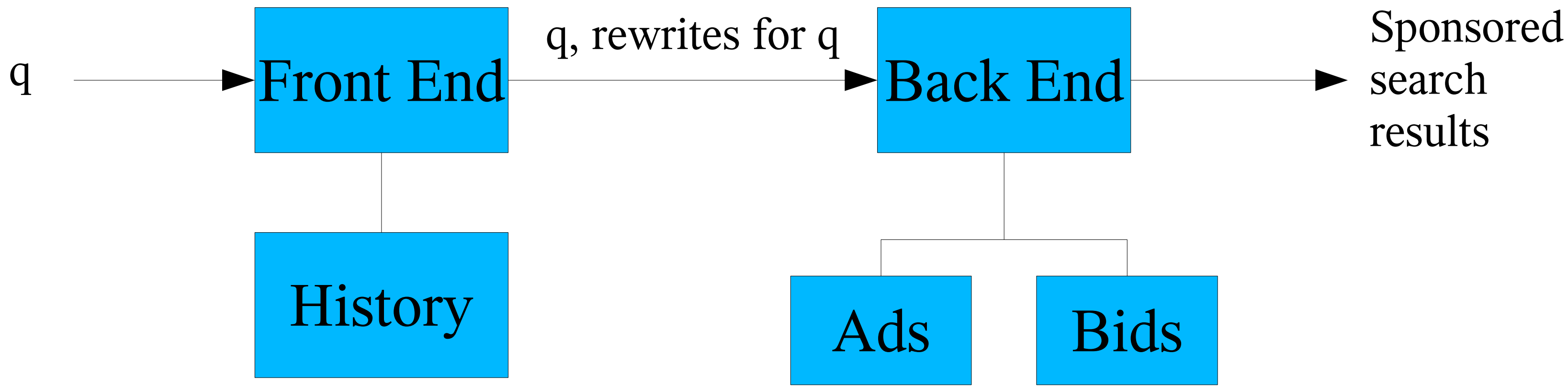
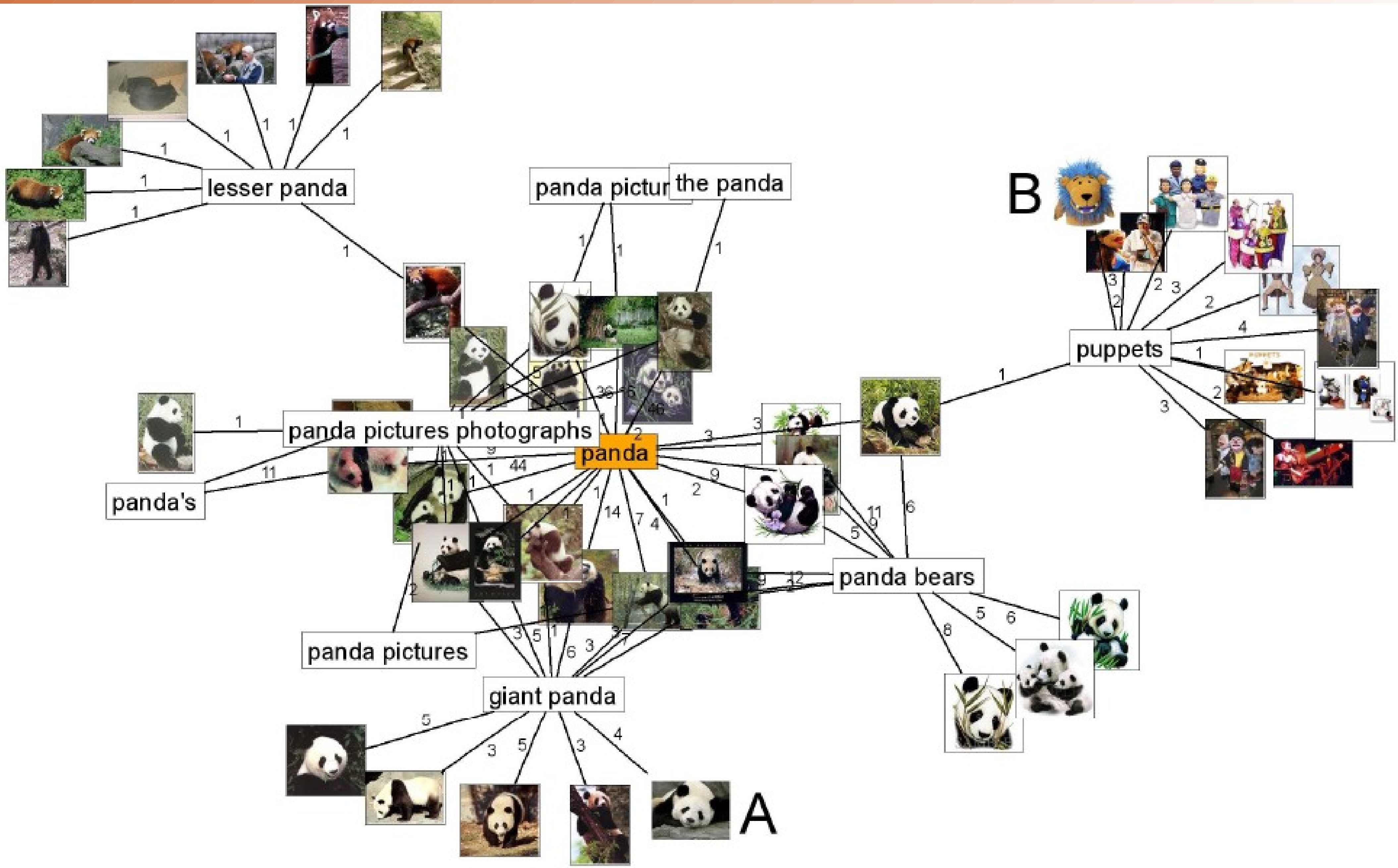


Click Graph

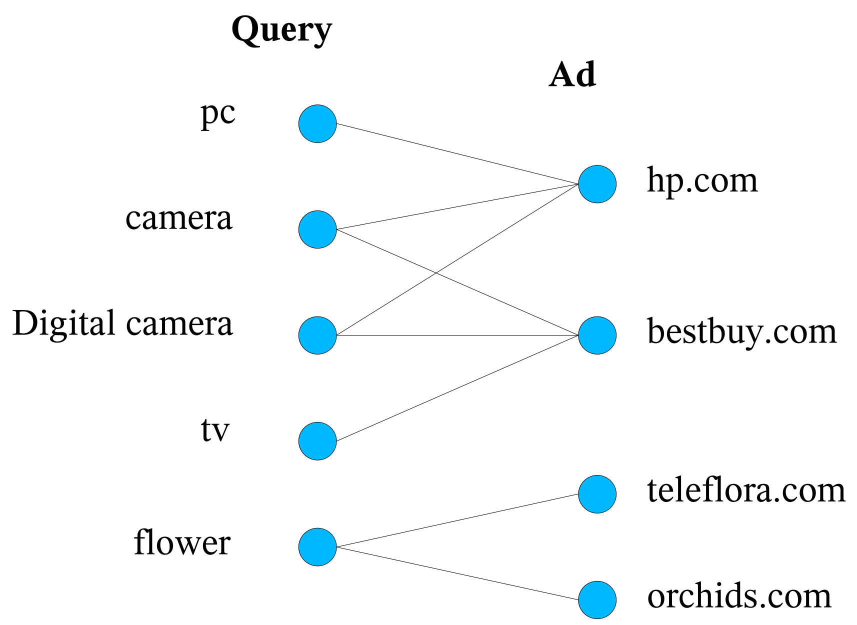


lesser panda
panda pictur
the panda
B
puppets
panda pictures photographs
panda
panda's
panda bears
panda pictures
giant panda
A

Click Graph

- Generated by back end
- Directed, weighted, bipartite graph
- Formally: $G = (Q, A, E)$
- Q: set of queries q
- A: set of ads α
- E: set of edges e from q to α, s.t. at least one user that issued q clicked on α
- Edge weights:
  - Impressions
  - Clicks
  - Expected click rate

Click Graph - example

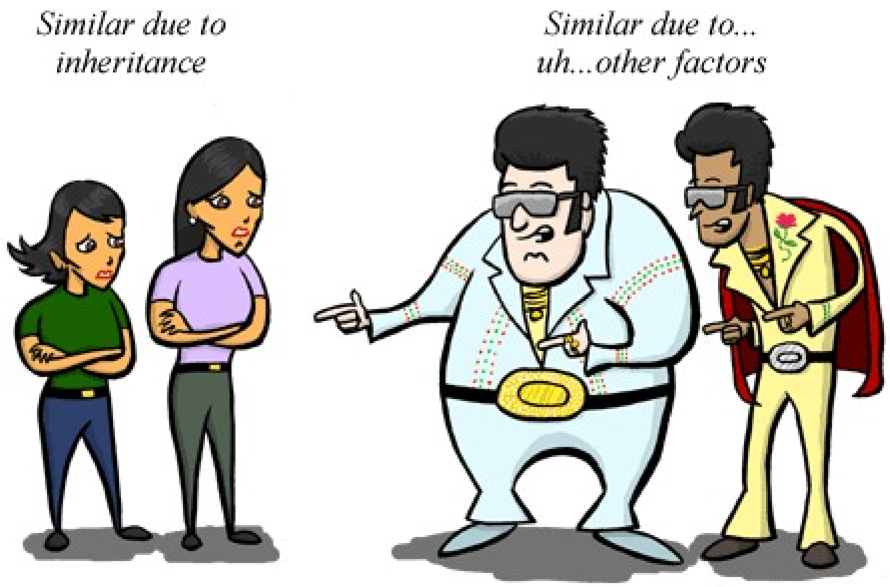


Query Similarity

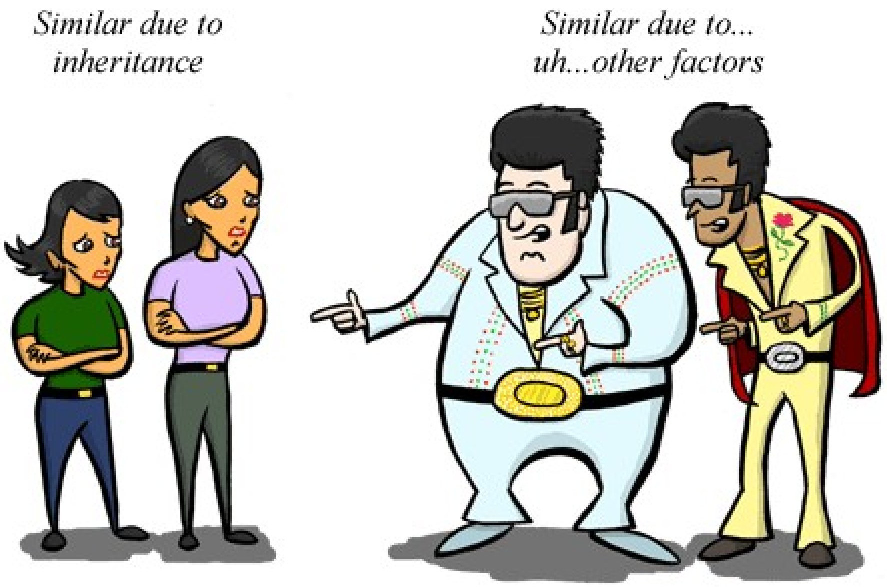
- Goal: find similar queries
- Intuition: queries with common ad clicks are similar
- Analogous to collaborative filtering (CF)
  - Users as queries; Recommendation as ads

Query Similarity

Query Similarity

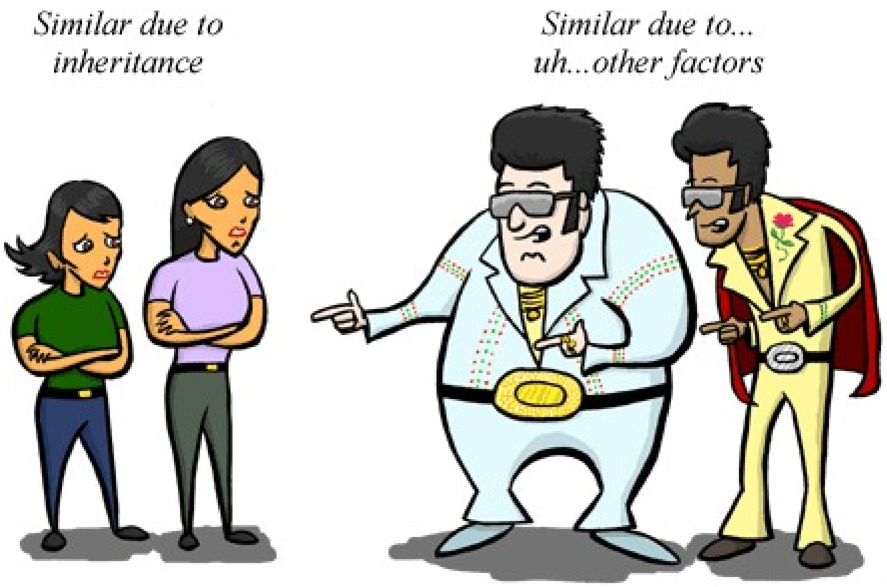


Query Similarity



Guys are similar if they like the similar girl!

Query Similarity



Guys are similar if they like the similar girl!
... and vice-versa!

Similarity: naïve approach

Idea: count number of common ads

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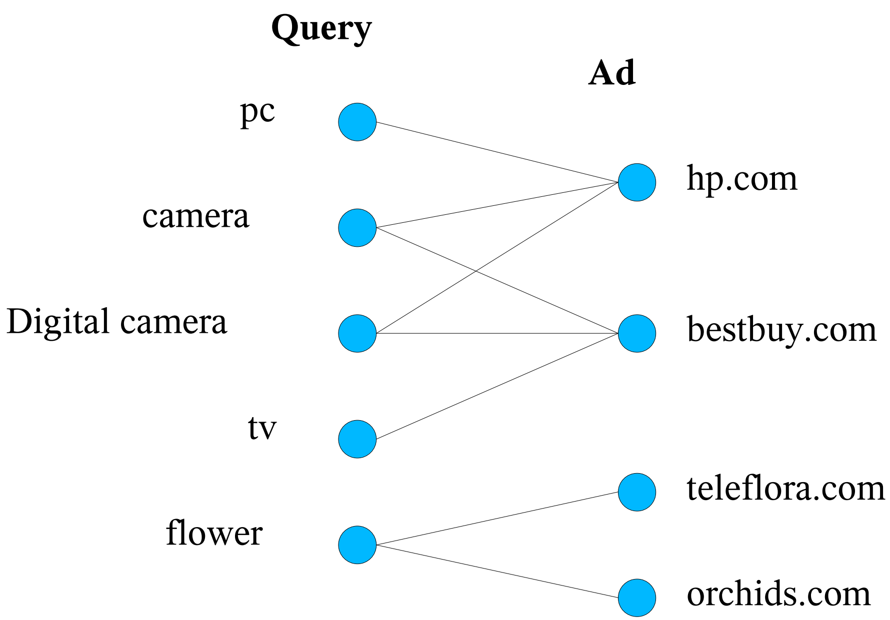
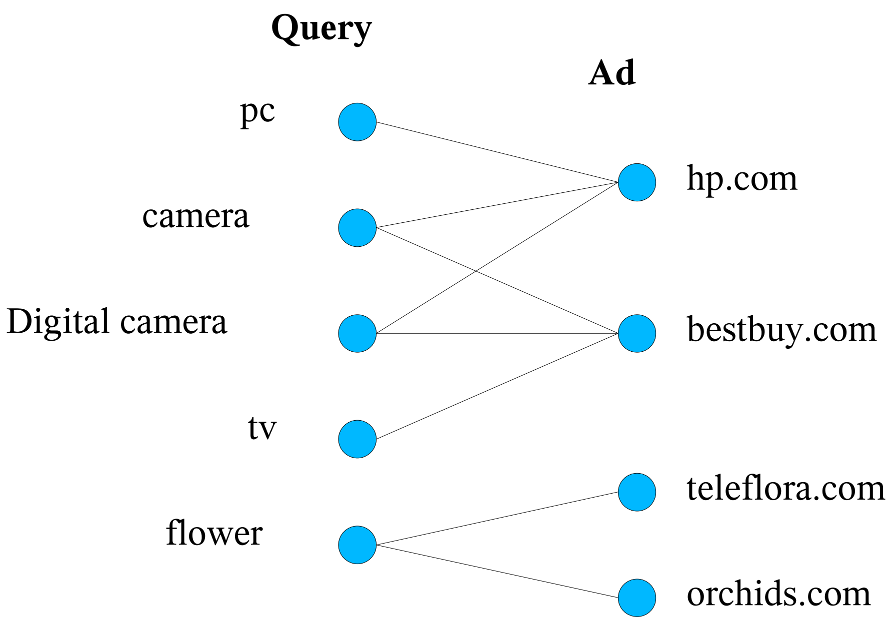


Similarity: naïve approach

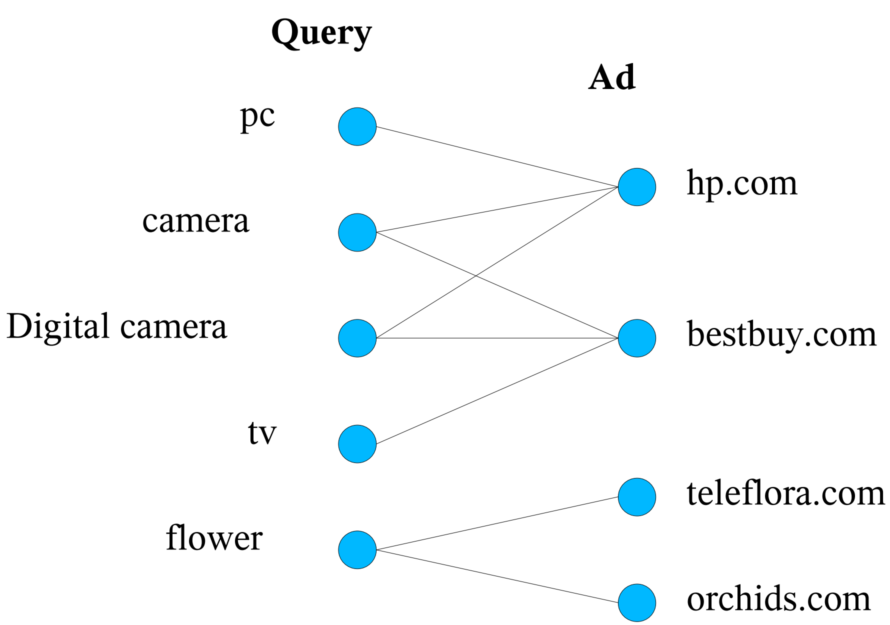
Idea: count number of common ads



	pc	camera	digital camera	tv	flower
pc	-	1	1	0	0
camera	1	-	2	1	0
digital camera	1	2	-	1	0
tv	0	1	1	-	0
flower	0	0	0	0	-

Similarity: naïve approach

Idea: count number of common ads



	pc	camera	digital camera	tv	flower
pc	-	1	1	0	0
camera	1	-	2	1	0
digital camera	1	2	-	1	0
tv	0	1	1	-	0
flower	0	0	0	0	-

Problem: sim(pc, tv) = 0

Similarity: Simrank

Idea: Two objects are similar if they are referenced by similar objects

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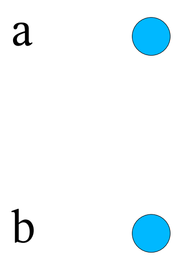
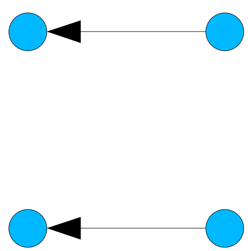


Similarity: Simrank

Idea: Two objects are similar if they are referenced by similar objects

a

b



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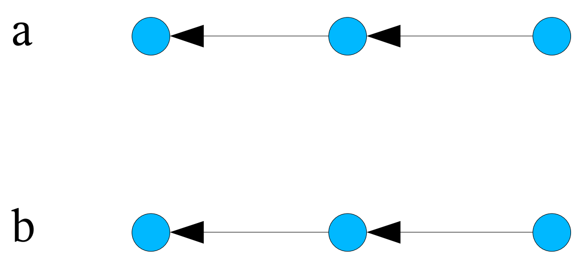

Similarity: Simrank

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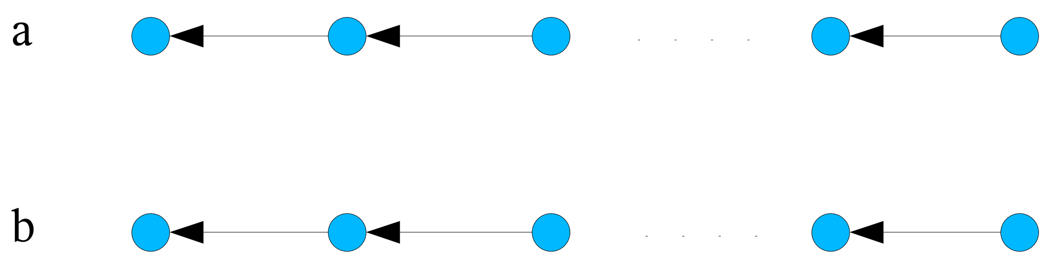

Similarity: Simrank

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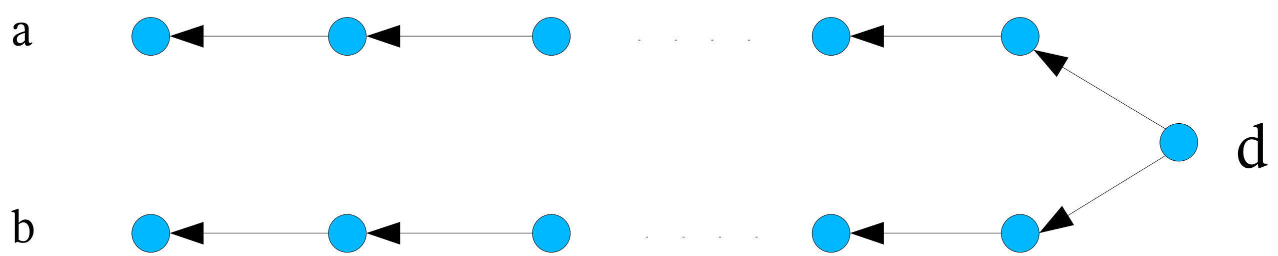

Similarity: Bipartite Simrank

Idea: Two objects of one type are similar if they are referenced by similar objects of second type

Similarity: Bipartite Simrank

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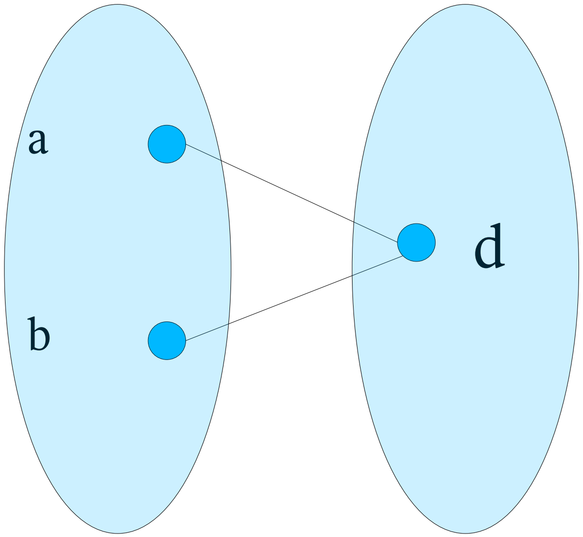

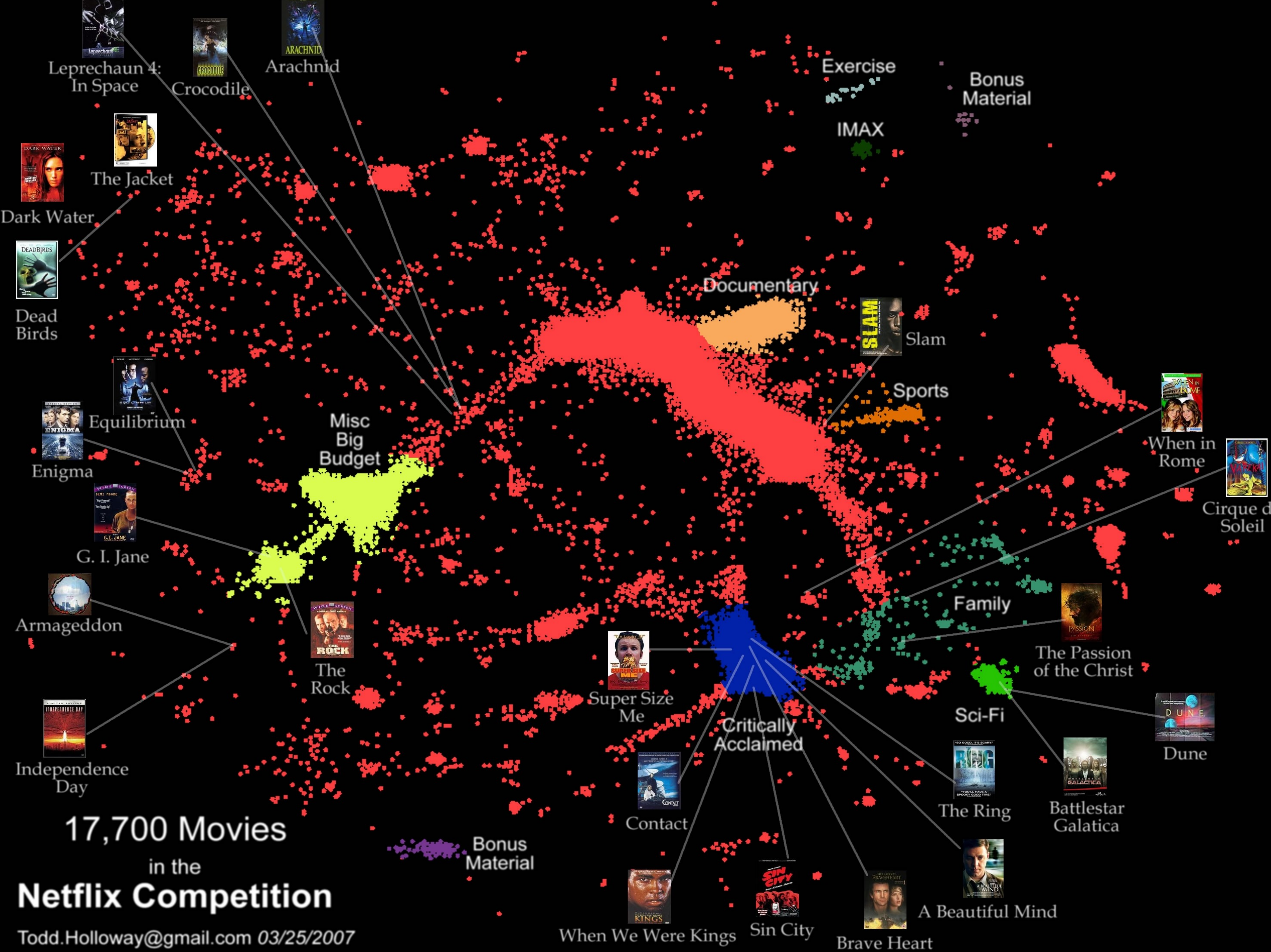
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Crocodile
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Exercise
Bonus Material
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Slam
Sports
Equilibrium
Enigma
Misc Big Budget
When in Rome
Cirque d Soleil
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in the
Netflix Competition
Bonus Material
A Beautiful Mind
When We Were Kings
Sin City
Brave Heart
Todd.Holloway@gmail.com 03/25/2007

Similarity: Bipartite Simrank

- Formally: E(x) is the set of neighbors of x
- N(x) is the number of neighbors of x
- For queries q and q', similarity s(q,q') is given as:

$$s(q,q') = \frac{C_1}{N(q)N(q')} \sum_{i \in E(q)} \sum_{j \in E(q')} s(i,j)$$

- Similarly, for ads α and α', similarity s(α,α') is given as:

$$s(\alpha,\alpha') = \frac{C_2}{N(\alpha)N(\alpha')} \sum_{i \in E(\alpha)} \sum_{j \in E(\alpha')} s(i,j)$$

- C_1, C_2 are constants in [0,1]

Similarity: Bipartite Simrank

- Example: Find s(a,c)

Let $C_1 = 0.8$

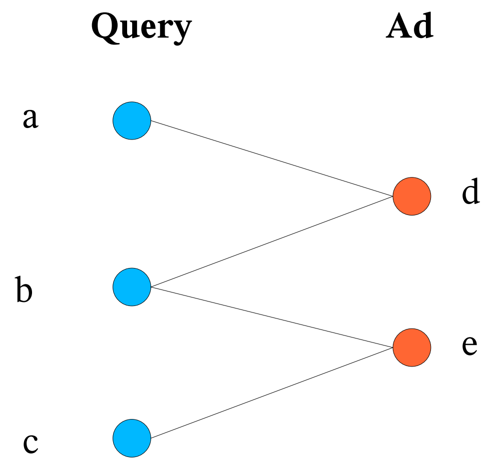
$$s(a,c) = \frac{C_1}{N(a)N(c)} \sum_{i \in E(a)} \sum_{j \in E(c)} s(i,j)$$

$$s(a,c) = 0.8 \,.\, s(d,e)$$

Iteration 1:

s(x,x) = 1, s(x,y) = 0

s(a,c) = 0



Similarity: Bipartite Simrank

- Iteration 2:

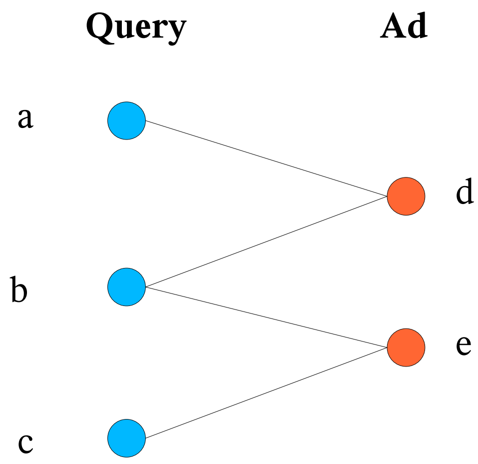
$$s(a,c) = 0.8\ .\ s(d,e)$$

$$s(a,c) = 0.8\ .\ \frac{C_2}{N(d)N(e)} \sum_{i \in E(d)} \sum_{j \in E(e)} s(i,j)$$

$$s(a,c) = 0.8\ .\ \{\frac{0.8}{2 \times 2}$$
$$(s(a,b) + s(a,c) + s(b,b) + s(b,c))\}$$

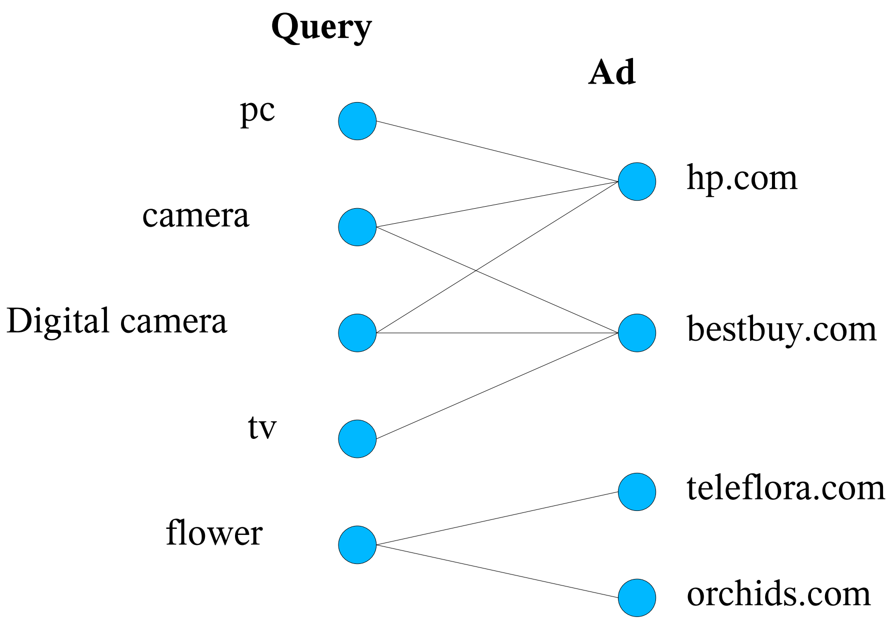
$$s(a,c) = 0.32\ .\ \{(0+0+1+0)\}$$

$$s(a,c) = 0.32$$



Similarity: Bipartite Simrank

Idea: Two objects of one type are similar if they are referenced by similar objects of second type



	pc	camera	digital camera	tv	flower
pc	-	0.619	0.619	0.437	0.000
camera	0.619	-	0.619	0.619	0.000
digital camera	0.619	0.619	-	0.619	0.000
tv	0.437	0.619	0.619	-	0.000
flower	0.000	0.000	0.000	0.000	-

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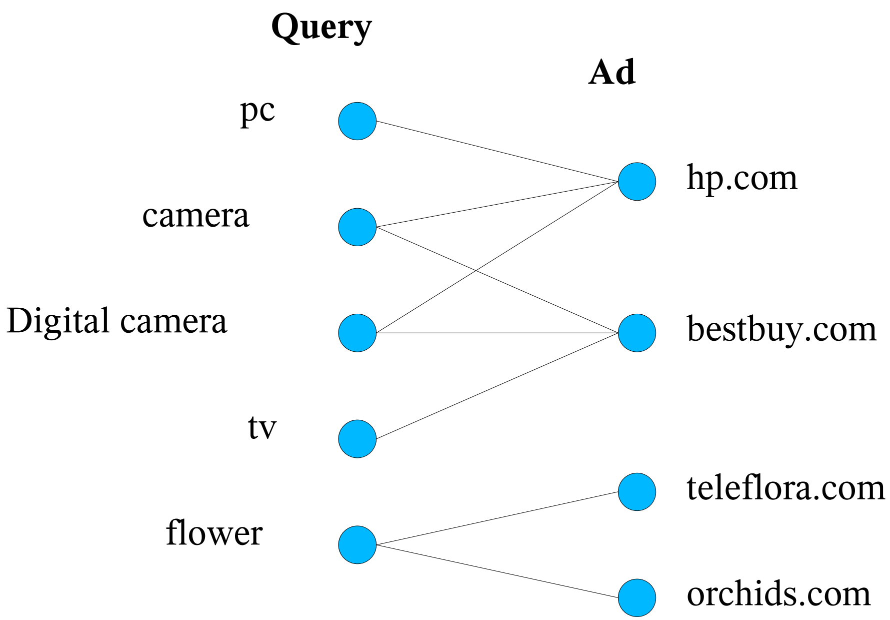

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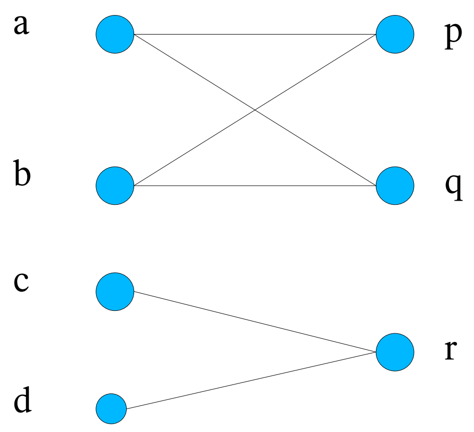
tv	0.437	0.619	0.619	-	0.000
flower	0.000	0.000	0.000	0.000	-

s(camera,tv) = s(camera, digital camera)

Similarity: Bipartite Simrank

- “evidence” not taken into account



Iteration	sim(a,b)	sim(c,d)
1	0.4	0.8
2	0.56	0.8
3	0.624	0.8
4	0.6496	0.8
5	0.65984	0.8
6	0.663936	0.8
7	0.6655744	0.8

- sim(a,b) < sim(c,d)
- Expected: sim(a,b) > sim(c,d)

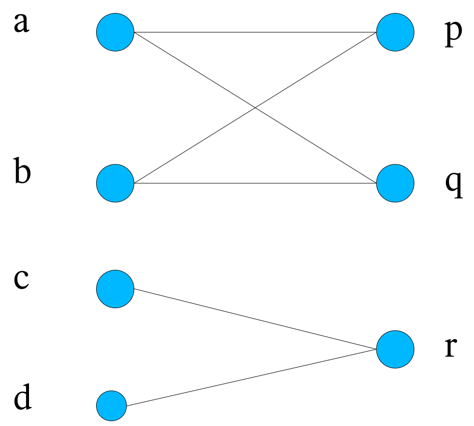
Similarity: Evidence Simrank

- “evidence”: Number of common neighbours
- Evidence function:

$$evidence(a,b) = \sum_{i=1}^{|E(a) \cap E(b)|} \frac{1}{2^i}$$

- Revised Simrank:
  - $s_{evidence}(q,q') = evidence(q,q')\ .\ s(q,q')$
  - $S_{evidence}(\alpha,\alpha') = evidence(\alpha,\alpha')\ .\ s(\alpha,\alpha')$

Similarity: Evidence Simrank

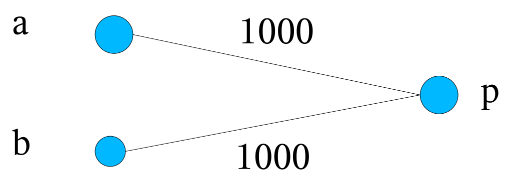


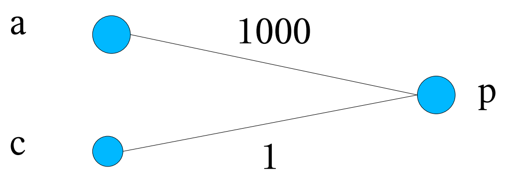
Iteration	sim(a,b)	sim(c,d)
1	0.3	0.4
2	0.42	0.4
3	0.468	0.4
4	0.4872	0.4
5	0.49488	0.4
6	0.497952	0.4
7	0.4991808	0.4

- sim(a,b) > sim(c,d) after 1st iteration

Similarity: Weighted Simrank

- Consistency Rules
  - If variance is less and edge weight more then simi-larity is more





  - Expected: sim(a,b) > sim(a,c)

Similarity: Weighted Simrank

- Consistency Rules
  - For equal variance, if edge weight is more then similarity is more

  - Expected: sim(a,b) > sim(a,c)

Similarity: Weighted Simrank

- Transition probability:

$$p(x, i) = \text{spread}(i)\ .\ \text{normalized\_weight}(x, i) = W(x, i)$$

$$\text{spread}(i) = e^{-\text{variance}(i)}$$

$$normalized\_weight(\alpha, i) = \frac{w(\alpha, i)}{\sum_{j \in E(\alpha)} w(\alpha, j)}$$

- Revised Simrank:

$$s_{weighted}(q, q') = evidence(q, q')\ .\ C_1\ .\ \sum_{i \in E(q)} \sum_{j \in E(q')} W(q, i) W(q', j) s_{weighted}(i, j)$$

$$s_{weighted}(\alpha, \alpha') = evidence(\alpha, \alpha')\ .\ C_2\ .\ \sum_{i \in E(\alpha)} \sum_{j \in E(\alpha')} W(\alpha, i) W(\alpha', j) s_{weighted}(i, j)$$

Scalability

- Query rewrites offline and in batch
- Space required: $O(N^2)$
  - N: total number of nodes (query+ad)
- Time Required: $O(kN^3)$
  - k: number of iterations
  - typical value, k=7
- Time complexity can be reduced to: $O(kN^2d)$
  - d: average of N(a).N(b)
  - d does not grow with N
- For 15 million queries, 14 million ads and 28 million edges, Simrank++ completes in 6 hours on a single machine

Experiments: baselines

- Three query rewriting techniques
  - Pearson:

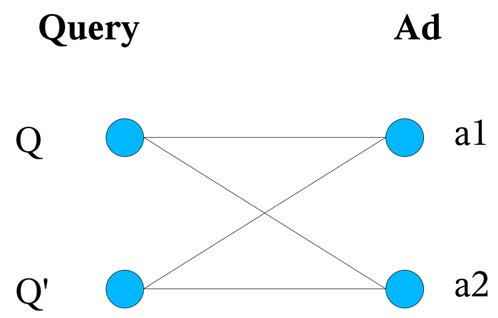
$$\mathrm{sim}_{pearson}(q,q') = \frac{\sum_{\alpha \in E(q) \cap E(q')} (w(q,\alpha) - \bar{w}_q)(w(q',\alpha) - \bar{w}_{q'})}{\sqrt{\sum_{\alpha \in E(q) \cap E(q')} (w(q,\alpha) - \bar{w}_q)^2 (w(q',\alpha) - \bar{w}_{q'})^2}}$$

  - Jaccard: $$\mathrm{sim}_{Jaccard}(q,q') = \frac{|E(q) \cap E(q')|}{|E(q) \cup E(q')|}$$

  - Cosine: $$\mathrm{sim}_{cosine}(q,q') = \arccos \frac{v(q) \,.\, v(q')}{\|v(q)\| \, \|v(q')\|}$$

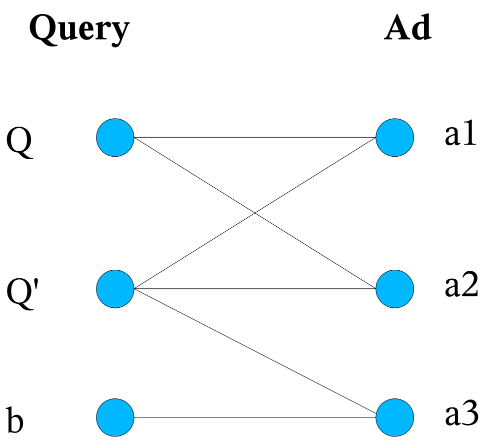
Experiments: baselines

- Example
  - $sim_{pearson}(Q,Q') = 1.414$
  - $sim_{Jaccard}(Q,Q') = 1.000$
  - $sim_{cosine}(Q,Q') = 0.841$



Experiments: baselines

- Example
  - $\text{sim}_{\text{pearson}}(Q,Q') = 1.414$
  - $\text{sim}_{\text{Jaccard}}(Q,Q') = 1.000$
  - $\text{sim}_{\text{cosine}}(Q,Q') = 0.841$



- However,
  - $\text{sim}_{\text{pearson}}(Q,b) = 0$
  - $\text{sim}_{\text{Jaccard}}(Q,b) = 0$
  - $\text{sim}_{\text{cosine}}(Q,b) = 0$

Experiments: Dataset

- Two week click graph from US Yahoo! Search
  - 15 million queries, 14 million ads, 28 million edges
- Edge weight: expected click rate
- Dataset partitioned into 5 big enough subgraphs
- Query set
  - Sampled from the same two-week period
  - Filter out the ones not present in subgraphs
  - 120 such queries

Experiments: Metrics

- Manual evaluation:
  - Manually assigned scored between 1-4 to every (query,rewrite) pair, by Yahoo! Team
  - Scores 1-2: relevant
  - Scores 3-4: irrelevant
  - $$precision(q,m) = \frac{relevant\ rewrites\ of\ q\ that\ m\ provides}{number\ of\ rewrites\ of\ q\ that\ m\ provides}$$
  - $$recall(q,m) = \frac{relevant\ rewrites\ of\ q\ that\ m\ provides}{number\ of\ relevant\ rewrites\ of\ q}$$

Experiments: Metrics

- Query Coverage:
  - Absolute number of queries for which there is at least one rewrite
- Rewriting Depth:
  - Number of rewrites for a given query

Experiments: Metrics

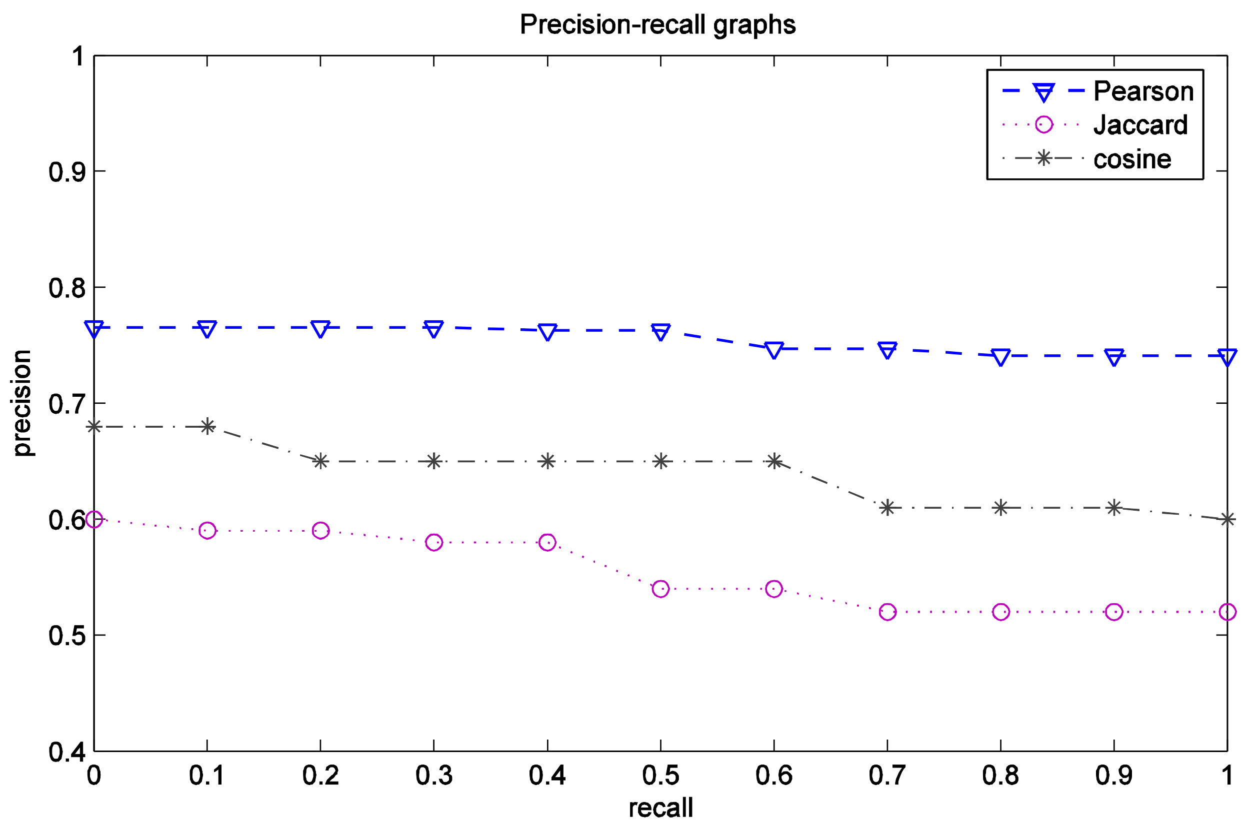
- Desirability:
  - Desirability function:

$$des(q_1,q_2) = \sum_{i \in E(q_1) \cap E(q_2)} \frac{1}{|E(q_2)|} \,.\, w(q_2,i)$$

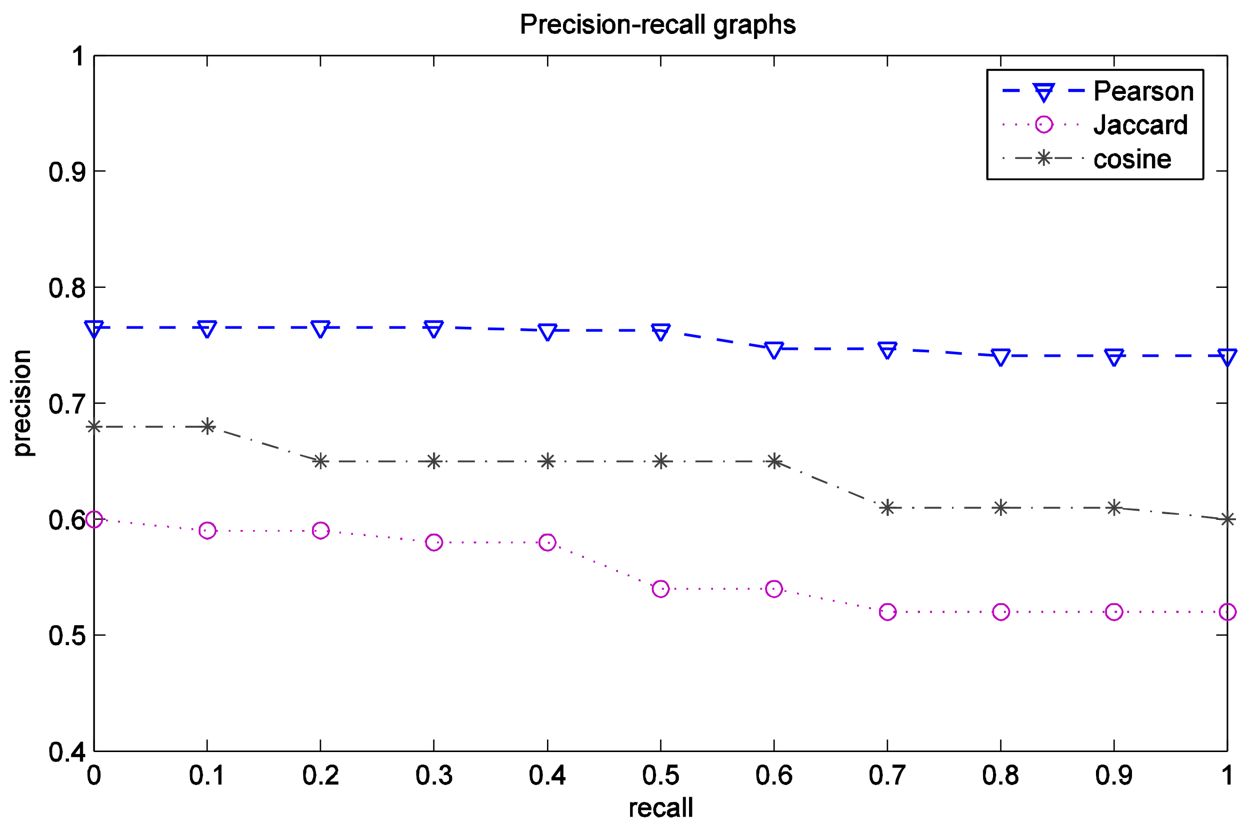
  - If $des(q_1,q_2) > des(q_1,q_3)$ then,

    $sim(q_1,q_2) > sim(q_1,q_3)$

Results: baselines

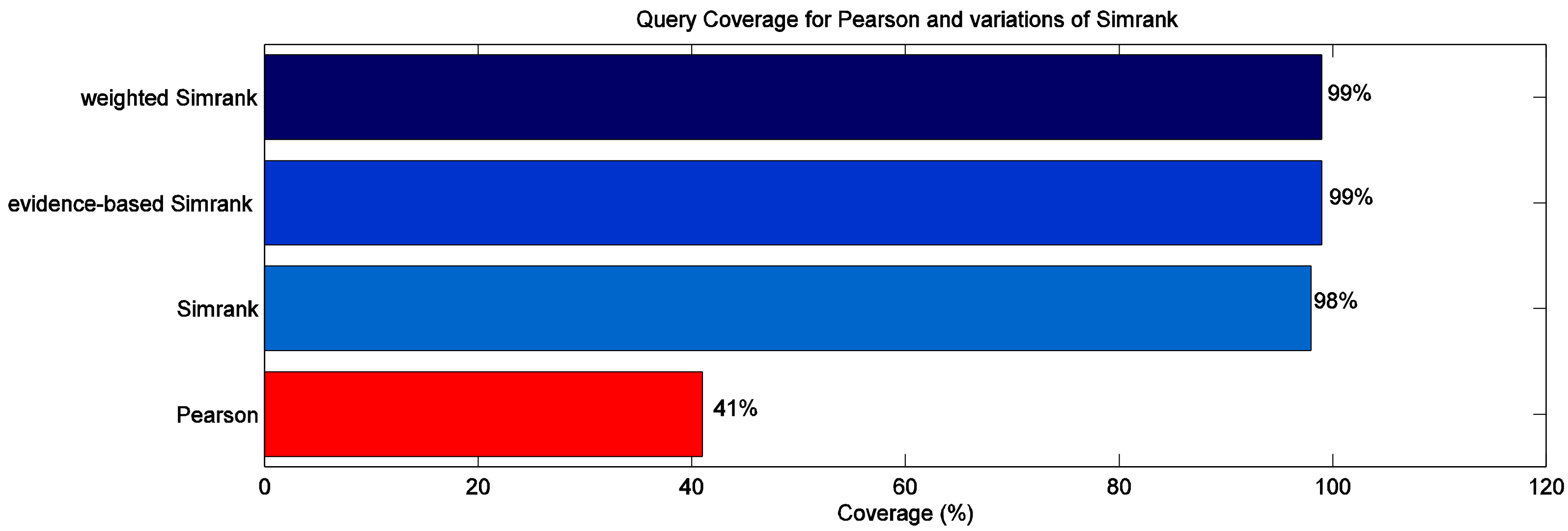


Results: baselines

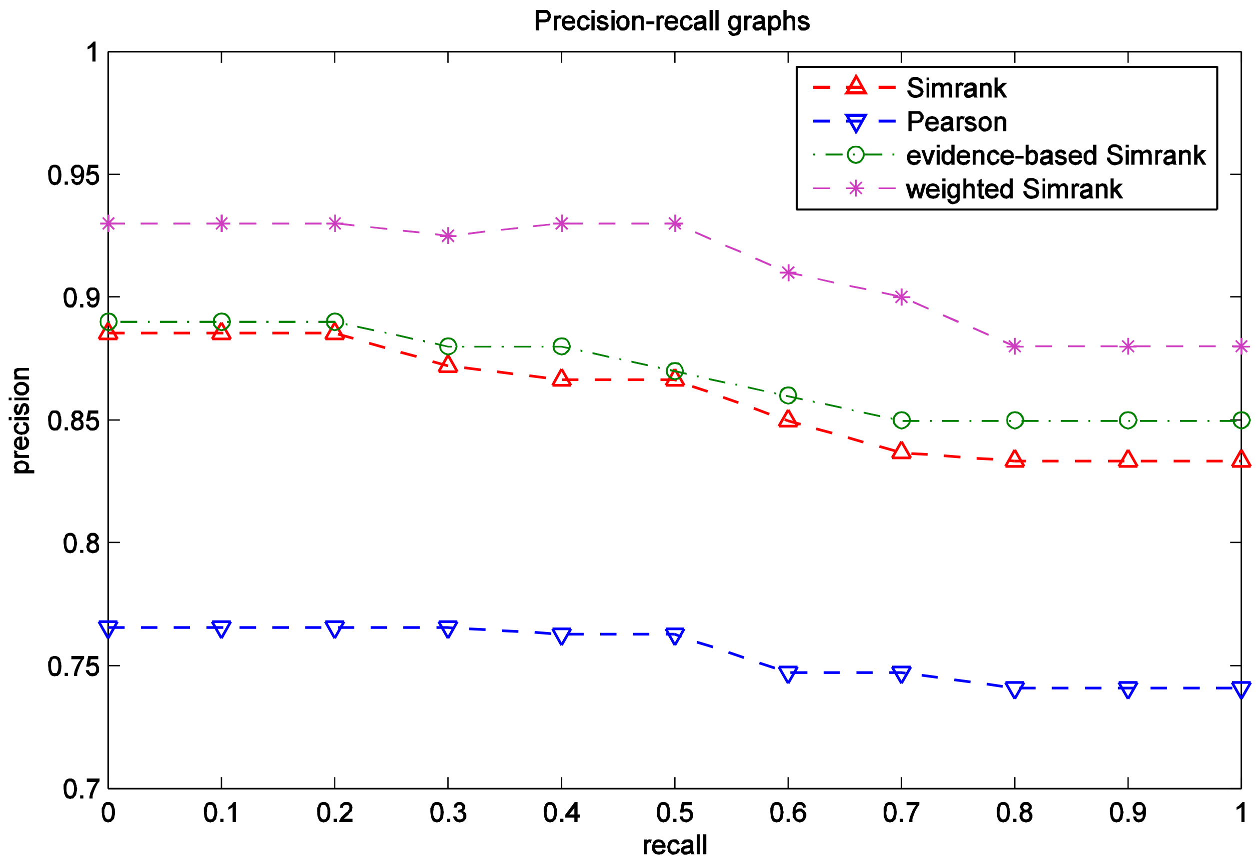


- Note: Pearson fares the best among baselines

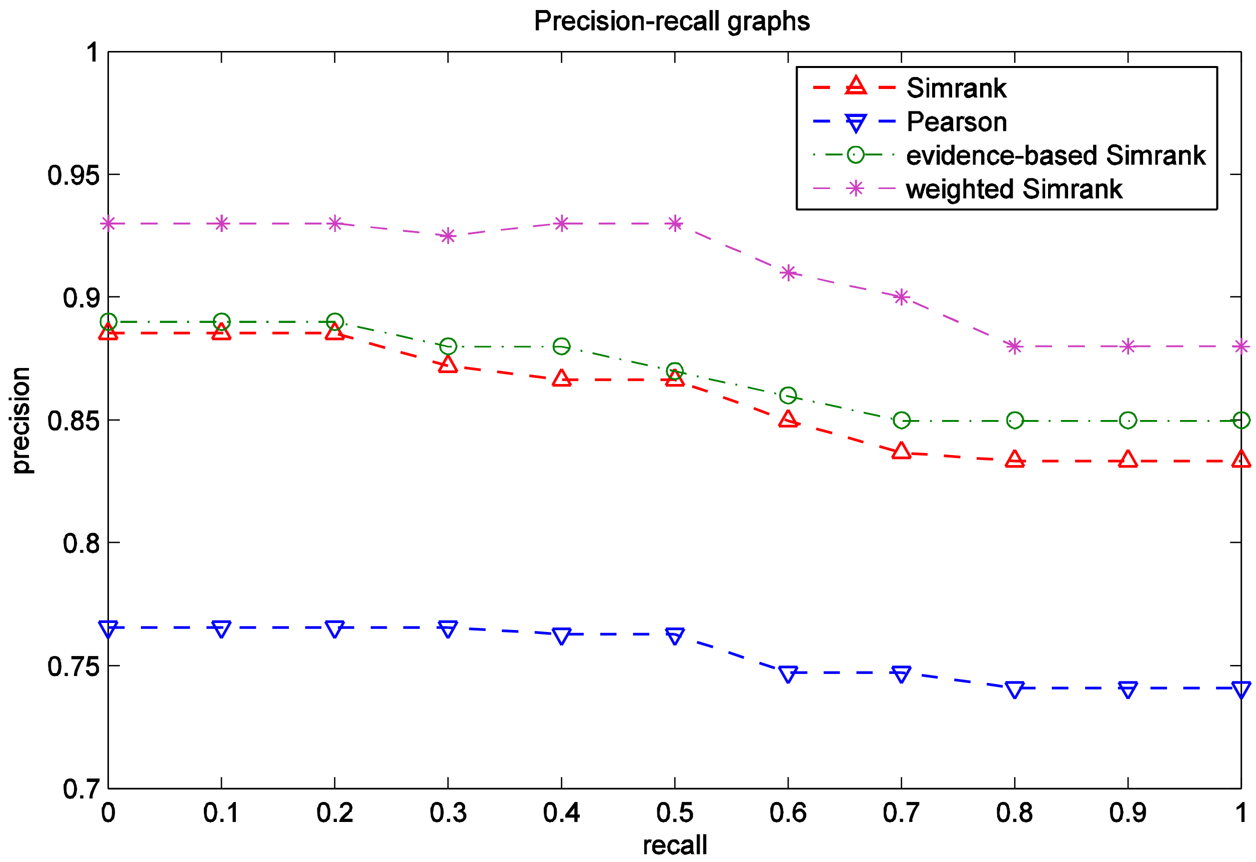
Results: query coverage



Results: precision-recall

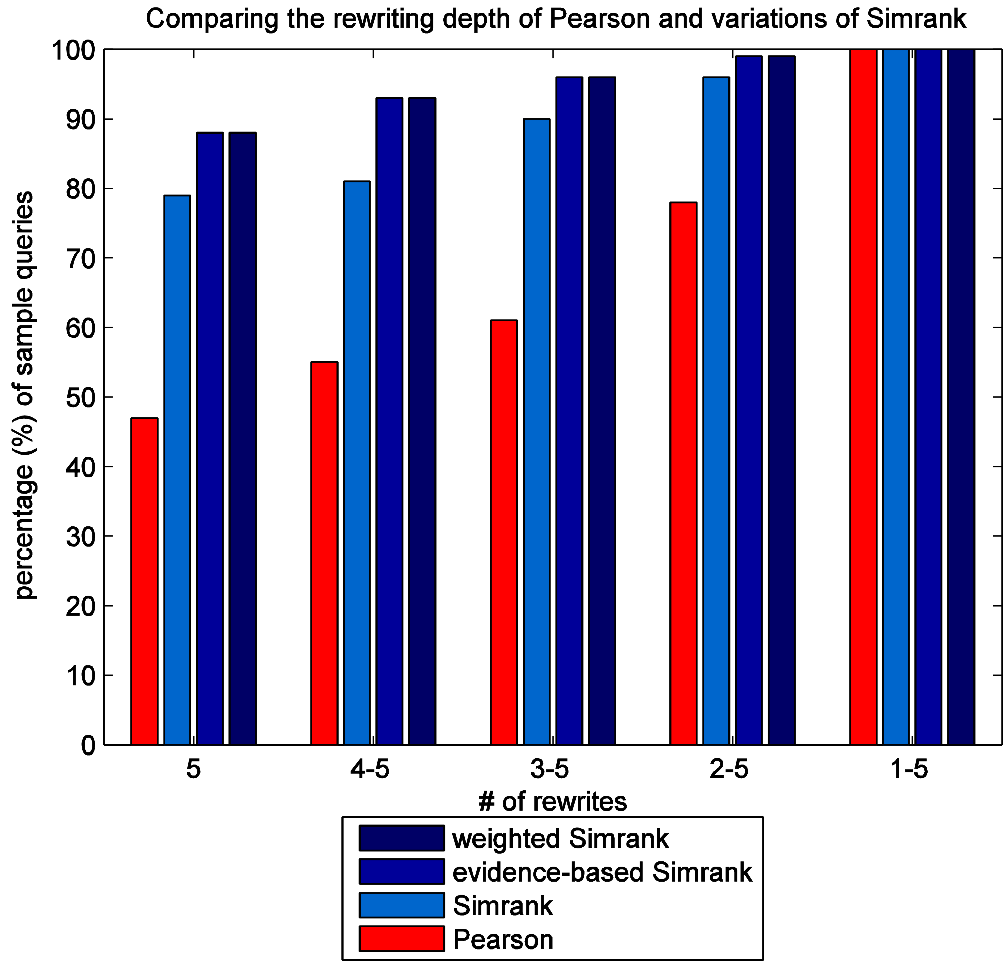


Results: precision-recall

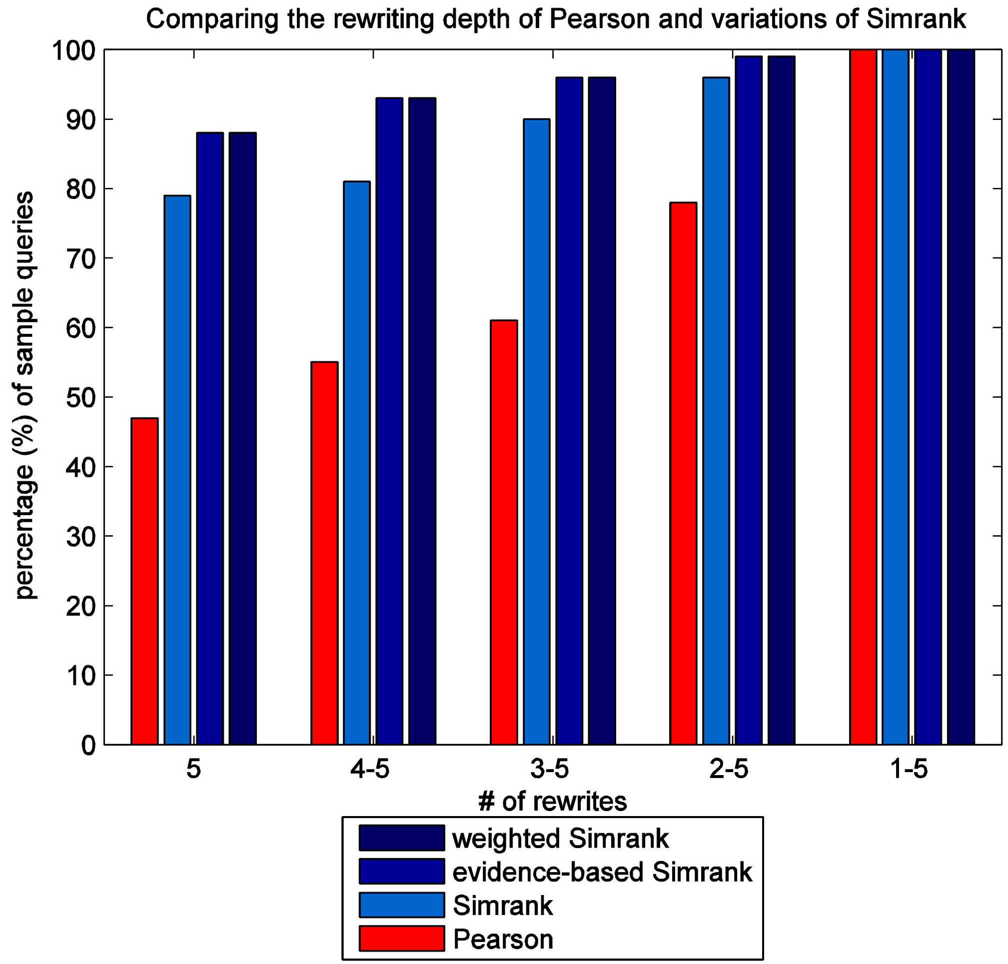


- Note: weighted simrank fares the best

Results: rewriting depth



Results: rewriting depth

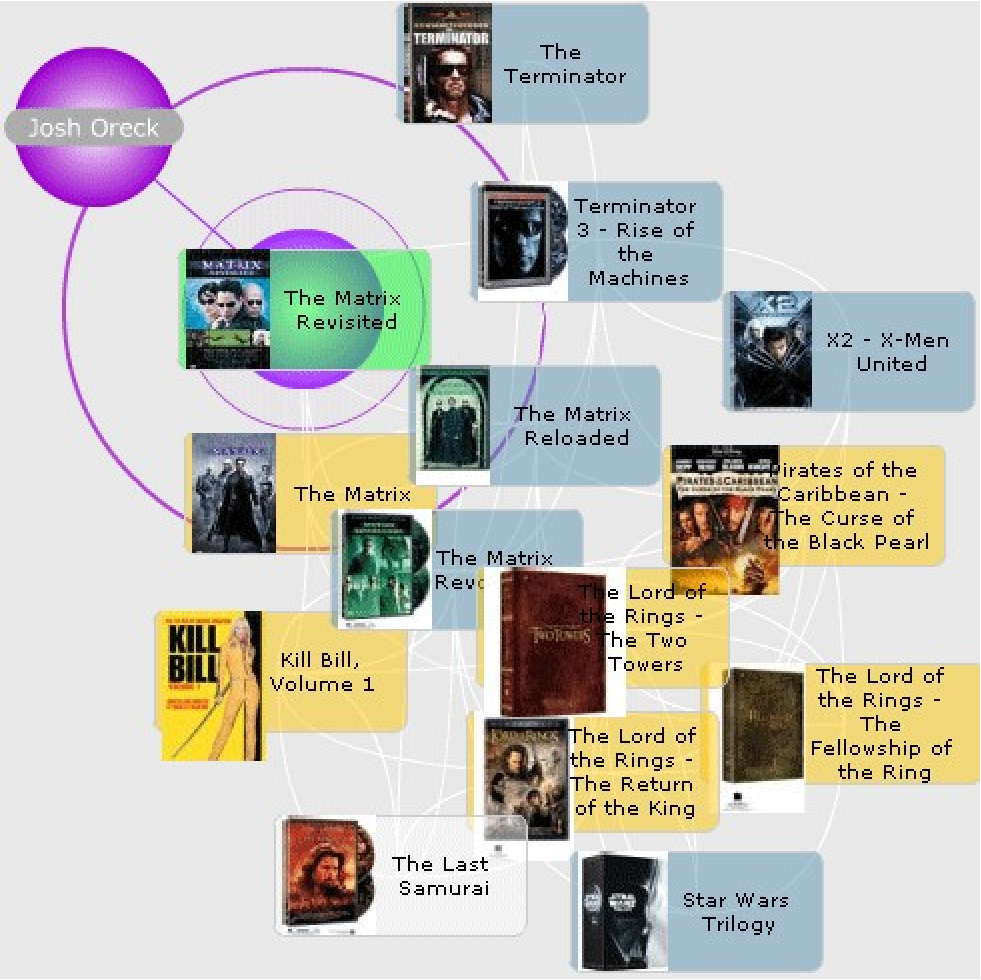


- Note: weighted simrank is among the best

Conclusion

- Two Simrank extensions
  - “evidence” supporting similarity
  - Weights of edges
- Weighted Simrank is overall the best
- Issues not addressed
  - Spam clicks
  - Semantic text-based similarities
  - Updating similarity scores with changes in click graph

Multi-partite?



What about more than two partitions?

THANKS