A Unified Framework of Recommending Diverse and Relevant Queries

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Outline

- Introduction
- Our Approach
- Experiments
- Summary

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Motivation

e.g.

Given query : 'abc'

rank

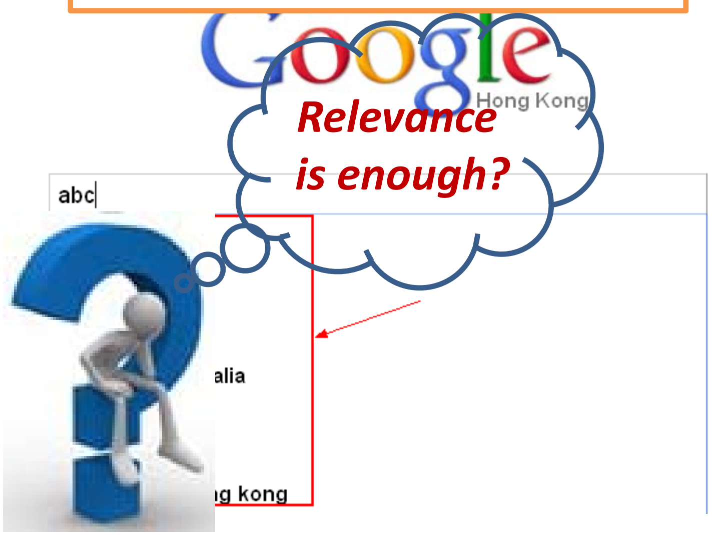
'abc shows'
'abc television'
'abc tv'

(1 … ant queries is enough?

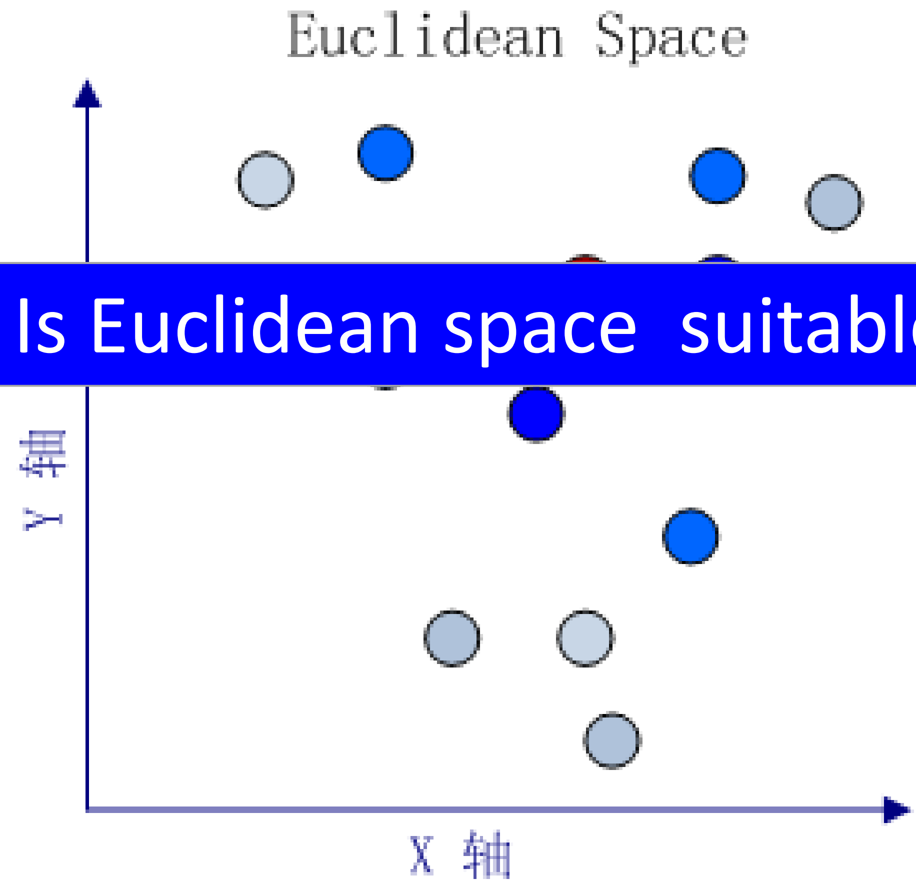
Very short

words are ambitious

users lack of domain-specific knowledge



Motivation

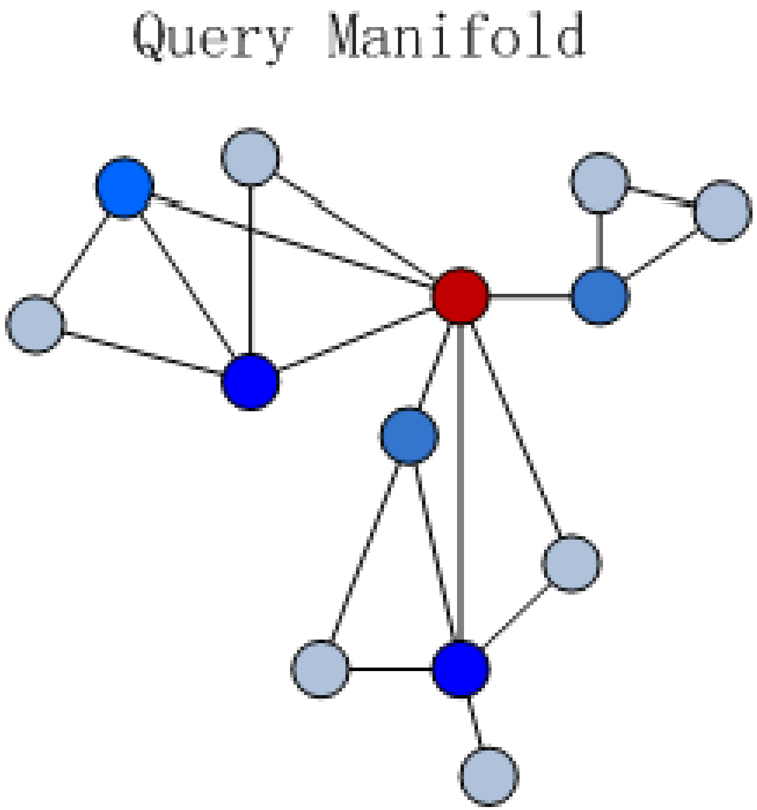


(2) Is Euclidean space suitable?

The **Red node** is the input query.

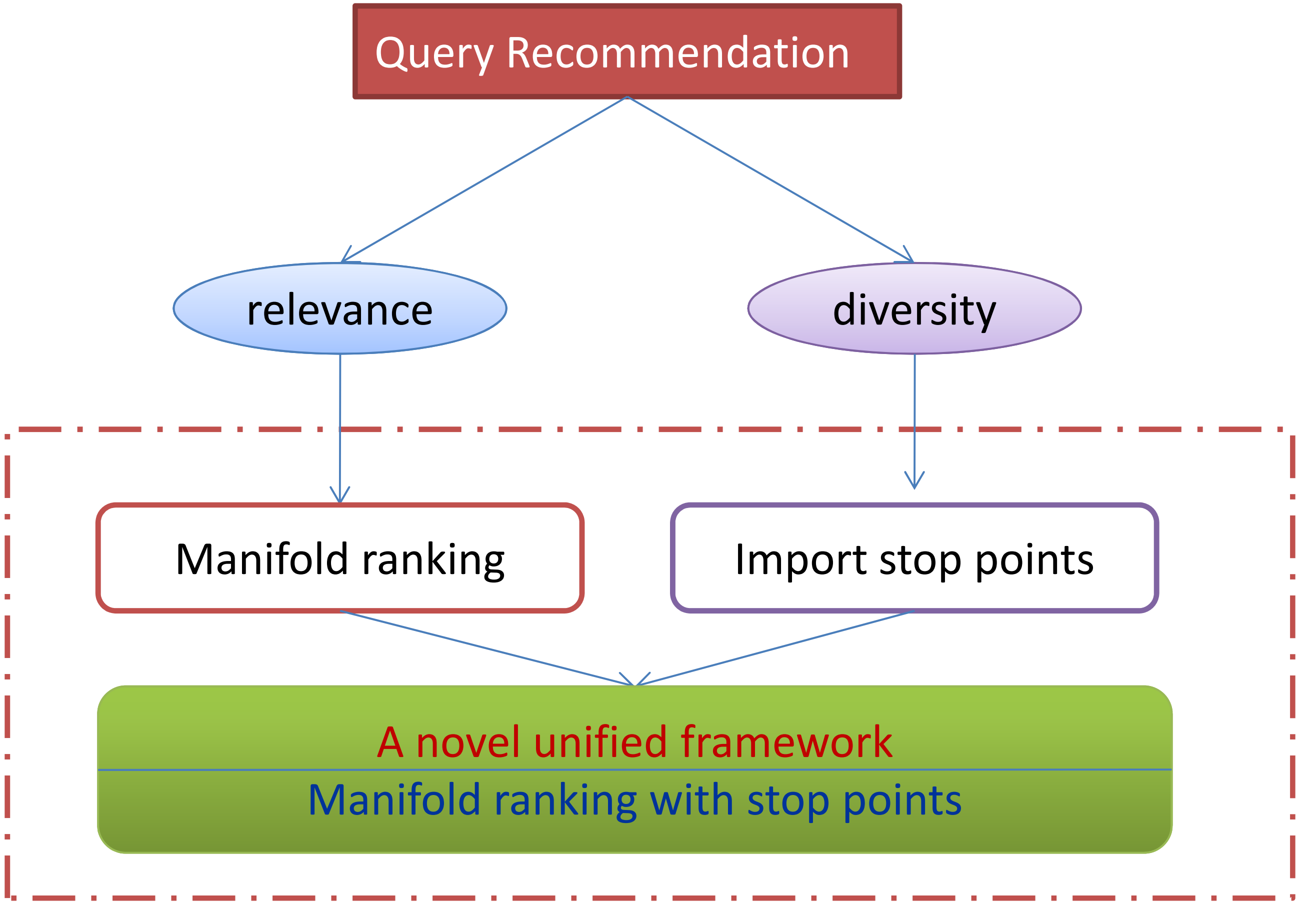
More **blue**, more relevant

Motivation



The **Red node** is the input query.
More **blue**, more relevant

Contribution



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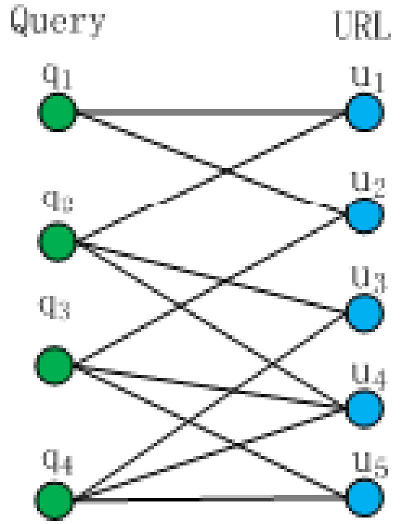
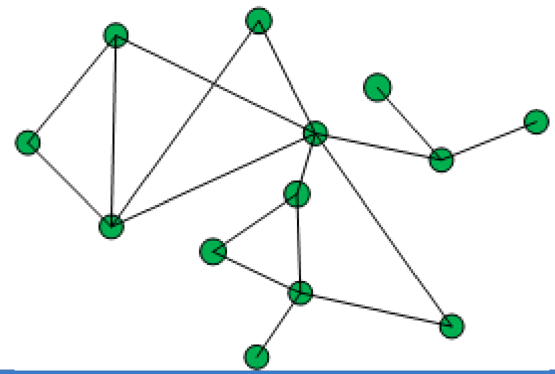
Our Approach



$$
\begin{array}{cccc}
\text{query}_1 & \text{query}_2 & \cdots & \text{query}_n \\
\begin{pmatrix} u_1 \\ u_2 \\ \vdots \\ u_m \end{pmatrix} & \begin{pmatrix} u_1 \\ u_2 \\ \vdots \\ u_m \end{pmatrix} & \cdots & \begin{pmatrix} u_1 \\ u_2 \\ \vdots \\ u_m \end{pmatrix}
\end{array}
$$

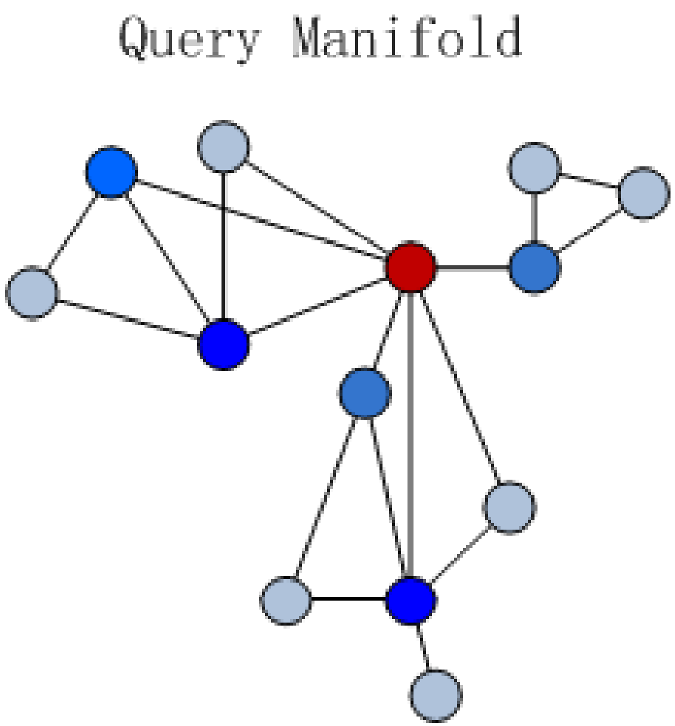
Affinity matrix W

$$w_{ij} = e^{\frac{-d(q_i, q_j)^2}{2\sigma^2}}$$



Our Approach

- Traditional manifold ranking process



W- affinity matrix
D – diagonal matrix

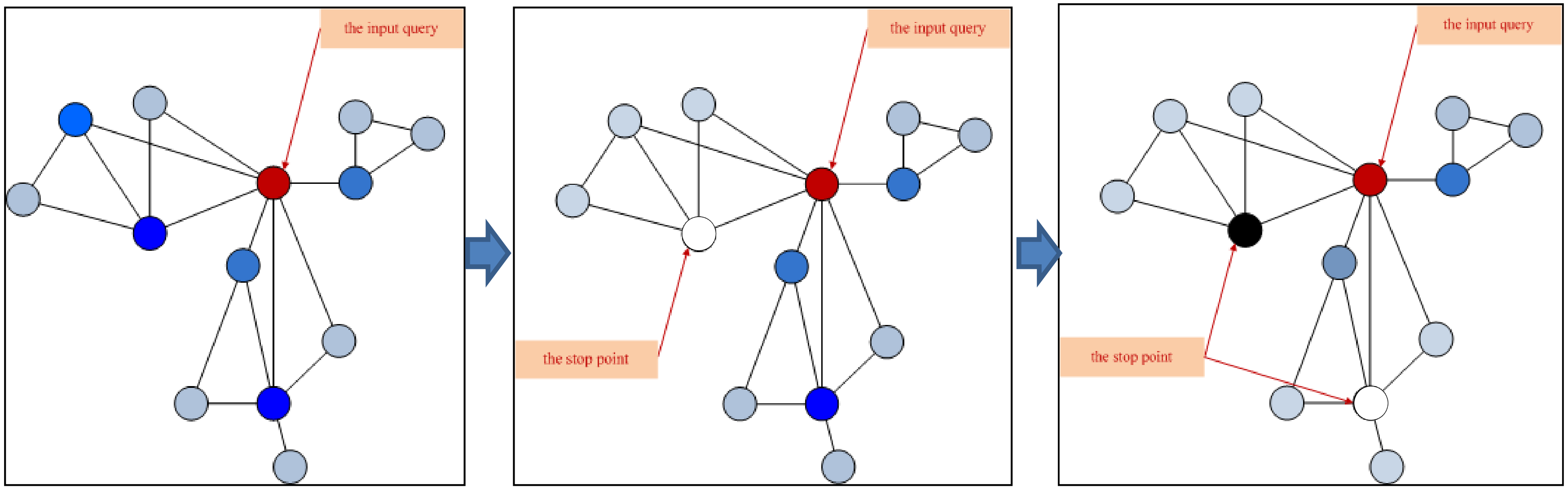
Step 1: $S = D^{-1/2} W D^{-1/2}$

Step 2: $f^{(t+1)} = \alpha S f^{(t)} + (1-\alpha) y$

Step 3: ranking scores f_i^*

Our Approach

- Manifold ranking with stop points



Our Approach

$$f^{(t+1)} = \alpha S f^{(t)} + (1-\alpha) y \quad (1)$$

$$\begin{pmatrix} f_R \\ f_T \end{pmatrix}^{(t+1)} = \alpha \begin{pmatrix} S_{RR} & S_{RT} \\ S_{TR} & S_{TT} \end{pmatrix} \begin{pmatrix} f_R \\ f_T \end{pmatrix}^{(t)} + (1-\alpha) \begin{pmatrix} y_R \\ y_T \end{pmatrix} \quad (2)$$

$$\begin{pmatrix} f_R \\ f_T \end{pmatrix}^{(t+1)} = \alpha \begin{pmatrix} S_{RR} & 0 \\ S_{TR} & 0 \end{pmatrix} \begin{pmatrix} f_R \\ f_T \end{pmatrix}^{(t)} + (1-\alpha) \begin{pmatrix} y_R \\ y_T \end{pmatrix} \quad (3)$$

$$f_R^{(t+1)} = \alpha S_{RR} f_R^{(t)} + (1-\alpha) y_R \quad (4)$$

T - set of stop points

R - set of free points

$$S = \begin{pmatrix} S_{RR} & S_{RT} \\ S_{TR} & S_{TT} \end{pmatrix}$$

$$S_{RT} = S_{TT} = 0$$

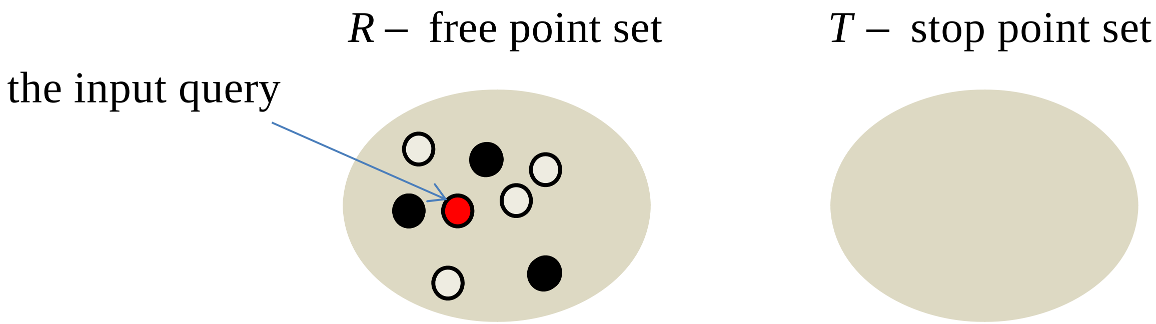
Our Approach

$$f_R^{(t+1)} = \alpha S_{RR} f_R^{(t)} + (1-\alpha) y_R$$

THEOREM 1. *The sequence* $\{f_R^{(t)}\}$ *converges to*

$$f_R^* = (1-\alpha)(I-\alpha S_{RR})^{-1} y_R.$$

Detailed Algorithm



Until *k recommendations* acquired

$$\overset{f_R^{(t)}}{\begin{pmatrix} f_R^{1} \\ f_R^{2} \\ \vdots \\ f_R^{n} \end{pmatrix}} = \alpha \overset{S_{RR}}{\begin{pmatrix} S_{RR}^{11} & S_{RR}^{12} & \cdots & S_{RR}^{1n} \\ S_{RR}^{21} & S_{RR}^{22} & \cdots & S_{RR}^{2n} \\ \vdots & \vdots & \vdots & \vdots \\ S_{RR}^{n1} & S_{RR}^{n2} & \cdots & S_{RR}^{nn} \end{pmatrix}} \overset{f_R^{(t-1)}}{\begin{pmatrix} f_R^{1} \\ f_R^{2} \\ \vdots \\ f_R^{n} \end{pmatrix}} + (1-\alpha) \overset{y_R}{\begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{pmatrix}}$$

$$f_R^{(0)} = 0 \qquad S_{RR} = D_{RR}^{-1/2} \cdot W_{RR} \cdot D_{RR}^{-1/2}$$

the input query

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Experiments

- Data Set
  - 15 million queries (from US users) sampled over one month in May, 2006.
  - Clean the raw data
    - ignoring non-English queries
    - replacing all non-alphanumeric characters in each query with whitespace.
    - frequency less than 3 was removed
  - After cleaning
    - 191,585 queries, 251,427 URLs and 318,947 edges.
    - 1.66 distinct URLs,1.27 distinct queries.

Experiments

- **Baselines**
  - **Pair-wise Based**
    - **Naïve** : only considers relevance
    - **MMR** (Maximal Marginal Relevance) : a linear combination of relevance and diversity
  - **Graph Based**
    - **Hitting time**: boost long tail queries
    - **Grasshopper**(Graph Random-walk with Absorbing StateS that HOPs among PEaks for Ranking) : absorbing random walk on the graph

Case Study

Table 1: Examples of query recommendations provided by different approaches (top 10 results)

query	Naive	Hitting_time	MMR	Grasshopper	Mani_sink
abc	abc shows	abc shows	abc shows	abc tv	abc tv
	abc television	abc television	abc breaking news	abc news	abc news
	abc tv	associated builders and contractors	associated builders and contractors	abc family	abc nightline
	abc news	abc tv	abc nightline	abc shows	abc family
	abc breaking news	news stories	abc tv	abc breaking news	associated builders and contractors
	abc family	abc news	abc television	nightline	abc shows
	abc sports	abc world news tonight	abc family	goodmorning america	abc daytime
	abc world news	abc family channel	abc sports	abc sports	goodmorning america
	world news tonight	espn sports	abc daytime	abc daytime	abc sports
	abc soap operas	abc nightline	goodmorning america	national news	abc soap operas
yamaha	yamaha america	yahama	yamaha america	yamaha motor	yamaha motor
	yamaha motor corp	yamaha america	yamaha atv parts	yamaha america	yamaha motor corp
	yamaha motor	yamaha motor corp	yamaha boat motors	yamaha motor corp	yamaha america
	yamaha motor co	yamaha motor co	yamaha motor corp	yamaha motorcycles	yamaha marine
	yamaha motorcycle	yamaha motor	yamaha snowmobiles	motorcycles	yamaha atv
	yamaha motors	yamaha motorcycle	yamaha motor	yamaha marine	yamaha snowmobiles
	yamaha motorcycles	yamaha snowmobiles	yamaha drums	yamaha atv	yamaha drums
	yamaha quads	yamaha quads	yamaha guitars	yamaha motorcycle parts	yamaha guitars
	yamaha snowmobiles	yamaha outboard motors	yamaha motorcycles	yamaha snowmobiles	yamaha quads
	yamaha scooters	bluebook motorcycles	yamaha atvs	yamaha quads	yamaha boat motors

Experiments

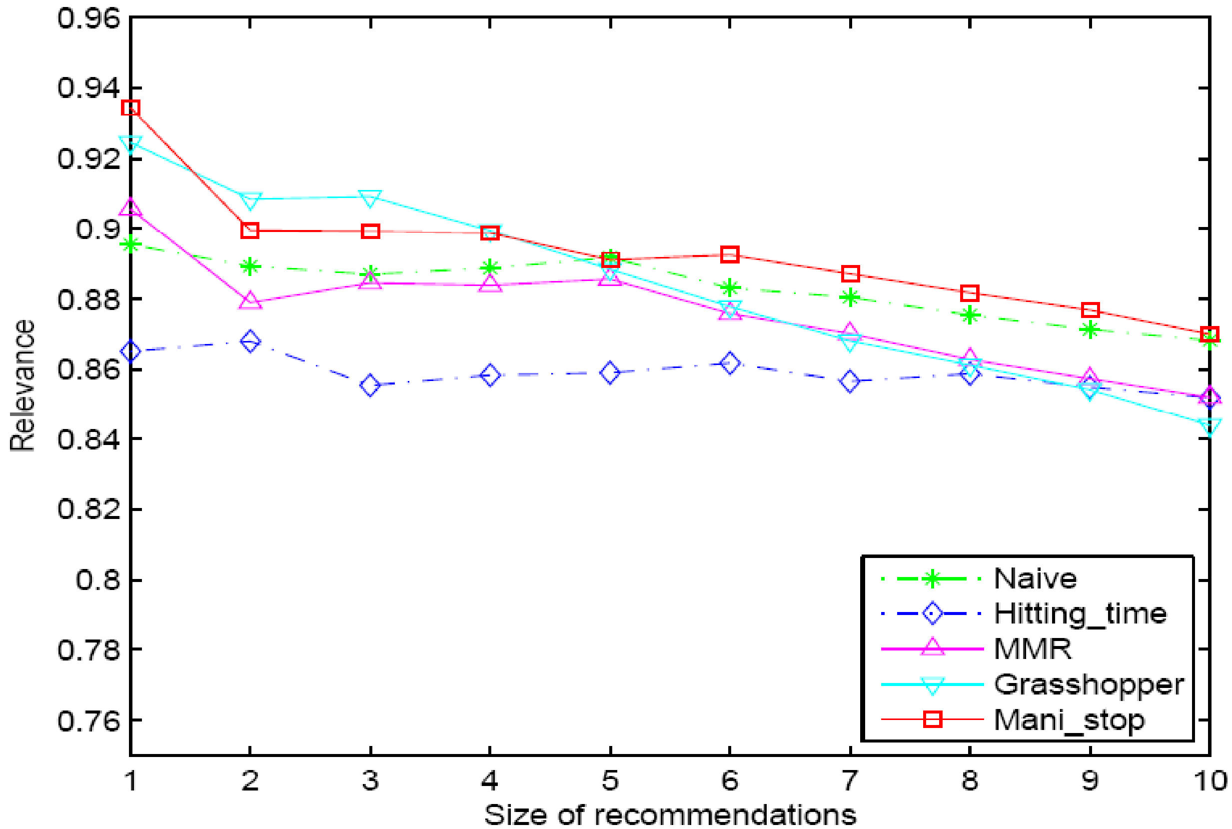
- **Automatic Evaluation**
  - Open Directory Project(ODP) <-> Relevance
  - Commercial search engine (i.e., Google) <-> Diversity
- **Evaluation metrics**
  - Relevance
  - Diversity
  - Q-measure

$$div\,rel(q) = \frac{1}{|U|} \sum_{q' \in U} r(q, q')$$

$$= \frac{(1 + \beta^2)}{\frac{\beta^2}{div(q)} + \frac{1}{rel(q)}},$$

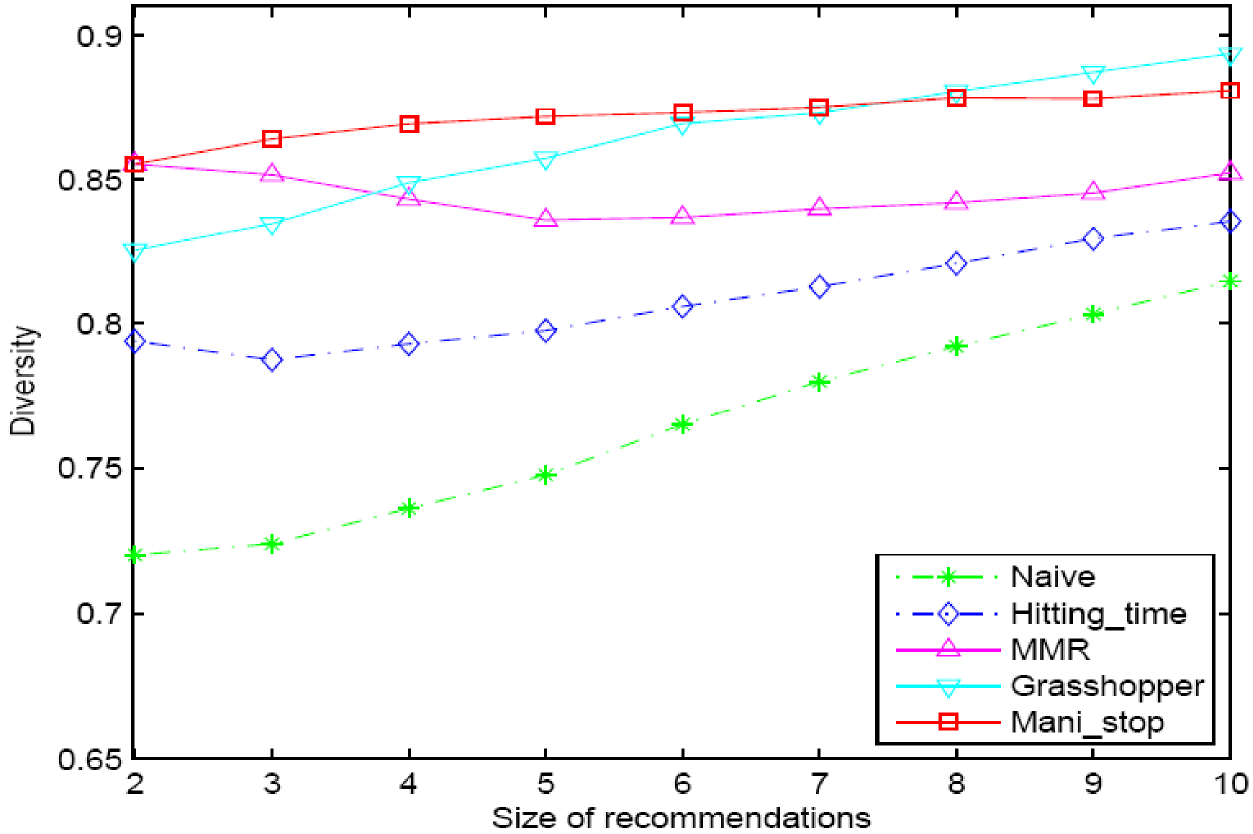
Experiments

Figure 1: Average Relevance of Query Recommendation over Different Recommendation Size under Five Approaches.



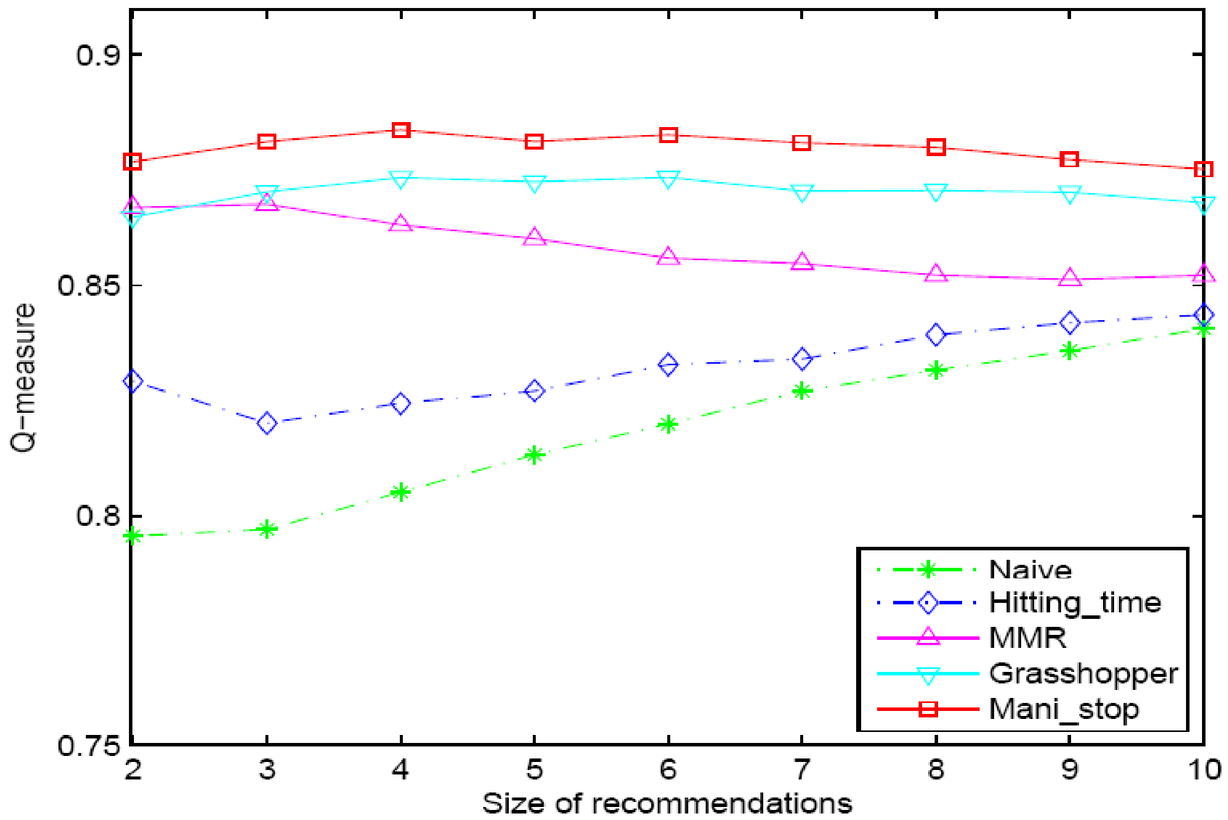
Experiments

Figure 2: Average Diversity of Query Recommendation over Different Recommendation Size under Five Approaches.



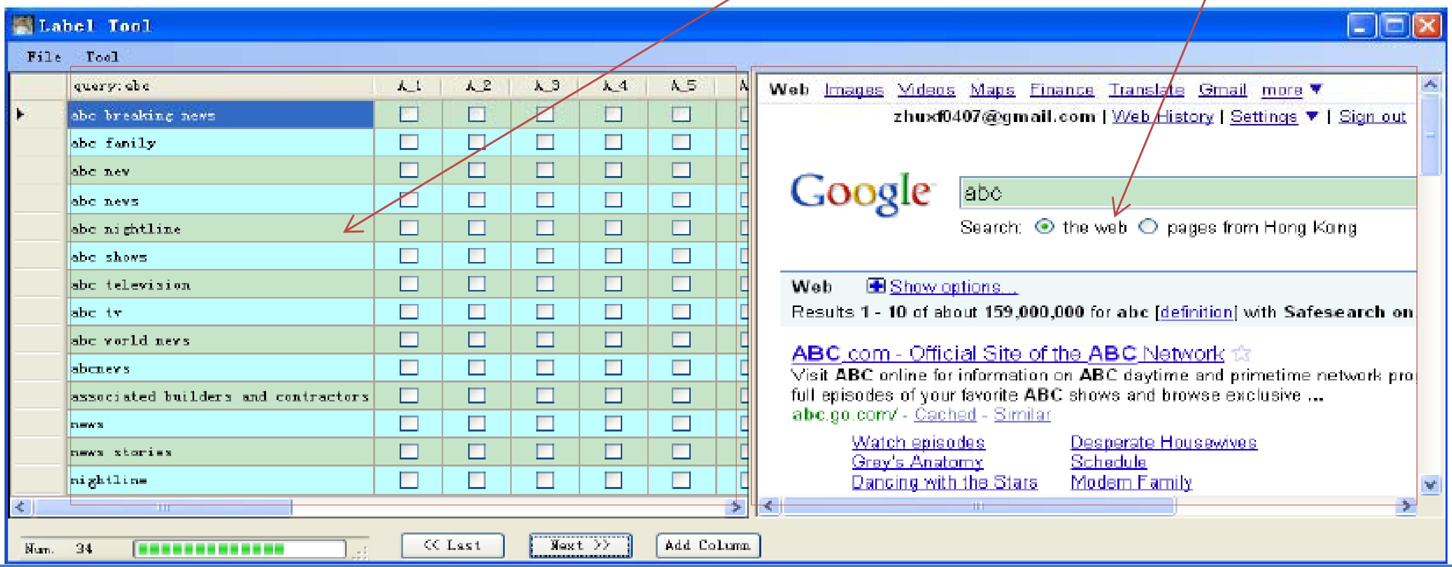
Experiments

Figure 3: Average Q-measure of Query Recommendation over Different Recommendation Size under Five Approaches.



Experiments

- **Manual Evaluation**
  - Recommendation pool
  - 3 human judges
  - Label tool



Experiments

- **Evaluation Metrics**
  - α-nDCG (α -normalized Discounted Cumulative Gain)

$$G(k) = \sum_{i=1}^{I} J_i(k)(1-\alpha)^{C_i(k-1)}$$

  - Intent-Coverage

$$Intent-Coverage(k) = \frac{1}{I}\sum_{i}^{I} B_i(k),$$

Experiments

Table 2: Performance of recommendation results over a sample of queries under five different approaches.

	α-nDCG@5	α-nDCG@10	Intent-Coverage@5	Intent-Coverage@10
Naive	0.717	0.689	0.300	0.536
Hitting_time	0.770 (7.4‡/*/*/*)	0.738 (7.1‡/*/*/*)	0.348 (16‡/*/*/*)	0.585 (9.3‡/*/*/*)
MMR	0.799 (11.4‡/3.8/*/*)	0.742 (7.7‡/0.5/*/*)	0.384 (28‡/10.3‡/*/*)	0.585 (9.1‡/0/*/*)
Grasshoppper	0.794 (10.7‡/3.1/-0.6/*)	0.768 (11.5‡/4.1/3.5‡/*)	0.373 (24.3‡/7.2/-2.9/*)	0.616 (14.9‡/5.1/5.3/*)
Mani_stop	0.838 (16.9‡/8.8‡/4.9‡/5.5‡)	0.806 (17‡/9.2‡/8.6‡/4.9‡)	0.436 (45.3‡/25.3‡/13.5‡/16.9‡)	0.665 (24.1‡/13.5‡/13.7‡/8‡)

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Summary

- A Novel Unified Model
  - Relevant and salient queries
  - Diverse
- Experimental results
  - Automatic evaluation
  - Manual evaluation

Thank you!

Q&A

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