# Machine Learning Approaches to Information Retrieval

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# Talk Outline

- Introduction to Information Retrieval
- Search by Type
- Factoid Search
- New Learning Algorithm for Ranking
- Information Desk
- Summary

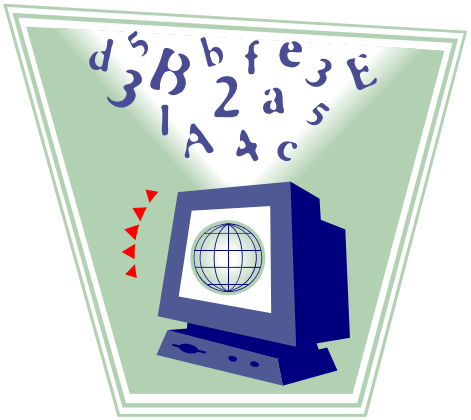
# Introduction to Information Retrieval

# What Is Information Retrieval?


I want to access information X

query

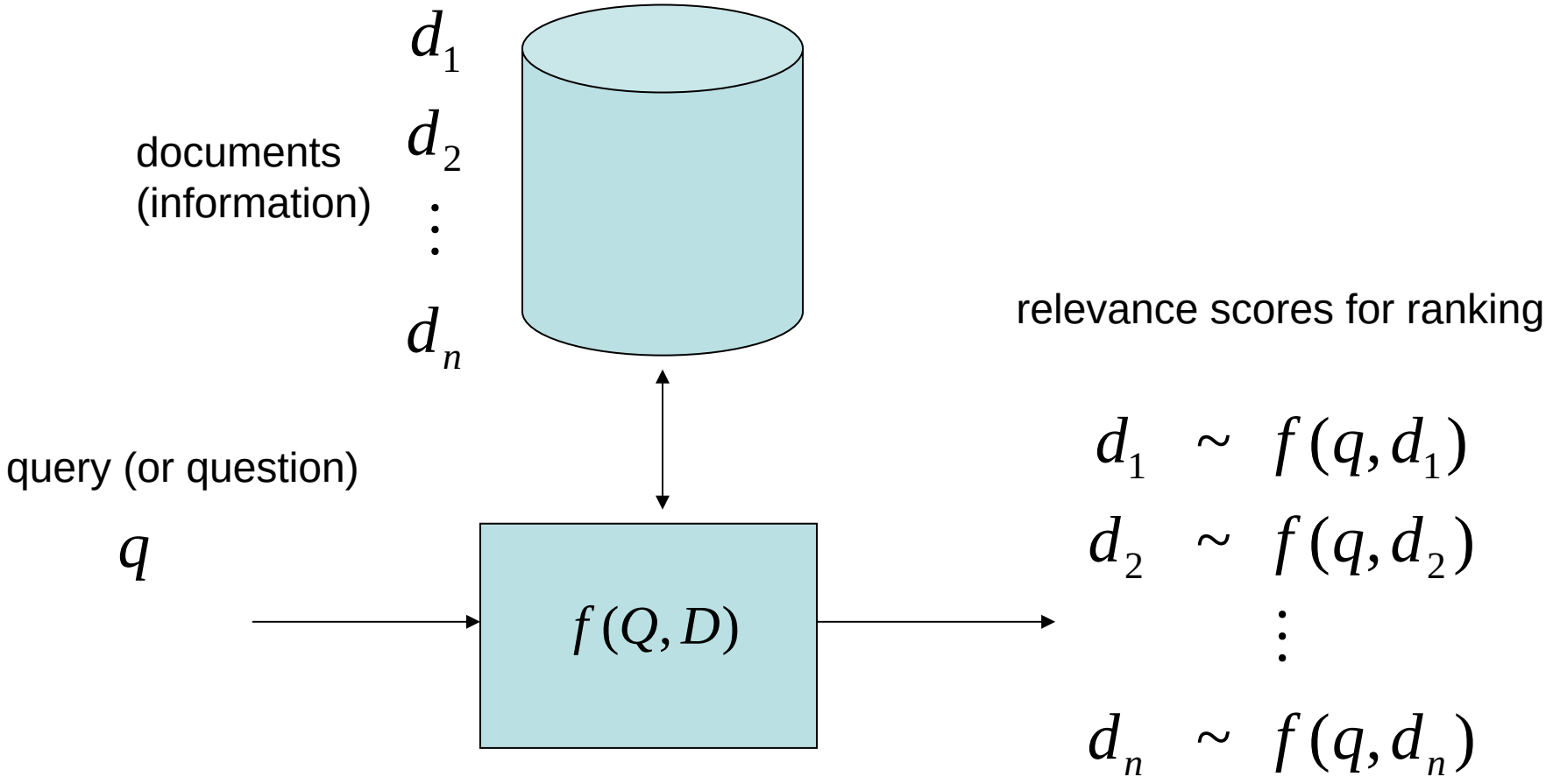
information



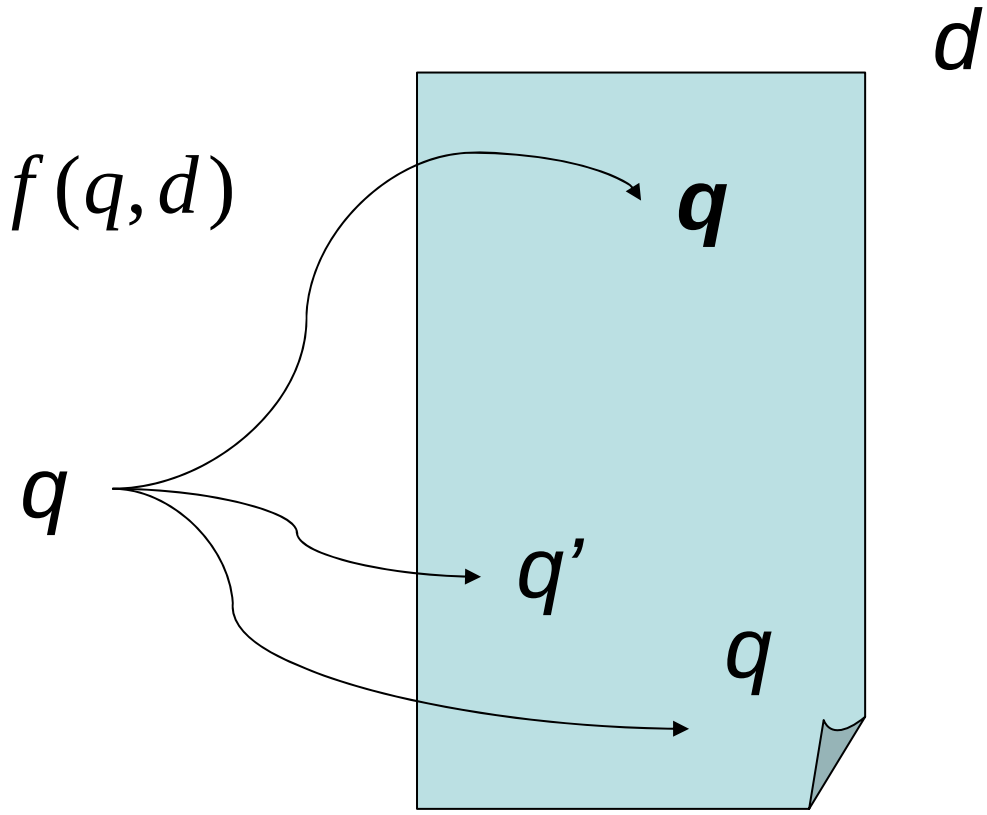
# Why Important?

# Current Approach
# Information Retrieval = Ranking

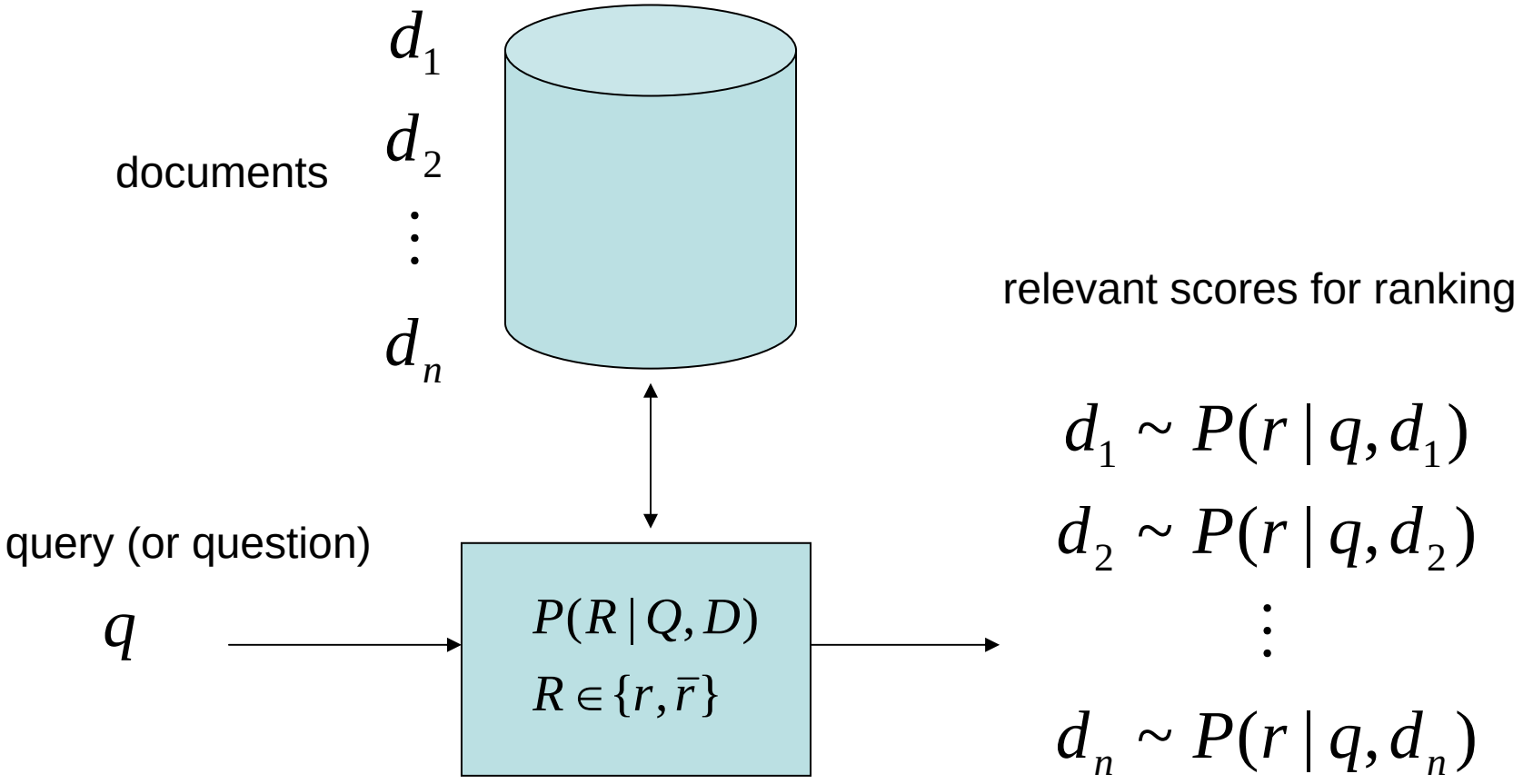
# General Model for Ranking



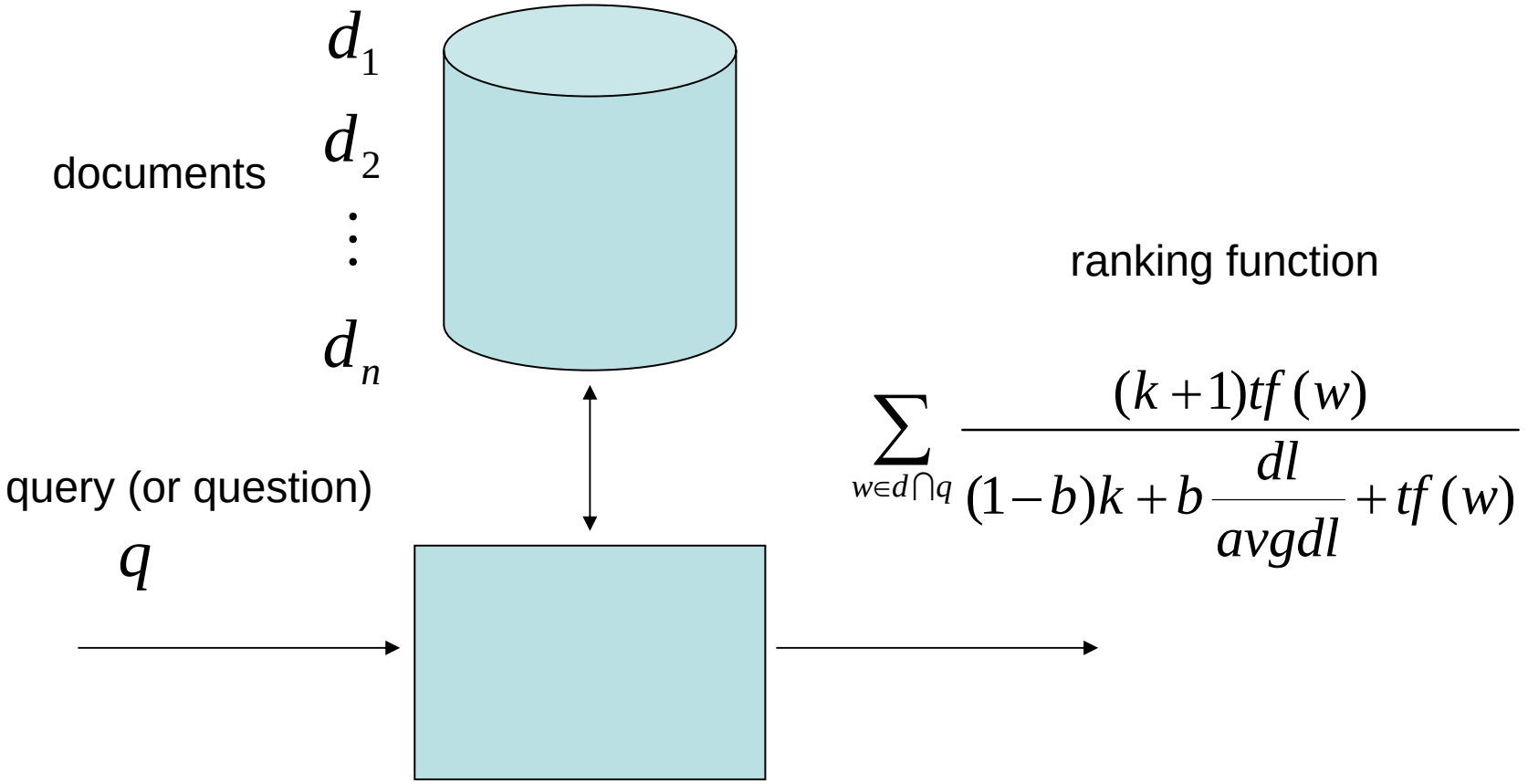
# Relevance: Matching between Query and Document



# Probabilistic Model



# Okapi or BM25
## (Robertson and Walker 1994)



# Language Mode

## (Ponte and Croft 1998; Lafferty and Zhai, 2001)

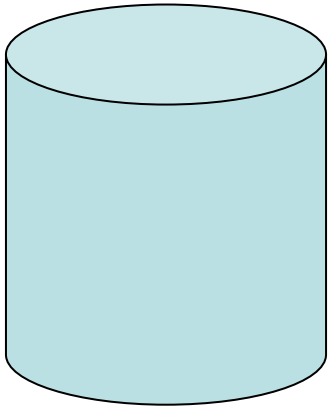
document = bag of words

$$d_1 = w_{11} w_{12} \cdots w_{1l_1}$$

$$d_2 = w_{21} w_{22} \cdots w_{2l_2}$$

$$\vdots$$

$$d_n = w_{n1} w_{n2} \cdots w_{nl_n}$$



$$q = w_{q1} w_{q2} \cdots w_{ql_q}$$

relevance scores for ranking

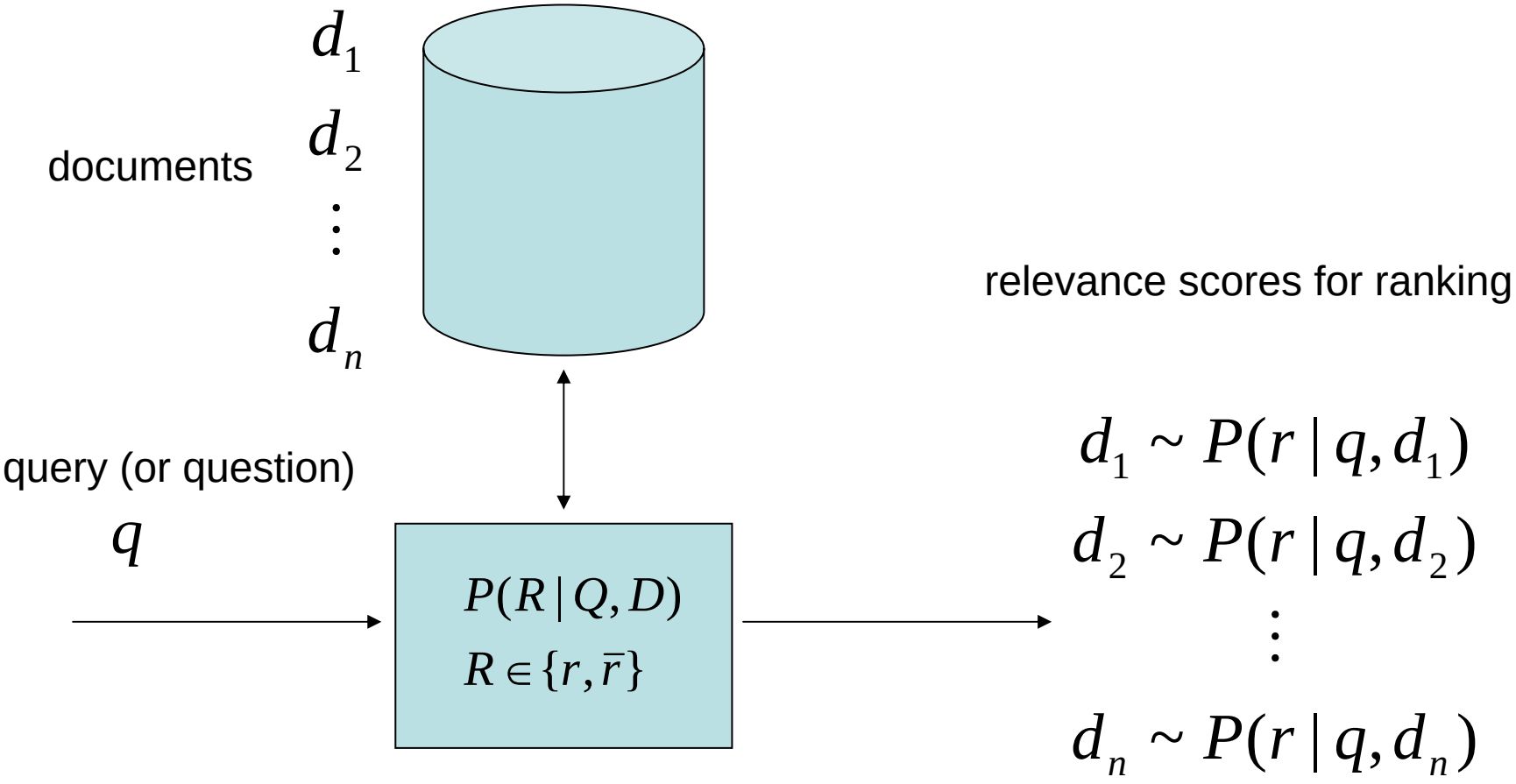
$$d_1 \sim P(q \mid d_1)$$

$$d_2 \sim P(q \mid d_2)$$

$$\vdots$$

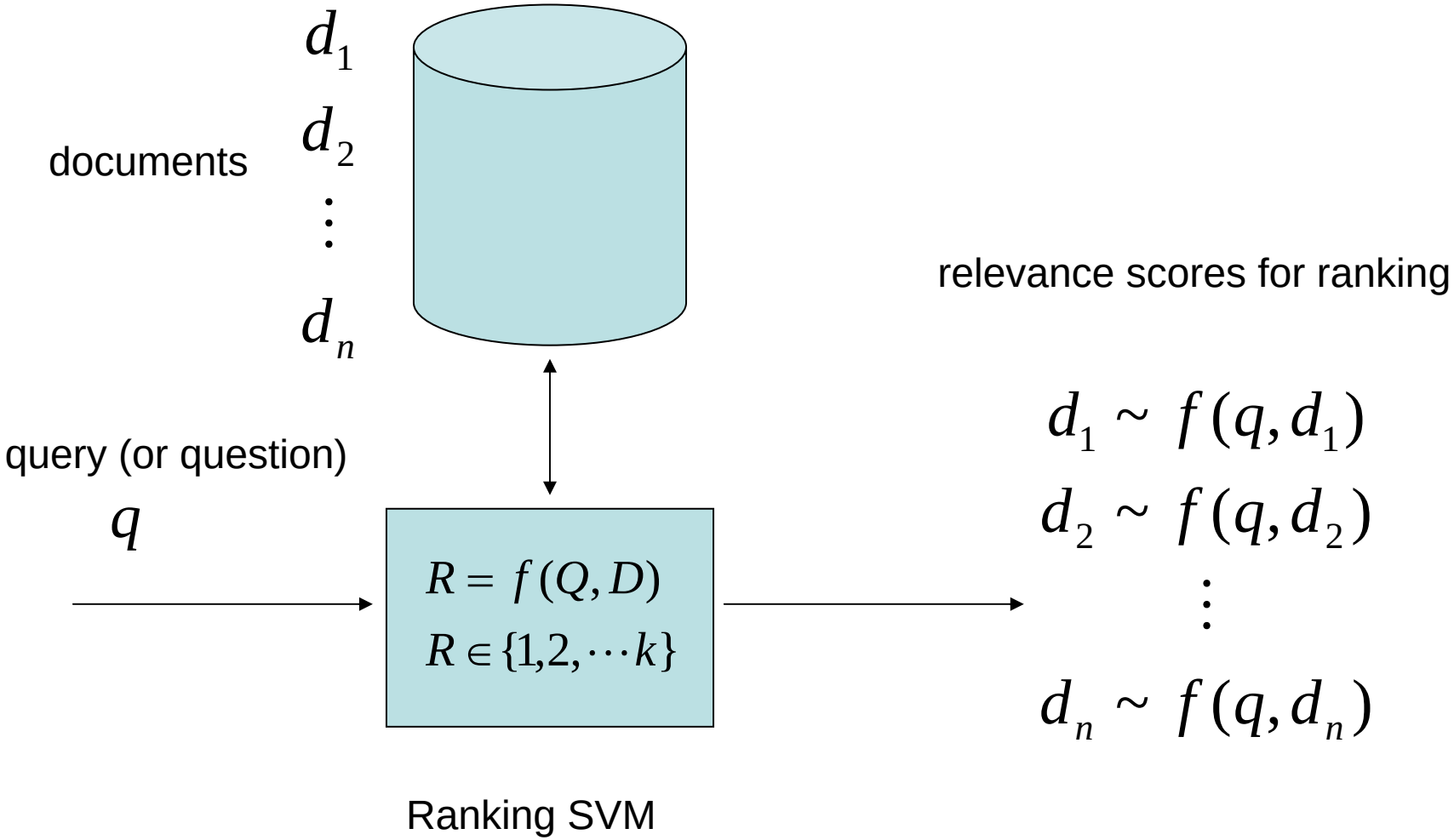
$$d_n \sim P(q \mid d_n)$$

# Classification Model

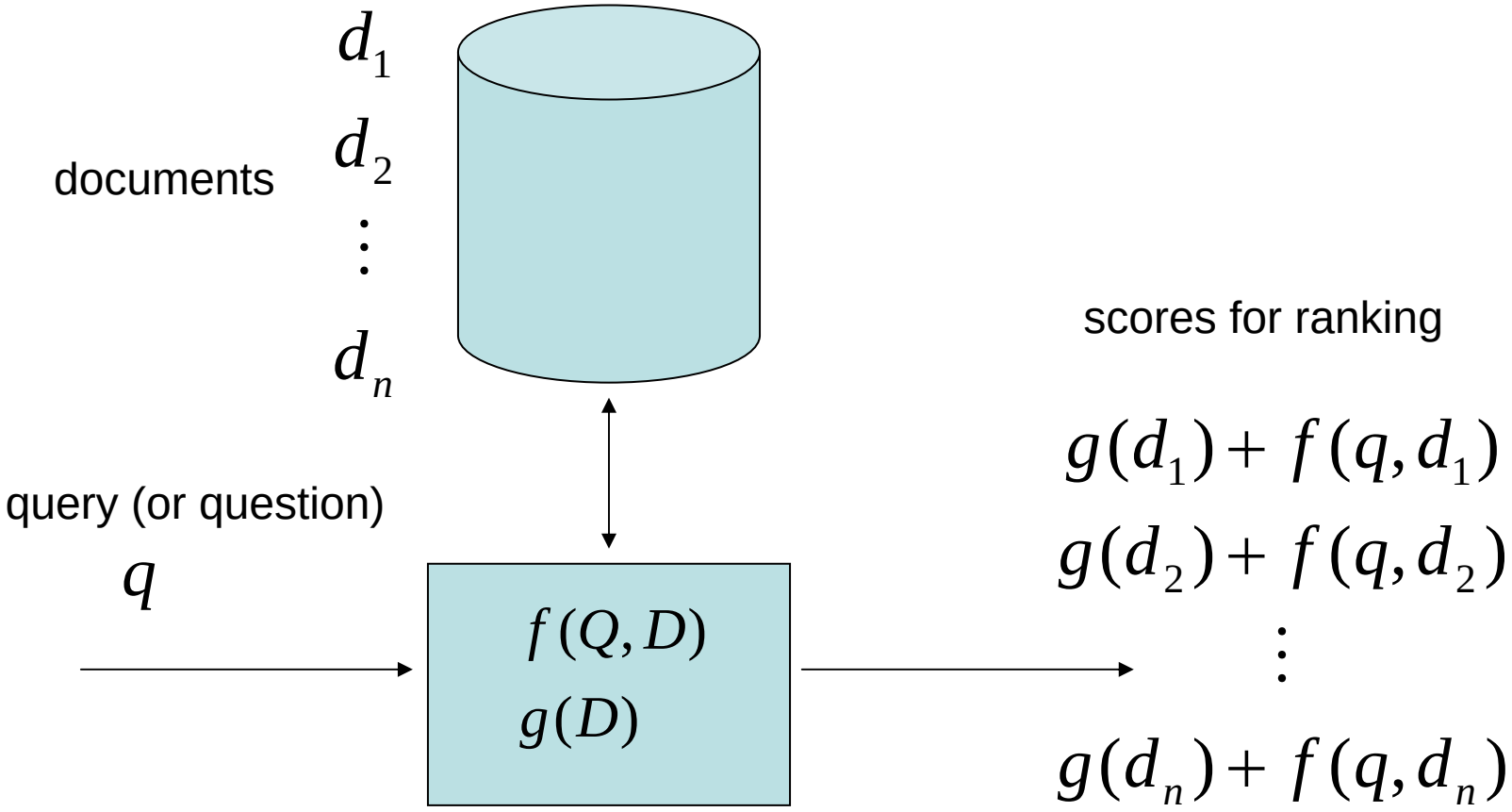


# Ordinal Regression Model

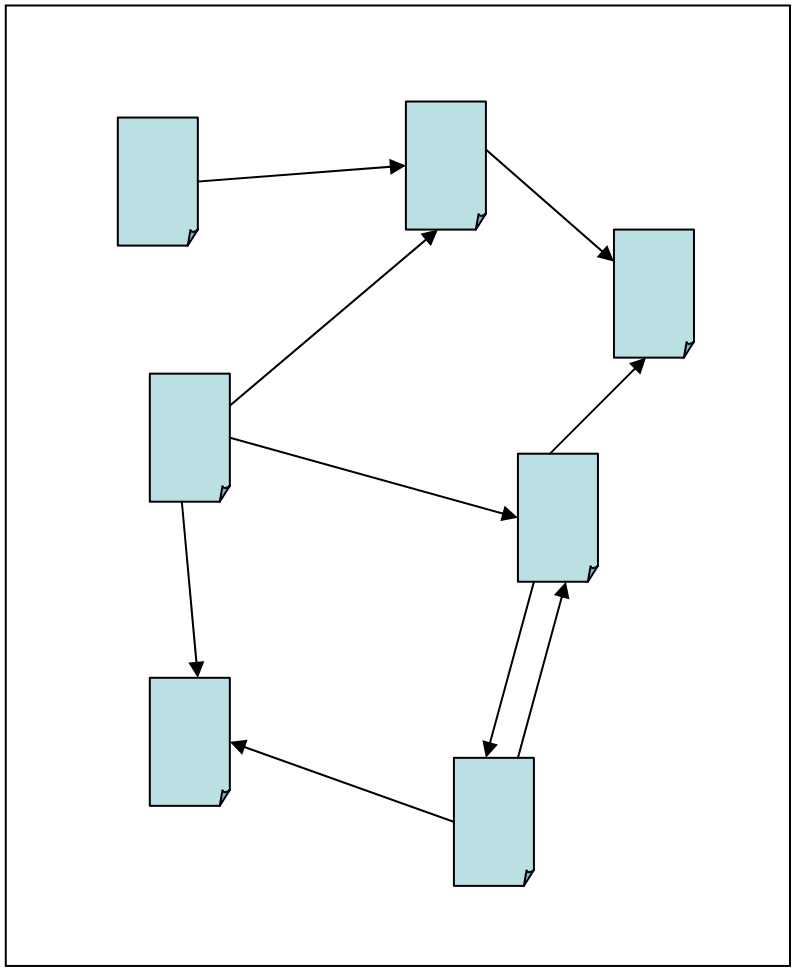
## (Herbrich et al., 2000; Joachims, 2002)



# General Model for Ranking (2)



# Page Rank
## (Brin and Page, 1998)



$$P(d_i) = \alpha \frac{1}{n} + (1-\alpha) \sum_{d_j \in M(d_i)} \frac{P(d_j)}{L(d_j)}$$

# Challenges

- Proximity
- Synonym and polysemi
- Quality and freshness of document (webpage)
- Spamming
- Information granularity
- Search need understanding
- Evaluation
- Personalization
- Training data collection (relevance feedback, click-through)

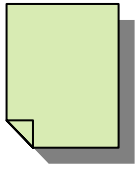
# Search by Document Type

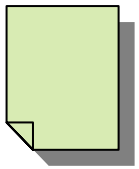
# Search by Document Type

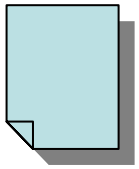
I want to find documents relevant to X in type Y

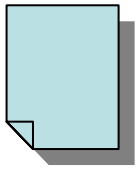
query

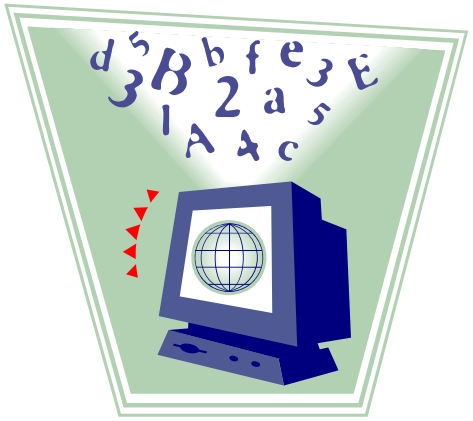
documents



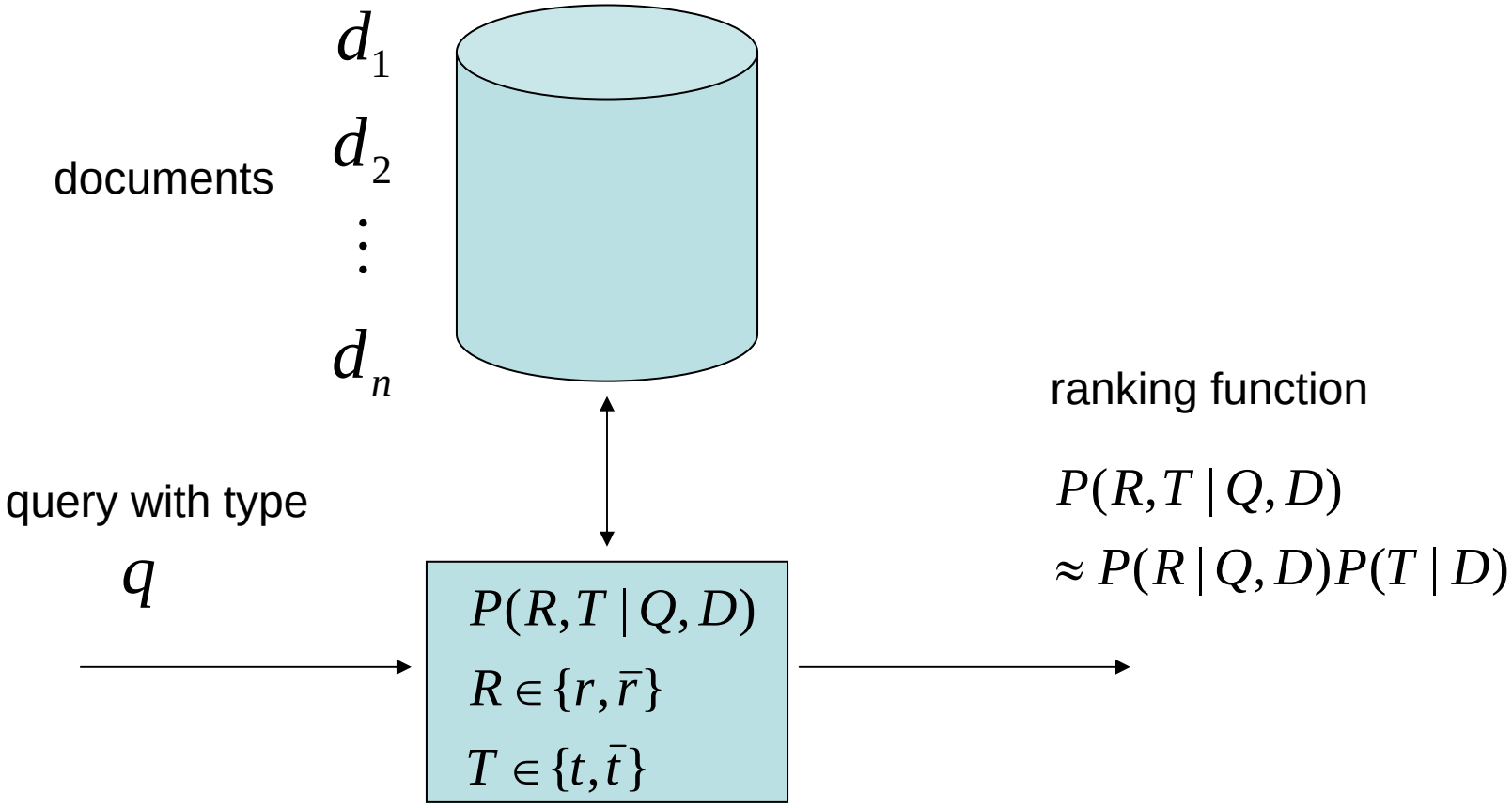








# Probabilistic Model



# Example – Manuals Search

- Query
  “create an external link”

- Document1
  **External Links**
  External links are to Web sites external to your Web site. You can create external links by using buttons, highlighting text, or creating hot spots on images.
  For example creating a linkage to the Far Eastern Economic Review [FEER] one would go to the FEER through the Internet. You might want to right click on the FEER logo or recent issue cover and save the image to your computer [must be saved as a graphical interface file - GIF]. To make either the button or the text or the picture (or all three) interactive you highlight what you want to connect and then you click the hyperlink tool, or the Edit-Hyperlink. Press the World Wide Web tab in the Create Hyperlink diaolgue box [see box below]. Whatever address you have in the running Net browser will show up in the box, or you can browse. In this case, the FEER address is there, one only need to press OK and the external hyperlink is created. All three examples to the right will link you to the FEER site.

- Document2
  **Creating an External Link**
  To create an anchor that is a link to another document:
  Select to select (by click and drag or by keyboard) the text for the link you are creating.
  Click the Link button (first case) or select the entry "Create or change link" in the Links menu (second case).
    In the first case, the cursor changes from an arrow to a hand to let you click the target document.
      If the target document is displayed in another Amaya window, click anywhere within that window to create the link.
      If the target document is not displayed in another Amaya window, press the F2 or Delete key, or click a part of the document which cannot be a valid target. A dialog prompts you for the location of the target document. Type the URI of the target document and then Confirm to create the link.
    In the second case, a dialog prompts you for the location of the target document.
      If the target document is displayed in another Amaya window and you want to select it by click, click the Click button then click anywhere within that window to create the link.
      If the target document is not displayed in another Amaya window, type the URI of the target document and then Confirm to create the link.

# Manuals Search -- Experiment

- MS intranet data
  - 50 queries from log of Microsoft Web
  - 1.22 answers per query (from 5000 documents)
- Evaluation Measure

$$RR_i = \frac{1}{Rank_i} \qquad MRR = \frac{\sum_{i=1}^{Q} RR_i}{Q}$$

- Results

| **Method** | **MRR** |
|---|---|
| Type Only | 0.3651 |
| Relevance Only | 0.5688 |
| Combined Model (our approach) | **0.7278** |

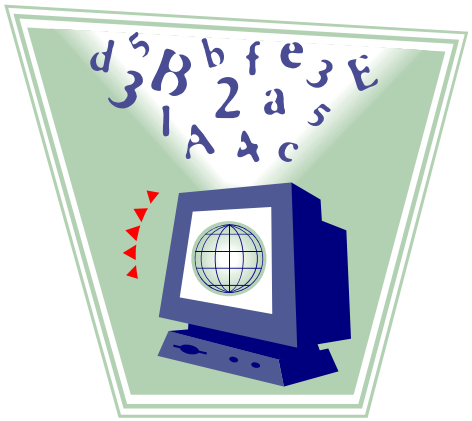
# Factoid Search

# People Search
## (Cao et al., 2005)

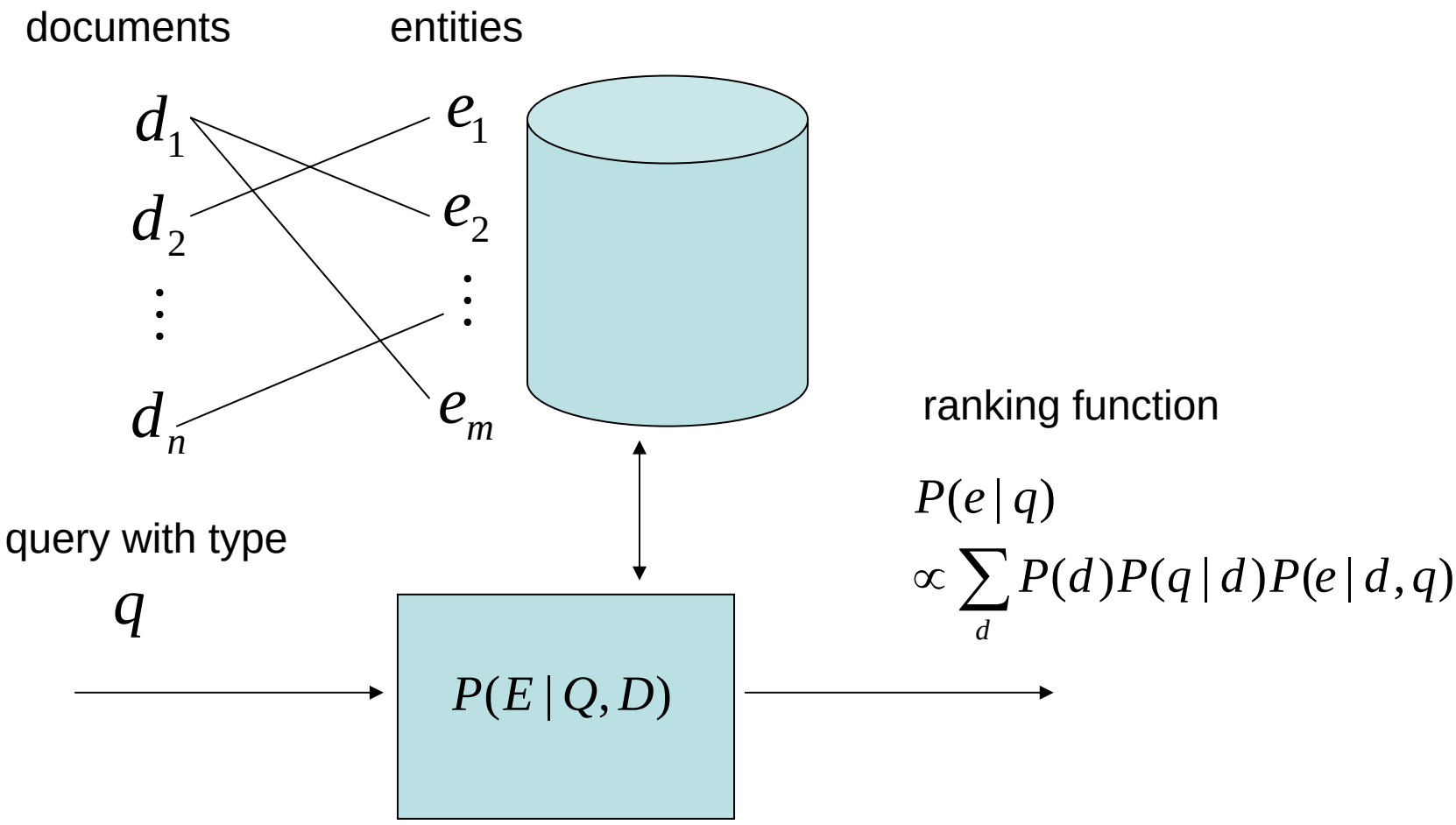
I want to find people related to X

query

people



# Probabilistic Model



# Example – People Search

- Query
  “Who knows about digital ink”

- Document
  Jian Wang, Ph.D.
  Senior Researcher & Research Manager
  Multimodal User Interface Group, Microsoft Research Asia
  Dr. Jian Wang is Research Manager of the Multimodal User Interface Group at Microsoft Research Asia (MSR Asia). Dr. Jian Wang's research specializations are ink and pen computing, usability, multimodal user interface, virtual reality and human cognition.
  The Multimodal UI Group's current research projects include: advanced digital ink parser, digital ink annotation and representation of digital ink for Tablet PC. The group previously invented an inline input and correction user interface for Asian languages called Modeless Input User Interface, which allows Chinese users of Office XP to smoothly enter English and Chinese text without constantly switching between input language modes.

- Answer
  Jian Wang

# People Search -- Experiment

- MSR Corpus
  - 32 queries searching in 3109 documents
  - 810 Candidates
- Evaluation Measure

$$Top-5\ Precision = \frac{\#\{persons\ which\ appear\ in\ both\ Top\text{-}5\ ranked\ candidates\ and\ ground\ truth\}}{5}$$

- Results

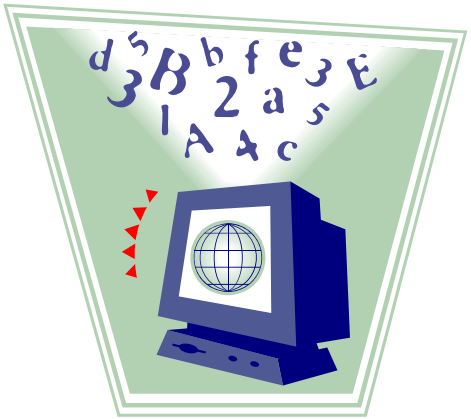
| **Method** | **Top-5 Precision** |
|---|---|
| Profile-based Model | 0.428 |
| Our Model | **0.563 (+31.5%)** |

# Time Search

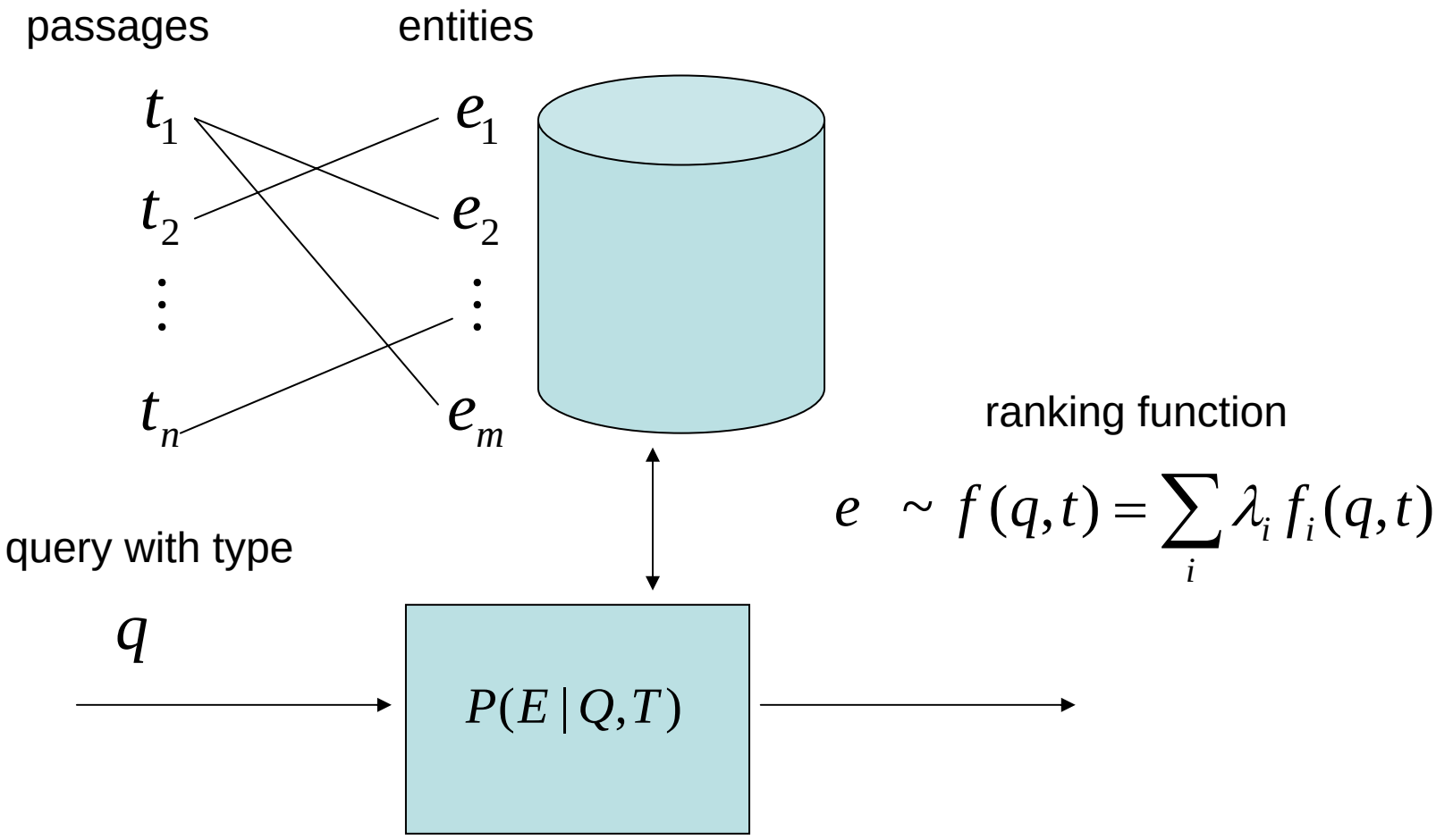
I want to find time related to X

query

dates



# Probabilistic Model



# Time Search -- Example

- Query:
  Nixon visit China

- Document:
  Nixon's most significant achievement in foreign affairs may have been the establishment of direct relations with the People's Republic of China after a 21-year estrangement. Following a series of low-level diplomatic contacts in 1970 and the lifting of U.S. trade and travel restrictions the following year, the Chinese indicated that they would welcome high-level discussions, and Nixon sent his national security adviser, Henry Kissinger, to China for secret talks. The thaw in relations became apparent with the “ping-pong diplomacy” conducted by American and Chinese table-tennis teams in reciprocal visits in 1971–72. Nixon's visit to China in February–March 1972, the first by an American president while in office, concluded with the Shanghai Communiqué, in which the United States formally recognized the “one-China” principle—that there is only one China, and that Taiwan is a part of China.

- Answer
  February–March 1972

# Time Search -- Experiment

- MS intranet data
  - 100 queries from log of http://msweb, containing ‘when’, ‘schedule’, ‘day’, and ‘time’
  - 8.73 answers per query (from 10000 documents)
- Evaluation Measure

$$RR_i = \frac{1}{Rank_i} \qquad MRR = \frac{\sum_{i=1}^{Q} RR_i}{Q}$$

- Results

| **Method** | **MRR** |
|---|---|
| Best Baseline | 0.5033 |
| Learning | **0.5809 (+15%)** |

# New Learning Algorithm for Ranking

# Ranking Learning

- Given:
  - $S = \{(\vec{x}_i, y_i)\}_{i=1}^{m} \subset X \times Y$, where $Y = \{r_1 \prec \cdots \prec r_q\}$
  - $\mathrm{H} = \{h : X \mapsto Y\}$ (hypothesis space)
  - $L : Y \times Y \mapsto R$ (loss function)
- Question: based on $S$ find $h^* = \arg\min \mathbf{E}\left(L(h(\vec{x}), y)\right)$
- ERM: choose $h^*_{ERM} = \operatorname{argmin} \sum_{i=1}^{m} L(h(\vec{x}_i), y_i)$
- SRM: choose $h^*_{SRM} = \operatorname{argmin} \sum_{i=1}^{m} L(h(\vec{x}_i), y_i) + \lambda Q(h)$

# Viewing Ranking as Classification

- Formulizing ranking problem as classification of example pairs

- Measuring the loss of $h$ by inversions

$$L(y_1, y_2, \hat{y}_1, \hat{y}_2) = \begin{cases} 1 & (y_1 \prec y_2) \wedge \neg(\hat{y}_1 \prec \hat{y}_2) \\ 1 & (y_1 \succ y_2) \wedge \neg(\hat{y}_1 \succ \hat{y}_2) \\ 0 & otherwise \end{cases}$$

# Viewing Ranking as Classification (cont')

- Given $S = \{(\vec{x}_i, y_i)\}_{i=1}^{m}$, find $h_{ERM}$ that minimizes

$$\sum_{i=1}^{m}\sum_{j=1}^{m} L(y_i, y_j, h(\vec{x}_i), h(\vec{x}_j))$$

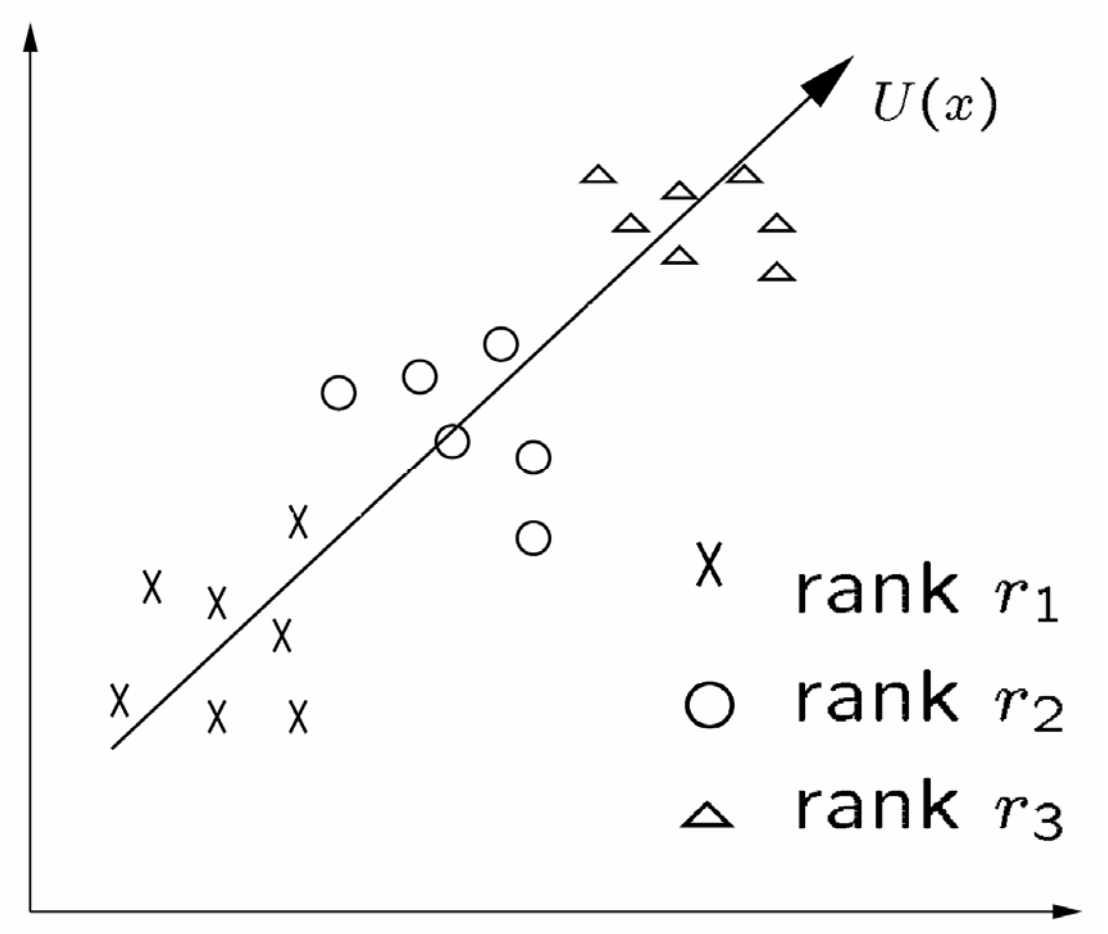
- Equivalently, find a $f_h$ that minimizes

$$\sum_{((\vec{x}_i^{(1)}, \vec{x}_i^{(2)}), z_i) \in S'} L_{0-1}\left( f_h(\vec{x}_i^{(1)}, \vec{x}_i^{(2)}), z_i \right),$$

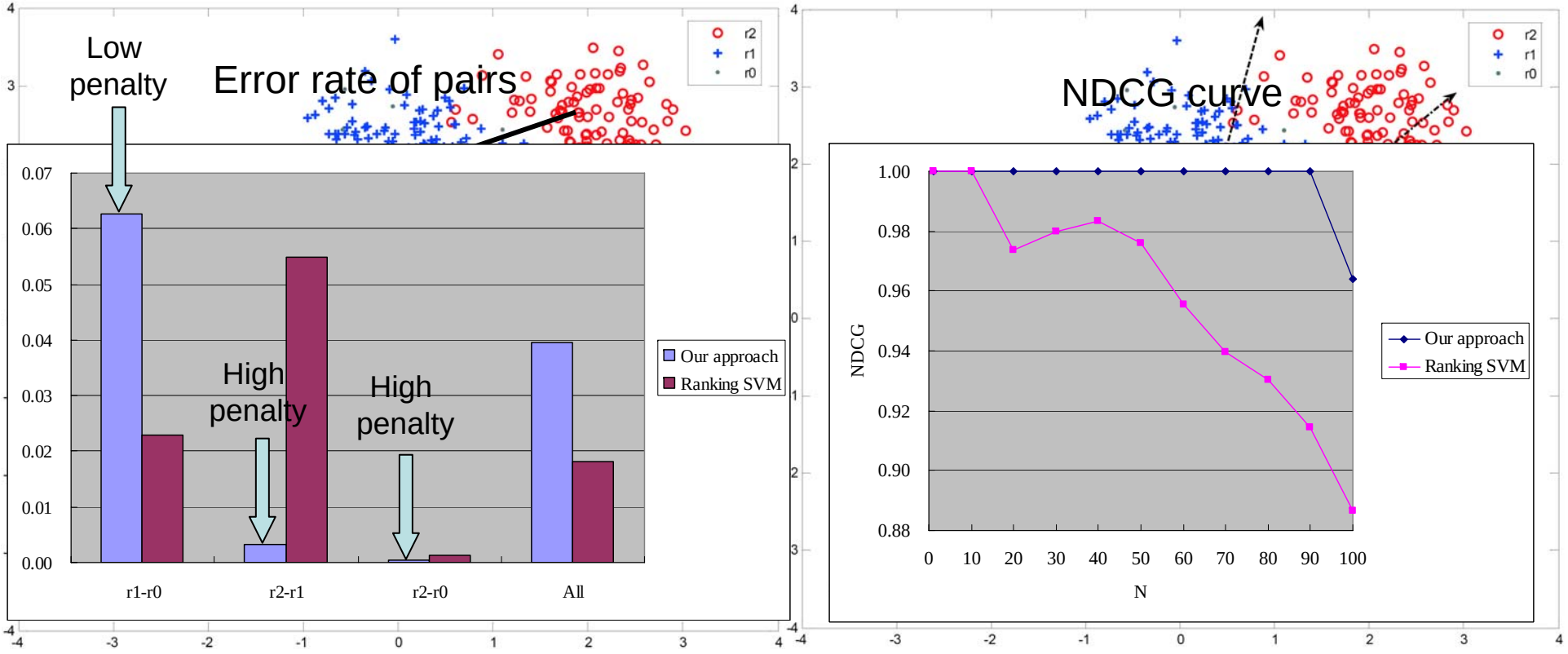
$$where\ S' = \left\{ \left( (\vec{x}_i, \vec{x}_j), z = \begin{cases} +1 & y_i \succ y_j \\ -1 & y_i \prec y_j \end{cases} \right) : (\vec{x}_i, y_i), (\vec{x}_j, y_j) \in S \right\}$$

# Ranking Model

- Model: instances are ranked by $U(x)$

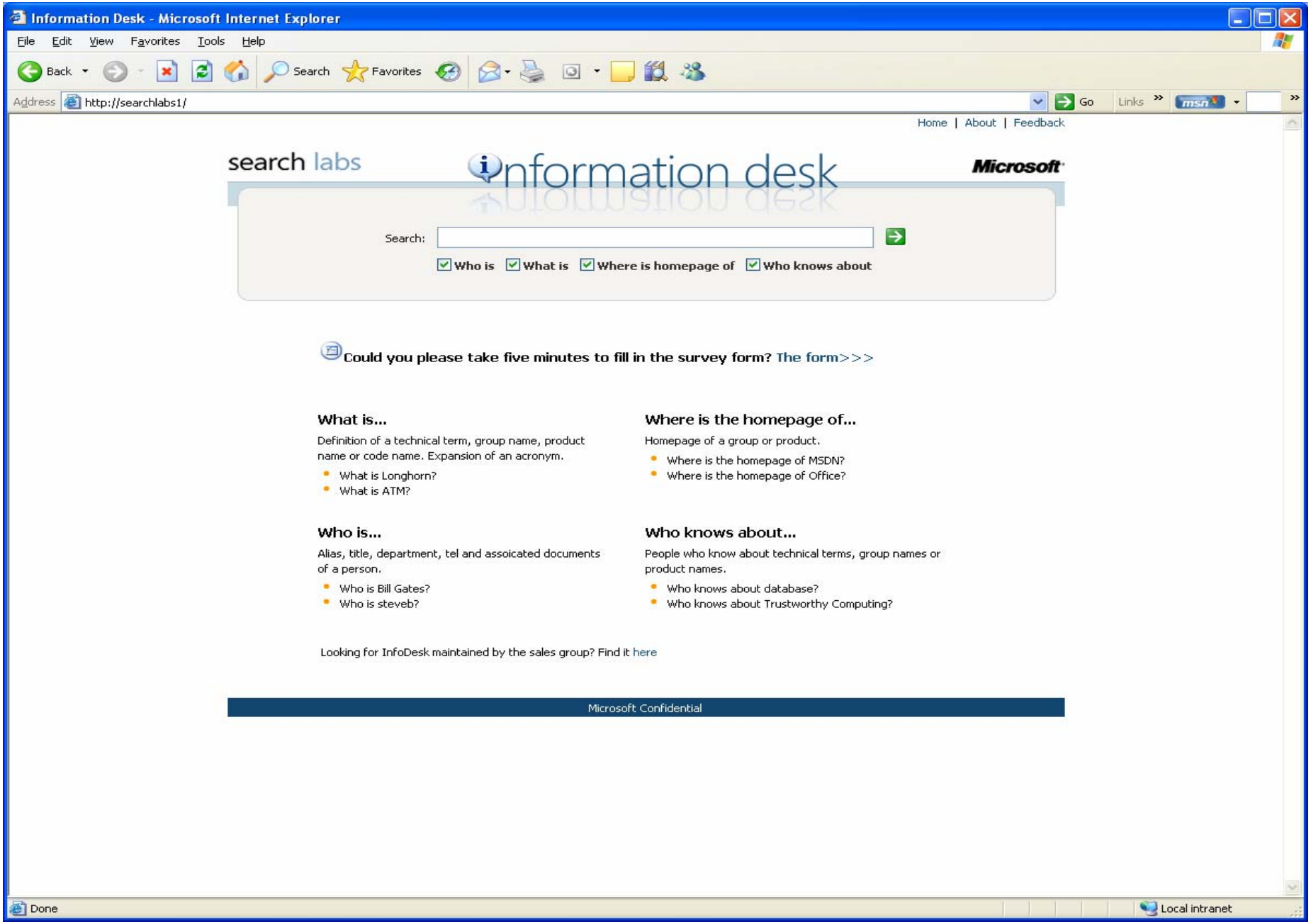


# Simulation Experiment 1

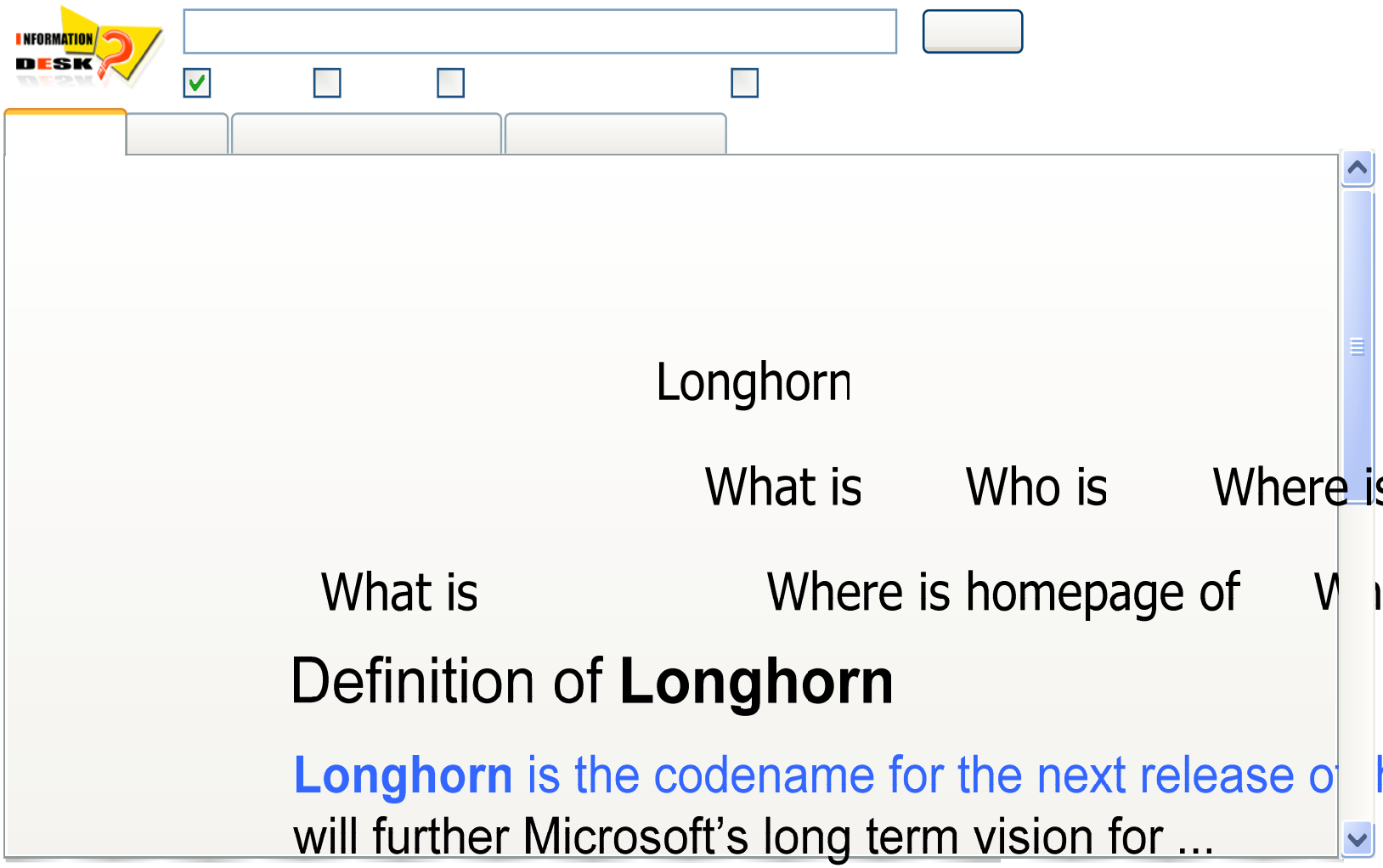


# Information Desk

(Li et al., 2005)

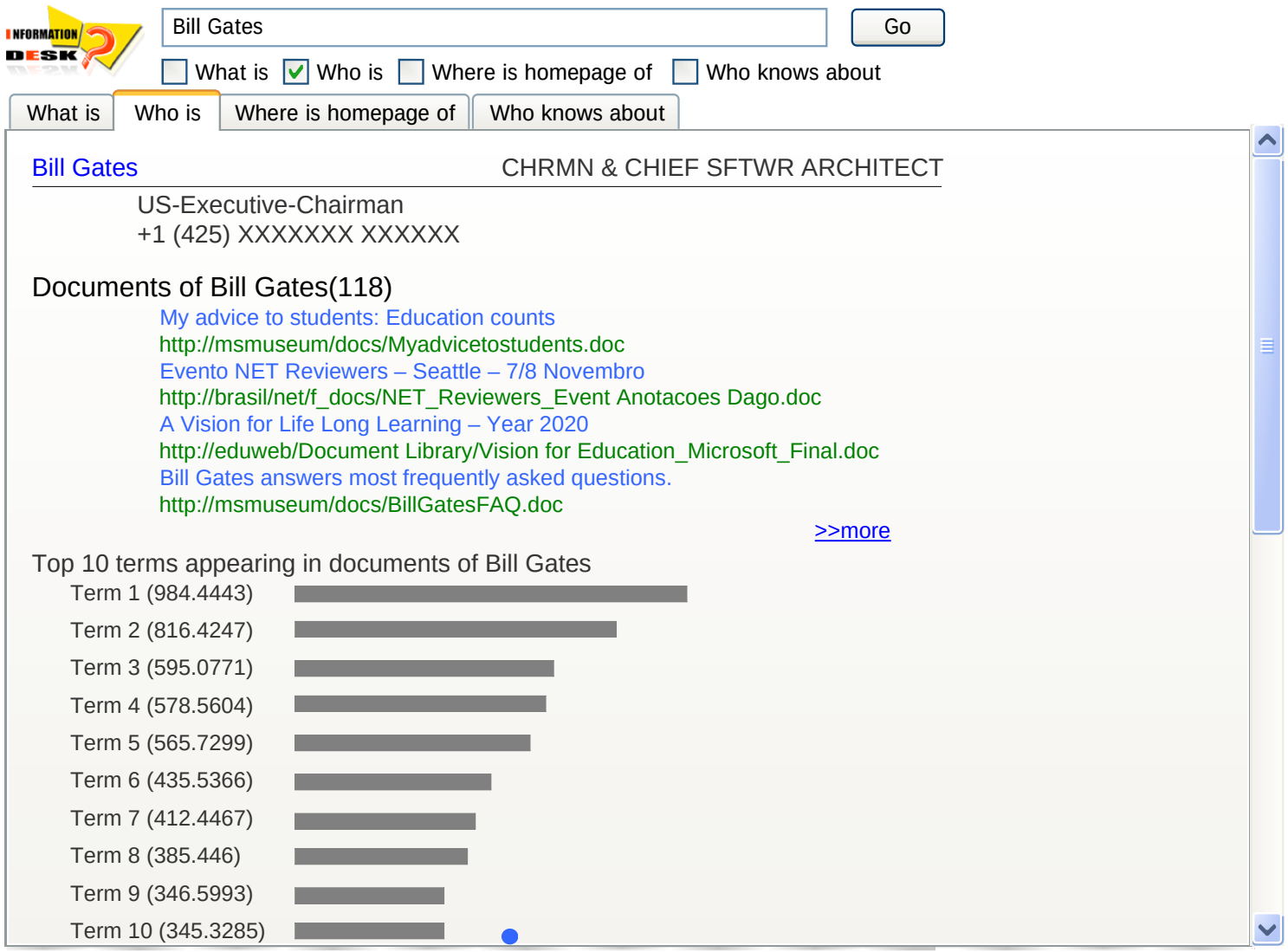

Information Desk - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites
Address http://searchlabs1/
Go Links
Home | About | Feedback
search labs
information desk
Microsoft
Search:
Who is What is Where is homepage of Who knows about
Could you please take five minutes to fill in the survey form? The form>>>
What is...
Definition of a technical term, group name, product name or code name. Expansion of an acronym.
What is Longhorn?
What is ATM?
Where is the homepage of...
Homepage of a group or product.
Where is the homepage of MSDN?
Where is the homepage of Office?
Who is...
Alias, title, department, tel and assoicated documents of a person.
Who is Bill Gates?
Who is steveb?
Who knows about...
People who know about technical terms, group names or product names.
Who knows about database?
Who knows about Trustworthy Computing?
Looking for InfoDesk maintained by the sales group? Find it here
Microsoft Confidential
Done
Local intranet

# Features -- ‘what is’

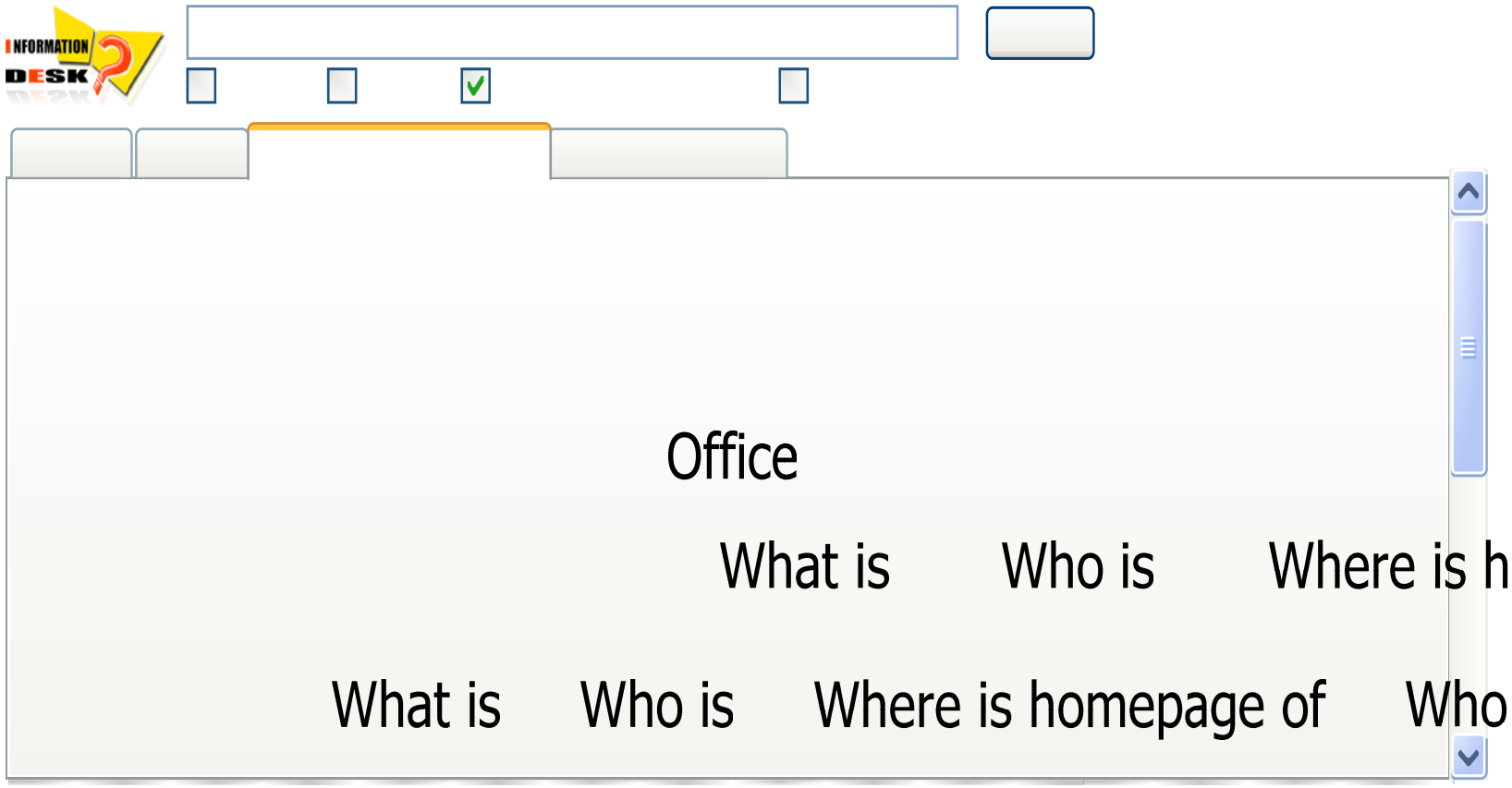



**Longhorn** is a platform that enables incredible user experiences

# Features – ‘who is’



# Features – ‘where is homepage of ’

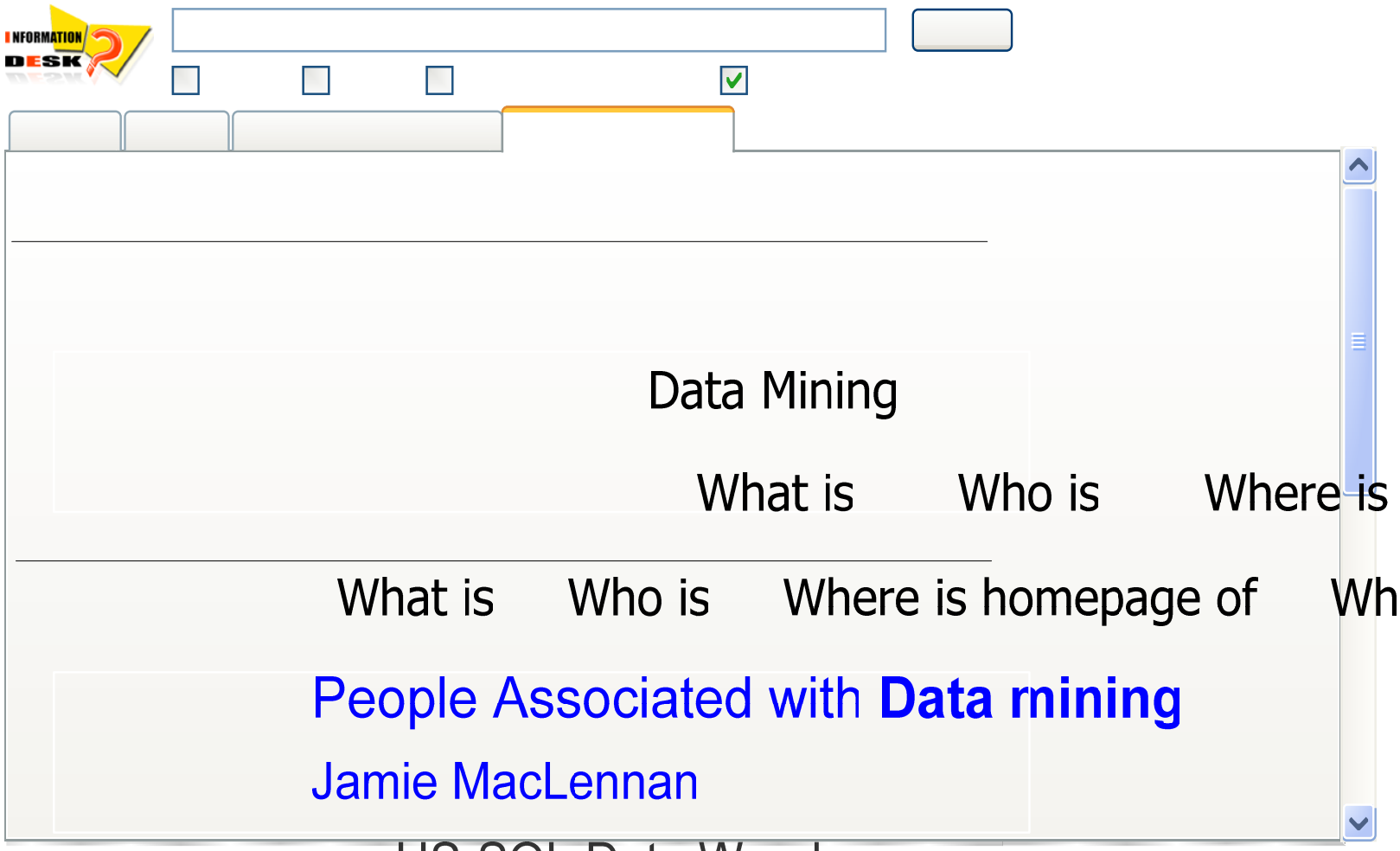



Homepages of **Office**

**Office** Portal Site

This is the internal site for Office

# Features - ‘who knows about’



# Summary

# Summary

- Information retrieval = helping people access information
- Currently search = ranking
- Matching between query and document
- Our work
  - Search by Document Type, Factoid Search
  - New learning algorithm for ranking
- Many issues to study

# References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