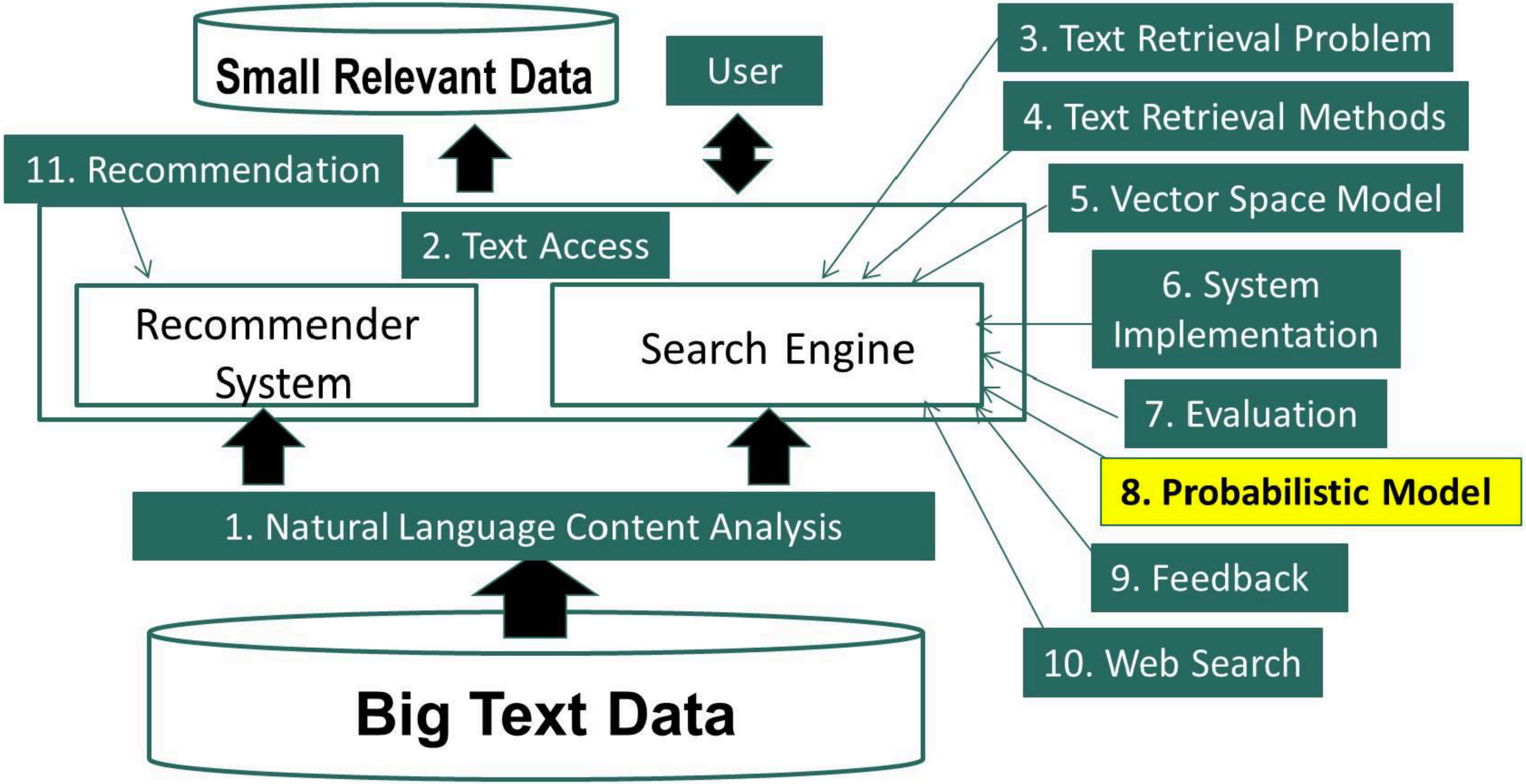
Information Retrieval & Text Mining

Probabilistic Retrieval Model:
Basic Idea

Dr. Iqra Safder
Information Technology University

Probabilistic Retrieval Model: Basic Idea



Many Different Retrieval Models

- **Similarity-based models**: $f(q,d) = similarity(q,d)$
  - Vector space model
- **Probabilistic models**: $f(d,q) = p(R=1|d,q)$, where $R \in \{0,1\}$
  - Classic probabilistic model
  - Language model
  - Divergence-from-randomness model
- **Probabilistic inference model**: $f(q,d) = p(d \rightarrow q)$
- **Axiomatic model**: $f(q,d)$ must satisfy a set of constraints
- These different models tend to result in similar ranking functions involving similar variables

Probabilistic Model

- We define ranking function that a given document **D** is relevant to a given query **Q**.
- We introduce binary random variable R ϵ {0, 1}
- We assume that **Q** and **D** are observations from random variable, in vector space model we assume they are vectors
- Problem of retrieval now becomes the problem to estimate the probability of relevance.

$$f(d,q) = p(R=1 | d,q), \quad R \in \{0,1\}$$

Many Different Retrieval Models

- **Probabilistic models**: $f(d,q) = p(R=1|d,q)$, $R \in \{0,1\}$
  - Classic probabilistic model → BM25
  - **Language model → Query Likelihood**

$$p(R=1|d,q) \approx p(q|d,R=1)$$

If a user likes document d, how likely would the user enter query q (in order to retrieve d)?

Probabilistic Retrieval Models: Basic Idea

Query	Doc	Rel
q	**d**	**R**
q1	d1	1
q1	d2	1
q1	d3	0
q1	d4	0
q1	d5	1
…		
q1	d1	0
q1	d2	1
q1	d3	0
q2	d3	1
q3	d1	1
q4	d2	1

Probabilistic Retrieval Models: Basic Idea

Query	Doc	Rel
q	**d**	**R**
q1	d1	1
q1	d2	1
q1	d3	0
q1	d4	0
q1	d5	1
…		
q1	d1	0
q1	d2	1
q1	d3	0
q2	d3	1
q3	d1	1
q4	d2	1

$$f(q,d)=p(R=1|d,q)=?$$

How can we estimate the probability of relevance?

Probabilistic Retrieval Models: Basic Idea

Query	Doc	Rel
q	**d**	**R**
q1	d1	1
q1	d2	1
q1	d3	0
q1	d4	0
q1	d5	1
…		
q1	d1	0
q1	d2	1
q1	d3	0
q2	d3	1
q3	d1	1
q4	d2	1

$$f(q,d)=p(R=1|d,q)=? \quad \frac{count(q,d,R=1)}{count(q,d)}$$

Probabilistic Retrieval Models: Basic Idea

Query	Doc	Rel
q	**d**	**R**
q1	d1	1
q1	d2	1
q1	d3	0
q1	d4	0
q1	d5	1
…		
q1	d1	0
q1	d2	1
q1	d3	0
q2	d3	1
q3	d1	1
q4	d2	1

$$f(q,d)=p(R=1|d,q)=? \quad \frac{count(q,d,R=1)}{count(q,d)}$$

$P(R=1|q1,d1) = ?$

$P(R=1|q1,d2) = ?$

$P(R=1|q1,d3) = ?$

Probabilistic Retrieval Models: Basic Idea

Query	Doc	Rel
q	**d**	**R**
q1	d1	1
q1	d2	1
q1	d3	0
q1	d4	0
q1	d5	1
…		
q1	d1	0
q1	d2	1
q1	d3	0
q2	d3	1
q3	d1	1
q4	d2	1

f(q,d)=p(R=1|d,q)=? $\dfrac{count(q,d,R=1)}{count(q,d)}$

P(R=1|q1,d1) = ? 1/2

P(R=1|q1,d2) = ? 2/2

P(R=1|q1,d3) = ? 0/2

Probabilistic Retrieval Models: Basic Idea

Query	Doc	Rel
q	**d**	**R**
q1	d1	1
q1	d2	1
q1	d3	0
q1	d4	0
q1	d5	1
…		
q1	d1	0
q1	d2	1
q1	d3	0
q2	d3	1
q3	d1	1
q4	d2	1

$$f(q,d)=p(R=1|d,q)=? \quad \frac{count(q,d,R=1)}{count(q,d)}$$

$P(R=1|q1,d1) = ?$ 1/2

$P(R=1|q1,d2) = ?$ 2/2

$P(R=1|q1,d3) = ?$ 0/2

What about unseen documents?

Unseen queries?

Query Likelihood Retrieval Model

Query	Doc	Rel
q	**d**	**R**
q1	d1	1
q1	d2	1
q1	d3	0
q1	d4	0
q1	d5	1
…		
q1	d1	0
q1	d2	1
q1	d3	0
q2	d3	1
q3	d1	1
q4	d2	1

$$f(q,d)=p(R=1|d,q)\approx \quad \mathbf{p(q|d,R=1)}$$

Approximations

In query likelihood, our assumption is that this probability of relevance can be approximated by the probability of a query given a document and relevance, p(q | d , R = 1). Intuitively, this probability just captures the following probability: if a user likes document d, how likely would the user enter query q in order to retrieve document d? The condition part contains document d and R = 1, which can be interpreted as the condition that the user likes document d.

Query Likelihood Retrieval Model

Query	Doc	Rel
q	**d**	**R**
q1	d1	1
q1	d2	1
q1	d3	0
q1	d4	0
q1	d5	1
…		
q1	d1	0
q1	d2	1
q1	d3	0
q2	d3	1
q3	d1	1
q4	d2	1

$$f(q,d)=p(R=1|d,q)\approx \mathbf{p(q|\overset{\text{User likes d}}{\overset{\uparrow\quad\uparrow}{d,R=1}})}$$

In query likelihood, our assumption is that this probability of relevance can be approximated by the probability of a query given a document and relevance, p(q | d , R = 1). Intuitively, this probability just captures the following probability: if a user likes document d, how likely would the user enter query q in order to retrieve document d? The condition part contains document d and R = 1, which can be interpreted as the condition that the user likes document d.

Query Likelihood Retrieval Model

Query	Doc	Rel
q	**d**	**R**
q1	d1	1
q1	d2	1
q1	d3	0
q1	d4	0
q1	d5	1
…		
q1	d1	0
q1	d2	1
q1	d3	0
q2	d3	1
q3	d1	1
q4	d2	1

$$\overset{\text{User likes d}}{} \qquad f(q,d)=p(R=1|d,q)\approx \mathbf{p(\underset{\underset{\text{How likely the user enters q}}{\uparrow}}{q}|\overset{\uparrow}{d},\overset{\uparrow}{R}=1)}$$

In query likelihood, our assumption is that this probability of relevance can be approximated by the probability of a query given a document and relevance, p(q | d , R = 1). Intuitively, this probability just captures the following probability: if a user likes document d, how likely would the user enter query q in order to retrieve document d? The condition part contains document d and R = 1, which can be interpreted as the condition that the user likes document d.

Query Likelihood Retrieval Model

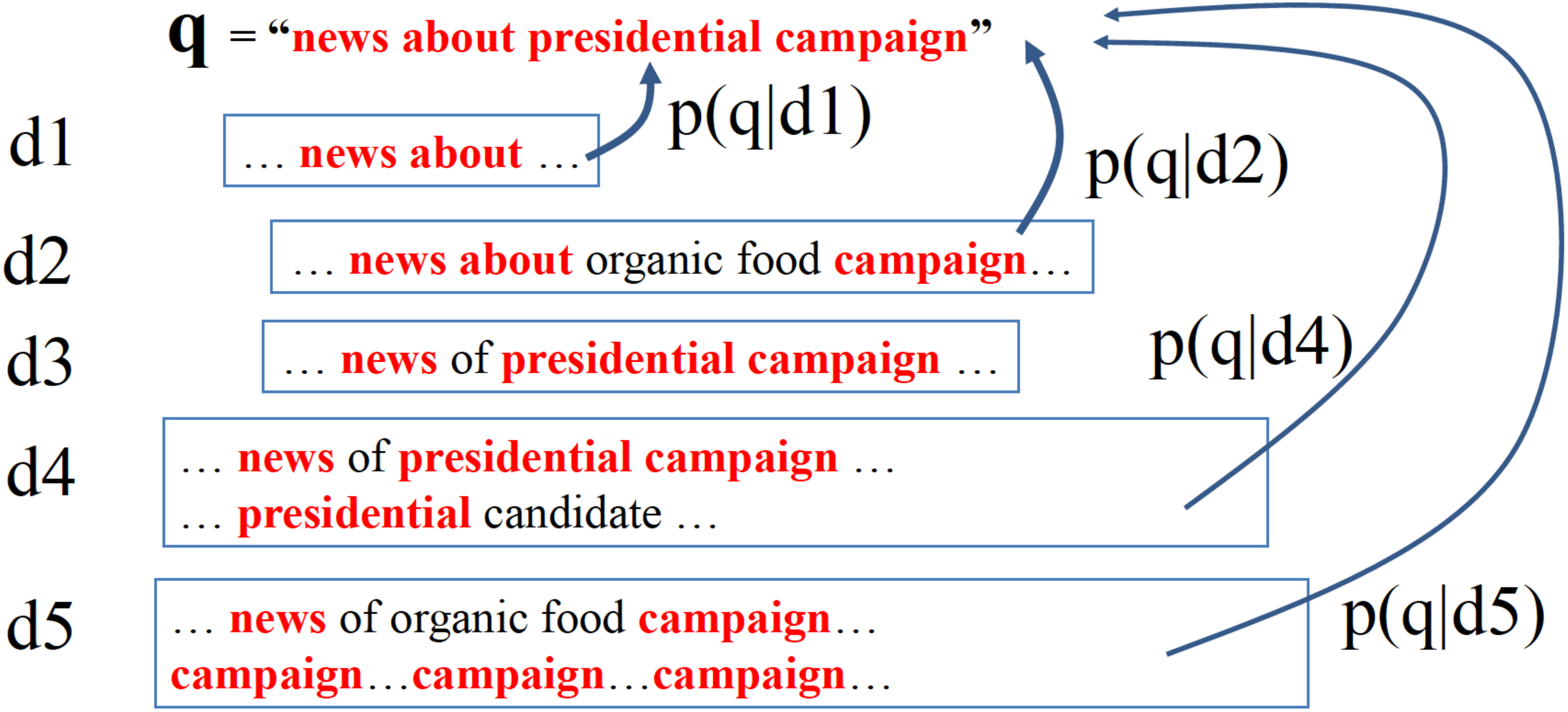
Query	Doc	Rel
q	**d**	**R**
q1	d1	1
q1	d2	1
q1	d3	0
q1	d4	0
q1	d5	1
…		
q1	d1	0
q1	d2	1
q1	d3	0
q2	d3	1
q3	d1	1
q4	d2	1

$$f(q,d)=p(R=1|d,q)\approx \mathbf{p(}\underset{\underset{\text{How likely the user enters q}}{\uparrow}}{\mathbf{q}}\mathbf{|}\overset{\overset{\text{User likes d}}{\uparrow\quad\uparrow}}{\mathbf{d,R=1}}\mathbf{)}$$

Assumption:

A user formulates a query based on an "**imaginary relevant document**"

Which doc is Most Likely the "Imaginary Relevant Doc"?



q = "**news about presidential campaign**"

d1 … **news about** …

$p(q|d1)$

d2 … **news about** organic food **campaign**…

$p(q|d2)$

d3 … **news** of **presidential campaign** …

d4 … **news** of **presidential campaign** …
… **presidential** candidate …

$p(q|d4)$

d5 … **news** of organic food **campaign**…
campaign…**campaign**…**campaign**…

$p(q|d5)$

Summary

- Relevance(q,d) = p(R=1|q,d) → p(q|d,R=1)
- **Query likelihood** ranking function: f(q,d)=p(q|d)
  - Probability that a user who likes d would pose query q
- How to compute p(q|d)? How to compute probability of text in general? → Language Model

p(q= “presidential campaign” **|d=** … **news** of **presidential campaign** … **presidential** candidate …)