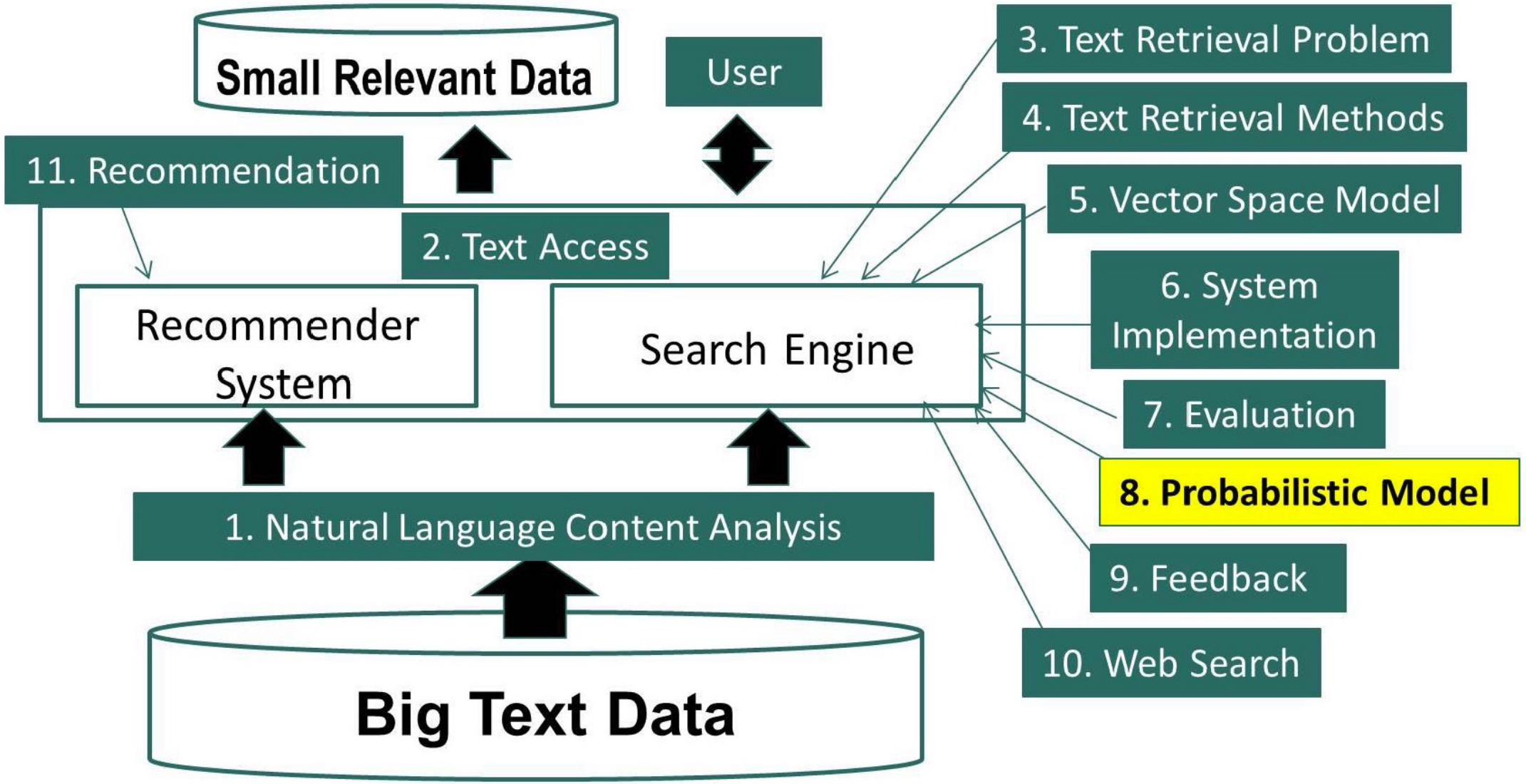
Information Retrieval

Probabilistic Retrieval Model:
Statistical Language Model

Dr. Iqra Safder

Probabilistic Retrieval Model: Basic Idea



Overview

- What is a Language Model?
- Unigram Language Model
- Uses of a Language Model

What is a Statistical Language Model (LM)?

- A probability distribution over word sequences
  - p("*Today is Wednesday*") ≈ 0.001
  - p("*Today Wednesday is*") ≈ 0.0000000000001
  - p("*The eigenvalue is positive*") ≈ 0.00001
- Context-dependent!

This may be a reasonable language model for describing general conversations, but it may be inaccurate for describing conversations happening at a mathematics conference, where the sequence *The eigenvalue is positive* may occur more frequently than *Today is Wednesday.*

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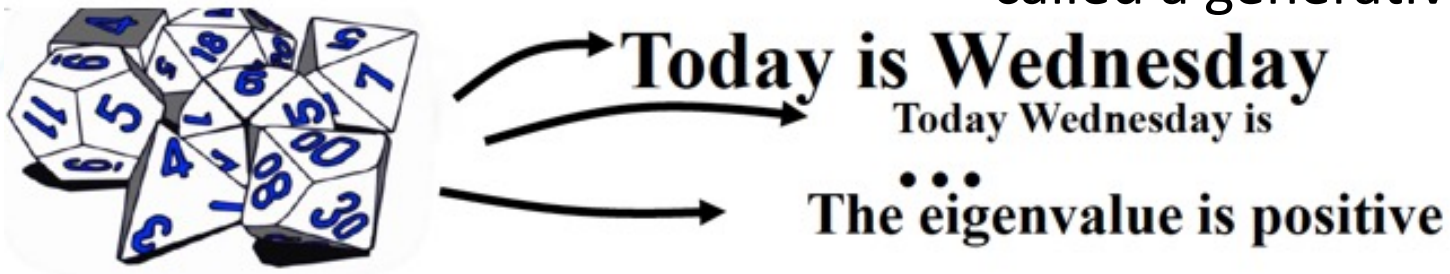
Given a language model, we can sample word sequences according to the distribution to obtain a text sample. In this sense, we may use such a model to "generate" text. Thus, a language model is also often called a generative model for text.



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  - Given that a user is interested in sports news, how likely would the user use "baseball" in a query? (information retrieval)

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Given probabilities of each word, the sum of all is = 1

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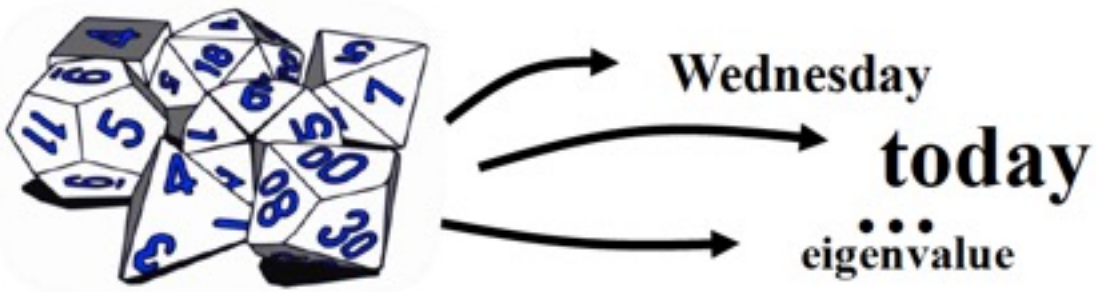


p("today is Wed")
= p("today")p("is")p("Wed")
= 0.0002 × 0.001 × 0.000015

Text Generation with Unigram LM

Unigram LM p(w|θ) → **Sampling** → **Document =?**

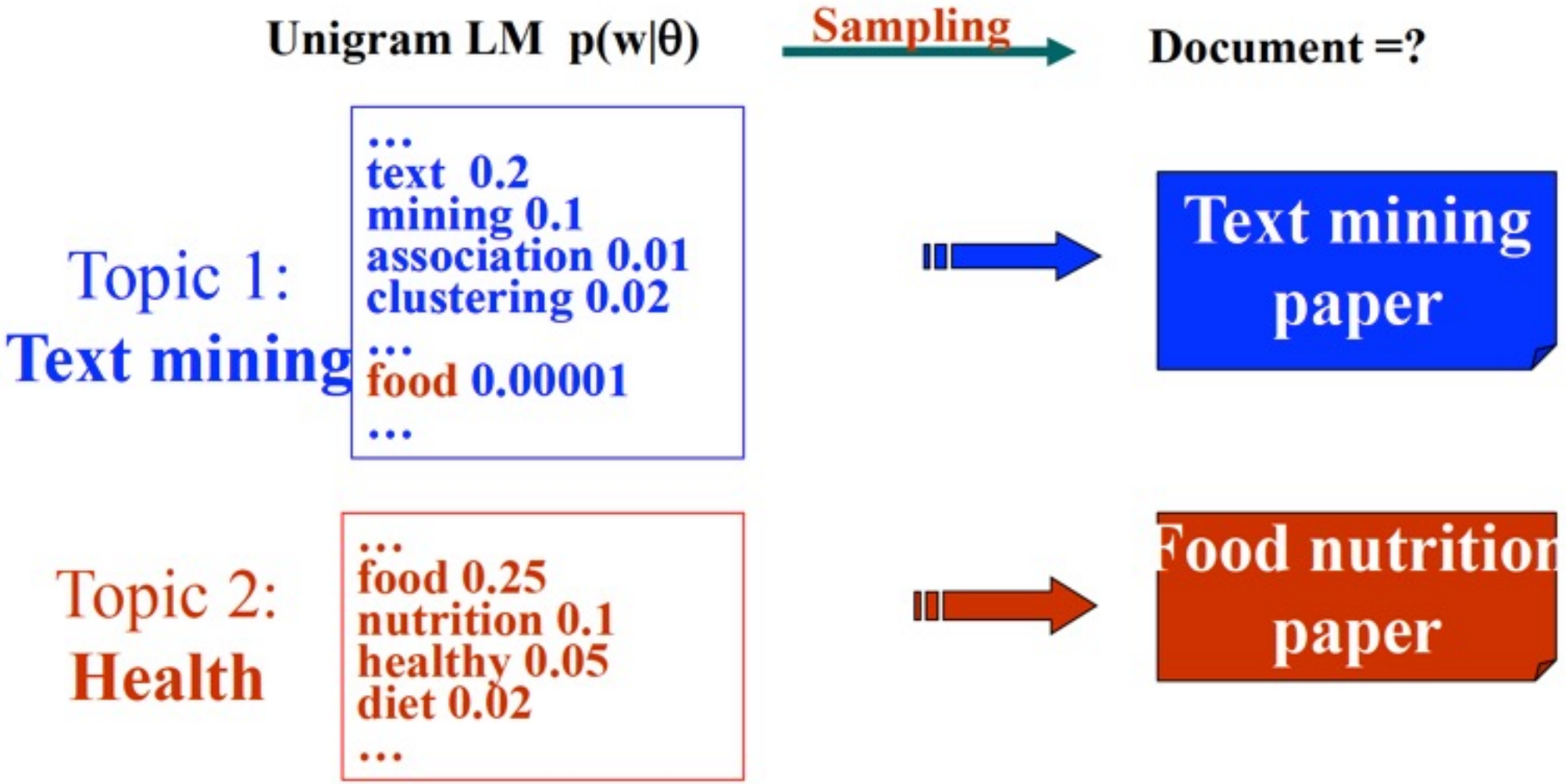
Topic 1: **Text mining**

…
text 0.2
mining 0.1
association 0.01
clustering 0.02
…
food 0.00001
…

Topic 2: **Health**

…
food 0.25
nutrition 0.1
healthy 0.05
diet 0.02
…

Text Generation with Unigram LM



Estimation of Unigram LM

Unigram LM p(w|θ)=?

Estimation

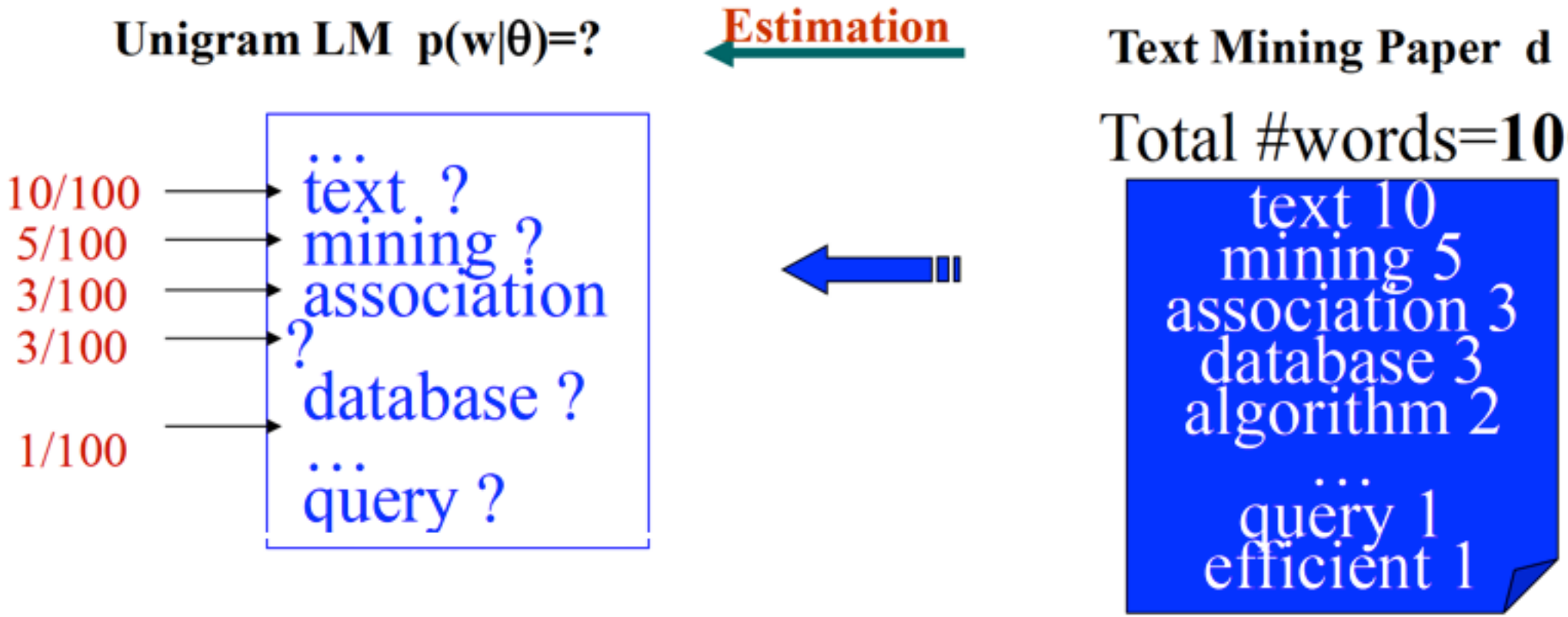
Text Mining Paper d

Total #words=**100**

…
text ?
mining ?
association ?
database ?
…
query ?

text 10
mining 5
association 3
database 3
algorithm 2
…
query 1
efficient 1

Estimation of Unigram LM



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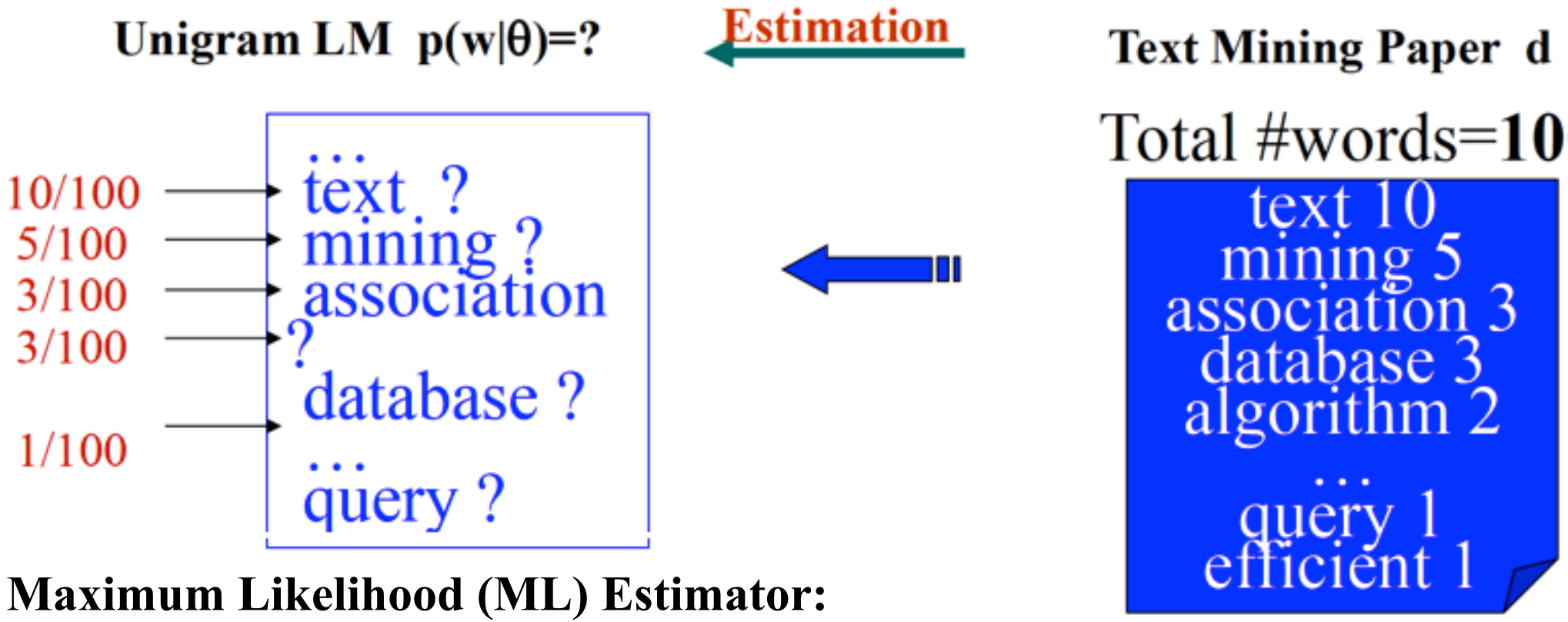
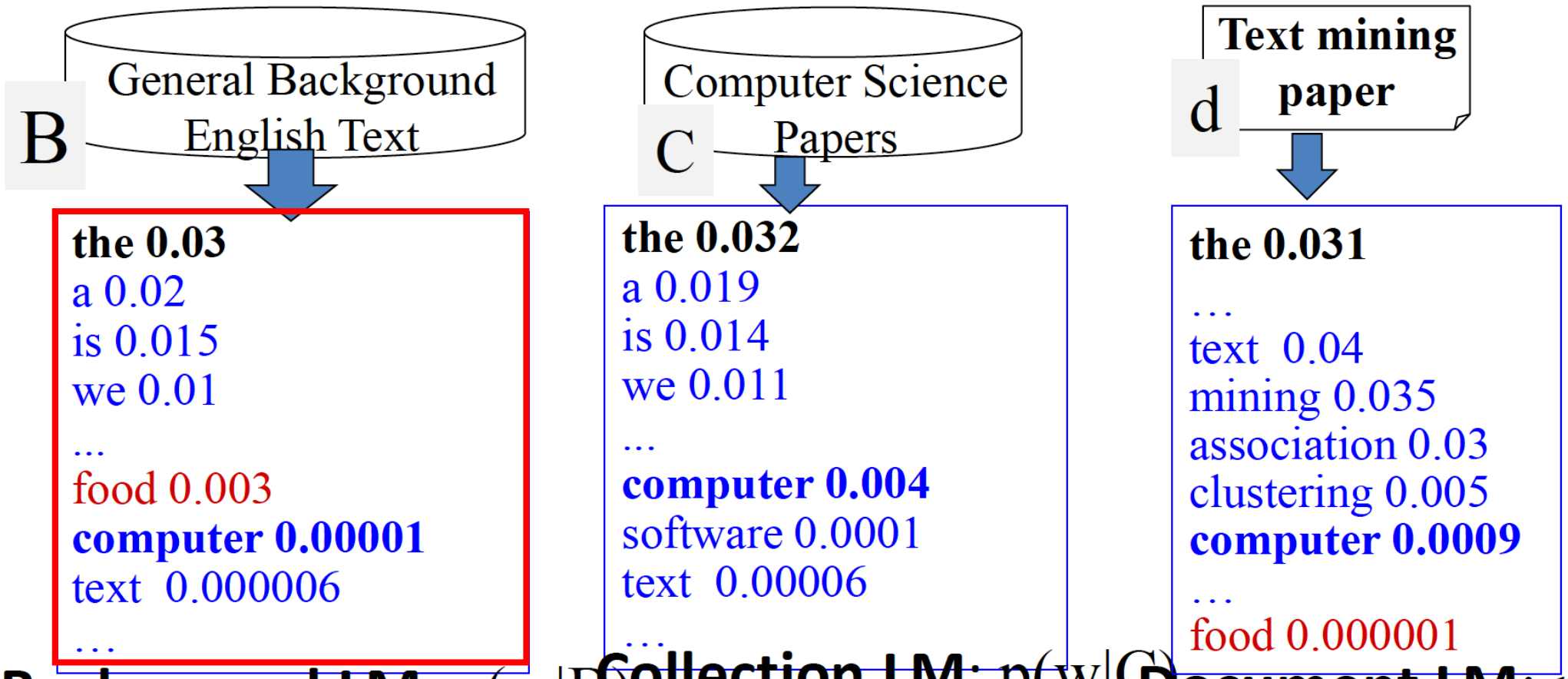


Maximum Likelihood (ML) Estimator:

$$p(w \mid \theta) = p(w \mid d) = \frac{c(w,d)}{|d|}$$

LMs for Topic Representation



Background LM: p(w|B) **Collection LM**: p(w|C) **Document LM**: p(w

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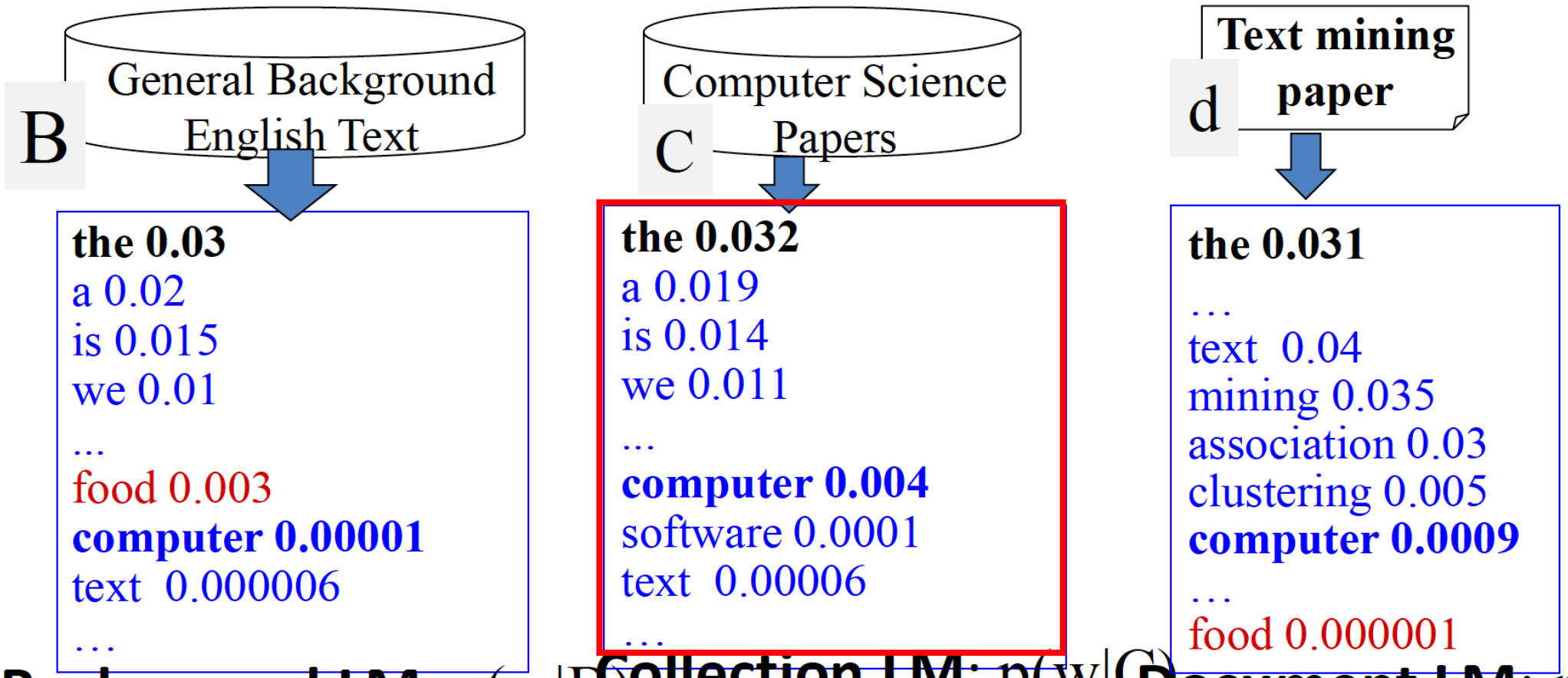

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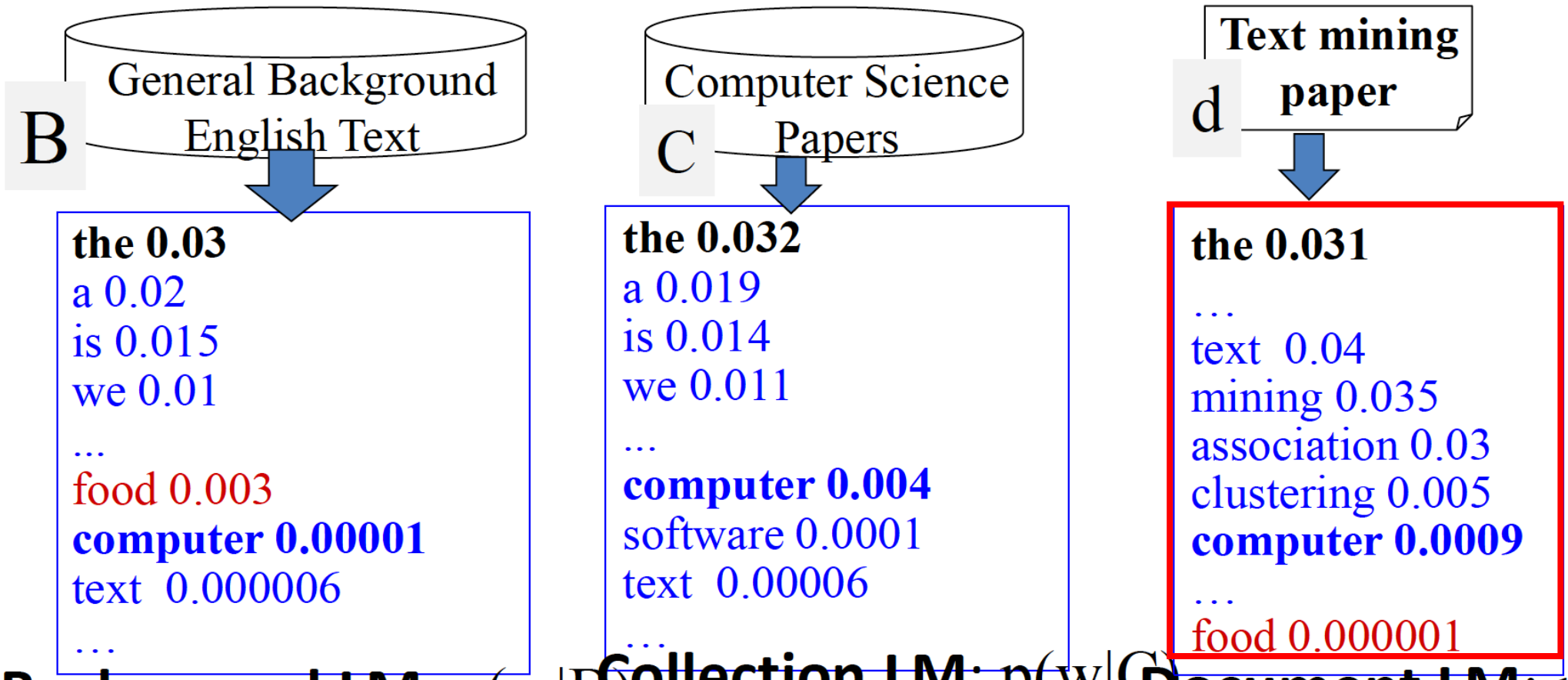

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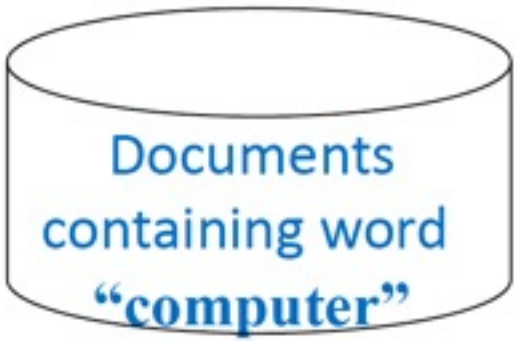
LMs for Association Analysis

What words are semantically related to "computer"?

Topic LM: p(w|"computer")

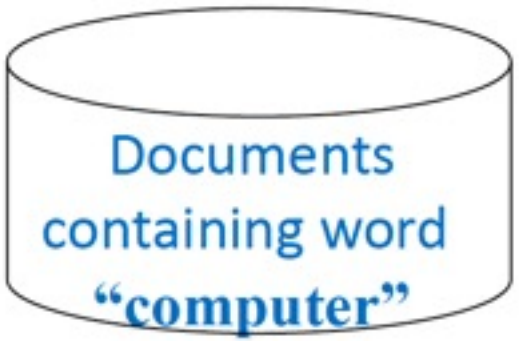


the 0.032
a 0.019
is 0.014
we 0.008
computer 0.004
software 0.0001

LMs for Association Analysis

What words are semantically related to "computer"?

Topic LM: p(w|"computer")



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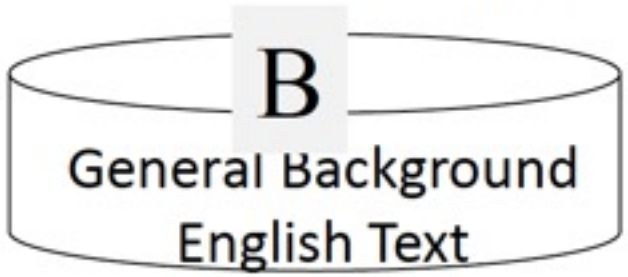

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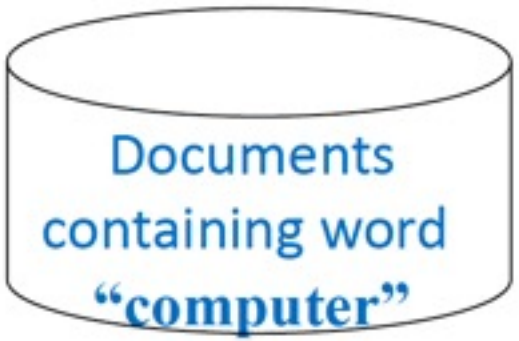

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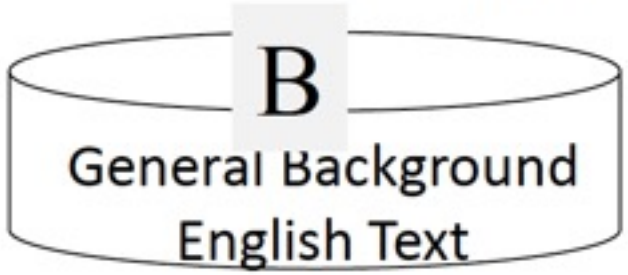
Normalized Topic LM:
p(w|"computer")/p(w|B)

Background LM: p(w|B)



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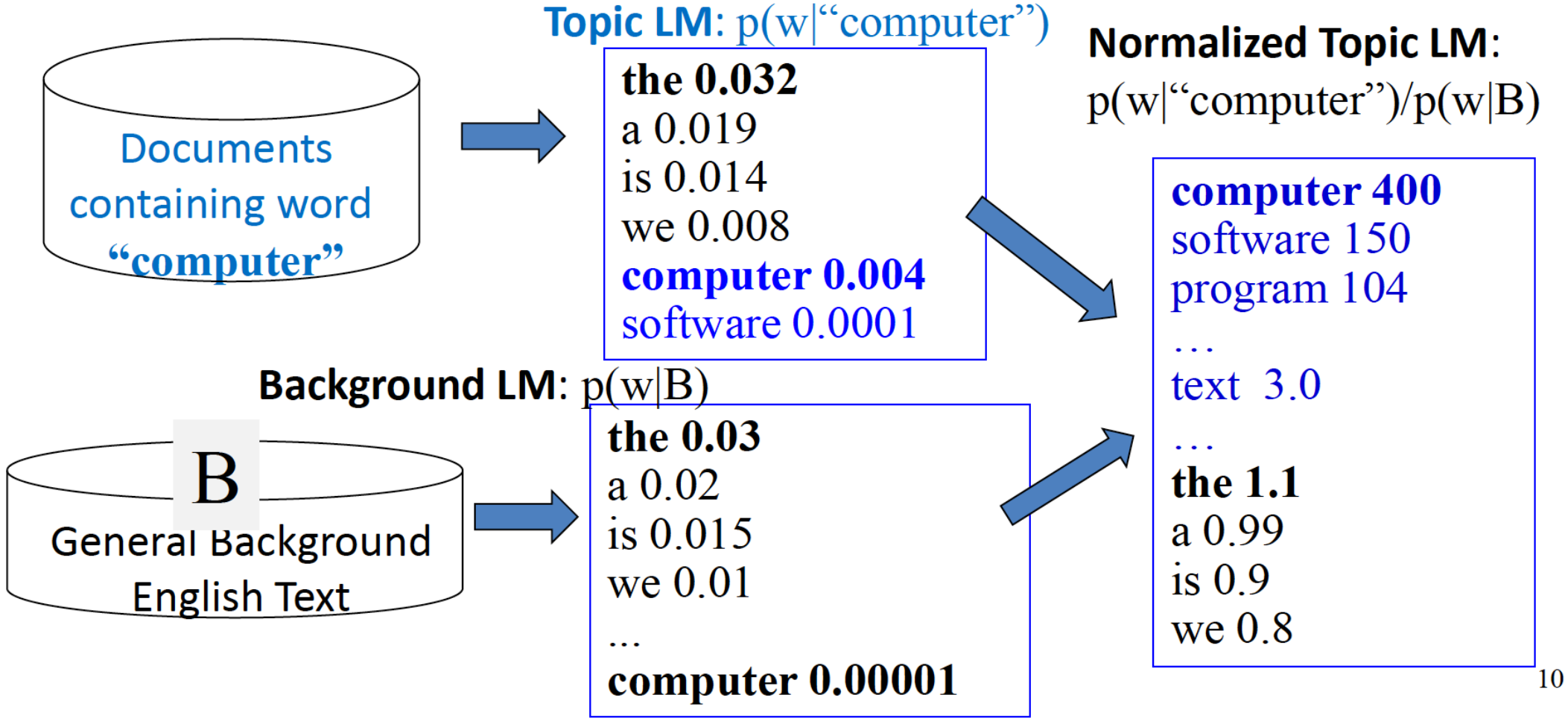

Summary

- Language Model = probability distribution over text
- Unigram Language Model = word distribution
- Uses of a Language Model
  - Representing topics
  - Discovering word associations

Additional Readings

- Chris Manning and Hinrich Schütze, Foundations of Statistical Natural Language Processing, MIT Press. Cambridge, MA: May 1999.
- Rosenfeld, R., "Two decades of statistical language modeling: where do we go from here?," *Proceedings of the IEEE* , vol.88, no.8, pp.1270,1278, Aug. 2000