Models for Retrieval and Browsing

- Structural Models and Browsing

Berlin Chen 2005

Reference:
1. *Modern Information Retrieval*, chapter 2
Taxonomy of Classic IR Models

User Task

Retrieval: Adhoc Filtering

Browsing

Structured Models

Non-Overlapping Lists
Proximal Nodes

Classic Models

Boolean
Vector
Probabilistic

Set Theoretic
Fuzzy
Extended Boolean

Algebraic
Generalized Vector
Latent Semantic
Indexing (LSI)
Neural Networks

Probabilistic
Inference Network
Belief Network
Hidden Markov Model
Probabilistic LSI
Language Model

Browsing

Flat
Structure Guided
Hypertext

probability-based
Structured Text Retrieval Models

- Structured Text Retrieval Models
  - Retrieval models which combine information on the text content with information on the document structure.
  - That is, the document structure is one additional piece of information which can be taken advantage.

- E.g.: Consider the following information need
  - Retrieve all docs which contain a page in which the string ‘atomic holocaust’ appears in italic in the text surrounding a Figure whose label contains the word ‘earth’.
    - ‘atomic holocaust’ and ‘earth’
    - Or a structural (more complex) query instead.

Too many docs retrieved!

- same-page( near( ‘atomic holocaust’, Figure(label( ‘earth’ ))))

classical IR model
Structured Text Retrieval Models (cont.)

• Drawbacks
  – Difficult to specify the structural query
    • An advanced user interface is needed
  – Structured text retrieval models include no ranking (open research problem!)

• Tradeoffs
  – The more expressive the model, the less efficient is its query evaluation strategy

• Two structured text retrieval models are introduced here
  – Non-Overlapping Lists
  – Proximal Nodes
Basic Definitions

• **Match point**: the position in the text of a sequence of words that match the query
  – Query: “atomic holocaust in Hiroshima”
  – Doc $d_j$: contains 3 lines with this string
  – Then, doc $d_j$ contains 3 match points

• **Region**: a contiguous portion of the text

• **Node**: a structural component of the text such as a chapter, a section, a subsection, etc.
  – That is, a region with predefined topological properties
Non-Overlapping Lists

- **Idea**: divide the whole text of a document in non-overlapping text regions which are collected in a list
  - Multiple list generated
    - A list for chapters
    - A list for sections
    - A list for subsections

1. Kept as separate and distinct data structures
2. Text regions from distinct lists might overlap!

$L_0$ \[\text{Chapter}\]
$L_1$ \[\text{Sections}\]
$L_2$ \[\text{SubSections}\]
$L_3$ \[\text{SubSubSections}\]
Non-Overlapping Lists (cont.)

• Implementation:
  – A single inverted file build, in which each structural component stands as an entry in the index (see next slide)
  – Each entry has a list of text regions as a list occurrences
  – Such a list could be easily merged with the traditional inverted file

• Example types of queries
  – Select a region which contains a given word (and doesn’t contain any regions) innermost structural component

  – Select a region A which does not contain any other region B of distinct lists

  – Select a region not contained within any other region outermost structural component
Non-Overlapping Lists (cont.)

Vocabulary

Component A

Component B

Component C

.....

Occurrences (a list of text regions)

(70, 200), (1330, 1420), ...

(415, 580), (5500, 5720), ...

(100, 130), .....

.....

A inverted-file structure for non-overlapping lists
Inverted Files

• **Definition**
  – An inverted file is a word-oriented mechanism for indexing a text collection in order to speed up the searching task

• **Structure of inverted file**
  – *Vocabulary*: is the set of all distinct words in the text
  – *Occurrences*: lists containing all information necessary for each word of the vocabulary (text position, frequency, documents where the word appears, etc.)
Inverted Files (cont.)

- **Text:**

That house has a garden. The garden has many flowers. The flowers are beautiful...

- **Inverted file**

<table>
<thead>
<tr>
<th>Vocabulary</th>
<th>Occurrences</th>
</tr>
</thead>
<tbody>
<tr>
<td>beautiful</td>
<td>70</td>
</tr>
<tr>
<td>flowers</td>
<td>45, 58</td>
</tr>
<tr>
<td>garden</td>
<td>18, 29</td>
</tr>
<tr>
<td>House</td>
<td>6</td>
</tr>
</tbody>
</table>

Different granularities for Occurrences
- Text position
- Doc position
Proximal Nodes

Navarro and Baeza-Yates, 1997

• **Idea**
  – Define a **strict hierarchical** index over the text. This enriches the previous model that used flat lists *(see next slide)*
  – Multiple index hierarchies might be defined
  – Two distinct index hierarchies might refer to text regions that overlap

• Each indexing structure is a strict hierarchy composed of
  – *Chapters, sections, subsections, paragraphs* or *lines*
  – Each of these components is called a **node**
    • Each node is associated with a text region
Proximal Nodes (cont.)

- One node might be contained within another node
- But, two nodes of a same hierarchy cannot overlap
- The inverted list for words complements the hierarchical index
Proximal Nodes (cont.)

• Query Language in regular expressions
  – Search for strings
  – References to structural components by name
  – Combination of these

• An example query: [(*section) with ("holocaust")]
  – Search for the sections, the subsections, and the subsubsections that contain the word “holocaust”
Proximal Nodes (cont.)

- Simple query processing for previous example
  - Traverse the inverted list for “holocaust” and **determine all match points** (all occurrence entries)
  - Use the match points to search in the hierarchical index for the structural components
    - Look for sections, subsections, and subsections containing that occurrence of the term
Proximal Nodes (cont.)

• Sophisticated query processing
  – Get the **first entry in the inverted list** for “holocaust”
  – Use this match point to search in the hierarchical index for the structural components until **innermost matching structural component** (the last and smallest one) found
    • At the bottom of the hierarchy
  – Check if innermost matching component includes the second entry in the inverted list for “holocaust”
  – If it does, check the two, the third entries, and so on. If not, traverse up to higher nodes then traverse down ....
  – This allows matching efficiently the nearby (or proximal) nodes
Proximal Nodes (cont.)

- **Conclusions**
  - The model allows formulating queries that are more sophisticated than those allowed by non-overlapping lists.
  - To speed up query processing, nearby nodes are inspected.
  - Types of queries that can be asked are somewhat limited (all nodes in the answer must come from a same index hierarchy!).
  - The model is a compromise between efficiency and expressiveness.

(*)section) with (“holocaust”)]
Models for Browsing

• **Premise**: the user is usually interested in browsing the documents instead of searching (specifying the queries)
  - User have goals to pursue in both cases
  - However, the goal of a searching task is clearer in the mind of the user than the goal of a browsing task

• Three types of browsing discussed here
  - Flat Browsing
  - Structure Guided Browsing
  - The Hypertext Model
Flat Browsing

• Documents represented as dots in
  – A two-dimensional plane
  – A one-dimensional plane (list)

• **Features**
  – Glance here and there looking for information within documents visited
    • Correlations among neighbor documents not taken into consideration
  – Add keywords of interest into original query
    • Relevance feedback or query expansion
  – Also, explore a single document in a flat manner (like a web page)

• **Drawbacks**
  – No indication about the context where the user is
Structure Guided Browsing

- Documents organized in a structure as a directory
  - Directories are hierarchies of classes which group documents covering related topics
  - E.g.: “Yahoo!” provides hierarchical directory

- Same idea applied to a single document
  - Chapter level, section level, etc.
  - The last level is the text itself (flat!)
  - A good UI needed for keeping track of the context
  - E.g.: the adobe acrobat pdf files
Structure Guided Browsing (cont.)

Contents

1 Minimum Classification Error (MCE) Approach in Pattern Recognition
   Wei Chen Araya Labs Research, Araya Inc., USA
   1.1 Introduction
   1.2 Optional Classifier from Bayes Decision Theory
   1.3 Discriminant Function Approach to Classifier Design
   1.4 Speech Recognition and Hidden Markov Modelling
      1.4.1 Hidden Markov Modelling of Speech
   1.5 MCE Classifier Design Using Discriminant Functions
      1.5.1 MCE Classifier Design Strategy
      1.5.2 Optimization Methods
      1.5.3 Other Optimization Methods
      1.5.4 HMM as a Discriminant Function
      1.5.5 Relation between MCE and MMI
      1.5.6 Discussions and Comments
   1.6 Embedded String Model Based MCE Training
      1.6.1 String Model Based MCE Approach
      1.6.2 Combined String Model Based MCE Approach
      1.6.3 Discriminative Feature Extraction
   1.7 Verification and Identification
      1.7.1 Speaker Verification and Identification
      1.7.2 Utterance Verification
   1.8 Summary

2 Minimum Bayes-Risk Methods in Automatic Speech Recognition
   Matthew Gock+ and William Byrne+ "IBM" Johns Hopkins University
   2.1 Minimum Bayes-Risk Classification Framework
      2.1.1 Likelihood Ratio Based Hypothesis Testing
      2.1.2 Maximum A-Posteriori Probability Classification
      2.1.3 Previous Studies of Application-Sensitive ASR
   2.2 Practical MBR Procedures for ASR
      2.2.1 Summation over Hidden State Sequences
      2.2.2 MBR Recognition with N-best Lists
      2.2.3 MBR Recognition with Lattices
   2.3 Segmented MBR Procedures
      2.3.1 Segmental Voting
      2.3.2 ROVER
Structure Guided Browsing (cont.)

Co-research with Prof. Lin-shan Lee
Implemented by Tehsuan Li, MingHan Li
Co-research with Prof. Lin-shan Lee
Implemented by Tehsuan Li, MingHan Li
Structure Guided Browsing (cont.)

• Additional facilities provided when searching

  - A history map identifies classes recently visited
  
  - Display occurrences (of terms) by showing the structures in a global context, in addition to the text positions
The Hypertext Model

• **Premise**: communication between writer and user
  
  – A sequenced organizational structure lies underneath most written text
  
  – The reader should not expect to fully understand the message conveyed by the writer by randomly reading pieces of text here and there
The Hypertext Model (cont.)

– Sometimes, we even can’t capture the information through sequential reading of the whole text

• E.g.: a book about “the history of the wars” is organized chronologically, but we only interested in “the regional wars in Europe”
  – Wars fought by each European country
  – War fought in Europe in chronological order

Rewrite the book?
Or defining a new structure?
The Hypertext Model (cont.)

- **Hypertext**
  - A high level *interactive navigational structure* allowing users to browse text non-sequentially
  - Consist of **nodes** (text regions) correlated by directed links in a graph structure
    - A **node** could be a chapter in a book, a section in an article, or a web page
    - Links are attached to specific strings inside the nodes

- Hypertexts provide the basis for HTML and HTTP
  - HTML: hypertext markup language
  - HTTP: hypertext transfer protocol
The Hypertext Model (cont.)

• **Features**
  – The process of navigating the hypertext is like a traversal of a directed graph

• **Drawbacks**
  – *Lost in hyperspace*: the user will lose track of the organizational structure of the hypertext when it is large
    • A hypertext map shows where the user is at all times (graphical user interface design)
  
  – But, the user is restricted to the intended flow of information previously convinced by the hypertext designer
    • Should take into account the needs of potential users

  *Analyzing before implementation*
  *Guiding tools needed (hypertext map)*
Trends and Research Issues

• Three main types of IR related products and systems
  - Library systems
  - Specialized retrieval systems
  - The Web

• Library systems
  – Much interest in cognitive and behavioral issues
  • Oriented particularly at a better understanding of which criteria the users adopt to judge relevance (most systems here adopt Boolean model)
    - Ranking strategies
    - User interface design
  – How to implement
Trends and Research Issues (cont.)

• **Specialized retrieval systems**
  – E.g. LEXIS-NEXIS: a system to access a very large collection of legal and business documents
  – How to retrieve almost all relevant documents without retrieving a large number of unrelated documents
    • Sophisticated ranking algorithms are desirable
Trends and Research Issues (cont.)

- **The Web**
  - User does not know what he wants or has great difficulty in properly formulating his request
  - Study how the paradigm adopted for the user interface affects the ranking
  - The indexes maintained by various Web search engine are almost disjoint
    - The intersection corresponds to less than 2% of the total number of page indexed
- **Meta-search**
  - Search engines which work by fusing the ranking generated by other search engines
Example System: Live Query Term Translation

• A Query Term Translation System developed at Academia Sinica (Prof. Lee-feng Chien)
  – Also use the meta-search strategy