CS6200
Information Retrieval

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Previously: Indexing Process

- Text Acquisition
- Index Creation
- Text Transformation

E-mail, Web pages, News articles, Memos, Letters

Document data store

Index
Query Process

User Interaction

Document data store

Ranking

Evaluation

Index

Log Data
Queries

Queries | Query Expansion | Spell Checking
Context | Presentation | Cross-Language Search
Information Needs

• An *information need* is the underlying cause of the query that a person submits to a search engine
  – sometimes called *query intent*

• Categorized using variety of dimensions
  – e.g., number of relevant documents being sought
  – type of information that is needed
  – type of task that led to the requirement for information
Queries and Information Needs

• A query can represent very different information needs
  – May require different search techniques and ranking algorithms to produce the best rankings

• A query can be a poor representation of the information need
  – User may find it difficult to express the information need
  – User is encouraged to enter short queries both by the search engine interface, and by the fact that long queries don’t work
Interaction

• Interaction with the system occurs
  – during query formulation and reformulation
  – while browsing the result

• Key aspect of effective retrieval
  – users can’t change ranking algorithm but can change results through interaction
  – helps refine description of information need
    • e.g., same initial query, different information needs
    • how does user describe what they don’t know?
ASK Hypothesis

• Belkin et al (1982) proposed a model called Anomalous State of Knowledge

• ASK hypothesis:
  – difficult for people to define exactly what their information need is, because that information is a gap in their knowledge
  – Search engine should look for information that fills those gaps

• Interesting ideas, little practical impact (yet)
Keyword Queries

• Query languages in the past were designed for professional searchers \textit{(intermediaries)}

\textit{User query:} Are there any cases which discuss negligent maintenance or failure to maintain aids to navigation such as lights, buoys, or channel markers?

\textit{Intermediary query:} NEGLECT! FAIL! NEGLIG! /5 MAINT! REPAIR! /P NAVIGAT! /5 AID EQUIP! LIGHT BUOY "CHANNEL MARKER"
Keyword Queries

• Simple, *natural language* queries were designed to enable everyone to search

• Current search engines do not perform well (in general) with natural language queries

• People trained (in effect) to use keywords
  – compare average of about 2.3 words/web query to average of 30 words/CQA query

• Keyword selection is not always easy
  – query refinement techniques can help
Query Reformulation

• Rewrite or transform original query to better match underlying intent
• Can happen implicitly or explicitly (suggestion)
• Many techniques
  – Query-based stemming
  – Spelling correction
  – Segmentation
  – Substitution
  – Expansion
Query-Based Stemming

• Make decision about stemming at query time rather than during indexing
  – improved flexibility, effectiveness
• Query is expanded using word variants
  – documents are not stemmed
  – e.g., “rock climbing” expanded with “climb”, not stemmed to “climb”
Stem Classes

• A *stem class* is the group of words that will be transformed into the same stem by the stemming algorithm
  – generated by running stemmer on large corpus
  – e.g., Porter stemmer on TREC News
    /bank banked banking bankings banks
    /ocean oceaneering oceanic oceanics oceanization oceans
    /polic polical polically police policeable policed
    -policement policer policers polices polcial
    -policically policier policiers policies policing
    -policization policize policly policy policing policys
Stem Classes

• Stem classes are often too big and inaccurate
• Modify using analysis of word co-occurrence
• Assumption:
  – Word variants that could substitute for each other should co-occur often in documents
    • e.g., reduces previous example /polic and /bank
      /policies policy
      /police policed policing
      /bank banking banks
Query Log

• Records all queries and documents clicked on by users, along with timestamp

• Used heavily for query transformation, query suggestion

• Also used for query-based stemming
  – Word variants that co-occur with other query words can be added to query
    • e.g., for the query “tropical fish”, “fishes” may be found with “tropical” in query log, but not “fishing”
    • Classic example: “strong tea” not “powerful tea”
Modifying Stem Classes

1. For all pairs of words in the stem classes, count how often they co-occur in text windows of $W$ words. $W$ is typically in the range 50-100.

2. Compute a co-occurrence or association metric for each pair. This measures how strong the association is between the words.

3. Construct a graph where the vertices represent words and the edges are between words whose co-occurrence metric is above a threshold $T$.

4. Find the connected components of this graph. These are the new stem classes.
Modifying Stem Classes

• Dices’ Coefficient is an example of a term association measure
  
  \[ 2 \frac{n_{ab}}{n_a + n_b} \]
  
  • where \( n_x \) is the number of windows containing \( x \)

• Two vertices are in the same connected component of a graph if there is a path between them
  
  – forms word clusters

• Example output of modification

• When would this fail?

/policies policy
/police policed policing
/bank banking banks
Query Segmentation

• Break up queries into important “chunks”
  – e.g., “new york times square” becomes “new york” “times square”

• Possible approaches:
  Treat each term as a concept
  \[[members] [rock] [group] [nirvana]\]
  Treat every adjacent pair of terms as a concept
  \[[members rock] [rock group] [group nirvana]\]
  Treat all terms within a noun phrase “chunk” as a concept
  \[[members] [rock group nirvana]\]
  Treat all terms that occur in common queries as a single concept
  \[[members] [rock group] [nirvana]\]
Query Expansion

Queries | Query Expansion | Spell Checking
Context | Presentation | Cross-Language Search
Query Expansion

• A variety of automatic or semi-automatic query expansion techniques have been developed
  – goal is to improve effectiveness by matching related terms
  – semi-automatic techniques require user interaction to select best expansion terms

• Query suggestion is a related technique
  – alternative queries, not necessarily more terms
The Thesaurus

• Used in early search engines as a tool for *indexing* and *query formulation*
  – specified preferred terms and relationships between them
  – also called *controlled vocabulary*
  – or *authority list*

• Particularly useful for *query expansion*
  – adding synonyms or more specific terms using query operators based on thesaurus
  – improves search effectiveness
# MeSH Thesaurus

<table>
<thead>
<tr>
<th>MeSH Heading</th>
<th>Neck Pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree Number</td>
<td>C10.597.617.576</td>
</tr>
<tr>
<td>Tree Number</td>
<td>C23.888.592.612.553</td>
</tr>
<tr>
<td>Tree Number</td>
<td>C23.888.646.501</td>
</tr>
<tr>
<td>Entry Term</td>
<td>Cervical Pain</td>
</tr>
<tr>
<td>Entry Term</td>
<td>Neckache</td>
</tr>
<tr>
<td>Entry Term</td>
<td>Anterior Cervical Pain</td>
</tr>
<tr>
<td>Entry Term</td>
<td>Anterior Neck Pain</td>
</tr>
<tr>
<td>Entry Term</td>
<td>Cervicalgia</td>
</tr>
<tr>
<td>Entry Term</td>
<td>Cervicodynia</td>
</tr>
<tr>
<td>Entry Term</td>
<td>Neck Ache</td>
</tr>
<tr>
<td>Entry Term</td>
<td>Posterior Cervical Pain</td>
</tr>
<tr>
<td>Entry Term</td>
<td>Posterior Neck Pain</td>
</tr>
</tbody>
</table>
Query Expansion

• Approaches usually based on an analysis of term co-occurrence
  – either in the entire document collection, a large collection of queries, or the top-ranked documents in a result list
  – query-based stemming also an expansion technique

• Automatic expansion based on general thesaurus not generally effective
  – does not take context into account
Term Association Measures

• *Dice’s Coefficient*

\[
\frac{2 \cdot n_{ab}}{n_a + n_b} \quad \text{rank} \quad \frac{n_{ab}}{n_a + n_b}
\]

• *(Pointwise) Mutual Information*

\[
\log \frac{P(a,b)}{P(a)P(b)} = \log N \cdot \frac{n_{ab}}{n_a \cdot n_b} \quad \text{rank} \quad \frac{n_{ab}}{n_a \cdot n_b}
\]
Term Association Measures

• Mutual Information measure favors low frequency terms

• Expected Mutual Information Measure (EMIM)

\[ P(a, b) \cdot \log \frac{P(a, b)}{P(a)P(b)} = \frac{n_{ab}}{N} \log \left( N \cdot \frac{n_{ab}}{n_a \cdot n_b} \right) \overset{\text{rank}}{=} n_{ab} \cdot \log \left( N \cdot \frac{n_{ab}}{n_a \cdot n_b} \right) \]

– actually only 1 part of full EMIM, focused on word occurrence
Term Association Measures

• *Pearson’s Chi-squared* \((x^2)\) *measure*
  
  – compares the number of co-occurrences of two words with the expected number of co-occurrences if the two words were independent
  
  – normalizes this comparison by the expected number
  
  – also limited form focused on word co-occurrence

\[
\frac{(n_{ab} - N \cdot \frac{n_a}{N} \cdot \frac{n_b}{N})^2}{N \cdot \frac{n_a}{N} \cdot \frac{n_b}{N}} \quad \text{rank} \quad \frac{(n_{ab} - \frac{1}{N} \cdot n_a \cdot n_b)^2}{n_a \cdot n_b}
\]
## Association Measure Summary

<table>
<thead>
<tr>
<th>Measure</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mutual information (MIM)</td>
<td>$\frac{n_{ab}}{n_a \cdot n_b}$</td>
</tr>
<tr>
<td>Expected Mutual Information (EMIM)</td>
<td>$n_{ab} \cdot \log(N \cdot \frac{n_{ab}}{n_a \cdot n_b})$</td>
</tr>
<tr>
<td>Chi-square ($\chi^2$)</td>
<td>$(n_{ab} - \frac{1}{N} \cdot n_a \cdot n_b)^2 \over n_a \cdot n_b$</td>
</tr>
<tr>
<td>Dice’s coefficient (Dice)</td>
<td>$\frac{n_{ab}}{n_a + n_b}$</td>
</tr>
</tbody>
</table>
Association Measure Example

<table>
<thead>
<tr>
<th>( MIM )</th>
<th>( EMIM )</th>
<th>( \chi^2 )</th>
<th>( Dice )</th>
</tr>
</thead>
<tbody>
<tr>
<td>trmm</td>
<td>forest</td>
<td>trmm</td>
<td>forest</td>
</tr>
<tr>
<td>itto</td>
<td>tree</td>
<td>itto</td>
<td>exotic</td>
</tr>
<tr>
<td>ortuno</td>
<td>rain</td>
<td>ortuno</td>
<td>timber</td>
</tr>
<tr>
<td>kuroshio</td>
<td>island</td>
<td>kuroshio</td>
<td>rain</td>
</tr>
<tr>
<td>ivirgarzama</td>
<td>like</td>
<td>ivirgarzama</td>
<td>banana</td>
</tr>
<tr>
<td>biofunction</td>
<td>fish</td>
<td>biofunction</td>
<td>deforestation</td>
</tr>
<tr>
<td>kapiolani</td>
<td>most</td>
<td>kapiolani</td>
<td>plantation</td>
</tr>
<tr>
<td>bstilla</td>
<td>water</td>
<td>bstilla</td>
<td>coconut</td>
</tr>
<tr>
<td>amalgreb</td>
<td>fruit</td>
<td>amalgreb</td>
<td>jungle</td>
</tr>
<tr>
<td>jackfruit</td>
<td>area</td>
<td>jackfruit</td>
<td>tree</td>
</tr>
<tr>
<td>adeo</td>
<td>world</td>
<td>adeo</td>
<td>rainforest</td>
</tr>
<tr>
<td>xishuangbanna</td>
<td>america</td>
<td>xishuangbanna</td>
<td>palm</td>
</tr>
<tr>
<td>frangipani</td>
<td>some</td>
<td>frangipani</td>
<td>hardwood</td>
</tr>
<tr>
<td>yuca</td>
<td>live</td>
<td>yuca</td>
<td>greenhouse</td>
</tr>
<tr>
<td>anthurium</td>
<td>plant</td>
<td>anthurium</td>
<td>logging</td>
</tr>
</tbody>
</table>

Most strongly associated words for “tropical” in a collection of TREC news stories. Co-occurrence counts are measured at the document level.
# Association Measure Example

<table>
<thead>
<tr>
<th></th>
<th>MIM</th>
<th>EMIM</th>
<th>$\chi^2$</th>
<th>Dice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>zoologico</td>
<td>water</td>
<td>arlsq</td>
<td>species</td>
</tr>
<tr>
<td></td>
<td>zapanta</td>
<td>species</td>
<td>happyman</td>
<td>wildlife</td>
</tr>
<tr>
<td></td>
<td>wrint</td>
<td>wildlife</td>
<td>outerlimit</td>
<td>fishery</td>
</tr>
<tr>
<td></td>
<td>wpfmc</td>
<td>fishery</td>
<td>sportk</td>
<td>water</td>
</tr>
<tr>
<td></td>
<td>weighout</td>
<td>sea</td>
<td>lingcod</td>
<td>fisherman</td>
</tr>
<tr>
<td></td>
<td>waterdog</td>
<td>fisherman</td>
<td>longfin</td>
<td>boat</td>
</tr>
<tr>
<td></td>
<td>longfin</td>
<td>boat</td>
<td>bontadelli</td>
<td>sea</td>
</tr>
<tr>
<td></td>
<td>veracruzana</td>
<td>area</td>
<td>sportfisher</td>
<td>habitat</td>
</tr>
<tr>
<td></td>
<td>ungutt</td>
<td>habitat</td>
<td>billfish</td>
<td>vessel</td>
</tr>
<tr>
<td></td>
<td>ulocentra</td>
<td>vessel</td>
<td>needlefish</td>
<td>marine</td>
</tr>
<tr>
<td></td>
<td>needlefish</td>
<td>marine</td>
<td>damaliscu</td>
<td>endanger</td>
</tr>
<tr>
<td></td>
<td>tunaboat</td>
<td>land</td>
<td>bontebok</td>
<td>conservation</td>
</tr>
<tr>
<td></td>
<td>tsolwana</td>
<td>river</td>
<td>taucher</td>
<td>river</td>
</tr>
<tr>
<td></td>
<td>olivacea</td>
<td>food</td>
<td>orangemouth</td>
<td>catch</td>
</tr>
<tr>
<td></td>
<td>motorroller</td>
<td>endanger</td>
<td>sheepshead</td>
<td>island</td>
</tr>
</tbody>
</table>

Most strongly associated words for “fish” in a collection of TREC news stories.
### Association Measure Example

<table>
<thead>
<tr>
<th>MIM</th>
<th>EMIM</th>
<th>$\chi^2$</th>
<th>Dice</th>
</tr>
</thead>
<tbody>
<tr>
<td>zapanta</td>
<td>wildlife</td>
<td>gefilte</td>
<td>wildlife</td>
</tr>
<tr>
<td>plar</td>
<td>vessel</td>
<td>mbmo</td>
<td>vessel</td>
</tr>
<tr>
<td>mbmo</td>
<td>boat</td>
<td>zapanta</td>
<td>boat</td>
</tr>
<tr>
<td>gefilte</td>
<td>fishery</td>
<td>plar</td>
<td>fishery</td>
</tr>
<tr>
<td>hapc</td>
<td>species</td>
<td>hapc</td>
<td>species</td>
</tr>
<tr>
<td>odfw</td>
<td>tuna</td>
<td>odfw</td>
<td>catch</td>
</tr>
<tr>
<td>southpoint</td>
<td>trout</td>
<td>southpoint</td>
<td>water</td>
</tr>
<tr>
<td>anadromous</td>
<td>fisherman</td>
<td>anadromous</td>
<td>sea</td>
</tr>
<tr>
<td>taiffe</td>
<td>salmon</td>
<td>taiffe</td>
<td>meat</td>
</tr>
<tr>
<td>mollie</td>
<td>catch</td>
<td>mollie</td>
<td>interior</td>
</tr>
<tr>
<td>frampton</td>
<td>nmf</td>
<td>frampton</td>
<td>fisherman</td>
</tr>
<tr>
<td>idfg</td>
<td>trawl</td>
<td>idfg</td>
<td>game</td>
</tr>
<tr>
<td>billingsgate</td>
<td>halibut</td>
<td>billingsgate</td>
<td>salmon</td>
</tr>
<tr>
<td>sealord</td>
<td>meat</td>
<td>sealord</td>
<td>tuna</td>
</tr>
<tr>
<td>longline</td>
<td>shellfish</td>
<td>longline</td>
<td>caught</td>
</tr>
</tbody>
</table>

Most strongly associated words for “fish” in a collection of TREC news stories. Co-occurrence counts are measured in windows of 5 words.
Association Measures

- Associated words are of little use for expanding the query “tropical fish”
- Expansion based on whole query takes context into account
  - e.g., using Dice with term “tropical fish” gives the following highly associated words:
    goldfish, reptile, aquarium, coral, frog, exotic, stripe, regent, pet, wet
- Impractical for all possible queries, other approaches used to achieve this effect
Other Approaches

• **Pseudo-relevance feedback**
  – expansion terms based on top retrieved documents for initial query

• **Context vectors**
  – Represent words by the words that co-occur with them
    – e.g., top 35 most strongly associated words for “aquarium” (using Dice’s coefficient):
      - zoology, cranmore, jouett, zoo, goldfish, fish, cannery, urchin, reptile, coral, animal, mollusk, marine, underwater, plankton, mussel, oceanography, mammal, species, exhibit, swim, biologist, cabrillo, saltwater, creature, reef, whale, oceanic, scuba, kelp, invertebrate, park, crustacean, wild, tropical
  
  – Rank words for a query by ranking context vectors
Other Approaches

• Query logs
  – Best source of information about queries and related terms
    • short pieces of text and click data
  – e.g., most frequent words in queries containing “tropical fish” from MSN log:
    stores, pictures, live, sale, types, clipart, blue, freshwater, aquarium, supplies
  – Query suggestion based on finding similar queries
    • group based on click data
  – Query reformulation/expansion based on term associations in logs
## Query Suggestion using Logs

<table>
<thead>
<tr>
<th>Orig. Query</th>
<th>NDCG@10</th>
<th>New Query</th>
<th>NDCG@10</th>
</tr>
</thead>
<tbody>
<tr>
<td>moths</td>
<td>0.1714</td>
<td>where do you find white moths</td>
<td>0.389</td>
</tr>
<tr>
<td>iron</td>
<td>0.0</td>
<td>normal iron levels for women</td>
<td>0.7315</td>
</tr>
<tr>
<td>getting organized</td>
<td>0.2341</td>
<td>free printable planner</td>
<td>0.4603</td>
</tr>
<tr>
<td>arizona game and fish</td>
<td>0.164</td>
<td>az fish and game</td>
<td>0.1712</td>
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<tr>
<td>kcs</td>
<td>0.0</td>
<td>kansas city southern</td>
<td>0.4026</td>
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<tr>
<td>starbucks</td>
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<td>sbux</td>
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<td>used car parts</td>
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<td>used auto parts</td>
<td>0.3083</td>
</tr>
<tr>
<td>used car parts</td>
<td>0.1197</td>
<td>salvage yards</td>
<td>0.3464</td>
</tr>
<tr>
<td>dinosaurs</td>
<td>0.0</td>
<td>dinosaurs pictures</td>
<td>0.224</td>
</tr>
<tr>
<td>map</td>
<td>0.0</td>
<td><a href="http://www.mapquest.com">www.mapquest.com</a></td>
<td>0.0792</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Orig. Query</th>
<th>NDCG@10</th>
<th>New Query</th>
<th>NDCG@10</th>
</tr>
</thead>
<tbody>
<tr>
<td>penguins</td>
<td>0.2578</td>
<td>official pittsburgh penguins website</td>
<td>0.5062</td>
</tr>
<tr>
<td>bellevue</td>
<td>0.103</td>
<td>bellevue washington</td>
<td>0.6823</td>
</tr>
<tr>
<td>tornadoes</td>
<td>0.468</td>
<td>questions and answers about tornadoes</td>
<td>0.7382</td>
</tr>
<tr>
<td>ocd</td>
<td>0.041</td>
<td>obsessive compulsive disorder</td>
<td>0.2107</td>
</tr>
<tr>
<td>kcs</td>
<td>0.0</td>
<td>kansas city southern</td>
<td>0.4026</td>
</tr>
<tr>
<td>kcs</td>
<td>0.0</td>
<td><a href="http://www.kcsi.com">www.kcsi.com</a></td>
<td>0.5049</td>
</tr>
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<td>0.0</td>
<td>permitted and prohibited items</td>
<td>0.0245</td>
</tr>
<tr>
<td>atari</td>
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<td>infogrames</td>
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<td>tornadoes</td>
<td>0.468</td>
<td>noaa tornadoes</td>
<td>0.6153</td>
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</tbody>
</table>
### Query Reformulation using Logs

<table>
<thead>
<tr>
<th>MSN Log</th>
<th>Original Query</th>
<th>Expanded Query</th>
<th>Original Query</th>
<th>Expanded Query</th>
</tr>
</thead>
<tbody>
<tr>
<td>hunting deaths</td>
<td>hunting #syn(deaths accidents)</td>
<td>railway accidents #syn(railway train) accidents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>new fuel sources</td>
<td>new #syn(fuel energy) sources</td>
<td>oscar winner selection Oscar winner #syn(selection promotion)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>educational standards #syn(educational teaching) standards</td>
<td>marine vegetation marine #syn(vegetation plants)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>automobile recalls #syn(automobile auto) recalls</td>
<td>overseas tobacco sales overseas #syn(tobacco cigarettes) sales</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>doctor assisted suicides #syn(doctor physicians) assisted suicides</td>
<td>food drug laws food drug #syn(laws act)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cheese production cheese #syn(production companies)</td>
<td>volkswagen mexico #syn(volkswagen vw) mexico</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>illegal immigrant wages illegal Immigrant #syn(wages working)</td>
<td>chevrolet trucks #syn(chevrolet chevy) trucks</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>发动机 Log</th>
<th>Original Query</th>
<th>Expanded Query</th>
<th>Original Query</th>
<th>Expanded Query</th>
</tr>
</thead>
<tbody>
<tr>
<td>hunting deaths</td>
<td>hunting #syn(deaths accidents)</td>
<td>railway accidents #syn(railway railroad) accidents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>new fuel sources</td>
<td>new #syn(fuel energy) sources</td>
<td>pearl farming pearl #syn(farming industry)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>educational standards #syn(educational teaching) standards</td>
<td>eskimo history eskimo #syn(history culture)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>automobile recalls #syn(automobile auto)</td>
<td>international art crime international art #syn(crime fraud)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>doctor assisted suicides #syn(doctor physicians) assisted suicides</td>
<td>wildlife extinction #syn(wildlife animals) extinction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cheese production cheese #syn(production prices)</td>
<td>blood alcohol fatalities blood alcohol #syn(fatalities deaths)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>illegal immigrant wages illegal #syn(immigrant workers) wages</td>
<td>windmill electricity windmill #syn(electricity power)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Spell Checking

Queries | Query Expansion | Spell Checking
Context | Presentation | Cross-Language Search
Spell Checking

• Important part of query processing
  – 10-15% of all web queries have spelling errors
• Errors include typical word processing errors but also many other types, e.g.

  pointer sisters
  brimingham news
  catamarn sailing
  hair extensions
  marshmellow world
  miniture golf courses
  psyhics
  home doceration

  realstateisting.bc.com
  akia 1080i manunal
  ultimatwarcade
  mainscourcebank
  dellottitouche
Spell Checking

• Basic approach: suggest corrections for words not found in *spelling dictionary*
• Suggestions found by comparing word to words in dictionary using similarity measure
• Most common similarity measure is *edit distance*
  – number of operations required to transform one word into the other
Edit Distance

- *Damerau-Levenshtein* distance
  - counts the minimum number of insertions, deletions, substitutions, or transpositions of single characters required
  - e.g., Damerau-Levenshtein distance 1
    - *extensions* → *extension* (insertion error)
    - *poiner* → *pointer* (deletion error)
    - *marshmellow* → *marshmallow* (substitution error)
    - *brimingham* → *birmingham* (transposition error)
  - **distance 2**
    - *doceration* → *deceration*
    - *deceration* → *decoration*
Edit Distance

• Dynamic programming algorithm (on board)
Edit Distance

• Number of techniques used to speed up calculation of edit distances
  – restrict to words starting with same character
  – restrict to words of same or similar length
  – restrict to words that sound the same

• Last option uses a *phonetic code* to group words
  – e.g. Soundex
Soundex Code

1. Keep the first letter (in upper case).
2. Replace these letters with hyphens: a,e,i,o,u,y,h,w.
3. Replace the other letters by numbers as follows:
   1: b,f,p,v
   2: c,g,j,k,q,s,x,z
   3: d,t
   4: l
   5: m,n
   6: r
4. Delete adjacent repeats of a number.
5. Delete the hyphens.
6. Keep the first three numbers or pad out with zeros.

extensions → E235; extensions → E235
marshmellow → M625; marshmallow → M625
brimingham → B655; birmingham → B655
poiner → P560; pointer → P536
Spelling Correction Issues

• Ranking corrections
  – “Did you mean...” feature requires accurate ranking of possible corrections

• Context
  – Choosing right suggestion depends on context (other words)
    – e.g., lawers → lowers, lawyers, layers, lasers, lagers
      but trial lawers → trial lawyers

• Run-on errors
  – e.g., “mainscourcebank”
  – missing spaces can be considered another single character error in right framework
Noisy Channel Model

- User chooses word $w$ based on probability distribution $P(w)$
  - called the \textit{language model}
  - can capture context information, e.g. $P(w_1|w_2)$
- User writes word, but noisy channel causes word $e$ to be written instead with probability $P(e|w)$
  - called \textit{error model}
  - represents information about the frequency of spelling errors
Noisy Channel Model

• Need to estimate probability of correction
  \[ P(w|e) = P(e|w)P(w) \]

• Estimate language model using context
  – e.g., \( P(w) = \lambda P(w) + (1 - \lambda)P(w|w_p) \)
  – \( w_p \) is previous word

• e.g.,
  – “fish tink”
  – “tank” and “think” both likely corrections, but \( P(\text{tank}|\text{fish}) > P(\text{think}|\text{fish}) \)
Noisy Channel Model

• Language model probabilities estimated using corpus and query log
• Both simple and complex methods have been used for estimating error model
  – simple approach: assume all words with same edit distance have same probability, only edit distance 1 and 2 considered
  – more complex approach: incorporate estimates based on common typing errors
Example Spellcheck Process

1. Tokenize the query.

2. For each token, a set of alternative words and pairs of words is found using an edit distance modified by weighting certain types of errors as described above. The data structure that is searched for the alternatives contains words and pairs from both the query log and the trusted dictionary.

3. The noisy channel model is then used to select the best correction.

4. The process of looking for alternatives and finding the best correction is repeated until no better correction is found.

   e.g.,
   miniture golfcurses
   miniature golfcourses
   miniature golf courses
Context

Queries | Query Expansion | Spell Checking

Context | Presentation | Cross-Language Search
Relevance Feedback

• User identifies relevant (and maybe non-relevant) documents in the initial result list
• System modifies query using terms from those documents and reranks documents
  – example of simple machine learning algorithm using training data
  – but, very little training data
• Pseudo-relevance feedback just assumes top-ranked documents are relevant - no user input
  – In machine learning, aka self-training or bootstrapping
Relevance Feedback Example

1. **Badmans Tropical Fish**
   A freshwater aquarium page covering all aspects of the tropical fish hobby. ... to Badman's Tropical Fish. ... world of aquariology with Badman's Tropical Fish. ...

2. **Tropical Fish**
   Notes on a few species and a gallery of photos of African cichlids.

3. **The Tropical Tank Homepage - Tropical Fish and Aquariums**
   Info on tropical fish and tropical aquariums, large fish species index with ... Here you will find lots of information on Tropical Fish and Aquariums. ...

4. **Tropical Fish Centre**
   Offers a range of aquarium products, advice on choosing species, feeding, and health care, and a discussion board.

5. **Tropical fish - Wikipedia, the free encyclopedia**
   Tropical fish are popular aquarium fish, due to their often bright coloration. ... Practical Fishkeeping • Tropical Fish Hobbyist • Koi. Aquarium related companies. ...

6. **Tropical Fish Find**
   Home page for Tropical Fish Internet Directory ... stores, forums, clubs, fish facts, tropical fish compatibility and aquarium ...

7. **Breeding tropical fish**
   ... interested in keeping and/or breeding Tropical, Marine, Pond and Coldwater fish ... Breeding Tropical Fish ... breeding tropical, marine, coldwater & pond fish. ...

8. **FishLore**
   Includes tropical freshwater aquarium how-to guides, FAQs, fish profiles, articles, and forums.

9. **Cathy's Tropical Fish Keeping**
   Information on setting up and maintaining a successful freshwater aquarium.

10. **Tropical Fish Place**
    Tropical Fish information for your freshwater fish tank ... great amount of information about a great hobby, a freshwater tropical fish tank. ...
Relevance Feedback Example

• If we assume top 10 are relevant, most frequent terms are (with frequency):
  a (926), td (535), href (495), http (357), width (345), com (343), nbsp (316), www (260), tr (239), htm (233), class (225), jpg (221)

• too many stopwords and HTML expressions

• Use only snippets and remove stopwords
  tropical (26), fish (28), aquarium (8), freshwater (5), breeding (4), information (3), species (3), tank (2), Badman’s (2), page (2), hobby (2), forums (2)
Relevance Feedback Example

• If document 7 (“Breeding tropical fish”) is *explicitly* indicated to be relevant, the most frequent terms are:
  - breeding (4), fish (4), tropical (4), marine (2), pond (2), coldwater (2), keeping (1), interested (1)

• Specific weights and scoring methods used for relevance feedback depend on retrieval model
Relevance Feedback

• Both relevance feedback and pseudo-relevance feedback are effective, but not used in many applications
  – pseudo-relevance feedback has reliability issues, especially with queries that don’t retrieve many relevant documents

• Some applications use relevance feedback
  – filtering, “more like this”

• Query suggestion more popular
  – may be less accurate, but can work if initial query fails
Context and Personalization

• If a query has the same words as another query, should results be the same regardless of
  – who submitted the query,
  – why the query was submitted,
  – where the query was submitted, or
  – what other queries were submitted in the same session?

• These other factors (the context) could have a significant impact on relevance
User Models

• Generate user profiles based on documents that the person looks at
  – such as web pages visited, email messages, or word processing documents on the desktop

• Modify queries using words from profile

• Generally not effective
  – imprecise profiles, information needs can change significantly
Query Logs

• Query logs provide important contextual information that can be used effectively

• Context in this case is
  – previous queries that are the same
  – previous queries that are similar
  – query sessions including the same query

• Query history for individuals could be used for caching or query transformation
Local Search

• Location is context

• *Local search* uses geographic information to modify the ranking of search results
  – location derived from the query text
  – location of the device where the query originated

• e.g.,
  – “underworld 3 cape cod”
  – “underworld 3” from mobile device in Hyannis
Local Search

• Identify the geographic region associated with web pages
  – use location metadata that has been manually added to the document,
  – or identify locations such as place names, city names, or country names in text

• Identify the geographic region associated with the query
  – 10-15% of queries contain some location reference

• Rank web pages using location information in addition to text and link-based features
Extracting Location Information

• Type of information extraction
  – ambiguity and significance of locations are issues

• Location names are mapped to specific regions and coordinates

• Matching done by inclusion, distance
Advertising

• *Sponsored search* - advertising presented with search results
• *Contextual advertising* - advertising presented when browsing web pages
• Both involve finding the most relevant advertisements in a database
  – An advertisement usually consists of a short text description and a link to a web page describing the product or service in more detail
Searching Advertisements

• Factors involved in ranking advertisements
  – similarity of text content to query
  – bids for keywords in query
  – popularity of advertisement

• Small amount of text in advertisement
  – dealing with vocabulary mismatch is important
  – expansion techniques are effective
Example Advertisements

**fish tanks at Target**
Find **fish tanks** Online. Shop & Save at Target.com Today.
www.target.com

**Aquariums**
540+ Aquariums at Great Prices.
fishbowls.pronto.com

**Freshwater Fish Species**
Everything you need to know to keep your setup clean and beautiful
www.FishChannel.com

**Pet Supplies at Shop.com**
Shop millions of products and buy from our trusted merchants.
shop.com

**Custom Fish Tanks**
Choose From 6,500+ Pet Supplies. Save On Custom **Fish Tanks**!
shopzilla.com

Advertisements retrieved for query “fish tank”
Searching Advertisements

• Pseudo-relevance feedback
  – expand query and/or document using the Web
  – use ad text or query for pseudo-relevance feedback
  – rank exact matches first, followed by stem matches, followed by expansion matches

• Query reformulation based on query log
Presentation

Queries | Query Expansion | Spell Checking
Context | Presentation | Cross-Language Search
Snippet Generation

**Tropical Fish**
One of the U.K.'s Leading suppliers of Tropical, Coldwater, Marine Fish and Invertebrates plus... next day fish delivery service ...
www.tropicalfish.org.uk/tropical_fish.htm  Cached page

- Query-dependent document summary
- Simple summarization approach
  - rank each sentence in a document using a *significance factor*
  - select the top sentences for the summary
  - first proposed by Luhn in 50’s
Sentence Selection

• Significance factor for a sentence is calculated based on the occurrence of significant words
  – If $f_{d,w}$ is the frequency of word $w$ in document $d$, then $w$ is a significant word if it is not a stopword and
    $$f_{d,w} \geq \begin{cases} 
      7 - 0.1 \times (25 - s_d), & \text{if } s_d < 25 \\
      7, & \text{if } 25 \leq s_d \leq 40 \\
      7 + 0.1 \times (s_d - 40), & \text{otherwise}
    \end{cases}$$
    where $s_d$ is the number of sentences in document $d$
  – text is bracketed by significant words (limit on number of non-significant words in bracket)
Sentence Selection

• Significance factor for bracketed text spans is computed by dividing the square of the number of significant words in the span by the total number of words.

• e.g.,

  \[ \text{w w w w w w w w w w w w.} \]
  (Initial sentence)

  \[ \text{w w s w s s w w s w w.} \]
  (Identify significant words)

  \[ \text{w w [s w s s w w s] w w.} \]
  (Text span bracketed by significant words)

• Significance factor = \( \frac{4^2}{7} = 2.3 \)
Snippet Generation

• Involves more features than just significance factor

• e.g. for a news story, could use
  – whether the sentence is a heading
  – whether it is the first or second line of the document
  – the total number of query terms occurring in the sentence
  – the number of unique query terms in the sentence
  – the longest contiguous run of query words in the sentence
  – a density measure of query words (significance factor)

• Weighted combination of features used to rank sentences
Snippet Generation

• Web pages are less structured than news stories
  – can be difficult to find good summary sentences
• Snippet sentences are often selected from other sources
  – metadata associated with the web page
    • e.g., <meta name="description" content= ...>
  – external sources such as web directories
    • e.g., Open Directory Project, http://www.dmoz.org
• Snippets can be generated from text of pages like Wikipedia
Snippet Guidelines

• All query terms should appear in the summary, showing their relationship to the retrieved page
• When query terms are present in the title, they need not be repeated
  – allows snippets that do not contain query terms
• Highlight query terms in URLs
• Snippets should be readable text, not lists of keywords
Clustering Results

• Result lists often contain documents related to different *aspects* of the query topic

• *Clustering* is used to group related documents to simplify

Example clusters for query “tropical fish”

- Pictures (38)
- Aquarium Fish (28)
- Tropical Fish Aquarium (26)
- Exporter (31)
- Supplies (32)
- Plants, Aquatic (18)
- Fish Tank (15)
- Breeding (16)
- Marine Fish (16)
- Aquaria (9)
Result List Example

1. **Badmans Tropical Fish**
   A freshwater aquarium page covering all aspects of the tropical fish hobby. ... to Badman's Tropical Fish. ... world of aquariology with Badman's Tropical Fish.

2. **Tropical Fish**
   Notes on a few species and a gallery of photos of African cichlids.

3. **The Tropical Tank Homepage - Tropical Fish and Aquariums**
   Info on tropical fish and tropical aquariums, large fish species index with ... Here you will find lots of information on Tropical Fish and Aquariums.

4. **Tropical Fish Centre**
   Offers a range of aquarium products, advice on choosing species, feeding, and health care, and a discussion board.

5. **Tropical fish - Wikipedia, the free encyclopedia**
   Tropical fish are popular aquarium fish, due to their often bright coloration. ... Practical Fishkeeping • Tropical Fish Hobbyist • Koi. Aquarium related companies.

6. **Tropical Fish Find**
   Home page for Tropical Fish Internet Directory ... stores, forums, clubs, fish facts, tropical fish compatibility and aquarium.

7. **Breeding tropical fish**
   ... interested in keeping and/or breeding Tropical, Marine, Pond and Coldwater fish. ... Breeding Tropical Fish ... breeding tropical, marine, coldwater & pond fish.

8. **FishLore**
   Includes tropical freshwater aquarium how-to guides, FAQs, fish profiles, articles, and forums.

9. **Cathy's Tropical Fish Keeping**
   Information on setting up and maintaining a successful freshwater aquarium.

10. **Tropical Fish Place**
    Tropical Fish information for your freshwater fish tank ... great amount of information about a great hobby, a freshwater tropical fish tank.
Clustering Results

• Requirements

• Efficiency
  – must be specific to each query and are based on the top-ranked documents for that query
  – typically based on snippets

• Easy to understand
  – Can be difficult to assign good labels to groups
  – Monothetic vs. polythetic classification
Types of Classification

• Monothetic
  – every member of a class has the property that defines the class
  – typical assumption made by users
  – easy to understand

• Polythethetic
  – members of classes share many properties but there is no single defining property
  – most clustering algorithms (e.g. K-means) produce this type of output
Classification Example

\[ D_1 = \{a, b, c\} \]
\[ D_2 = \{a, d, e\} \]
\[ D_3 = \{d, e, f, g\} \]
\[ D_4 = \{f, g\} \]

• Possible monothetic classification
  – \{D_1, D_2\} (labeled using a) and \{D_2, D_3\} (labeled e)

• Possible polythetic classification
  – \{D_2, D_3, D_4\}, D_1
  – labels?
Result Clusters

• Simple algorithm
  – group based on words in snippets

• Refinements
  – use phrases
  – use more features
    • whether phrases occurred in titles or snippets
    • length of the phrase
    • collection frequency of the phrase
    • overlap of the resulting clusters,

<table>
<thead>
<tr>
<th>Phrase</th>
<th>Count</th>
<th>Titles</th>
<th>Snippets</th>
</tr>
</thead>
<tbody>
<tr>
<td>aquarium</td>
<td>5</td>
<td>1, 3, 4, 5, 8</td>
<td></td>
</tr>
<tr>
<td>freshwater</td>
<td>4</td>
<td>1, 8, 9, 10</td>
<td></td>
</tr>
<tr>
<td>species</td>
<td>3</td>
<td>2, 3, 4</td>
<td></td>
</tr>
<tr>
<td>hobby</td>
<td>3</td>
<td>1, 5, 10</td>
<td></td>
</tr>
<tr>
<td>forums</td>
<td>2</td>
<td>6, 8</td>
<td></td>
</tr>
</tbody>
</table>
Faceted Classification

• A set of categories, usually organized into a hierarchy, together with a set of facets that describe the important properties associated with the category
• Manually defined
  – potentially less adaptable than dynamic classification
• Easy to understand
  – commonly used in e-commerce
## Example Faceted Classification

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Books</td>
<td>7,845</td>
</tr>
<tr>
<td>Home &amp; Garden</td>
<td>2,477</td>
</tr>
<tr>
<td>Apparel</td>
<td>236</td>
</tr>
<tr>
<td>Home Improvement</td>
<td>169</td>
</tr>
<tr>
<td>Jewelry &amp; Watches</td>
<td>76</td>
</tr>
<tr>
<td>Sports &amp; Outdoors</td>
<td>71</td>
</tr>
<tr>
<td>Office Products</td>
<td>68</td>
</tr>
<tr>
<td>Toys &amp; Games</td>
<td>62</td>
</tr>
<tr>
<td>Everything Else</td>
<td>44</td>
</tr>
<tr>
<td>Electronics</td>
<td>26</td>
</tr>
<tr>
<td>Baby</td>
<td>25</td>
</tr>
<tr>
<td>DVD</td>
<td>12</td>
</tr>
<tr>
<td>Music</td>
<td>11</td>
</tr>
<tr>
<td>Software</td>
<td>10</td>
</tr>
<tr>
<td>Gourmet Food</td>
<td>6</td>
</tr>
<tr>
<td>Beauty</td>
<td>4</td>
</tr>
<tr>
<td>Automotive</td>
<td>4</td>
</tr>
<tr>
<td>Magazine Subscriptions</td>
<td>3</td>
</tr>
<tr>
<td>Health &amp; Personal Care</td>
<td>3</td>
</tr>
<tr>
<td>Wireless Accessories</td>
<td>2</td>
</tr>
<tr>
<td>Video Games</td>
<td>1</td>
</tr>
</tbody>
</table>

### Categories for “tropical fish”
Example Faceted Classification

<table>
<thead>
<tr>
<th>Subcategories and facets for “Home &amp; Garden”</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Home &amp; Garden</strong></td>
</tr>
<tr>
<td>Kitchen &amp; Dining (149)</td>
</tr>
<tr>
<td>Furniture &amp; Décor (1,776)</td>
</tr>
<tr>
<td>Pet Supplies (368)</td>
</tr>
<tr>
<td>Bedding &amp; Bath (51)</td>
</tr>
<tr>
<td>Patio &amp; Garden (22)</td>
</tr>
<tr>
<td>Art &amp; Craft Supplies (12)</td>
</tr>
<tr>
<td>Home Appliances (2)</td>
</tr>
<tr>
<td>Vacuums, Cleaning &amp; Storage (107)</td>
</tr>
<tr>
<td><strong>Brand</strong></td>
</tr>
<tr>
<td>&lt;brand names&gt;</td>
</tr>
<tr>
<td><strong>Seller</strong></td>
</tr>
<tr>
<td>&lt;vendor names&gt;</td>
</tr>
<tr>
<td><strong>Discount</strong></td>
</tr>
<tr>
<td>Up to 25% off (563)</td>
</tr>
<tr>
<td>25% - 50% off (472)</td>
</tr>
<tr>
<td>50% - 70% off (46)</td>
</tr>
<tr>
<td>70% off or more (46)</td>
</tr>
<tr>
<td><strong>Price</strong></td>
</tr>
<tr>
<td>$0-$24 (1,032)</td>
</tr>
<tr>
<td>$25-$49 (394)</td>
</tr>
<tr>
<td>$50-$99 (797)</td>
</tr>
<tr>
<td>$100-$199 (206)</td>
</tr>
<tr>
<td>$200-$499 (39)</td>
</tr>
<tr>
<td>$500-$999 (9)</td>
</tr>
<tr>
<td>$1000-$1999 (5)</td>
</tr>
<tr>
<td>$5000-$9999 (7)</td>
</tr>
</tbody>
</table>
Cross-Language Search

Queries | Query Expansion | Spell Checking
Context | Presentation | Cross-Language Search
Cross-Language Search

• Query in one language, retrieve documents in multiple other languages
• Involves query translation, and probably document translation
• Query translation can be done using bilingual dictionaries
• Document translation requires more sophisticated statistical translation models – similar to some retrieval models
Cross-Language Search
Translation

• Web search engines use translation
  – e.g. for query “pecheur france”

Le pêcheur de France archives @ peche poissons - [ Translate this page ]

Le pêcheur de France Les média Revues de pêche Revue de presse Archives de la revue
Le pêcheur de France janvier 2003 n°234 Le pêcheur de France mars 2003 ...

– translation link translates web page
– uses statistical machine translation models
Statistical Translation Models

• Models require *parallel corpora* for training
  – probability estimates based on *aligned* sentences

• Translation of unusual words and phrases is a problem
  – also use *transliteration* techniques
    • e.g., Qathafi, Kaddafi, Qadafi, Gadafi, Gaddafi, Kathafi, Kadhafi, Qadhafi, Qazzafi, Kazafi, Qaddafy, Qadafy, Quadhaffi, Gadhdhafi, al-Qaddafi, Al-Qaddafi
Statistical Translation Models

- Translation models
  - “Adequacy”
  - Assign better scores to accurate (and complete) translations

- Language models
  - “Fluency”
  - Assign better scores to natural target language text

- Compare: Error models and language models for spelling correction
  - Warren Weaver: “When I see an article in Russian, I say, ‘This is really written in English, but in some strange symbols. I will now proceed to decode.’”
I did not unfortunately receive an answer to this question.

Blue word links aren’t observed in data.

Features for word-word links: lexica, part-of-speech, orthography, etc.
Word Translation Models

- Usually directed: each word in the target generated by one word in the source
- Many-many and null-many links allowed
- Classic IBM models of Brown et al.
- Used now mostly for word alignment, not translation
Phrase Translation Models

Not necessarily syntactic phrases

Division into phrases is hidden

Auf diese Frage habe ich leider keine Antwort bekommen

I did not unfortunately receive an answer to this question

Score each phrase pair using several features

Phrase= 0.212121, 0.0550809; lex= 0.0472973, 0.0260183; lcount=2.718

What are some other features?
Phrase Translation Models

• Capture translations in context
  – *en Amerique*: to America
  – *en anglais*: in English

• State-of-the-art for several years

• Each source/target phrase pair is scored by several weighted features.

• The weighted sum of model features is the whole translation’s score.

• Phrases don’t overlap (cf. language models) but have “reordering” features.
I did not unfortunately receive an answer to this question.

*Parse trees with deeper structure have also been used.*
Single-Tree Translation Models

- Either source or target has a hidden tree/parse structure
  - Also known as “tree-to-string” or “tree-transducer” models
- The side with the tree generates words/phrases in tree, not string, order.
- Nodes in the tree also generate words/phrases on the other side.
- English side is often parsed, whether it’s source or target, since English parsing is more advanced.
I did not unfortunately receive an answer to this question.
Tree-Tree Translation Models

• Both sides have hidden tree structure
  – Can be represented with a “synchronous” grammar
• Some models assume isomorphic trees, where parent-child relations are preserved; others do not.
• Trees can be fixed in advance by monolingual parsers or induced from data (e.g. Hiero).
• Cheap trees: project from one side to the other
Projecting Hidden Structure

Annotations From Existing English Tools

[PLACE]

[National laws] applying in [Hong Kong]

Induced Annotations for Chinese
Projection

- Train with bitext
- Parse one side
- Align words
- Project dependencies
- Many to one links?
- Non-projective and circular dependencies?