Data Warehousing
資料倉儲

Social Network Analysis, Link Mining, Text and Web Mining

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http://mail.im.tku.edu.tw/~myday/
2011-05-10
<table>
<thead>
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<td>100/02/15</td>
<td>Introduction to Data Warehousing</td>
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<td>Social Network Analysis, Link Mining, Text and Web Mining</td>
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<td>Project Presentation</td>
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<td>15</td>
<td>100/05/24</td>
<td>Final Exam (畢業班考試)</td>
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Learning Objective

• Social Network Analysis
• Link Mining
• Text and Web Mining
Social Network Analysis

• A social network is a social structure of people, related (directly or indirectly) to each other through a common relation or interest

• Social network analysis (SNA) is the study of social networks to understand their structure and behavior

Source: (c) Jaideep Srivastava, srivasta@cs.umn.edu, Data Mining for Social Network Analysis
Social Network Analysis

• Using Social Network Analysis, you can get answers to questions like:
  – How highly connected is an entity within a network?
  – What is an entity's overall importance in a network?
  – How central is an entity within a network?
  – How does information flow within a network?

Source: http://www.fmsasg.com/SocialNetworkAnalysis/
Alice has the highest degree centrality, which means that she is quite active in the network. However, she is not necessarily the most powerful person because she is only directly connected within one degree to people in her clique—she has to go through Rafael to get to other cliques.

Source: http://www.fmsasg.com/SocialNetworkAnalysis/
Social Network Analysis: Degree Centrality

• Degree centrality is simply the number of direct relationships that an entity has.

• An entity with high degree centrality:
  – Is generally an active player in the network.
  – Is often a connector or hub in the network.
  – Is not necessarily the most connected entity in the network (an entity may have a large number of relationships, the majority of which point to low-level entities).
  – May be in an advantaged position in the network.
  – May have alternative avenues to satisfy organizational needs, and consequently may be less dependent on other individuals.
  – Can often be identified as third parties or deal makers.

Source: http://www.fmsasg.com/SocialNetworkAnalysis/
Rafael has the highest betweenness because he is between Alice and Aldo, who are between other entities. Alice and Aldo have a slightly lower betweenness because they are essentially only between their own cliques. Therefore, although Alice has a higher degree centrality, Rafael has more importance in the network in certain respects.
Social Network Analysis: Betweenness Centrality

- Betweenness centrality identifies an entity's position within a network in terms of its ability to make connections to other pairs or groups in a network.

- An entity with a high betweenness centrality generally:
  - Holds a favored or powerful position in the network.
  - Represents a single point of failure—take the single betweenness spanner out of a network and you sever ties between cliques.
  - Has a greater amount of influence over what happens in a network.

Rafael has the highest closeness centrality because he can reach more entities through shorter paths. As such, Rafael's placement allows him to connect to entities in his own clique, and to entities that span cliques.
Social Network Analysis: Closeness Centrality

• Closeness centrality measures how quickly an entity can access more entities in a network.

• An entity with a high closeness centrality generally:
  – Has quick access to other entities in a network.
  – Has a short path to other entities.
  – Is close to other entities.
  – Has high visibility as to what is happening in the network.

Source: http://www.fmsasg.com/SocialNetworkAnalysis/
Social Network Analysis: Eigenvalue

Alice and Rafael are closer to other highly close entities in the network. Bob and Frederica are also highly close, but to a lesser value.

Source: http://www.fmsasg.com/SocialNetworkAnalysis/
Social Network Analysis: Eigenvalue

• Eigenvalue measures how close an entity is to other highly close entities within a network. In other words, Eigenvalue identifies the most central entities in terms of the global or overall makeup of the network.

• A high Eigenvalue generally:
  – Indicates an actor that is more central to the main pattern of distances among all entities.
  – Is a reasonable measure of one aspect of centrality in terms of positional advantage.

Source: http://www.fmsasg.com/SocialNetworkAnalysis/
Hubs are entities that point to a relatively large number of authorities. They are essentially the mutually reinforcing analogues to authorities. Authorities point to high hubs. Hubs point to high authorities. You cannot have one without the other.

Social Network Analysis: Hub and Authority

- Entities that many other entities point to are called Authorities. In Sentinel Visualizer, relationships are directional—they point from one entity to another.
- If an entity has a high number of relationships pointing to it, it has a high authority value, and generally:
  - Is a knowledge or organizational authority within a domain.
  - Acts as definitive source of information.

# Social Network Analysis

![Network Metrics Table]

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Degree</th>
<th>Betweenness</th>
<th>Closeness</th>
<th>Eigenvalue</th>
<th>Hub</th>
<th>Authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osama bin Laden</td>
<td>Person</td>
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<td>0.920432092358</td>
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<td>0.6816</td>
</tr>
</tbody>
</table>

Social Network Analysis

Source: http://www.fmsasg.com/SocialNetworkAnalysis/
Link Mining

Link Mining
(Getoor & Diehl, 2005)

• Link Mining
  – Data Mining techniques that take into account the links between objects and entities while building predictive or descriptive models.

• Link based object ranking, Group Detection, Entity Resolution, Link Prediction

• Application:
  – Hyperlink Mining
  – Relational Learning
  – Inductive Logic Programming
  – Graph Mining

Source: (c) Jaideep Srivastava, srivasta@cs.umn.edu, Data Mining for Social Network Analysis
Characteristics of Collaboration Networks
(Newman, 2001; 2003; 3004)

• Degree distribution follows a power-law
• Average separation decreases in time.
• Clustering coefficient decays with time
• Relative size of the largest cluster increases
• Average degree increases
• Node selection is governed by preferential attachment

Source: (c) Jaideep Srivastava, srivasta@cs.umn.edu, Data Mining for Social Network Analysis
Social Network Techniques

- Social network extraction/construction
- Link prediction
- Approximating large social networks
- Identifying prominent/trusted/expert actors in social networks
- Search in social networks
- Discovering communities in social network
- Knowledge discovery from social network

Source: (c) Jaideep Srivastava, srivast@cs.umn.edu, Data Mining for Social Network Analysis
Social Network Extraction

• Mining a social network from data sources
• Three sources of social network (Hope et al., 2006)
  – Content available on web pages
    • E.g., user homepages, message threads
  – User interaction logs
    • E.g., email and messenger chat logs
  – Social interaction information provided by users
    • E.g., social network service websites (Facebook)

Source: (c) Jaideep Srivastava, srivasta@cs.umn.edu, Data Mining for Social Network Analysis
Social Network Extraction

• IR based extraction from web documents
  – Construct an “actor-by-term” matrix
  – The terms associated with an actor come from web pages/documents created by or associated with that actor
  – IR techniques (TF-IDF, LSI, cosine matching, intuitive heuristic measures) are used to quantify similarity between two actors’ term vectors
  – The similarity scores are the edge label in the network
    • Thresholds on the similarity measure can be used in order to work with binary or categorical edge labels
    • Include edges between an actor and its k-nearest neighbors

• Co-occurrence based extraction from web documents

Source: (c) Jaideep Srivastava, srivasta@cs.umn.edu, Data Mining for Social Network Analysis
Link Prediction

• Link Prediction using supervised learning (Hasan et al., 2006)
  – Citation Network (BIOBASE, DBLP)
  – Use machine learning algorithms to predict future co-authorship
    • Decision three, k-NN, multilayer perceptron, SVM, RBF network
  – Identify a group of features that are most helpful in prediction
  – Best Predictor Features
    • Keywork Match count, Sum of neighbors, Sum of Papers, Shortest distance

Source: (c) Jaideep Srivastava, srivasta@cs.umn.edu, Data Mining for Social Network Analysis
Identifying Prominent Actors in a Social Network

- Compute scores/ranking over the set (or a subset) of actors in the social network which indicate degree of importance / expertise / influence
  - E.g., Pagerank, HITS, centrality measures
- Various algorithms from the link analysis domain
  - PageRank and its many variants
  - HITS algorithm for determining authoritative sources
- Centrality measures exist in the social science domain for measuring importance of actors in a social network

Source: (c) Jaideep Srivastava, srivasta@cs.umn.edu, Data Mining for Social Network Analysis
Identifying Prominent Actors in a Social Network

• Brandes, 2011
• Prominence $\rightarrow$ high betweenness value
• Betweenness centrality requires computation of number of shortest paths passing through each node
• Compute shortest paths between all pairs of vertices

Source: (c) Jaideep Srivastava, srivasta@cs.umn.edu, Data Mining for Social Network Analysis
Text and Web Mining

- Text Mining: Applications and Theory
- Web Mining and Social Networking
- Mining the Social Web: Analyzing Data from Facebook, Twitter, LinkedIn, and Other Social Media Sites
- Web Data Mining: Exploring Hyperlinks, Contents, and Usage Data
- Search Engines – Information Retrieval in Practice
Text Mining

Web Mining and Social Networking
Mining the Social Web:
Analyzing Data from Facebook, Twitter, LinkedIn, and Other Social Media Sites

http://www.amazon.com/Mining-Social-Web-Analyzing-Facebook/dp/1449388345
Web Data Mining:
Exploring Hyperlinks, Contents, and Usage Data

http://www.amazon.com/Web-Data-Mining-Data-Centric-Applications/dp/3540378812
Search Engines: Information Retrieval in Practice
Text Mining

• Text mining (text data mining)
  – the process of deriving high-quality information from text
• Typical text mining tasks
  – text categorization
  – text clustering
  – concept/entity extraction
  – production of granular taxonomies
  – sentiment analysis
  – document summarization
  – entity relation modeling
    • i.e., learning relations between named entities.

http://en.wikipedia.org/wiki/Text_mining
Web Mining

• Web mining
  – discover useful information or knowledge from the **Web hyperlink structure, page content, and usage data.**

• Three types of web mining tasks
  – Web structure mining
  – Web content mining
  – Web usage mining

Processing Text

• Converting documents to *index terms*

• Why?
  – Matching the exact string of characters typed by the user is too restrictive
    • i.e., it doesn’t work very well in terms of effectiveness
  – Not all words are of equal value in a search
  – Sometimes not clear where words begin and end
    • Not even clear what a word is in some languages
      – e.g., Chinese, Korean

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Text Statistics

• Huge variety of words used in text but

• Many statistical characteristics of word occurrences are predictable
  – e.g., distribution of word counts

• Retrieval models and ranking algorithms depend heavily on statistical properties of words
  – e.g., important words occur often in documents but are not high frequency in collection

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Tokenizing

• Forming words from sequence of characters
• Surprisingly complex in English, can be harder in other languages
• Early IR systems:
  – any sequence of alphanumeric characters of length 3 or more
  – terminated by a space or other special character
  – upper-case changed to lower-case

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Tokenizing

• Example:
  – “Bigcorp's 2007 bi-annual report showed profits rose 10%.” becomes
  – “bigcorp 2007 annual report showed profits rose”

• Too simple for search applications or even large-scale experiments

• Why? Too much information lost
  – Small decisions in tokenizing can have major impact on effectiveness of some queries

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Tokenizing Problems

- Small words can be important in some queries, usually in combinations
  - xp, ma, pm, ben e king, el paso, master p, gm, j lo, world war ll
- Both hyphenated and non-hyphenated forms of many words are common
  - Sometimes hyphen is not needed
    - e-bay, wal-mart, active-x, cd-rom, t-shirts
  - At other times, hyphens should be considered either as part of the word or a word separator
    - winston-salem, mazda rx-7, e-cards, pre-diabetes, t-mobile, spanish-speaking

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Tokenizing Problems

• Special characters are an important part of tags, URLs, code in documents

• Capitalized words can have different meaning from lower case words
  – Bush, Apple

• Apostrophes can be a part of a word, a part of a possessive, or just a mistake
  – rosie o'donnell, can't, don't, 80's, 1890's, men's straw hats, master's degree, england's ten largest cities, shriner's

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Tokenizing Problems

- Numbers can be important, including decimals
  - nokia 3250, top 10 courses, united 93, quicktime 6.5 pro, 92.3 the beat, 288358

- Periods can occur in numbers, abbreviations, URLs, ends of sentences, and other situations
  - I.B.M., Ph.D., cs.umass.edu, F.E.A.R.

- Note: tokenizing steps for queries must be identical to steps for documents

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
**Tokenizing Process**

- First step is to use parser to identify appropriate parts of document to tokenize
- Defer complex decisions to other components
  - word is any sequence of alphanumeric characters, terminated by a space or special character, with everything converted to lower-case
  - everything indexed
  - example: 92.3 → 92 3 but search finds documents with 92 and 3 adjacent
  - incorporate some rules to reduce dependence on query transformation components

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Tokenizing Process

• Not that different than simple tokenizing process used in past
• Examples of rules used with TREC
  – Apostrophes in words ignored
    • o’connor → oconnor  bob’s → bobs
  – Periods in abbreviations ignored
    • I.B.M. → ibm  Ph.D. → ph d

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Stopping

• Function words (determiners, prepositions) have little meaning on their own
• High occurrence frequencies
• Treated as stopwords (i.e. removed)
  – reduce index space, improve response time, improve effectiveness
• Can be important in combinations
  – e.g., “to be or not to be”

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Stopping

• Stopword list can be created from high-frequency words or based on a standard list

• Lists are customized for applications, domains, and even parts of documents
  — e.g., “click” is a good stopword for anchor text

• Best policy is to index all words in documents, make decisions about which words to use at query time

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Stemming

• Many morphological variations of words
  – *inflectional* (plurals, tenses)
  – *derivational* (making verbs nouns etc.)

• In most cases, these have the same or very similar meanings

• Stemmers attempt to reduce morphological variations of words to a common stem
  – usually involves removing suffixes

• Can be done at indexing time or as part of query processing (like stopwords)

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Stemming

• Generally a small but significant effectiveness improvement
  – can be crucial for some languages
  – e.g., 5-10% improvement for English, up to 50% in Arabic

<table>
<thead>
<tr>
<th>Word</th>
<th>Meaning</th>
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<tbody>
<tr>
<td>kitab</td>
<td>a book</td>
</tr>
<tr>
<td>kitabi</td>
<td>my book</td>
</tr>
<tr>
<td>alkitab</td>
<td>the book</td>
</tr>
<tr>
<td>kitabuki</td>
<td>your book (f)</td>
</tr>
<tr>
<td>kitabuka</td>
<td>your book (m)</td>
</tr>
<tr>
<td>kitabuhu</td>
<td>his book</td>
</tr>
<tr>
<td>kata</td>
<td>to write</td>
</tr>
<tr>
<td>maktaba</td>
<td>library, bookstore</td>
</tr>
<tr>
<td>maktab</td>
<td>office</td>
</tr>
</tbody>
</table>

Words with the Arabic root ktb

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Stemming

• Two basic types
  – Dictionary-based: uses lists of related words
  – Algorithmic: uses program to determine related words

• Algorithmic stemmers
  – suffix-s: remove ‘s’ endings assuming plural
    • e.g., cats → cat, lakes → lake, wiis → wii
    • Many false negatives: supplies → supplie
    • Some false positives: ups → up

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Porter Stemmer

• Algorithmic stemmer used in IR experiments since the 70s
• Consists of a series of rules designed to the longest possible suffix at each step
• Effective in TREC
• Produces *stems* not *words*
• Makes a number of errors and difficult to modify

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Porter Stemmer

• Example step (1 of 5)

Step 1a:

- Replace *sses* by *ss* (e.g., *stresses* → *stress*).
- Delete *s* if the preceding word part contains a vowel not immediately before the *s* (e.g., *gaps* → *gap* but *gas* → *gas*).
- Replace *ied* or *ies* by *i* if preceded by more than one letter, otherwise by *ie* (e.g., *ties* → *tie*, *cries* → *cri*).
- If suffix is *us* or *ss* do nothing (e.g., *stress* → *stress*).

Step 1b:

- Replace *eed*, *eedly* by *ee* if it is in the part of the word after the first non-vowel following a vowel (e.g., *agreed* → *agree*, *feed* → *feed*).
- Delete *ed*, *edly*, *ing*, *ingly* if the preceding word part contains a vowel, and then if the word ends in *at*, *bl*, or *iz* add *e* (e.g., *fished* → *fish*, *pirating* → *pirate*), or if the word ends with a double letter that is not *ll*, *ss* or *zz*, remove the last letter (e.g., *falling* → *fall*, *dripping* → *drip*), or if the word is short, add *e* (e.g., *hoping* → *hope*).
- Whew!
Porter Stemmer

<table>
<thead>
<tr>
<th>False positives</th>
<th>False negatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>organization/organ</td>
<td>european/europe</td>
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<tr>
<td>generalization/generic</td>
<td>cylinder/cylindrical</td>
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<tr>
<td>numerical/numerous</td>
<td>matrices/matrix</td>
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<tr>
<td>policy/police</td>
<td>urgency/urgent</td>
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<tr>
<td>university/universe</td>
<td>create/creation</td>
</tr>
<tr>
<td>addition/additive</td>
<td>analysis/analyses</td>
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<tr>
<td>negligible/negligent</td>
<td>useful/usefully</td>
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<tr>
<td>execute/executive</td>
<td>noise/noisy</td>
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<tr>
<td>past/paste</td>
<td>decompose/decomposition</td>
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<tr>
<td>ignore/ignorant</td>
<td>sparse/sparsity</td>
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<tr>
<td>special/specialized</td>
<td>resolve/resolution</td>
</tr>
<tr>
<td>head/heading</td>
<td>triangle/triangular</td>
</tr>
</tbody>
</table>

- Porter2 stemmer addresses some of these issues
- Approach has been used with other languages

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Krovetz Stemmer

• Hybrid algorithmic-dictionary
  – Word checked in dictionary
    • If present, either left alone or replaced with “exception”
    • If not present, word is checked for suffixes that could be removed
      • After removal, dictionary is checked again

• Produces words not stems
• Comparable effectiveness
• Lower false positive rate, somewhat higher false negative

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Stemmer Comparison

Original text:
Document will describe marketing strategies carried out by U.S. companies for their agricultural chemicals, report predictions for market share of such chemicals, or report market statistics for agrochemicals, pesticide, herbicide, fungicide, insecticide, fertilizer, predicted sales, market share, stimulate demand, price cut, volume of sales.

Porter stemmer:
document describ market strategi carri compani agricultur chemic report predict market share chemic report market statist agrochem pesticid herbicid fungicid insecticid fertil predict sale market share stimul demand price cut volum sale

Krovetz stemmer:
document describe marketing strategy carry company agriculture chemical report prediction market share chemical report market statistic agrochem pesticide herbicide fungicide insecticide fertilizer predict sale stimulate demand price cut volume sale

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Phrases

• Many queries are 2-3 word phrases

• Phrases are
  
  – More precise than single words
    • e.g., documents containing “black sea” vs. two words “black” and “sea”
  
  – Less ambiguous
    • e.g., “big apple” vs. “apple”

• Can be difficult for ranking
  
  • e.g., Given query “fishing supplies”, how do we score documents with
    – exact phrase many times, exact phrase just once, individual words in same sentence, same paragraph, whole document, variations on words?

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Phrases

• Text processing issue – how are phrases recognized?

• Three possible approaches:
  – Identify syntactic phrases using a \textit{part-of-speech} (POS) tagger
  – Use word \textit{n-grams}
  – Store word positions in indexes and use \textit{proximity operators} in queries

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
POS Tagging

• POS taggers use statistical models of text to predict syntactic tags of words
  – Example tags:
    • NN (singular noun), NNS (plural noun), VB (verb), VBD (verb, past tense), VBN (verb, past participle), IN (preposition), JJ (adjective), CC (conjunction, e.g., “and”, “or”), PRP (pronoun), and MD (modal auxiliary, e.g., “can”, “will”).

• Phrases can then be defined as simple noun groups, for example

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Pos Tagging Example

Original text:
Document will describe marketing strategies carried out by U.S. companies for their agricultural chemicals, report predictions for market share of such chemicals, or report market statistics for agrochemicals, pesticide, herbicide, fungicide, insecticide, fertilizer, predicted sales, market share, stimulate demand, price cut, volume of sales.

Brill tagger:
### Example Noun Phrases

<table>
<thead>
<tr>
<th>TREC data</th>
<th>Patent data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency</strong></td>
<td><strong>Phrase</strong></td>
</tr>
<tr>
<td>65824</td>
<td>united states</td>
</tr>
<tr>
<td>61327</td>
<td>article type</td>
</tr>
<tr>
<td>33864</td>
<td>los angeles</td>
</tr>
<tr>
<td>18062</td>
<td>hong kong</td>
</tr>
<tr>
<td>17788</td>
<td>north korea</td>
</tr>
<tr>
<td>17308</td>
<td>new york</td>
</tr>
<tr>
<td>15513</td>
<td>san diego</td>
</tr>
<tr>
<td>15009</td>
<td>orange county</td>
</tr>
<tr>
<td>12869</td>
<td>prime minister</td>
</tr>
<tr>
<td>12799</td>
<td>first time</td>
</tr>
<tr>
<td>12067</td>
<td>soviet union</td>
</tr>
<tr>
<td>10811</td>
<td>russian federation</td>
</tr>
<tr>
<td>9912</td>
<td>united nations</td>
</tr>
<tr>
<td>8127</td>
<td>southern california</td>
</tr>
<tr>
<td>7640</td>
<td>south korea</td>
</tr>
<tr>
<td>7620</td>
<td>end recording</td>
</tr>
<tr>
<td>7524</td>
<td>european union</td>
</tr>
<tr>
<td>7436</td>
<td>south africa</td>
</tr>
<tr>
<td>7362</td>
<td>san francisco</td>
</tr>
<tr>
<td>7086</td>
<td>news conference</td>
</tr>
<tr>
<td>6792</td>
<td>city council</td>
</tr>
<tr>
<td>6348</td>
<td>middle east</td>
</tr>
<tr>
<td>6157</td>
<td>peace process</td>
</tr>
<tr>
<td>5955</td>
<td>human rights</td>
</tr>
<tr>
<td>5837</td>
<td>white house</td>
</tr>
</tbody>
</table>

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Word N-Grams

• POS tagging too slow for large collections
• Simpler definition – phrase is any sequence of $n$ words – known as $n$-grams
  – bigram: 2 word sequence, trigram: 3 word sequence, unigram: single words
  – N-grams also used at character level for applications such as OCR
• N-grams typically formed from overlapping sequences of words
  – i.e. move n-word “window” one word at a time in document

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
N-Grams

• Frequent n-grams are more likely to be meaningful phrases
• N-grams form a Zipf distribution
  – Better fit than words alone
• Could index all n-grams up to specified length
  – Much faster than POS tagging
  – Uses a lot of storage
    • e.g., document containing 1,000 words would contain 3,990 instances of word n-grams of length $2 \leq n \leq 5$

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Google N-Grams

• Web search engines index n-grams
• Google sample:

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of tokens</td>
<td>1,024,908,267,229</td>
</tr>
<tr>
<td>Number of sentences</td>
<td>95,119,665,584</td>
</tr>
<tr>
<td>Number of unigrams</td>
<td>13,588,391</td>
</tr>
<tr>
<td>Number of bigrams</td>
<td>314,843,401</td>
</tr>
<tr>
<td>Number of trigrams</td>
<td>977,069,902</td>
</tr>
<tr>
<td>Number of fourgrams</td>
<td>1,313,818,354</td>
</tr>
<tr>
<td>Number of fivegrams</td>
<td>1,176,470,663</td>
</tr>
</tbody>
</table>

• Most frequent trigram in English is “all rights reserved”
  – In Chinese, “limited liability corporation”

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Document Structure and Markup

• Some parts of documents are more important than others

• Document parser recognizes structure using markup, such as HTML tags
  – Headers, anchor text, bolded text all likely to be important
  – Metadata can also be important
  – Links used for link analysis

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Example Web Page

Tropical fish

From Wikipedia, the free encyclopedia

Tropical fish include fish found in tropical environments around the world, including both freshwater and salt water species. Fishkeepers often use the term tropical fish to refer only those requiring fresh water, with saltwater tropical fish referred to as marine fish.

Tropical fish are popular aquarium fish, due to their often bright coloration. In freshwater fish, this coloration typically derives from iridescence, while salt water fish are generally pigmented.

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Example Web Page

<html>
<head>
<meta name="keywords" content="Tropical fish, Airstone, Albinism, Algae eater, Aquarium, Aquarium fish feeder, Aquarium furniture, Aquascaping, Bath treatment (fishkeeping), Berlin Method, Biotope"/>
...<title>Tropical fish - Wikipedia, the free encyclopedia</title>
</head>
<body>
...
<h1 class="firstHeading">Tropical fish</h1>
...<p><b>Tropical fish</b> include <a href="/wiki/Fish" title="Fish">fish</a> found in <a href="/wiki/Tropics" title="Tropics">tropical</a> environments around the world, including both <a href="/wiki/Fresh_water" title="Fresh water">freshwater</a> and <a href="/wiki/Sea_water" title="Sea water">salt water</a> species. <a href="/wiki/Fishkeeping" title="Fishkeeping">Fishkeepers</a> often use the term <i>tropical fish</i> to refer only those requiring fresh water, with saltwater tropical fish referred to as <i>a href="/wiki/List_of_marine_aquarium_fish_species" title="List of marine aquarium fish species">marine fish</i>.<p>
<Tropical fish are popular <a href="/wiki/Aquarium" title="Aquarium">aquarium</a> fish, due to their often bright coloration. In freshwater fish, this coloration typically derives from <a href="/wiki/Iridescence" title="Iridescence">iridescence</a>, while saltwater fish are generally <a href="/wiki/Pigment" title="Pigment">pigmented</a>.<p>
...<body></html>
Link Analysis

• Links are a key component of the Web
• Important for navigation, but also for search
  – e.g., <a href="http://example.com">Example website</a>
  – “Example website” is the anchor text
  – “http://example.com” is the destination link
  – both are used by search engines

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Anchor Text

• Used as a description of the content of the destination page
  – i.e., collection of anchor text in all links pointing to a page used as an additional text field

• Anchor text tends to be short, descriptive, and similar to query text

• Retrieval experiments have shown that anchor text has significant impact on effectiveness for some types of queries
  – i.e., more than PageRank

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
PageRank

• Billions of web pages, some more informative than others
• Links can be viewed as information about the popularity (*authority?*) of a web page
  – can be used by ranking algorithm
• *Inlink* count could be used as simple measure
• Link analysis algorithms like PageRank provide more reliable ratings
  – less susceptible to link spam

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Random Surfer Model

• Browse the Web using the following algorithm:
  – Choose a random number \( r \) between 0 and 1
  – If \( r < \lambda \):
    • Go to a random page
  – If \( r \geq \lambda \):
    • Click a link at random on the current page
  – Start again

• PageRank of a page is the probability that the “random surfer” will be looking at that page
  – links from popular pages will increase PageRank of pages they point to

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Dangling Links

• Random jump prevents getting stuck on pages that
  – do not have links
  – contains only links that no longer point to other pages
  – have links forming a loop

• Links that point to the first two types of pages are called *dangling links*
  – may also be links to pages that have not yet been crawled

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
PageRank

- PageRank (PR) of page C = PR(A)/2 + PR(B)/1
- More generally,

\[
PR(u) = \sum_{v \in B_u} \frac{PR(v)}{L_v}
\]

- where \( B_u \) is the set of pages that point to \( u \), and \( L_v \) is the number of outgoing links from page \( v \) (not counting duplicate links)
PageRank

• Don’t know PageRank values at start
• Assume equal values (1/3 in this case), then iterate:
  – first iteration: \( PR(C) = \frac{0.33}{2} + 0.33 = 0.5, \) \( PR(A) = 0.33, \) and \( PR(B) = 0.17 \)
  – second: \( PR(C) = \frac{0.33}{2} + 0.17 = 0.33, \) \( PR(A) = 0.5, \) \( PR(B) = 0.17 \)
  – third: \( PR(C) = 0.42, \) \( PR(A) = 0.33, \) \( PR(B) = 0.25 \)
• Converges to \( PR(C) = 0.4, \) \( PR(A) = 0.4, \) and \( PR(B) = 0.2 \)

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
PageRank

• Taking random page jump into account, 1/3 chance of going to any page when $r < \lambda$
• $PR(C) = \frac{\lambda}{3} + (1 - \lambda) \cdot (\frac{PR(A)}{2} + \frac{PR(B)}{1})$
• More generally,

$$PR(u) = \frac{\lambda}{N} + (1 - \lambda) \cdot \sum_{v \in B_u} \frac{PR(v)}{L_v}$$

– where $N$ is the number of pages, $\lambda$ typically 0.15

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
1: procedure PAGE_RANK(G)
2:    \[ G \text{ is the web graph, consisting of vertices (pages) and edges (links).} \]
3:    \[(P, L) \leftarrow G \]
4:    \[ I \leftarrow \text{a vector of length } |P| \]
5:    \[ R \leftarrow \text{a vector of length } |P| \]
6:    \[ \text{for all entries } I_i \in I \text{ do} \]
7:    \[ I_i \leftarrow 1/|P| \]
8:    \[ \text{end for} \]
9:    \[ \text{while } R \text{ has not converged do} \]
10:   \[ \text{for all entries } R_i \in R \text{ do} \]
11:      \[ R_i \leftarrow \lambda/|P| \]
12:      \[ \text{end for} \]
13:     \[ \text{for all pages } p \in P \text{ do} \]
14:        \[ Q \leftarrow \text{the set of pages such that } (p, q) \in L \text{ and } q \in P \]
15:        \[ \text{if } |Q| > 0 \text{ then} \]
16:           \[ \text{for all pages } q \in Q \text{ do} \]
17:              \[ R_q \leftarrow R_q + (1 - \lambda)I_p/|Q| \]
18:           \[ \text{end for} \]
19:        \[ \text{else} \]
20:           \[ \text{for all pages } q \in P \text{ do} \]
21:              \[ R_q \leftarrow R_q + (1 - \lambda)I_p/|P| \]
22:           \[ \text{end for} \]
23:        \[ \text{end if} \]
24:        \[ I \leftarrow R \]
25:     \[ \text{end if} \]
26:   \[ \text{end while} \]
27: return R
28: end procedure
A PageRank Implementation

• Preliminaries:
  – 1) Extract links from the source text. You'll also want to extract the URL from each document in a separate file. Now you have all the links (source-destination pairs) and all the source documents
  – 2) Remove all links from the list that do not connect two documents in the corpus. The easiest way to do this is to sort all links by destination, then compare that against the corpus URLs list (also sorted)
  – 3) Create a new file I that contains a (url, pagerank) pair for each URL in the corpus. The initial PageRank value is $1/#D$ ($#D =$ number of urls)

• At this point there are two interesting files:
  – [L] links (trimmed to contain only corpus links, sorted by source URL)
  – [I] URL/PageRank pairs, initialized to a constant

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
A PageRank Implementation

- Preliminaries - Link Extraction from .corpus file using Galago
  
  \[\text{DocumentSplit} \rightarrow \text{IndexReaderSplitParser} \rightarrow \text{TagTokenizer}\]
  
  \[\text{split} = \text{new DocumentSplit ( filename, filetype, new byte[0], new byte[0] )}\]
  
  \[\text{index} = \text{new IndexReaderSplitParser ( split )}\]
  
  \[\text{tokenizer} = \text{new TagTokenizer ( )}\]
  
  \[\text{tokenizer.setProcessor ( NullProcessor ( Document.class ) )}\]
  
  \[\text{doc} = \text{index.nextDocument ( )}\]
  
  \[\text{tokenizer.process ( doc )}\]
  
  - \text{doc.identifier contains the file’s name}
  
  - \text{doc.tags now contains all tags}
  
  - \text{Links can be extracted by finding all tags with name “a”}
  
  - \text{Links should be processed so that they can be compared with some file name in the corpus}

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
A PageRank Implementation

Iteration:
• Steps:
  1. Make a new output file, R.
  2. Read L and I in parallel (since they're all sorted by URL).
  3. For each unique source URL, determine whether it has any outgoing links:
     4. If not, add its current PageRank value to the sum: T (terminals).
     5. If it does have outgoing links, write (source_url, dest_url, Ip/|Q|), where Ip is the current PageRank value, |Q| is the number of outgoing links, and dest_url is a link destination. Do this for all outgoing links. Write this to R.
  6. Sort R by destination URL.
  7. Scan R and I at the same time. The new value of Rp is:
     (1 - lambda) / #D (a fraction of the sum of all pages)
     plus: lambda * sum(T) / #D (the total effect from terminal pages),
     plus: lambda * all incoming mass from step 5.()
  8. Check for convergence
  9. Write new Rp values to a new I file.

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
A PageRank Implementation

• Convergence check
  – Stopping criteria for this types of PR algorithm typically is of the form $||\text{new} - \text{old}|| < \tau$ where new and old are the new and old PageRank vectors, respectively.
  – Tau is set depending on how much precision you need. Reasonable values include 0.1 or 0.01. If you want really fast, but inaccurate convergence, then you can use something like $\tau=1$.
  – The setting of tau also depends on N (= number of documents in the collection), since $||\text{new-old}||$ (for a fixed numerical precision) increases as N increases, so you can alternatively formulate your convergence criteria as $||\text{new} - \text{old}|| / N < \tau$.
  – Either the L1 or L2 norm can be used.

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Link Quality

• Link quality is affected by spam and other factors
  – e.g., *link farms* to increase PageRank
  – *trackback links* in blogs can create loops
  – links from comments section of popular blogs
    • Blog services modify comment links to contain `rel=nofollow` attribute
    • e.g., “Come visit my `<a rel=nofollow href="http://www.page.com">web page</a>.””

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Trackback Links

Blog A

Post a

Link

Blog B

Post b

Trackback links

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Information Extraction (IE)

• Automatically extract structure from text
  – annotate document using tags to identify extracted structure

• Named entity recognition (NER)
  – identify words that refer to something of interest in a particular application
  – e.g., people, companies, locations, dates, product names, prices, etc.
Named Entity Recognition (NER)

Fred Smith, who lives at 10 Water Street, Springfield, MA, is a long-time collector of *tropical fish*.

```xml
<p>&lt;PersonName&gt;&lt;GivenName&gt;Fred&lt;/GivenName&gt; &lt;Sn&gt;Smith&lt;/Sn&gt; &lt;/PersonName&gt;, who lives at &lt;address&gt;&lt;Street&gt;10 Water Street&lt;/Street&gt;, &lt;City&gt;Springfield&lt;/City&gt;, &lt;State&gt;MA&lt;/State&gt;&lt;/address&gt;, is a long-time collector of &lt;b&gt;tropical fish.&lt;/b&gt;&lt;/p&gt;
```

- Example showing semantic annotation of text using XML tags
- Information extraction also includes document structure and more complex features such as *relationships* and *events*
Named Entity Recognition

• **Rule-based**
  – Uses *lexicons* (lists of words and phrases) that categorize names
    • e.g., locations, peoples’ names, organizations, etc.
  – Rules also used to verify or find new entity names
    • e.g., “<number> <word> street” for addresses
    • “<street address>, <city>” or “in <city>” to verify city names
    • “<street address>, <city>, <state>” to find new cities
    • “<title> <name>” to find new names

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Named Entity Recognition

• Rules either developed manually by trial and error or using machine learning techniques

• Statistical
  – uses a probabilistic model of the words in and around an entity
  – probabilities estimated using training data (manually annotated text)
  – Hidden Markov Model (HMM)
  – Conditional Random Field (CRF)

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Named Entity Recognition

• Accurate recognition requires about 1M words of training data (1,500 news stories)
  – may be more expensive than developing rules for some applications

• Both rule-based and statistical can achieve about 90% effectiveness for categories such as names, locations, organizations
  – others, such as product name, can be much worse

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Internationalization

• 2/3 of the Web is in English
• About 50% of Web users do not use English as their primary language
• Many (maybe most) search applications have to deal with multiple languages
  – monolingual search: search in one language, but with many possible languages
  – cross-language search: search in multiple languages at the same time

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Internationalization

• Many aspects of search engines are language-neutral

• Major differences:
  – Text encoding (converting to Unicode)
  – Tokenizing (many languages have no word separators)
  – Stemming

• Cultural differences may also impact interface design and features provided

Source: Croft et al. (2008) Search Engines: Information Retrieval in Practice
Chinese “Tokenizing”

1. Original text
旱灾在中国造成的影响
(the impact of droughts in China)

2. Word segmentation
旱灾 在 中国 造成 的 影响
drought at china make impact

3. Bigrams
旱灾 灾在 在中 中国 国造
造成 成的 的影 影响
Summary

• Social Network Analysis
• Link Mining
• Text and Web Mining
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