Data Mining and Information Retrieval

PageRank and Web Spam

Ranking Web Pages

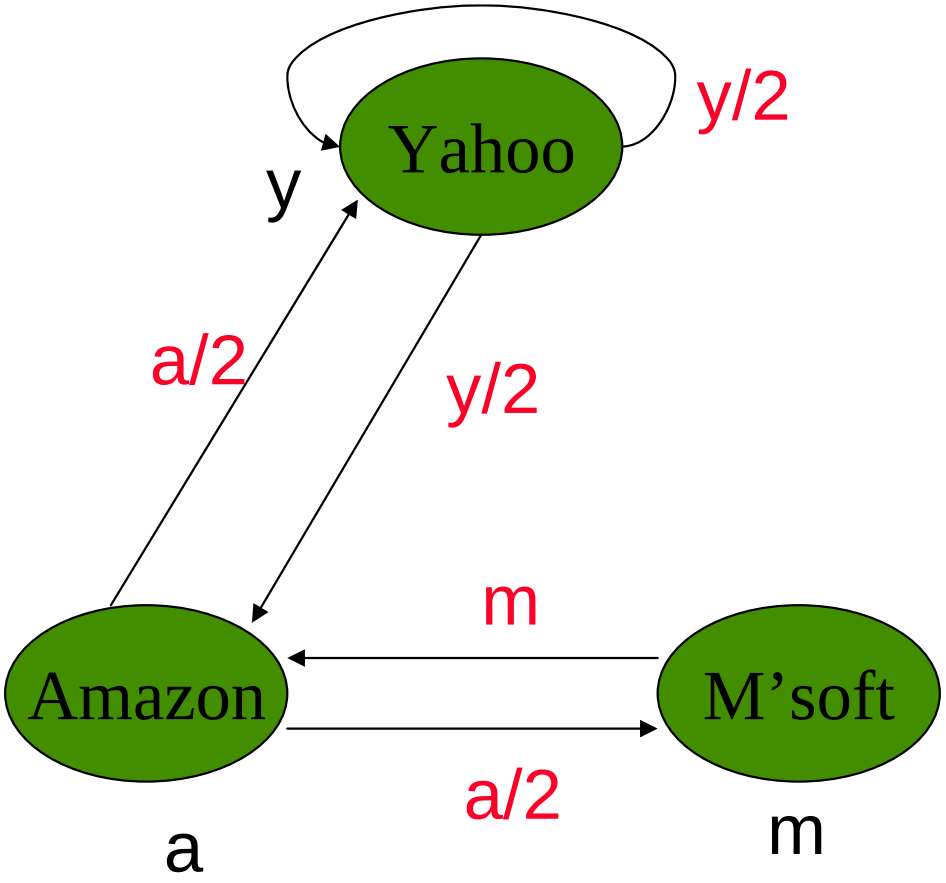
- Web pages are not equally “important”
  - www.joe-schmoe.com v www.stanford.edu
- Inlinks as votes
  - www.stanford.edu has 23,400 inlinks
  - www.joe-schmoe.com has 1 inlink
- Are all inlinks equal?
  - Recursive question!

Simple Recursive Formulation

- Each link's vote is proportional to the importance of its source page
- If page P with importance x has n outlinks, each link gets x/n votes
- Page P's own importance is the sum of the votes on its inlinks

Simple "Flow" Model

The web in 1839



$$y = y/2 + a/2$$
$$a = y/2 + m$$
$$m = a/2$$

Solving the Flow Equations

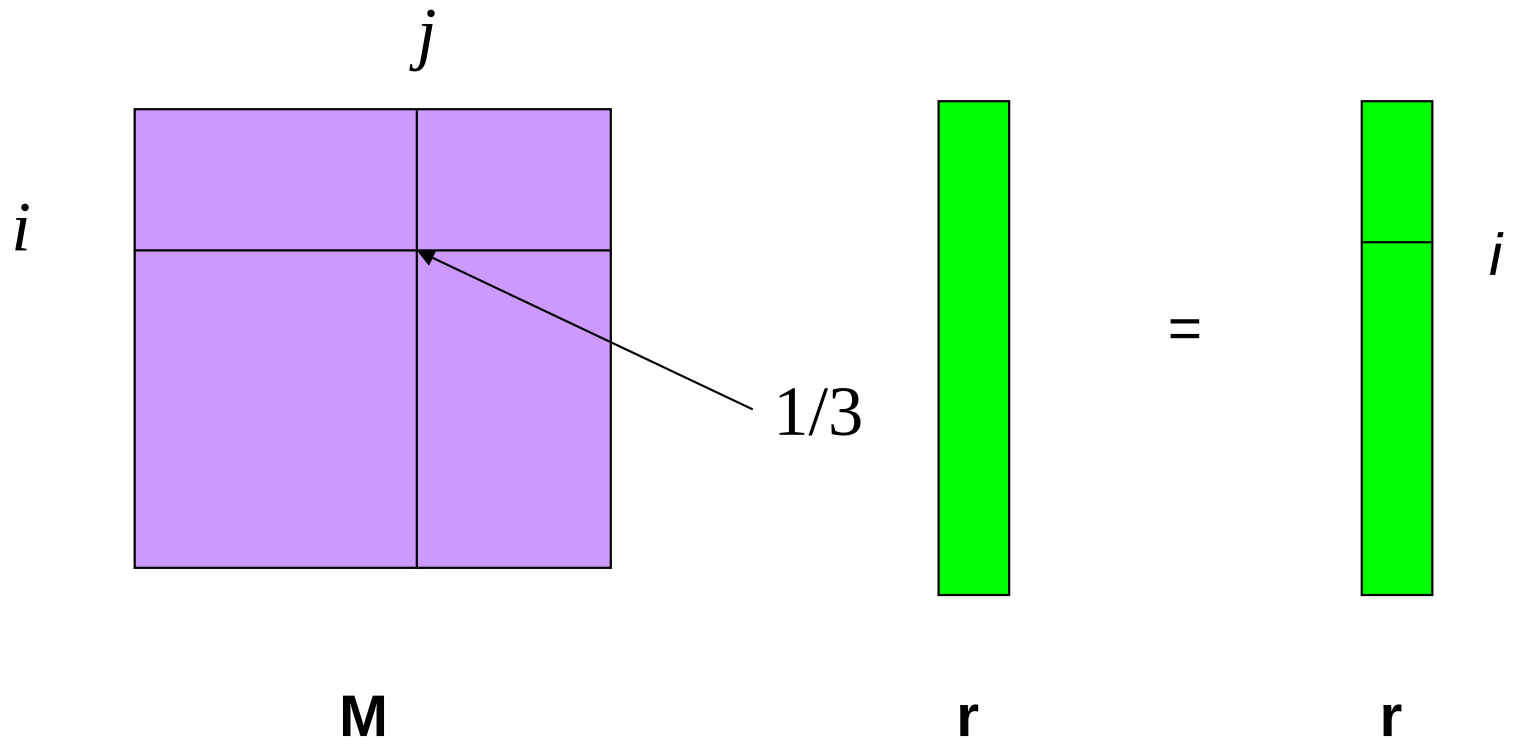
- 3 equations, 3 unknowns, no constants
  - No unique solution
  - All solutions equivalent modulo scale factor
- Additional constraint forces uniqueness
  - y+a+m = 1
  - y = 2/5, a = 2/5, m = 1/5
- Gaussian elimination method works for small examples, but we need a better method for large graphs

Matrix formulation

- Matrix **M** has one row and one column for each web page
- Suppose page j has n outlinks
  - If j $\rightarrow$ i, then M_{ij}=1/n
  - Else M_{ij}=0
- **M** is a column stochastic matrix
  - Columns sum to 1
- Suppose **r** is a vector with one entry per web page
  - r_i is the importance score of page i
  - Call it the rank vector

Example

Suppose page *j* links to 3 pages, including *i*



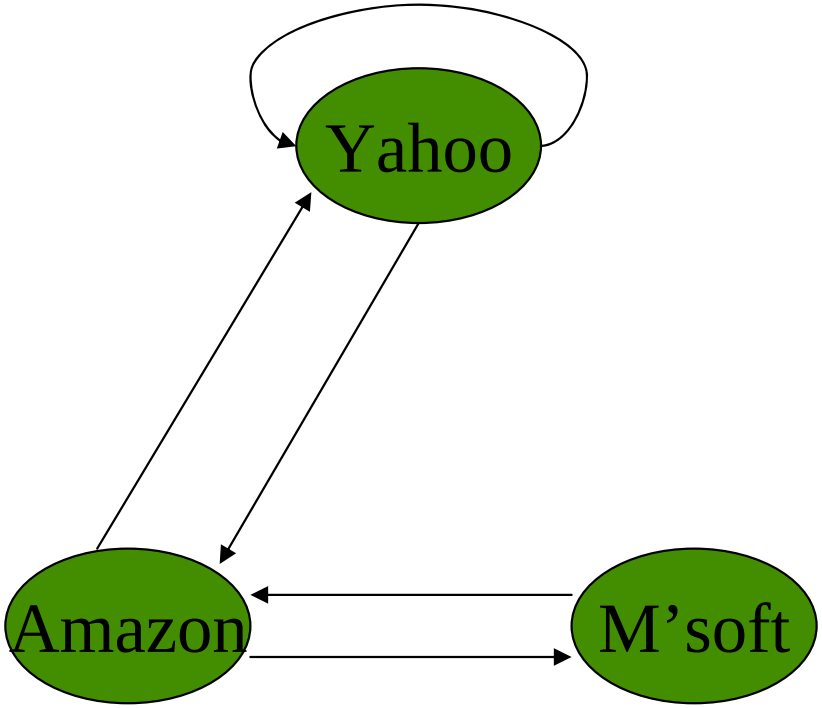
Eigenvector formulation

- The flow equations can be written

$$r = Mr$$

- So the rank vector is an eigenvector of the stochastic web matrix
  - In fact, its first or principal eigenvector, with corresponding eigenvalue 1

Example



$$y = y/2 + a/2$$
$$a = y/2 + m$$
$$m = a/2$$

	y	a	m
y	1/2	1/2	0
a	1/2	0	1
m	0	1/2	0

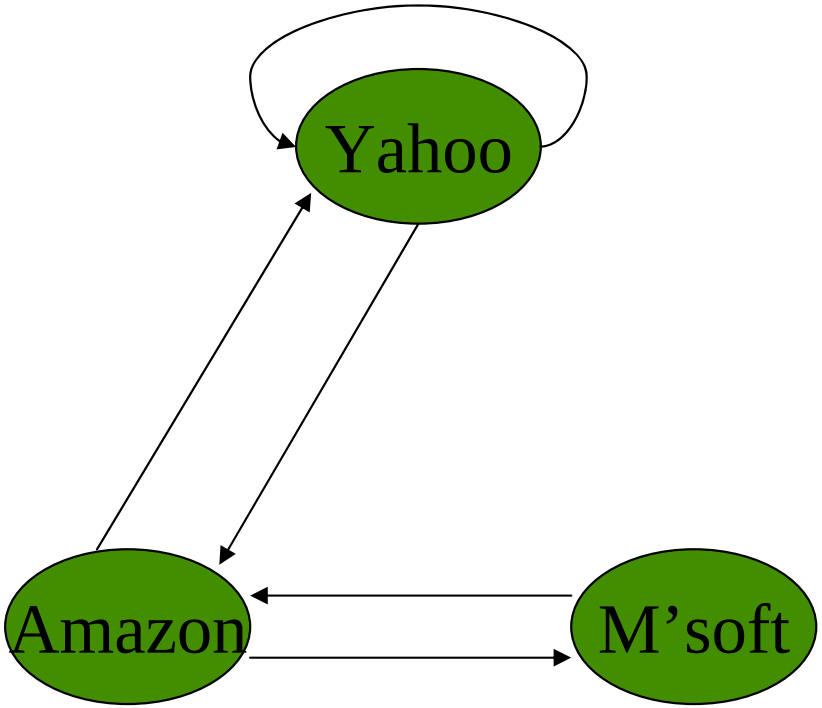
r = Mr

$$\begin{bmatrix} y \\ a \\ m \end{bmatrix} = \begin{bmatrix} 1/2 & 1/2 & 0 \\ 1/2 & 0 & 1 \\ 0 & 1/2 & 0 \end{bmatrix} \begin{bmatrix} y \\ a \\ m \end{bmatrix}$$

Power Iteration method

- Simple iterative scheme
- Suppose there are N web pages
- Initialize: $\mathbf{r}^0 = [1/N,\ldots,1/N]^T$
- Iterate: $\mathbf{r}^{k+1} = \mathbf{M}\mathbf{r}^k$
- Stop when $|\mathbf{r}^{k+1} - \mathbf{r}^k|_1 < \varepsilon$
  - $|\mathbf{x}|_1 = \sum_{1 \le i \le N} |x_i|$ is the L_1 norm
  - Can use any other vector norm

Power Iteration Example



	y	a	m
y	1/2	1/2	0
a	1/2	0	1
m	0	1/2	0

$$\begin{pmatrix} y \\ a \\ m \end{pmatrix} = \begin{pmatrix} 1/3 \\ 1/3 \\ 1/3 \end{pmatrix} \begin{pmatrix} 1/3 \\ 1/2 \\ 1/6 \end{pmatrix} \begin{pmatrix} 5/12 \\ 1/3 \\ 1/4 \end{pmatrix} \begin{pmatrix} 3/8 \\ 11/24 \\ 1/6 \end{pmatrix} \cdots \begin{pmatrix} 2/5 \\ 2/5 \\ 1/5 \end{pmatrix}$$

Random Walk Interpretation

- Imagine a random web surfer
  - At any time t, surfer is on some page P
  - At time t+1, the surfer follows an outlink from P uniformly at random
  - Ends up on some page Q linked from P
  - Process repeats indefinitely
- Related to *Markov Chain* model

PageRank

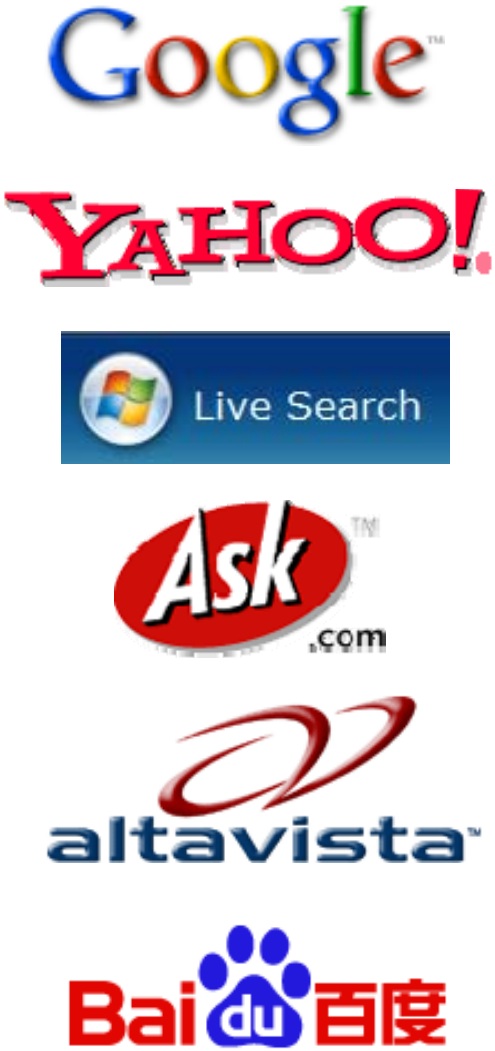
A page is important if many other important pages point to it

$$P_0 = d \sum_i P_i / out(i) + (1-d)$$

- P_0: PageRank Score of page p_0
- d: Damping factor ≈ 0.85
- P_i: PageRank Score of page p_i that points to page p_0
- $out(i)$: Out degree of page p_i
- $(1-d)$: Random jump probability ≈ 0.15

What is Web Spam?

World Wide Web and Search Engines



- Increasing exposure on the World Wide Web may yield significant financial gains for the Web site owners!
- The increasing importance of search engines to commercial Web sites has given rise to a phenomenon called "Web Spam"!

Why Web Spam

- E-commerce is rapidly growing
  - Projected to $329 billion by 2010
- More traffic → more money
- Large fraction of traffic from Search Engines
- Increase Search Engine referrals:
  - Place ads ☺
  - Provide genuinely better content ☺
  - Create Web spam… ☹

Web Spam Examples

(you know it when you see it)

Defining Web Spam

- Spam Web page
  - A page created for the sole purpose of attracting search engine referrals (to this page or some other “target” page)
- Ultimately a judgment call
  - Some Web pages are borderline cases

Why Web Spam is Bad

- Bad for users
  - Makes it harder to satisfy information need
  - Leads to frustrating search experience
- Bad for search engines
  - Wastes bandwidth, CPU cycles, storage space
  - Pollutes corpus (infinite number of spam pages!)
  - Distorts ranking of results

Detecting Web Spam

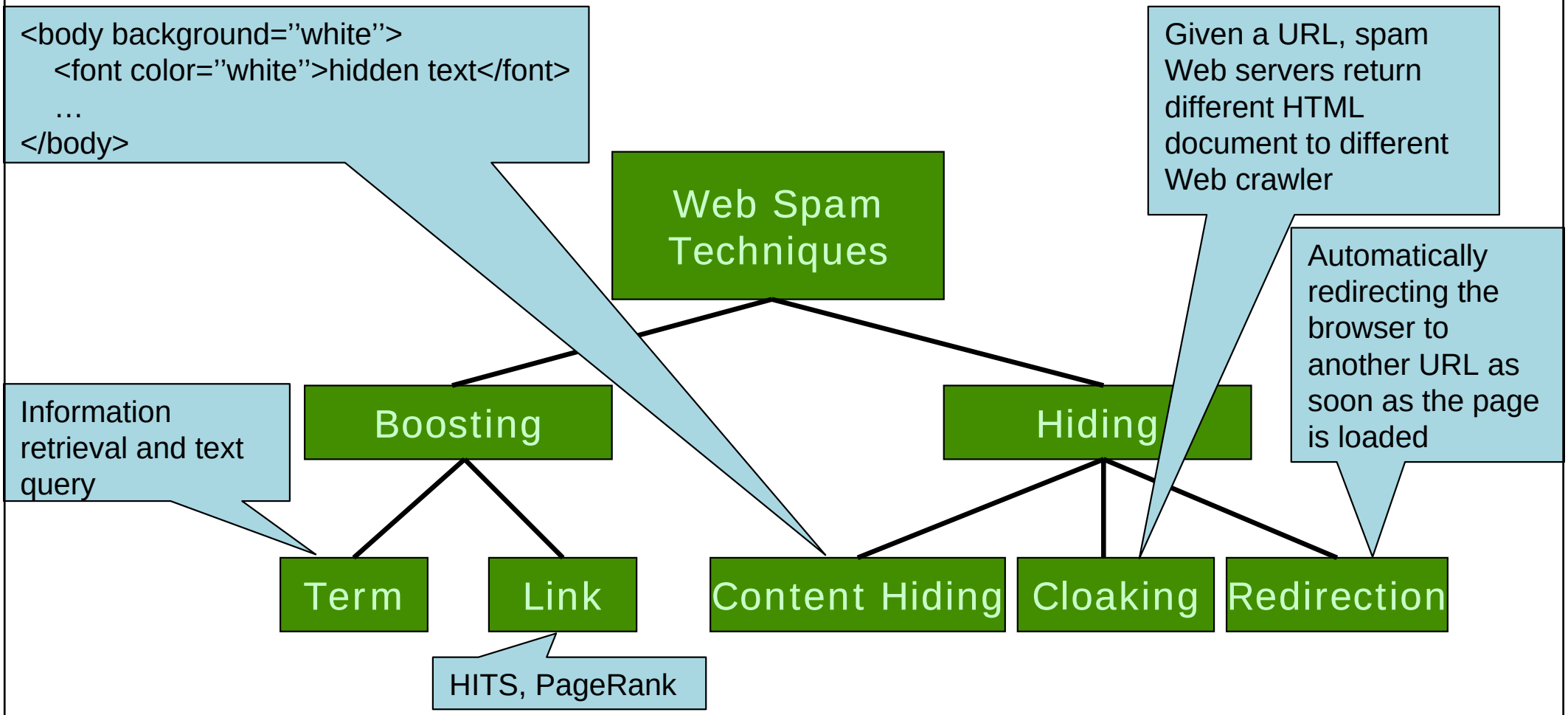
- Spam detection: A classification problem
  - Given salient features of a Web page, decide whether the page is spam
- Which “salient features”?
  - Need to understand spamming techniques to decide on features
  - Finding right features is “alchemy”, not science

Preliminary of Web Spam Detection

- Ask yourself a question:
  - Why Web spam exists?
  - Spammers did, because they are trying to mislead Web search engines
- Thus, in order to detect Web spam
  - Thinking in the spammers' way
  - If I am a spammer, what shall I do to mislead the search engines as much as possible?
- So, before going to detect Web spam
  - Try to understand how a search engine ranks Web pages…

Web Spam Taxonomy

Web Spam = misleading search engines to obtain higher-than-deserved ranking



How to Detect Web Spam

- Ask yourself following questions
  - What kind of features can be useful to detect spam Web pages?
  - Once we get those features, what kind of data mining methods can be used to detect spam Web pages?
  - Once we have Web spam detection methods, what kind of evaluation metrics can be used to evaluate the results?

Reading References

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- M. Bianchini, M. Gori and F. Scarselli. "*Inside PageRank.*" ACM Transactions on Internet Technology, 2005.
- A. Langville and C. Meyer. "*Deeper inside PageRank.*" Internet Mathematics, 2005.
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Search Engine Webmaster Guidelines

- Google
  - http://www.google.com/support/webmasters/bin/answer.py?answer=35769
- Yahoo!
  - http://help.yahoo.com/l/us/yahoo/search/
- Microsoft Live Search
  - http://search.msn.com/docs/siteowner.aspx?t=SEARCH_WEBMASTER_REF_GuidelinesforOptimizingSite.htm