HY463 - Συστήματα Ανάκτησης Πληροφοριών
Information Retrieval (IR) Systems

Web Searching

I: History and Basic Notions, Crawling
II: Link Analysis Techniques
III: Web Spam Page Identification

Γιάννης Τζίτζικας

Διάλεξη : 7-8-9
Ημερομηνία : 17-22-24 / 3 / 2006

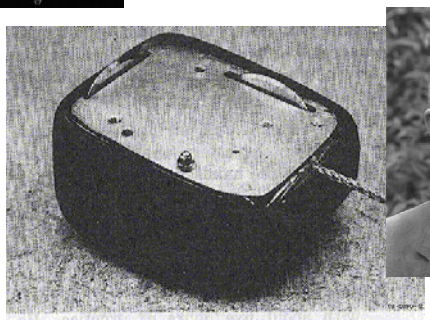
Διάρθρωση Διάλεξης Ι

- Ιστορική Αναδρομή
- Ανάκτηση Πληροφοριών από τον Ιστό: Προκλήσεις και Απαιτήσεις
- Ο νόμος του Zipf και ο Ιστός
- Η δομή του γράφου του Ιστού
- Κατάλογοι (Yahoo/ODP) έναντι Μηχανών Αναζήτησης
  - Automatic Document Classification
  - Automatic Document Hierarchies
- Έρπειν (Crawling/Spidering)
  - Διάσχιση (spidering/crawling)
  - Depth/Breadth and Technical Details
  - Directed (Topic/Link/…) Spidering
  - Multi-Threaded Spidering
- Αποθήκευση και Ευρετηρίαση Σελίδων

Προϊστορία

- 1965:
  - Ο Ted Nelson συνέλαβε και ανέπτυξε την ιδέα του **υπερκειμένου** (hypertext)

- Τέλη δεκαετίας 60:
  - Ο Doug Engelbart επινόησε το **ποντίκι** και πρώτος υλοποίησε το υπερκείμενο.



- 1970's:
  - Ανάπτυξη του ARPANET

Άρα οι ιδέες και η βασική τεχνολογία υπήρχε από το 70. Έπρεπε να έρθει η εποχή των PC και της ευρείας αλληλοσύνδεσης για να εμπνευστούμε και να φτιάξουμε τον Παγκόσμιο Ιστό.

Το **Παγκόσμιος Ιστος** (the World Wide Web)

1990: Αναπτύχθηκε από τον **Tim Berners-Lee** (στο CERN) για την οργάνωση των ερευνητικών εγγράφων που ήταν διαθέσιμα στο Διαδίκτυο

- Ανέπτυξε το πρωτόκολο HTTP, όρισε τα URLs και τη γλώσσα HTML, και υλοποίησε τον πρώτο "web server."
- Συνδυασμός 2 ιδεών:
- Έγγράφων διαθέσιμων με FTP
- Διασύνδεση εγγράφων (υπερκείμενο)

Η Ιστορία των **Πλοηγητών** (Web Browsers)

- Early browsers were developed in **1992**
  - Erwise, ViolaWWW
- In **1993**, Marc Andreessen and Eric Bina at UIUC NCSA developed the **Mosaic browser** and distributed it widely.

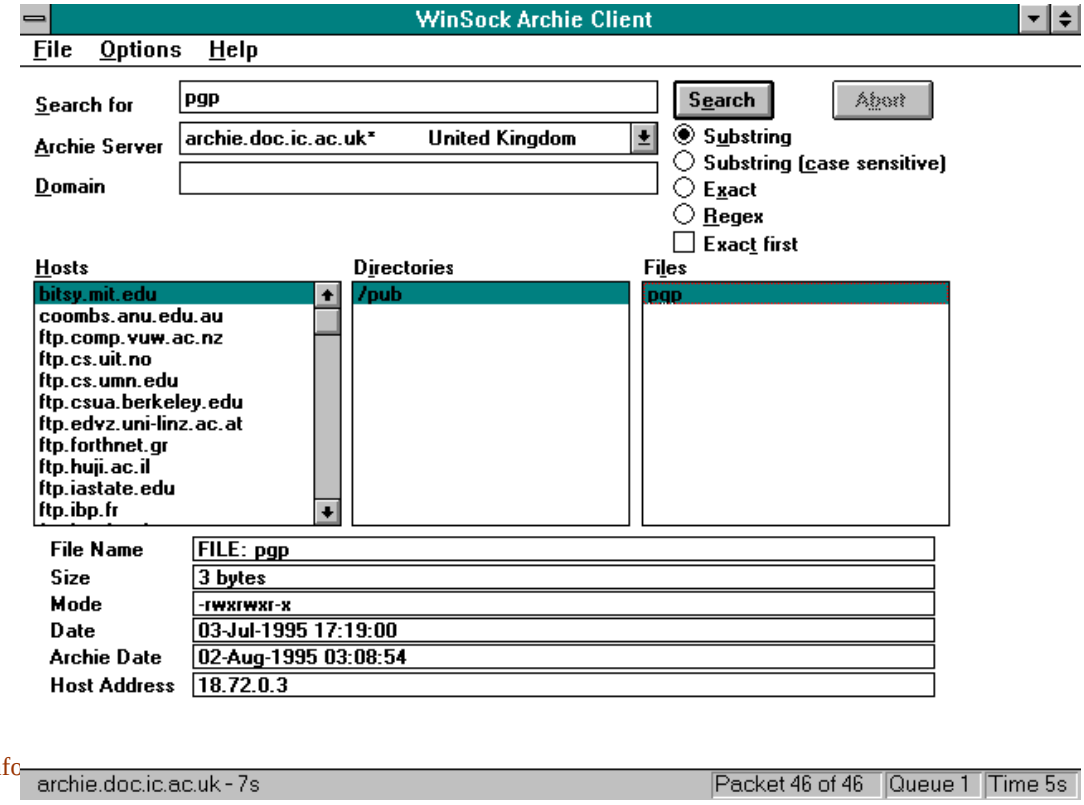
- **1994:** Andreessen joined with James Clark (Stanford Prof. and Silicon Graphics founder) to form Mosaic Communications Inc. (which became **Netscape** to avoid conflict with UIUC).

- **1995:** Microsoft licensed the original Mosaic from UIUC and used it to build **Internet Explorer**.

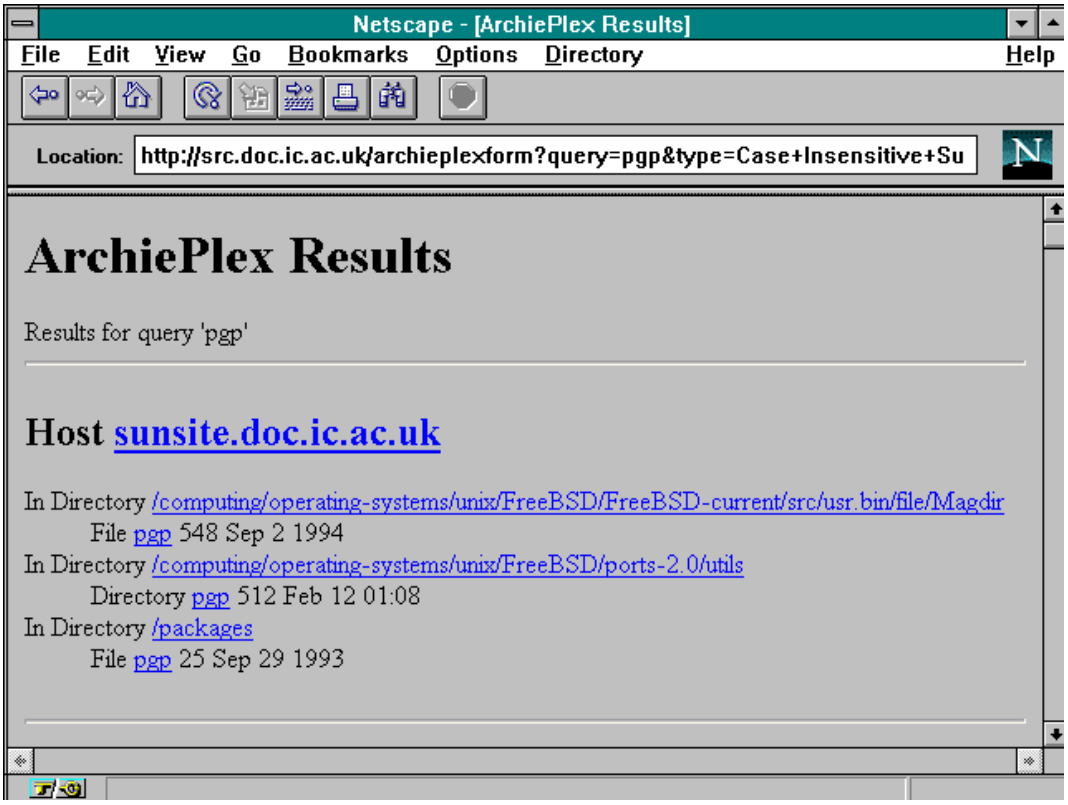
Η Ιστορία των **Μηχανών Αναζήτησης**
Search Engine Early History: **FTP, Archie**

- By late 1980's many files were available by **anonymous FTP**.
- In **1990**, Alan Emtage of McGill Univ. developed **Archie** (short for "archives")
  - Assembled lists of files available on many FTP servers.
  - Allowed regex search of these filenames.

Archie Client



Archie via WWW gateway



Η Ιστορία των **Μηχανών Αναζήτησης**
Search Engine Early History: **Gopher**

- In **1993**, Veronica and Jughead were developed to search names of text files available through **Gopher** servers.

- *Gopher* is a menu-driven Internet browser
- Presents users with a hierarchy of items and directories **much like a file system.**
  - The Gopher interface resembles a file system since a file system is a good model for organizing documents and services;
  - the user sees what amounts to one big networked information system containing primarily **document items**, **directory items**, and **search items** (the latter allowing searches for documents across subsets of the information base).
- Servers return either directory lists or documents.

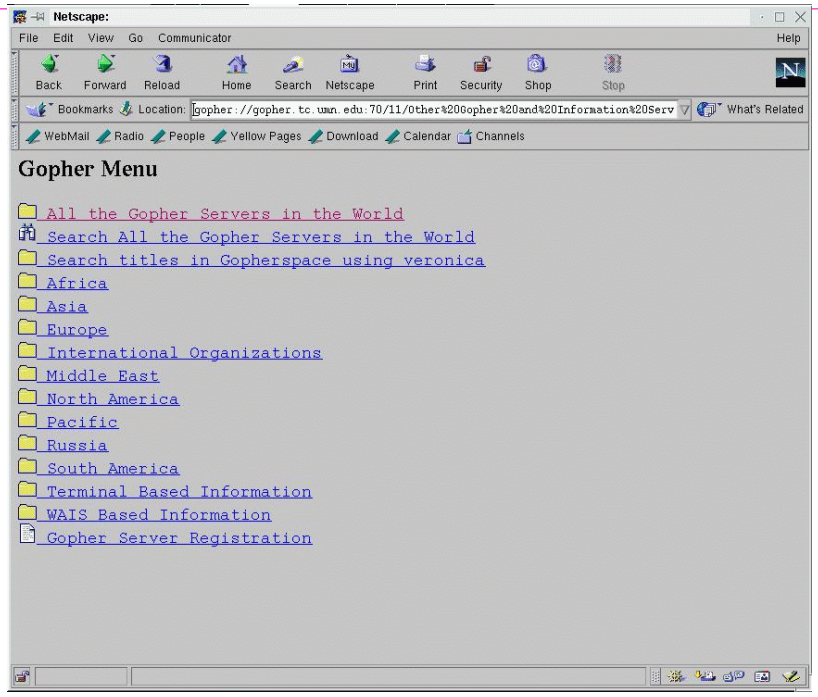
Η Ιστορία των **Μηχανών Αναζήτησης**
Search Engine Early History: **Gopher** (II)

- Each item in a directory is identified by
  - a **type** (the kind of object the item is),
  - **user-visible name** (used to browse and select from listings),
  - an opaque **selector string** (typically containing a pathname used by the destination host to locate the desired object),
  - a **host name** (which host to contact to obtain this item), and
  - an **IP port number** (the port at which the server process listens for connections).
- The user only sees the user-visible name. The client software can locate and retrieve any item by the trio of selector, hostname, and port.
- To use a search item, the client submits a query to a special kind of Gopher server: a **search server**. In this case, the client sends the selector string (if any) and the list of words to be matched. The response yields "virtual directory listings" that contain items matching the search criteria.

Gopher (III)

- **Veronica** has three phases that are performed periodically:
  - Harvesting. **Collects** all the menu entries and file names for all items in Gopherspace and **extracts** all the keywords.
    Indexing. Creates a **searchable index** with the keywords "harvested".
    Searching. When you enter a specific keyword, veronica searches its harvested index and prints out (displays) all the matching entries and their addresses, thereby providing a list that you can then search.

Gopher via WWW gateway



Try: http://gopher.quux.org:70/Software/Gopher

Η Ιστορία των **Μηχανών Αναζήτησης του Ιστού**

- **1993**: early **web robots (**else called **spiders** or **robots)** were built to collect URL's:
  - Wanderer, ALIWEB (Archie-Like Index of the WEB), WWW Worm (indexed URL's and titles for regex search)

- **1994a**: Stanford grad students David Filo and Jerry Yang started manually collecting popular web sites into a topical hierarchy called **Yahoo**.
- **1994b**: Brian Pinkerton developed WebCrawler as a class project at U Wash. (eventually became part of **Excite** and AOL).
- **1994c**: Fuzzy Maudlin, a grad student at CMU developed **Lycos**. First to use a standard IR system as developed for the DARPA Tipster project. First to index a large set of pages.
- **1995**: DEC developed **Altavista**. Used a large farm of Alpha machines to quickly process large numbers of queries. Supported boolean operators, phrases, and "reverse pointer" queries.

Η Ιστορία των **Μηχανών Αναζήτησης του Ιστού**

- In 1998, Larry Page and Sergey Brin, Ph.D. students at Stanford, started **Google**. Main advance is use of *link analysis* to rank results partially based on authority.

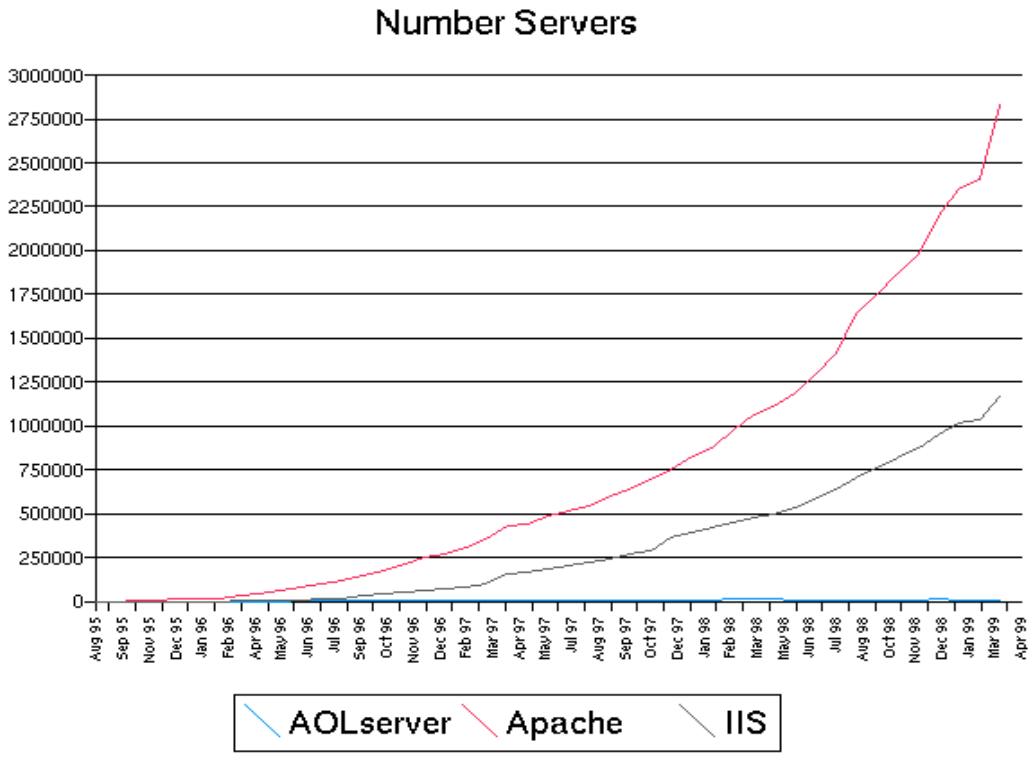
Ανάκτηση Πληροφοριών από τον Ιστό: **Προκλήσεις**

- Distributed Data: Documents spread over millions of different web servers.
- Volatile Data: Many documents change or disappear rapidly (e.g. dead links).
  - 23% of pages change daily
  - .com pages: 40% change daily, half-life=10 days (in 10 days half of the pages are gone)
- Large Volume: Billions of separate documents.
- Unstructured and Redundant Data: No uniform structure, HTML errors, up to 30% (near) duplicate documents.
- Quality of Data: No editorial control, false information, poor quality writing, typos, spam, etc.
- Heterogeneous Data: Multiple media types (images, video, VRML), languages, character sets, etc.

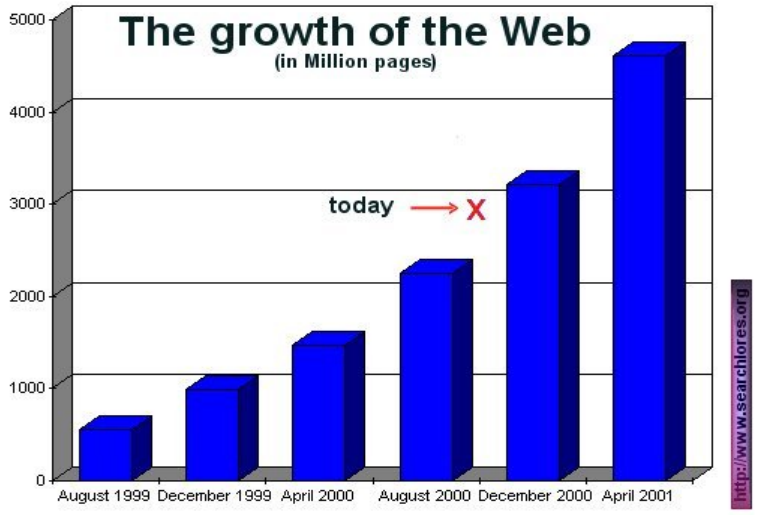
Ανάκτηση Πληροφοριών από τον Ιστό: **Προκλήσεις και Απαιτήσεις**

- Gathering techniques
- Scalable Index Structures efficiently updatable
- Improve the discrimination ability

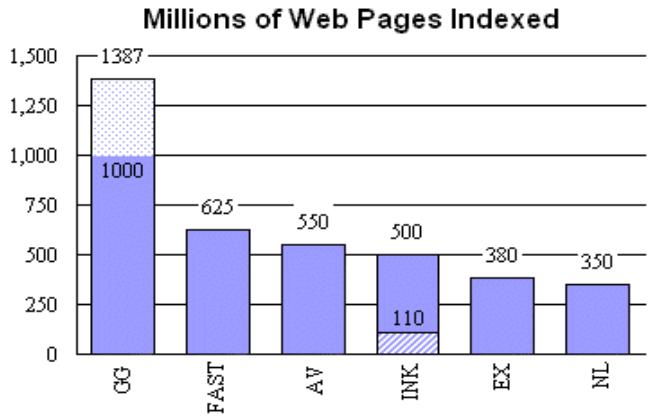
Number of Web Servers



Number of Web Pages



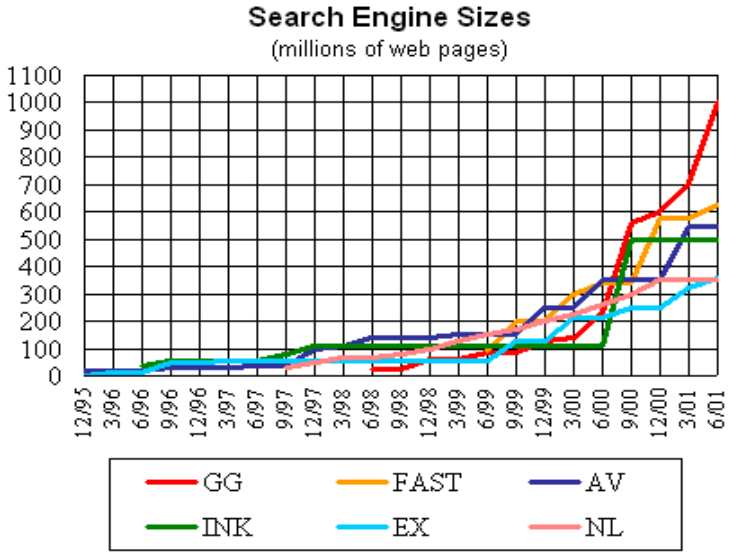
Number of Web Pages Indexed



SearchEngineWatch, Aug. 15, 2001

Assuming about 20KB per page,
1 billion pages is about 20 terabytes of data.

Growth of Web Pages Indexed



SearchEngineWatch, Aug. 15, 2001

Google lists current number of pages searched.
May 2005: **8 billion pages**

Ο νόμος του Ziph στον Παγκόσμιο Ιστό

Ο Νόμος του Ziph για τα κείμενα:

- *Η συχνότητα της i-th πιο συχνά εμφανιζόμενης λέξης είναι 1/i φορές η συχνότητα της πιο συχνής.*
  - *Πιο ακριβές: $1/i^{\theta}$ όπου θ μεταξύ 1.5 και 2*

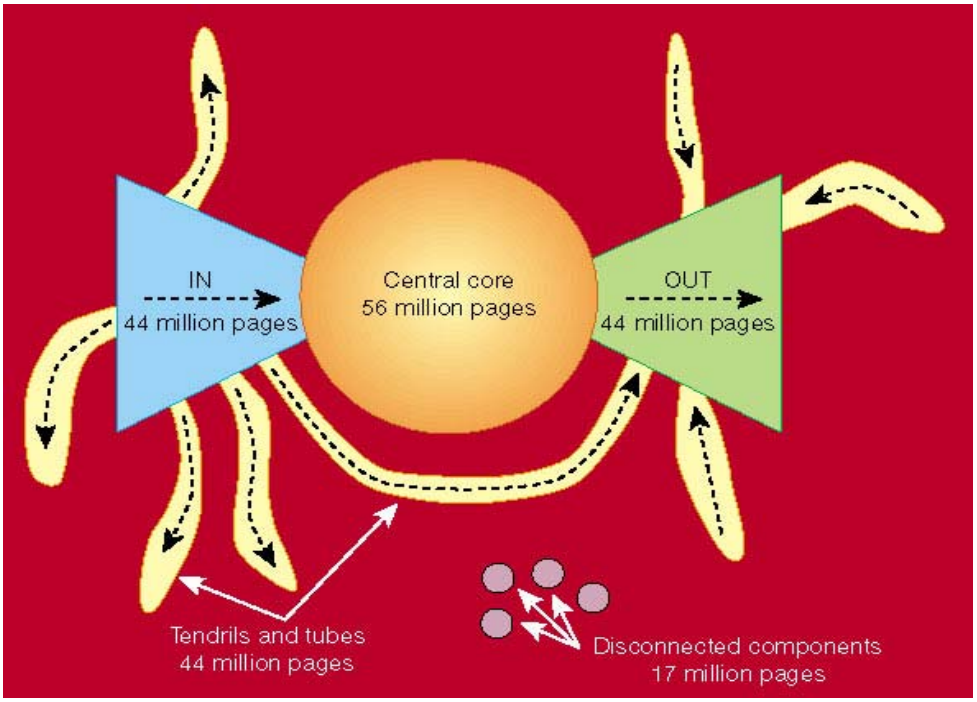
Ο Νόμος του Ziph στον Παγκόσμιο Ιστό:

- Number of in-links/out-links to/from a page has a Zipfian distribution.
  - the probability that a node has in-degree *i* is proportional to *1/i^x*, for some *x > 1*.
- Length of web pages has a Zipfian distribution.
- Number of hits to a web page has a Zipfian distribution.

Graph structure in the Web (I)

- Most (over 90%) of nodes form a single connected component if links are treated as *undirected* edges.
- This connected web breaks naturally into four pieces.
  - (1) The first piece is a central core, all of whose pages can reach one another along directed links -- this "giant strongly connected component" (*SCC*) is at the heart of the web.
  - *(2) IN* consists of pages that can reach the *SCC*, but cannot be reached from it
    - - possibly new sites that people have not yet discovered and linked to.
  - *(3) OUT* consists of pages that are accessible from the *SCC*, but do not link back to it,
    - such as corporate websites that contain only internal links.
  - (4) *TENDRILS* contain pages that cannot reach the *SCC,* and cannot be reached from the *SCC*.
- Each of the other three sets contain about 44 million pages -- thus, all four sets have roughly the same size.

Graph Structure of the Web (II)



http://www9.org/w9cdrom/160/160.html

Graph Structure in the Web (III)

- The diameter of the central core (*SCC*) is at least 28
- The diameter of the graph as a whole is over 500
- For randomly chosen source and destination pages, the probability that any path exists from the source to the destination is only 24%.
- If a directed path exists, its average length will be about 16.
- If an undirected path exists (i.e., links can be followed forwards or backwards), its average length will be about 6.
- In a sense the web is much like a complicated organism, in which the local structure at a microscopic scale looks very regular like a biological cell, but the global structure exhibits interesting morphological structure (body and limbs) that are not obviously evident in the local structure. Therefore, while it might be tempting to draw conclusions about the structure of the web graph from a local picture of it, such conclusions may be misleading.

Εύρεση πληροφορίας στον Παγκόσμιο Ιστό

Χειροποίητες Ταξινομίες Ιστού (Manual Hierarchical Web Taxonomies)

- Yahoo approach of using human editors to assemble a large hierarchically structured directory of web pages.
  - http://www.yahoo.com/
- Open Directory Project is a similar approach based on the distributed labor of volunteer editors ("net-citizens provide the collective brain"). Used by most other search engines. Started by Netscape.
  - http://www.dmoz.org/

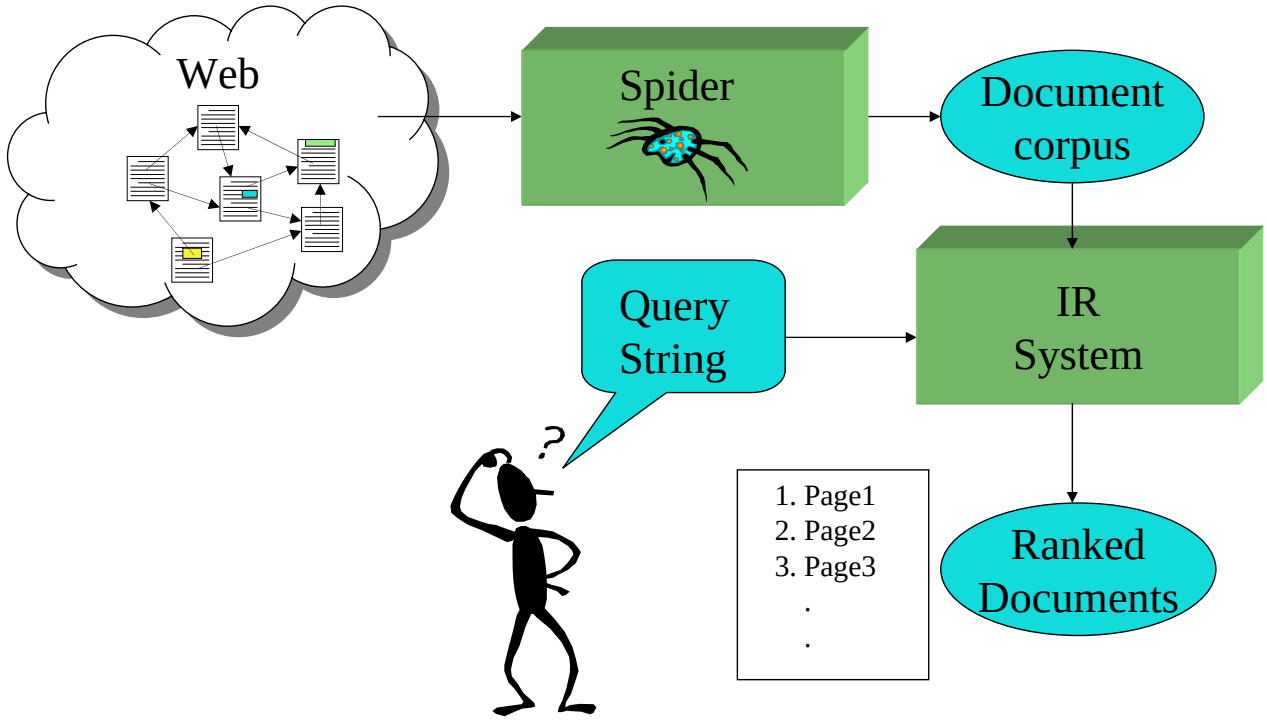
Αυτόματη Ταξινόμηση Σελίδων
(Automatic Document Classification)

- Manual classification into a given hierarchy is labor intensive, subjective, and error-prone.
- **Text categorization** methods provide a way to automatically classify documents.
- Best methods based on training a *machine learning* (*pattern recognition*) system on a labeled set of examples (*supervised learning*).

Αυτόματες Ιεραρχίες Εγγράφων
(Automatic Document Hierarchies)

- Manual hierarchy development is labor intensive, subjective, and error-prone.
- It would nice to automatically construct a meaningful hierarchical taxonomy from a corpus of documents.
- This is possible with hierarchical text clustering (unsupervised learning).
  - Hierarchical Agglomerative Clustering (HAC)
  - ***Θα μιλήσουμε για Ομαδοποίηση (Clustering) σε επόμενο μάθημα***

Ανάκτηση Πληροφοριών στον Ιστό



Γενική μορφή ενός Ευρετηρίου για ανάκτηση πληροφοριών από τον Ιστό

- **Crawling («έρπειν»)**

		Indexing Items					
		k_1	k_2	. . .	k_j	. . .	k_t
Web pages	d_1	$c_{1,1}$	$c_{2,1}$	. . .	$c_{i,1}$	. . .	$c_{t,1}$
	d_2	$c_{1,2}$	$c_{2,2}$	. . .	$c_{i,2}$	. . .	$c_{t,2}$
	. . .	. . .	. . .	. . .	. . .	. . .	. . .
	d_i	$c_{1,j}$	$c_{2,j}$	. . .	$c_{i,j}$	. . .	$c_{t,j}$
	. . .	. . .	. . .	. . .	. . .	. . .	. . .
	d_N	$c_{1,N}$	$c_{2,N}$	. . .	$c_{i,N}$	. . .	$c_{t,N}$

From	To
d2	d3
d2	d4
d4	d1
d10	d20

- **Ευρετηρίαση (Indexing)**

Crawling/Spidering

Spiders (Robots/Bots/Crawlers)

- Start with a comprehensive **set of root URL's** from which to start the search.
- **Follow all links** on these pages recursively to find additional pages.
- Index all **novel** found pages in an inverted index as they are encountered.
- May allow users to directly submit pages to be indexed (and crawled from).

Αλγόριθμος Διάσχισης (Spidering Algorithm)

```
Initialize queue (Q) with initial set of known URL's.
Until Q empty or page or time limit exhausted:
    Pop URL, L, from front of Q.
    If L is not an HTML page (.gif, .jpeg, .ps, .pdf, .ppt…)
        continue loop.
    If already visited L, continue loop.
    Download page, P, for L.
    If cannot download P (e.g. 404 error, robot excluded)
        continue loop.
    Index P (e.g. add to inverted index or store cached copy).
    Parse P to obtain list of new links N.
    Append N to the end of Q.
```


Crawling: Σχετικά Ζητήματα

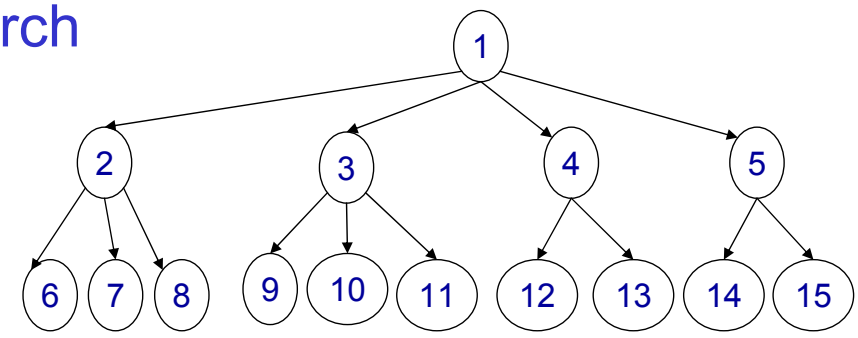
- What pages should the crawler download ?
  - In most cases it cannot download all, thus we need to prioritize the URLs
- How should the crawler refresh pages?
- How should the load on the visited Web sites by minimized ?
- How should the crawling process be parallelized ?

Στρατηγικές Διάσχισης (Crawling)

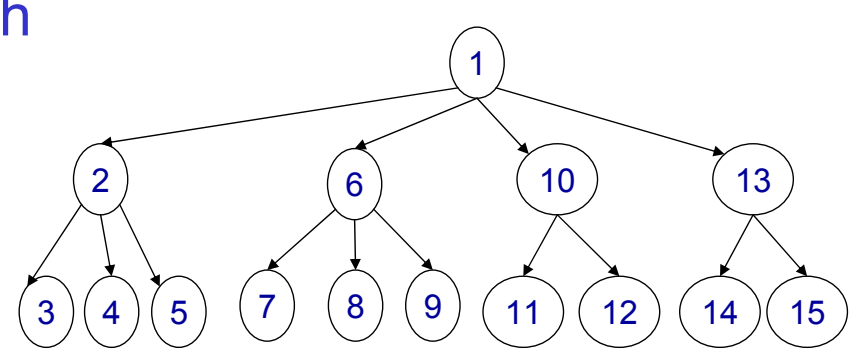
- (I) Breadth-first Search
- (II) Depth-first Search
- (III) Importance-first Search
  - Topic-directed search
  - Link-directed search
  - Location-directed search
  - Weighted combination of the above

Crawling Strategies (Στρατηγικές Διάσχισης)

(I) Breadth-first Search



(II) Depth-first Search



Crawling Strategy Trade-Off's

- (I) Breadth-first
  - explores uniformly outward from the root page but requires **memory of all nodes on the previous level** (exponential in depth). Standard spidering method.
- (II) Depth-first
  - requires **memory of only depth times branching-factor** (linear in depth) but gets "lost" pursuing a single thread.

Both strategies implementable using a queue of links (URL's).

- How new links added to the queue determines search strategy.
- FIFO (append to end of Q) gives breadth-first search.
- LIFO (add to front of Q) gives depth-first search.
- Heuristically ordering the Q gives a "focused crawler" that directs its search towards "interesting" pages.

Αλγόριθμος Διάσχισης (Spidering Algorithm)

```
Initialize queue (Q) with initial set of known URL's.
Until Q empty or page or time limit exhausted:
    Pop URL, L, from front of Q.
    If L is not an HTML page (.gif, .jpeg, .ps, .pdf, .ppt…)
        continue loop.
    If already visited L, continue loop.
    Download page, P, for L.
    If cannot download P (e.g. 404 error, robot excluded)
        continue loop.
    Index P (e.g. add to inverted index or store cached copy).
    Parse P to obtain list of new links N.
    Append N to the end of Q.      // =>Breadth First Search)
    Insert N at the beginning of Q  // =>Depth First Search)
```

(III) Importance-first Search

- Objective: Download and index **important** pages first
- Questions:
  - A/ What is the meaning of importance ?
  - B/ How a crawler operates ?
    - How a crawler guesses good pages to visit ?
  - C/ How we should refresh pages ?

A/ What is the meaning of importance ? (Importance Metrics)

Value(p) = k1 **ContentVal**(p) + k2 **PopularityVal**(p) + k3 **LocVal**(url(p))

- **ContentValue**(p)
  - can be based on a **driving query q**
  - e.g. ContentValue(p)= Cosine(vec(text(p)), **q**)
  - Notice that **idf** (inverse document frequency) can be only estimated
    - We would know its value if we had downloaded all pages of the Web
  - We could call this *topic-directed search*
- **Popularity**(p)
  - backlink count: | { p' | p' -> p }|
  - Related to *citation count* (coming from bibliometrics)
  - Again, this can be only estimated
  - We could call this *link-directed search*
- **LocationValue**(url(p))
  - e.g. high if ".com", low if it contains "home", low if it contains many slashes «/»
  - We could call this *location-directed search*

You could think many other metrics

B/ How a crawler operates ? (crawler models)

Design a crawler that if possible visits high importance pages before lower ranked ones (given an imporance metric).

Crawler models:

- ***Crawl & Stop***
  - Starts at its initial page p0 and stops after visiting K pages
  - Ideally these should be the K pages with the highest value
    - But this it is again impossible to know (unless downloading the entire Web)
- ***Crawl & Stop with Threshold***
  - Starts at its initial page p0 and stops after visiting K pages whose **value** is greater than a threshold
  - …

(C) Page Refresh Keeping Spidered Pages Up to Date

- Web is very dynamic: many new pages, updated pages, deleted pages, etc.
- **Periodically** check spidered pages for updates and deletions:
  - Just look at **header info** (e.g. META tags on last update) to determine if page has changed, only reload entire page if needed.
- **Track how often** each page is updated and preferentially return to pages which are historically more dynamic.
- Preferentially update pages that are **accessed more often** to optimize freshness of more popular pages.

Avoiding Page Duplication

- Must detect when revisiting a page that has already been spidered (web is a graph not a tree).
- Must efficiently index visited pages to allow rapid recognition test.
  - Tree indexing (e.g. trie)
  - Hashtable
- Index page using URL as a key.
  - Must canonicalize URL's (e.g. delete ending "/")
  - Not detect duplicated or mirrored pages.
- Index page using textual content as a key.
  - Requires first downloading page.

URL Syntax and Link Extraction

- URL Syntax
  - <scheme>://<authority><path>?<query>#<fragment>
  - An *authority* has the syntax:
    - <host>:<port-number>
  - A *query* passes variable values from an HTML form and has the syntax:
    - <variable>=<value>&<variable>=<value>…
  - A *fragment* is also called a *reference* or a *ref* and is a pointer within the document to a point specified by an anchor tag of the form:
    - <A NAME="<fragment>">
- Link Extraction
  - Must find all links in a page and extract URLs.
  - Must complete relative URL's using current page URL:
    - <a href="project"> to http://www.csd.uoc.gr/~hy463/project
    - <a href="../index.html"> to http://www.csd.uoc.gr/~hy463/index.html
  - BASE tag in the header section of an HTML file changes the base URL for all relative pointers:
    - <BASE HREF="<base-URL>">

Κανονικοποίηση Συνδέσμων (Link Normalization)

- Equivalent variations of ending directory normalized by removing ending slash.
  - http://www.csd.uoc.gr/~hy463/
  - http://www.csd.uoc.gr/~hy463
- Internal page fragments (ref's) removed:
  - http://www.csd.uoc.gr/~hy463/index.html
  - http://www.csd.uoc.gr/~hy463/index.html#grades
- http://WWW.cSd.uoc.gR:80/ equiv with http://www.csd.uoc.gr:

Link Extraction in Java

- Java Swing contains an HTML parser.
- In HandleStartTag, if it is an "A" tag, take the HREF attribute value as an initial URL.
- Complete the URL using the base URL:
  - new URL(URL baseURL, String relativeURL)
  - Fails if baseURL ends in a directory name but this is not indicated by a final "/"
  - Append a "/" to baseURL if it does not end in a file name with an extension (and therefore presumably is a directory).

Also:
http://htmlparser.sourceforge.net/javadoc_1_3/org/htmlparser/parserapplications/LinkExtractor.html

Restricting Crawling

- Restrict spider to a particular site.
  - Remove links to other sites from the queue Q.
- Restrict spider to a particular directory.
  - Remove links not in the specified directory.
- Obey page-owner restrictions (robot exclusion).
  - Web sites and pages can specify that robots should not crawl/index certain areas.
  - Two ways:
    - Robots Exclusion Protocol: Site wide specification of excluded directories.
    - Robots META Tag: Individual document tag to exclude indexing or following links.

Robots Exclusion Protocol

- Site administrator puts a "robots.txt" file at the root of the host's web directory.
  - www.enet.gr/robots.txt
  - http://www.cnn.com/robots.txt
- File is a list of excluded directories for a given robot (user-agent).
  - Exclude all robots from the entire site:

```
User-agent: *
Disallow: /
```

Robot Exclusion Protocol Examples

- Exclude specific directories:

```
User-agent: *
Disallow: /tmp/
Disallow: /cgi-bin/
Disallow: /users/paranoid/
```

- Exclude a specific robot:

```
User-agent: GoogleBot
Disallow: /
```

- Allow a specific robot:

```
User-agent: GoogleBot
Disallow:
```

- Some Details
  - Only use blank lines to separate different User-agent disallowed directories.
  - One directory per “Disallow” line.
  - No regex patterns in directories.

Δείτε:
www.enet.gr/robots.txt:
User-agent: *
Disallow: /past/
Disallow: /online/

http://www.cnn.com/robots.txt

```
User-agent: *
Disallow:   /cgi-bin
Disallow:   /TRANSCRIPTS
Disallow:   /development
Disallow:   /third
Disallow:   /beta
Disallow:   /java
Disallow:   /shockwave
Disallow:   /JOBS
Disallow:   /pr
Disallow:   /Interactive
Disallow:   /alt_index.html
Disallow:   /webmaster_logs
Disallow:   /newscenter
Disallow:      /virtual
Disallow:      /DIGEST
Disallow:      /QUICKNEWS
Disallow:      /SEARCH
```

```
User-agent:Mozilla/3.01 (hotwired-
      test/0.1)
Disallow:   /cgi-bin
Disallow:   /TRANSCRIPTS
Disallow:   /development
Disallow:   /third
Disallow:   /beta
Disallow:   /java
Disallow:   /shockwave
Disallow:   /JOBS
Disallow:   /pr
Disallow:   /Interactive
Disallow:   /alt_index.html
Disallow:   /webmaster_logs
Disallow:   /newscenter
Disallow:      /virtual
Disallow:      /DIGEST
Disallow:      /QUICKNEWS
Disallow:      /SEARCH
```

```
User-agent: GoogleBot
Disallow: /cgi-bin
Disallow: /java
Disallow: /images
Disallow: /development
Disallow:   /third
Disallow: /beta
Disallow: /webmaster_logs
Disallow: /virtual
Disallow: /shockwave
Disallow: /TRANSCRIPTS
Disallow:   /newscenter
Disallow:  /virtual
Disallow:  /DIGEST
Disallow:  /QUICKNEWS
Disallow:  /SEARCH
Disallow:   /alt_index.html
```

Robots META Tag

- Include META tag in HEAD section of a specific HTML document.
  - <meta name="robots" content="none">
- Content value is a pair of values for two aspects:
  - index | noindex: Allow/disallow indexing of this page.
  - follow | nofollow: Allow/disallow following links on this page.
- Special values:
  - all = index,follow
  - none = noindex,nofollow
- Examples:

<meta name="robots" content="noindex,follow">
<meta name="robots" content="index,nofollow">
<meta name="robots" content="none">

Robot Exclusion Issues

- META tag is newer and less well-adopted than "robots.txt".
- Standards are conventions to be followed by "good robots."
- Companies have been prosecuted for "disobeying" these conventions and "trespassing" on private cyberspace.
- "Good robots" also try not to "hammer" individual sites with lots of rapid requests.
  - "Denial of service" attack.

Multi-Threaded Crawling

- Bottleneck is network delay in downloading individual pages.
- Best to have multiple threads running in parallel each requesting a page from a different host.
- Distribute URL's to threads to guarantee equitable distribution of requests across different hosts to maximize throughput and avoid overloading any single server.
- Early Google spider had multiple co-ordinated crawlers with about 300 threads each, together able to download over 100 pages per second.

Αποθήκη Σελίδων (Page Repository)

- Objective
  - for storing pages downloaded by crawler
  - provide a fast API for indexer
- Challenges
  - scalability
    - seamlessly distribute the repository across a **cluster of computers and disks**
      - one computer is not enough
  - dual access mode
    - **random access**: retrieve quickly a specific page (given its id)
    - **streaming access**: retrieve quickly the entire set or a subset (e.g. all .edu) pages
  - large bulk updates
    - high rate of modifications (additions/deletions of pages, read vs. write accesses)
  - obsolete pages
    - detect and remove obsolete pages

Σχεδιάζοντας μια **Κατανεμημένη Αποθήκη Σελίδων** (Distributed Page Repository)

- (A) Page distribution across nodes
  - Uniform (all nodes are treated identically)
  - Hash distribution policy
    - allocation of pages to nodes depends on the page identifier (URL)
- (B) Physical page organization within a single node
  - Operations to support (page addition/insertion, high speed streaming,random page access)
  - Hash-based organization
    - treats a disk as a set of hash buckets each of which is small to fit in memory
    - pages are allocated to buckets depending on their URL
  - Log-based organization
    - incoming pages are appended. Random access is supported using a separate B-tree index
  - Hybrid approaches (e.g. Hash-Log organization)

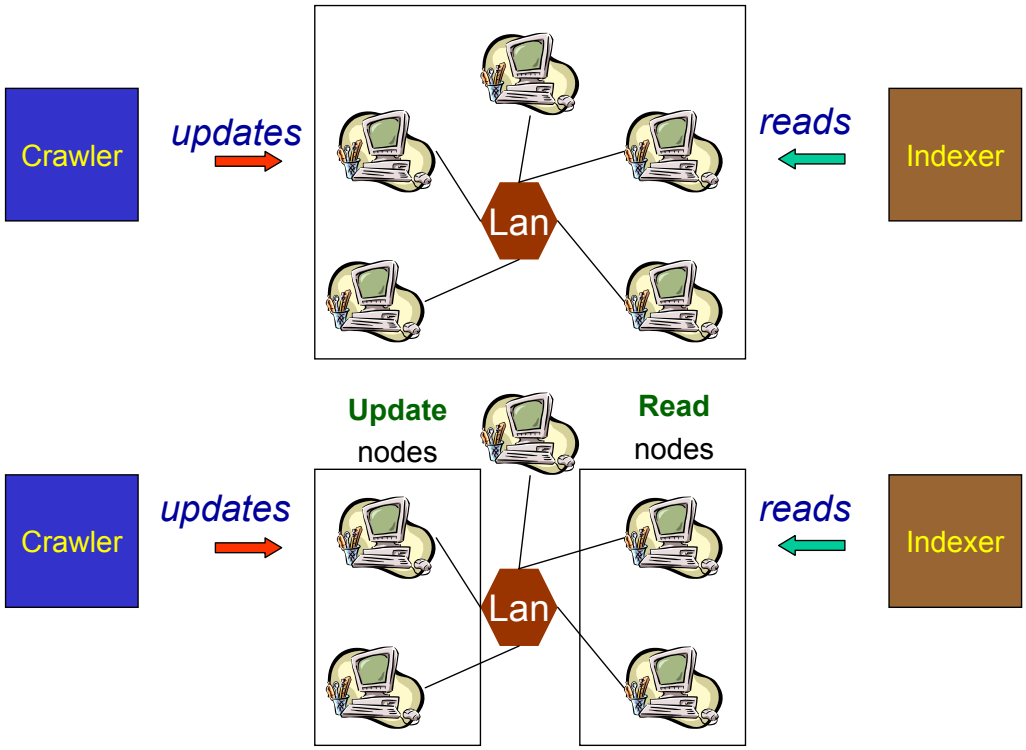
Σχεδιάζοντας μια **Κατανεμημένη Αποθήκη Σελίδων** (II)

- (C) Update strategies: Execution Mode
  - **Steady mode**
    - crawler runs without any stop
  - **Batch mode**
    - crawler is executed periodically (e.g. twice every month)
    - stops by time-limit or by amount of pages found
    - **Batch mode Partial**
      - recrawls only a specific set of pages or sites at each execution
    - **Batch mode Complete**
      - recrawls the entire collection at each execution

Σχεδιάζοντας μια **Κατανεμημένη Αποθήκη Σελίδων (III)**

- (C) Update strategies: InPlace vs. Shadowing updates
  - **In-Place updates**
    - pages received from the crawler are directly integrated into the repository's existing collections (possibly replacing older versions)
  - **Shadowing**
    - pages from crawler are stored separately and updates are applied in a separate step
    - allows separating between **update** and **read** accesses
      - a single storage node does not have to concurrently handle page addition and page retrieval
      - may degrade the freshness of the repository

Updates: In-Place vs. Shadowing (with read and update nodes)

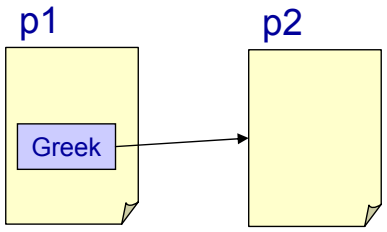


Ευρετηρίαση Ιστοσελίδων

Τύποι Ευρετηρίων

- Ευρετήριο **Κειμένων**
  - Π.χ. **Ανεστραμμένα Αρχεία (Inverted list)**, Αρχεία Καταλήξεων, Αρχεία Υπογραφών
- Ευρετήριο **Συνδέσμων** (Link Index)
  - connectivity graph of the Web (nodes: pages, edges: links)
  - common tasks (find pages that point to page p, find pages pointed by p)
  - billion nodes => efficient data structure
- Ευρετήριο **Χρησιμότητας** (Utility Index)
  - e.g. Site -> page index, PageRank index, etc
  - ...

Ευρετηρίαση Ιστοσελίδων: **Anchor Text Indexing**



vector(p2) = <Greek, … , >

- Extract **anchor text** (between <a> and) of each link followed.
- Anchor text is usually **descriptive** of the document to which it points.
- Add anchor text to the content of the destination page to provide additional relevant keyword indices.

<A HREF="www.csd.uoc.gr/~hy463"> IR Course in Greek </A>

Ευρετηρίαση Ιστοσελίδων: **Anchor Text Indexing (II)**

- Used by Google:
  - Evil Empire
  - IBM
- Many times anchor text is not useful:
  - "click here"
- Increases content more for popular pages with many in-coming links, increasing recall of these pages.
- May even give higher weights to tokens from anchor text.

Ευρετηρίαση Ιστοσελίδων: Κατασκευή Ανεστραμμένου Αρχείου

- For each term with a have a sorted list of locations.
- Extra: we store if the words appears in bold face, in heading, …
  - Commonly we multiply their weight with a constant
- Building the index
  - due to frequent update rate, usually we **rebuild** the index (incremental updates perform poorly)
- Partitioning the index
  - by pages
    - each node is responsible for a disjoint set of pages
  - by terms
    - each node is responsible for a disjoint set of terms
  - *(θα μιλήσουμε για αυτά σε επόμενο μάθημα (Distributed IR))*
- Pipelined index build (loading (LAN) preprocessing (CPU) and flushing (DISK) concurrently

Διάρθρωση Διάλεξης

- Ιστορική Αναδρομή
- Web Challenges and Requirements for IR
- Zipf Law in the Web
- Graph Structure of the Web
- Yahoo/ODP vs Search Engines
  - Automatic Document Classification
  - Automatic Document Hierarchies
- Crawling/Spidering
  - Διάσχιση (spidering/crawling)
  - Depth/Breadth and Technical Details
  - Directed (Topic/Link/…) Spidering
  - Multi-Threaded Spidering
- Αποθήκευση και Ευρετηρίαση Σελίδων

***Read**: Searching the Web, A. Arasu, J. Cho, H. Garcia-Molina, A. Paepcke and S. Raghavan,TOIT*