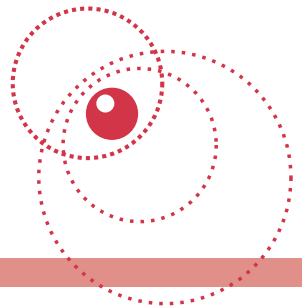

Web mining

The World Wide Web, Web Crawling

26 September 2011

Pierre Senellart

TELECOM ParisTech

The Internet

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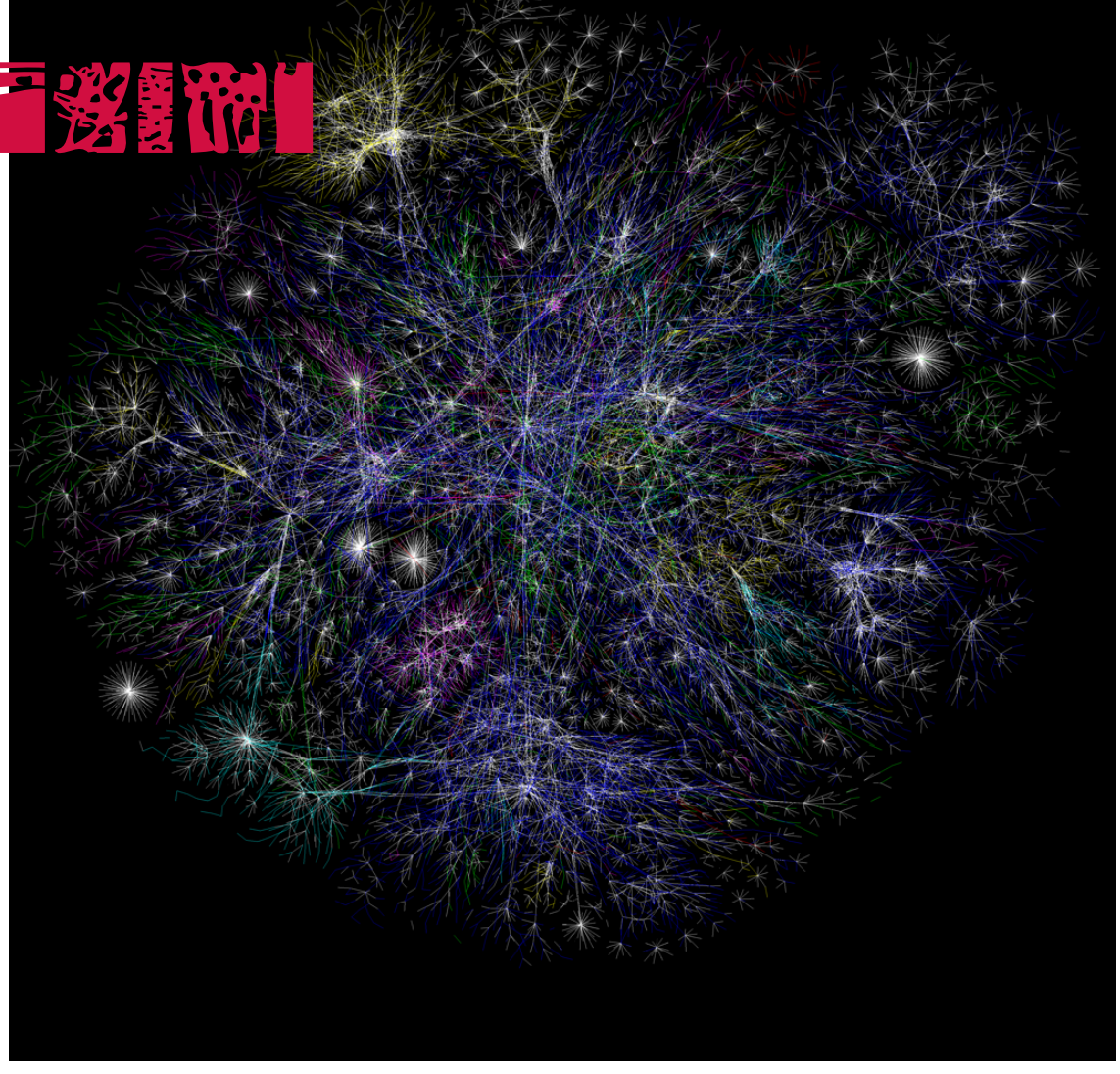

http://www.opte.org/

A stack of communication protocols, on top of each other.

Application	HTTP, FTP, SMTP, DNS	
Transport	TCP, UDP, ICMP	(sessions, reliability. . .)
Network	IP (v4, v6)	(routing, addressing)
Link	Ethernet, 802.11 (ARP)	(addressing local machines)
Physical	Ethernet, 802.11 (physical)	

- Addressing machines and routing over the Internet
- Two versions of the IP protocol on the Internet: IPv4 (very well spread) and IPv6 (support still a bit experimental)
- IPv4: 4-byte addresses assigned to each computer, e.g., 137.194.2.24. Institutions are given ranges of such addresses, to assign as they will.
- Problem: only 2^{32} possible addresses (actually, a large number of them cannot be assigned to new hosts, for multiple reasons). This means many hosts connected to the Internet do not have an IPv4 address and some network address translation (NAT) occurs.
- IPv6: 16-byte addresses; much larger address space! Addresses look like 2001:660:330f:2::18 (meaning 2001:0660:0330f:0002:0000:0000:0000:0018). Other nice features (multicast, autoconfiguration, etc.).

- One of the two main transport protocols used on IP, with UDP (User Datagram Protocol)
- Contrarily to UDP, provides reliable transmission of data (acknowledgments)
- Data is divided into small datagrams that are sent over the network, and possibly reordered at the end point
- Like UDP, each TCP transmission indicates a source and a destination port number (between 0 and 65535) to distinguish it from other traffic
- A client usually select a random port number for establishing a connection to a fixed port number on a server
- The port number on a server conventionally identifies an application protocol on top of TCP/IP: 22 for SSH, 25 for SMTP, 110 for POP3...

- IPv4 addresses are hard to memorize, and a given service (e.g., a Web site) may change IP addresses (e.g., new Internet service provider)
- Even more so for IPv6 addresses!
- DNS: a UDP/IP-based protocol for associating human-friendly names (e.g., `www.google.com`, `weather.yahoo.com`) to IP addresses
- Hierarchical domain names: `com` is a top-level domain (TLD), `yahoo.com` is a subdomain thereof, etc.
- Hierarchical domain name resolution: root servers with fixed IPs know who is in charge of TLDs, servers in charge of a domain know who is in charge of a subdomain, etc.
- Nothing magic with `www.google.com`: just a subdomain of `google.com`.

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Internet: physical network of computers (or hosts)

World Wide Web, Web, WWW: logical collection of hyperlinked documents

- static and dynamic
- public Web and private Webs
- each document (or Web page, or resource) identified by a URL

1969 ARPANET (the ancestor of the Internet)

1974 TCP (Vinton G. Cerf & Robert E. Kahn, Turing award winners 2004)

1990 World Wide Web, HTTP, HTML (Tim Berners-Lee, Robert Cailliau)

1993 Mosaic (the first public successful graphical browser, ancestor of Netscape)

1994 Yahoo! (David Filo, Jerry Yang)

1994 Foundation of the W3C

1995 Amazon.com, Ebay

1995 Internet Explorer

1995 AltaVista (Louis Monier, Michael Burrows)

1998 Google (Larry Page, Sergey Brin)

2001 Wikipedia (Jimmy Wales)

Sources: [Electronic Software Publishing Corporation, 2008], [BBC, 2006]

2004 Mozilla Firefox

2005 YouTube

`https://www.example.com:443/path/to/doc?name=foo&town=bar#para`

scheme hostname port path query string fragment

scheme: way the resource can be accessed; generally http or https

hostname: domain name of a host (cf. DNS); hostname of a website may start with `www.`, but not a rule.

port: TCP port; defaults: 80 for `http` and 443 for `https`

path: logical path of the document

query string: optional additional parameters (dynamic documents)

fragment: optional subpart of the document

Relative URLs with respect to a context (e.g., the URL above):

`/titi`	`https://www.example.com/titi`
`tata`	`https://www.example.com/path/to/tata`

- For content: HTML/XHTML, but also PDF, Word documents, text files, XML (RSS, SVG, MathML, etc.)...
- For presenting this content: CSS, XSLT
- For animating this content: JavaScript, AJAX, VBScript...
- For interaction-rich content: Flash, Java, Sliverlight, ActiveX...
- Multimedia content: images, sounds, videos...
- And on the server side: any programming language and database technology to serve this content, e.g., PHP, JSP, Java servlets, ASP, ColdFusion, etc.

Quite complex to manage! Being a Web developer nowadays requires mastering a lot of different technologies; designing a Web client requires being able to handle a lot of different technologies!

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- Graphical browsers (cf. next slide)
- Text browsers: w3m, lynx, links (free software, Windows, Mac OS, Linux, Unix); rarely used nowadays
- Other browsers: audio browsers, etc.
- But also: spiders for siphoning a Web site, search engine crawlers (see later on), machine translation software. . .

A very large variety of clients! Web standards (mainly, HTML, CSS, HTTP) are supposed to describe what their interpretation of a Web page should be. In reality, more complex (tag soup).

	Engine	Share	Distribution
Internet Explorer	Trident	40%	with Windows
Firefox	Gecko	25%	Windows, MacOS, Unix FS
Google Chrome	WebKit	20%	Windows, MacOS, Linux FS
Safari	WebKit	8%	MacOS, Windows FC
Opera	Presto	2%	Windows, MacOS, Unix, mobiles FC

FC: free of charge (free as a beer)
FS: free software (free as a man)

Market shares: various sources, precise numbers hard to obtain. IE continually decreasing over the last years.

Trident remains the worst standard-compliant rendering engine.

- Google Chrome has known impressive success (only 3 years since its initial release)
- Versions of Internet Explorer 6, 7, 8, 9 still all heavily used (especially in the enterprise world); IE6 is the browser coming with initial releases of Windows XP browser.

Server	Share	Distribution
Apache	60%	Windows, Mac OS, Linux, Unix FS
Microsoft IIS	30%	with some versions of Windows
lighthttpd	1%	Windows, Mac OS, Linux, Unix FS
Unidentifiable	9%	

- Market share: according to some studies by Opera and Netcraft, precise numbers do not really mean anything.
- Many large software companies have either their own Web server or their own modified version of Apache (notably, GFE/GWS for Google).
- lighthttpd is (as its name suggests!) lighter (i.e., less feature-rich, but faster in some contexts) than Apache.
- The versions of Microsoft IIS released with consumer versions of Windows are very limited.

A large number of different search engines, with market shares varying a lot from country to country.

- At the world level, the big 3:
  - **Google** vastly dominating (more than 90% market share in France!)
  - **Yahoo!** still resists to its main competitor (15% in the US, 50% in Japan)
  - **Bing** (formerly known as MSN, Microsoft Live Search) recent progression (perhaps 10% of the global market)
- In some countries, local search engines dominate the market (Baidu with 75% in China, Naver in Korea...)

In July 2009, Microsoft and Yahoo! announced a major agreement:

- Yahoo! stops developing its own search engine (launched in 2003, after the buyouts of Inktomi and Altavista) and will use Bing instead;
- Yahoo! will provide the advertisement services used in Bing.

Operational, but does not concern Yahoo! Japan, which on the contrary uses Google as engine.

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formalized by the W3C (World Wide Web Consortium) formed of industrials (Microsoft, Google, Apple. . .) and academic institutions (ERCIM, MIT, etc.)

- open format: possible processing by a wide variety of software and hardware
- text files with tags
- describes the structure and content of a document, focus on accessibility
- (theoretically) no presentation information (this is the role of CSS)
- no description of dynamic behaviors (this is the role of server-side languages, JavaScript, etc.)

- HTML is a language alternating text and tags (`<blabla>` or `</blabla>`)
  - Tags allow structuring each part of a document, and are used for instance by a browser to lay out the document.
- HTML files
  - are structured in two main parts: the header `<head> ... </head>`) and the body `<body> ... </body>`)
- In HTML, blanks (spaces, tabs, carriage returns) are generally equivalent and only serve to delimit words, tags, etc. The number of blanks does not matter.

Syntax: (opening and closing tag)

```
<tag attributes>content</tag>
```

or (element with no content)

```
<tag attributes>
```

tag keyword referring to some particular HTML element

content may contain text and other tags

attributes represent the various parameters associated with the element, as a list of `name="value"` or `name='value'`, separated by spaces (quotes are not always mandatory, but they become mandatory if `value` has "exotic" characters)

- Names of elements and attributes are usually written in lowercase, but `<head>` and `<HeAd>` are equivalent.
- Tags are opened and closed in the right order (`<b><i></i></b>` and not `<b><i></b></i>`).
- Strict rules specify which tags can be used inside which.
- Under some conditions, a tag can be implicitly closed, but these conditions are complex to describe.
- `<!--foobar-->` denotes a comment, which is not to be interpreted by a Web client.

```
<!DOCTYPE html PUBLIC "-//W3C//DTD HTML 4.01//EN"
"http://www.w3.org/TR/html4/strict.dtd">
<html lang="en">
  <head>
    <!-- Header of the document -->
  </head>
  <body>
    <!-- Body of the document -->
  </body>
</html>
```

- The doctype declaration `<!DOCTYPE ...>` specify which HTML version is used.
- The language of the document is specified with the `lang` attribute of the main `<html>` tag.

The header of a document is delimited by the tags `<head> ... </head>`.

- The header contains meta-informations about the document, such as its title, encoding, associated files, etc. The two most important items are:
  - The character set of the page, usually at the very beginning of the header

```
<meta http-equiv="Content-Type"
      content="text/html; charset=utf-8">
```

  - The title of the page (the only required item inside the header). This is the information displayed in the title bar of Web browsers.

```
<title>My great website</title>
```

: character repertoire, assigning to each character, whatever its script or language, an integer number.

Examples

A	$\rightarrow$	65	ε	$\rightarrow$	949
é	$\rightarrow$	233	א	$\rightarrow$	1488

Character set: concrete method for representing a Unicode character.

Examples (é)

iso-8859-1	`11101001`	only for some characters
utf-8	`11000011 10101001`	
utf-16	`11101001 00000000`	

utf-8 has the advantage of being able to represent all Unicode characters, in a way compatible with the legacy ASCII encoding.

- `<body> ... </body>` tags delimit the body of a document.
- The body is structured into sections, paragraphs, lists, etc.
- 6 tags describe sections, by decreasing order of importance:
  - `<h1>Title of the page</h1>`
  - `<h2>Title of a main section</h2>`
  - `<h3>Title of a subsection</h3>`
  - `<h3>Title of a subsubsection</h3>`
  - ...
- `<p> ... </p>` tags delimit paragraphs of text. All text paragraphs should be delimited thusly.
- Directly inside `<body> ... </body>` can only appear block elements: `<p>`, `<h1>`, `<form>`, `<hr>`, `<ul>`, `<table>` ... in addition to the `<div>` tag which denotes a block without precise semantics.

- What differetiates Web pages (hypertext pages) from normal documents: links!
- Introduced with `<a> ... </a>`
- Navigating a link can bring to:
  - a resource on another server or another file of the same server
  - another part of the same document

Links are made using the `href` attribute of the `<a>` tag, whose content will be the link:

```
<a href="http://www.cnrs.fr/">
  <img src="images/cnrs.gif" alt="CNRS">
</a>

<a href="bio/indexbioinfo.html">Bioinformatics</a>
```

- Anchors serve to reach a precise point in the document.
  - They are defined, either on an existing tag by using the `id` attribute, or with an `<a id="...">` :

```
<h3 id="tutorials">Tutorials</h3>
<a id="tutorials">
```

  - Then, one can link to this anchor:

```
<a href="#tutorials">tutorials</a>
<a href="http://www.w3.org/#tutorials">tutorials</a>
```

  - Commonly, the old `<a name="...">` syntax is used.

- HTML 4.01 (1999) strict (as described earlier) and transitional

```
<!DOCTYPE html PUBLIC "-//W3C//DTD HTML 4.01//EN"
"http://www.w3.org/TR/html4/strict.dtd">
```

```
<!DOCTYPE html PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN"
"http://www.w3.org/TR/html4/loose.dtd">
```

- XHTML 1.0 (2000) strict and transitional

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
"http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
```

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
"http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
```

- XHTML 1.1 and XHTML 2.0: mostly a failure, unusable and unused in today's Web
- HTML 5: the future standard, in development

- A lot of the HTML documents on the Web date back from before HTML 4.01
- In practice: many Web pages do not respect any standards at all (with or without doctype declarations) $\Longrightarrow$ browsers do not respect these standards $\Longrightarrow$ tag soup!
- When dealing with pages from the real Web, necessary to use all sorts of heuristics to interpret a Web page.

XHTML: an XML format

- Tags without content `<img>`, are written `<img />` in XHTML.
- Some elements can be left unclosed in HTML (`<ol><li>one <li>two </ol>`), but closing is mandatory in XHTML.
- Attribute values can be written without quotes (`<img src=toto.png alt=toto>`) in HTML, quotes are required in XHTML.
- Element and attribute names are not case-sensitive in HTML (`<HTMl laNg=fr>`), but are in XHTML (everything must be in lowercase).
- Attributes `xmlns` and `xml:lang` on the `<html>` tag in XHTML.
- And some other small subtleties. . .

- XHTML 2.0: initiative of the W3C, incompatible with HTML 4.01/XHTML 1.0, major changes
- HTML 5: initiative of browser developers, compatible with HTML 4.01/XHTML 1.0, incremental but numerous changes
- XHTML 2.0 abandoned in July 2009
- HTML 5 features start appearing in recent browsers (Internet Explorer excepted, which has however indicated its interest)
- HTML 5 offers the choice between syntactic conventions inherited from both HTML 4.01 and XHTML
- New features: 2D drawing (`<canvas>`), multimedia (`<audio>` , `<video>`), better structuring elements (`<section>` , `footer`), etc.

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- Application protocol at the basis of the World Wide Web
  - Latest and most widely used version: HTTP/1.1

- Client request:

```
GET /MarkUp/ HTTP/1.1
Host: www.w3.org
```

- Server response:

```
HTTP/1.1 200 OK
...
Content-Type: text/html; charset=utf-8

<!DOCTYPE html ...> ...
```

  - Two main HTTP methods: GET and POST (HEAD is also used in place of GET, to retrieve meta-information only).
  - Additional headers, in the request and the response
  - Possible to send parameters in the request (key/value pairs).

- Simplest type of request.
- Possible parameter are sent at the end of a URL, after a ‘?’
- Not applicable when there are too many parameters, or when their values are too long.
- Method used when a URL is directly accessed in a browser, when a link is followed, and for some forms.

Example (Google query)

URL: `http://www.google.com/search?q=hello`

Corresponding HTTP GET request:

```
GET /search?q=hello HTTP/1.1
Host: www.google.com
```

- Method only used for submitting forms.

Example

```
POST /php/test.php HTTP/1.1
Host: www.w3.org
Content-Type: application/x-www-form-urlencoded
Content-Length: 100

type=search&title=The+Dictator&format=long&country=US
```

- By default, parameters are sent (with GET or POST) in the form: `name1=value1&name2=value2`, and special characters (accented characters, spaces...) are replaced by codes such as +, `%20`. This way of sending parameters is called `application/x-www-form-urlencoded`.
- For the POST method, another heavier encoding can be used (several lines per parameter), similar to the way emails are built: mostly useful for sending large quantity of information. Encoding named `multipart/form-data`.

- The HTTP response always starts with a status code with three digits, followed by a human-readable message (e.g., 200 OK).
- The first digit indicates the class of the response:
  1. Information
  2. Success
  3. Redirection
  4. Client-side error
  5. Server-side error

200	OK
301	Permanent redirection
302	Temporary redirection
304	No modification
400	Invalid request
401	Unauthorized
403	Forbidden
404	Not found
500	Server error

- Different domain names can refer to the same IP address, i.e., the same physical machine (e.g., `www.google.fr` and `www.google.com`)
- When a machine is contacted by TCP/IP, it is through its IP address
- No *a priori* way to know which precise domain name to contact
- In order to serve different content according to the domain name (virtual host): header `Host:` in the request (only header really required)

Example

```
GET /search?hl=fr&q=hello HTTP/1.1
Host: www.google.fr
```

- The browser behaves differently depending on the content type detected: display a Web page with the layout engine, display an image, load an external application, etc.
- MIME classification of content types (e.g., `image/jpeg`, `text/plain`, `text/html`, `application/xhtml+xml`, `application/pdf` etc.)
- For a HTML page, or for text, the browser must also know what character set is used (this has precedence over the information contained in the document itself)
- Also returned: the content length (can be used to display a progress bar)

Example

```
HTTP/1.1 200 OK
Content-Type: text/html; charset=UTF-8
Content-Length: 3046
```

- Web clients and servers can identify themselves with a character string
- Useful to serve different content to different browsers, detect robots...
- ... but any client can say it's any other client!
- Historical confusion on naming: all common browsers identify themselves as Mozilla!

Example

```
User-Agent: Mozilla/5.0 (X11; U; Linux x86_64; fr;
rv:1.9.0.3) Gecko/2008092510 Ubuntu/8.04 (hardy)
Firefox/3.0.3

Server: Apache/2.0.59 (Unix) mod_ssl/2.0.59 OpenSSL/0.9.8e
PHP/5.2.3
```

- HTTP allows for protecting access to a Web site by an identifier and a password
  - Attention: (most of the time) the password goes through the network uncrypted (but for instance, just encoded in Base64, revertible encoding)
  - HTTPS (variant of HTTP that includes encryption, cryptographic authentication, session tracking, etc.) can be used instead to transmit sensitive data

Example

```
GET ... HTTP/1.1
Authorization: Basic dG90bzp0aXRp
```

- A Web client can specify to the Web server:
  - the content type it can process (text, images, multimedia content), with preferrence indicators
  - the languages preferred by the user
- The Web server can thus propose different file formats, in different languages.
- In practice, content negociation on the language works, and is used, but content negociation on file types does not work because of bad default configuration of some browsers.

Example

```
Accept: text/html,application/xhtml+xml,application/xml;
q=0.9,*/*;q=0.8
Accept-Language: fr,fr-fr;q=0.8,en-us;q=0.5,en;q=0.3
```

- Information, as key/value pairs, that a Web server asks a Web client to keep and retransmit with each HTTP request (for a given domain name).
- Can be used to keep information on a user as she is visiting a Web site, between visits, etc.: electronic cart, identifier, and so on.
- Practically speaking, most often only stores a session identifier, connected, on the server side, to all session information (connected or not, user name, data. . .)
- Simulates the notion of session, absent from HTTP itself

Example

```
Set-Cookie: session-token=RJYBsG//azkfZrRazQ3SPQhlo1FpkQka2;
path=/; domain=.amazon.de;
expires=Fri Oct 17 09:35:04 2008 GMT

Cookie: session-token=RJYBsG//azkfZrRazQ3SPQhlo1FpkQka2
```

- A client can ask for downloading a page only if it has been modified since some given date.
  - Most often not applicable, the server giving rarely a reliable last modification date (difficult to obtain for dynamically generated content!).

Example

```
If-Modified-Since: Wed, 15 Oct 2008 19:40:06 GMT

304 Not Modified
Last-Modified: Wed, 15 Oct 2008 19:20:00 GMT
```

- When a Web browser follows a link or submits a form, it transmits the originating URL to the destination Web server.
- Even if it is not on the same server!

Example

```
Referer: http://www.google.fr/
```

The World Wide Web

Web crawlers

- Discovering new URLs
- Identifying duplicates
- Crawling architecture
- Recrawling URLs?

Conclusion

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Conclusion

- crawlers, (Web) spiders, (Web) robots: autonomous user agents that retrieve pages from the Web
- Basics of crawling:
  1. Start from a given URL or set of URLs
  2. Retrieve and process the corresponding page
  3. Discover new URLs (cf. next slide)
  4. Repeat on each found URL
- No real termination condition (virtual unlimited number of Web pages!)
- Graph-browsing problem

  deep-first: not very adapted, possibility of being lost in robot traps

  breadth-first

  combination of both: breadth-first with limited-depth deep-first on each discovered website

- From HTML pages:
  - hyperlinks `<a href="...">...</a>`
  - media `<img src="...">` `<embed src="...">` `<object data="...">`
  - frames `<frame src="...">` `<iframe src="...">`
  - JavaScript links `window.open("...")`
  - etc.
- Other hyperlinked content (e.g., PDF files)
- Non-hyperlinked URLs that appear anywhere on the Web (in HTML text, text files, etc.): use regular expressions to extract them
- Referrer URLs
- Sitemaps [sitemaps.org, 2008]

Web-scale

- The Web is infinite! Avoid robot traps by putting depth or page number limits on each Web server
- Focus on important pages [Abiteboul et al., 2003] (cf. lecture on the Web graph)

- Web servers under a list of DNS domains: easy filtering of URLs
- A given topic: focused crawling techniques [Chakrabarti et al., 1999, Diligenti et al., 2000] based on classifiers of Web page content and predictors of the interest of a link.
- The national Web (cf. public deposit, national libraries): what is this? [Abiteboul et al., 2002]
- A given Web site: what is a Web site? [Senellart, 2005]

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Conclusion

A hash function is a deterministic mathematical function transforming objects (numbers, character strings, binary...) into fixed-size, seemingly random, numbers. The more random the transformation is, the better.

Example

Java hash function for the `String` class:

$$\sum_{i=0}^{n-1} s_i \times 31^{n-i-1} \bmod 2^{32}$$

where s_i is the (Unicode) code of character i of a string s.

Problem

Identifying duplicates or near-duplicates on the Web to prevent multiple indexing

trivial duplicates: same resource at the same canonized URL:

```
http://example.com:80/toto
http://example.com/titi/../toto
```

exact duplicates: identification by hashing

near-duplicates: (timestamps, tip of the day, etc.) more complex!

Edit distance. Count the minimum number of basic modifications (additions or deletions of characters or words, etc.) to obtain a document from another one. Good measure of similarity, and can be computed in $O(mn)$ where m and n are the size of the documents. But: does not scale to a large collection of documents (unreasonable to compute the edit distance for every pair!).

Shingles. Idea: two documents similar if they mostly share the same succession of k-grams (succession of tokens of length k).

Example

I like to watch the sun set with my friend.
My friend and I like to watch the sun set.

S ={i like, like to, my friend, set with, sun set, the sun, to watch, watch the, with my}
T ={and i, friend and, i like, like to, my friend, sun set, the sun, to watch, watch the}

- Similarity: Jaccard coefficient on the set of shingles:

$$J(S,T) = \frac{|S \cap T|}{|S \cup T|}$$

- Still costly to compute! But can be approximated as follows:
  1. Choose N different hash functions
  2. For each hash function h_i and each set of shingles $S_k = \{s_{k1} \ldots s_{kn}\}$, store $\phi_{ik} = \min_j h_i(s_{kj})$
  3. Approximate $J(S_k, S_l)$ as the proportion of ϕ_{ik} and ϕ_{il} that are equal
- Possibly to repeat in a hierarchical way with super-shingles (we are only interested in very similar documents)

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- Recrawling URLs?

Conclusion

Standard for robot exclusion: robots.txt at the root of a Web server [Koster, 1994].

```
User-agent: *
Allow: /searchhistory/
Disallow: /search
```

- Per-page exclusion (*de facto* standard).

```
<meta name="ROBOTS" content="NOINDEX,NOFOLLOW">
```

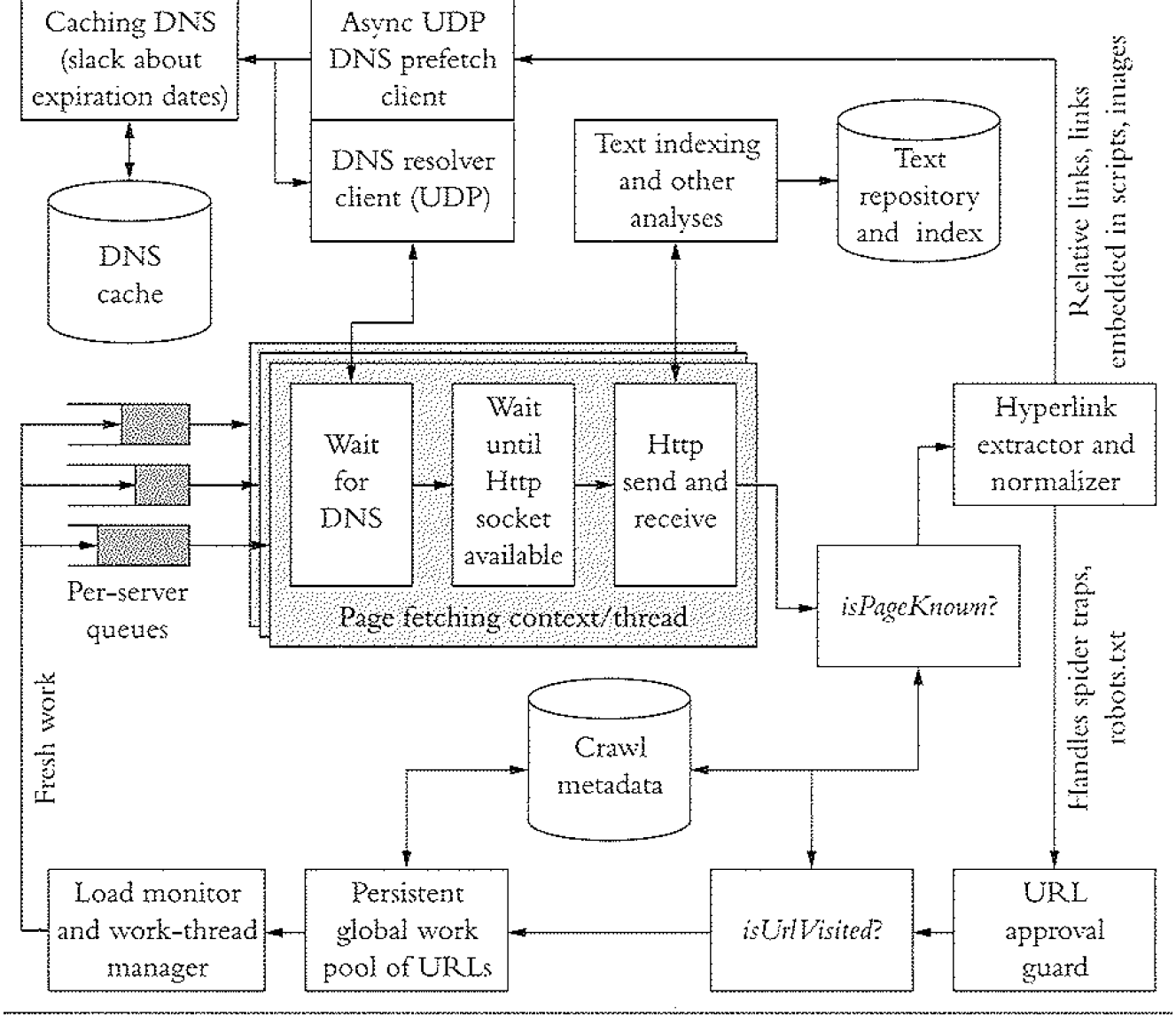
- Per-link exclusion (*de facto* standard).

```
<a href="toto.html" rel="nofollow">Toto</a>
```

- Avoid Denial Of Service (DOS), wait 100ms/1s between two repeated requests to the same Web server

Network delays, waits between requests:

- Per-server queue of URLs
- Parallel processing of requests to different hosts:
  - multi-threaded programming
  - asynchronous inputs and outputs (`select`, classes from `java.util.concurrent`): less overhead
- Use of keep-alive to reduce connexion overheads


Caching DNS (slack about expiration dates)
Async UDP DNS prefetch client
DNS resolver client (UDP)
DNS cache
Text indexing and other analyses
Text repository and index
Relative links, links embedded in scripts, images
Wait for DNS
Wait until Http socket available
Http send and receive
Page fetching context/thread
Per-server queues
Hyperlink extractor and normalizer
isPageKnown?
Handles spider traps, robots.txt
Fresh work
Crawl metadata
Load monitor and work-thread manager
Persistent global work pool of URLs
isUrlVisited?
URL approval guard

The World Wide Web

Web crawlers

- Discovering new URLs
- Identifying duplicates
- Crawling architecture
- Recrawling URLs?

Conclusion

- Content on the Web changes
- Different change rates:

  online newspaper main page: every hour or so
  published article: virtually no change
- Continuous crawling, and identification of change rates for adaptive crawling: how to know the time of last modification of a Web page?

Two timestamping mechanism in HTTP: entity tags and modification dates. Potentially provided with all requests:

```
ETag: "497bef-1fcb-47f20645"
Last-Modified: Tue, 01 Apr 2008 09:54:13 GMT
```

Etag: unique identifier for the provided document, should change if the document changes; can be used in requests with `If-Match` and `If-None-Match`.

Lat-Modified: last modification time; can be used in requests with `If-Modified-Since` and `If-Unmodified-Since`.

- Information generally provided and very reliable for static content (often includes media files in CMS).
- Information hardly ever provided (or with dummy *now* date) for dynamic content, CMS, etc.

Two additional (redundant) items of freshness information, for caches and proxies:

```
Cache-Control: max-age=60, private
Expires: Tue, 01 Apr 2008 13:25:55 GMT
```

max-age: maximum time in second a document remains fresh.

Expires: time when a document stops being fresh.

- Often provided...
- ...but with 0 or very low expiration delay.
- $\Rightarrow$ does not give any interesting information.

Very frequent in CMS:

- either as a global timestamps (*Last modified:*);
- or on individual items: news stories, blogs, etc. (is the global timestamp the max of the individual ones?);
- possibly also in meta-data on the Web page: comments, Dublin Core `<meta>` tags.

- Quite easy to identify and extract from the Web page (keywords, date recognition).
- Informal: sometimes partial (no time indication), often without timezone.
- Might not always be trustworthy.

Files of other types than HTML may have semantic timestamping mechanism:

PDF, Office suite documents, etc.: both creation and modification date available in metadata. Quite reliable.

RSS feeds: reliable semantic timestamps.

Images, Sounds: EXIF (or similar) metadata. Not always reliable, and the capture date of a picture may have nothing in common with its publication date.

Semantic external content used for dating a HTML Web page:

- Possibility of mapping a RSS feed to Web page content
- Sitemaps provided by the Web site owner. Allows for providing both timestamps and change rate indications (*hourly*, *monthly*...), but these functionalities are not often used. A few CMS produce all of this: ideal case!

1. Check HTTP timestamp.
2. Check content timestamp.
3. Compare a hash of the page with a stored hash.
4. Non-significant differences (ads, fortunes, request timestamp):
   - only hash text content, or “useful” text content;
   - compare distribution of *n*-grams (shingling);
   - or even compute edit distance with previous version.

Adapting strategy to each different archived website?

The Internet

The World Wide Web

Web crawlers

Conclusion

What you should remember

- The Web is not the same thing as Internet!
- Variety of protocols, languages, technologies used on the Web.
- Crawling as a graph-browsing problem.
- Shingling for identifying duplicates.
- Numerous engineering issues in building a Web-scale crawler.

- Wget, a simple yet effective Web spider (free software)
- Heritrix, a Web-scale highly configurable Web crawler, used by the Internet Archive (free software)
- HTML Parser, TagSoup: Java libraries for parsing real-world Web pages

To go further

- A good textbook [Chakrabarti, 2003]
- Main references:
  - HTML 4.01 recommendation [W3C, 1999]
  - HTTP/1.1 RFC [IETF, 1999]

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