ĐẠI HỌC
BÁCH KHOA

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SOICT

HA NOI UNIVERSITY OF SCIENCE AND TECHNOLOGY
SCHOOL OF INFORMATION AND COMMUNICATION TECHNOLOGY

Introduction to
Data Science
(IT4142E)

Contents

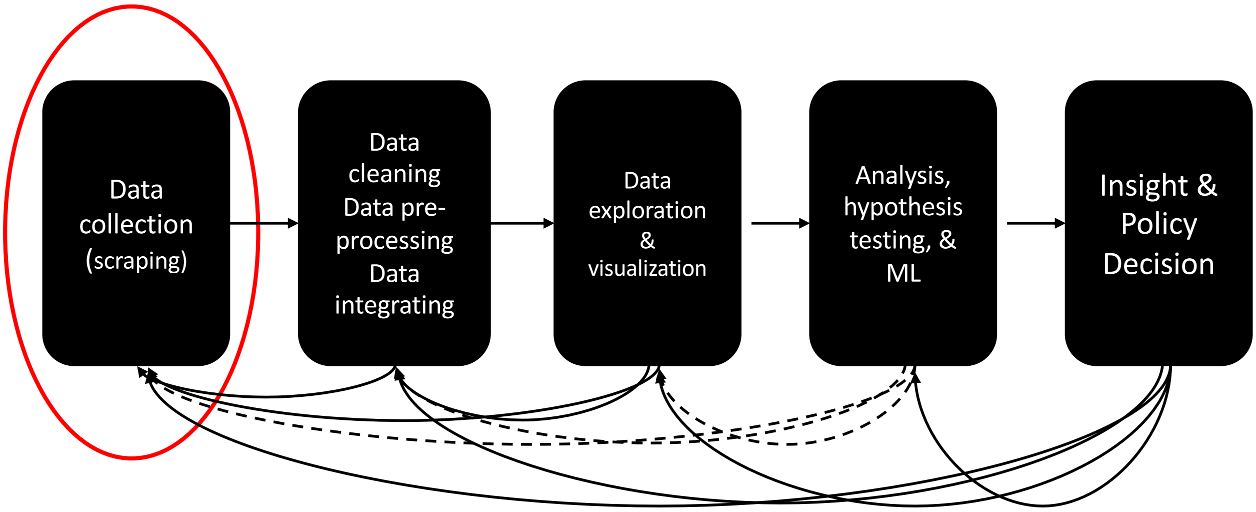
- ❑ Lecture 1: Overview of Data Science
- ❑ **Lecture 2: Data crawling and preprocessing**
- ❑ Lecture 3: Data cleaning and integration
- ❑ Lecture 4: Exploratory data analysis
- ❑ Lecture 5: Data visualization
- ❑ Lecture 6: Multivariate data visualization
- ❑ Lecture 7: Machine learning
- ❑ Lecture 8: Big data analysis
- ❑ Lecture 9: Capstone Project guidance
- ❑ Lecture 10+11: Text, image, graph analysis
- ❑ Lecture 12: Evaluation of analysis results

Outline

- Internet crawlers
- Scrapy framework

Introduction

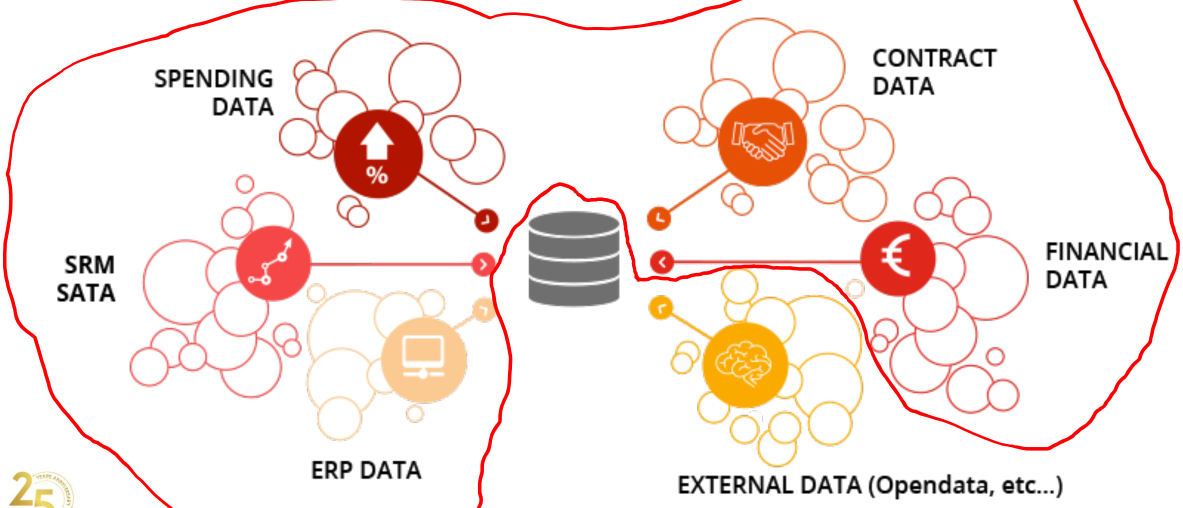
Recall: insight-driven DS methodology


Data collection (scraping)
Data cleaning Data pre-processing Data integrating
Data exploration & visualization
Analysis, hypothesis testing, & ML
Insight & Policy Decision

What is Data Scraping?

- First (crucial) step of data science
  - Gathering all relevant data for future data analysis
    - Both internal and external data

INTERNAL DATA (inside the enterprise/organization)



How to access the data?

- Everything depends on the type of source!
  - Internal data:
    - Databases, data warehouses
    - Flat files
      - Structured (Excel, log files..)
      - Unstructured
        - Readable by humans
          - Text
          - Screen display
          - Reports
  - External data
    - API (SOAP or REST): https://youtu.be/bPNfu0IZhoE
    - Flat files (same as internal data)

Examples of open-source data

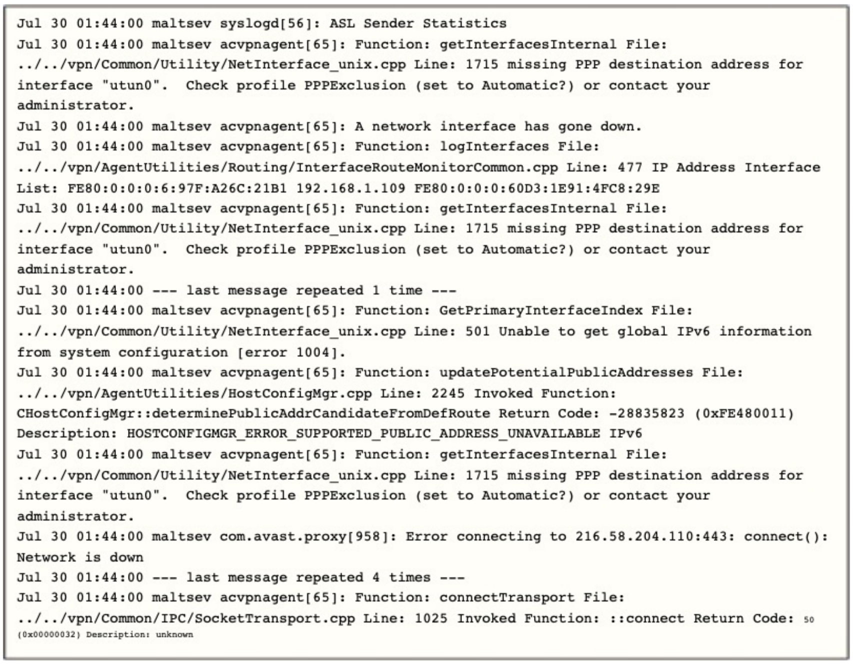
- Global Health Facts (www.globalhealthfacts.org/)—Health-related data about countries in the world
- UNdata (http://data.un.org/)—Aggregator of world data from a variety of source
- World Health Organization(www.who.int/research/en/)—Again, a variety ofhealth-related datasets such as mortality and life expectancy
- OECD Statistics (http://stats.oecd.org/)—Major source for economic indicators
- World Bank (http://data.worldbank.org/)—Data for hundreds of indicators and developer-friendly
- Census Bureau (www.census.gov/)—Find extensive demographics here.
- Data.gov (http://data.gov/)—Catalog for data supplied by government organizations. Still relatively new, but has a lot of sources.
- Data.gov.uk (http://data.gov.uk/)—The Data.gov equivalent for the United Kingdom.
- data.gouv.fr (http://data.gouv.fr) — The French equivalent
- DataSF (http://datasf.org/)—Data specific to SanFrancisco.
- NYC DataMine (http://nyc.gov/data/)—Just like the above, but for New York.
- ParisData (http://opendata.paris.fr) — Paris
- OpenData La Rochelle (https://opendata.larochelle.fr/) — La Rochelle

Accessing the data via APIs

- Numerous services are available online *via* http
- Data transfer is made following a **protocol** ruling exchange formats
- Such exchanges are well-structured, well-documented, easy to parse (*a.k.a.* analyze) and minimize ambiguities
- Such exchange formats are usually difficult to read for a human
- Protocols used
  - SOAP: structured using XML
  - REST: often structured using JSON
- Example: parkings with available spots in La Rochelle:
  - https://opendata.larochelle.fr/dataset/stationnement-parking-tarifs-synthetiques/

Accessing the data via log files

- Log files contain a sequential history of events in a process
  - API, network activity…
- Log entries are generally time-stamped and in chronological order
- Enable to analyse the process's activity and its interactions with its environment



```
Jul 30 01:44:00 maltsev syslogd[56]: ASL Sender Statistics
Jul 30 01:44:00 maltsev acvpnagent[65]: Function: getInterfacesInternal File:
../../vpn/Common/Utility/NetInterface_unix.cpp Line: 1715 missing PPP destination address for
interface "utun0".  Check profile PPPExclusion (set to Automatic?) or contact your
administrator.
Jul 30 01:44:00 maltsev acvpnagent[65]: A network interface has gone down.
Jul 30 01:44:00 maltsev acvpnagent[65]: Function: logInterfaces File:
../../vpn/AgentUtilities/Routing/InterfaceRouteMonitorCommon.cpp Line: 477 IP Address Interface
List: FE80:0:0:0:6:97F:A26C:21B1 192.168.1.109 FE80:0:0:0:60D3:1E91:4FC8:29E
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from system configuration [error 1004].
Jul 30 01:44:00 maltsev acvpnagent[65]: Function: updatePotentialPublicAddresses File:
../../vpn/AgentUtilities/HostConfigMgr.cpp Line: 2245 Invoked Function:
CHostConfigMgr::determinePublicAddrCandidateFromDefRoute Return Code: -28835823 (0xFE480011)
Description: HOSTCONFIGMGR_ERROR_SUPPORTED_PUBLIC_ADDRESS_UNAVAILABLE IPv6
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Jul 30 01:44:00 maltsev com.avast.proxy[958]: Error connecting to 216.58.204.110:443: connect():
Network is down
Jul 30 01:44:00 --- last message repeated 4 times ---
Jul 30 01:44:00 maltsev acvpnagent[65]: Function: connectTransport File:
../../vpn/Common/IPC/SocketTransport.cpp Line: 1025 Invoked Function: ::connect Return Code: 50
(0x00000032) Description: unknown
```
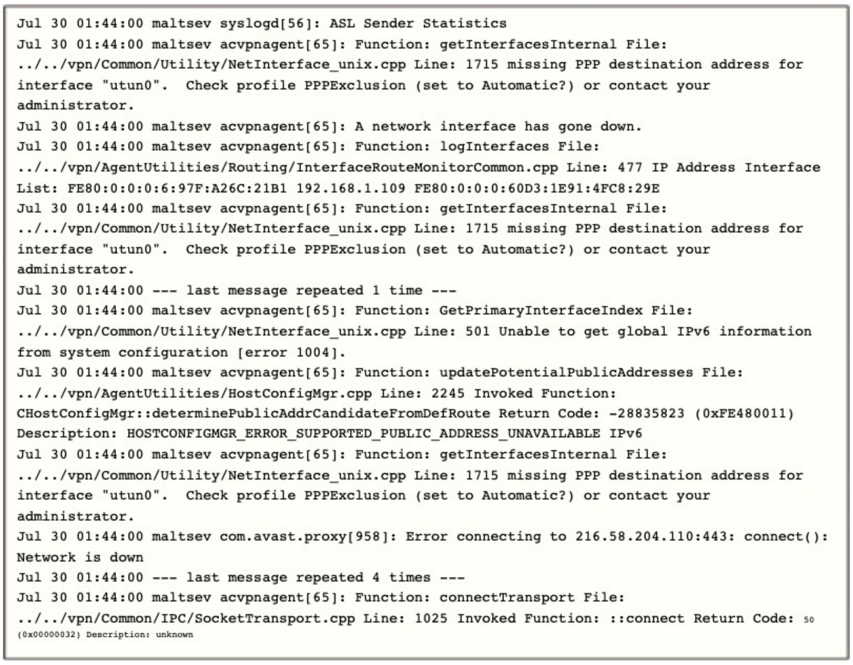

Source : wikipedia

Accessing the data via log files

- Most often used standard format: **syslog**
  - Date of emission
  - Name of the device
  - Process that triggered emission
  - Priority Level
  - Message contents
  - Message category
  - Seriousness level
- **ELK** is certainly the most used open-source platform for logging (including log visualization)



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Source : wikipedia

Definitions

Data scraping, screen scraping, report mining, web scraping

Accessing the data via data scraping

- Data scraping is used when the system to request does not have interface nor API to access the data
- Data scraping is a technique for extracting data from a document published in order to be read by humans
  - Often, web-pages from which we want to gather information
  - But also, any other kind of information formated to be displayed on a screen / text terminal

Some limits of data scraping

- The operator that publishes these documents might not like data scraping, because it might lead to
  - The system’s overload
  - A loss of revenues generated by the ads on the webpage
  - A loss of control over the documents provided
    - Intellectual property issues
- Data scraping is usually reserved to cases where there is no alternative

What is screen mining?

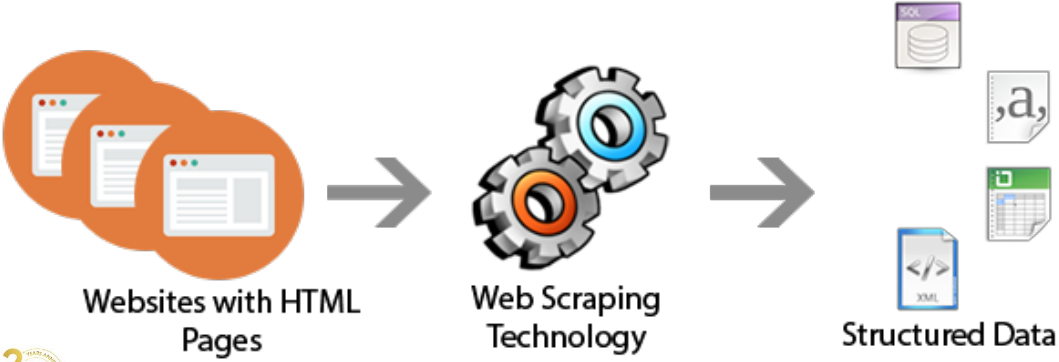
- Consists in extracting the text from the displaying screen of a device
- Usual screen scraping methods use bitmap screenshots and OCR
- In some cases, a program is used to simulate the user’s behavior and contol the GUI
  - Hence, a sequence of screens can be automatically captured and fed to a database

What is report mining?

- Consists in extracting the text from the reports written and formatted to be readable by humans (PDF, text, etc.)
  - Simple and quick way to access data without the need for an API
- Examples of softwares: Tabula, import in Tableau

What is web scraping?

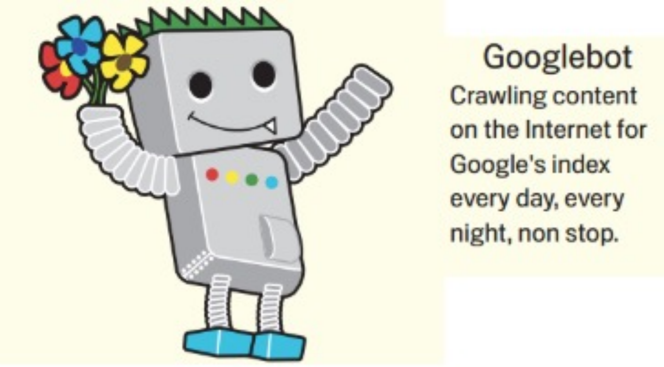
- Web pages are text files using a markup-based language (HTML and XHTML) that often contain relevant data
- However, most web pages are conceived for a final (human) user, not for their automatic use
  - That is why web scraping tools were conceived
- In order to defend themselves from web scraper, some sites use defense methods (limiting the number of requests / IP, CAPTCHA…)



Web crawler

Web crawler

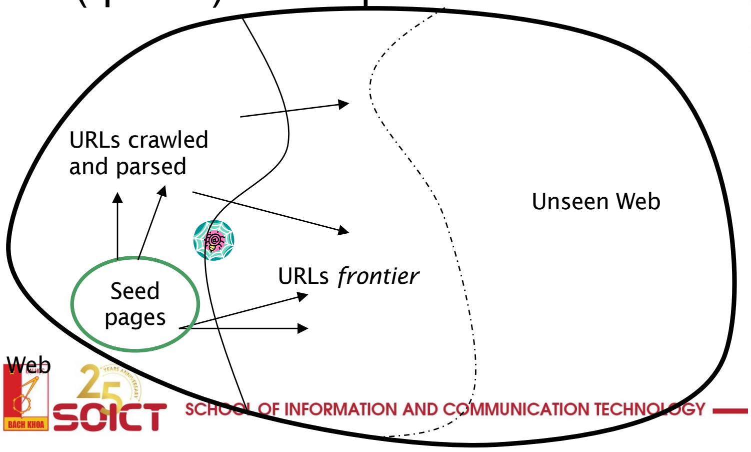
- A Spider, also known as a robot or a crawler, is actually a program that follows, or ”crawls” links throughout the Internet, grabbing content from sites and adding it to the database.
  - Crawler
  - Spider
  - Robot
  - Web agent

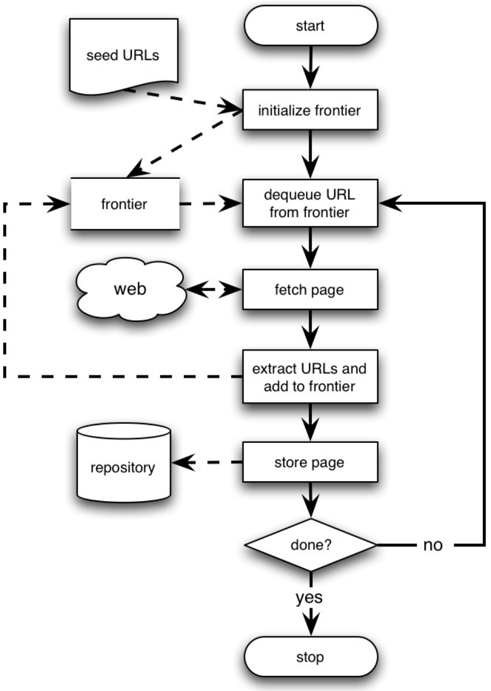


Googlebot
Crawling content on the Internet for Google's index every day, every night, non stop.

Basic crawling operation

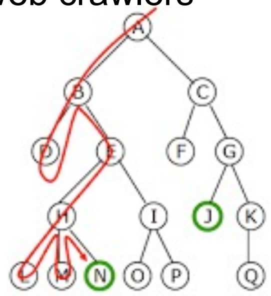
- Begin with known "seed" URLs
- Fetch and parse them
  - Extract URLs they point to
  - Place the extracted URLs on a queue
- Fetch each URL on the frontier (queue) and repeat

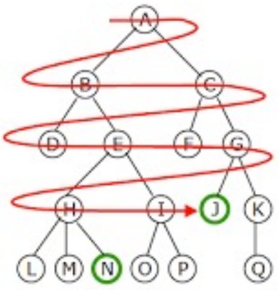




Crawling policy

- Behavior of a Web crawler is the outcome of a combination of policies
  - *Selection policy* which states the pages to download
  - *Re-visit policy* which states when to check for changes to the pages
  - *Politeness policy* that states how to avoid overloading website
  - *Parallelization policy* that states how to coordinate distributed web crawlers





Web crawling challenges

- The Internet is huge
  - Googlebot are distributed
- Filtering interested/non-interested/malicious pages
  - Spam pages
  - Spider traps – pages that are dynamically generated
- Content freshness
  - Crawlers should be catchup with new, up-to-date contents
- Content deduplication
  - Site mirrors and duplicate pages

Trading-off exploitation vs. exploration

- Exploitation
  - the crawling of pages where the expected value can be predicted with a high confidence
- Exploration
  - the search for new sources of relevant pages

Politeness

- Explicit
  - Specified by webmasters on which parts of the site can be crawled (robots.txt)
- Implicit
  - Avoid hitting any site too often to consume too much webserver resource

Robots.txt

- Protocol for giving spiders “robots” limited access to a website, originally from 1994
  - www.robotstxt.org/wc/norobots.html
- Website announces its request on what can(not) be crawled
  - For a server, create a file `/robots.txt`
  - This file specifies access restrictions
- Example

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

User-agent: searchengine
Disallow:
```

Web-scraping

Some principles

Web scraping

- Web scraping constists in extracting **relevant** information from a web page in order to re-use this data in another framework and / or under another form

Difference between web scraping and web crawling

- The difference between web scraping and crawling lies in its **final goal**
  - Web crawling creates a copy of existing data
  - Web scraping extracts specific data for analysis
    - The final goal of data scraping is data science
    - Hence, it converts un-structured data available in the web into more structured data, that can be analysed
- Example:
  - What Google, Yahoo or Bing does is web crawling
  - Their indexing is based on web crawling

Use-cases

- **Private use:** online services; comparing information from different websites (*e.g.* price comparison of flight tickets / fares for the same itinerary but with different companies
- **Academic research:** the web is a huge multi-domain data source that can provide researchers with a huge volume of data (for machine learning for instance, see Chapter 5)
- **Marketing analysis**: the traces we leave on the web are getting more and more numerous and allow companies to grasp our preferences, routines, etc. This data is used for marketing, and personalizing ads

Extraction modes

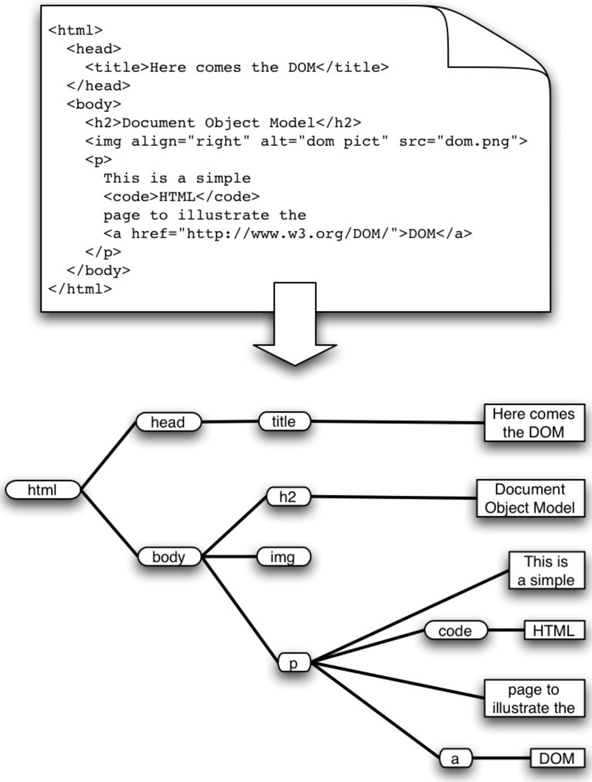
- **Semi-automatic extraction**: using a software or an app to suck / clean selected contents from one or several web pages
  - Only the contents that is relevant to the user
  - This is what we will do during exercises / homework
- **Automatic extraction** : using a software or an app to create a corpus of web-pages linked with each other
  - All contents is extracted
  - The software / app emulates a web browser that visits pages and is able to follow all hyperlinks to generate the corpus of all web-pages

Extraction techniques

- In order to extract information from web pages, the most usual methods use **XPath**
- XPath is a W3C standard to find elements in a XML document
  - W3C is the organization that rules on the web standards
- XPath uses the hierarchical structure of nodes (and attributes) of an XML document, and therefore requires a precise document structure
- HTML documents *partly* respect a hierarchical format with XML tags
  - Parsers need to be flexible

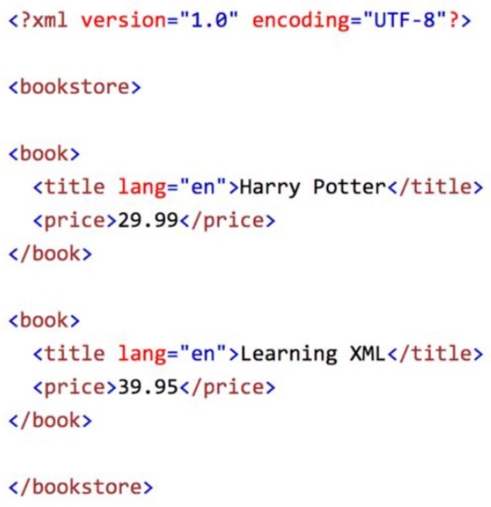
HTML code structure

- HTML has the structure of a Document Object Model (DOM) tree
- DOM tree varies from page to page, even for the same catalog
    - Due to dynamic contents, dynamic ads, etc.

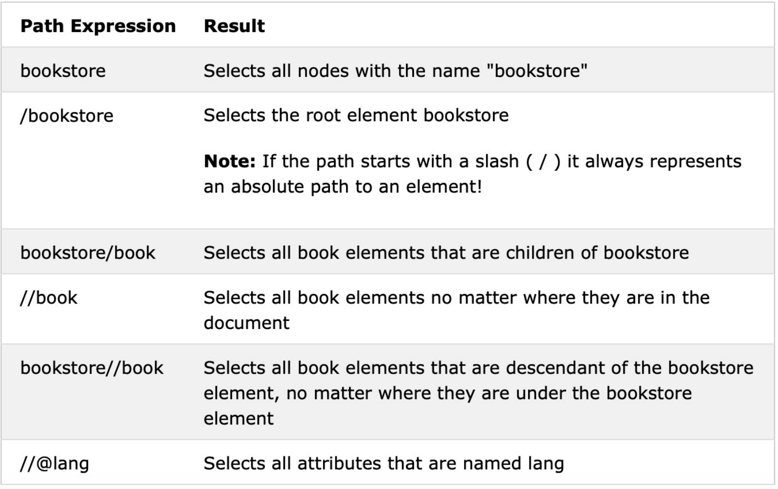


```
<html>
  <head>
    <title>Here comes the DOM</title>
  </head>
  <body>
    <h2>Document Object Model</h2>
    <img align="right" alt="dom pict" src="dom.png">
    <p>
      This is a simple
      <code>HTML</code>
      page to illustrate the
      <a href="http://www.w3.org/DOM/">DOM</a>
    </p>
  </body>
</html>
```

Xpath: example



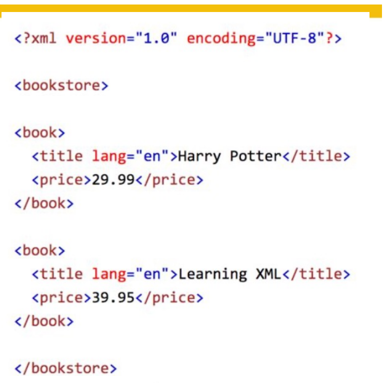
```
<?xml version="1.0" encoding="UTF-8"?>

<bookstore>

<book>
  <title lang="en">Harry Potter</title>
  <price>29.99</price>
</book>

<book>
  <title lang="en">Learning XML</title>
  <price>39.95</price>
</book>

</bookstore>
```



Path Expression	Result
bookstore	Selects all nodes with the name "bookstore"
/bookstore	Selects the root element bookstore **Note:** If the path starts with a slash (/) it always represents an absolute path to an element!
bookstore/book	Selects all book elements that are children of bookstore
//book	Selects all book elements no matter where they are in the document
bookstore//book	Selects all book elements that are descendant of the bookstore element, no matter where they are under the bookstore element
//@lang	Selects all attributes that are named lang

Practice it yourself on https://www.w3schools.com/xml/xpath_examples.asp

Xpath: example



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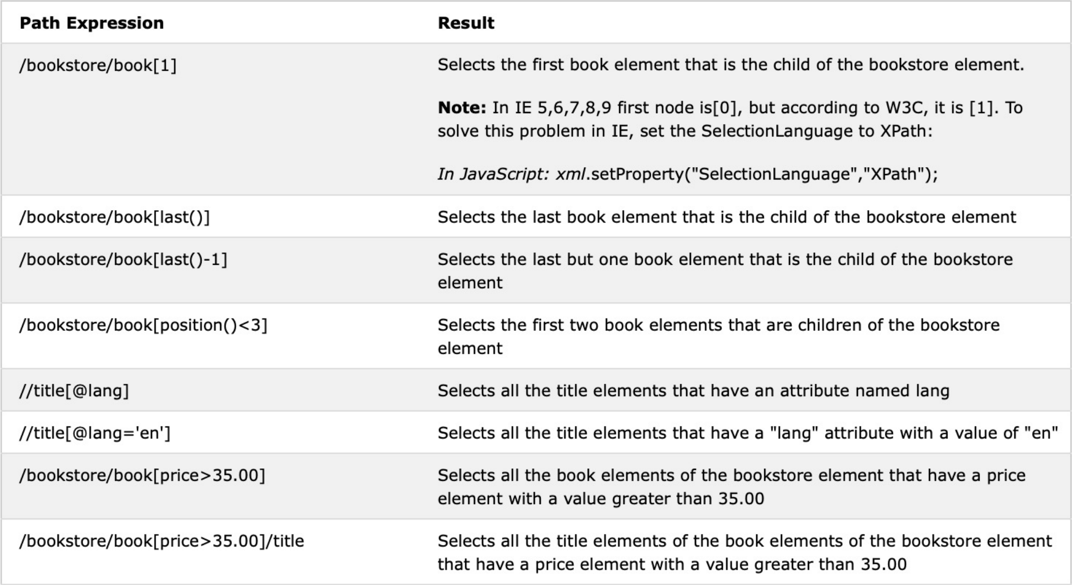


Path Expression	Result
/bookstore/book[1]	Selects the first book element that is the child of the bookstore element. **Note:** In IE 5,6,7,8,9 first node is[0], but according to W3C, it is [1]. To solve this problem in IE, set the SelectionLanguage to XPath: *In JavaScript: xml*.setProperty("SelectionLanguage","XPath");
/bookstore/book[last()]	Selects the last book element that is the child of the bookstore element
/bookstore/book[last()-1]	Selects the last but one book element that is the child of the bookstore element
/bookstore/book[position()<3]	Selects the first two book elements that are children of the bookstore element
//title[@lang]	Selects all the title elements that have an attribute named lang
//title[@lang='en']	Selects all the title elements that have a "lang" attribute with a value of "en"
/bookstore/book[price>35.00]	Selects all the book elements of the bookstore element that have a price element with a value greater than 35.00
/bookstore/book[price>35.00]/title	Selects all the title elements of the book elements of the bookstore element that have a price element with a value greater than 35.00

Technical limitations

- **Inconsistent / cahotic organization of the information**
  - Relevant information might be formatted in a different way within different websites, or even within one single website
- **Evolutions in the information structure**
  - Some data scraping programs are meant to be run on a routine, over time, to suck all freshly added info
  - As the website structure might evolve with time, the criteria that were settled initially to select relevant information might become obsolete
  - This problem arises most often for websites that use Content Management Systems *(e.g.* Wordpress) that allow to change for the graphical theme
    - As changes in the graphical theme often imply changes in the document structure

Technical limitations

- **Access restrictions**
  - Some website contents are exclusively available for authentified users
  - There are tools that can emulate authentication procedure, one has to possess a registered login/password, and provide it to the extraction tool
- **Dynamically generated contents**
  - Some pages don't load all content from the first request
  - Instead, they dynamically load the contents according to the browser's actions
    - These actions triggering queries on the website's database, *e.g.* mySQL
  - Even though some tools can emulate this type of interactions, most often, the analysis is made on the HTML contents generated from the first request

Technical limitations

- As stated before, the website publisher might not like data scraping, because it might lead to
  - The system's overload
  - A loss of revenues generated by the ads on the webpage
  - A loss of control over the documents provided
    - Intellectual property issues
- Website administrators might use some of the following tools to prevent « non-human » traffic
  - **Time limitations for each request**
    - Limitation in the number of hits / second for instance
    - A hit is the fact of going from one page to another, from the same domain
    - Reason for using this type of limitations is that humans usually take much longer to go from one page to another than a data scraper

Technical limitations

- Website administrators might use some of the following tools to prevent « non-human » traffic
  - **Time limitations for each request**
  - **IP address-based Denial of Service (DoS)**
    - Automatically triggered when a website receives too many requests from one IP address
    - DoS is often used in case of cyber-attacks
  - **Bandwidth limitations**
  - **Verification that the user is human**
    - *e.g.* CAPTCHA, etc.

Ethical / legal aspects

- Legal aspects regarding web-content reproductions are
  - Unclear in most countries
    - Note the European regulation « General Data Protection Regulation » (GDPR)
  - Differ largely from one country to another
- Is it OK to cite contents from another site, even if one provides the reference?
  - Tough question!
  - On one hand, intellectual property is respected because credit is given to the original author
  - On the other hand, the original author looses traffic on his/her own website, which might cause a loss of revenue (ads, etc.)

Ethical / legal aspects

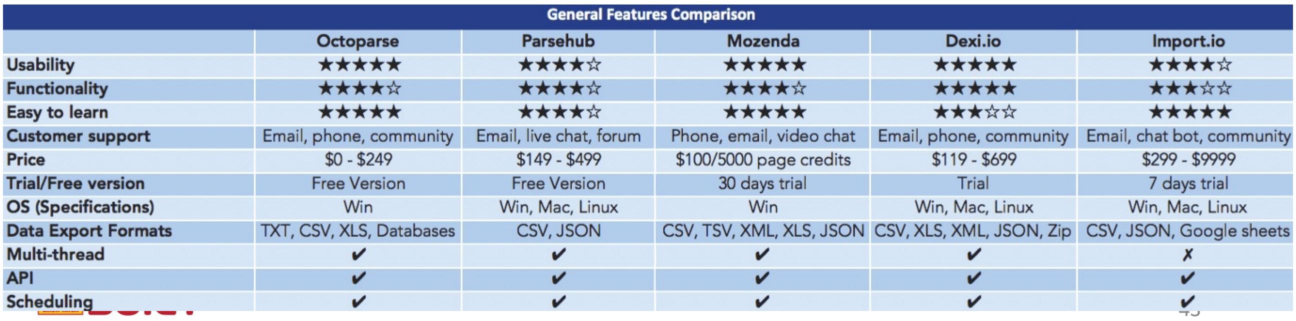
- A good practice is to inform the website's administrator that you have the intention to use their website's contents
  - No formal request is legally required, but the advantage of asking is twofold
    - You might obtain an agreement, thus avoiding some of the previously cited technical limitations
    - The administrator might give you info or means to access the webpage contents, *e.g. via* APIs
  - In exchange, the administrator might ask you to add his/her URL(s) on your own website (if any) to enhance their ranking by search engines
    - **Win-win** situation!

Practice

Web-scraping with *web-scraper* and Scrapy

Web scraping tools

- There are numerous web scraping tools, with different interface types:
  - Programming
    - Software libraries: **Scrapy**, Beautifulsoup (Python), PhantomJS
  - Cloud: ScrapingHub, Dexi.io...
  - Stand-alone: ParseHub, OctoParse...
  - Web-browser plugins:
    - Data Scraper - Easy Web Scraping, Instant Data Scraper, **Web Scraper**



General Features Comparison

	Octoparse	Parsehub	Mozenda	Dexi.io	Import.io
Usability	★★★★★	★★★★☆	★★★★★	★★★★★	★★★★☆
Functionality	★★★★☆	★★★★☆	★★★★☆	★★★★★	★★★☆☆
Easy to learn	★★★★★	★★★★☆	★★★★★	★★★☆☆	★★★★★
Customer support	Email, phone, community	Email, live chat, forum	Phone, email, video chat	Email, phone, community	Email, chat bot, community
Price	$0 - $249	$149 - $499	$100/5000 page credits	$119 - $699	$299 - $9999
Trial/Free version	Free Version	Free Version	30 days trial	Trial	7 days trial
OS (Specifications)	Win	Win, Mac, Linux	Win	Win, Mac, Linux	Win, Mac, Linux
Data Export Formats	TXT, CSV, XLS, Databases	CSV, JSON	CSV, TSV, XML, XLS, JSON	CSV, XLS, XML, JSON, Zip	CSV, JSON, Google sheets
Multi-thread	✔	✔	✔	✔	✗
API	✔	✔	✔	✔	✔
Scheduling	✔	✔	✔	✔	✔

Why using Web-Scraper and Scrapy?

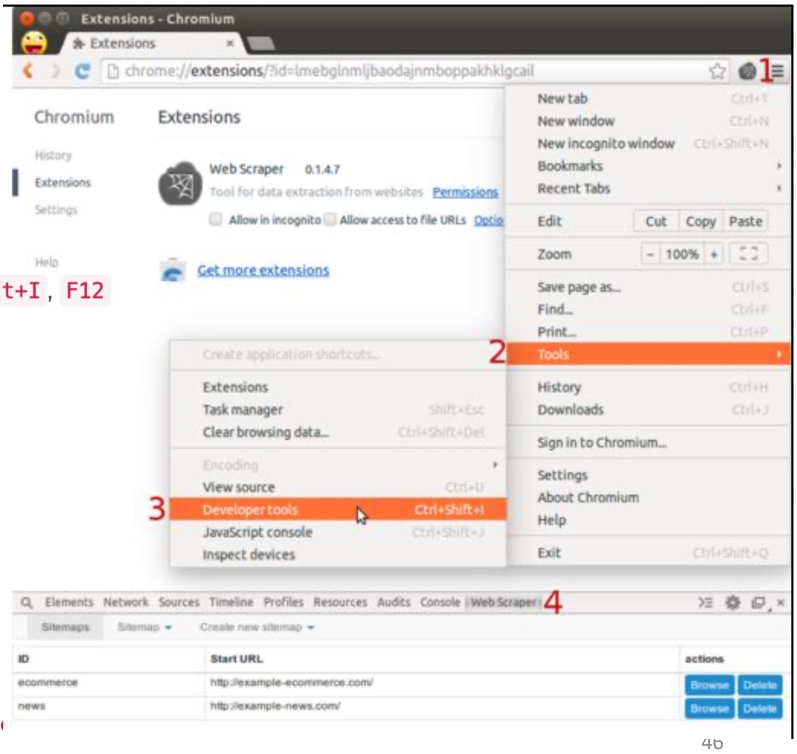
- Web-Scraper
  - Simple to install and to use
  - Easy to understand
  - Free for non-cloud usage
- Scrapy
  - Example of an effective Python library
  - Open-source web scraping framework
  - More refined than Web-Scraper

Practice

Web-scraper

Opening web-scraper

- Web Scraper is integrated into Chrome Developer tools
- You can install the extension from Chrome store or Firefox browser Add-ons.
- Keyboard shortcuts to open Developer tools:
  - Windows, Linux: `Ctrl+Shift+I`, `F12`
  - Mac `Cmd+Opt+I`
- After opening Developer tools, open *Web Scraper* tab



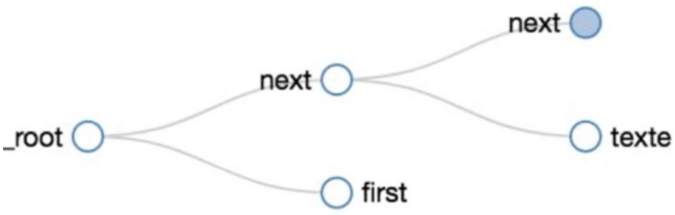
ID	Start URL	actions
ecommerce	http://example-ecommerce.com/	Browse Delete
news	http://example-news.com/	Browse Delete

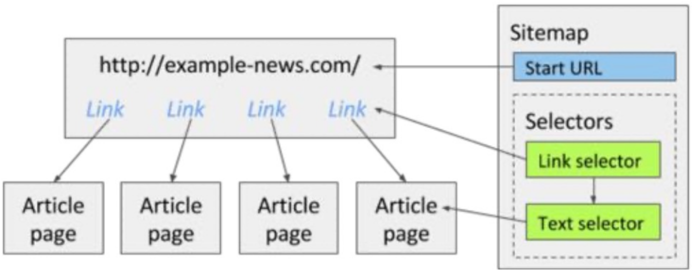
Web-scraper: sitemap

- To start with, the user must specify the URL from which information should be extracted
- The URL can be parameterized so as to scrap multiple pages, *e.g.* by specifying the page numbers
  - Example
    - **http://example.com/page/[0-20:10]** corresponds the the URLs:
      - http://example.com/page/0
      - http://example.com/page/10
      - http://example.com/page/20

Web-scraper: selectors hierarchy

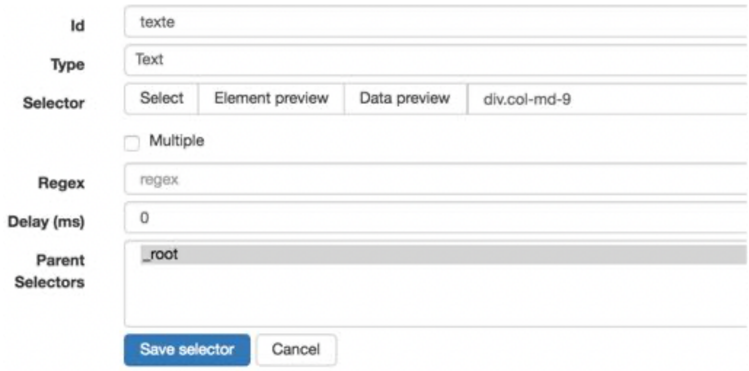
- Web-Scraper uses a hiararchy of **selectors**
  - Data extraction selectors
  - Link selectors for site navigation
  - Element selectors
- A selector references an element in the XPath hierarchy
- From any element, one can select its descendants
- Information lie in the tree leaves
  - Text
  - Image
  - Table





Web-scraper: text selector

- Text selector is the most simple selector
  - Used for text selection
- Extract text from the selected element **and** from all its child elements.
- HTML will be stripped and only text will be returned (ignor <script> and <style> tags). New line <br> tags will be replaced with newline characters.
- You can additionally apply a regular expression to resulting data.

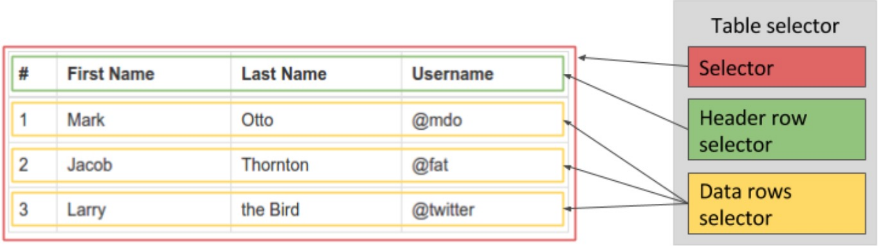


Id	texte
Type	Text
Selector	Select | Element preview | Data preview | div.col-md-9
	□ Multiple
Regex	regex
Delay (ms)	0
Parent Selectors	_root

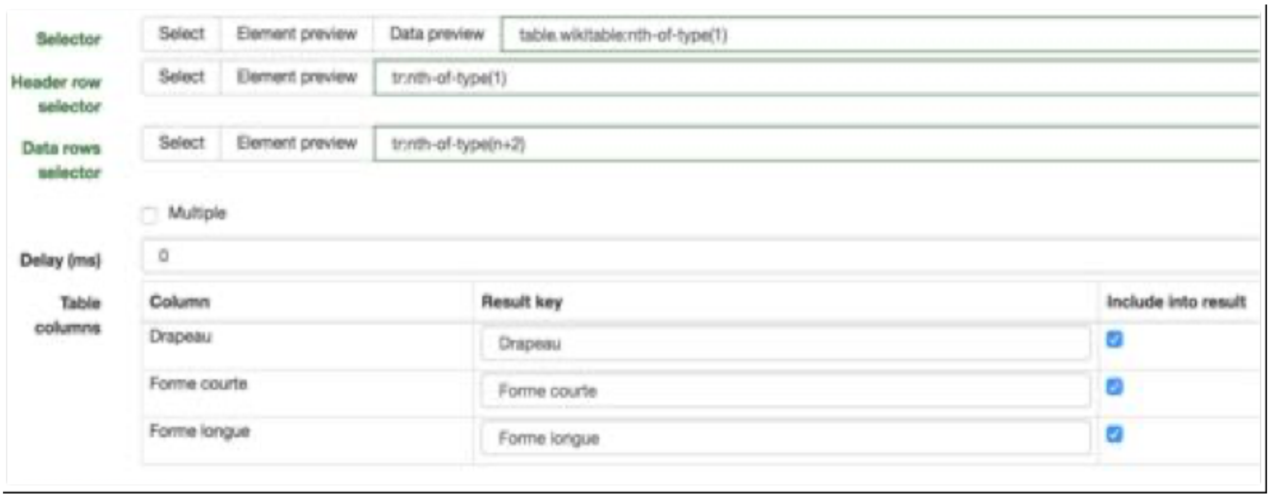
- Element Preview
  - Highlighting the selected text
- Data Preview
  - Result data
- The right part contains the Xpath selector

Web-scraper: table selector

- Composite selector
- Check « Multiple » to select all rows



#	First Name	Last Name	Username
1	Mark	Otto	@mdo
2	Jacob	Thornton	@fat
3	Larry	the Bird	@twitter



Selector	Select | Element preview | Data preview | table.wikitable:nth-of-type(1)
Header row selector	Select | Element preview | tr:nth-of-type(1)
Data rows selector	Select | Element preview | tr:nth-of-type(n+2)
	□ Multiple
Delay (ms)	0

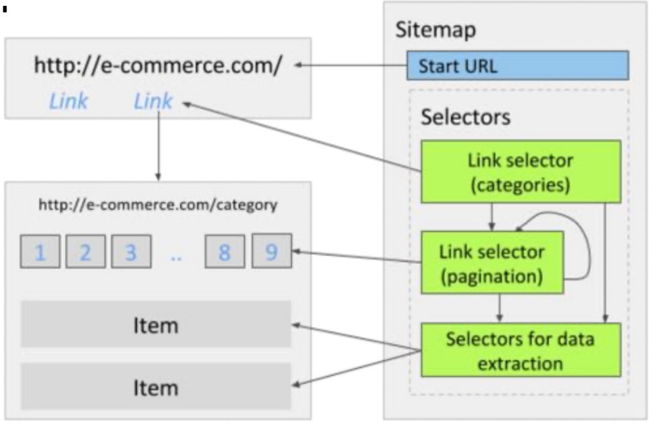
Table columns

Column	Result key	Include into result
Drapeau	Drapeau	☑
Forme courte	Forme courte	☑
Forme longue	Forme longue	☑

Web-scraper: link selector

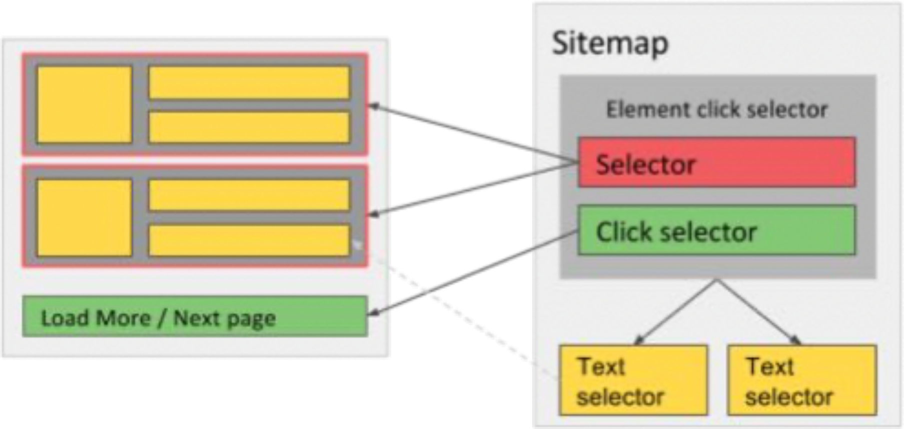
- Link selector is used for link selection and website navigation.
  - If you use *Link selector* without any child selectors then it will extract the link and the href attribute of the link
  - If you add child selectors to *Link selector* then these child selectors will be used in the page that this link was leading to
  - Link selectors

    be recursive


http://e-commerce.com/
Link
Link
http://e-commerce.com/category
1
2
3
..
8
9
Item
Item
Sitemap
Start URL
Selectors
Link selector (categories)
Link selector (pagination)
Selectors for data extraction

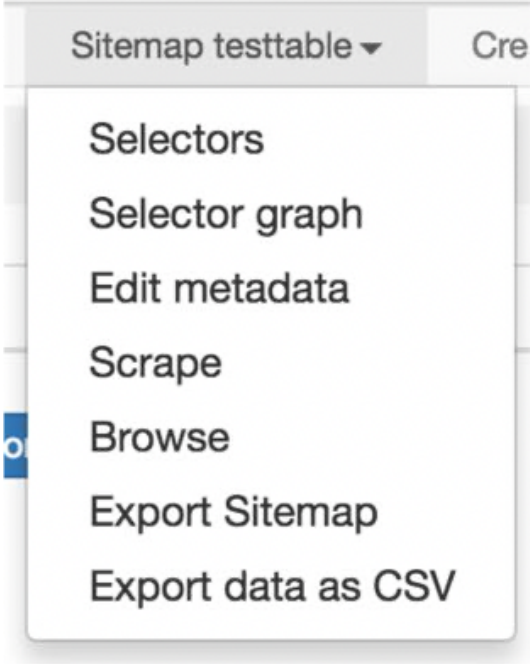
Web-scraper: click selector

- Click selectors are used when it is necessary to emulate a click



Web-scraper: data export

- To be able to export data, one needs to
  - Scrape the page(s)
    - A popup opens up on the selected URL
    - Selectors are triggered according to the graph
    - Data is fetched and exported
- Web Scraper browser extension supports data export in CSV format
- Web Scraper Cloud supports data export in CSV, XLSX and JSON formats



Web-scraper: demo

- https://youtu.be/n7fob_XVsbY

References

- https://www.webscraper.io/tutorials
- https://www.webscraper.io/documentation

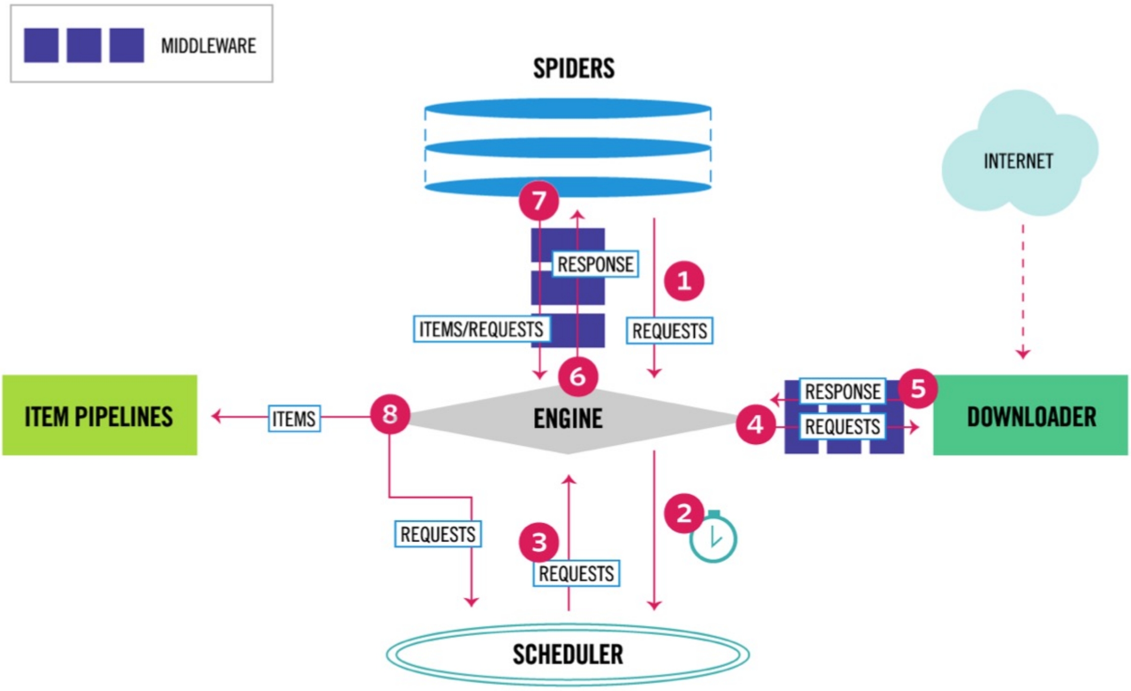
Practice

Scrapy

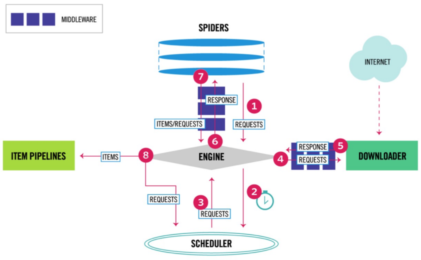
Intro

- Whereas Web Scraper is a web-browser extension enabling semi-automatic extraction…
- … Scrapy is a more complete open-source Python library
  - Scrapy can handle by itself « annoying stuff », such as
    - Throttling
    - Concurrency
    - XML sitemaps
    - Filtering duplicated URLs
    - Retry on Error

Scrapy components



Scrapy components



- Scrapy Engine
  - controlling the data flow between all components
- Scheduler
  - receives requests from the engine and enqueues them for feeding them later
- Downloader
  - Fetching web pages and feeding them to the engine
- Spiders
  - parse responses and extract items or additional requests to follow
- Item pipeline
  - processing the items once they have been extracted by the spiders
- Downloader middlewares
  - Process requests when they pass from the Engine to the Downloader and vice-versa
- Spider middlewares
  - specific hooks that sit between the Engine and the Spiders
  - process spider input (responses) and output (items and requests)

Exercises / homework

1. **XPath**
   - Learn it by yourself on https://www.w3schools.com/xml/xpath_examples.asp

2. **WebScraper** tutorial
   - https://www.webscraper.io/tutorials

3. **Scrapy**

   a) https://doc.scrapy.org/en/latest/intro/tutorial.html
   - Define your own data structures
   - Write spider
   - Leverage Built-in Xpath and CSS selectors to extract desired data
   - Built-in Json, csv, xml output
   - Interactive shell console

   b) https://doc.scrapy.org/en/latest/topics/media-pipeline.html
   - Downloading and processing files and images

   c) « Web Scraping in Python using Scrapy _ Codementor »: PDF in the Google Teams

The PageRank Citation Ranking: Bring Order to the web

(Adapted from Fei Li presentation on PageRank)

Motivation and Introduction

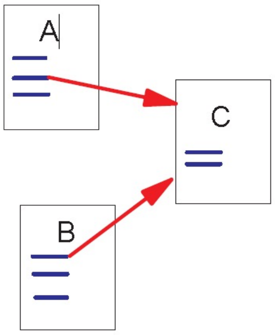
- New challenges for information retrieval on the World Wide Web.
  - Huge number of web pages: 150 million by1998, 1000 billion by 2008
  - Diversity of web pages: different topics, different quality, etc.
- What is PageRank?
  - A method for rating the importance of web pages objectively and mechanically using the link structure of the web.

The History of PageRank

- PageRank was developed by Larry Page (hence the name Page-Rank) and Sergey Brin.
- It is first as part of a research project about a new kind of search engine. That project started in 1995 and led to a functional prototype in 1998.
- Shortly after, Page and Brin founded Google.
- Since then
  - There are large numbers of Search Engine Optimization (SEO).
  - SEO use different trick methods to make a web page more important under the rating of PageRank.

Link Structure of the Web

- 150 million web pages → 1.7 billion links



Backlinks and Forward links:

➢A and B are C's backlinks

➢C is A and B's forward link

Intuitively, a webpage is important if it has a lot of backlinks.

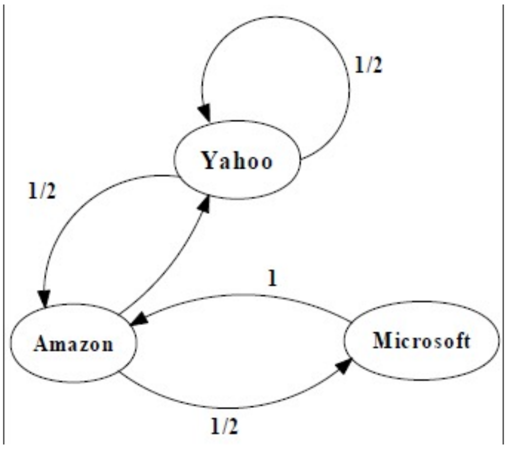
What if a webpage has only one link off www.cnn.com?

A Simple Version of PageRank

- u: a web page
- Bu: the set of u's backlinks
- Nv: the number of forward links of page v
- c: the normalization factor to make
    - $||R||_{L1} = 1$ ($||R||_{L1} = |R_1 + \ldots + R_n|$)

$$R(u) = c \sum_{v \in B_u} \frac{R(v)}{N_v}$$

An example of Simplified PageRank



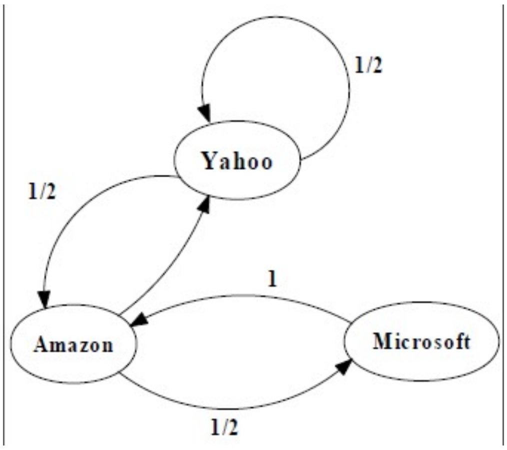
$$M = \begin{bmatrix} 1/2 & 1/2 & 0 \\ 1/2 & 0 & 1 \\ 0 & 1/2 & 0 \end{bmatrix}.$$

$$\begin{bmatrix} \text{yahoo} \\ \text{Amazon} \\ \text{Microsoft} \end{bmatrix} = \begin{bmatrix} 1/3 \\ 1/3 \\ 1/3 \end{bmatrix}$$

$$\begin{bmatrix} 1/3 \\ 1/2 \\ 1/6 \end{bmatrix} = \begin{bmatrix} 1/2 & 1/2 & 0 \\ 1/2 & 0 & 1 \\ 0 & 1/2 & 0 \end{bmatrix} \begin{bmatrix} 1/3 \\ 1/3 \\ 1/3 \end{bmatrix}$$

PageRank Calculation: first iteration

An example of Simplified PageRank



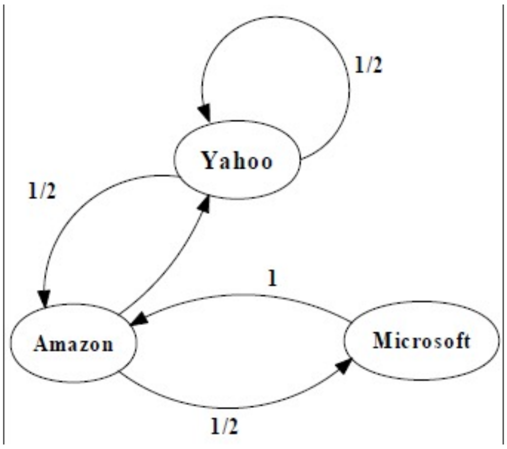
$$M = \begin{bmatrix} 1/2 & 1/2 & 0 \\ 1/2 & 0 & 1 \\ 0 & 1/2 & 0 \end{bmatrix}.$$

$$\begin{bmatrix} \text{yahoo} \\ \text{Amazon} \\ \text{Microsoft} \end{bmatrix} = \begin{bmatrix} 1/3 \\ 1/3 \\ 1/3 \end{bmatrix}$$

$$\begin{bmatrix} 5/12 \\ 1/3 \\ 1/4 \end{bmatrix} = \begin{bmatrix} 1/2 & 1/2 & 0 \\ 1/2 & 0 & 1 \\ 0 & 1/2 & 0 \end{bmatrix} \begin{bmatrix} 1/3 \\ 1/2 \\ 1/6 \end{bmatrix}$$

PageRank Calculation: second iteration

An example of Simplified PageRank



$$M = \begin{bmatrix} 1/2 & 1/2 & 0 \\ 1/2 & 0 & 1 \\ 0 & 1/2 & 0 \end{bmatrix}.$$

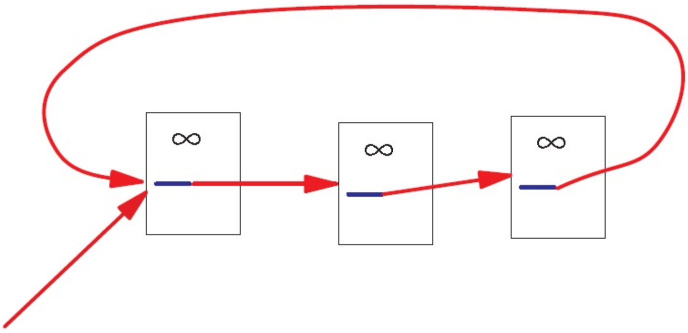
$$\begin{bmatrix} \text{yahoo} \\ \text{Amazon} \\ \text{Microsoft} \end{bmatrix} = \begin{bmatrix} 1/3 \\ 1/3 \\ 1/3 \end{bmatrix}$$

$$\begin{bmatrix} 3/8 \\ 11/24 \\ 1/6 \end{bmatrix} \begin{bmatrix} 5/12 \\ 17/48 \\ 11/48 \end{bmatrix} \ldots \begin{bmatrix} 2/5 \\ 2/5 \\ 1/5 \end{bmatrix}$$

Convergence after some iterations

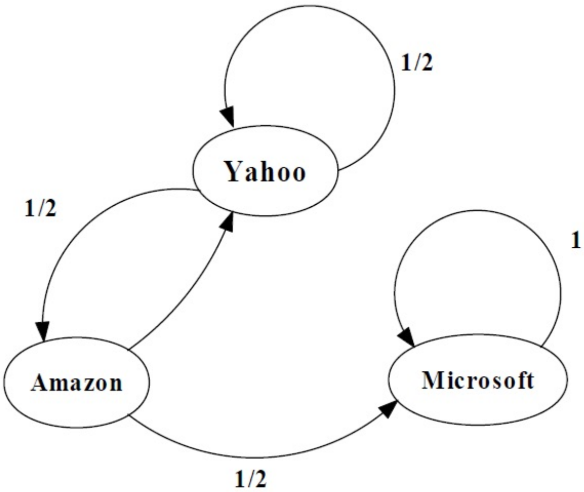
A Problem with Simplified PageRank

A loop:



During each iteration, the loop accumulates rank but never distributes rank to other pages!

An example of the Problem

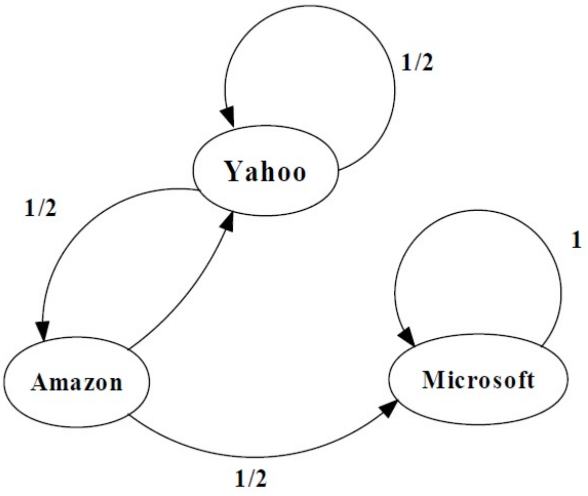


$$M = \begin{bmatrix} 1/2 & 1/2 & 0 \\ 1/2 & 0 & 0 \\ 0 & 1/2 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \text{yahoo} \\ \text{Amazon} \\ \text{Microsoft} \end{bmatrix} = \begin{bmatrix} 1/3 \\ 1/3 \\ 1/3 \end{bmatrix}$$

$$\begin{bmatrix} 1/3 \\ 1/6 \\ 1/2 \end{bmatrix} = \begin{bmatrix} 1/2 & 1/2 & 0 \\ 1/2 & 0 & 0 \\ 0 & 1/2 & 1 \end{bmatrix} \begin{bmatrix} 1/3 \\ 1/3 \\ 1/3 \end{bmatrix}$$

An example of the Problem

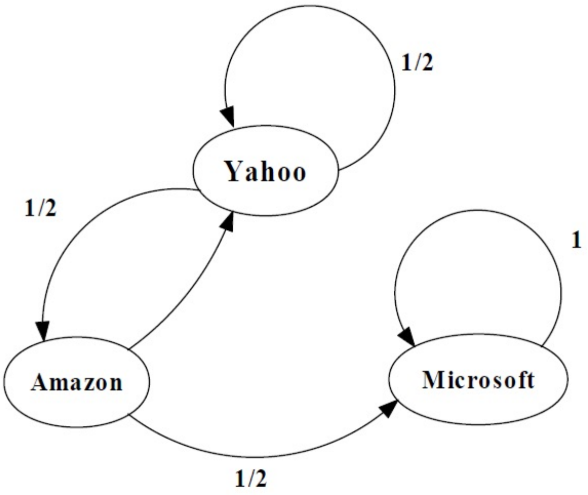


$$M = \begin{bmatrix} 1/2 & 1/2 & 0 \\ 1/2 & 0 & 0 \\ 0 & 1/2 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \text{yahoo} \\ \text{Amazon} \\ \text{Microsoft} \end{bmatrix} = \begin{bmatrix} 1/3 \\ 1/3 \\ 1/3 \end{bmatrix}$$

$$\begin{bmatrix} 1/4 \\ 1/6 \\ 7/12 \end{bmatrix} = \begin{bmatrix} 1/2 & 1/2 & 0 \\ 1/2 & 0 & 0 \\ 0 & 1/2 & 1 \end{bmatrix} \begin{bmatrix} 1/3 \\ 1/6 \\ 1/2 \end{bmatrix}$$

An example of the Problem



$$M = \begin{bmatrix} 1/2 & 1/2 & 0 \\ 1/2 & 0 & 0 \\ 0 & 1/2 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \text{yahoo} \\ \text{Amazon} \\ \text{Microsoft} \end{bmatrix} = \begin{bmatrix} 1/3 \\ 1/3 \\ 1/3 \end{bmatrix}$$

$$\begin{bmatrix} 5/24 \\ 1/8 \\ 2/3 \end{bmatrix} \begin{bmatrix} 1/6 \\ 5/48 \\ 35/48 \end{bmatrix} \quad .... \quad \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

Random Walks in Graphs

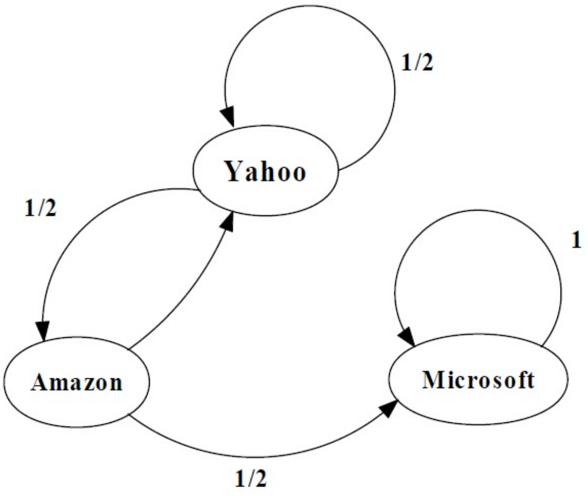
- The Random Surfer Model
  - The simplified model: the standing probability distribution of a random walk on the graph of the web. simply keeps clicking successive links at random
- The Modified Model
  - The modified model: the “random surfer” simply keeps clicking successive links at random, but periodically “gets bored” and jumps to a random page based on the distribution of E

Modified Version of PageRank

$$R'(u) = c_1 \sum_{v \in B_u} \frac{R'(v)}{N_v} + c_2 E(u)$$

E(u): a distribution of ranks of web pages that “users” jump to when they “gets bored” after successive links at random.
For uniform random jump: E(i) = 1/n

An example of Modified PageRank



$$M = \begin{bmatrix} 1/2 & 1/2 & 0 \\ 1/2 & 0 & 0 \\ 0 & 1/2 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \text{yahoo} \\ \text{Amazon} \\ \text{Microsoft} \end{bmatrix} = \begin{bmatrix} 1/3 \\ 1/3 \\ 1/3 \end{bmatrix}$$

$C_1 = 0.8$ $C_2 = 0.2$

$$\begin{bmatrix} 0.333 \\ 0.333 \\ 0.333 \end{bmatrix} \begin{bmatrix} 0.333 \\ 0.200 \\ 0.467 \end{bmatrix} \begin{bmatrix} 0.280 \\ 0.200 \\ 0.520 \end{bmatrix} \begin{bmatrix} 0.259 \\ 0.179 \\ 0.563 \end{bmatrix} \dots \begin{bmatrix} 7/33 \\ 5/33 \\ 21/33 \end{bmatrix}$$

Dangling Links

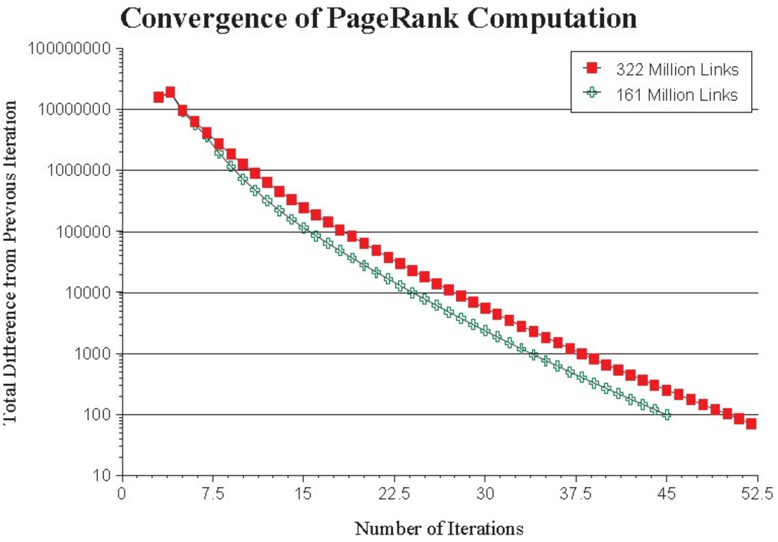
- Links that point to any page with no outgoing links
- Most are pages that have not been downloaded yet
- Affect the model since it is not clear where their weight should be distributed
- Do not affect the ranking of any other page directly
- Can be simply removed before pagerank calculation and added back afterwards

PageRank Implementation

- Convert each URL into a unique integer and store each hyperlink in a database using the integer IDs to identify pages
- Sort the link structure by ID
- Remove all the dangling links from the database
- Make an initial assignment of ranks and start iteration
  - Choosing a good initial assignment can speed up the pagerank
- Adding the dangling links back.

Convergence Property

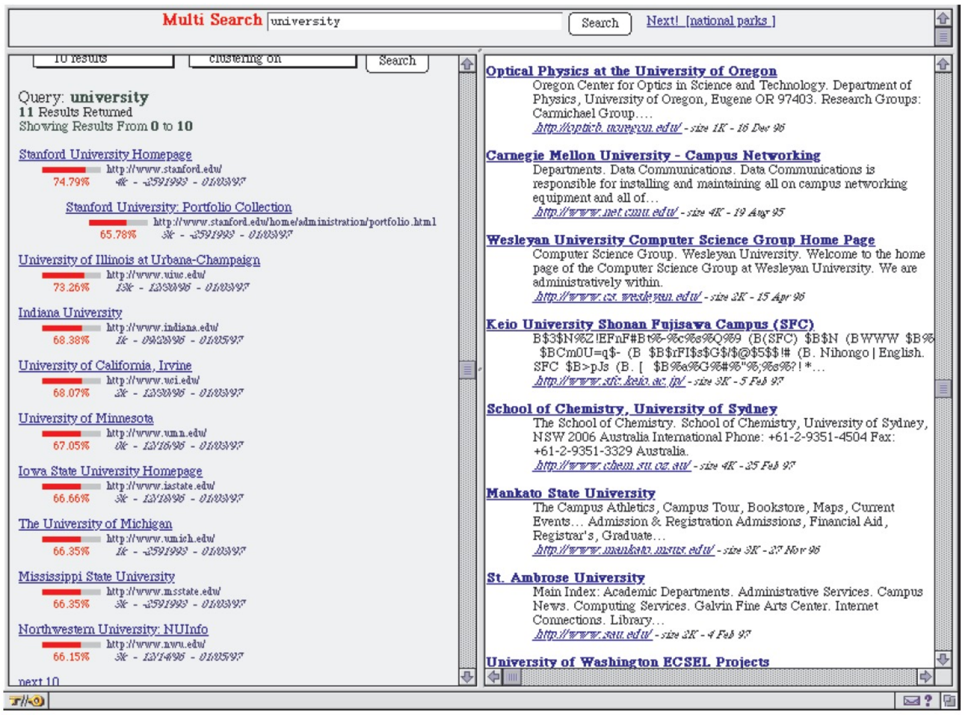
- PR (322 Million Links): 52 iterations
- PR (161 Million Links): 45 iterations
- Scaling factor is roughly linear in logn



Searching with PageRank

- Two search engines:
  - Title-based search engine
  - Full text search engine
- Title-based search engine
  - Searches only the “Titles”
  - Finds all the web pages whose titles contain all the query words
  - Sorts the results by PageRank
  - Very simple and cheap to implement
  - Title match ensures high precision, and PageRank ensures high quality
- Full text search engine
  - Called Google
  - Examines all the words in every stored document and also performs PageRank (Rank Merging)
  - More precise but more complicated

Searching with PageRank



Query: **university**
11 Results Returned
Showing Results From **0** to **10**

Stanford University Homepage
http://www.stanford.edu/
74.79% 4k - 25/19/93 - 01/03/97

Stanford University: Portfolio Collection
http://www.stanford.edu/home/administration/portfolio.html
65.78% 3k - 25/19/93 - 01/03/97

University of Illinois at Urbana-Champaign
http://www.uiuc.edu/
73.26% 13k - 12/30/96 - 01/03/97

Indiana University
http://www.indiana.edu/
68.38% 1k - 09/28/96 - 01/05/97

University of California, Irvine
http://www.uci.edu/
68.07% 2k - 12/30/96 - 01/03/97

University of Minnesota
http://www.umn.edu/
67.05% 0k - 12/16/96 - 01/03/97

Iowa State University Homepage
http://www.iastate.edu/
66.66% 5k - 12/18/96 - 01/03/97

The University of Michigan
http://www.umich.edu/
66.35% 1k - 25/19/93 - 01/03/97

Mississippi State University
http://www.msstate.edu/
66.35% 5k - 25/19/93 - 01/03/97

Northwestern University: NUInfo
http://www.nwu.edu/
66.15% 5k - 12/14/96 - 01/05/97

next 10

Optical Physics at the University of Oregon
Oregon Center for Optics in Science and Technology. Department of Physics, University of Oregon, Eugene OR 97403. Research Groups: Carmichael Group....
http://optics.uoregon.edu/ - size 1K - 16 Dec 96

Carnegie Mellon University - Campus Networking
Departments. Data Communications. Data Communications is responsible for installing and maintaining all on campus networking equipment and all of...
http://www.net.cmu.edu/ - size 4K - 19 Aug 95

Wesleyan University Computer Science Group Home Page
Computer Science Group. Wesleyan University. Welcome to the home page of the Computer Science Group at Wesleyan University. We are administratively within.
http://www.cs.wesleyan.edu/ - size 2K - 15 Apr 96

Keio University Shonan Fujisawa Campus (SFC)
B$3$N%Z!EFnF#Bt%-%c%s%Q%9 (B(SFC) BN (BWWW $B% $BCm0U=q$- (B BrFIsG$/$@$5$$!# (B. Nihongo | English. SFC $B>pJs (B. [$B%a%G%#%"%;%s%?!*...
http://www.sfc.keio.ac.jp/ - size 3K - 5 Feb 97

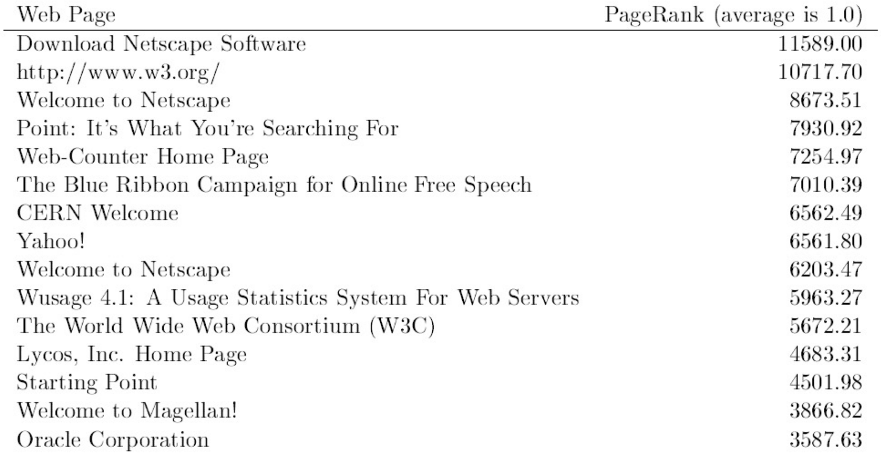
School of Chemistry, University of Sydney
The School of Chemistry. School of Chemistry, University of Sydney, NSW 2006 Australia International Phone: +61-2-9351-4504 Fax: +61-2-9351-3329 Australia.
http://www.chem.su.oz.au/ - size 4K - 25 Feb 97

Mankato State University
The Campus Athletics, Campus Tour, Bookstore, Maps, Current Events... Admission & Registration Admissions, Financial Aid, Registrar's, Graduate...
http://www.mankato.msus.edu/ - size 3K - 27 Nov 96

St. Ambrose University
Main Index: Academic Departments. Administrative Services. Campus News. Computing Services. Galvin Fine Arts Center. Internet Connections. Library...
http://www.sau.edu/ - size 2K - 4 Feb 97

University of Washington ECSEL Projects

Searching with PageRank



Web Page	PageRank (average is 1.0)
Download Netscape Software	11589.00
http://www.w3.org/	10717.70
Welcome to Netscape	8673.51
Point: It's What You're Searching For	7930.92
Web-Counter Home Page	7254.97
The Blue Ribbon Campaign for Online Free Speech	7010.39
CERN Welcome	6562.49
Yahoo!	6561.80
Welcome to Netscape	6203.47
Wusage 4.1: A Usage Statistics System For Web Servers	5963.27
The World Wide Web Consortium (W3C)	5672.21
Lycos, Inc. Home Page	4683.31
Starting Point	4501.98
Welcome to Magellan!	3866.82
Oracle Corporation	3587.63

Top 15 Page Ranks: July 1996

Personalized PageRank

- Important component of PageRank calculation is E
  - A vector over the web pages (used as source of rank)
  - Powerful parameter to adjust the page ranks
- E vector corresponds to the distribution of web pages that a random surfer periodically jumps to

PageRank vs. Web Traffic

- Some highly accessed web pages have low page rank possibly because
  - People do not want to link to these pages from their own web pages (the example in their paper is pornographic sites…)
  - Some important backlinks are omitted
  - use usage data as a start vector for PageRank.

Conclusion

- PageRank is a global ranking of all web pages based on their locations in the web graph structure
- PageRank uses information which is external to the web pages – backlinks
- Backlinks from important pages are more significant than backlinks from average pages
- The structure of the web graph is very useful for information retrieval tasks.

VIỆN CÔNG NGHỆ THÔNG TIN VÀ TRUYỀN THÔNG

SCHOOL OF INFORMATION AND COMMUNICATION TECHNOLOGY

Thank you
for your
attention!!!

soict.hust.edu.vn/ fb.com/groups/soict