POLITECNICO DI MILANO

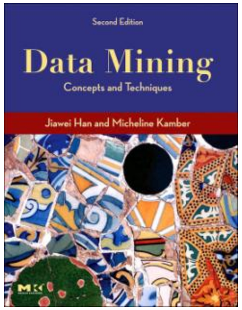
Web Mining

Data Mining and Text Mining (UIC 583 @ Politecnico di Milano)

Daniele Loiacono

References

- Jiawei Han and Micheline Kamber, "Data Mining: Concepts and Techniques", The Morgan Kaufmann Series in Data Management Systems (Second Edition)
  - Chapter 10

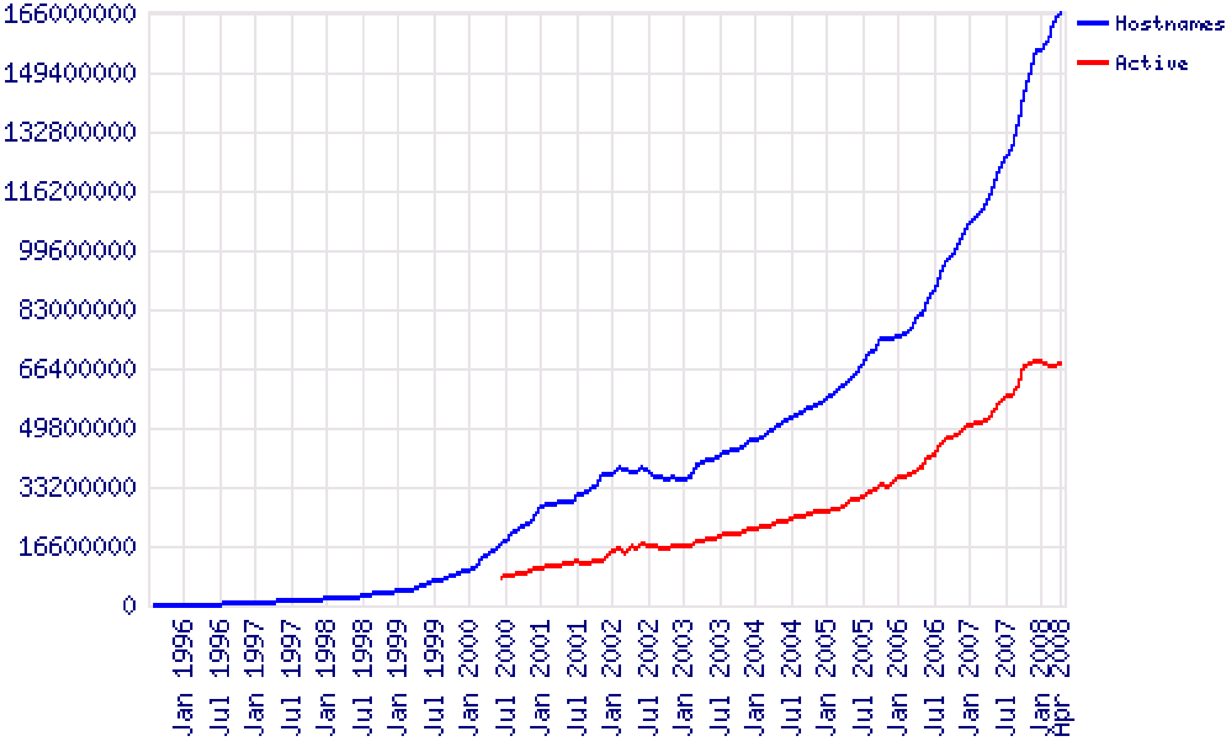


- **Web Mining Course** by *Gregory-Platesky Shapiro* available at www.kdnuggets.com

- Federico Facca and Pier Luca Lanzi. **Mining Interesting Knowledge from Weblogs: A Survey**. *Journal of Data and Knowledge Engineering*, 53(3):225–241, 2005.

How big is the Web?

165,719,150 Web Sites @Apr 2008 (Netcraft Survey)



What is Web Mining?

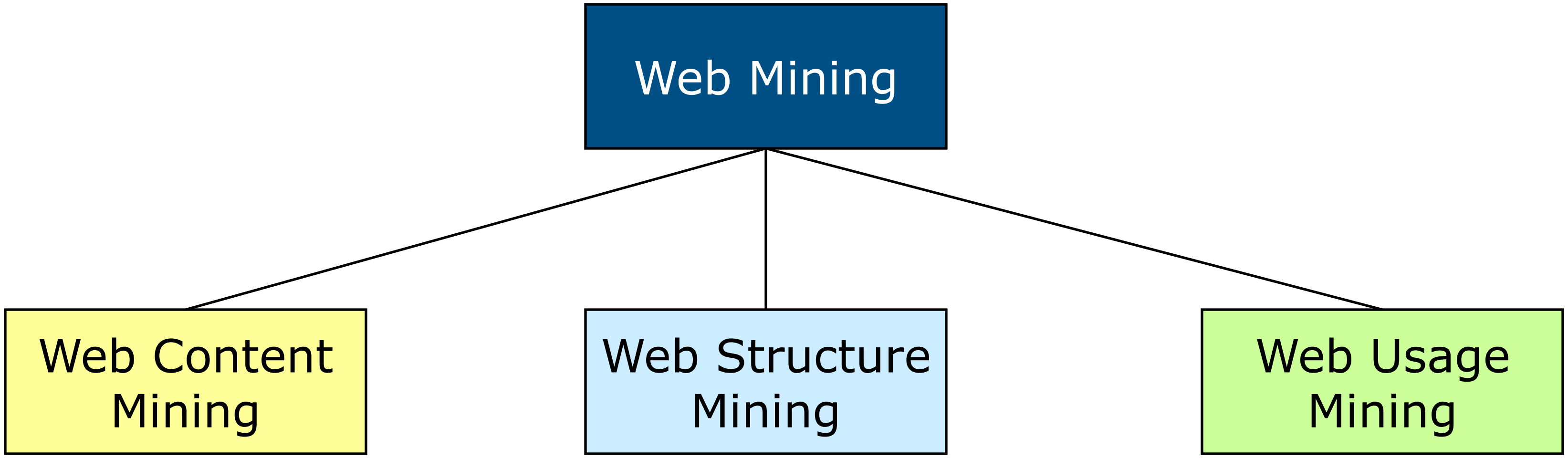
Discovering interesting and useful information from Web content and usage

- Examples
  - Web search, e.g. Google, Yahoo, MSN, Ask, …
  - Specialized search: e.g. Froogle (comparison shopping), job ads (Flipdog)
  - eCommerce
  - Recommendations (Netflix, Amazon, etc.)
  - Improving conversion rate: next best product to offer
  - Advertising, e.g. Google Adsense
  - Fraud detection: click fraud detection, …
  - Improving Web site design and performance

Web Mining Challenges

- Huge amount of data
- Complexity of Web pages
  - Different styles
  - Different contents
- Highly dynamic and rapidly growing information
  - Number of sites is rapidly growing
  - Information is constantly updated
- Web serves many user communities
  - Users with different interests, background and purposes
  - “99% of the Web information is useless to 99% of Web users”

Web Mining Taxonomy



Web Mining

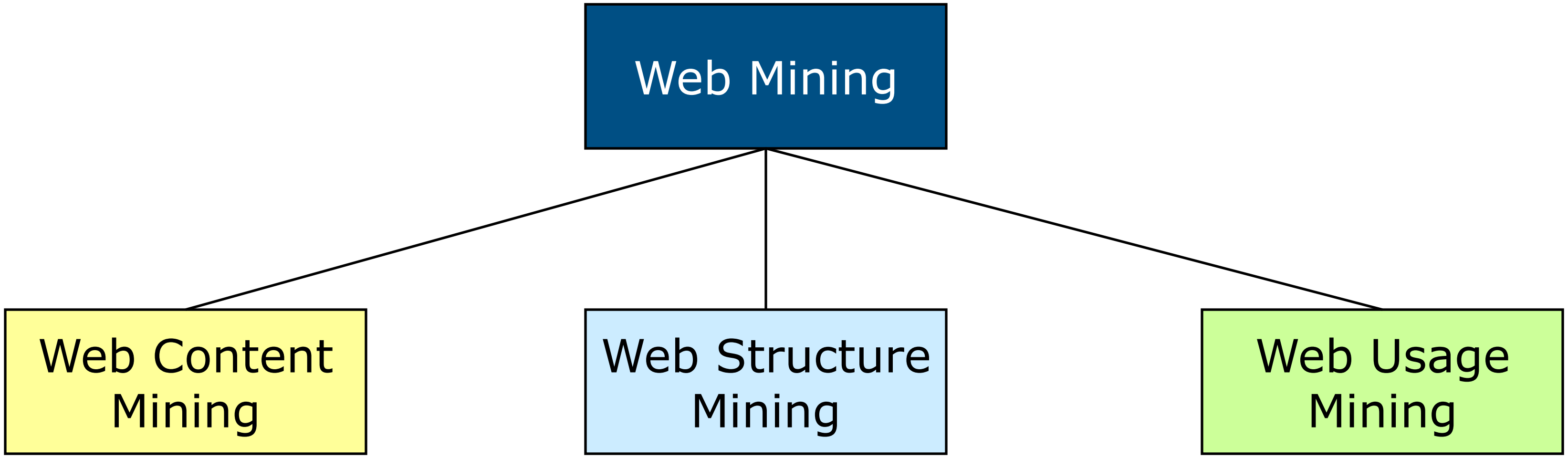
Web Content Mining

Web Structure Mining

Web Usage Mining

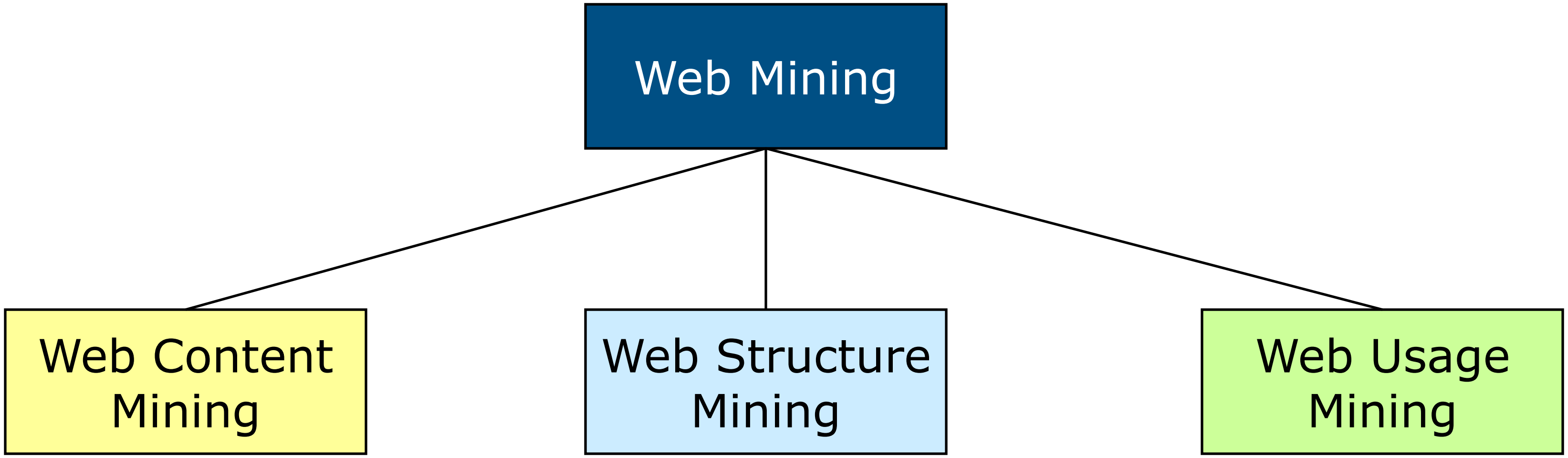
- ❑ Summarization of Web pages
- ❑ Summarization of Web searches
- ❑ Mining multimedia Web content
- ❑ Web pages classification
- ❑ …

Web Mining Taxonomy



- ❑ Mining linking structure
- ❑ Discover authoritative pages
  - PageRank
- ❑ Discover hub

Web Mining Taxonomy



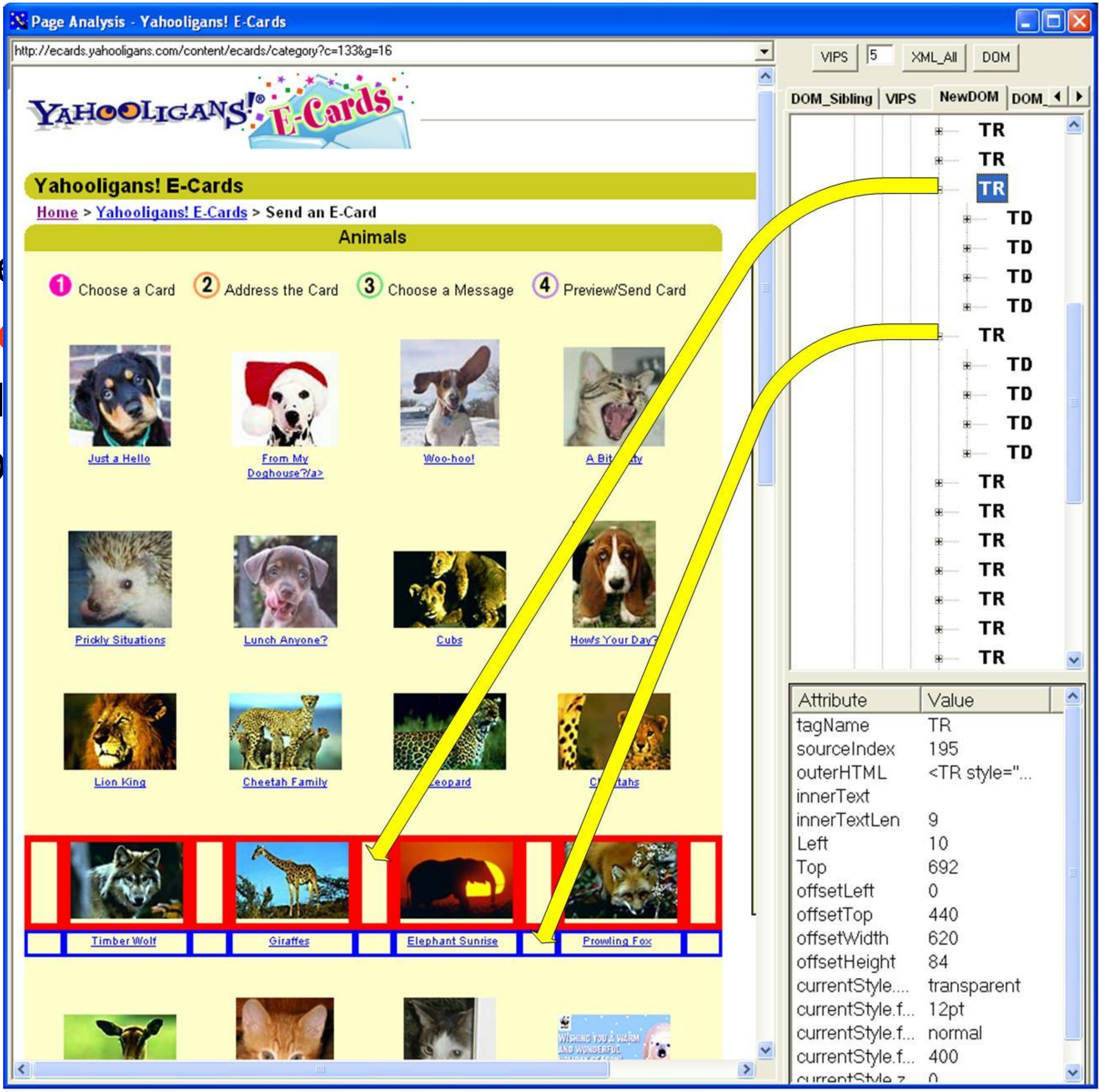
- Mining weblogs to discover usage patterns
- Applications:
  - Personalization of Web content
  - Improve Web design

Mining Web Page Layout Structure

- Web page is more than plain text
- Web page structure is defined by the **DOM** (Document Object Model) tree, where nodes are the **HTML tags**
- Issues
  - Not all the pages follows the standards
  - DOM tree does not always reflect the page semantic

Mining Web Page Layout Structure

- Web
- Web ent Object Mode
- Issue
  - N
  - D antic



Attribute	Value
tagName	TR
sourceIndex	195
outerHTML	<TR style="...
innerText	
innerTextLen	9
Left	10
Top	692
offsetLeft	0
offsetTop	440
offsetWidth	620
offsetHeight	84
currentStyle....	transparent
currentStyle.f...	12pt
currentStyle.f...	normal
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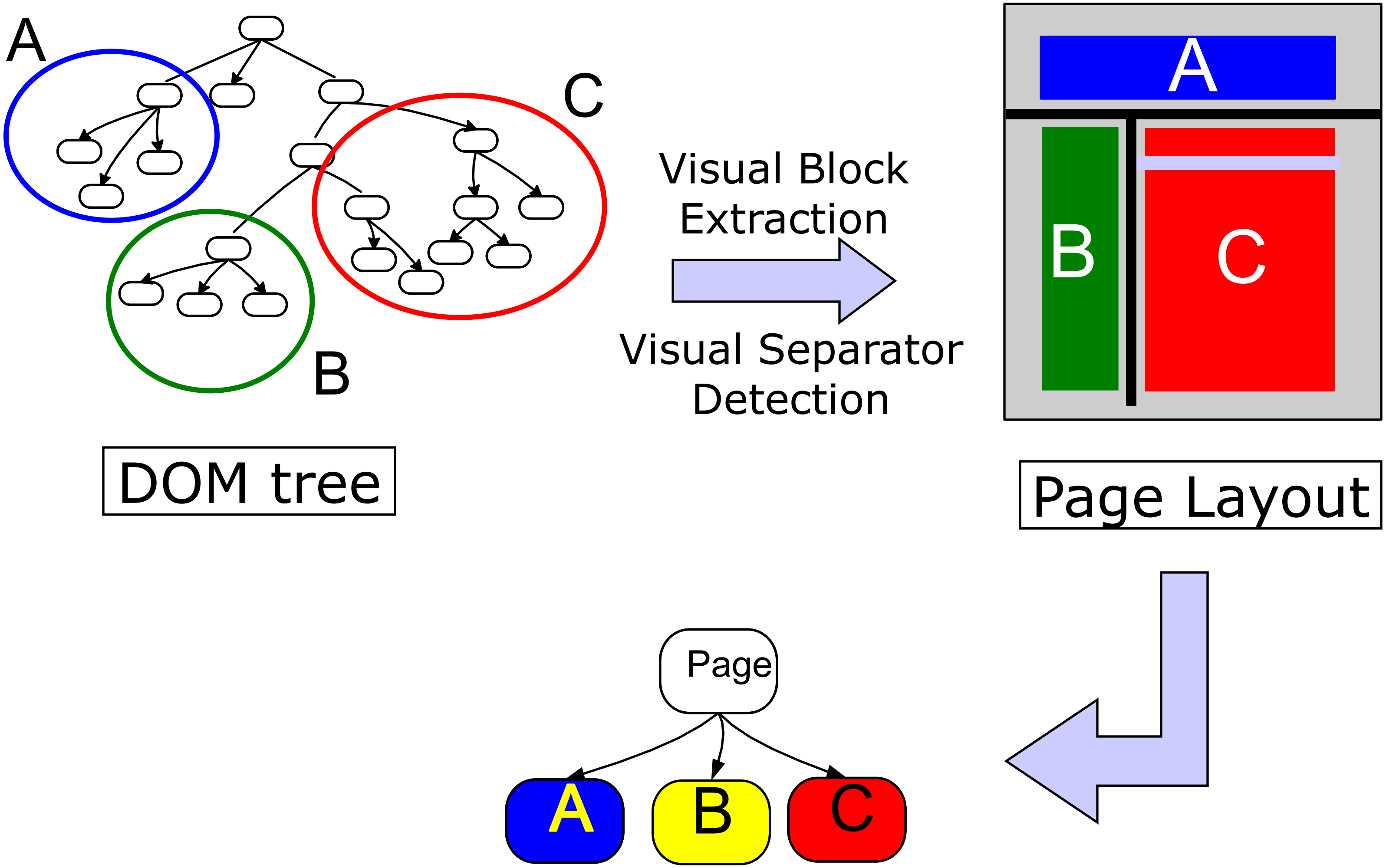
currentStyle.z	0

Vision-based Page Segmentation



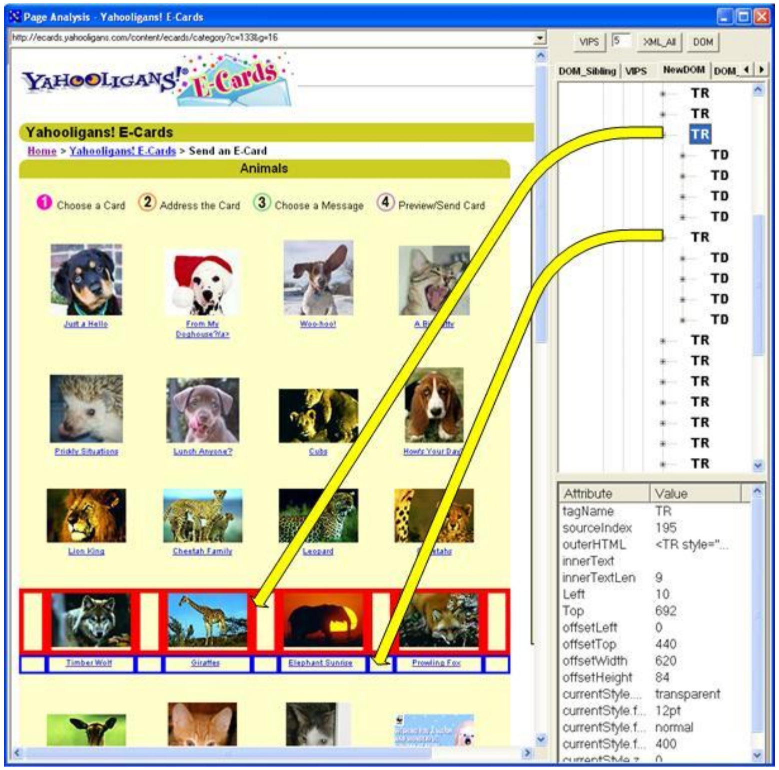
DOM tree

Visual Block Extraction

Visual Separator Detection

Page Layout

Example of Web Page Segmentation



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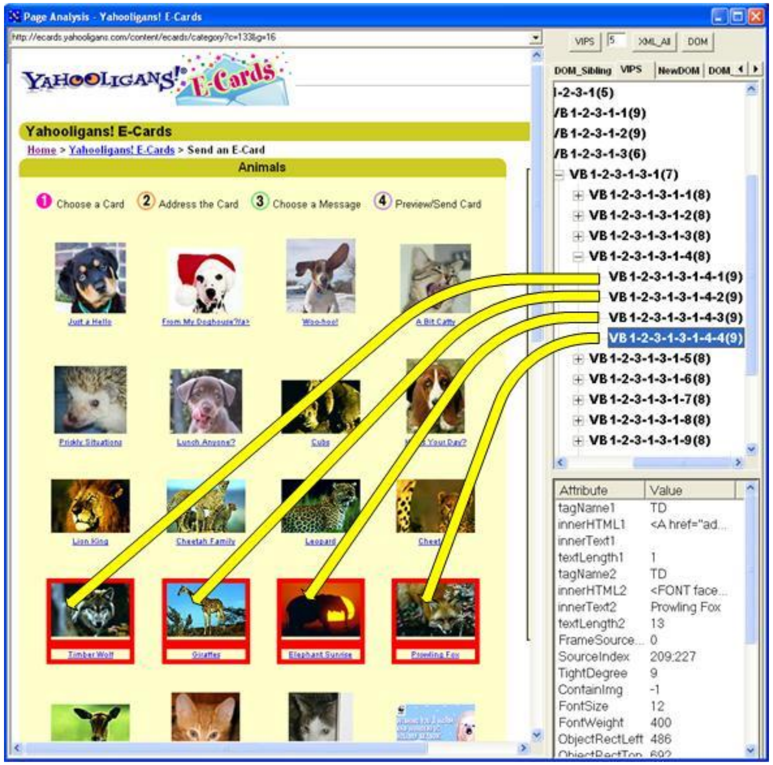
currentStyle....	transparent
currentStyle.f...	12pt
currentStyle.f...	normal
currentStyle.f...	400
currentStyle.z...	0

(DOM Structure)



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VB 1-2-3-1-3-1-4-4(9)
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VB 1-2-3-1-3-1-6(8)
VB 1-2-3-1-3-1-7(8)
VB 1-2-3-1-3-1-8(8)
VB 1-2-3-1-3-1-9(8)

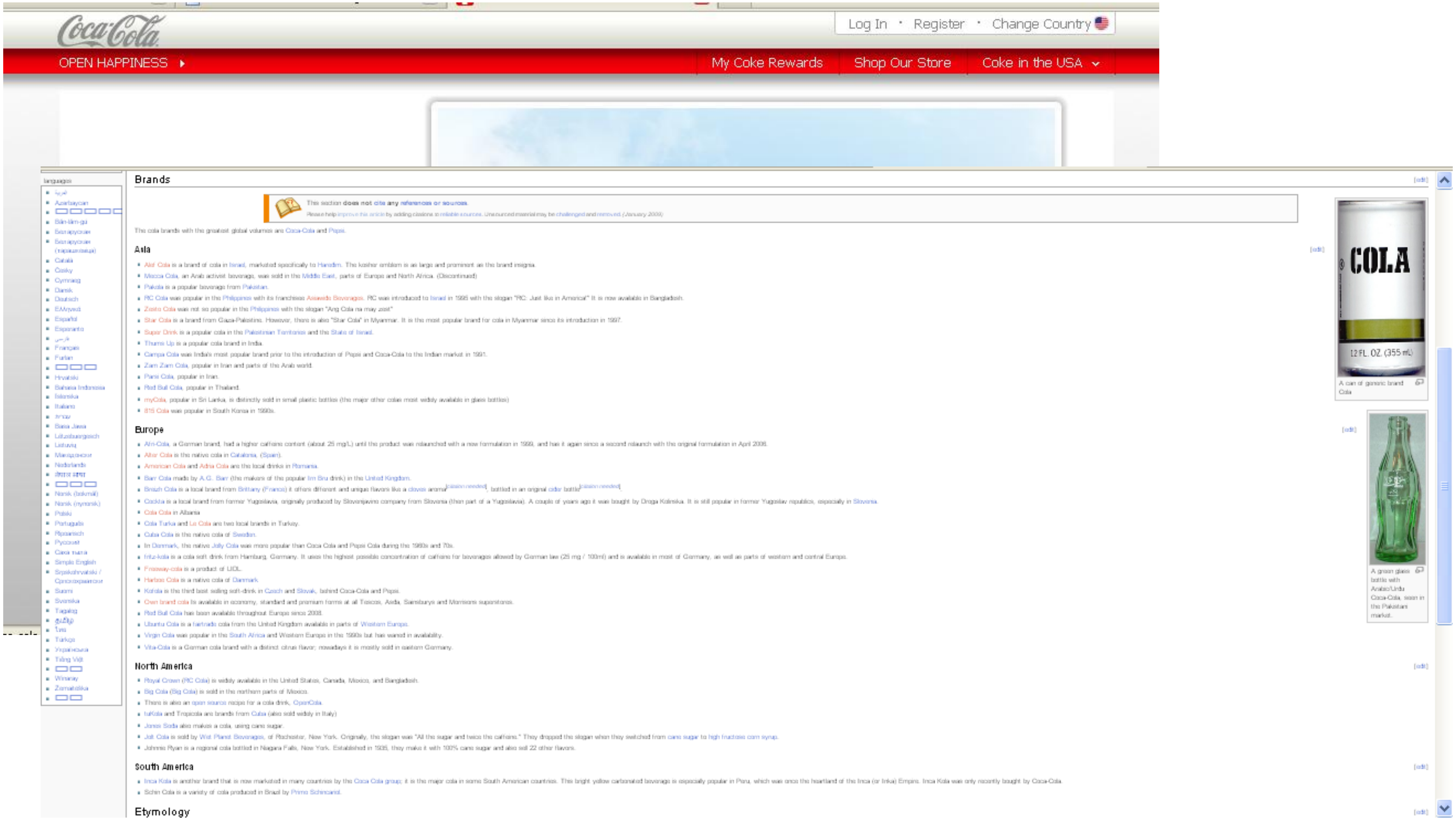
Attribute	Value
tagName1	TD
innerHTML1	<A href="ad...
innerText1	
textLength1	1
tagName2	TD
innerHTML2	<FONT face...
innerText2	Prowling Fox
textLength2	13
FrameSource...	0
SourceIndex	209:227
TightDegree	9
ContainImg	-1
FontSize	12
FontWeight	400
ObjectRectLeft	486
ObjectRectTop	692

(VIPS Structure)

Mining Web's Link Structure

- How to identify **authoritative** page?
- The answer is in the **Web linkage structure**
- Issues in Web linkage
  - Links do not always represent endorsements (e.g., adv)
  - Important competitors do not usually link each other
  - Authoritative pages are generally not self-descriptive
- To discover authorities we should also look for **hub pages**
  - Hub are pages that provide **collections of links to authorities**
  - Hub pages are not necessary highly linked
  - Hub pages implicitly confer authorities on focused topics
- **Hub and authoritative pages have a mutual reinforcement relationship**
  - A good hub page points to many good authorities, a good authority is a page pointed by many good hub pages

Examples



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- Azərbaycan
- □□□□□
- Bân-lâm-gú
- Беларуская
- Беларуская (тарашкевіца)
- Català
- Česky
- Cymraeg
- Dansk
- Deutsch
- Ελληνικά
- Español
- Esperanto
- فارسی
- Français
- Furlan
- □□□
- Hrvatski
- Bahasa Indonesia
- Íslenska
- Italiano
- עברית
- Basa Jawa
- Lëtzebuergesch
- Lietuvių
- Македонски
- Nederlands
- नेपाल भाषा
- □□□
- Norsk (bokmål)
- Norsk (nynorsk)
- Polski
- Português
- Ripoarisch
- Русский
- Саха тыла
- Simple English
- Srpskohrvatski / Српскохрватски
- Suomi
- Svenska
- Tagalog
- தமிழ்
- ไทย
- Türkçe
- Українська
- Tiếng Việt
- □□
- Winaray
- Žemaitėška
- □□

Brands

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The cola brands with the greatest global volumes are Coca-Cola and Pepsi.

Asia

- Alof Cola is a brand of cola in Israel, marketed specifically to Haredim. The kosher emblem is as large and prominent as the brand insignia.
- Mecca Cola, an Arab activist beverage, was sold in the Middle East, parts of Europe and North Africa. (Discontinued)
- Pakola is a popular beverage from Pakistan.
- RC Cola was popular in the Philippines with its franchisee Asiawide Beverages. RC was introduced to Israel in 1995 with the slogan "RC: Just like in America!" It is now available in Bangladesh.
- Zesto Cola was not so popular in the Philippines with the slogan "Ang Cola na may zest"
- Star Cola is a brand from Gaza-Palestine. However, there is also "Star Cola" in Myanmar. It is the most popular brand for cola in Myanmar since its introduction in 1997.
- Super Drink is a popular cola in the Palestinian Territories and the State of Israel.
- Thums Up is a popular cola brand in India.
- Campa Cola was India's most popular brand prior to the introduction of Pepsi and Coca-Cola to the Indian market in 1991.
- Zam Zam Cola, popular in Iran and parts of the Arab world.
- Parsi Cola, popular in Iran.
- Red Bull Cola, popular in Thailand.
- myCola, popular in Sri Lanka, is distinctly sold in small plastic bottles (the major other colas most widely available in glass bottles)
- 815 Cola was popular in South Korea in 1990s.

Europe

- Afri-Cola, a German brand, had a higher caffeine content (about 25 mg/L) until the product was relaunched with a new formulation in 1999, and has it again since a second relaunch with the original formulation in April 2006.
- Alter Cola is the native cola in Catalonia, (Spain).
- American Cola and Adria Cola are the local drinks in Romania.
- Barr Cola made by A.G. Barr (the makers of the popular Irn Bru drink) in the United Kingdom.
- Breizh Cola is a local brand from Brittany (France) it offers different and unique flavors like a cloves aroma[citation needed], bottled in an original cider bottle[citation needed].
- Cockta is a local brand from former Yugoslavia, originally produced by Slovenijavino company from Slovenia (then part of a Yugoslavia). A couple of years ago it was bought by Droga Kolinska. It is still popular in former Yugoslav republics, especially in Slovenia.
- Cola Cola in Albania
- Cola Turka and Lo Cola are two local brands in Turkey.
- Cuba Cola is the native cola of Sweden.
- In Denmark, the native Jolly Cola was more popular than Coca Cola and Pepsi Cola during the 1960s and 70s.
- fritz-kola is a cola soft drink from Hamburg, Germany. It uses the highest possible concentration of caffeine for beverages allowed by German law (25 mg / 100ml) and is available in most of Germany, as well as parts of western and central Europe.
- Freeway-cola is a product of LIDL.
- Harboe Cola is a native cola of Denmark.
- Kofola is the third best selling soft-drink in Czech and Slovak, behind Coca-Cola and Pepsi.
- Own brand cola is available in economy, standard and premium forms at all Tescos, Asda, Sainsburys and Morrisons superstores.
- Red Bull Cola has been available throughout Europe since 2008.
- Ubuntu Cola is a fairtrade cola from the United Kingdom available in parts of Western Europe.
- Virgin Cola was popular in the South Africa and Western Europe in the 1990s but has waned in availability.
- Vita-Cola is a German cola brand with a distinct citrus flavor; nowadays it is mostly sold in eastern Germany.

North America

- Royal Crown (RC Cola) is widely available in the United States, Canada, Mexico, and Bangladesh.
- Big Cola (Big Cola) is sold in the northern parts of Mexico.
- There is also an open source recipe for a cola drink, OpenCola.
- tuKola and Tropicola are brands from Cuba (also sold widely in Italy)
- Jones Soda also makes a cola, using cane sugar.
- Jolt Cola is sold by Wet Planet Beverages, of Rochester, New York. Originally, the slogan was "All the sugar and twice the caffeine." They dropped the slogan when they switched from cane sugar to high fructose corn syrup.
- Johnnie Ryan is a regional cola bottled in Niagara Falls, New York. Established in 1935, they make it with 100% cane sugar and also sell 22 other flavors.

South America

- Inca Kola is another brand that is now marketed in many countries by the Coca Cola group; it is the major cola in some South American countries. This bright yellow carbonated beverage is especially popular in Peru, which was once the heartland of the Inca (or Inka) Empire. Inca Kola was only recently bought by Coca-Cola.
- Schin Cola is a variety of cola produced in Brazil by Primo Schincariol.

Etymology

A can of generic brand Cola

A green glass bottle with Arabic/Urdu Coca-Cola, seen in the Pakistani market.

Hyperlink-Induce Topic Search (1)

- Startup
  - **Root set** built from results from an index-based search engine
  - **Base set** built including pages linked by and linking to the root set pages
- Authority weight, a_p, and hub weight, h_p, are iteratively computed

$$a_p = \sum_{\forall q : q \rightarrow p} h_q \qquad h_p = \sum_{\forall q : q \leftarrow p} a_q$$

- In matrix form

$$\begin{cases} \vec{h} = \boxed{A}\vec{a} = \cdots = (AA^T)^k\vec{h} \\ \vec{a} = A^T\vec{h} = \cdots = (A^TA)^k\vec{a} \end{cases}$$

Adiacency Matrix

- The **authority weight vector** and the **hub weight vector** if normalized converge to the eigenvectors of AA^T and A^TA

Hyperlink-Induce Topic Search (2)

- Underlying assumptions:
  - Links convey endorsement
  - Pages co-linked by a certain page are likely to be related to the same topic
- VIPS-based approach
  - **Block-to-page** relationship

$$Z_{ij} = \begin{cases} 1/s_i, & \text{if block } i \text{ point to page } j \\ 0, & \text{otherwise} \end{cases}$$

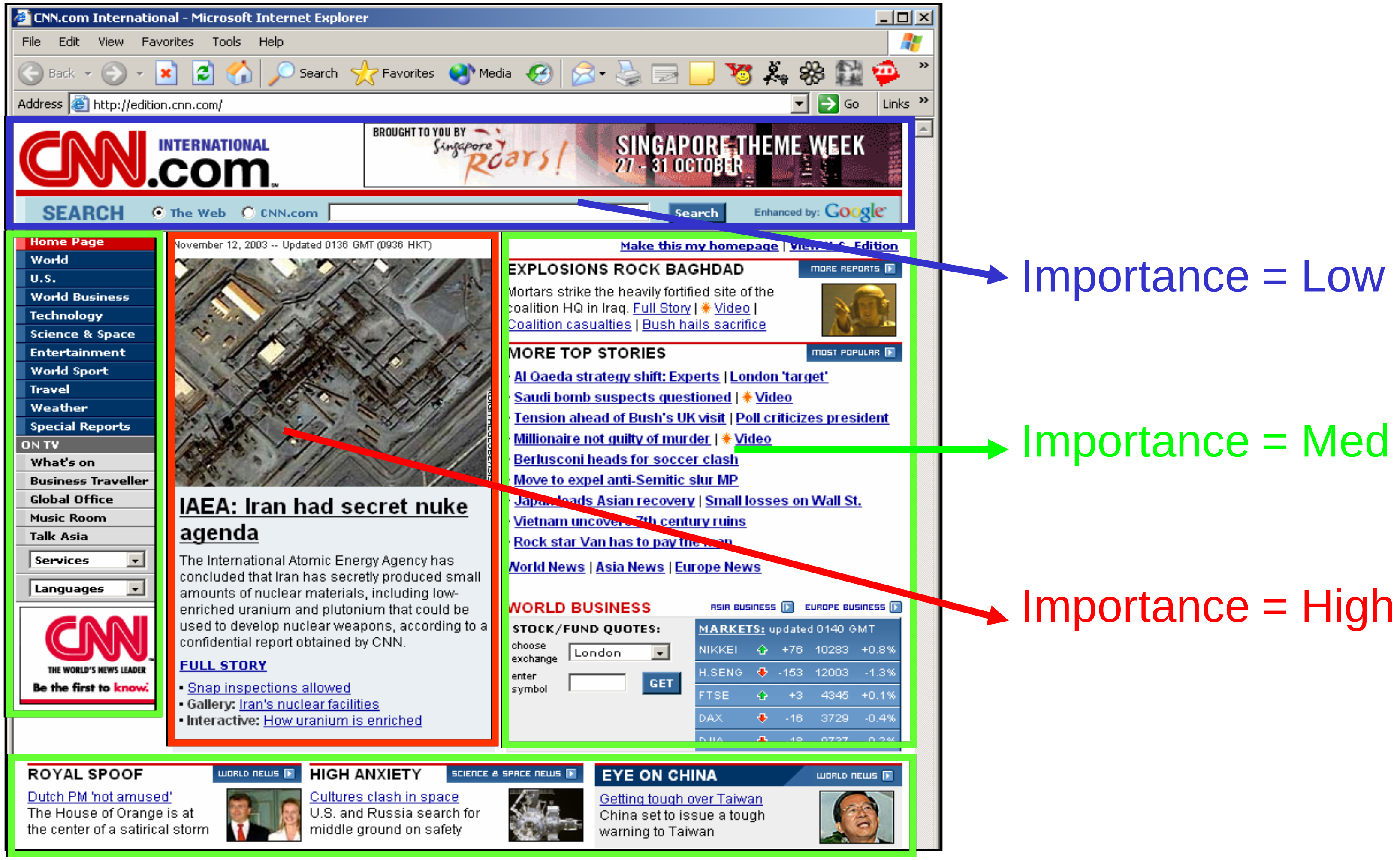
    where s_i is the number of pages linked by block i
  - **Page-to-block** relationship

$$X_{ij} = \begin{cases} f_{p_i}(b_j), & \text{if } b_j \in p_i \\ 0, & \text{otherwise} \end{cases}$$

    where $f_p(b)$ represents how b is important in page p
  - Adjacency matrix can be defined as

$$W_P = XZ$$

Hyperlink-Induce Topic Search (3)



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Importance = Low

Importance = Med

Importance = High

Mining Multimedia Data on the Web

- Is different from general-purpose multimedia data mining
  - Multimedia data is embedded in Web pages
  - Links and surrounding text might help the data mining process
- VIPS algorithm is the basis to extract knowledge
  - A **bock-to-image** relationship can be built
  - The block-to-image relationship can be integrated with a block-level link analysis
  - The resulting **image graph** reflect the semantic relationship between the images
- The image graph can be used for classification and clustering purposes

Web Usage Mining

Web usage mining is the extraction of interesting knowledge from server log files

- Applications
  - Mining logs of a single user
    - Web content personalization
  - Mining logs of groups of users
    - Supporting Web design
- Issues
  - Where is the data?
  - How to preprocess the data?
  - Which mining techniques?

Data sources

- Logs can be collected at different levels
  - Server side
  - Proxy side
  - Client side

Data sources: server side

- Web server log
  - Standard format (e.g., LogML)
  - Large amount of information (IP, request info, etc.)
  - User session can be difficult to identify
  - Special buttons (e.g., *Back, Stop*) cannot be tracked
- TCP/IP packet sniffer
  - Data collected in real-time
  - Data from different web servers can be merged easily
  - Some special buttons can be tracked (e.g. *Stop*)
  - Does not scale very well
- Exploiting the server application layer
  - Very effective
  - Not always possible
  - Requires ad-hoc solutions for each web server

Data sources: proxy side

- Almost the same information available on server side
- Data of **groups of users** accessing to **huge groups of web servers**
- Sessions can be anyway identified

Data sources: client side

- Collecting data with JavaScript or Java applets
- Exploiting a modified Web browser
- Perfect identification of the user session
- Requires user collaboration

Preprocessing: data cleaning

- Data cleaning consists of removing from Web logs useless data for mining purposes
- Content requests (e.g. images) are usually easily removed
- Robots and Web spiders should be removed on the basis of
  - Remote hostname
  - Access to robots.txt
  - Navigation pattern

Preprocessing: session identification and reconstruction

- Goals
  - Identifying the session of different users
  - Reconstruction the navigation path in identified session
- Challenges
  - Proxy
  - Browser caching and special buttons
- Solutions
  - Cookies
  - URL rewriting
  - JavaScript (e.g. SurfAid)
  - Consistency of navigation path
  - Timeout heuristic for session termination

Applications

- Personalization of Web content
  - Behavior anticipation
  - Recommendation of interesting links
  - Content reorganizations
- Pre-fetching and caching
  - Caching and pre-fetching of content to reduce the server response time
- Support to Web design
  - Analysis of frequent patterns to improve the usability of Web sites
- E-commerce
  - Analysis of customer behaviors (attrition, fidelity, etc.)

Preprocessing: content retrieving

- Generally URLs are the only information available on pages
- A richer information about visited pages may help the discovering of interesting Web usage patterns
- Main approaches
  - Pages categorization
    - Pre-defined
    - Automatically discovered with Web mining techniques
  - Semantic Web for Web Usage Mining
    - Ontology mapping
    - Learning of ontology from data
    - Extraction of concept-based navigation paths

Mining Techniques

- The main techniques used for the analysis of collected data are
  - Association rules

    A.html, B.html => C.html

  - Sequential patterns extraction
    - General purpose algorithm (e.g., AprioriAll)
    - Ad hoc solution for Web logs (WAP-mine)
  - Clustering of sessions
    - Based on sequence alignment
    - *Association rule hypergraph partitioning*
      - build a graph representing frequent patterns
      - Edges weighting based on pattern relevance
      - Partitioning of graph to extract users’ behaviors