Data (and Links) on the Web

Alberto Mendelzon

University of Toronto

http://www.cs.toronto.edu/~mendel

Joint work with Gus Arocena, Attila Barta, George Mihaila, Tova Milo, Davood Rafiei, Greg Keast, Elaine Toms, Joan Cherry

Outline

- Data on the Web

  semistructured data: data models, query languages

- What about links?

- Two link-centric projects

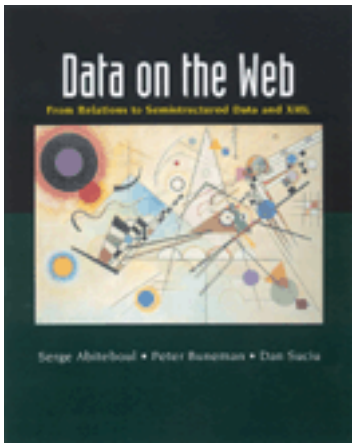
  WebSQL/WebOQL : unstructured/semistructured data + links

  TOPIC: exploiting links to evaluate page reputations

- Future Work

Data on the Web

Abiteboul, Buneman, Suciu, 2000.



Excellent survey of semistructured data

Semistructured Data

60's:	Data in files, structure in application programs
70's,80's:	Data and structure (schema) in DBMS
90's:	Data on the Web, where is the schema?
"Schemaless":	**HTML**
"Self-Describing":	**XML**

Example: an XML document

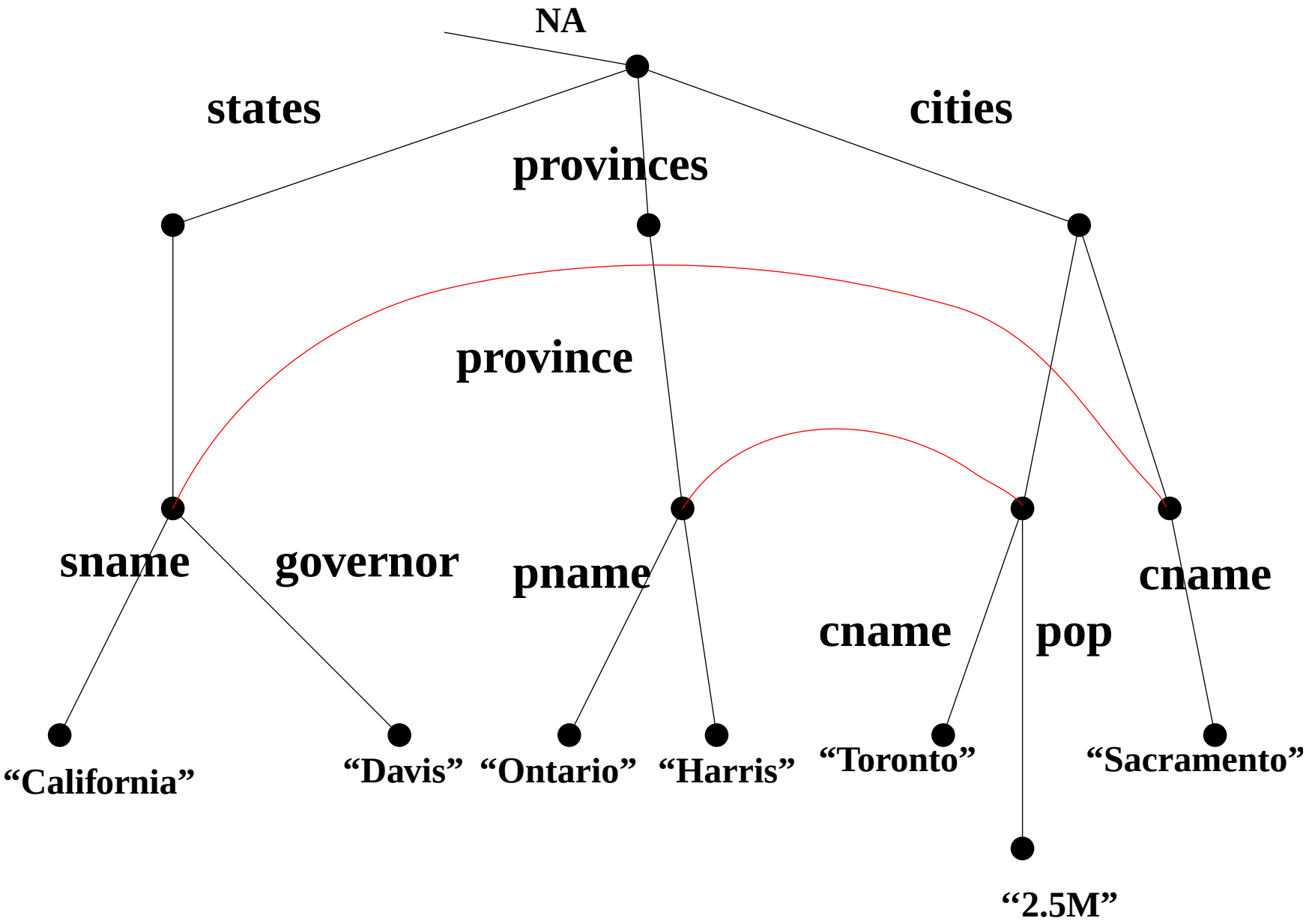
```
<north-america>
<states>
    <state id = “s1”>
        <sname California </sname>
        <capital idref=‘‘c1”>
        <governor> Gray Davis </governor>
    </state>
...
</states>
<provinces>
    <province id = “p1”>
        <pname> Ontario </pname>
        <capital idref ‘‘c2”>
        <premier> Mike Harris </premier>
    </province>
...
</provinces>
```

XML Document (cont.)

```
<cities>
    <city id = “c1”>
        <cname> Sacramento </cname>
        <state-of idref = “s1”>
    </city>

    <city id = “c2”>
        <cname> Toronto </cname>
        <pop> 2.5M </pop>
        <province-of idref = “p1”>
    </city>
...
</cities>
...
</north-america>
```

Graph Representation



State of the Art

- Data Models

  Pioneering work: OEM, LORE/LOREL, UnQL

  Data models for XML:XML Schema, DOM, RDF

- Query Languages

  SS QL's: LOREL, UnQL, ...

  XML QL's: XML-QL, XSLT, XQL

- Indexing

- Storage Mappings

What about the links?

Entry for *link* in index of DOTW book:

- pp. 45-46: XLink and XPointer
- pp. 189: “If Web data follows the same patterns as Web documents, then we should expect links to become prevalent.”

The Web is not just semistructured data: it’s autonomous distributed pieces of unstructured, semistructured, and structured data, interconnected by link

Some link-aware projects

- Strudel (AT&T)
- Tiramisu (Washington)
- Araneus (Rome)
- AutoWeb(Milan)
- SQUEAL (MIT)
- COIR (NEC)
- FLORID (Freiburg)
- WebSQL/WebOQL (Toronto)

WebSQL: Unstructured data + links

- Integrate ***Browsing*** & ***Searching***
- Data Model;

  Document (URL, title, type, length, text, modif)

  Anchor (base, label, href)

- Query Language: SQL + regexps
- Semantics:
  - Materialize a fragment of the database
  - Compute the answer on this fragment

Search Automation

- Find documents about Toronto that reside in servers in Canada

```
SELECT d.url,d.title
FROM Document d SUCH THAT d MENTIONS "Toronto"
WHERE d.url CONTAINS ".ca$"
```

- Find documents about WebSQL that point to U of T

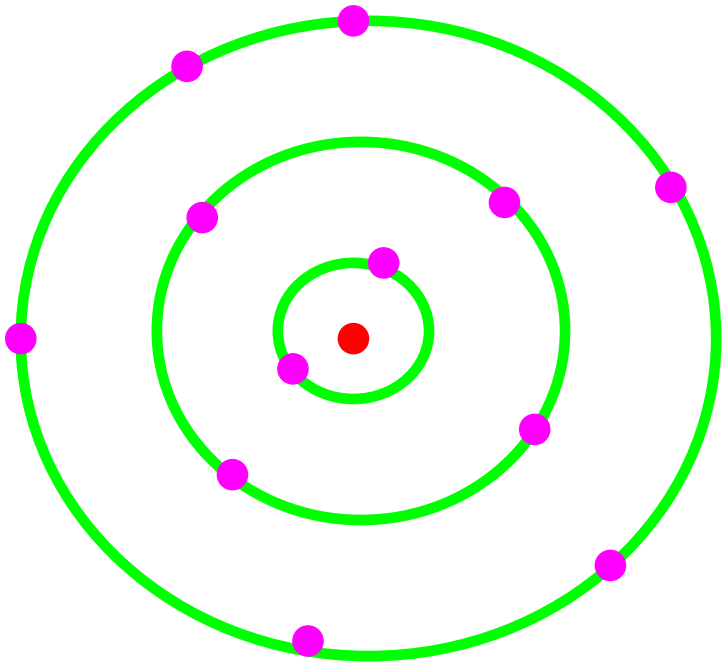
```
DEFINE INDEX "HotBot";

SELECT d.url
FROM  Document d SUCH THAT d MENTIONS "WebSQL",
          Anchor a SUCH THAT base = d,
WHERE a.href CONTAINS "toronto.edu"
OR a.href CONTAINS "utoronto.ca"
```

Search and Navigation

- Documents about “excursions” near WWW9 home page

SELECT d.url, d.title
FROM Document d
SUCH THAT “www9.org” **(->| ->-> | ->->->)** d
WHERE d.text **CONTAINS** “excursions”



Path Regular Expressions

- Alphabet (Link types)

#>	interior link: same document
->	local link: same server
=>	global link: different server
=	null path

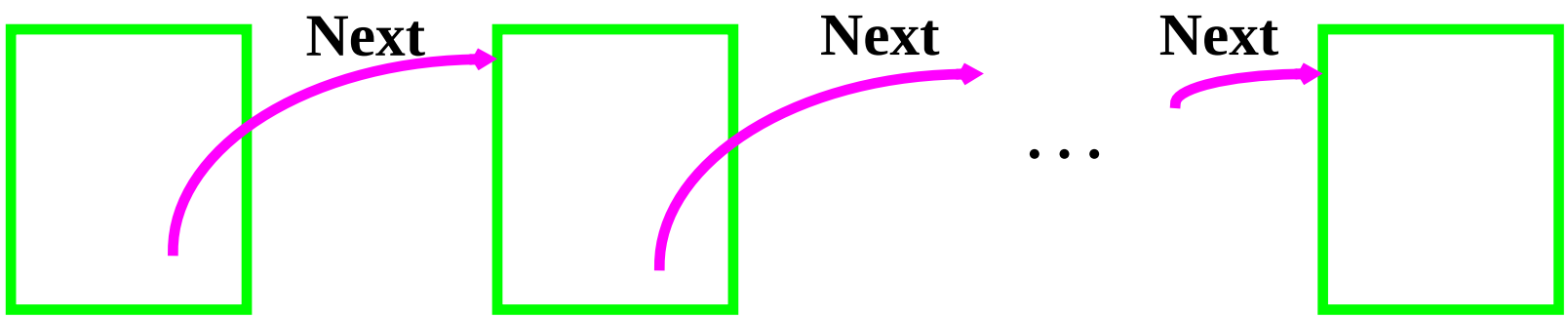
- Regexps Over Link Types

-> | =>	path of length one, either local or global
->*	local path of any length
=>->*	idem, but in other servers
(->|=>)*	the reachable portion of the Web

User-Defined Link Types

DEFINE LINK [next] **AS** label **CONTAINS** “Next”;

SELECT d.url
FROM Document d
SUCH THAT “http://the.starting.document” **[next]*** d,
WHERE d.title **CONTAINS** “Canada”;



Example applications

- Indexing an On-line Manual
- Indexing Publication List

Index of Online Publications

- Need pairs <URL of .ps, Metadata>

Internet

Alberto Mendelzon and Tova Milo, **Formal Models of the Web,** to appear in *Proc. PODS'97, Tucson, May 1997.*

Gustavo Arocena, Alberto Mendelzon, George Mihaila, **Applications of a Web Query Language,** to appear in *Proc.6th Int'l. WWW Conf., Santa Clara, April 1997.*

Alberto Mendelzon, George Mihaila, Tova Milo, **Querying the World Wide Web,** in *Proc. PDIS'96, Miami, December 1996.*

SELECT a.href, a.label
FROM Anchor a
SUCH THAT base = "http://www.cs.utoronto.ca/~mendel/papers.html"

A (partial) list of publications

- S. Abiteboul, S. Cluet, T. Milo, A Database Interface for Files Update . *Proc. ACM SIGMOD Int. Conf. on Management of D 1995* San Jose, May 1995.
- Y. Afek and G. Stupp, Synchronization power depends on the register size. In *Proc. of the 34th Ann. IEEE Symp. on Foundations of Computer Science*, pages 196–205, Novemb 1993.
- Y. Afek and G. Stupp, Delimiting the power of bounded size synchronization objects. In *Proc. of the 13th Ann. ACM Symp Principles of Distributed Computing*, pages 42–51, August 19
- Y. Afek, D. Dauber, and D. Touitou, Wait–free Made Fast. In

DEFINE CONTEXT BEGIN = <LI>, **END** = <LI>;

SELECT e.href, e.context
FROM Anchor e **SUCH THAT**
base = “http://www.math.tau.ac.il/~milo/dept/papers.html”
WHERE e.href **CONTAINS** “.ps”

Adding Structure to Unstructured Data (140K)
Peter Buneman, Susan Davidson, Mary Fernandez and Dan Suciu
Technical Report MS–CIS–96–21, CIS Department, University of Pennsylvania.
See here for the abstract.

A Query Language and Optimization Techniques for Unstructured Data (144K)
Peter Buneman, Susan Davidson, Gerd Hillebrand and Dan Suciu
Technical Report MS–CIS–96–09, CIS Department, University of Pennsylvania.
An extended abstract of this work appears in *SIGMOD Proceedings*, 1996.
See here for the abstract.

A Query Language for Multidimensional Arrays: Design, Implementation, and Optimization Techniques (87K)
Leonid Libkin, Rona Machlin and Limsoon Wong
SIGMOD Proceedings, 1996.
See here for the abstract.

DEFINE LINK [here] **AS** label **CONTAINS** "he**re"**
SELECT e.url, d.text
FROM Document d **SUCH THAT**
"http://www.cis.upenn.edu/~db/langs/allpapers.html" [here] d,
d [here] e;

Programmatic Interface

```
public static void main(String args[]) {
   String query = “SELECT x.url, x.title, x.length, x.date “+
   ” FROM Document x SUCH THAT x MENTIONS\”Java\”;”;

   try{
      WebSQLServer eng = new WebSQLServer(query, new Mon());
      for (Enumeration e = eng.elements();
e.hasMoreElements(); ) {
         Vector tuple = (Vector) e.nextElement();
         for (int i = 0; i < eng.tupleSize; i++) {
            System.out.print(tuple.elementAt(i));
            System.out.print(“ “);
         }
         System.out.println();
      }
   }catch(Exception e){System.out.println(“Couldn’t create
server.”);}
}
```

WebOQL: semistructured data + links

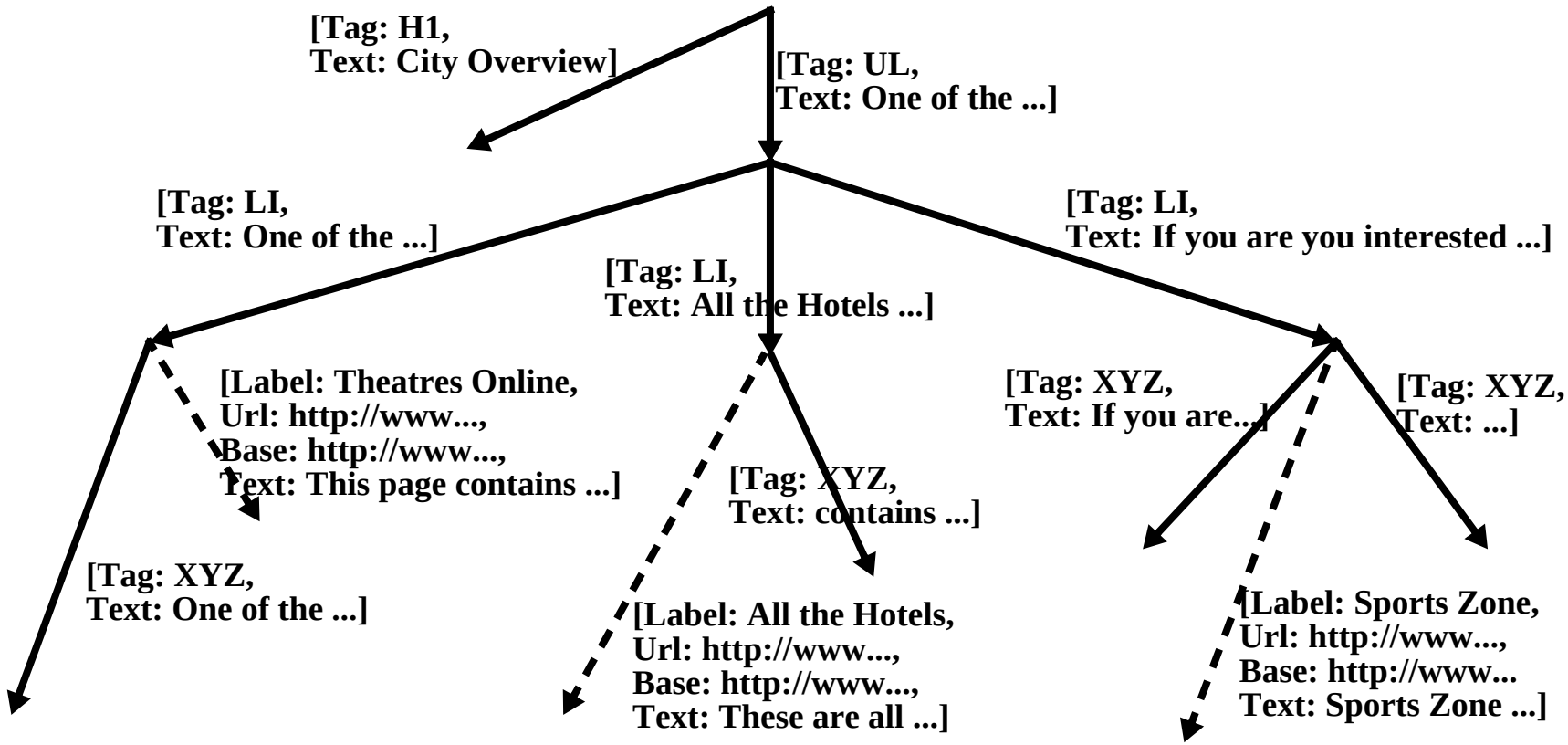
- WebSQL: Web as graph of atomic objects
- WebOQL: Web as graph of structured objects
- Query:
  - the Web
  - a single page
  - a set of related pages
- Restructure:
  - HTML to HTML
  - HTML to databases
  - Databases to HTML

City Overview

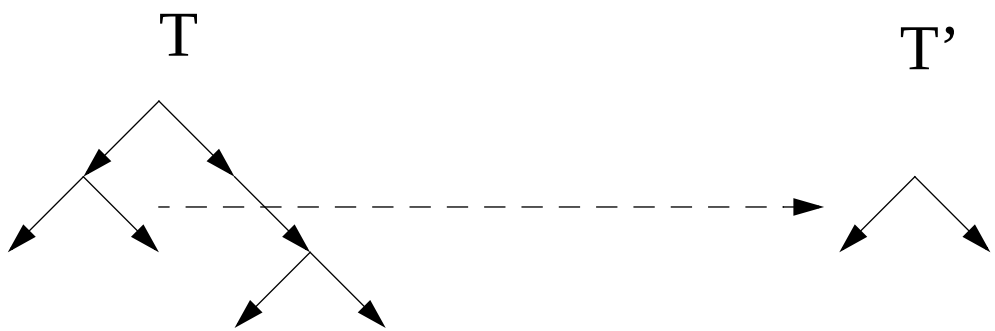
- One of the most attractive aspects of our city is the variety of cultural activities. You can purchase tickets for several theatres from Theatres Online.
- All the hotels on the Web provide discounts to cyber–clients !
- If you are interested in live sports, then you must visit Sports Zone . You can also buy tickets from them.

Data Model

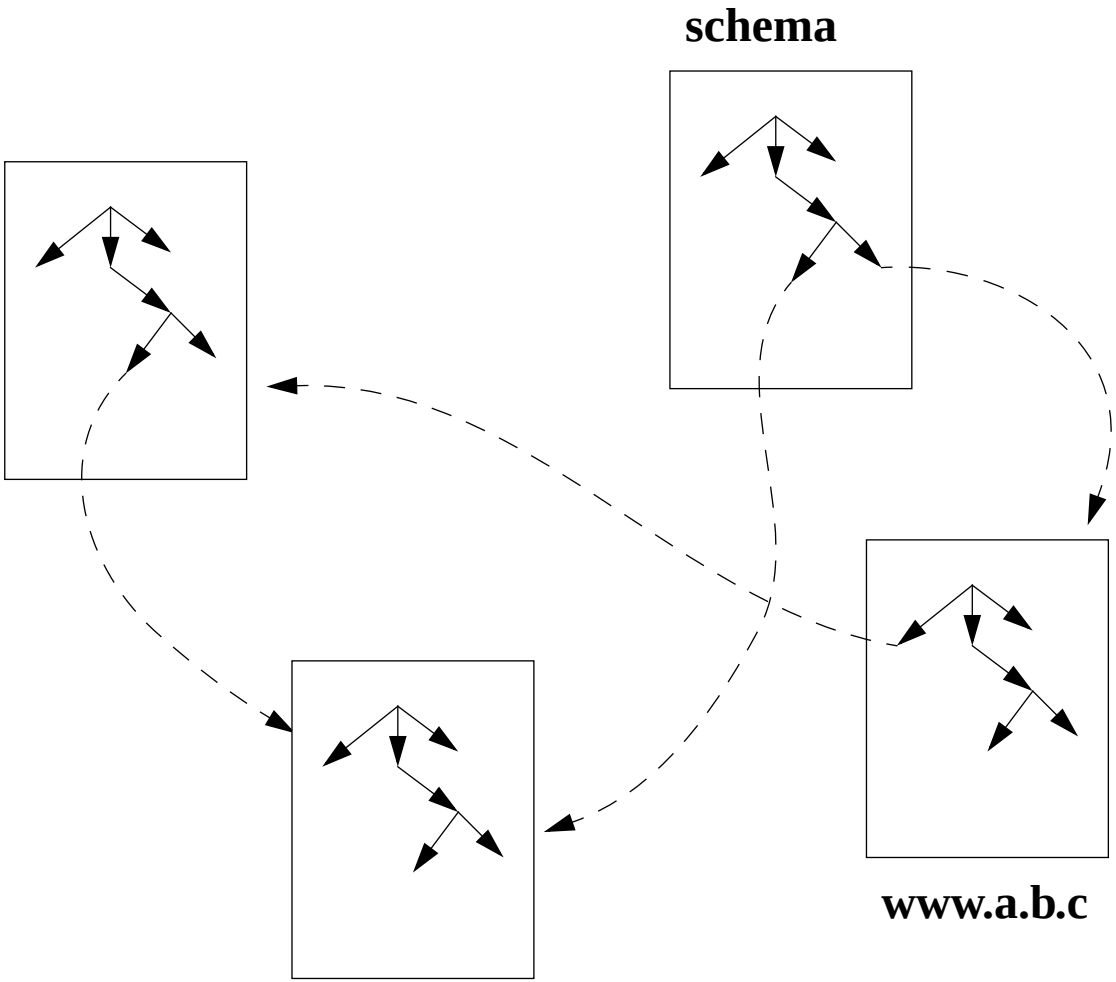
- Records as Labels on Arcs
- Internal and External Arcs



Tree operators

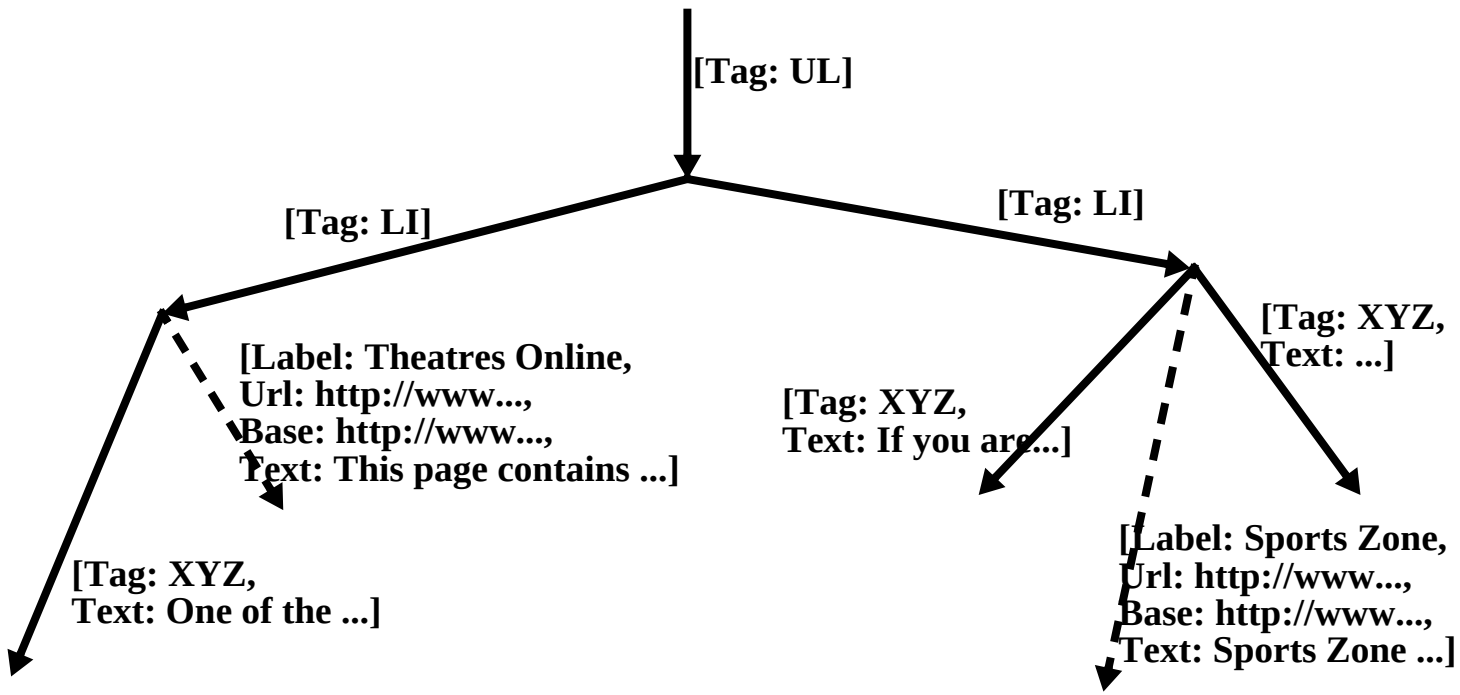


Webs



Query: list elements containing “ticket”

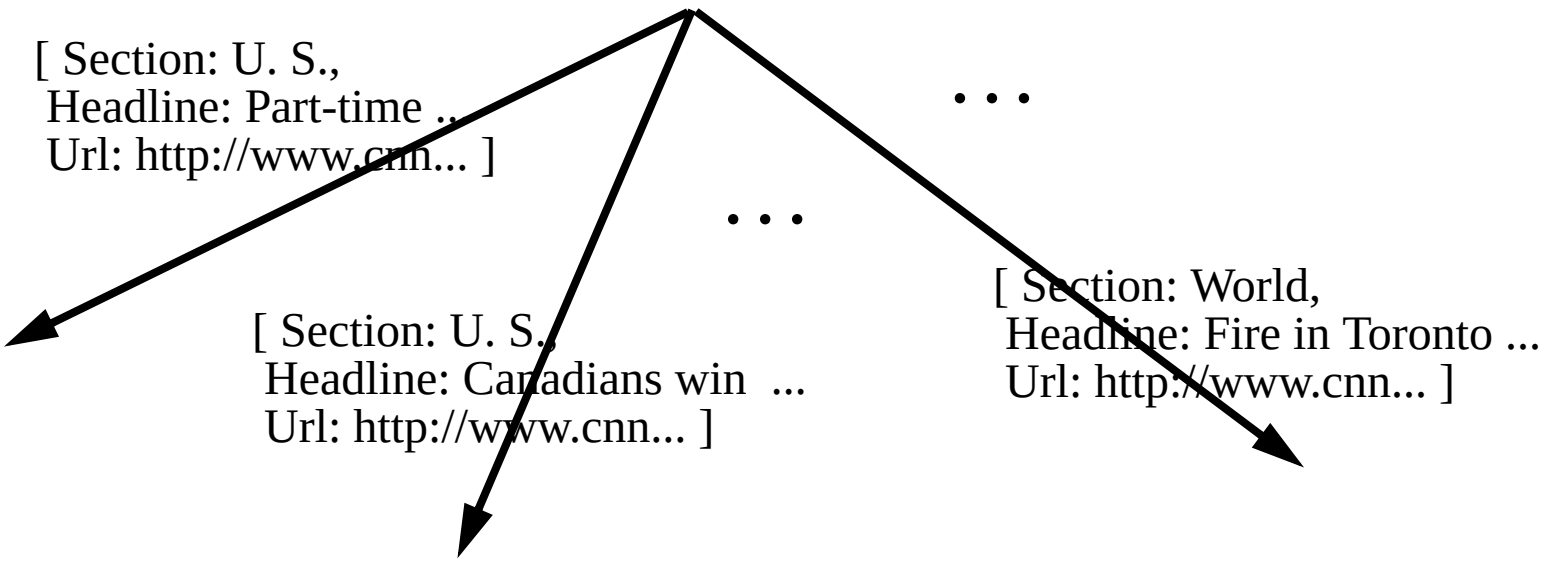
doc **:=** “http://www.citynet.com/overview.html”**;**
[Tag “UL” /
select y
from y **in** doc !’
where y’**.**text ~ “ticket”]



CNN Home page

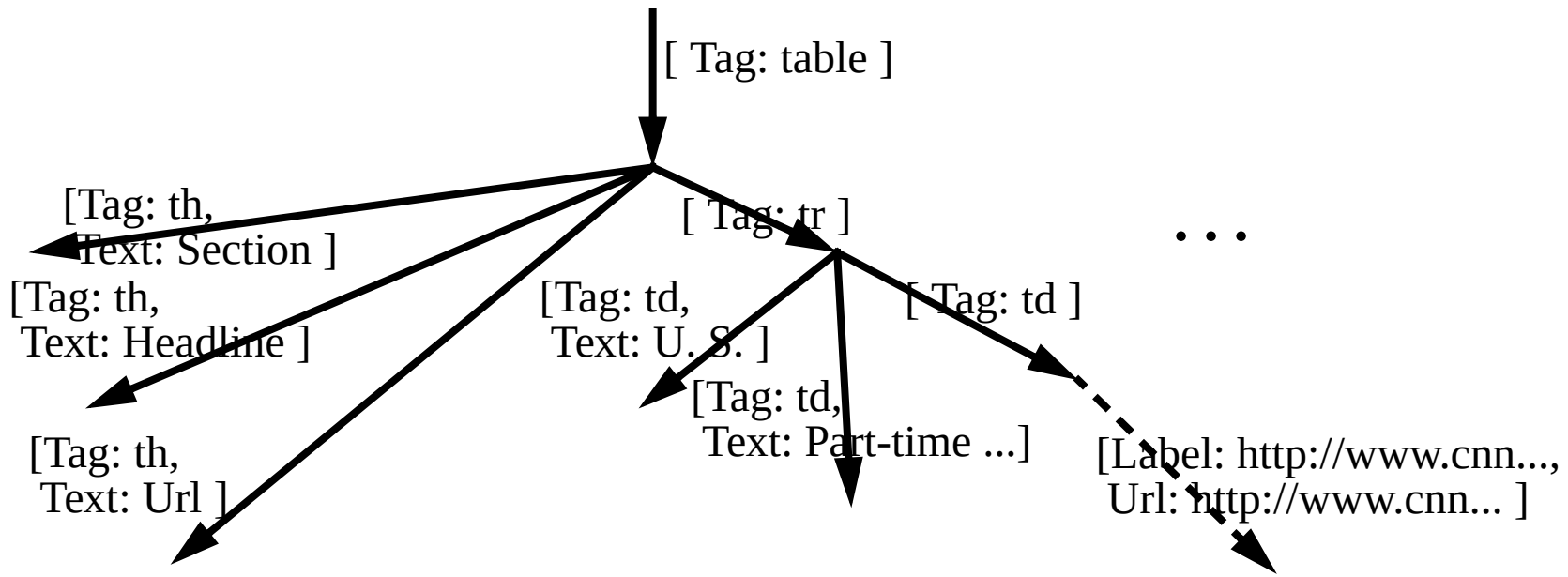
Extracting CNN's Headlines

select [Section:Y.text, Headline:z.text, Url:z'.url]
from X in "http://www.cnn.com" via ^*[text ~ "T O P"],
Y in X!!!' via ^*[tag = "blockquote"],
z in Y!'



Restructuring the Result into HTML

[Tag:“table”/
[Tag:“th”, Text:“Section”] + [Tag:“th”, Text:“Headline”] + [Tag:“th”, Text:“Url”]+
select [Tag:”tr”/ [Tag:”td”, Text:Y.text] + [Tag:”td”, Text:z.text] +
[Tag:”td”/ [Label:z’.url, Url:z’.url]]
]
from X in “http://www.cnn.com” via ^*[text ~ “T O P”],
Y in X!!!’ via ^*[tag = “blockquote”], z in Y!’
]



Generating a new Web

Table = [previous query]

select [y’] **as** y.Text
from x **in** Table’!!!, **y** in x

creates one page for each Section, with the Section name as URL

Easy to do in WebOQL

Extract all headings

Extract all images

Linearize page hierarchy

Flatten hierarchy into table

Create Web views

Extract pictures of faculty

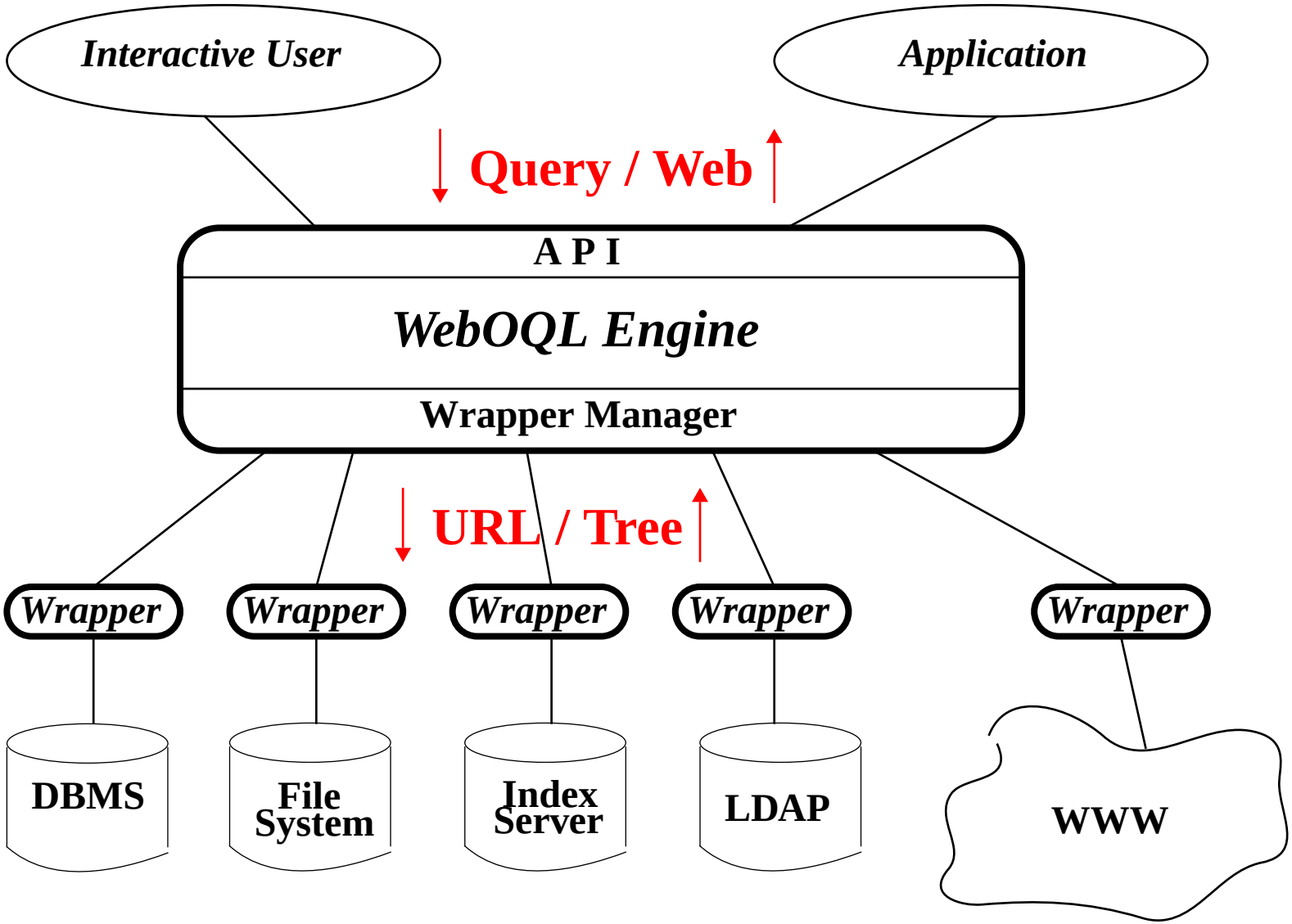
```
SCAN
"http://www.cs.toronto.edu/DCS/People/Faculty/index.html"
USING
    ANY
    <BODY>
       MANY
       <UL>
          {<LI> <A HREF = MemberPage> MemberName </A> </LI>}
       </UL>
    </BODY>
AND
   MemberPage
USING
   ...<IMG SRC = Jpg ".jpg$">
GIVING
  <HTML>
     <TABLE>
        {<TR>
           <TD> text(MemberName) </TD>
           <TD> <IMG SRC = Jpg> </TD>
        </TR>}
     </TABLE>
 </HTML>
```

Generated WebOQL

```
[Tag:”html”/
  [Tag:”table”/
    select [Tag:”tr”/
             [Tag:”td”/[Text:MemberName.text]] +
             [Tag:”td”/[Src:Jpg.src, Tag:”img”]]
           ]
    from V__ is “http://www/DCS/People/Faculty/index.html”,
         V_0 in V__!’ via [Tag = “ul”] until true,
         V_1 in V_0’,
         MemberName is V_1’&,
         MemberPage is MemberName,
         V_2 in browse(MemberPage.url)
             via ^*[Src ~ “.jpg$” and Tag = “img”],
         Jpg is V_2&
    where V__!.Tag = “body” and V_1.Tag = “li” and
MemberName.Tag =
“a”
  ]
];
```

```
<!-- Generated by WebOQL 1.0 -->
<html>
  <table>
    <tr>
      <td>
T.S. Abdelrahman, MSc, PhD
      </td>
      <td>
        <IMG  SRC="http://www.cs.toronto.edu/gifs/Faculty/
tsa.jpg">
      </td>
    </tr>
    <tr>
      <td>
R.M. Baecker, MSc, PhD
      </td>
      <td>
        <IMG  SRC="http://www.cs.toronto.edu/gifs/Faculty/
rmb.jpg">
      </td>
    </tr>
    <tr>
      <td>
A. Bonner, MSc, PhD (Erin) ...
```

System Architecture



Computing Page Reputations

(Rafiei and Mendelzon, WWW9)

- How do we rank a large number of pages relevant to a query, so the ***good*** ones appear first? (search engine company's problem)
- Given a page and a topic, how ***good*** is this page on this topic? (tenure committee's problem)
- Given a page (or a site), what topics is this page ***good*** on? (webmaster's problem)
- ***Good*** means reputable, authoritative, well-known, up-to-date,...

Idea:

- Analyze links to compute Rank(p,t) = goodness of page p on t

Page Rank

(Brin and Page 1998, Google; Geller 1978 in bibliometrics)

A page is good if lots of good pages point to it.

One level random walk model:

At each step:

- with prob p>0 jump to a random page, or
- with prob (1-p) follow a random link from the current page

Page Rank of page p = probability, in the limit, of hitting page p

Problems with PageRank

- topic- independent: a page may be good for one topic but not another

- good pages may not point to each other: BMW does not point to Mercedes

Hubs and Authorities

(Kleinberg, 1998)

Given a set of pages relevant to topic t:

A page is a good hub for t if it points to good authorities on t

A page is a good authority on t if good hubs for t point to it

Algorithm to find authorities on t:

- Issue the query t to a search engine
- Take the first N answers, add pages at distance 1
- Compute authorities for t within this set

A two-level random walk model

- with prob d>0 jump to random page **that contains term t**
- with prob (1-d) follow random link **forward/backward** from the current page, alternating directions

Pages accumulate

- forward visits
- backward visits

- **A(p,t)** = probability of a forward visit to page p when searching for term t = **Authority rank** of page p on term t
- **H(p,t)** = probability of a backward visit to page p when searching for term t = **Hub rank** of page p on term t

Theorem If d>0, the two-level random walk has unique stationary probability distributions A(p,t) and H(p,t).

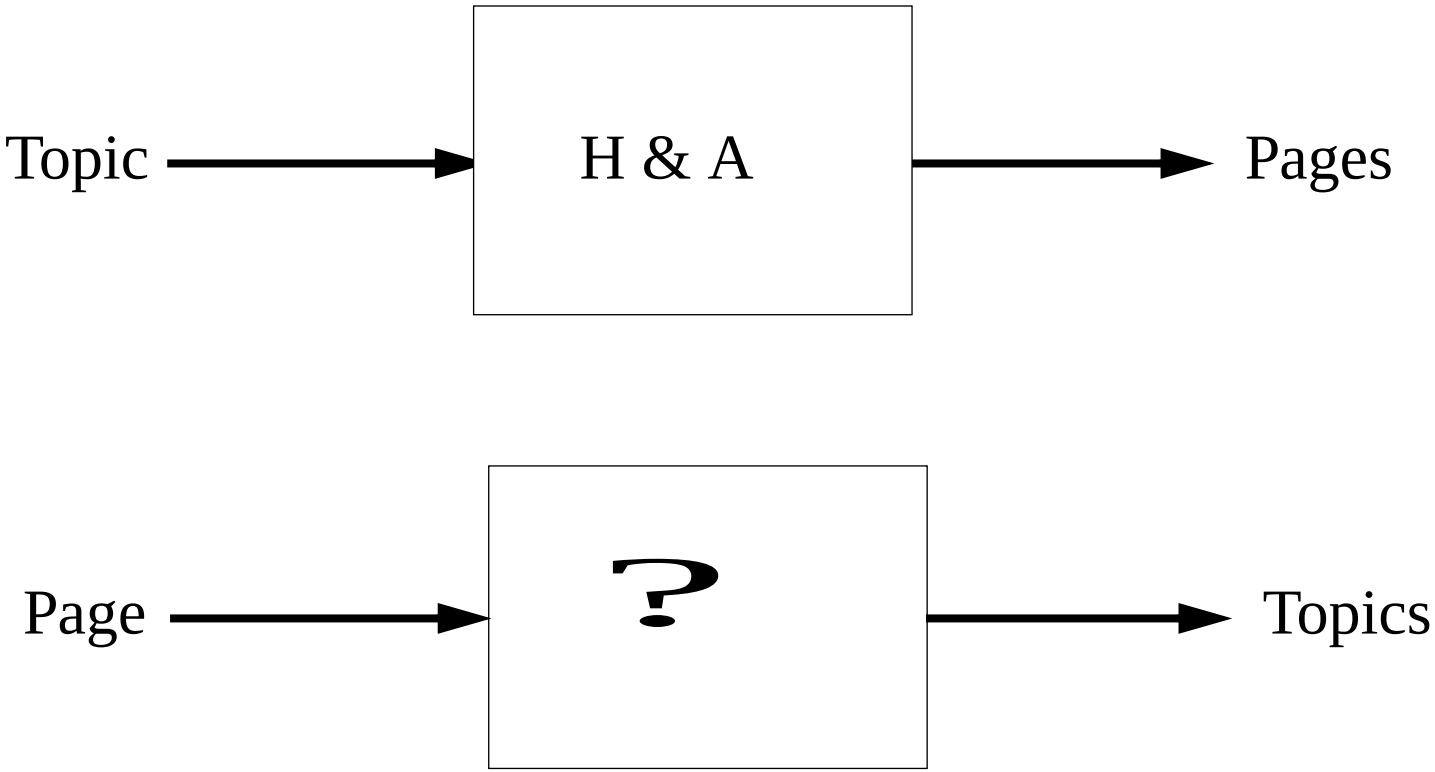
(Does this model Kleinberg's algorithm?

No: See Lempel and Moran, WWW9, Borodin et al, WWW10)

Does Hubs&Authorities solve our ranking problems?

- Search engine problem: yes
- Tenure committee's problem: maybe
- Webmaster's problem: no

Inverting H&A computation



Two Solutions

- *Global solution*: a large crawl of the web is available. Find authorities on each term t
- *Local solution*: approximate the global solution by starting with some set of pages and the terms that appear in them, and iteratively expanding this set

Global Solution (bottom up)

For every page p and term t

$$A(p,t) = H(p,t) = \frac{1}{2N_t}, \text{ if t appears in p}$$

$$A(p,t) = H(p,t) = 0 \text{ otherwise.}$$

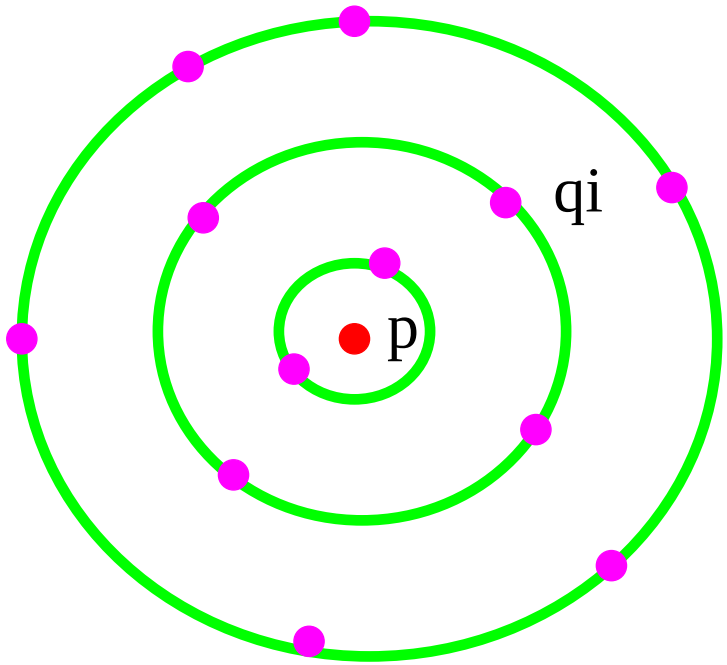
While changes occur

$$A(p,t) = (1-d)\sum_{q \to p} \frac{H(q,t)}{Out(q)} + \begin{cases} \frac{d}{2N_t} & \text{if t appears in page p;} \\ 0 & \end{cases}$$

$$H(p,t) = (1-d)\sum_{p \to q} \frac{A(q,t)}{In(q)} + \begin{cases} \frac{d}{2N_t} & \text{if t appears in page p} \\ 0 & \end{cases}$$

Local Solution: **(top down)**

Set of pages:



Set of terms: all terms t that appear in p or some of the qi's

Local algorithm (Using the one-level model for simplicity)

$$R(p,t) = \frac{d}{N_t}$$

For $i = 1,2,\ldots,k$

For each path $q_1 \rightarrow q_2 \rightarrow \ldots \rightarrow q_i \rightarrow p$,

For each term t in page q_1

$$R(p,t) = R(p,t) + \left(\frac{(1-d)^i}{\prod_{j=1}^{i} Out(q_i)} \right) \frac{d}{N_t}$$

TOPIC: Approximating the local algorithm

- Given page p
  - Find 500 pages q that link to p (using Altavista)
  - From each q "snippet," extract all terms t
  - Remove internal links and duplicate snippets
  - Remove stop words and rare terms
  - Apply the local algorithm with d = 0.10, k = 1, Out(q) = 7.2

Penetration and Focus

(Mendelzon and Rafiei, IEEE Bull. Data Eng., 2000)

For d and Out(q) constant, the local algorithm reduces to

$R(p,t) \sim I(p,t) / N_t$

where $I(p,t)$ = number of pages that contain t and point to p, N_t = number of pages that contain t

R(p,t) = fraction of pages on t that point to p: ***penetration*** of page p on topic t

Can also define

F(p,t) = fraction of pages pointing to p that are about p: ***focus*** of page p on topic t

TOPIC - Netscape

File Edit View Go Communicator Help

Back Forward Reload Home Search Netscape Print Security Shop Stop

Bookmarks Location: http://www.cs.toronto.edu/db/topic/ What's Related

My Yahoo! for i Datek Online Tr Google Welcome to Cons CIBC PC Banking CSC2531 Home Pa The Oxfor

UNIVERSITY OF TORONTO

Department of

Computer Science

TOPIC

URL:http://

Powered by: AltaVista

Links to download: 300 **or** term/phrase:

Submit Query

About TOPIC

Example: authorities on (+censorship +net)

- www.eff.org

  Anti-censorship, Join the Blue Ribbon, Blue Ribbon Campaign, Electronic Frontier Foundation

- www.cdt.org

  Center for Democracy and Technology, Communications Decency Act, Censorship, Free Speech, Blue Ribbon

- www.aclu.org

  ACLU, American Civil Liberties Union, Communications Decency Act

Example: Personal Home Pages

- www.w3.org/People/Berners-Lee

  History of the Internet, Tim Berners-Lee, Internet History, W3C

- www-db.stanford.edu/~ullman

  Jeffrey D. Ullman, Database Systems, Data Mining, Programming Languages

Examples: Institutional Home Pages

- www.db-stanford.edu:

  Database research, data warehousing, database systems, data mining, Stanford

- www.almaden.ibm.com:

  IBM Almaden, search engines, data mining, microscopy, visualization

Examples: Canadian CS Departments

- www.cs.toronto.edu:

  Women hockey, computer vision, department of Computer Science, University of Toronto, archive, Russian

- www.cs.ualberta.ca:

  University of Alberta, virtual reality, chess, language, artificial

- www.cs.ubc.ca:

  confocal, periodic table, anime, Computer Science, manga, Mathematics

TOPIC as search engine ranking method

- Given query t, rank answer pages p by R(p,t)
- Experiment: 467 queries obtained from major search engine company. For each query, rerank top 100 engine hits by TOPIC ranking
- Evaluation with human subjects in progress by FIS (Keast et al, ACM/IEEE DL Conf., 2001)

Netscape

File Edit View Go Communicator Help

Bookmarks Location: http://www/~mendel/google.html What's Related

My Yahoo!for: Datek Online Tr Google Welcome to Cons CIBC PC Banking CSC2531 Home Pa The Oxfor

- **class action**

1. [01] securities.stanford.edu/ 0.023049
2. [43] members.aol.com/CClass450/ 0.001814
3. [24] www.classactionlitigation.com/ 0.001374
4. [13] www.classact-lawsuit.com/ 0.000881
5. [16] www.acer.com/aac/main/settle.htm 0.000843
6. [09] www.masoniteclaims.com/ 0.000813
7. [11] www.web-access.net/~aclark/frames45.htm 0.000471
8. [42] www.lawnewsnetwork.com/practice/corporatelaw/news/A16887-2000Feb23.html 0.000296
9. [06] www.classactionpl.com/ 0.000281
10. [07] www.irbc.com/ 0.000228
11. [46] www.techweb.com/wire/story/TWB19981217S0010 0.000175
12. [50] www.kinsella.com/engle/ 0.000137
13. [41] www.classactionreports.com/ 0.000108
14. [02] www.tappi.org/paperu/classAction/classAction.htm 0.000000
15. [03] philipmorris.com/engleweb/Lawsuit.asp 0.000000
16. [04] www.women4fatherhood.org/we.html 0.000000
17. [05] locklaw.com/classact/classact.html 0.000000
18. [08] www.internetnews.com/bus-news/article/0,2171,3_402581,00.html 0.000000
19. [10] www.al.com/news/huntsville/Jul2000/29-e19760.html 0.000000
20. [12] www.consumerclassactionlawyers.com/ 0.000000
21. [14] slashdot.org/articles/00/02/02/1655251.shtml 0.000000
22. [15] www.overlawyered.com/topics/class.html 0.000000
23. [17] www.boston.com/dailyglobe2/207/business/Microsoft_wins_5th_class_action_lawsuit+.shtml 0.000000
24. [18] www.100toplawsites.com/Law/classaction/100/35k 0.000000
25. [19] www.classaction.xe.com/ 0.000000
26. [20] www.canada.cnet.com/news/0-1003-200-1461561.html 0.000000
27. [21] www.amcity.com/kansascity/stories/1999/05/31/editorial2.html 0.000000
28. [22] www.wirednews.com/news/politics/0,1283,34063,00.html 0.000000
29. [23] www.thestandard.com/article/display/0,1151,17024,00.html 0.000000
30. [25] www.insure.com/lawsuits/classaction.html 0.000000

Limitations

- Topics vs. terms
- Search engines provide non-random samples
- All links are equal
- Some topics not well-represented on the Web

Current Work

- Implementing the global algorithm (UofA, using Internet Archive snapshot)
- Incorporating TOPIC rank into search engine
- Evaluation of TOPIC as search engine rank function

Summary

- Unstructured data + links: *WebSQL*
- Semistructured data + links: *WebOQL*
- Exploiting links for reputation ranking: *TOPIC*