Crawling important sites on the Web

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Research performed at INRIA and now commercialized by Xyleme

2nd ECDL Workshop on Web Archiving – 9/19/2002

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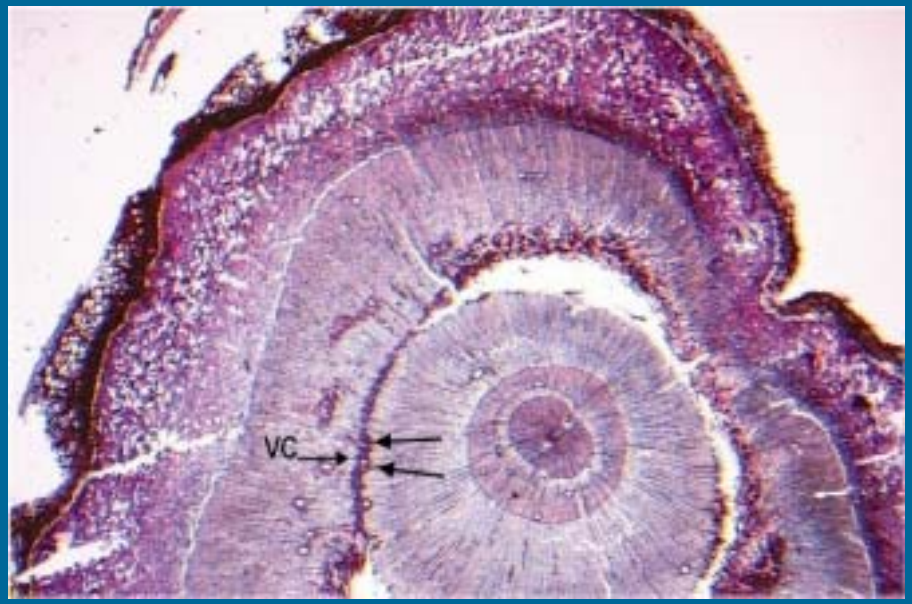
Organization

- Xyleme Acquisition Architecture
  - Technical overview
  - Specific services: Site-based acquisition and focused crawling
- Online computation of Page Importance
- Xyleme Monitoring Services
  - The challenge: monitoring data on the Web
  - Technical overview
  - Sample applications: copy tracker, version management

Xyleme Acquisition Architecture



Overview

- A cluster of Linux PCs. Applications are in C++. Communications using Corba.
- The Crawler is composed of several modules:
  - The Fetcher retrieves web pages
  - The Scheduler decides which are the pages to read next
  - The Metadata Manager stores information about URLs (e.g. last date of crawl, page importance)
- We crawl about 4 million pages/PC/day on average
  Each PC is in charge of 200 million URLs
- The system has been running since mid-2000. We have 8 PCs, each equipped with 2Gb of memory. We know about 1.5 billion pages.

Metadata Module

- Metadata about each URL is stored on disk
- We assign an ID to each URL
  - Stored in main memory: 1Gb for 100million URLs
  - Online page rank is also stored in memory
- We use an evaluation of the change rate of pages
  - Based on the Last Date of Change (HTTP Header)
  - Based on the number of changes that we detected

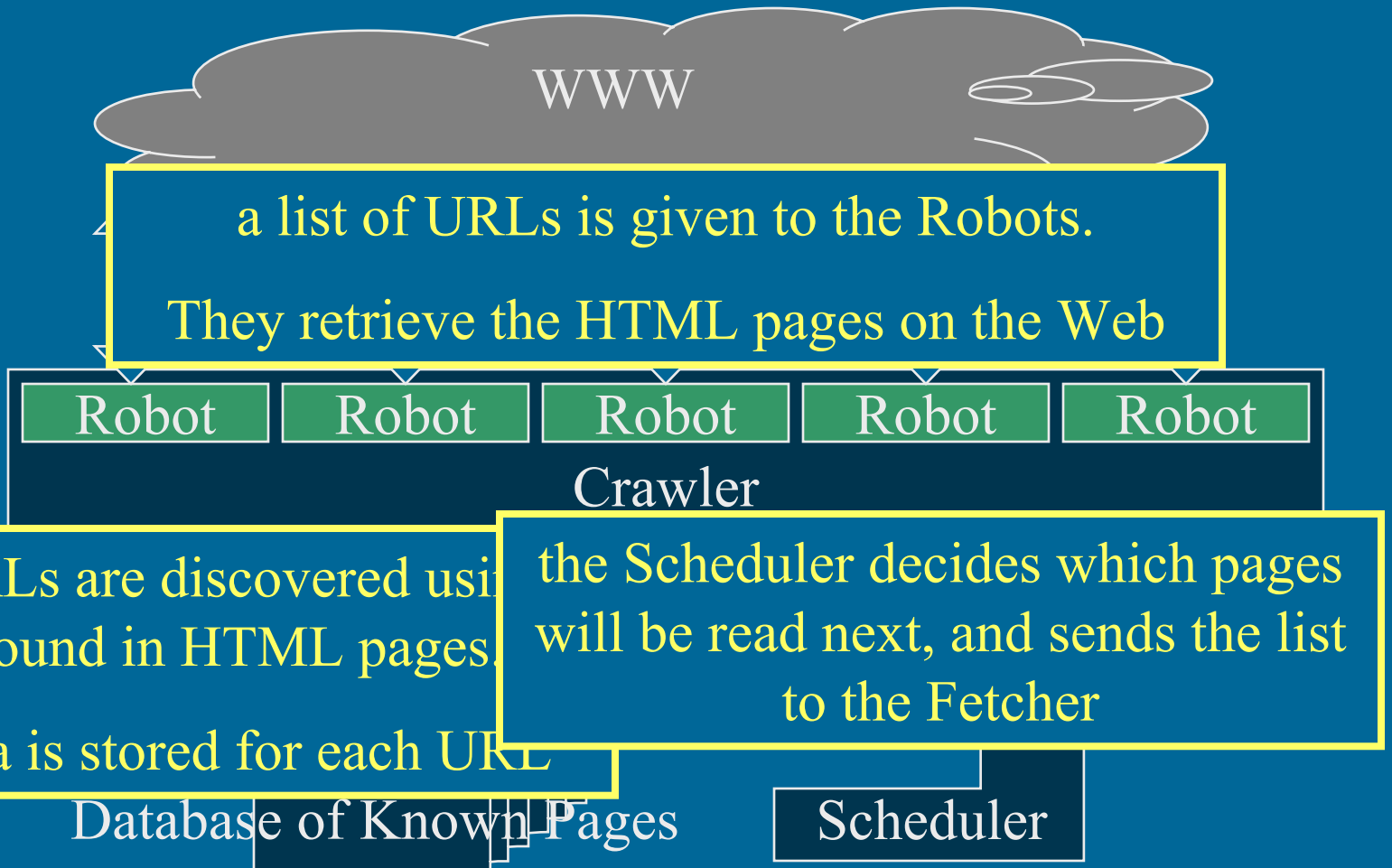
Fetcher Module

- 200 robots are running simultaneously on a single PC
  - Peak rate is 200 pages/s (e.g. 17 million/day)
  - We use persistent objects in memory to avoid rapid 'firing'
- DNS Caching: On each PC, pages are grouped by domain to minimize the cost of DNS (Domain Name Server) resolution.
  - Currently 200.000 domain names per PC.
- To efficiently access each URL metadata, the ID table is stored in main memory:
  - 100 million URLs for 1Gb of memory
- A list of pages that are waiting to be read
  - up to 10 million

Scheduler Module (Refresh Policy)

- The goal is to balance bandwidth resources between the discovery of new pages and refreshing others
- Decision is based on the minimization of a cost function
- Refresh strategy is based on:
  - Importance of the page
  - Staleness of the page
  - Estimated change rate of the page
  - Publication or Subscription requests

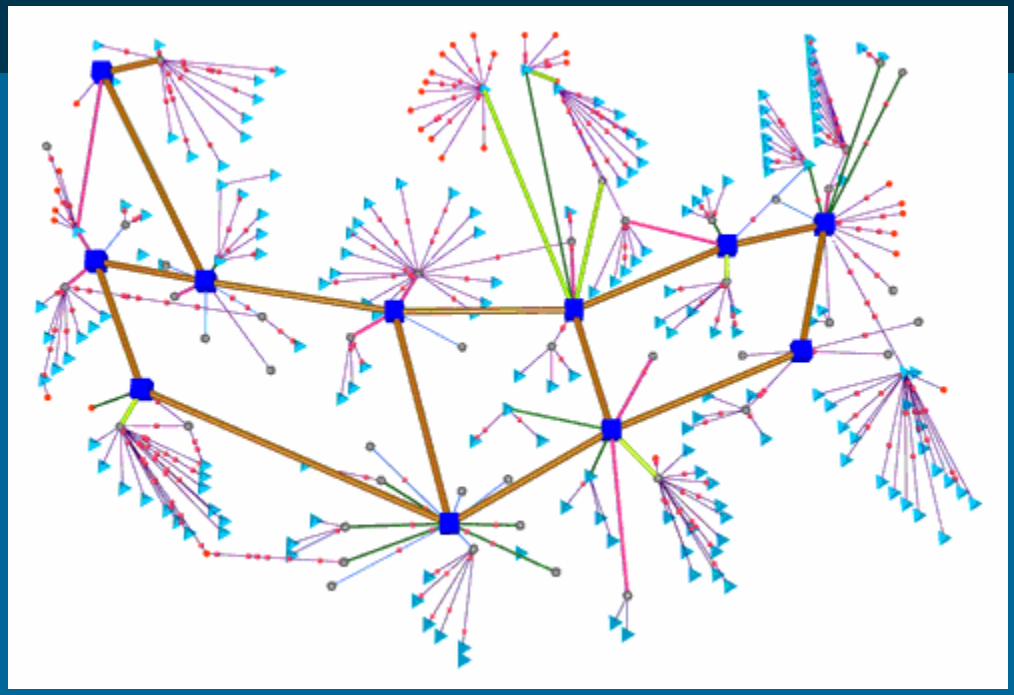
Page Life Cycle



Issues

- Site vs. Page archiving
  - The Web:
    - Physical granularity = HTML pages
    - The problem is inconsistent data and links
    - Logical granularity?
  - Snapshot view of a web site
    - What is a site?
    - There are technical issues (rapid firing, …)
- Focused Crawling
  - We allow to publish specific documents or URLs in Xyleme (refresh frequency, access rights, …)
  - We allow ‘on-demand’ crawling (with low latency response time)

Online computation of Page Importance



What is page importance?

- “Le Louvre” homepage is more important than an unknown person’s homepage
- Important pages are pointed by:
  - Other important pages
  - Many unimportant pages
- This leads to Google definition of PageRank
  - Based on the link structure of the web
  - used with remarkable success by Google for ranking results
- Useful but not sufficient for web archiving

Modeling the Web

- The Web as a graph: We view the WWW as a directed graph G.
  - Web pages are vertices, HTML links are edges.

- A graph as a matrix:

  G a graph with n vertices can be presented as a matrix L[1..n,1..n] such that:
  - L is nonnegative, i.e. $L[i,j] \geq 0$
  - L[i,j]>0 if and only if there is an edge from vertex <i> to vertex <j>

- There are several natural ways to encode a graph as a matrix:
  - Google defines the outdegree and set L[i,j]=1/out[i]
  - Kleinberg proposes to set K[i,j]=1 if there is a link from i to j and then use $L={}^{t}K*K$

Importance Definition

- In short, page importance is the fixpoint X of the equation $L*X = X$

- We define the importance of a page by an inductive way and compute it using a fixpoint
- The importance is represented as a vector x in an *n* dimensional space.
- The equation is: $x_{k+1}=L*x_k$

Our Algorithm

- With off-line algorithms, it is necessary to store the link matrix and to compute page importance in an off-line process
- In general, off-line algorithms are started after a full snapshot-crawl of the Web

- Our algorithm:
  - Computes the page importance (characteristic vector) and does not require any assumption on the graph
  - starts even when a (large) part of the matrix is still unknown
  - helps deciding which new part of the matrix should be acquired
  - is integrated in the crawling process
  - works on-line even while the graph is being updated

- It has been presented in "Computing web page importance without storing the graph of the web (extended abstract)", *IEEE Data Engineering Bulletin, Volume 25, March 2002* "

Static Graphs: OPIC Algorithm

- We assign to each page a small amount of ‘cash’. The ‘cash’ is distributed among its children when the page is read.
- The page importance for a given page is found using the history of ‘cash’ that was stored.

- ‘cash’ is stored in main memory for each page
- A unique disk access per page read is necessary to update the history of the page that is read

Crawling Strategies

- Our algorithm works with any crawling strategy as long as each page is visited infinitely often.

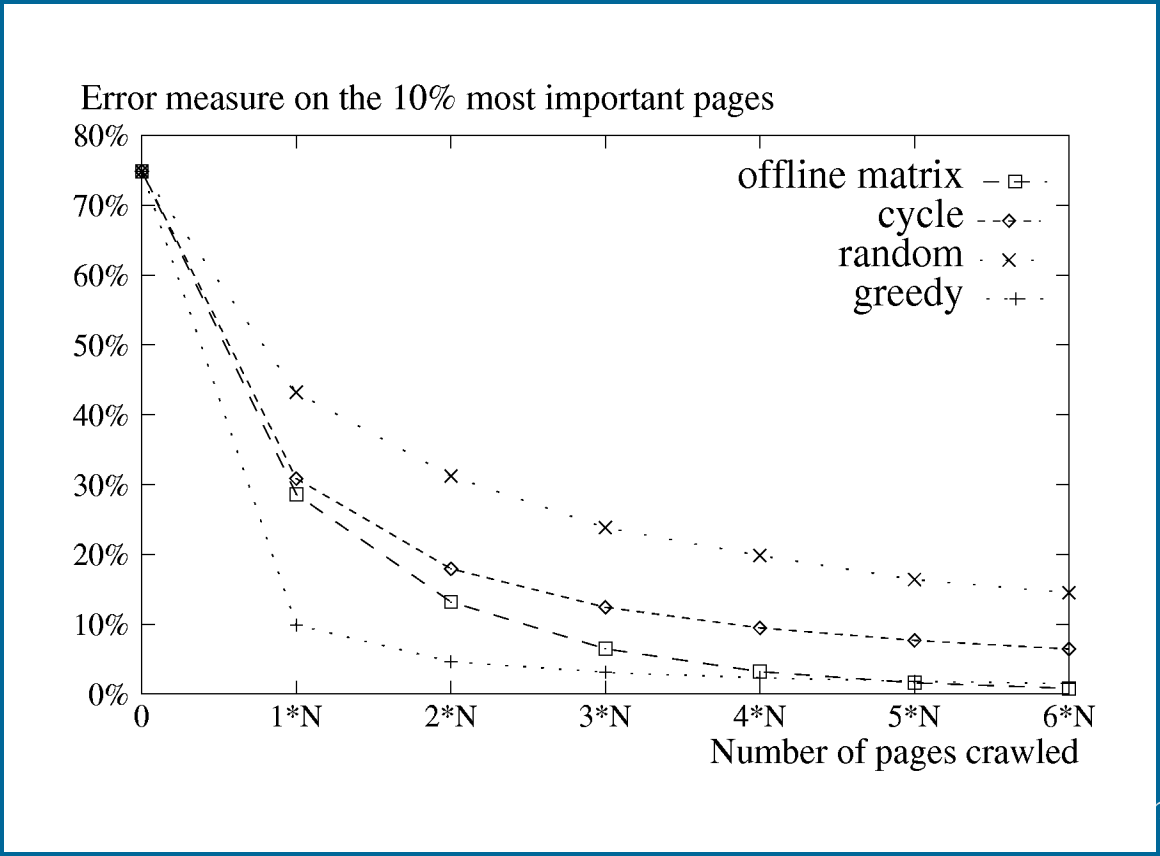
  It does not impose any constraints on the order of pages to visit
- Simple crawling strategies are:
  - Random: all pages have equal probability to be choosen
  - Greedy: choose the page with largest amount of ‘cash’
  - Cycle: systematic strategy that cycles around the set of pages
- The crawling strategy in Xyleme is close to Greedy since it is tailored to optimize our knowledge of the Web
- Convergence is faster with Greedy since pages have more cash on average

A changing graph

- The Web changes continuously, so does the importance of pages.
- Our adaptive algorithm works by considering only the recent part of the ‘cash’ history for each page
- The time window corresponding to the ‘recent history’ may be defined as:
  - A fixed number of measures for each page
  - A fixed period of time for each page
  - A single value that interpolates the history for a specific period of time
- When the number of nodes changes, there are some difficulties.
  More precisely, the page importance of previously existing pages decreases automatically.

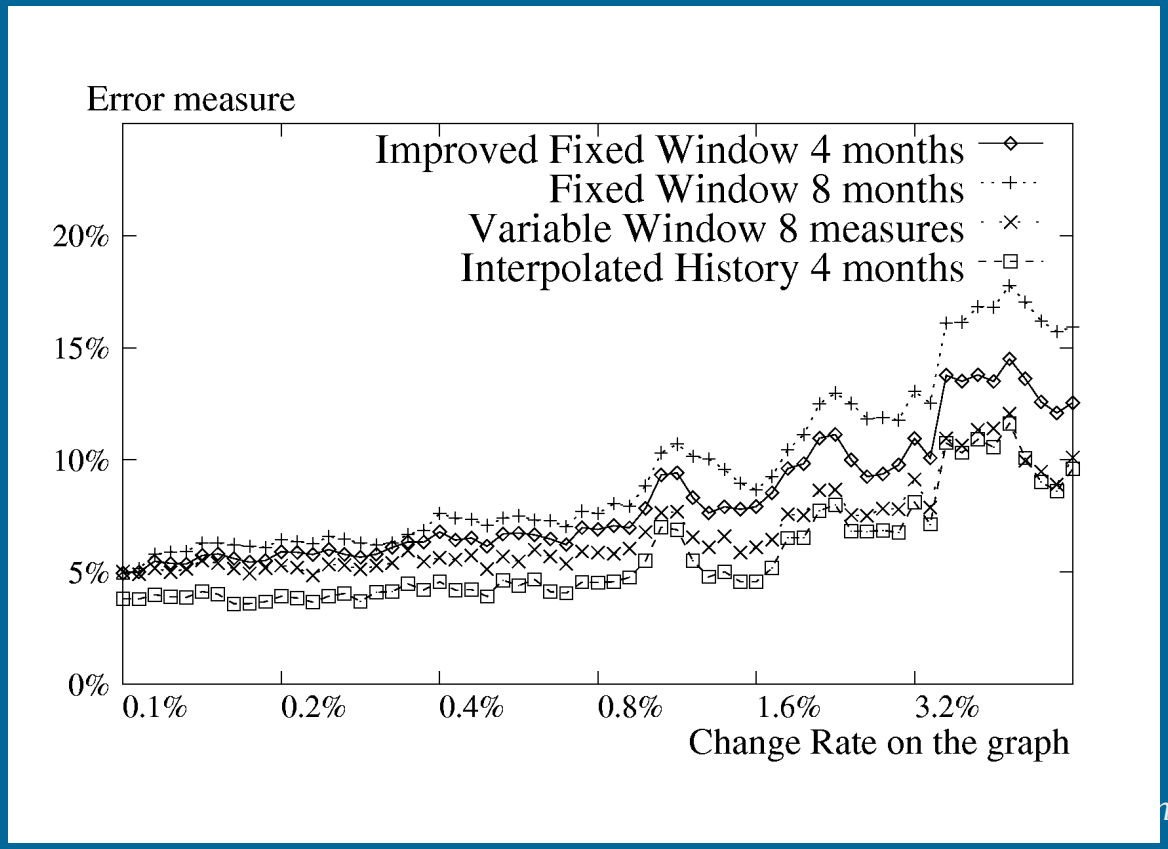
Experiments on synthetic data

- Convergence on important pages



Experiments on synthetic data

- Impact of the window policy



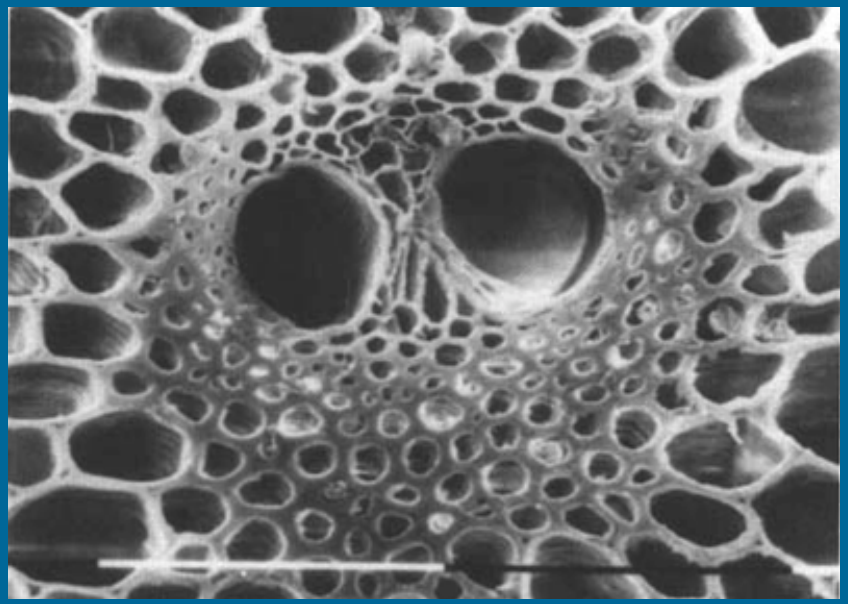
Experiments on Web data

- Experiments where conducted using the crawlers of Xyleme (e.g. 8 PCs with 1.5Gb of memory)
- Crawling strategy is close to Greedy
- History is managed using the Interpolation policy
- Experiments lasted for several months, we discovered close to one billion URLs and read 400 millions of them
- Importance of read pages seems correct (with limited human checking).
- We could also give importance estimates for pages that were never read
- The size of the window was first too small, then we set it to 3 months

New directions: site vs. pages

- Limitation of page importance
  - Google page importance works well when links have a strong semantic
  - More and more web pages are automatically generated and most links have little semantics
- More limitation
  - Refresh at the page level presents drawbacks
- So we also use link topology between sites and not only between pages

Xyleme Monitoring Services



What data is there to monitor?

- Documents: HTML but also doc, pdf, ps…
- Many data exchange formats such as asn1, bibtex…
- New official data exchange format: XML
- Hidden web: database queries behind forms or scripts
- Multimedia data: ignored here
- Public vs. private (Intranet or Internet+passwd)
- Static vs. dynamic

What is changing?

- Universal data exchange format (XML) is coming
  - Universal data exchange format
  - Marriage of document and database worlds
  - Standard query language: XQuery
  - Growing very slowly on public web (less than 1%); very fast on Intranet
- Web services (SOAP) are coming
  - Format for exporting services
  - Format for encapsulating queries
- Semantic web is announced
  - RDF for data
  - WSDL+UDDI for services

What is not changing fast or even getting worse

- More and more data
  - More and more junk
  - More and more stale data
- The simplicity of HTML
  - An asset first, now a handicap (OK for documents not data)
  - Very primitive query mechanism (keywords)
- No real change control mechanism
  - Web user is a passive observer
  - To detect change, keep reading a page

Subscription Language

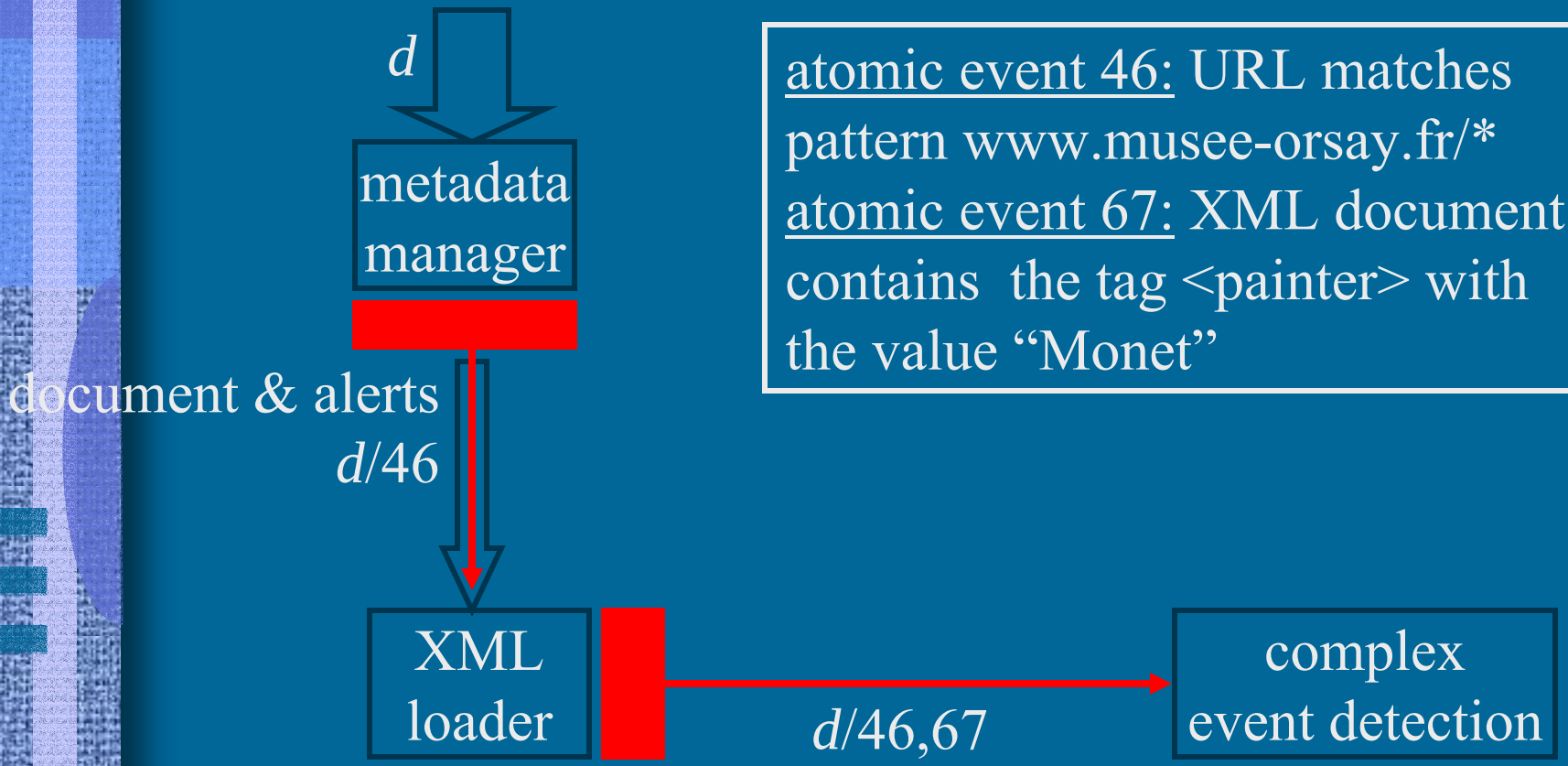
- SQL-like language based on *'atomic events'*.
- Combines the use of monitoring queries and continuous queries.
- The language can be extended by adding new types of atomic events.
- Uses the XML Query Language for continuous queries. "Querying the XML Documents of the Web", V. Aguilera, S. Cluet, F. Boiscuvier, Tech. Report

```
subscription myPaintings
    % what are the new painting entries
    in Musee d'Orsay
    monitoring newPainting
    select URL
            where URL extends
    www.musee-orsay.fr/*
    and <painter> contains "Monet"

    % manage the changes
    continuous delta
            select ... from ... where
            when monthly
notify daily % send me a daily report
```

Step 1: Atomic Event Detection

5 millions of pages/day

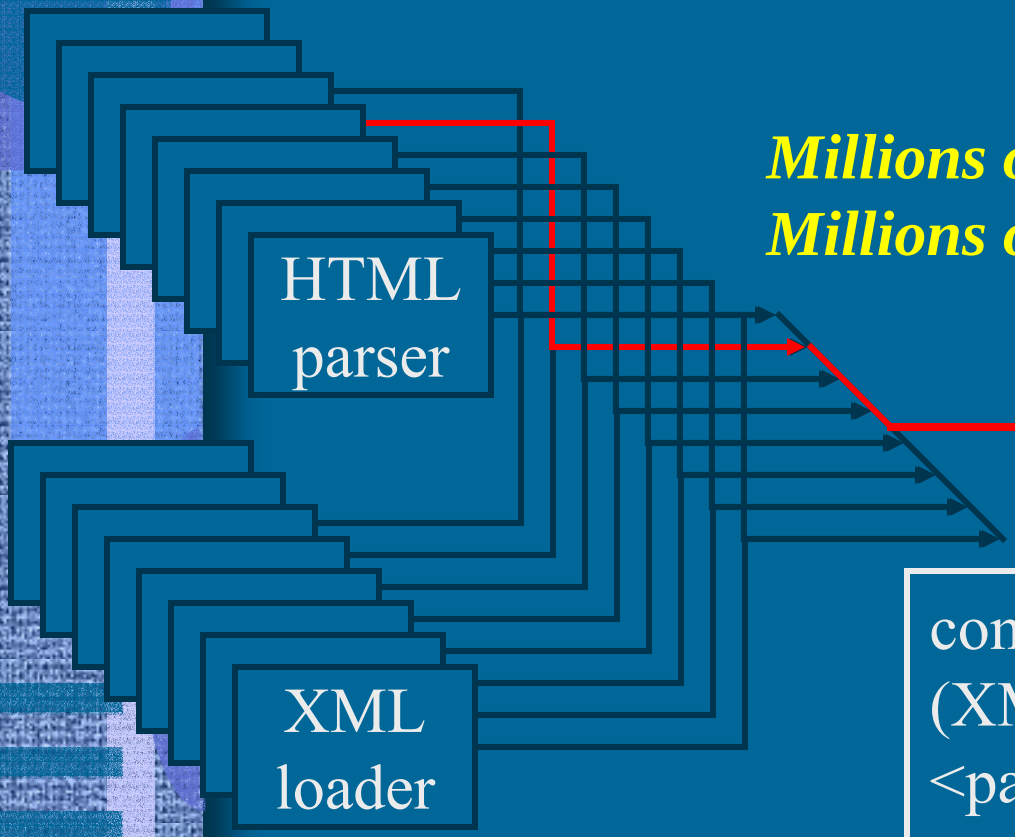


atomic event 46: URL matches pattern www.musee-orsay.fr/*
atomic event 67: XML document contains the tag <painter> with the value "Monet"

Alerters

- Each Alerter can be viewed as a plug-in that acts on a document flow.
- All sorts of Atomic events can be detected: URL pattern detection, Keywords, XPath expressions, Page rank…
- Can be distributed.
- Some advanced alerts are:
  - Long string look-ups
  - Finding XML Patterns (e.g. XPath)
  - Comparing digital signature of text documents (copy tracker)

Step 2: Complex Event Detection



Millions of alerts of pages/day
Millions of subscriptions

complex
event detection

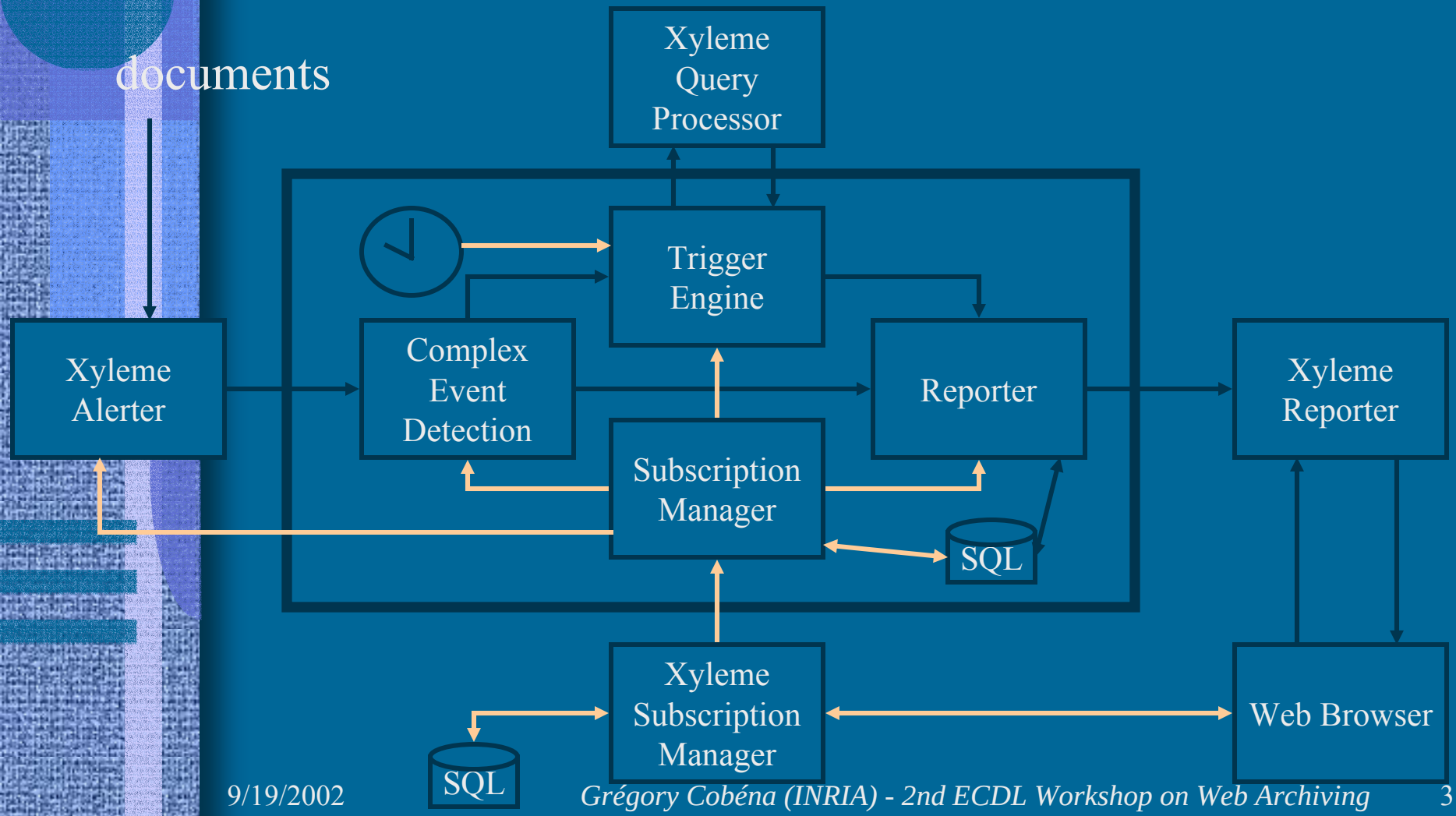
complex event 12: 67 & 46
(XML document contains the tag <painter> with value “Monet”
and URL matches pattern www.musee-orsay.fr/*)

Complex Events Algorithm

- The formal problem is NP-hard
- We proposed several possible algorithms
- Experimental (simulation) values proved the effectiveness of our solutions
- The Hash-Tree based algorithm is well suited for our application:
  - 10 million Complex Events
  - 1 million Atomic Events
  - 100 Atomic events detected per document

  0.8 ms to process a document. ~2 million documents per day (on each PC).

Architecture



Monitoring Applications

- Web surveillance
  - Anti-criminal intelligence, business intelligence
  - Classification, extracting data of interest, extracting knowledge
- Copy tracking
  - a press agency wants to check that people are not publishing illegally copies of their wires
- Web portal management
  - Dangling pointers, unreachable pages, incorrect pages, …
  - Archiving, version management, temporal queries
  - monitoring changes, subscription and notification, …

Web archiving

- We discussed an experience in archiving the French web
- Monitoring is used to increase librarians knowledge of the Web
- Monitoring is also used for specific applications such as detecting deep-Web sources (e.g. http forms)

Conclusion

- Very challenging problem
  - Complexity due to the volume of data
  - Complexity due to heterogeneity
  - Complexity due to lack of cooperation from data sources
- Other issues:
  - Hidden or deep Web, …

New directions

- Site based architecture
  - Site-based crawling
  - Site-based archives
  - Site-based importance
- Active web sites
  - Friendly sites willing to cooperate
  - Web services provide the infrastructure
  - Support for triggers

Thanks