Niagra People

- Faculty

  David J. DeWitt
  Jeffrey Naughton

- Graduate Students

Jianjun Chen	**Leonidas Galanis**
Anurag Gupta	**Jaewoo Kang**
Vishal Kathuria	**Qiong Luo**
Naveen Prakash	**Ravishankar Ramamurthy**
Feng Tian	**Yuan Wang**
Chun Zhang	

- Niagra Alumni

Rushan Chen	**Bruce Jackson**
Jun Li	**Jayavel Shanmugasundaram**
Kristin Tufte	

1

NIAGRA Status Update

2

Goals of the Project:

- At last year's meeting, we stated the goals were to:
  – improve the precision of Internet searching
  – allow queries over the whole Internet (the "FROM *" clause)
  – monitor the Internet for changes
- Not (quite) finished yet...

3

What have we done since?

- Investigated storing and querying XML in an RDBMS (see VLDB paper).
- Completed three prototypes:
  – A "text-in-context" XML search engine.
  – An XML-QL query engine.
  – An XML-QL trigger engine.
- This presentation will cover the prototypes.

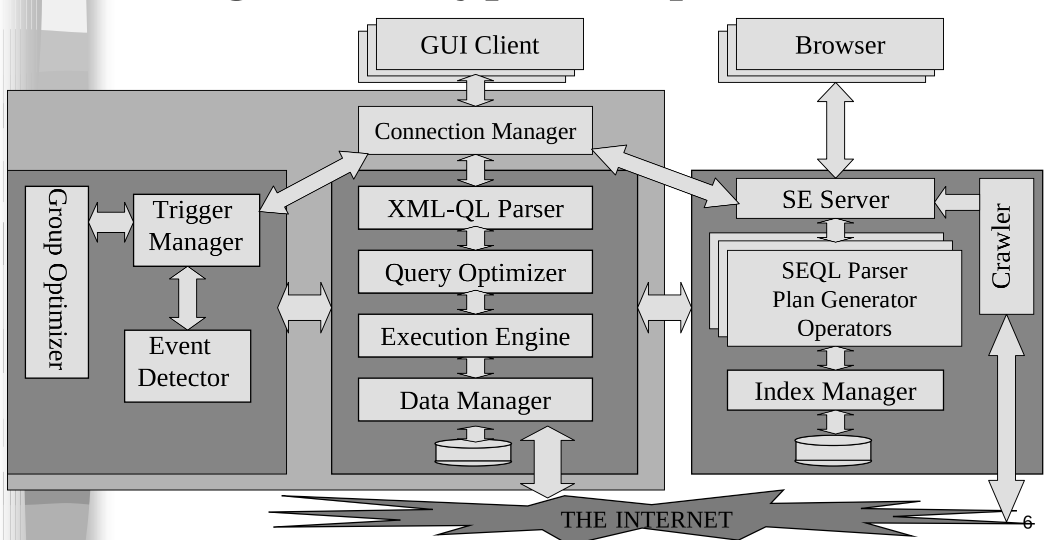
4

Why not use RDBMS?

- Poor efficiency for certain specialized operations.
- More important reason:
  – RDBMS: system must know full schema at data load time, vs.
  – NIAGRA: user must know fragment of schema at query time

5

Niagra Prototype Components



6

Text-in-Context XML SE

- Rather than ask:

  What are all the documents that contain the string “Montreal”?

  We can ask:

  What are all the documents that contain ship departure information for a ship whose name is “Montreal”?

7

How it works:

- “Off-line” crawls web to find and index documents.
- Executes “SEQL” queries over index.
- Two uses:
  - stand alone (from GUI), or
  - part of query engine.

8

XML-QL Query Engine

- Evaluates queries expressed in XML-QL (language developed at ATT.)
- Looks like strange SQL with path expressions (but even uglier.)
- Result is XML

9

Search Engine vs. XML-QL

Search Engine Query:

Find all XML *files* with ship departure events where the departing ship's name is "Montreal"?

XML-QL Query:

What is a list of departure dates for ships named "Montreal"?

10

Ex: Fragment of XML file...

```
<port>
        <portname> Hong Kong </portname>
        <departure>
                <ship>
                        <shipname>Montreal</shipname>
                        <cargo>Software CDs</cargo>
                </ship>
                <date>January 1, 2000</date>
        </departure>
        .
        .
</port>
```

11

XML-QL Query...

```
WHERE <port>
              <portname> $v1</>
              <departure>
                  <ship>
                     <shipname> “Montreal” </>
                  </>
                  <date> $v2</date>
              </>
    </> content_as $v3
    IN “*”
CONSTRUCT <departinfo>
       $v3
</>
```

12

Important Question

- Which documents should be consulted to answer an XML-QL query? We support three approaches:
  - Explicitly listed documents ("in foo.xml")
  - Documents conforming to DTD ("conforms to *some_dtd.xml*")
  - Documents that satisfy search engine predicates extracted from query

13

Example of third approach:

- Given the previous XML-QL query finding departures of ships named "Montreal", the system will extract this Search Engine query:

port CONTAINS
(portname AND
departure CONTAINS
(ship CONTAINS (**shipname** IS "Montreal")
AND date))))

14

Control Flow for Query

- So full flow of typical XML-QL query:
  - User submits XML-QL query
  - System extracts SEQL query from XML-QL, passes it to search engine
  - Search engine returns list of URLs
  - XML-QL engine fetches documents in URL list (aided by local cache), evaluates query
  - Answer returned to the user.

15

XML-QL Trigger Engine

- Goal:
  - Allow users to define “triggers” on XML files using XML-QL predicates.
  - Scale to huge numbers of triggers by exploiting “on-the-fly” aggregation of triggers

16

Rest of presentation...

- More detail about the SE, QE, and Trigger Engine.
- A short demo.
- Wrap-up (future directions, questions.)
- Note: during the “demo session” this afternoon Niagra project members will be available for more in-depth information...

17

Future work

- Just getting started! major next tasks:
- Rewrite prototypes in C++ (instead of Java)
- Parallelize and run them on cluster:
  - 36 dual 550MHz Pentium IIIs
  - 1 GB RAM each (36 GB total)
  - 45 GB disk each (1.6 TB total)
- Distributed query engine.

18

A “Text-in-Context” XML Search Engine

19

Traditional Search Engines

- Traditional search engines on the web:
  - Keyword searching
  - Return too many results!
  - Lots of manual work to screen through search results
- What do we do differently?

20

Our Search Engine

- Search in context (here comes XML!)
- More powerful queries, more accurate results
- Flavors of queries (SEQL) supported:
  - **Find books with title “Java Programming” and price less than $50**
  - **Find titles of articles containing words “XML” and “search” that are less than 5 words apart**
  - **In the speech spoken by “Antonio”, find the line that contains “merchandise”**
- So, how do we process these?

21

The Workhorse: Inverted Index

- Full text indexing
  - Document considered as a sequence of words
  - Both element names and their contents are indexed
- Lexicons records collections of index terms
  - Three types of lexicons in search engine: Text, Element, DTD
- Inverted lists indicate occurrences of index terms

22

Inverted Index Structure

Lexicons	Inverted Lists
<book>	<1; (19,27)(28,36)> <2; (1,9)> … …
<title>	<1; (20,23)(29,32)> <2; (2,5)> … …
“java”	<1; 21, 30> <2; 4> … …
“programming”	<1; 22,31> … …

- **An inverted list records occurrences of an indexed term**
  - e.g., <1; (19,27)(28,36)>: element “<book>” appears in doc1 from word number 19 to 27, as well as word number 28 to 36. (two “<book>” elements in doc1)
  - e.g., <1; 21,30>: text word “java” appears twice in doc1 at word numbers 21 and 30
- **Containment & proximity relationships checked by positions**
  - e.g. “<book>” (<1;(20,23)>) contains “<title>” (<1;(19,27)>)
  - e.g. “java” (<1;21>) appears next to “programming” (<1;22>) in doc1
- **Inverted list sorted in increasing order of docno & positions**

23

Why Inverted Index?

- Simple
- Fast on popular and useful information retrieval queries
- Highly tolerant of unstructured data, and data with different structures
- Preserves data source and document boundary
- Good scalability

Suitable for Web Information Processing

24

SEQL: Search Engine Query Language

1. Find books with title “Java Programming” and price less than 50

book contains (title is “Java Programming”
and price < 50)

2. Find titles of articles containing words “XML” and “search” that are less than 5 words apart

title containedin (article contains
distance (“XML”, “search”) < 5)

3. Find the line in “Antonio”s speech that contains “merchandise”

line contains (“merchandise” containedin
speech contains (speaker is “Antonio”))

SEQL Operators

- A complete set of operations:
  - containment: CONTAINS, CONTAINEDIN
  - boolean: AND, OR, EXCEPT
  - proximity (text words only): IS, DISTANCE
  - numerical: >, >=, <, <=, =
  - DTD conformant: conformsto
- Inputs and outputs of operators are inverted lists

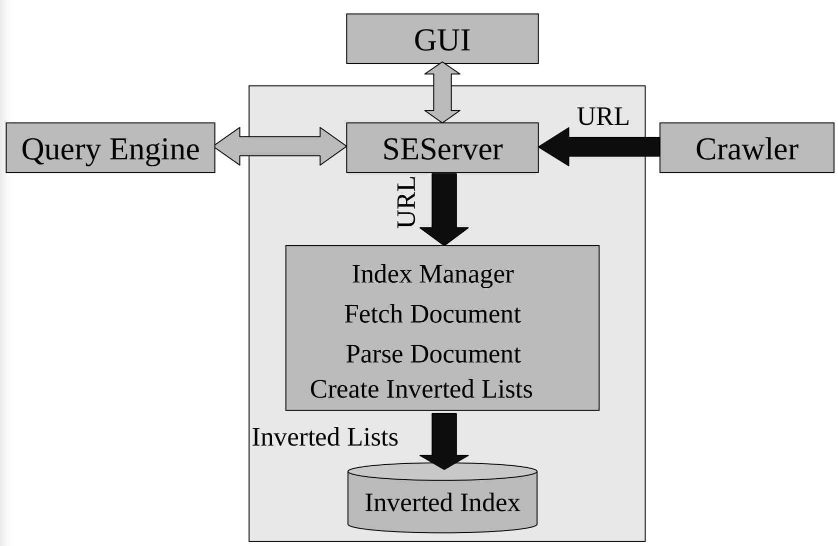
13

Process of Indexing

- Crawler finds an URL, gives it to SEServer
- SEServer passes URL to Index Manager
- Index Manager:
  - – fetches document, assigns doc number
  - – parses it into a sequence of index terms
  - – puts terms and positions into lexicons and inverted lists
  - – merges with rest of index

27

Process of Indexing



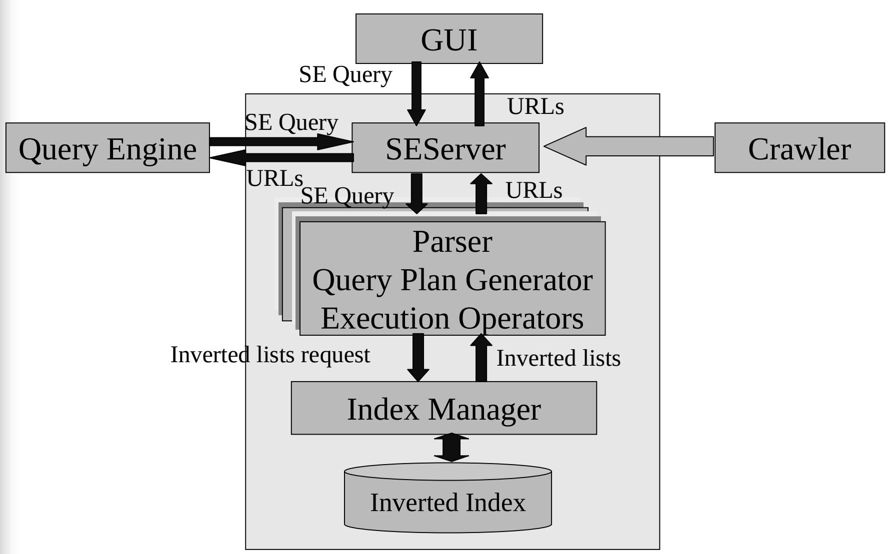
28

Query Processing

- SEServer accepts SEQL query from GUI or Query Engine
- Parser parses query, generates execution plan
- SE Operators contacts Index Manager
- Index Manager serves inverted lists
- SE Operators execute query plan

29

Query Processing



30

Future Work

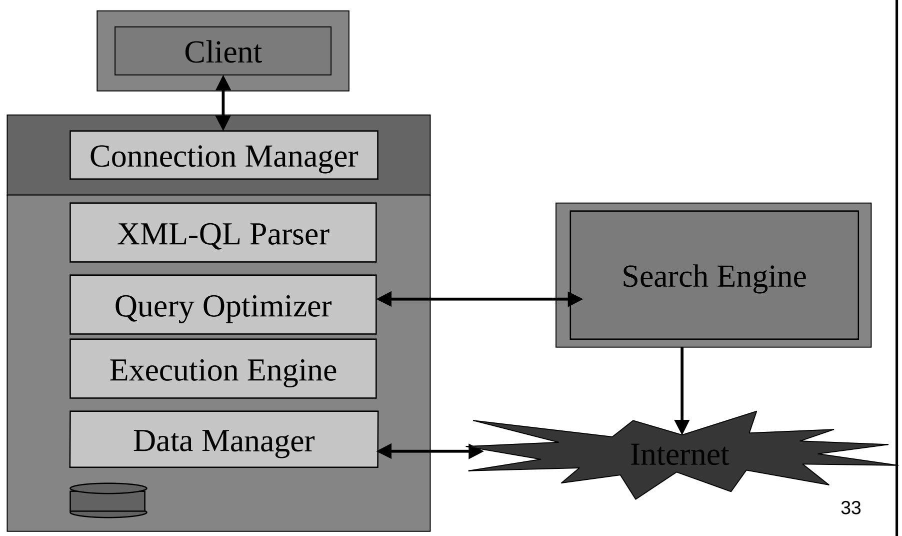
- Scalability with parallel processing
- Expedite indexing process
- Query Optimization
- Support for database queries (selection, projection, path expression, join)
- Crawler

31

Niagra Query Engine

32

Query Engine Architecture



33

Connection Manager

- Persistent connection with the client
- Client-Server communication is in XML
- Handles queries for SE, QE and Trigger Manager

34

Example DTDs

- http://www.publications.com/books.dtd

```
<!ELEMENT book (author+, title) >
<!ELEMENT author (#PCDATA) >
<!ELEMENT title (#PCDATA) >
```

- http://www.publications.com/article.dtd

```
<!ELEMENT article (author+, title, year) >
<!ELEMENT author (#PCDATA) >
<!ELEMENT title (#PCDATA) >
<!ELEMENT year (#PCDATA)
```

35

A Simple XML-QL Query

- **WHERE**

```
<book>
        <author> $a </>
        <title> $t </>
</> IN "*" conform_to "http://www.publications.org/book.dtd",
<article>
        <author> $a </>
        <year> 1995 </>
</> IN "*" conform_to "http://www.publications.org/article.dtd"
CONSTRUCT <title> $t </>
```

- Give me the name of all books that have an author who wrote an article in the year 1995

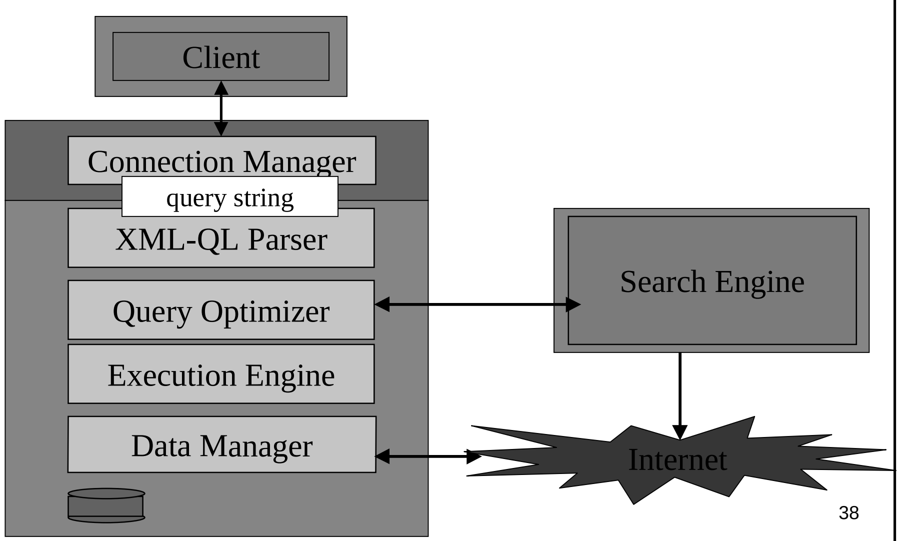
36

XML-QL

- W3 recommended XML-QL
- Three ways of specifying data sources
  - IN “*”
  - IN “*” Conform_to “http://www.publications.org/book.dtd”
  - IN “http://www.bookstore.com/book.xml”
- Supports features like regular expression, tag variables, etc.

37

Query Engine Execution Flow



38

Query Engine

- Multiple Query Threads
- Parser
  - query string -> logical plan
- Optimizer
  - logical plan -> physical plan
- Execution Engine
  - Runs each operator concurrently

39

XML-QL Parser

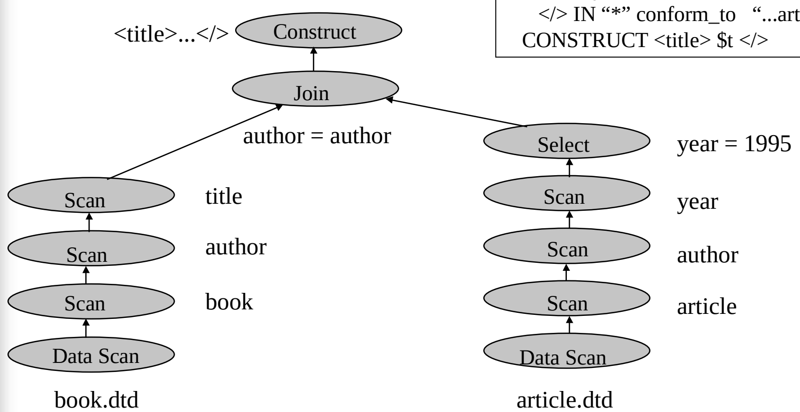
- Creates a syntax tree from the XML-QL query
- Generates a logical plan from the syntax tree
- Operators :
  - Data Scan, Scan, Select, Join, Construct

40

20

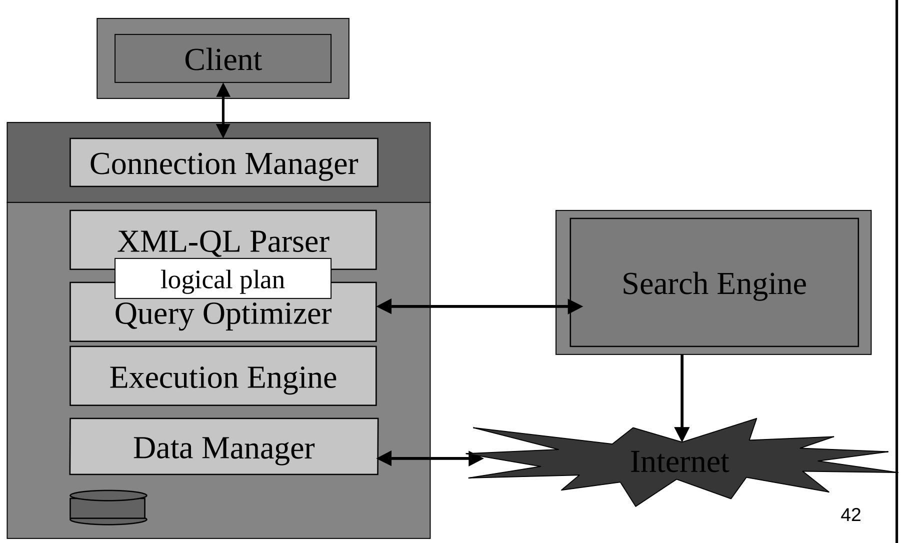
Logical Plan

```
WHERE
    <book>
        <author> $a </>
        <title> $t </>
    </> IN "*" conform_to "...book.dtd",
    <article>
        <author> $a </>
        <year> 1995 </>
    </> IN "*" conform_to   "...article.dtd"
CONSTRUCT <title> $t </>
```



41

Query Engine Execution Flow



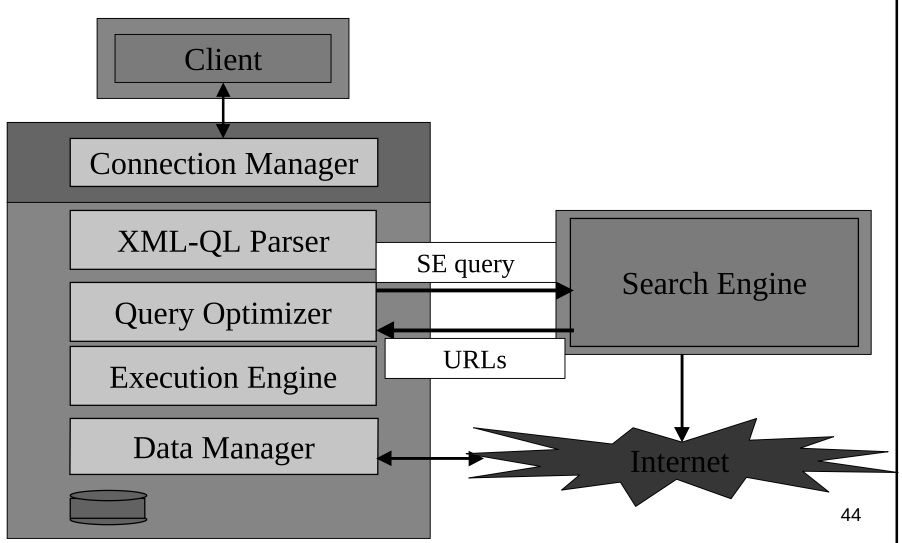
42

Query Optimizer

- Generates the SE Query to be sent to the Search Engine
- Generated SE queries
  - (book CONTAINS
    (author AND title))
    conformsto "http://www.publications.org/book.dtd"
  - (article CONTAINS
    ((year = 1995) AND author))
    conformsto "http://www.publications.org/article.dtd"

43

Query Engine Execution Flow



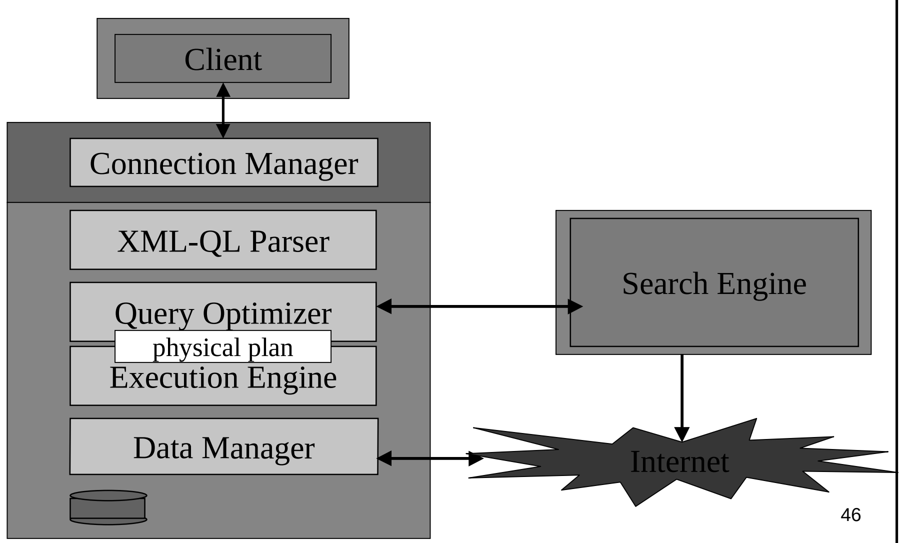
44

Query Optimizer (contd.)

- Retrieves URLs of qualifying data sources from the SE
- Passes URLs to the data scan node
- Selects an algorithm for executing each operator
- Gives the physical plan to the Execution Engine

45

Query Engine Execution Flow



46

Execution Engine

- Creates streams to connect different physical operators
- Puts each physical operator in a physical operator queue
- Operator threads run these operators concurrently

47

Data Manager

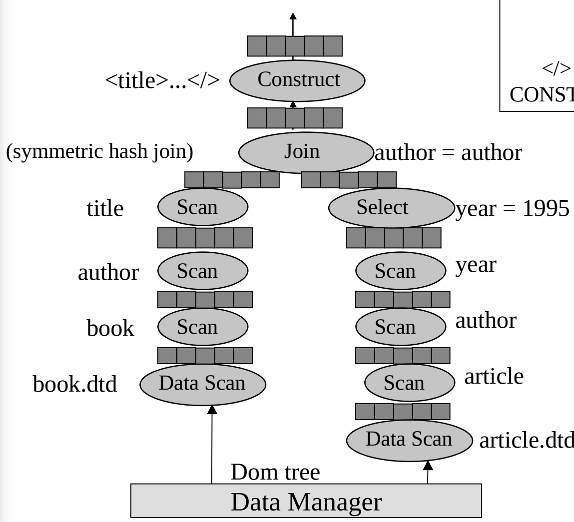
- Handles request for XML files from the execution engine
- Returns DOM trees to the Data Scan operators
- Caches the XML files

48

24

Physical Plan

```
WHERE
      <book>
            <author> $a </>
            <title> $t </>
      </> IN "*" conform_to "...book.dtd",
       <article>
            <author> $a </>
            <year> 1995 </>
     </> IN "*" conform_to   "...article.dtd"
CONSTRUCT <title> $t </>
```



49

Future Work

- Complete query optimizer
- Scalable and distributed implementations
- Different algorithms for operators
- IDREFs, XML Schema

50

NiagraCQ: A Scalable Continuous Query System over Internet

51

Motivation

- Continuous queries: persistent XML-QL queries to obtain new results automatically
- Large amount of frequently changing information on Internet
- An example
  - Whenever the stock price for a company in the Computer Service industry drops by more than 5%, give me its stock price and profile
- Challenge: system scalability with arbitrary XML-QL queries

52

Group optimization

- Key assumption: many queries are similar
- Key advantage: share computation among grouped queries
- Limitations of previous approaches:
  - Can only handle a small number of simple queries
  - Unsuitable for dynamic continuous query environment

53

Incremental Group Optimization

- Strategy:
  - Queries are classified into groups based on their expression signatures
  - A new query is merged into one or more existing groups (instead of re-grouping all the queries in the system)

54

Expression Signature

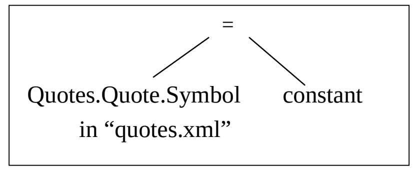
Definition: The same syntax structure in different queries, but with potentially different constant values

Two trivial continuous queries:

Where <Quotes> <Quote>
<Symbol>**INTC**</>
</> </> element_as $g
in "http://www.nasdaq.com/quotes.xml"
construct $g

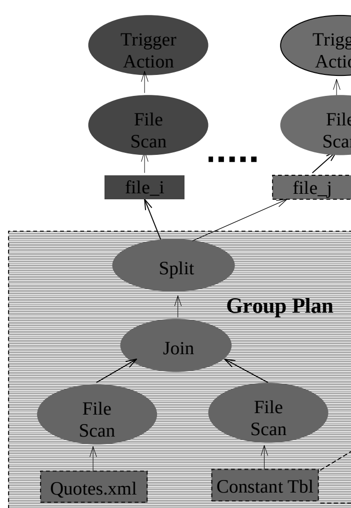
Where <Quotes> <Quote>
<Symbol>**MSFT**</>
</> </> element_as $g
in "http://www.nasdaq.com/quotes.xml"
construct $g

Expression Signature



Group

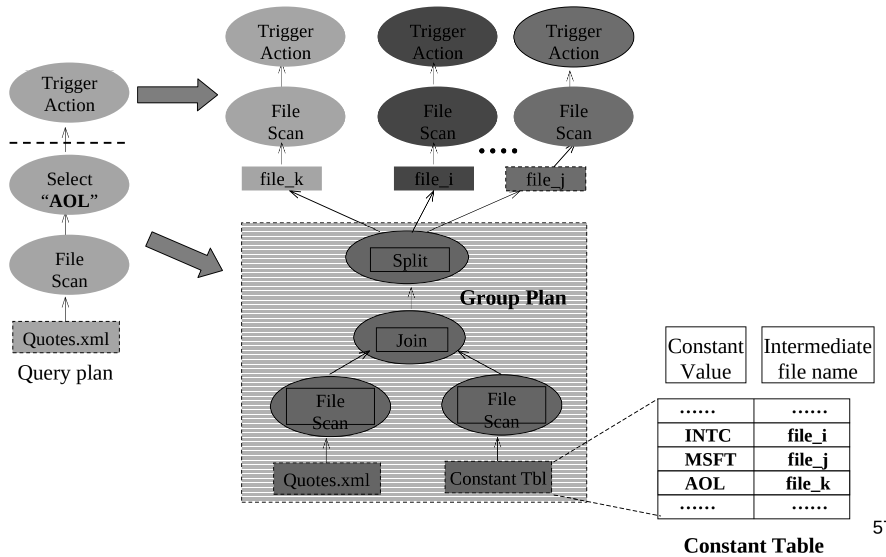
- Signature
- Constant Table
- Execution Plan



Constant Value	Intermediate file name
……	……
INTC	**file_i**
MSFT	**file_j**
……	……

Constant Table

Incremental Grouping Example



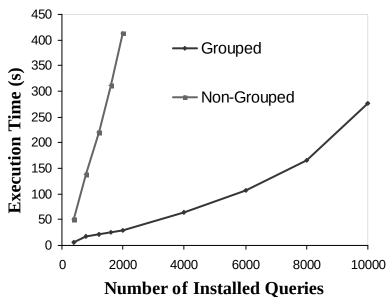
57

Query Split with Intermediate files

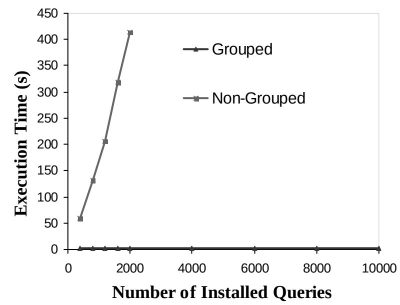
- Incremental group optimizer may split a query into multiple queries
- Split operator stores its output tuples into the appropriate intermediate files
- Intermediate files are monitored like data files
- Upper level queries are triggered by the changes on their files
- Key Advantages
  - Avoid unnecessary invocation
  - Be able to utilize a common query engine

58

Performance Results



1000 tuples modified
All installed queries fired



1000 tuples modified
100 queries fired

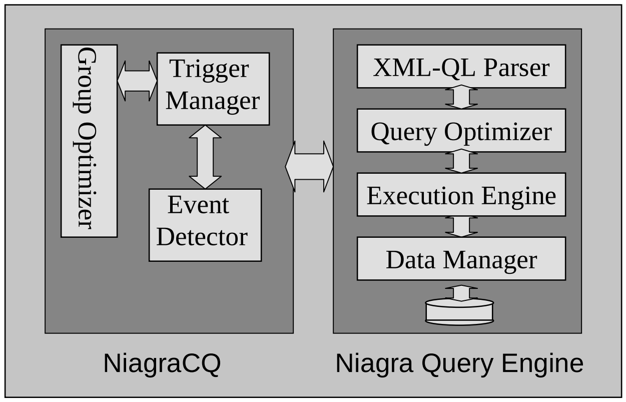
Grouping Timer-based Queries

- NiagraCQ Interface

  CREATE CQ_name
  XML-QL query
  DO action
  {START start_time} {EVERY time_interval} {EXPIRE expiration_time}

- Timer-based queries: time_interval > 0 (e.g. 10 min, 1 hour, 1 day etc)
- Change-based queries: time_interval = 0
- Challenges due to different time_intervals

NiagraCQ Architecture



Conclusions and Future Work

- Incremental group optimization significantly improves system performance
- NiagraCQ can be scaled to support a large number of continuous queries
- A cost model for group optimizer
- Grouping queries with multiple join operators
- Dynamic regrouping
- Distributed continuous query processing