The Continued Saga of DB-IR Integration

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Agenda
1. Motivation
2. An Introduction to IR
3. Requirements for DB-IR
4. Semi-structured Data
5. Industrial DB-IR Examples: Oracle, Verity
6. DB Approaches
7. IR & Hybrid Approaches
8. Open Problems
9. Bibliography

Disclaimer
• This tutorial reflects the personal biases, preferences and limitations of the presenters ☺
• It does not cover everything done in DB+IR
• It does not cover related areas such as other XML problems, multimedia, spatial databases, etc.
1. Motivation

- Types of data
- DB & IR Views
- Possible Solutions
- Applications
- Search Problems

Different Views on Data

Data and Databases
RDB vs. IR

- DBs allow structured querying
- Queries and results (tuples) are different objects
- Soundness & completeness expected
- All results are equally good
- User is expected to know the structure

- IR only supports unstructured querying
- Queries and results are both documents
- Results are usually imprecise & incomplete
- Some results are more relevant than others
- User is expected to be dumb

The Notion of Relevance

- Data retrieval: semantics tied to syntax
- Information retrieval: ambiguous semantics
- Relevance:
  - Depends on the user
  - Depends on the context (task, time, etc)
  - Corollary: The Perfect IR System does not exist

Evaluation: First Quality, next Efficiency

- Precision
- Recall
- Relevant Documents
Evaluation: Comparing Systems

TREC: Collection + Queries + Answers

Possible Architectures

- IR on top of RDBs
- IR supported via functions in an RDB
- IR on top of a relational storage engine
- Middleware layer on top of RDB & IR systems
- RDB functionality on top of an IR system
- Integration via an XML database & query language

Problems of the IR view

- Very simple query language
  - Is natural language the solution?
- No query optimization
- Does not handle the complete answer
Problems of the DB view

• The syndrome of the formal model
  – Model is possible because of structure
• The syndrome of “search then rank”
  – Large answers
  – Optimization is useless
  – Quality vs. Speed
  – E.g. XQuery
• What is a Data Base?
• Are RDBs really a special case of IR systems?

Applications for Integrated Systems

• E-commerce search
• Intranets & enterprise data
• Customer support (e.g. CRM)
• News archives, bulletin boards, etc.
• Personal information (e.g. My Life Bits)
• P2P Web Search

Challenges posed by the Web

• Integration of autonomous data sources
  – Data/information integration
• Supporting heterogeneous data
  – How to do effective querying in the presence of structured and text data
  – How to support IR-style querying on DBs
    • Because now users seem to know IR/keyword style querying more, even though structure is good because it supports structured querying!
    • How to support imprecise queries
Enterprise Search is Different

- Sophisticated systems run by librarians are morphing into simple self-service web-based search
  - Must be scalable, reliable, highly available
- Data is different
  - Heterogeneous in format & structure (documents, DBs, etc)
  - Less volume & better quality
- Searching is also different
  - Less & better queries, different tasks
  - Focus in recall rather than precision
- Other issues: security, able to search but not to see

What is a Bad Interface/Result?

- No search box
- Inability to judge user intent
  - No spell checking
  - No context disambiguation (cricket: game or bug?)
  - No recommendation system, no user feedback
- Too many hits: answer overload
  - Return 10,000 hits when the average user looks only at the top-20
- The most relevant item is not at the top of the list
- Too many similar documents
  - Poor duplicate detection, poor clustering/categorization
  - Inability to understand why a document has been returned
  - No KWIC
- Lack of Meta information
  - Size, format, date, etc.

Cost of a Bad Search

- Information is useless if no one can find it
  - ROI for employee productivity
  - ROI for customer satisfaction
  - Cost of people using out-of-date information
  - Cost of people using wrong information
  - Cost of recreating information which cannot be found
  - Cost of opportunity for not finding the information
Some Examples - I
Where is the search box?

Some Examples – II
“ultra seek” or “ultraseek”?

Some Examples - III
Looking for “k-means” in lotus.com
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2. Introduction to IR through Web Retrieval

- IR challenges posed by the Web
- Logical view of text
- Similarity models
- IR system architecture
- IR query languages & interfaces

Bag-of-Words Representation

Full-text continuum: ambiguity vs. completeness trade-off
Challenges in Current IR Systems

Document Base: Web
- Largest public repository of data (more than 6 billion static pages?)
- Today, there are more than 60 million Web servers
- Well connected graph with out-link and in-link power law distributions

Web Retrieval
- Problems:
  - volume
  - fast rate of change and growth
  - dynamic content
  - redundancy
  - organization and data quality
  - diversity
- Deal with data overload
Challenges in Current IR Systems

Web Users

- Cultural and educational diversity
- Short queries
  - Inherent to users or due to the query language?
- Different goals:
  - Information need
  - Navigational need
  - Transactional need
- Short patience
  - Few queries posed & few answers seen
- Other problems: concurrency, scale, ...

Challenges in Current IR Systems

Context

Dynamic Interaction
Interaction
- Inexperienced users
- Dynamic information needs
- Varying task: querying, browsing...
- No content overview
- Poor query language, no help
- Poor preview, no visualization
- Missing answers: partial Web coverage, invisible Web, different words or media, ...
- Useless answers

Challenges in Current IR Systems

Web Retrieval Architecture
Centralized parallel architecture
Algorithmic Challenges

- Crawling:
  - Quantity
  - Freshness
  - Quality
  - Politeness vs. Usage of Resources

- Ranking
  - Words, links, usage logs, ... , metadata
  - Spamming of all kinds of data
  - Good precision, unknown recall

Text Similarity Models

- Vector model:
  - words are dimensions
  - tf-idf is used for weights

- Set Models:
  - Boolean, Fuzzy sets, ...

- Algebraic Models:
  - Vector, LSI, etc.

- Probabilistic Models:
  - Probabilistic, Inference & belief networks

Index

- Inverted index
- Lists sorted by weight
  - global (e.g. Pagerank)
  - local (e.g. word weights)
- Hashing + set operations
- Compressed
- Incremental updates
Parallel Case

- Collection is divided per server
- Local indexes are used
  - Document partitioning
- Brokers distribute queries and merge results
- Simpler to build and update
- Good load balance, low concurrency
- In theory a global partitioned index achieves higher concurrency but has lower load balance and more difficult to build & maintain

Non-word based Applications

- Suffix trees
- Linear building time
- Linear space (but larger than data)
- Suffix arrays
- Linear building time, less space
- Powerful search:
  - any substring
  - approximate search
  - regular expressions
- Applications: biology, music, linguistic, etc.

Link Ranking

- Incoming links count (Li, 1997)
- HITS (Kleinberg, 1998)
  - Authorities: good pages
  - Hubs: good links
- PageRank (Page & Brin, 1998)
  - Random walk + random jumps if “bored”
- Many variations of these ideas
- Good to find communities, spam, etc.
- Application to other problems (e.g. ranking relations)
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3. Requirements for DB-IR

- Motivating Applications
- Data and Query Requirements
- Sample Use Cases

Sample Paper on the Web
Bibliography Entry

<proceedings>
  <inproceedings>
    <author>Ricardo Baeza-Yates</author>
    <author>Gonzalo Navarro</author>
    <title>XQL and Proximal Nodes</title>
    ...
  </inproceedings>
</proceedings>

• Describes metadata for the workshop article
• The XML data conforms to the DBLP schema (DTD)

Paper Content in XML

<workshop date="28 July 2000">
  <title>XML and Information Retrieval: A SIGIR 2000 Workshop</title>
  <editors>David Carmel, Yoelle Maarek, Aya Soffer</editors>
  <proceedings>
    <paper id="1">
      <title>XQL and Proximal Nodes</title>
      <author>Ricardo Baeza-Yates</author>
      <author>Gonzalo Navarro</author>
      <abstract>We consider the recently proposed language ...</abstract>
      <section name="Introduction">Searching on unstructured text is becoming more important with XML ...</section>
      </paper>
    ...
  </proceedings>
</workshop>

• The XML data conforms to the publisher’s DTD

A Digital Library Application

• Web interface for the citation
• Access Content

Citations

Similar Documents
Applications Areas

- Scientific, Technical and Medical Reference Books, Journals, Publications
- Case Law and Litigation Materials
- Regulatory and Business Filings
- Maintenance, Repairs and Operations Manuals
- Product Documentation
  - Design
  - Procurement (SRM)
  - Customer Service (CRM)
- Collaboration, Portals
- Web, Intranet, Group & Personal Repositories
- Represents "80% of enterprise data"

Data Requirements

- Text, Documents, Images, Application Files, Multimedia Content
- Structured Data
  - Relations: Refers (From, To)
  - Hierarchies: proceedings/paper/section
- Semi-structured Data
  - Editorial comments on the paper
- Assumption: XML provides a reasonably way to capture the requirements above

Publishing Relational Data

<table>
<thead>
<tr>
<th>USERS</th>
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<tr>
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Queries on Views - Integration

Heterogeneous Sources - P2P

Query Requirements Overview

- Developing the web application
- Structure-only
- Content-only
- Content and Structure
Proteomics Portal (courtesy T. Topaloglou, Protana)

- Map the proteins seen in experiments to the scientific literature

DB-IR Query Requirements

- Express arbitrary Full-Text (FT) searches
- Select the substructures where the FT condition applies (search context)
- Select the substructures to be returned (return context)
- Choose how to determine relevance for results and (weighted) queries
- Access and combine the relevance scores
- Limit answer to top-k
- Support approximate structural searches

S. Amer-Yahia, N. Koudas, D. Srivastava, ICDE 2003 Tutorial
- Full composition of FT and structural queries

Additional DB-IR Requirements

- Efficient and scalable query evaluation, supported by
  - Indexes (FT and structural)
  - Optimizer (plans and operators)
- Rich functionality for presenting answers
  - Visual interfaces
    - Highlight the FT terms in context
- Support queries on integrated views
- Query heterogeneous structure
  - Within a single collection
  - Across peer sources
  - In data repository crawled from web sources
Sample Use Cases

- Quick overview of the range of possible DB-IR requirements
  - Identify search and return contexts
  - Motivate relevance
  - Illustrate composition

- Extension of use cases from Full-text XQuery
  (http://www.w3.org/TR/xmldsig-core-full-text-use-cases)

Finding Text in Elements

- Find all book titles containing the word "usability"
- Find all books with the phrase "usability tests" in book or chapter titles
  - Multiple search contexts, different return
- Find all books with the phrase "usability tests" (even across elements)
- Find all book titles for books with abstracts mentioning software developers (interpreted as having broad terms “software” near “developer”)
  - Proximity
  - Thesaurus (developer, programmer)

Finding Text in Structure

- Find the first two sections mentioning "task" in chapters on "conducting usability tests" with the book abstract not mentioning "software"
  - Structured search contexts
    - book/chapter/section
    - book/chapter
    - book/abstract
- Do the above ignoring footnotes in chapters but not in abstracts
  - Modifies the search contexts
  - Match the contexts approximately
Ranking

- Find how relevant to "usability" are the books
- Find the best two books on "usability tests"
  - Take into account reviewers comments
- Return all books with only the sections highly relevant to "usability"
- Rank on both approximate structure and content matching the sections mentioning "task" in chapters on "conducting usability tests" with the book abstract not mentioning "software"

Composing Queries

- For books with "usability" in the title create a flat list of all titles and the authors
- Find the 10 most relevant books about conducting "usability tests" which have more than one author and are published after "2000"
- Find all books published after "2001" which share a subject with the 10 most relevant books on "usability" that have titles mentioning "software" and "developer"

The (VLDB-only) DB-IR Saga

![Graph showing paper distribution by year]
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4. Semistructured Data

- XQuery
- XQuery & Full-text
- Structured Text Models
  - Proximal Nodes

XQuery History

- SQL
- OQL
- XQuery
- XML-QL
- XSL
- XSLT
- XQL
- XQuery 1.0
- XQuery 0.99
- XPath 2.0
- XPath 1.0
- Quilt
- Lorel
- XSL 1.0

Patterns
### XML Query Language Comparison

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<th>Function</th>
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<th>XSLT</th>
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### XML Query Language Comparison

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<td>Yes</td>
</tr>
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</table>

- Structure: Ordered, labeled forest
- Selectivity: Based on XML Information Set, PSVI
- Nested queries: Has node identity
- XPath operators: DTDs (from SGML, IR style)
- XSLT operators: XML Scheme (DB style)
- XQuery operators: Provide data types

XML Query Data Model

- Joint with XPath 2.0, XSL 2.0
  - Last version of Feb 2004
- Ordered, labeled forest
- Based on XML Information Set, PSVI
- Has node identity
- DTDs (from SGML, IR style)
- XML Scheme (DB style)
- Provide data types

XQuery and the Data Model
XML Query Formal Semantics

- XQuery is a functional language
  - A query is an expression
  - Expressions can be nested with full generality
  - A pure functional language with impure syntax

- Static Semantics
  - Type inference rules
  - Structural subsumption

- Dynamic Semantics
  - Value inference rules
  - Define the meaning of XQuery expressions in terms of the XML Query Data Model

XQuery Expressions

- Element constructors
- Path expressions
- Restructuring
  - FLWOR expressions
  - Conditional expressions
  - Quantified expressions
- Operators and functions
- List constructors
- Expressions that test or modify data types

Path Expressions

```xml
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<bib>
  <book year="1994">
    <title>TCP/IP Illustrated</title>
    <author>
      <last>Stevens</last>
      <first>W.</first>
    </author>
    <publisher>Addison-Wesley</publisher>
    <price>65.95</price>
  </book>
</bib>
```

- XQuery uses the abbreviated syntax of XPath for path expressions
- `document("bib.xml")`
- `/bib/book/author`
- `/bib/book/author[author[last="Stevens" and first="W."]]`
FLWOR Expressions

- FOR - LET - WHERE - ORDER BY - RETURN
- Similar to SQL's SELECT - FROM - WHERE

for $book in document("bib.xml")//book
where $book/publisher = "Addison-Wesley"
return
  <book>
    { $book/title, $book/author }
  </book>

SQL vs. XQuery

"Find item numbers of books"

- SQL:
  SELECT itemno
  FROM items AS i
  WHERE description LIKE 'Book'
  ORDER BY itemno;

- XQuery:
  FOR $i IN //item_tuple
  WHERE contains($i/description, "Books")
  RETURN $i/itemno ORDERBY(.)

"List names of users and descriptions of the items they offer"

- SQL:
  SELECT u.name, i.description
  FROM users AS u, items AS i
  WHERE u.userid = i.offered_by
  ORDER BY name, description;

- XQuery:
  FOR $u in //user_tuple, $i in //item_tuple
  WHERE $u/userid = $i/offered_by
  RETURN <offering> { $u/name, $i/description } </offering> ORDERBY(name, description)
The patient was taken to the operating room where she was placed in a supine position and anesthesia induced under general anesthesia. A Foley catheter was placed to decompress the bladder and the abdomen was then prepped and draped in sterile fashion. A curvilinear incision was made in the midline immediately infraumbilical and the subcutaneous tissue was divided using electrocautery.
XQuery Implementations

- Software AG's Tamino XML Query
- Microsoft, Oracle,
- Lucent Galax
- GMD-IPS/itex X-Hive
- XML Global
- SourceForge XQuench, Saxon, eXist, XQuery Lite
- Fatdog
- Qexo (GNU Kawa) - compiles to Java byte code
- Openlink, CL-XML (Common Lisp), Kweelt,...
- Soda3, DB4XML and about 15 more

Why XQuery?

- Expressive power
- Easy to learn (?)
- Easy to implement (?)
- Optimizable in many environments
- Related to concepts people already know
- Several current implementations
- The accepted W3C XML Query Language

Structured Text Models

- Trade-off: expressiveness vs. efficiency
  - Hybrid model (flat fields)
  - PAT expressions
  - Overlapped lists
  - Reference lists
  - Proximal nodes
  - Region algebra
    - Proposed as Algebra for XML-IR-DB Sandwich
  - p-strings
  - Tree matching

- Hierarchical structure
- Set-oriented language
- Avoid traversing the whole database
- Bottom-up strategy
- Solve leaves with indexes
- Operators work with near-by nodes
- Operators cannot use the text contents
- Most XPath and XQuery expressions can be solved using this model

Proximal Nodes: Data Model

- Text = sequence of symbols (filtered)
- Structure = set of independent and disjoint hierarchies or "views"
- Node = Constructor + Segment
- Segment of node ⊇ segment of children
- Text view, to modelize pattern-matching queries
- Query result = subset of some view

Proximal Nodes: Hierarchies
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5. Industrial DB-IR Examples: Oracle, Verity

- DB View: Oracle
- IR View: Verity
- Provided by them!
- Thanks to
  - Omar Alonso (Oracle)
  - Prabakhar Raghavan (Verity)

A DB Example: Oracle

- Oracle Text
  - Complete API for building any type of search application
  - Features range from basic keyword searching to advanced techniques like classification and information visualization
- Oracle Ultra Search
  - Out-of-the-box solution that requires no coding
  - Can search across OCS components, websites, databases, files, email, and Portal
  - Built on top of Oracle Text
- Included free with the standard system
Common Myths about Oracle Search (according to Oracle)

- Database-Integrated Search Technology is slow
- Oracle’s Search Technology is less functional than specialized search-only engines
- Major sites must run specialized search engines
- Oracle is expensive
- Oracle is complex
- Oracle’s search technology will not scale out
- You can only search database-resident content with Oracle

Oracle Text Search Functionality

- Fully integrated with the database
- Premier text search quality (TREC-8 win)
- Advanced linguistics: built-in extensible thesaurus, themes, geists, fuzzy, internationalization features for multilingual applications, etc.
- Document services: multilingual highlighting, themes, navigation ...
- XML support
- Classification (TREC-10 win)
- Statistical Text Processing: Clustering
  - Integrated with JDeveloper Java IDE
- Filters for 100+ document formats
- Specialized indexes for catalogs, classification, XPath searches
- Visualisation
- Integrated web-crawler and out-of-the-box-GUI with Ultra Search
Quality
- Link awareness
  - Popular pages and hubs
  - Website structure
  - Page structure
- Duplicate elimination
  - Remove URLs with duplicate or near duplicate content
- Spelling correction
  - Component that uses a dictionary and data from query logs
  - Did you mean …?
- KWIC (Key Word In Context)
  - Highlights relevant parts of the document
  - No need to open the URL if it doesn’t look relevant

Performance
- Oracle Text integrates with and benefits from features like
  - Data partitioning
  - RAC
  - Query optimization
- Common and rare queries
  - Small index on URL and title for common queries
  - Large index on document content for rare queries
- Query Relaxation
  - Enables you to execute most restrictive query first
  - Then relaxing the search

Ease of Use
- Users want a simple and easy to use search interface
- Hide all the complexity and expose simple interface
- Ultra Search
- Two search modes
  - Basic: simple search box where search results are sorted by relevance
  - Advanced: interface with more options where user has more control over the collection
Personalization

• Know user search patterns
  – What do they search?
  – When do they search?
• Search query log analysis
  – Which queries were made?
  – Which queries were successful?
  – How many times was each query made?

Advanced Features

• Classification
  – Supervised classification of content
  – Two ways: rules or training sets
  – You can group a number of categories into a taxonomy
    Very useful for defining a common vocabulary in an enterprise
• Clustering
  – Unsupervised classification of patterns into groups
  – The engine analyzes the document collection and outputs a set of clusters with documents on it
  – Very useful for discovering patterns or nuggets in collections
    Could be used as a starting point when there is no taxonomy present

Information Visualization

• Present searched information in ways other than hit-lists
• Shows relationship across items in addition to satisfying query results
• Better IR using visual metaphors
• Very useful for
  – Navigation through large data sets
  – Discover relationships and associations between items
  – Focus + context tasks
• Number of visualizations available
  – StretchViewer
  – Interactive Viewer (ThemeMap, Cluster visualization)
  – Integration with 3rd party vendors
Is Oracle’s Text Search Complex?

• Easy to Develop
  - Simple SQL and PL/SQL interface
  - Can be used by any developer that knows SQL
  - Using any language: Java, JSP, PL/SQL, C, etc.
  - Choice of datastores
    - Stored in the database
    - Stored in the file system
    - Stored on the web (URL)
    - User-defined datastore
• Easy to Deploy
• Easy to Maintain

Oracle Text API

• Three index types
  - context: classic text searching
  - ctxcat: catalog searching
  - ctxrule: classification/routing applications
• Extensions to SQL
  - select title from my_table where contains(text, 'Java') > 0;
  - select title from my_categories where matches(myquery, mydoc) > 0;

Oracle Text API – II

• Operators: Boolean expressions, phrases, proximity, fuzzy, stemming, wildcards, accumulate scores, term weighting, XPath, etc.
• Packages
  - CTX_DOC: document services
  - CTX_QUERY: query feedback
  - CTX_REPORT: index information
  - CTX_OUTPUT: logging
  - CTX_THES: thesaurus features
  - CTX_CLS: training set
  - CTX_ADM: administration
  - CTX_DDL: create/manages index preferences, sections, stop lists
An IR Example: Verity
Structured data

- **Indexing databases**
  - Used to import data from ODBC databases into Verity indexes ("collections")
  - Similar to Verity gateways to other backend repositories e.g., Lotus Notes, Exchange, Documentum, Filenet, etc.

- **Parametric selection for search**
  - Intersect full-text search with range queries/selection
  - When a field is a taxonomy (e.g., Continent/Country/City/Street), you have relational taxonomies = Cartesian product of taxonomies

Database indexing – 2 choices

- "Export" to XML or Bulk Insert File
- ODBC Gateway

  - The common theme to either approach is to preserve the database structure in the index, such that you can query/display/sort on fields of integer, float, date, string, "attachment" data types.

“Export” to XML or BIF - Overview

- Many applications use a database as a storage component.
- Verity may not have an official gateway to that system because the APIs may not exist and/or a simpler solution exists.
- Sample list of applications that may be indexed using this approach:
  - MatrixOne, Siebel, Intervenew, Fatwire, Virage, many others
- The general concept is to temporarily export the database row/field structure in a Verity compatible format.
- A variety of integration languages have been used – including, but not limited to ASP, Java/USP/UDBC, Perl/ODBC, etc.
Verity Gateways

- Pre-built Gateways provide access to the most common enterprise repositories
- Gateway developer’s kit enables you to build custom gateways to virtually any application
- K2 Enterprise enforces existing security models
  - Including native security of applications accessed by Verity Gateways
  - Ensures end-users can only view the information that they are authorized to access

Verity Gateways

Pre-built Verity Gateways
- Available for the following repositories:
  - Documentum
  - File Systems (NFTS and UNIX)
  - HTTP
  - Lotus Notes
  - Microsoft Exchange
  - ODBC databases

Verity Gateway Development Kit
- Quickly and easily build secure custom gateways to additional repositories

ODBC gateway

- Verity product that uses ODBC (Data-Direct drivers) to stream records from database into Verity collections.
- A graphical tool (MMC plug-in) is used to build the text-based configurations that control the desired mapping behavior.
ODBC GW - Certified Platforms

- Windows (with access to Oracle, DB2, Microsoft SQL Server)
- Solaris (with access to Oracle and DB2)
- AIX (with access to Oracle and DB2)
- HP-UX (with access to Oracle and DB2)
- Linux (with access to Oracle and DB2)
- Other databases such as Informix, Sybase, MySQL and others are supported
  Gateway uses ODBC 3.5 API calls to insure compatibility

Feature Highlights

- SQL statements that select fields from one or more tables (gateway join)
- Full Data Type support
  - Blobs, unsigned/signed integers, floats, dates
  - Filebyname – treat field as file system path and automatically follow and index
- Multi-row records
- Compound primary keys
- Efficient spidering
  - Event-driven updates – use database triggers
  - Where clauses can be used for crawling limit

Verity K2 Enterprise Search - Parametric Selection

- Intuitive interface enables users to easily sort and filter information by selecting pre-set parameters and searching through filtered text fields and document content for specific text
Verity K2 Enterprise Search -
Parametric Selection Example

Verity K2 Enterprise Search -
Relational Taxonomies

- Allows users to quickly narrow down information in the way that makes the most sense to them
  - Users take alternate paths through the same topics or categories to quickly and easily narrow down on the information they need
  - Users can navigate to information using two or more taxonomies at once
- Dramatically improve the finding experience for data with attributes

Verity K2 Enterprise Search -
Relational Taxonomies Example
6. DB Approaches

- IR on Relational Data
  - Keyword search
- IR on XML
  - Keyword search
  - Full QL + IR extension
  - Algebras and Evaluation

6-1. IR on Relational: Keywords

- BANKS
  - Gaurav Bhalotia, Arvind Hulgeri, Charuta Nakhe, Soumen Chakrabarti, S. Sudarshan, **Keyword Searching and Browsing in Databases using BANKS**, ICDE 2002
- DBXplorer
  - Sanjay Agrawal, Surajit Chaudhuri, Gautam Das, **DBXplorer: A System for Keyword-Based Search over Relational Databases**, ICDE 2002
- DISCOVER
  - Vageris Hristidis, Yannis Papakonstantinou: **DISCOVER: Keyword Search in Relational Databases**, VLDB 2002
Keyword Search

- Keywords could be:
  - In the same tuple
  - In the same relation
  - In the Data or the Metadata
  - Connected through primary-foreign key relationships

- Results can be scored based on:
  - Distance of keywords within a tuple
  - Distance between keywords in # edges
  - IR-style ranking
  - Random walk probability (PageRank style)
  - Some combination of the above

Example Query [V. Hristidis]

```
Results:
ORDERS
ORDERKEY CUSTKEY TOTALPRICE CLERK ...
1000105 12312 $5,000 John Smith
1000111 12312 $3,000 Mike Miller
1000125 10001 $7,000 Mike Miller
1000110 10002 $8,000 Keith Brown

CUSTOMER
CUSTKEY NAME NATIONKEY ...
12312 Brad Lou 01
10001 George Walters 01
10013 John Roberts 01

NATION
NATIONKEY NAME REGIONKEY ...
01 USA N.America
```

6-2. IR on XML: Keywords

- **XKeyword**
  - V. Hristidis, Y. Papakonstantinou, A. Balmin, Keyword proximity search on XML graphs, ICDE 2003

- **XSearch**

- **XRANK**
XSearch Example

<proceedings>
  <inproceedings>
    <author>Moshe Y. Vardi</author>
    <title>Querying Logical Databases</title>
  </inproceedings>
  <inproceedings>
    <author>Victor Vianu</author>
    <title>A Web Odyssey: From Codd to XML</title>
  </inproceedings>
</proceedings>

The Content-Only Approach

Find papers by Vianu on the topic of “logical databases”

Search: Vianu logical databases

• Each document in the corpus is treated as a unit.
• A document containing some of the three query terms is considered as a result.

The document contains the three query terms. Hence, it is returned by a standard search engine. BUT
XQuery+FT Query Language

FOR $i$ IN document("bib.xml")//inproceedings
WHERE $i$/author contains 'Vianu'
AND $i$/title contains 'Logical'
AND $i$/title contains 'Databases'
RETURN
  <result>
    <author> $i$/author </author>
    <title> $i$/title </title>
  </result>

• Much more complicated query expression than search box
• Extensive knowledge of the document structure is required to write the query
• Still need to choose a mechanism for ranking the results

Requirements from the Search Tool

• A simple syntax that can be used by naive users
• Search results should include XML fragments and not necessarily full documents
• The XML fragments in an answer, should be semantically related
  – For example, a paper and an author should be in an answer only if the paper was written by this author
• Search results should be ranked
• Search results should be returned in "reasonable" time

XSEarch Query Syntax

• A query is a list of query terms
• A query term can be a
  – Keyword, e.g., database
  – Tag, e.g., inproceedings:
  – Tag-keyword combination, e.g., author:Vianu
• Optionally preceded by a +
The Example Revisited

- Find papers by Vianu on the topic of "logical databases"

logical +database inproceedings: author:Vianu

The keyword database of Vianu under the must appear in the fragment, in the fragment, increases the rank of this fragment.

XSEarch: author:Vianu title:

Good Result!
title and author elements ARE semantically related

XSEarch: author:Vianu title:

Bad Result!
title and author elements ARE NOT semantically related
Example (1)

Circled nodes belong to different inproceedings entities

Example (2)

Circled nodes belong to the same inproceedings entity (see MLCAS in Li, Yu, Jagadish, Schema-Free XQuery, VLDB 2004)

Query Processing and Ranking

- Document fragments are extracted using indexes.
- Extracted fragments are returned ranked by the estimated relevance.
Result Ranking

Several factors increase the rank of a result
- Similarity between query and result
- Weight of labels appearing in the result
- Characteristics of result tree

TF-ILF
- Extension of TF-IDF, classical in IR
  - Term Frequency: number of occurrences of a query term in a fragment
  - Inverse Leaf Frequency: number of leaves containing a query term divided by number of leaves in the corpus

\[ tf(k, n_l) := \frac{occ(k, n_l)}{\max\{occ(k', n_l) \mid k' \in \text{words}(n_l)\}} \]

\[ ilf(k) := \log \left( 1 + \frac{|N|}{\left| \{n' \in N \mid k \in \text{words}(n')\} \right|} \right) \]

TF-ILF is the product between \( tf \) and \( ilf \)

6-2. IR on XML: TeXQuery

- Composability: conversion back and forth from FullMatch to XQuery data model (within TeXQuery expression)
TeVXQuery Expressions

- Contains
  $\text{FTContainsExpr := ContextExpr "ftcontains" FTSelection}$
  returns true if a node in ContextExpr satisfies FTSelection

  //book
  //section ftcontains ("usability" && "software")
  //title

- Score
  $\text{FTScoreExpr := ContextExpr "ftscore" FTWeightedSelection}$
  returns a sequence of scores (for ranking and top-k)

  //book ftscore ("usability" weight 0.8
  && $i/topic weight 0.2)

TeVXQuery Full-Text Model

QL-IR Design Choices

- SQL/MM structured text proposal
  - Functions have IR sublanguage as an argument, so the expression string can be constructed as a query
  - Explicit mark_subtexts() function supports highlighting matches

- TeXQuery
  - IR sublanguage grammar exposed and fully composable with XQuery
  - Implementation defined positions and scores
6-2. IR on XML: TIX Algebra

- TIX is an extension of the bulk XML algebra TAX that manipulates collections of scored trees with matching defined via scored pattern trees
  S. Al-Khalifa, C. Yu, H. Jagadish, Querying structure text in an XML database, SIGMOD 2003

- Find document components in articles that
  - Are part of an article written by an author with last name ''Doe'' and are about ''search engine''
  - Relevance to ''internet'' and ''information retrieval'' is desirable (but not necessary)

Scoring:
\[ \text{$4$.score} = \text{ScoringFunction} \left( \text{"search engine"}, \text{"internet", "information retrieval"} \right) \]
\[ \text{$1$.score} = \text{$4$.score} \]

Example Scored Pattern

Scored Selection
A scored pattern tree \((P)\) and A projection list \((PL)\)

- Combine multiple scores (from multiple pattern matches) by keeping the maximum

**Scored Joins**

- Find relevant document components in articles as before
- For articles containing such components, find the reviews with similar titles

**Scoring:**

$6.score = ScoringFunction("search engine", "internet", "information retrieval")$

$2.score = 6.score$

$8.score = ScoreSim(3.content, 8.content)$

$1.score = ScoreBar(8.score, 6.score)$

**IR-style Operations**

- Threshold
  - Projection that retains input trees where at least one node has a top-k score, or a score higher than a threshold
- Pick
  - Projection that uses a condition with functions that can traverse the tree to remove redundant answers
- Operations implemented using stack-based algorithms on regions
Query Evaluation with Relevance

R. Fagin, A. Lotem, M. Naor, Optimal aggregation algorithms for middleware, JCSS 2003 (Garlic System 1995)

- Threshold Algorithm
  - Given m sorted lists with object rankings
  - Aggregate the rankings from each list for each object
  - Return the top k ranked objects
  - Instance Optimal Solution: do sorted access (and the corresponding random access) until you know you have seen the top k answers
- IR Application: objects are document (fragments) and each list has the relevance of each document for a given keyword

Agenda

1. Motivation
2. An Introduction to IR
3. Requirements for DB-IR
4. Semi-structured Data
5. Industrial DB-IR Examples: Oracle, Verity
6. DB Approaches
7. IR & Hybrid Approaches
8. Open Problems
9. Bibliography

7. Hybrid & IR Approaches

- Overview of Approaches
- Retrieval Models
- Indexing
- INEX
- Ranking XML
Overview of Approaches

- RBD + IR: Two different APIs
- RDB + IR Hybrid: QUIQ, MOA, HySpirit, ...
- RBD “text search” accelerator
  - Text content is transformed to flat XML
  - XML is searched using an IR API
  - Results can be later combined with SQL
- IR System with SQL support
  - Special indexes for atomic data types
- XML Databases
  - Atomic data types as attributes (metadata)
  - Implementation on top of structured text models?

QUIQ (Kabra et al, 2003)

- Tuple: <tag-name, tag-type, tag-value>
- Query: match-filter-quality
  - Result: AND of match & filter
  - Match are approximate constraints
  - Filter are exact constraints
  - Relevance is adjusted by quality
- Indexing: built on top of a RDBMS
  - Non-text data is mapped to pseudo-words
  - Unified index & common TF-IDF model
  - Deferred update operations
- Evaluation: 60% faster than a RDBMS text extension

Retrieval Models

- Relational Model: DB2XML, XML-QL, TSIMMIS, LOREL
- Object-oriented Model: SOX, StruQL, ...
- Extended Vector Model
- Weighted Boolean Model: XQL, ...
- Probabilistic Model: XIRQL, ELIXIR, JunuXML, ...
Indexing

- Flat File: add information, SQL accelerators, ...
- Semi-structured:
  - Field based: no overlapping, Hybrid model, ...
  - Segment based: Overlapped list, List of references, p-strings
  - Tree based: Proximal Nodes, XRS, ...
- Structured:
  - IR/DB, Path-based, Position-based, Multidimensional
- Indexes:
  - Structure + Value index (XML on top of RDBs):
    - Toxin, Dataguides, T-indexes, Index Fabric, etc.
  - Integrated Full-text and Structure index:
    - Proximal Nodes, Region Algebra, String Indexing, ...

XPath over Proximal Nodes (Navarro & Ortega, 2003)

- A fast implementation of XPath subset
- Maps XPath expressions into Proximal Nodes algebra
- Format translation of Axes
- Node + Text index
- Lazy evaluation

<table>
<thead>
<tr>
<th>Query</th>
<th>XPN</th>
<th>Xmd</th>
<th>xKat</th>
<th>Grup</th>
<th>Saxon</th>
<th>MS</th>
<th>Tails</th>
</tr>
</thead>
<tbody>
<tr>
<td>/text/book/cell/boss/chap</td>
<td>1.5</td>
<td>20.5</td>
<td>8.8</td>
<td>3.4</td>
<td>4.0</td>
<td>3.3</td>
<td>2.5</td>
</tr>
<tr>
<td>/text/ccrop/color</td>
<td>0.5</td>
<td>2.8</td>
<td>2.0</td>
<td>0.7</td>
<td>3.3</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>/text::color</td>
<td>1.8</td>
<td>58.9</td>
<td>8.8</td>
<td>3.8</td>
<td>4.1</td>
<td>3.2</td>
<td>2.5</td>
</tr>
<tr>
<td>/text/chap::</td>
<td>0.9</td>
<td>22.7</td>
<td>8.8</td>
<td>3.7</td>
<td>4.0</td>
<td>4.2</td>
<td>2.5</td>
</tr>
<tr>
<td>/text::title</td>
<td>0.4</td>
<td>9.9</td>
<td>9.8</td>
<td>0.7</td>
<td>3.4</td>
<td>1.8</td>
<td>3.7</td>
</tr>
<tr>
<td>/following-sibling::title</td>
<td>0.5</td>
<td>2.6</td>
<td>9.8</td>
<td>0.7</td>
<td>3.3</td>
<td>1.3</td>
<td>2.5</td>
</tr>
</tbody>
</table>

INEX

- Initiative for the Evaluation of XML
- Three types of tasks:
  - Content only search
  - Content & Structure Search
  - Clustering
- Started in 2002
- Cooperative relevance assessment
- About 40 groups per year
Ranking XML

- Content only:
  - exploit hierarchical structure
  - exploit importance of tags
- Content & structure:
  - Query languages with uncertainty & vagueness
  - Data types with vague predicates
  - Strict & fuzzy structural conditions
  - Dynamic \( tf \times idf \)

Integrated IR (Bremer & Gertz)

- Extension to XQuery
- Based on XML fragments
- Schemas are extended DataGuides
  - Enumeration of all rooted label paths
- Ancestor relationships from structural joins
- RANKBY-operator
  - based on local & dynamic \( tf\times idf \)
- New node enumeration encoding
- Path & term-index
  - Other smaller indexes (in total less than 60%)
- More than 10 times faster than other XQuery prototypes

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8. Open Problems

- Heterogenous data
- Ranking tuples & XML
- New retrieval models
- DB issues for documents
- Simple/succinct vs. complex/verbose QL
  - Define an XQuery core?
- Optimization and algebras
- Efficient algorithms
- Indexing & searching
- Quality evaluation (Web, XML)

Thank You

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Come to SIGIR 2005, Salvador, Bahia, Brazil (August)

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