Query Engines for Web-Accessible XML Data

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Adding XML Support to an OODB

I will present:

- an extension to ODMG ODL, called ***XML-ODL***;
- an extension to ODMG OQL, called ***XML-OQL***;
- a mapping from XML-ODL to ODL;
- a translation scheme from XML-OQL queries into efficient OQL code.

Design Goals

We wanted to:

- provide full XML functionality to the data model and query language of an existing DBMS (λ-DB);
- provide uniform access of:
  - database data,
  - database-resident XML data (both schema-based & schema-less), and
  - web-accessible XML data (native form),

  in the same query language;
- facilitate effective data storage and efficient query evaluation based on schema information (when available);
- provide clear, compositional semantics;
- avoid data translation.

Why Object-Oriented Databases?

- It is easier and more natural to map nested XML elements to nested collections than to flat tables;
- The translation of syntactic extensions into the core query language may create many levels of nested queries. But SQL supports very limited forms of query nesting, group-by, sorting, etc.

  e.g. it is difficult to translate an XML query that constructs XML elements on the fly into SQL.
- OQL can become a full-fledged XML query language with minimal effort. OQL already provides:
  - sorting,
  - arbitrary nesting of queries,
  - grouping & aggregation,
  - universal & existential quantification,
  - random access of list sub-elements.

Related Work

- Many XML query languages (XQL, Quilt, XML-QL, Lorel, Ozone, POQL, WebOQL, X-OQL,…) and a possible standard (XQuery).
- Some XML projects use OODB technology: Lore, YAT/Xyleme, eXcelon, …
- More recently (June 2001), XQuery has been given typing rules and formal semantics (a mapping from XQuery to Core XQuery).

What is New Here?

- The design of our language extensions was driven by semantics, not standards.
- We provide complete, compositional semantics, which is also used as an effective translation scheme.
- In our semantics:
  - schema-less, schema-based, and web-accessible XML data, as well as OODB data, can be handled together in the same query;
  - schema-less queries do not have to change when a schema is given (static errors supersede run-time errors);
  - schema information, when provided, is utilized for effective storage and efficient query processing.

XML-OQL = OQL + Syntactic Extensions

Path expressions:

- e.A — tag projection
- e._ — any projection
- e.* — wildcard projection (all descendants)
- e.@A — XML attribute projection
- e[\v→e'] — filtering
- e[e'] — indexing

Element construction:

- <tag> e_1, ..., e_n </tag>

Entry points:

- retrieve("handle") — database-resident XML data
- document("file.xml") — native form

An XML-OQL Example

```
select <bib> <author> b.author.lastname </author>,
             <title> b.title </title>,
             <related> select <title> r.title </title>
                       from r in b.@related_to
             </related>
       </bib>
  from b in document("bibliography.xml").bib.*.book
 where b.year>1995
   and count(b.author)>2
   and b.title like "% Emacs %“
```

```
<bib>
 <vendor id="id0_1">
   <name>Amazon</name>
   <email>webmaster@amazon.com</email>
   <book  ISBN="0-8053-1755-4"   related_to="0-7482-6284-4 07365-6522-7">
      <title>Learning GNU Emacs</title>
      <publisher>O'Reilly</publisher>
      <year>1996</year>
      <price>40.33</price>
      <author> <firstname>Debra</firstname> <lastname>Cameron</lastname></author>
      <author> <firstname>Bill</firstname> <lastname>Rosenblatt</lastname></author>
      <author> <firstname>Eric</firstname> <lastname>Raymond</lastname> </author>
   </book>
 </vendor>
</bib>
```

Result

```
<bib>
 <author>"Cameron", "Rosenblatt", "Raymond"</author>,
 <title>”Learning GNU Emacs”</title>,
 <related>
   <title>”GNU Emacs and XEmacs”</title>,
   <title>”GNU Emacs Manual”</title>
 </related>
</bib>
```

Schema-Less (Generic) Mapping

A fixed ODL schema for storing schema-less XML data:

```
class XML_element ( extent Elements )
{    attribute          element_type      element;
};
union element_type switch ( element_kind )
{    case TAG:              node_type     tag;
     case PCDATA:           string        data;
};
struct node_type
{    string                          name;
     list< attribute_binding >       attributes;
     list< XML_element >             content;
};
```

Translation of XML-OQL Paths

For example, e.A is translated into:

```
select y
from x in e,
        y in ( case x.element of
                  PCDATA: list( ),
                  TAG: if  x.element.tag.name = "A"
                           then x.element.tag.content
                           else list( )
               end )
```

Wildcard projection, e.*, requires a transitive closure (a recursive OQL function).

XML-ODL

XML-ODL incorporates Xduce-style XML types into ODL:

()	identity
A[t]	tagged type
$\{A_1:s_1,\ldots,A_n:s_n\}$ t	type with attributes ($s_1,\ldots,s_n$ are simple types)
t_1, t_2	concatenation
$t_1 \mid t_2$	alternation
t*	repetition
t?	optionality
any	schema-less XML
integer	
string	

XML[t] may appear anywhere an ODL type is expected.

XML-ODL Example

```
<!ELEMENT bib (vendor*)>
<!ELEMENT vendor (name, email, book*)>
<!ATTLIST vendor id ID #REQUIRED>
<!ELEMENT book (title, publisher?, year?, price, author+)>
<!ATTLIST book ISBN ID #REQUIRED>
<!ATTLIST book related_to IDrefs>
<!ELEMENT author (firstname?, lastname)>
```

```
bib[ vendor[ { id: ID }
                ( name[string],
                  email[string],
                  book[ { ISBN: ID,
                          related_to: bib.vendor.book.ISBN* }
                          ( title[string],
                            publisher[string]?,
                            year[integer],
                            price[integer],
                            author[ firstname[string]?,
                                    lastname[string] ]+ )
                  ]* )
          ]*
   ]
```

XML-ODL to ODL Mapping

Some mapping rules:

[A[t]]	→	[t]
[t_1, t_2]	→	**struct** { [t_1] fst; [t_2] snd; }
[t_1 | t_2]	→	**union** (utag) { **case** LEFT: [t_1] left; **case** RIGHT: [t_2] right; }
[t*]	→	list< [t] >

If it has an ID attribute, [{A_1:s_1,…,A_n:s_n} t] is mapped to a class; otherwise, it is mapped to a struct.

XML-OQL to OQL Mapping

$[\ t\ ]^{x}_{e.A}$ maps the XML path e.A into OQL code, given that the type of e is t and the mapping of e is x.

Some mapping rules:

$[\ A[t]\ ]^{x}_{e.A} \rightarrow$ x

$[\ B[t]\ ]^{x}_{e.A} \rightarrow$ empty

$$[\ t_1, t_2\ ]^{x}_{e.A} \rightarrow \begin{cases} [\ t_1\ ]^{x.fst}_{e.A} & \text{if } [\ t_2\ ]^{x.snd}_{e.A} \text{ is empty} \\ [\ t_2\ ]^{x.snd}_{e.A} & \text{if } [\ t_1\ ]^{x.fst}_{e.A} \text{ is empty} \\ \text{struct } \{ \text{ fst: } [\ t_1\ ]^{x.fst}_{e.A}\text{; snd: } [\ t_2\ ]^{x.snd}_{e.A}\text{; } \} \end{cases}$$

$$[\ t^*\ ]^{x}_{e.A} \rightarrow \begin{cases} \text{empty} & \text{if } [\ t\ ]^{x}_{e.A} \text{ is empty} \\ \text{select } [\ t\ ]^{v}_{e.A} \text{ from v in x} \end{cases}$$

No searching (transitive closure) is needed for e.*

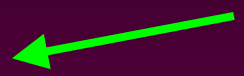
Search Engine for Web XML Files

These are the XML documents stored in their native form at remote locations. For example,

document("*").*.bib.*.author.*.name

XML inverse indexes can be coded in ODL:

```
struct word_spec { doc, level, location };
struct tag_spec { doc, level, ordinal, begin_loc, end_loc };
class XML_word ( key word extent word_index )
{ attribute string word;
  attribute set< word_spec > occurs;
};
class XML_tag ( key tag extent tag_index )
{ attribute string tag;
  attribute set< tag_spec > occurs;
};
```



document fragment

XML-OQL path expressions over web-accessible XML data can now be translated into OQL code over these indexes.

Translating Web XML-OQL

The path expression e.A is mapped to:

```
select y.doc, y.level, y.begin_loc, y.end_loc
from x in e,
        a in tag_index,
        y in a.occurs
where a.tag="A"
   and x.doc=y.doc
   and x.level+1=y.level
   and x.begin_loc<y.begin_loc
   and x.end_loc>y.end_loc
```

A typical query optimizer will use the primary index of tag_index (a B^+-tree) to find the elements with tag "A".

Much influenced by Niagara, but well integrated with the rest XML-OQL.

You May Ask …

- Compositional semantics is fine for proving the soundness of rules, but is it effective for implementing high-performance systems?
- Why don't you use a semi-structured algebra?
- OODBs are a dead beat now. Why don't you use a relational database?
- OK, this framework looks fine for XML-OQL. What about "real" XML query languages, such as XQuery?
- What about DTDs and XML Schemas?

Final Thoughts

- There are many benefits in storing and retrieving both XML and database data in the same system and language.
- There is common ground between XML Schema and ODL and between XQuery and OQL that we can take advantage of.
- OODB technology has a great potential for storing/retrieving XML data.

Current status: we have built a prototype system on top of λ-DB (an ODMG-based OODBMS).