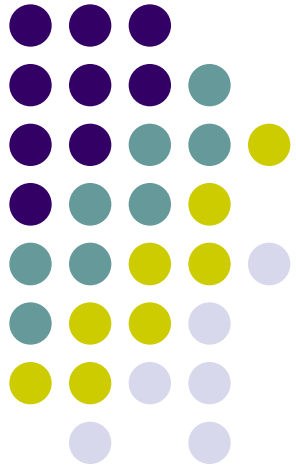
NPRG039

Advanced Aspects and New Trends in XML (and Related) Technologies

RNDr. Irena Holubová, Ph.D.

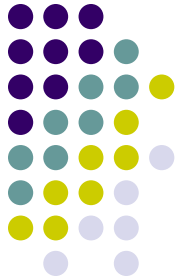
holubova@ksi.mff.cuni.cz



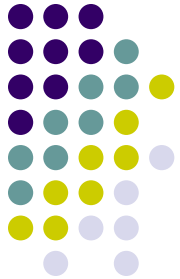
Lecture 4. Support of XML in Oracle DB

http://www.ksi.mff.cuni.cz/~holubova/NPRG039/

Oracle XML Database (XML DB)

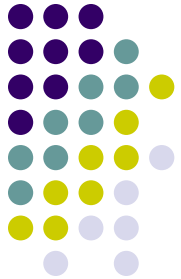


- Collection of XML technologies built into Oracle DB
  - XML-enabled database
  - Storage, retrieval, processing of XML data
- Topics:
  - XML data storage
    - XML Schema annotations
    - XML storage comparison
  - Generating XML from SQL data
  - XML data retrieval
  - XML data updates
  - XML data indexing
  - Evolution of XML applications



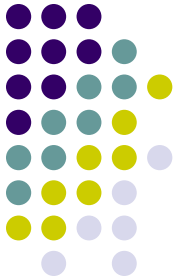
XML Data Storage

XMLType



- Native data type for storing XML data
  - Similar to, e.g., data type DATE
    - Table column type, parameter, return value or variable in PL/SQL procedures, ...
  - Content must be well-formed
- Types of storage:
  1. Storing intact into a **CLOB** XMLType column
  2. **Native storing** of XMLType column
  3. **Shredding** into relational tables (object-relational storage)
- Built-in member functions:
  - Creating an XMLType instance from various resources
  - Extracting XML content
  - Operating XML content
  - Validating against XSDs
  - XSL transformations

XMLType
CLOB storage



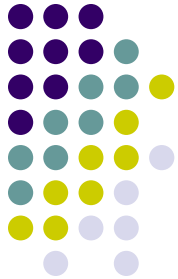
- Advantages:
  - Best preserves original format
  - Maximum flexibility for XML schema evolution
- Disadvantages:
  - Expensive querying and updates
    - Require building a DOM tree

```
CREATE TABLE product (
  id VARCHAR(10),
  name VARCHAR2(100),
  description XMLType )
XMLTYPE COLUMN description
  STORE AS CLOB;
```

```
INSERT INTO product (id, name, description)
  VALUES ('XDK', 'XML Developer''s Kit',
    XMLTYPE('<DESCRIPTION><KEYWORD>xdk</KEYWORD> is a
set of standards-based utilities that help to build XML
applications.</DESCRIPTION>'));
```

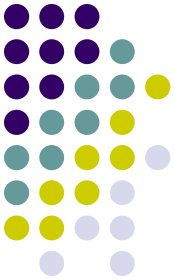
XMLType

XML Schema-based Storage



- Object-relational structure specified by an XSD
  - Defines how to shred an XML document into SQL objects
- Advantages:
  - Speeding up queries and updates (= exploitation of efficient implementation of SQL queries)
- Each XSD must be first registered under a unique URL
  - To be referenced from XML Schema-based XMLTypes
  - Registration:
    - Creating SQL objects
    - (Optional) generation of a default table
      - XML DB Repository

Registration of an XSD



```
BEGIN
  DBMS_XMLSCHEMA.registerSchema(
    SCHEMAURL=>'http://xmlns.oracle.com/xml/content.xsd',
    SCHEMADOC=>'<?xml version="1.0" encoding="UTF-8"?>
  <xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
    <xs:element name="DESCRIPTION">
      <xs:complexType mixed="true">
        <xs:choice minOccurs="0" maxOccurs="unbounded">
           <xs:element name="KEYWORD" type= "xs:string"
                       maxOccurs="unbounded"/>
        </xs:choice>
      </xs:complexType>
    </xs:element>
  </xs:schema>',
    LOCAL=>true,
    GENTYPES=>true,
    GENTABLES=>false);
END;
```

For current user

Generate types

Generate tables

During Registration

- SQL objects to store XMLType are generated
- Default tables are created

```
SELECT object_name, object_type FROM user_objects;
```

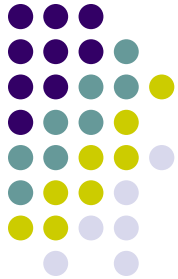
```
OBJECT_NAME  OBJECT_TYPE
-------------------------
KEYWORD209_COLL   TYPE
DESCRIPTION208_T  TYPE
…
```

```
describe KEYWORD209_COLL;
```

```
"KEYWORD209_COLL" AS VARRAY(2147483647) OF VARCHAR2(4000 CHAR)
```

XMLType

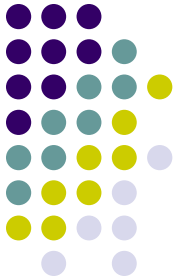
XML Schema-based Storage



```
CREATE TABLE product (
  id VARCHAR(10),
  name VARCHAR2(100),
  description XMLType )
XMLType COLUMN description
XMLSCHEMA "http://xmlns.oracle.com/xml/content.xsd"
ELEMENT "DESCRIPTION"
```

```
INSERT INTO product (id, name, description)
  VALUES ('XDK', 'XML Developer''s Kit',
  XMLTYPE('<DESCRIPTION><KEYWORD>xdk</KEYWORD> is a set of
standards-based utilities that help to build XML
applications.</DESCRIPTION>').createSchemaBasedXML
  ('http://xmlns.oracle.com/xml/content.xsd'));
```

XMLType Tables

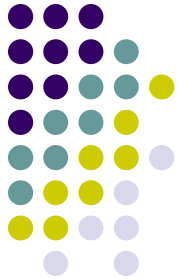


```
CREATE TABLE product2 OF XMLType;
```

```
CREATE TABLE product2 OF XMLType
XMLSCHEMA "http://xmlns.oracle.com/xml/content.xsd"
ELEMENT "DESCRIPTION";
```

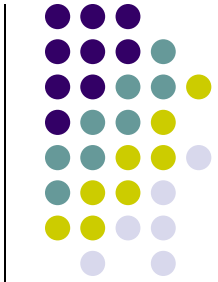
```
INSERT INTO product2 VALUES (
  XMLTYPE(
    bfilename('XMLDIR', 'productdata1.xml'),
    nls_charset_id('AL32UTF8')));
```

Default XML Schema-based DB Structure



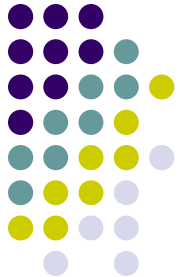
- `complexType` → SQL type
  - Oracle is an object-relational RDBMS
  - Tables are created from objects
- An element/attribute defined by the `complexType` → SQL attribute of the SQL type
  - By default inlined
- 47 XML Schema data types → 19 scalar SQL data types
- Element with `maxOccurs` > 1 → collection attribute
  - By default VARRAY stored in a LOB
- XML Schema type/element/attribute names → SQL type/attribute names

Introducing Binary XML Storage



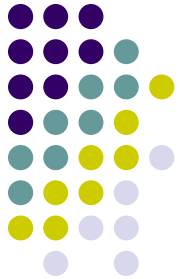
- Oracle 10g:
  - Structured (object-relational) − a set of objects (shredding)
  - Unstructured (text-based) − CLOB
- Oracle 11g adds:
  - Binary (native) − post-parse, binary format specifically designed for XML data
  - Hybrid − mix of storage models for different parts of XML data

Binary Storage Models



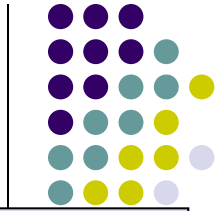
- **Structured storage** = default
- **Unstructured storage**: `STORE AS CLOB`
- **Binary storage** + usage of XML schema:
  1. Non-schema-based − possibly existing schema is ignored
     - But validation can be made explicitly
  2. Single XML schema − all rows/columns must conform to the schema
  3. Multiple XML schemas − each row can reference own XML schema
     - Non-schema based documents can be allowed
  - `CREATE TABLE` options:
    - `STORE AS BINARY XML`
    - `STORE AS BINARY XML XMLSCHEMA ...`
    - `STORE AS BINARY XML XMLSCHEMA ... ALLOW NONSCHEMA`
    - `STORE AS BINARY XML ALLOW ANYSCHEMA`
    - `STORE AS BINARY XML ALLOW ANYSCHEMA ALLOW NONSCHEMA`

Structured Storage



- By default:
  - Collections are mapped into SQL VARRAY values
  - Entire contents of such a VARRAY is serialized using a single LOB column
- Idea:
  - Optimal insertion and retrieval of entire document
- Limitations: indexing, updating, retrieval of individual members of the collection
- Overriding of default storage:
  - STORE AS clause of CREATE TABLE
  - Annotations of XML schema

STORE AS Clause – Sample Data



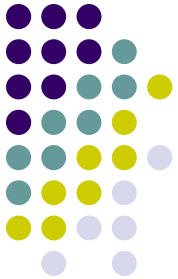
```
<xs:schema
  targetNamespace="http://xmlns.oracle.com/xdb/documentation/purchaseOrder"
  xmlns:po="http://xmlns.oracle.com/xdb/documentation/purchaseOrder"
  xmlns:xs="http://www.w3.org/2001/XMLSchema" version="1.0">
  <xs:element name="PurchaseOrder" type="po:PurchaseOrderType"/>
   <xs:complexType>
    <xs:sequence>
        <xs:element name="Reference" type="po:ReferenceType"/>
        <xs:element name="Actions" type="po:ActionsType"/>
        <xs:element name="Reject" type="po:RejectionType" minOccurs="0"/>
        <xs:element name="Requestor" type="po:RequestorType"/>
        <xs:element name="User" type="po:UserType"/>
        <xs:element name="CostCenter" type="po:CostCenterType"/>
        <xs:element name="ShippingInstructions"
                    type="po:ShippingInstructionsType"/>
        <xs:element name="SpecialInstructions"
                    type="po:SpecialInstructionsType"/>
        <xs:element name="LineItems" type="po:LineItemsType"/>
        <xs:element name="Notes" type="po:NotesType"/>
      </xs:sequence>
    </xs:complexType>
    <xs:complexType name="LineItemsType">
      <xs:sequence>
        <xs:element name="LineItem" type="po:LineItemType"
                    maxOccurs="unbounded"/>
      </xs:sequence>
    </xs:complexType>

    ...
 </xs:schema>
```

STORE AS Clause

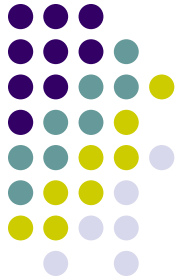
```
CREATE TABLE purchaseorder_as_table
  OF XMLType (UNIQUE ("XMLDATA"."Reference"),
              FOREIGN KEY ("XMLDATA"."User")
                REFERENCES hr.employees (email))
ELEMENT "http://xmlns.oracle.com/purchaseOrder.xsd#PurchaseOrder"
  VARRAY "XMLDATA"."Actions"."Action"
    STORE AS TABLE action_table1
      ((PRIMARY KEY (NESTED_TABLE_ID, SYS_NC_ARRAY_INDEX$)))
  VARRAY "XMLDATA"."LineItems"."LineItem"
    STORE AS TABLE lineitem_table1
      ((PRIMARY KEY (NESTED_TABLE_ID, SYS_NC_ARRAY_INDEX$)))
  LOB ("XMLDATA"."Notes")
    STORE AS (TABLESPACE USERS ENABLE STORAGE IN ROW
      STORAGE(INITIAL 4K NEXT 32K));
```

(EN/DISABLE) in/outlining

STORE AS Clause

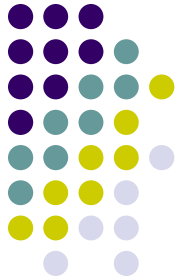


```
CREATE TABLE purchaseorder_as_column (
  id NUMBER,
  xml_document XMLType,
  UNIQUE (xml_document."XMLDATA"."Reference"),
  FOREIGN KEY (xml_document."XMLDATA"."User")
    REFERENCES hr.employees (email))

  XMLTYPE COLUMN xml_document
  XMLSCHEMA "http://xmlns.oracle.com/xdb/documentation/purchaseOrder.xsd"
  ELEMENT "PurchaseOrder"

  VARRAY xml_document."XMLDATA"."Actions"."Action"
    STORE AS TABLE action_table2
      ((PRIMARY KEY (NESTED_TABLE_ID, SYS_NC_ARRAY_INDEX$)))
  VARRAY xml_document."XMLDATA"."LineItems"."LineItem"
    STORE AS TABLE lineitem_table2
      ((PRIMARY KEY (NESTED_TABLE_ID, SYS_NC_ARRAY_INDEX$)))
  LOB (xml_document."XMLDATA"."Notes")
    STORE AS (TABLESPACE USERS ENABLE STORAGE IN ROW
      STORAGE(INITIAL 4K NEXT 32K));
```



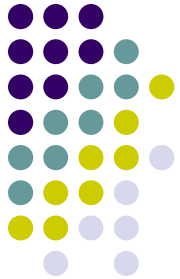
XML Schema Annotations

XML Schema Annotations



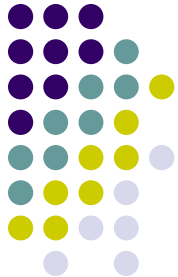
- To control the mapping between XSD and storage methods
- Namespace: http://xmlns.oracle.com/xdb
  - Prefix: xdb
- Attribute types:
  - Default table − name and storage options of the default XMLType table
  - SQL names − SQL names for element in the schemas
  - SQL types − SQL data types for simple and complex XML Schema types
  - Maintain DOM − whether to preserve DOM fidelity of an element
    - XML DB adds position descriptor for comments, PIs, sibling element order, ... → increases storage overhead
  - Storage options − for optimizing storage

Annotating Attributes (1)



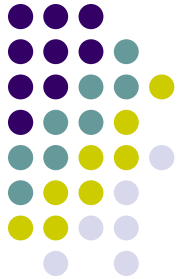
- Element `schema`:
  - **`xdb:storeVARRAYAsTable`**
    - **true** = store collection elements (`maxOccurs` > 1) in nested object tables
    - **false** = collection is serialized as a VARRAY in a LOB column
  - **`xdb:mapUnboundedStringToLob`**
    - **true** = unbounded strings/binary data are stored to BLOB/CLOB
    - Default: false → VARCHAR2(4000) / RAW(2000)
- Global complex types:
  - **`xdb:SQLType`**
    - Name of the SQL type
      - To avoid XML DB-generated names for complex types
      - To change storage from object-relational to VARCHAR2, RAW, CLOB, BLOB
  - **`xdb:maintainDOM`**
    - **true** (default) = the complex type should maintain DOM fidelity

Annotating Attributes (2)



- XML elements:
  - **`xdb:SQLName`**
    - Specifies the name of the attribute within the SQL object that maps to this XML element
  - **`xdb:SQLType`**
    - Name of SQL type corresponding to the element
  - **`xdb:SQLCollType`**
    - The name of the SQL collection type
      - For elements with `maxOccurs` > 1
  - **`xdb:maintainDOM`**

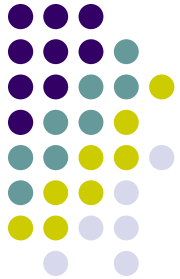
Annotating Attributes (3)



- **`xdb:SQLInline`**
  - **true** (default) = embedded attribute
  - **false** = a REF value is stored (or a collection of REF values, if `maxOccurs` > 1)
- **`xdb:maintainOrder`**
  - **true** (default) = collection is mapped to VARRAY
  - **false** = collection is mapped to a nested table
- **`xdb:defaultTable`**
  - Name of the table into which XML instances are stored
    - A link from XML DB repository is created to this table
- **`xdb:tableProps`**, **`xdb:columnProps`**
  - Default table properties in SQL appended to the CREATE TABLE

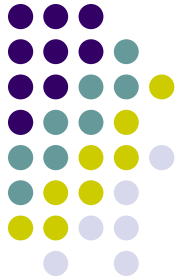
```
<xs:complexType name="LineItemsType" xdb:SQLType="LINEITEMS_T">
  <xs:sequence>
    <xs:element name="LineItem" type="LineItemType" maxOccurs="unbounded"
                xdb:SQLName="LINEITEM" xdb:SQLCollType="LINEITEM_V"/>
  </xs:sequence>
</xs:complexType>

<xs:complexType name="LineItemType" xdb:SQLType="LINEITEM_T">
  <xs:sequence>
    <xs:element name="Description" type="DescriptionType"
                xdb:SQLName="DESCRIPTION"/>
    <xs:element name="Part" type="PartType" xdb:SQLName="PART"/>
  </xs:sequence>
  <xs:attribute name="ItemNumber" type="xs:integer"
                xdb:SQLName="ITEMNUMBER" xdb:SQLType="NUMBER"/>
</xs:complexType>

<xs:complexType name="PartType" xdb:SQLType="PART_T">
  <xs:attribute name="Id" xdb:SQLName="PART_NUMBER" xdb:SQLType="VARCHAR2">
    <xs:simpleType>
      <xs:restriction base="xs:string">
        <xs:minLength value="10"/>
        <xs:maxLength value="14"/>
      </xs:restriction>
    </xs:simpleType>
  </xs:attribute>
  <xs:attribute name="Quantity" type="moneyType" xdb:SQLName="QUANTITY"/>
  <xs:attribute name="UnitPrice" type="quantityType" xdb:SQLName="UNITPRICE"/>
</xs:complexType>
```

XML Schema Annotations

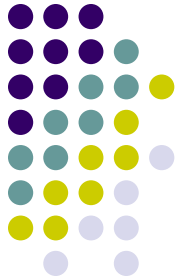


- Too many options → the most common strategy:
  - Specify the name of the default table
    - `defaultTable`
  - Specify the name and data type for each element and data type
    - `SQLName`, `SQLType`, `SQLCollType`
- Note that:
  - `SQLName` – SQL names for XML elements
  - `SQLCollName` – SQL names for elements with `maxOccurs` > 1
  - `SQLType` – SQL names for all simple types or complex types that do not use default mapping

XML Schema Annotations

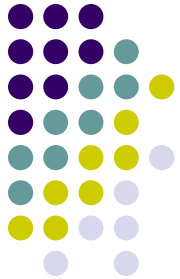


- Recommendations:
  - Avoid preserving DOM fidelity
  - Store subtrees/complex types as CLOB when no XPath queries are required
    - xdb:SQLType="CLOB"
  - Store large unbounded XML elements using nested tables
    - xdb:storeVARRAYAsTable="true"
- Important:
  - SQL is case-insensitive, but names in SQL code are implicitly uppercase, unless you enclose them in double-quotes
  - XML is case-sensitive – you must refer to SQL names in XML code using the correct case: uppercase SQL names must be written as uppercase



XML Storage Comparison

How to Store XML Data?

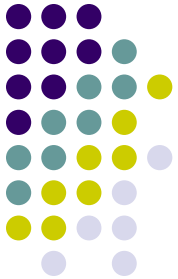


- XMLType or Relational tables?
  - Data-centric documents: structured
    - Efficient retrieval
    - No need to preserve XML format
    - If necessary: XMLType Views
  - Document-centric documents: XMLType
  - Hybrid documents: ?
- XMLType schema based storage?
  - No (CLOB): DTD based documents, changing XSDs
  - Yes: intensive data retrieval/updates
- XMLType table or column?
  - Column: We need to store relational data along with XML documents
    - Example: create time, create owner, ...

Quality	Structured	Unstructured	Binary
Throughput	– XML decomposition can result in reduced throughput when ingesting retrieving the entire content of an XML document.	+ High throughput when ingesting and retrieving the entire content of an XML document.	++ High throughput. Fast DOM loading.
Space efficiency (disk)	++ Extremely space-efficient.	– Consumes the most disk space, due to insignificant whitespace and repeated tags.	+ Space-efficient.
Data flexibility	– Limited flexibility. Only documents that conform to the XML schema can be stored in the XMLType table or column.	+ Flexibility in the structure of the XML documents that can be stored in an XMLType column or table.	+ Flexibility in the structure of the XML documents that can be stored in an XMLType column or table.
XML schema flexibility	– Relatively inflexible. Data and metadata are stored separately. Cannot use multiple XML schemas for the same XMLType table.	+ Flexible. Data and metadata are stored together. Cannot use multiple XML schemas for the same XMLType table.	++ Flexible. Can store data and metadata together or separately. Can use multiple XML schemas for the same XMLType table.
Update operations (DML)	++ In-place, piecewise update.	– When any part of the document is updated, the entire document must be written back to disk.	+ In-place, piecewise update for SecureFile LOB storage.

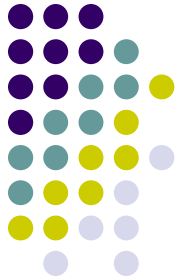
Quality	Structured	Unstructured	Binary
XML fidelity	– DOM fidelity: A DOM created from an XML document that has been stored in the database will be identical to a DOM created from the original document. However, insignificant whitespace may be discarded.	+ Document fidelity: Maintains the original XML data, byte for byte. In particular, all original whitespace is preserved.	– DOM fidelity (see structured storage description).
XPath-based queries	++ XPath operations can often be evaluated using XPath rewrite, leading to significantly improved performance, particularly with large collections of documents.	– XPath operations are evaluated by constructing a DOM from the CLOB data and using functional evaluation. Expensive when performing operations on large documents or large collections of documents. XMLIndex indexing can improve performance of XPath-based queries.	+ Streaming XPath evaluation avoids DOM construction and allows evaluation of multiple XPath expressions in a single pass. Navigational XPath evaluation is significantly faster than with unstructured storage. XMLIndex indexing can improve performance of XPath-based queries.
SQL constraint support	+ SQL constraints are supported.	– SQL constraints are not available.	+ SQL constraints are supported.

Quality	Structured	Unstructured	Binary
Support for SQL scalar data types	+ Yes	– No	+ Yes
Indexing support	B-tree, Oracle Text, and function-based indexes.	XMLIndex, function-based, and Oracle Text indexes.	XMLIndex, function-based, and Oracle Text indexes.
Optimized memory management	+ XML operations can be optimized to reduce memory requirements.	– XML operations on the document require creating a DOM from the document.	+ XML operations can be optimized to reduce memory requirements.
Validation upon insert	XML data is partially validated when it is inserted.	XML schema-based data is partially validated when it is inserted.	+ XML schema-based data is fully validated when it is inserted.



Generating XML from SQL Data

SQL/XML in Oracle (1)



- **XMLELEMENT**
  - Returns an XML element in an XMLType when given:
    - XML element name
    - Optional list of XML attributes (`XMLATTRIBUTES`())
    - Optional list of values as the content of the new element
      - Other XML elements or
      - XML fragments (`XMLFOREST`())
- **XMLATTRIBUTES**
  - Used within `XMLELEMENT`() to specify attributes for the element.

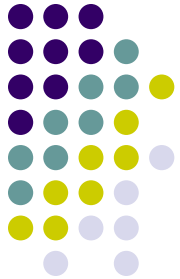
XMLELEMENT, XMLATTRIBUTES

```
CREATE TABLE employees (
  employee_id VARCHAR(10),
  first_name VARCHAR2(100),
  last_name  VARCHAR2(100),
  job_id VARCHAR2(100),
  hire_date DATE,
  salary NUMBER,
  email VARCHAR2(100),
  phone_number  VARCHAR2(100),
  department_id VARCHAR(10));
```

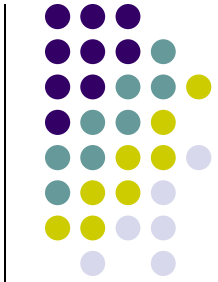
```
SELECT
  XMLELEMENT("Employee",
    XMLATTRIBUTES(employee_id AS "empno",
                  job_id AS "job"),
    XMLELEMENT("Name",
               first_name || ' ' || last_name),
    'is hired on ',
    hire_date) AS result
  FROM employees WHERE rownum=1;
```

```
<Employee empno="100" job="AD_PRES">
  <Name>Steven King</Name>is hired on 17-JUN-87
</Employee>
```

SQL/XML in Oracle (2)

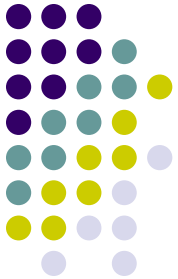


- **XMLFOREST**
  - Returns an XML fragment in an XMLType when given a list of named expressions for the XML elements
  - Each expression specifies the name of an XML element and its content
- **XMLCONCAT**
  - Returns an XML fragment in an XMLType by concatenating a list of XML elements/values
- **XMLAGG**
  - Returns an XML fragment in an XMLType by aggregating XML fragments, with the option of XML element sorting



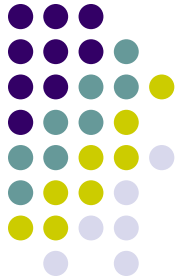
XML Data Retrieval

XMLType Member Functions (1)



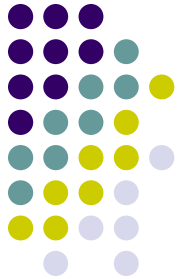
- **`XMLType`**, **`createXML`**, **`createSchemaBasedXML`**, **`createNonSchemaBasedXML`**
  - Create XMLTypes from XML data stored in VARCHAR2, CLOB, or other XMLTypes
- **`getClobVal`**, **`getBlobVal`**, **`getNumberVal`**, **`getStringVal`**
  - Gets the CLOB, BLOB, NUMBER, or String value in VARCHAR2 from the XMLType
  - `getNumberVal` can be used only when the content of XMLType is numeric
- **`transform`**
  - Transforms the XML content in XMLType with the XSL stylesheet specified

XMLType, getCLOBVal



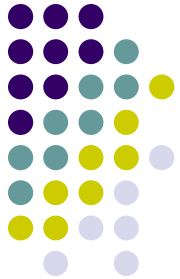
```
CREATE TABLE xml_table OF XMLType;
CREATE TABLE table_with_xml_column
  (filename VARCHAR2(64), xml_document XMLType);

INSERT INTO xml_table
  VALUES (XMLType(bfilename('XMLDIR', 'purchaseOrder.xml'),
          nls_charset_id('AL32UTF8')));
INSERT INTO table_with_xml_column (filename, xml_document)
  VALUES ('purchaseOrder.xml',
          XMLType(bfilename('XMLDIR', 'purchaseOrder.xml'),
          nls_charset_id('AL32UTF8')));

SELECT x.OBJECT_VALUE.getCLOBVal()
  FROM xml_table x;
SELECT x.xml_document.getCLOBVal()
  FROM table_with_xml_column x;
```

XMLType Member Functions (2)



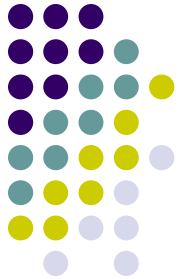
- **`isFragment`**
  - Checks if the XMLType is an XML document fragment or a well-formed document
- **`isSchemaBased`**, **`getSchemaURL`**, **`getRootElement`**, **`getNamespace`**
  - Checks the XML schema–related information of XMLType and returns respective information if exists
- **`isSchemaValidated`**, **`isSchemaValid`**, **`schemaValidation`**, **`setSchemaValidated`**
  - Checks and updates the XML Schema validation status of XMLType

Oracle SQL Extensions



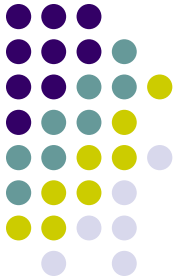
- **`existsNode`**
  - Checks if the XML nodes or node sets specified by an XPath expression exist
- **`extract`**
  - Extracts nodes or node sets based on the XPath expression and returns an XMLType instance containing the resulting node(s)
- **`extractValue`**
  - Returns scalar content, such as numbers or strings, when passed an XPath expression pointing to an XML element with only a single text child

SQL/XML
XMLTable, XMLQuery



- **`XMLQuery`**
  - XQuery-expression evaluation
- **`XMLTable`**
  - Shreds the result of an XQuery-expression evaluation into the relational rows and columns of a new, virtual table
  - Further inserting, SQL querying, ...

XMLQuery

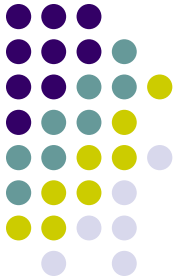


```
SELECT warehouse_name,
       XMLQuery(
         'for $i in /Warehouse
          where  $i/Area > 80000
          return <Details>
                   <Docks num="{$i/Docks}"/>
                   <Rail>{if ($i/RailAccess = "Y")
                          then "true" else "false"}
                   </Rail>
                 </Details>'
         PASSING warehouse_spec RETURNING CONTENT)
           big_warehouses
  FROM warehouses;
```

XMLTable

```
SELECT xtab.poref, xtab.priority, xtab.contact
  FROM purchaseorder,
       XMLTable('for $i in /PurchaseOrder
                 let $spl := $i/SpecialInstructions
                 where $i/CostCenter eq "A10"
                 return <PO>
                          <Ref>{$i/Reference}</Ref>
                          {if ($spl eq "Next Day Air" or
                               $spl eq "Expedite") then
                             <Type>Fastest</Type>
                           else if ($spl eq "Air Mail") then
                             <Type>Fast</Type>
                           else ()}
                          <Name>{$i/Requestor}</Name>
                        </PO>'
                PASSING OBJECT_VALUE
                COLUMNS poref    VARCHAR2(20) PATH '/PO/Ref',
                        priority VARCHAR2(8)  PATH '/PO/Type'
                                 DEFAULT 'Regular',
                        contact  VARCHAR2(20) PATH '/PO/Name')
         xtab;
```

XMLTable

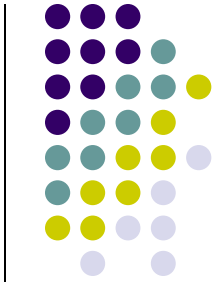


```
POREF                  PRIORITY CONTACT
---------------------- -------- --------------------
SKING-20021009123336   Fastest  Steven A. King
SMCCAIN-200210091233   Regular  Samuel B. McCain
SMCCAIN-200210091233   Fastest  Samuel B. McCain
```

- The result without `COLUMNS`: Table with single column containing the resulting XML fragments

Oracle XQuery Extension

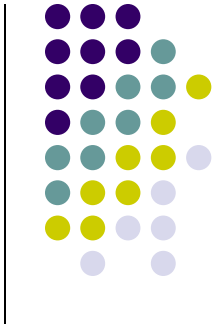
ora:contains



```
ora:contains (input_text, text_query
  [, policy_name] [, policy_owner])
```

- Returns:
  - Positive integer when the `input_text` matches `text_query`
    - The higher the number, the more relevant the match
  - Zero otherwise
- Can be used in:
  - XPath expression inside XQuery expression
  - SQL functions existsNode, extract, extractValue
- `input_text` – single text node/attribute

ora:contains Example

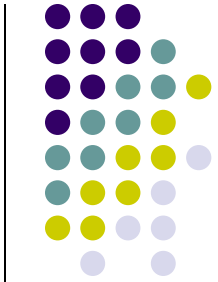


```
SELECT ID
  FROM PURCHASE_ORDERS_xmltype
  WHERE existsNode(DOC,
            '/purchaseOrder/comment[
             ora:contains(text(),
               "($lawns AND wild) OR flamingo") > 0]',
            'xmlns:ora="http://xmlns.oracle.com/xdb"'
          ) = 1 ;
```

- Full-text operators
  - e.g., $ = all words with the same linguistic stem, i.e., lawn or lawns

Oracle XQuery Extension

ora:matches

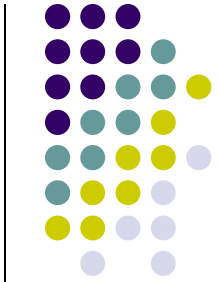


```
ora:matches (target_string, match_pattern
  [, match_parameter])
```

- Returns:
  - **true** – if `target_string` argument matches regular-expression `match_pattern` argument
  - **false** – otherwise
- Optional `match_parameter` is a code that qualifies matching
  - Case-sensitivity etc.

Oracle XQuery Extension

ora:replace

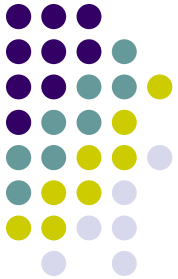


```
ora:replace (target_string, match_pattern,
replace_string [, match_parameter])
```

- Each occurrence in `target_string` that matches `match_pattern` is replaced by `replace_string`
- Returns: new string that results from the replacement
- Optional `match_parameter` is a code that qualifies matching
  - Case-sensitivity etc.

Oracle XQuery Extension

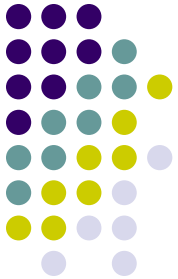
ora:view



```
ora:view ([db-schema STRING,] db-table STRING)
  RETURNS document-node(element())*
```

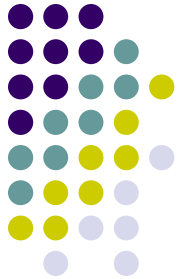
- Creates XML views over the relational data, on the fly
- Parameters:
  - `db-schema` – optional database schema
  - `db-table` – database table or view
- Returns: unordered sequence of document nodes, one for each row of `db-table`
  - SQL/XML standard is used:
    - Relational column names become XML element names
    - Column elements are wrapped together in a ROW element

ora:view Example



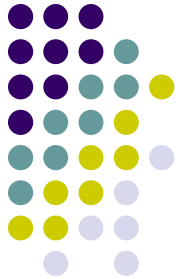
```
SELECT XMLQuery(
  'for $i in ora:view("REGIONS"), $j in ora:view("COUNTRIES")
   where $i/ROW/REGION_ID = $j/ROW/REGION_ID and
         $i/ROW/REGION_NAME = "Asia"
   return $j'
  RETURNING CONTENT) AS asian_countries
FROM DUAL;
```

```
ASIAN_COUNTRIES
----------------------------------------
<ROW>
  <COUNTRY_ID>AU</COUNTRY_ID>
  <COUNTRY_NAME>Australia</COUNTRY_NAME>
  <REGION_ID>3</REGION_ID>
</ROW>
<ROW>
  <COUNTRY_ID>CN</COUNTRY_ID>
  <COUNTRY_NAME>China</COUNTRY_NAME>
  <REGION_ID>3</REGION_ID>
</ROW>
```



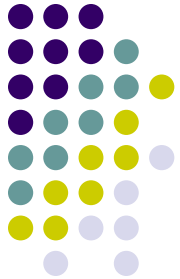
XML Data Updates

Oracle SQL Extensions



- No support for standard **XQuery Update Facility**
- **`updateXML`**
  - Replaces XML nodes of any kind
- **`insertChildXML`**
  - Inserts XML element or attribute nodes as children of a given element node
- **`insertXMLbefore`**
  - Insert XML nodes of any kind immediately before a given node
- **`appendChildXML`**
  - Inserts XML nodes of any kind as the last child nodes of a given element node
- **`deleteXML`**
  - Deletes XML nodes of any kind

updateXML



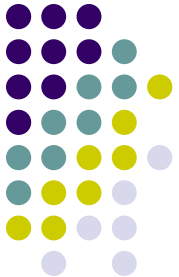
- Accepts:
  - XMLType instance
  - Set of XPath expression – string value pairs
- Updates XPath-referred elements or attributes with the provided values

```
SELECT updateXML (
  column_name,
  'XPath1', 'text1',
  …,
  'XPathN', 'textN',
  'Namespace1 NamespaceN')
FROM table_name;
```

```
SELECT updateXML(XMLType(
    '<Employee xmlns:app1="www.example.com/ns1"
               xmlns:app2="www.example.com/ns2">
      <Name app1:type="Customer">Janet Jones</Name>
      <Job app2:type="IT">Manager</Job>
      <Salary app2:type="Hidden">12000</Salary>
      <Commission app2:type="Hidden">3400</Commission>
    </Employee>'),
    '/Employee/Name/text()', 'Janet Lee',
    '/Employee/Name/@app1:type', 'Important Customer',
    '/Employee/Job/@app2:type', 'Hidden',
    '/Employee//*[@app2:type="Hidden"]', null,
    'xmlns:app1="www.example.com/ns1"
     xmlns:app2="www.example.com/ns2"') AS result
  FROM dual;
```

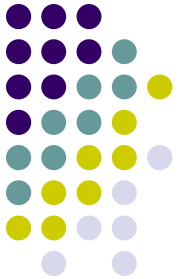
```
<Employee xmlns:app1="www.example.com/ns1"
          xmlns:app2="www.example.com/ns2">
  <Name app1:type="Important Customer">Janet Lee</Name>
  <Job/>
  <Salary/>
  <Commission/>
</Employee>
```

insertChildXML



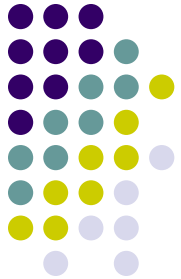
```
UPDATE purchaseorder
  SET OBJECT_VALUE =
    insertChildXML(OBJECT_VALUE,
      '/PurchaseOrder/LineItems',
      'LineItem',
      XMLType(
      '<LineItem ItemNumber="222">
        <Description>The Harder They Come</Description>
        <Part Id="953562951413"
              UnitPrice="22.95"
              Quantity="1"/>
       </LineItem>'))
  WHERE existsNode(OBJECT_VALUE,
   '/PurchaseOrder[Reference="AMCEWEN-20021009123336171PDT"]')
        = 1;
```

insertXMLbefore

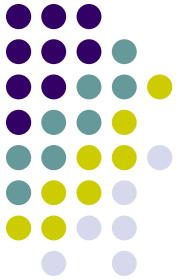


```
UPDATE purchaseorder
  SET OBJECT_VALUE =
    insertXMLbefore(OBJECT_VALUE,
      '/PurchaseOrder/LineItems/LineItem[1]',
      XMLType('<LineItem ItemNumber="314">
                  <Description>Brazil</Description>
                  <Part Id="314159265359"
                        UnitPrice="69.95"
                        Quantity="2"/>
                </LineItem>'))
  WHERE existsNode(OBJECT_VALUE,
   '/PurchaseOrder[Reference="AMCEWEN-20021009123336171PDT"]')
        = 1;
```

deleteXML

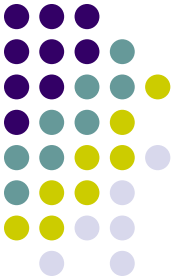


```
UPDATE purchaseorder
  SET OBJECT_VALUE =
      deleteXML(OBJECT_VALUE,
        '/PurchaseOrder/LineItems/LineItem[@ItemNumber="222"]')
  WHERE existsNode(OBJECT_VALUE,
   '/PurchaseOrder[Reference="AMCEWEN-20021009123336171PDT"]')
      = 1;
```



Indexing XMLType Data

Indexing XMLType Data



- Idea: improvement of performance of often and expensive queries
- Storage types:
  - Structured: B-tree indexes on columns and tables
  - Unstructured and hybrid: XMLIndex
    - For CLOB parts
  - Function-based indexes:
    - `XMLQuery`, `XMLExists`, `XMLCast`, `extract`, `extractValue`, `existsNode`
  - Oracle Text Indexes: `ora:contains`
    - full-text

Function-based Index

- On an XMLType table or column
  - XML schema-based or not
  - Storage structured, unstructured, or binary XML
- Function-based index: Created by evaluating the specified function for each row in the target table or column and storing the value in the index
  - B-tree index or bitmap index

```
CREATE TABLE po_clob OF XMLType
  XMLTYPE STORE AS CLOB
  ELEMENT
    "http://localhost:8080/purchaseOrder.xsd#PurchaseOrder";

CREATE UNIQUE INDEX po_fn_based_ix ON po_clob
  (extractValue(OBJECT_VALUE, '/PurchaseOrder/Reference'));
```

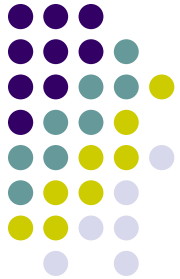
Function-based Index

- Structured storage:
  - Element/attribute being targeted by the function must be a singleton
    - Not a collection
  - If the function being indexed is extractValue, Oracle tries to rewrite it to not function-based index

```
CREATE INDEX po_fn_based_ix ON purchaseorder
  (extractValue(OBJECT_VALUE, '/PurchaseOrder/Reference'));
```

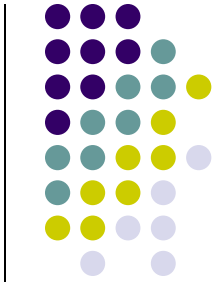
```
CREATE INDEX po_fn_based_ix ON purchaseorder p
(p."XMLDATA"."REFERENCE");
```

Components of an XMLIndex Index



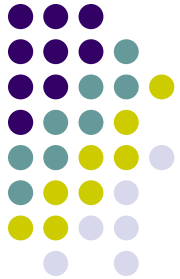
- Path index – indexes the XML tags of a document and identifies its various document fragments
- Order index – indexes the hierarchical positions of the nodes in an XML document
  - parent–child, ancestor–descendant, sibling relations
- Value index – indexes values of an XML document
- Not indexed parts:
  - Applications of XPath functions
    - Except ora:contains
  - Other axes
  - Expressions using the union operator

Path Table



- Implements XMLIndex
- Columns:
  - **`PATHID`** – unique identifier for the XPath path to the node
  - **`RID`** – rowid of the table used to store the XML data
  - **`ORDER_KEY`** – decimal order key that identifies the hierarchical position of the node
  - **`LOCATOR`** – Fragment-location information. Used for fragment extraction
  - **`VALUE`** – text of attribute/simple element node

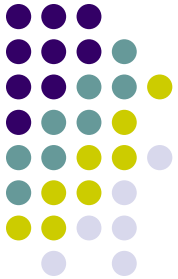
Path Table



PATHID	Indexed XPath
1	/PurchaseOrder
2	/PurchaseOrder/Reference
3	/PurchaseOrder/Actions
4	/PurchaseOrder/Actions/Action
5	/PurchaseOrder/Actions/Action/User

PATHID	RID	ORDER_KEY	VALUE
1	R1	1	——
2	R1	1.1	SBELL-20021009123336O1PDT
3	R1	1.2	——
4	R1	1.2.1	——
5	R1	1.2.1.1	SVOLLMAN
1	R2	1	——
2	R2	1.1	ABEL-20021127121040897PST

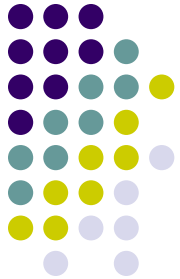
XMLIndex – Usage



```
CREATE INDEX po_xmlindex_ix ON po_clob (OBJECT_VALUE)
INDEXTYPE IS XDB.XMLIndex;
```

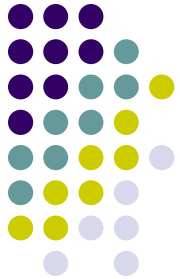
```
CREATE INDEX po_xmlindex_hybrid_ix ON li_clob
  (extract(OBJECT_VALUE, '/PurchaseOrder/LineItems'))
  INDEXTYPE IS XDB.XMLIndex;
```

```
DROP INDEX po_xmlindex_hybrid_ix ;
```



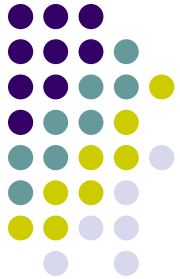
Evolution of XML Applications

Evolution of XML Applications



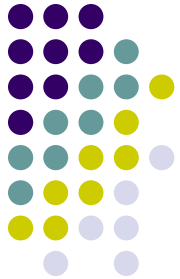
- XML application – an application processing XML data
  - Well-formed, valid against a schema
- Problem:
  - Applications are usually dynamic, user requirements change, new information come, …
  - Structure of data needs to be changed
    - Old schema S_{old}, new schema S_{new}
  - We still want to work with both old and new data
    - Without any loss if possible

Evolution of XML Applications



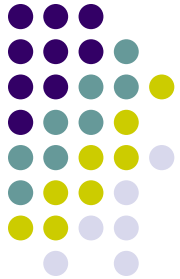
- Approaches:
  - XML schema/data evolution
    - The old data valid against S_{old} are transformed to be valid against S_{new}
    - User poses queries over S_{new}
  - XML data versioning
    - We must preserve all versions $V_1, V_2, \ldots V_n$ of the data
    - User poses queries over any V_i; $1 \leq i \leq n$
      - Retrieves data from all versions $V_1, V_2, \ldots V_n$
      - Retrieves data from $V_1, V_2, \ldots V_i$

Oracle Types of Schema Evolution



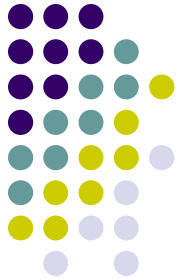
- **Copy-based:**
  - All documents that conform to S_{old} are copied to a temporary location
  - S_{old} is deleted
  - S_{new} is registered
  - Instance documents are inserted into their new locations from the temporary area
    - Before insertion the data are transformed to conform new schema
- **In-place:**
  - Does not require copying, deleting, inserting existing data
  - Much faster, but restricted:
    - Not changing the storage model
    - Changes do not invalidate existing documents
      - Existing documents are/can be made conformant with the new schema

Copy-Based Schema Evolution



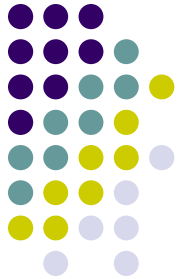
- Existing XML instance documents need to be revalidated
- PL/SQL function **`DBMS_XMLSCHEMA.copyEvolve`**
  - Copies existing instance documents to temporary XMLType tables
  - Drops S_{old} and deletes the associated instance documents
  - Registers S_{new}
  - Transforms and copies the backed-up instance documents to new XMLType tables

DBMS_XMLSCHEMA.copyEvolve



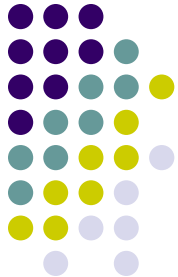
```
procedure copyEvolve(schemaURLs          IN XDB$STRING_LIST_T,
                     newSchemas          IN XMLSequenceType,
                     transforms          IN XMLSequenceType := NULL,
                     preserveOldDocs     IN BOOLEAN := false,
                     mapTabName          IN VARCHAR2 := NULL,
                     generateTables      IN BOOLEAN := true,
                     force               IN BOOLEAN := false,
                     schemaOwners        IN XDB$STRING_LIST_T := NULL
                     parallelDegree      IN PLS_INTEGER := 0,
                     options             IN PLS_INTEGER := 0);
```

DBMS_XMLSCHEMA.copyEvolve



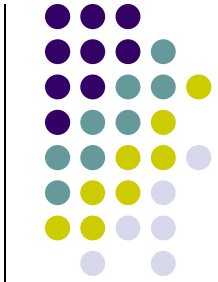
- **`schemaURLs`** – VARRAY of URLs of XML schemas to be evolved
  - VARCHAR2(4000)
- **`newSchemas`** – VARRAY of new XML schema documents
  - XMLType instances
  - The same order as corresponding URLs
- **`transforms`** – VARRAY of XSL documents
  - XMLType instances
  - Applied to XML schema based documents to make them conform to the new schemas
  - The same order as the corresponding URLs
- **`preserveOldDocs`**
  - true = the temporary tables holding old data are not dropped
- **`mapTabName`** – name of table that maps old XMLType table or column names to names of corresponding temporary tables

DBMS_XMLSCHEMA.copyEvolve



- **`generateTables`**
  - false = XMLType tables or columns will not be generated after registering new schemas
    - preserveOldDocs must be true and mapTabName must not be NULL
- **`force`**
  - true = errors during the registration of new schemas are ignored
    - e.g., circular dependencies
- **`schemaOwners`** – VARRAY of names of schema owners
- **`parallelDegree`** – degree of parallelism to be used during the data-copy stage
- **`options`** – miscellaneous options
  - COPYEVOLVE_BINARY_XML – register the new XML schemas for binary XML data and create the new tables or columns with binary XML as the storage model

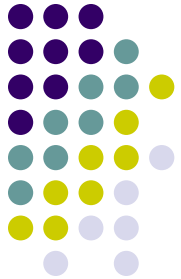
copyEvolve example



```
BEGIN
  DBMS_XDB.createResource(
    '/schemas/revisedPurchaseOrder.xsd',
    bfilename('XMLDIR', 'revisedPurchaseOrder.xsd'),
    nls_charset_id('AL32UTF8'));
  DBMS_XDB.createResource(
    '/schemas/evolvePurchaseOrder.xsl',
    bfilename('XMLDIR', 'evolvePurchaseOrder.xsl'),
    nls_charset_id('AL32UTF8'));
  DBMS_XMLSCHEMA.copyEvolve(
    xdb$string_list_t('http://localhost:8080/schemas/purchaseOrder.xsd'),
    XMLSequenceType(XDBURIType('/schemas/revisedPurchaseOrder.xsd').getXML()),
    XMLSequenceType(XDBURIType('/schemas/evolvePurchaseOrder.xsl').getXML()));
END;
```

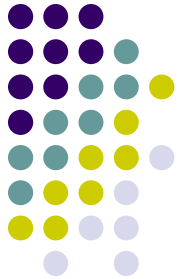
- Indexes, triggers, constraints related to the XMLType tables that are dependent on the schemas are not preserved

In-Place XML Schema Evolution



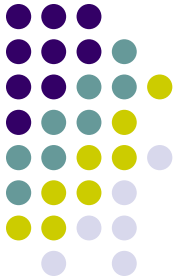
- Changes to an XML schema without requiring that existing data be copied, deleted, and reinserted
- **`DBMS_XMLSCHEMA.inPlaceEvolve`**
  - Constructs S_{new} by applying changes specified in a diffXML document
  - Validates S_{new}
  - Constructs DDL statements to evolve the disk structures used to store the XML instance documents associated with S_{new}
  - Executes these DDL statements
  - Replaces S_{old} with S_{new}
- Backward compatibility
  - Any possible instance document that would validate against S_{old} must also validate against S_{new}

Supported Operations



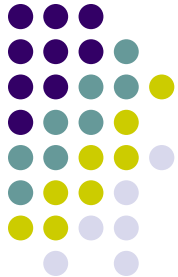
- Add an optional element to a complex type or group
- Add an optional attribute to a complex type or attribute group
- Convert an element from simple type to complex type with simple content
  - Supported only if the storage model is binary XML
- Modify the value attribute of an existing `maxLength` element
  - The value can only be increased, not decreased
- Add an enumeration value
- Add a global element
- Add a global attribute

Supported Operations



- Add or delete a global complex type
- Add or delete a global simple type
- Change the `minOccurs` attribute value
  - The value of `minOccurs` can only be decreased
- Change the `maxOccurs` attribute value
  - The value of `maxOccurs` can only be increased, and only for data stored as binary XML
- Add or delete a global `group` or `attributeGroup`
- Change the `xdb:defaultTable` attribute value
- Add, modify, or delete a comment or processing instruction

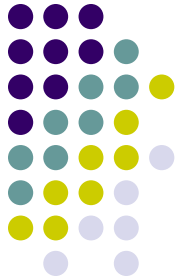
DBMS_XMLSCHEMA.inPlaceEvolve



```
procedure inPlaceEvolve(schemaURL IN VARCHAR2,
                        diffXML   IN XMLType,
                        flags     IN NUMBER);
```

- **schemaURL** – URL of the XML schema to be evolved
  - VARCHAR2
- **diffXML** – XML document that conforms to the xdiff XML schema
  - XMLType instance
- **flags** – bit mask that controls the behavior of the procedure
  - INPLACE_EVOLVE – perform in-place XML schema evolution
  - INPLACE_TRACE – perform all steps necessary for in-place evolution, except executing the DDL statements and overwriting the old XML schema with the new, then write both the DDL statements and the new XML schema to a trace file

diffXML Parameter

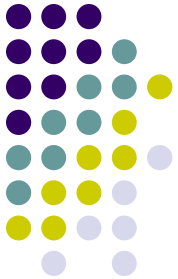


- XML document that specifies the changes to be applied to an XML schema for in-place evolution
- Sequence of operations that describe the changes between S_{old} with S_{new}.
- The changes are applied in order
- Can be created using:
  - The XMLDiff JavaBean
  - The xmldiff command-line utility
  - SQL function XMLDiff

diffXML Example

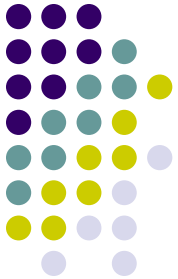
```
<?xml version="1.0" encoding="UTF-8"?>
<xd:xdiff xsi:schemaLocation="http://xmlns.oracle.com/xdb/xdiff.xsd
          xmlns:xd="http://xmlns.oracle.com/xdb/xdiff.xsd"
          xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
          xmlns:oraxdfns_0="http://booklist.oracle.com">
    <?oracle-xmldiff operations-in-docorder="true" output-model="snapshot"
        diff-algorithm="global"?>
    <xd:delete-node xd:node-type="element" xd:xpath="/oraxdfns_0
              :booklist[1]/oraxdfns_0:book[2]"/>
    <xd:update-node xd:node-type="attribute"
         xd:parent-xpath="/oraxdfns_0:booklist[1]/oraxdfns_0:book[3]/oraxdfns_0
              :title[1]" xd:attr-local="country">
                <xd:content>US</xd:content>
    </xd:update-node>
    <xd:append-node xd:node-type="element" xd:parent-xpath="/oraxdfns_0
              :booklist[1]/oraxdfns_0:book[4]">
        <xd:content>
            <oraxdfns_0:description> This is a classic </oraxdfns_0:description>
        </xd:content>
    </xd:append-node>
    <xd:insert-node-before xd:node-type="element" xd:xpath="/oraxdfns_0
              :booklist[1]/oraxdfns_0:book[5]/oraxdfns_0:author[1]">
        <xd:content>
            <oraxdfns_0:edition>Hardcover</oraxdfns_0:edition>
        </xd:content>
    </xd:insert-node-before>
    <xd:update-node xd:node-type="text" xd:xpath="/oraxdfns_0
           :booklist[1]/oraxdfns_0:book[5]/oraxdfns_0:price[1]/text()[1]">
        <xd:content>12.99</xd:content>
    </xd:update-node>
</xd:xdiff>
```

Creating diffXML



```
SELECT XMLDIFF(
XMLTYPE('<?xml version="1.0"?>
<bk:book xmlns:bk="http://nosuchsite.com">
  <bk:tr>
    <bk:td>
      <bk:chapter>Chapter 1.</bk:chapter>
    </bk:td>
    <bk:td>
      <bk:chapter>Chapter 2.</bk:chapter>
    </bk:td>
  </bk:tr>
</bk:book>'),
XMLTYPE('<?xml version="1.0"?>
<bk:book xmlns:bk="http://nosuchsite.com">
  <bk:tr>
    <bk:td>
      <bk:chapter>Chapter 1.</bk:chapter>
    </bk:td>
  <bk:td/>
 </bk:tr>
</bk:book>'))
FROM DUAL;
```

Creating diffXML



```
<xd:xdiff xsi:schemaLocation="http://xmlns.oracle.com/xdb/xdiff.xsd
          http://xmlns.oracle.com/xdb/xdiff.xsd"
          xmlns:xd="http://xmlns.oracle.com/xdb/xdiff.xsd"
          xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
          xmlns:bk="http://nosuchsite.com">
  <?oracle-xmldiff operations-in-docorder="true" output-model="snapshot"
   diff-algorithm="global"?>
  <xd:delete-node xd:node-type="element"
                  xd:xpath="/bk:book[1]/bk:tr[1]/bk:td[2]/bk:chapter[1]"/>
</xd:xdiff>
```

References

- Mark Scardina, Ben Chang, Jinyu Wang: Oracle Database 10g XML & SQL: Design, Build, & Manage XML Applications in Java, C, C++, & PL/SQL, McGraw-Hill http://books.google.cz/books?id=cHt2YN5_JI8C
- Oracle XML DB Developer's Guide 10g Release 2: http://download.oracle.com/docs/cd/B19306_01/appdev.102/b14259/toc.htm
- Oracle XML DB Developer's Guide 11g Release 1: http://download.oracle.com/docs/cd/B28359_01/appdev.111/b28369/toc.htm
- Oracle XML DB Developer's Guide 11g Release 2: http://download.oracle.com/docs/cd/E11882_01/appdev.112/e10492/toc.htm