Chapter 7 - XML
XML Origin and Usages

- Defined by the WWW Consortium (W3C)
- Originally intended as a document markup language, not a database language
  - Documents have tags giving extra information about sections of the document
  - For example:
    - `<title> XML </title>`
    - `<slide> XML Origin and Usages </slide>`
  - Meta-language: used to define arbitrary XML languages/vocabularies (e.g. XHTML)
- Derived from SGML (Standard Generalized Markup Language)
  - standard for document description
    - enables document interchange in publishing, office, engineering, ...
  - main idea: separate form from structure
- XML is simpler to use than SGML
  - roughly 20% complexity achieves 80% functionality
XML Origin and Usages (cont.)

- XML documents are to some extent self-describing
  - Tags represent metadata
  - Metadata and data are combined in the same document
    - semi-structured data modeling
- Example

```
<bank>
  <account>
    <account-number> A-101 </account-number>
    <branch-name> Downtown </branch-name>
    <balance> 500 </balance>
  </account>
  <depositor>
    <account-number> A-101 </account-number>
    <customer-name> Johnson </customer-name>
  </depositor>
</bank>
```
Forces Driving XML

- **Document Processing**
  - Goal: use document in various, evolving systems
  - structure – content – layout
  - grammar: markup vocabulary for mixed content

- **Data Bases and Data Exchange**
  - Goal: data independence
  - structured, typed data – schema-driven – integrity constraints

- **Semi-structured Data and Information Integration**
  - Goal: integrate autonomous data sources
  - data source schema not known in detail – schemata are dynamic
  - schema might be revealed through analysis only after data processing
XML Language Specifications

- XML Link
- XML Pointer
- XPath
- XQuery
- XML Schema
- XML Namespace
- eXtensible Markup Language
- Unicode
- Standardized Generalized Markup Language
- Document Type Definition
- XSL
- XSLT
- XSL-FO
- XHML
- XML Metadata Interchange
- Unified Modeling Language
- Meta Object Facility
- Cascading Style Sheets
- XML Pointer
- XML Metadata Interchange
- Unified Modeling Language
- Meta Object Facility
- Document Type Definition
XML Documents

- XML documents are text (unicode)
  - markup (always starts with '<' or '&')
    - start/end tags
    - references (e.g., &lt, &amp, ...)
    - declarations, comments, processing instructions, ...
  - data (character data)
    - characters '<' and '&' need to be indicated using references (e.g., &lt) or using the character code
    - alternative syntax: <![CDATA[ (a<b)&(c<d) ]]>  

- XML documents are well-formed
  - logical structure
    - (optional) prolog (XML version, ...)
    - (optional) schema
    - root element (possibly nested)
    - comments, ...
  - correct sequence of start/end tags (nesting)
  - uniqueness of attribute names
  - ...

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XML Documents: Elements

- **Element**: section of data beginning with `<tagname>` and ending with matching `</tagname>`
- Elements must be properly **nested**
  - Formally: every start tag must have a unique matching end tag, that is in the context of the same parent element.
- Mixture of text with sub-elements is legal in XML
  - Example:
    ```xml
    <account>
      This account is seldom used any more.
      <account-number> A-102 </account-number>
      <branch-name> Perryridge </branch-name>
      <balance> 400 </balance>
    </account>
    ```
  - Useful for document markup, but discouraged for data representation
XML Documents: Attributes

- **Attributes**: can be used to describe elements
- Attributes are specified by *name=value* pairs inside the starting tag of an element
- Example
  ```xml
  <account acct-type = "checking" >
    <account-number> A-102 </account-number>
    <branch-name> Perryridge </branch-name>
    <balance> 400 </balance>
  </account>
  ```
- Attribute names must be unique within the element
  ```xml
  <account acct-type = "checking" monthly-fee=5" >
  ```
XML Documents: IDs and IDREFs

- An element can have at most one attribute of type ID.
- The ID attribute value of each element in an XML document must be distinct.
  ➔ ID attribute (value) is an 'object identifier'.
- An attribute of type IDREF must contain the ID value of an element in the same document.
- An attribute of type IDREFS contains a set of (0 or more) ID values. Each ID value must contain the ID value of an element in the same document.
- IDs and IDREFs are untyped, unfortunately.
  - Example below: The owners attribute of an account may contain a reference to another account, which is meaningless; owners attribute should ideally be constrained to refer to customer elements.
XML data with ID and IDREF attributes

<bank-2>
  <account account-number="A-401" owners="C100 C102">  
      <branch-name> Downtown </branch-name>
      <balance> 500 </balance>
  </account>
  ...
  <customer customer-id="C100" accounts="A-401">  
      <customer-name> Joe </customer-name>
      <customer-street> Monroe </customer-street>
      <customer-city> Madison </customer-city>
  </customer>
  <customer customer-id="C102" accounts="A-401 A-402">  
      <customer-name> Mary </customer-name>
      <customer-street> Erin </customer-street>
      <customer-city> Newark </customer-city>
  </customer>
</bank-2>
XML Document Schema

- XML documents may optionally have a schema
  - standardized data exchange, ...
- Schema restricts the structures and data types allowed in a document
  - document is valid, if it follows the restrictions defined by the schema
- Two important mechanisms for specifying an XML schema
  - Document Type Definition (DTD)
    - contained in the document, or
    - stored separately, referenced in the document
  - XML Schema
Document Type Definition - DTD

- Original mechanism to specify type and structure of an XML document
  - What elements can occur
  - What attributes can/must an element have
  - What subelements can/must occur inside each element, and how many times.
- DTD does not constrain data types
  - All values represented as strings in XML
- Special DTD syntax
  - `<!ELEMENT element (subelements-specification) >`
  - `<!ATTLIST element (attributes) >`
Element Specification in DTD

- Subelements can be specified as
  - names of elements, or
  - #PCDATA (parsed character data), i.e., character strings
  - EMPTY (no subelements) or ANY (anything can be a subelement)

- Structure is defined using regular expressions
  - sequence \((subel, subel, \ldots)\), alternative \((subel | subel | \ldots)\)
  - number of occurrences
    - "?" - 0 or 1 occurrence
    - "+" - 1 or more occurrences
    - "*" - 0 or more occurrences

- Example

```xml
<!ELEMENT depositor (customer-name account-number)>
<!ELEMENT customer-name(#PCDATA)>
<!ELEMENT account-number (#PCDATA)>
<!ELEMENT bank ( (account | customer | depositor)+)>
```
Example: Bank DTD

<!DOCTYPE bank-2[
  <!ELEMENT account (branch-name, balance)>  
  <!ATTLIST account
    account-number   ID          #REQUIRED
    owners               IDREFS   #REQUIRED>
  <!ELEMENT customer(customer-name, customer-street, customer-city)>  
  <!ATTLIST customer
    customer-id        ID   #REQUIRED
    accounts            IDREFS  #REQUIRED>

  ... declarations for branch, balance, customer-name, customer-street and customer-city

]>
Describing XML Data: XML Schema

- XML Schema is closer to the general understanding of a (database) schema
- XML Schema supports
  - Typing of values
    - E.g. integer, string, etc
  - Constraints on min/max values
  - Typed references
  - User defined types
  - Specified in XML syntax (unlike DTDs)
  - Integrated with namespaces
  - Many more features
    - List types, uniqueness and foreign key constraints, inheritance ..
- BUT: significantly more complicated than DTDs
XML Schema Structures

- **Datatypes (Part 2)**
  Describes types of scalar (leaf) values

- **Structures (Part 1)**
  Describes types of complex values (attributes, elements)
  - Regular tree grammars
    - repetition, optionality, choice recursion

- **Integrity constraints**
  Functional (keys) & inclusion dependencies (foreign keys)

- **Subtyping (similar to OO models)**
  Describes inheritance relationships between types

- **Supports schema reuse**
XML Schema Structures (cont.)

- Elements: tag name & simple or complex type
  
  ```
  <xs:element name="sponsor" type="xsd:string"/>
  <xs:element name="action" type="Action"/>
  ```

- Attributes: tag name & simple type
  
  ```
  <xs:attribute name="date" type="xsd:date"/>
  ```

- Complex types
  
  ```
  <xs:complexType name="Action">
    <xs:sequence>
      <xs:elemref name="action-date"/>
      <xs:elemref name="action-desc"/>
    </xs:sequence>
  </xs:complexType>
  ```
XML Schema Structures (cont.)

- **Sequence**
  ```xml
  <xs:sequence>
    <xs:element name="congress" type=xsd:string/>
    <xs:element name="session" type=xsd:string/>
  </xs:sequence>
  ```

- **Choice**
  ```xml
  <xs:choice>
    <xs:element name="author" type="PersonName"/>
    <xs:element name="editor" type="PersonName"/>
  </xs:choice>
  ```

- **Repetition**
  ```xml
  <xs:element name="section" type="Section"
    minOccurs="1" maxOccurs="unbounded"/>
  ```
Namespaces

- A single XML document may contain elements and attributes defined for and used by multiple software modules
  - Motivated by modularization considerations, for example
- Name collisions have to be avoided
- Example:
  - A **Book** XSD contains a Title element for the title of a book
  - A **Person** XSD contains a Title element for an honorary title of a person
  - A **BookOrder** XSD reference both XSDs
- Namespaces specifies how to construct universally unique names
XML Schema Version of Bank DTD

```xml
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
    targetNamespace="http://www.banks.org"
    xmlns="http://www.banks.org">

<xsd:element name="bank" type="BankType"/>
<xsd:element name="account">
    <xsd:complexType>
        <xsd:sequence>
            <xsd:element name="account-number" type="xsd:string"/>
            <xsd:element name="branch-name" type="xsd:string"/>
            <xsd:element name="balance" type="xsd:decimal"/>
        </xsd:sequence>
    </xsd:complexType>
</xsd:element>

<xsd:complexType name="BankType">
    <xsd:choice minOccurs="1" maxOccurs="unbounded">
        <xsd:element ref="account"/>
        <xsd:element ref="customer"/>
        <xsd:element ref="depositor"/>
    </xsd:choice>
</xsd:complexType>

..... definitions of customer and depositor ....
</xsd:complexType>
</xsd:schema>
```
XML Document Using Bank Schema

<bank xmlns="http://www.banks.org"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="http://www.banks.org Bank.xsd">
  <account>
    <account-number> ... </account-number>
    <branch-name> ... </branch-name>
    <balance> ... </balance>
  </account>
  ...
</bank>
Application Programming with XML

- Application needs to work with XML data/document
  - Parsing XML to extract relevant information
  - Produce XML
    - Write character data
    - Build internal XML document representation and Serialize it

- Generic XML Parsing
  - Simple API for XML (SAX)
    - “Push” parsing (event-based parsing)
      - Parser sends notifications to application about the type of document pieces it encounters
      - Notifications are sent in “reading order” as they appear in the document
    - Preferred for large documents (high memory efficiency)
  - Document Object Model (DOM) – w3c recommendation
    - “One-step” parsing
      - Generates in-memory representation of the document (parse tree)
    - DOM specifies the types of parse tree objects, their properties and operations
      - Independent of programming language (uses IDL)
      - Bindings available to specific programming languages (e.g., Java)

- Parsing includes
  - checking for well-formedness
  - optionally checking for validity (often used for debugging only)
Transforming and Querying XML Data

- **XPath**
  - path expressions for selecting document parts
  - not originally designed as a stand-alone language

- **XSLT**
  - transformations from XML to XML and XML to HTML
  - primarily designed for style transformations
  - recursive pattern-matching paradigm
    - difficult to optimize in a DBMS context

- **XQuery**
  - XML query language with a rich set of features
  - XQuery builds on experience with existing query languages: XPath, Quilt, XQL, XML-QL, Lorel, YATL, SQL, OQL, ...
XML Data Model

- There is no uniform XML data model
  - different approaches with different goals
    - XML Information Set, DOM Structure Model, XPath 1.0 data model, XQuery data model
- Common denominator: an XML document is modeled as a tree, with nodes of different node types
  - Document, Element, Attribute, Text, Namespace, Comment, Processing Instruction
- XQuery data model builds on a tree-based model, but extends it to support
  - sequences of items
    - nodes of different types (see above) as well as atomic values
    - can contain heterogeneous values, are ordered, can be empty
  - typed values and type annotations
    - result of schema validation
    - type may be unknown
- Closure property
  - XQuery expressions operate on/produce instances of the XQuery Data Model
Example

```xml
<?xml version = "1.0"?>
<!-- Requires one trained person -->
<procedure title = "Removing a light bulb">
  <time unit = "sec">15</time>
  <step>Grip bulb.</step>
  <step>Rotate it
    <warning>slowly</warning> counterclockwise.
  </step>
</procedure>
```

one possible instance of the XQuery data model
Processing XML Data: XPath

- XPath is used to address (select) parts of documents using path expressions.
- A path expression consists of one or more steps separated by “/”
  - Each step in an XPath expression maps a node (the context node) into a set of nodes.
- Result of path expression: set of values that along with their containing elements/attributes match the specified path.
  - E.g.: `/bank-2/customer/customer-name` evaluated on the bank-2 data returns:
    - `<customer-name> Joe </customer-name>`
    - `<customer-name> Mary </customer-name>`
  - E.g.: `/bank-2/customer/cust-name/text( )` returns the same names, but without the enclosing tags.
XPath

- The initial “/” denotes root of the document (above the top-level tag)
- In general, a step has three parts:
  - The **axis** (direction of movement: child, descendant, parent, ancestor, following, preceding, attribute, … - 13 axes in all - )
  - A **node test** (type and/or name of qualifying nodes)
  - Some **predicates** (refine the set of qualifying nodes)
- Path expressions are evaluated left to right
  - Each step operates on the set of instances produced by the previous step
- Selection predicates may follow any step in a path, in [ ]
  - E.g. `/bank-2/account[balance > 400]`
    - returns account elements with a balance value greater than 400
    - `/bank-2/account[balance]` returns account elements containing a balance subelement
- Attributes are accessed using “@”
  - E.g. `/bank-2/account[balance > 400]/@account-number`
    - returns the account numbers of those accounts with balance > 400
  - IDREF attributes are not dereferenced automatically (more on this later)
**XPath Summary**

- **Strengths:**
  - Compact and powerful syntax for navigating a tree, but not as powerful as a regular-expression language
  - Recognized and accepted in XML community
  - Used in other XML processors/specifications such as XPointer, XSLT, XQuery

- **Limitations:**
  - Operates on one document (no joins)
  - No grouping or aggregation
  - No facility for generating new output structures
XQuery

- XQuery is a general purpose query language for XML data
- Standardized by the World Wide Web Consortium (W3C)
- XQuery is derived from
  - the **Quilt** ("Quilt" refers both to the origin of the language and to its use in “knitting” together heterogeneous data sources) query language, which itself borrows from
  - **XPath**: a concise language for navigating in trees
  - **XML-QL**: a powerful language for generating new structures
  - **SQL**: a database language based on a series of keyword-clauses: SELECT - FROM - WHERE
  - **OQL**: a functional language in which many kinds of expressions can be nested with full generality
XQuery – Main Constituents

- Path expressions
  - Inherited from XPath
  - An XPath expression maps a node (the context node) into a set of nodes

- Element constructors
  - To construct an element with a known name and content, use XML-like syntax:
    
    ```xml
    <book isbn = "12345">
      <title>Huckleberry Finn</title>
    </book>
    ```
  - If the content of an element or attribute must be computed, use a nested expression enclosed in `{ }`
    
    ```xml
    <book isbn = "${x}"$
    ${b/title }
    </book>
    ```

- FLWOR - Expressions
XQuery: The General Syntax Expression FLWOR

- **FOR clause**, **LET clause** generate list of tuples of bound variables (order preserving) by
  - iterating over a set of nodes (possibly specified by an XPath expression), or
  - binding a variable to the result of an expression
- **WHERE clause** applies a predicate to filter the tuples produced by FOR/LET
- **ORDER BY clause** imposes order on the surviving tuples
- **RETURN clause** is executed for each surviving tuple, generates ordered list of outputs
- Associations to SQL query expressions
  - for $\leftrightarrow$ SQL from
  - where $\leftrightarrow$ SQL where
  - order by $\leftrightarrow$ SQL order by
  - return $\leftrightarrow$ SQL select
- let allows temporary variables, and has no equivalent in SQL
Evaluating FLWOR Expressions

input sequence

```
FOR $X, $Y ..
LET $Z ..
```

output sequence

```
RETURN ..
```

tuple stream

$X$, $Y$, $Z$

```
ok!
ok!
WHERE ..
ORDER BY ..
```

```
RETURN ..
```

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FLWOR - Examples

- Simple FLWR expression in XQuery
  - Find all accounts with balance > 400, with each result enclosed in an `<account-number>` .. `</account-number>` tag
    ```xquery
    for $x in /bank-2/account
    let $acctno := $x/@account-number
    where $x/balance > 400
    return <account-number> {$acctno} </account-number>
    ```
  - Let and Where clause not really needed in this query, and selection can be done in XPath.
    - Query can be written as:
      ```xquery
      for $x in /bank-2/account[balance>400]
      return <account-number> {$x/@account-number} </account-number>
      ```
Nesting of Expressions

- Here: nesting inside the return clause
- Example: inversion of a hierarchy

<book>
  <title> <author> <author> </author> <author> </author> </title>
</book>
<book>
  <title> <author> <author> <author> </author> </author> </title>
</book>

FOR $a$ IN fn:distinct-values(//author)
ORDER BY $a$/name
RETURN
  <author>
    <name> { $a$/text() } </name>
    { FOR $b$ IN //book[author = $a$]
        RETURN $b$/title }
  </author>
XQuery: Joins

- Joins are specified in a manner very similar to SQL:

  ```xml
  for $a in /bank/account, 
  $c in /bank/customer, 
  $d in /bank/depositor
  where $a/account-number = $d/account-number 
  and $c/customer-name = $d/customer-name
  return <cust-acct>{ $c $a }</cust-acct>
  ```

- The same query can be expressed with the selections specified as XPath selections:

  ```xml
  for $a in /bank/account 
  $c in /bank/customer 
  $d in /bank/depositor[
    account-number =$a/account-number and 
    customer-name = $c/customer-name]
  return <cust-acct>{ $c $a }</cust-acct>
  ```
XQJ – Main Concepts

- Similar to JDBC, but for XQuery statements
  - data source, connection, (prepared) XQuery expression (statement)
    - XQuery variable identifier instead of parameter markers ("?"")
  - Query result is a sequence (XQSequence)
    - iterate through sequence items using XQSequence.next()
    - retrieve Java DOM objects using XQSequence.getObject()
    - retrieve atomic values as character string or mapped to Java data types
    - individual items or the complete stream can be "written" to the SAX API
- Support for "serializing" an XQuery result
  - to file, Java writer, string
  - as (X)HTML
XQuery - Status

- XQuery 1.0 is a w3c recommendation since January 2007
- XQuery API for Java™ (XQJ) is final (JSR) since 2009
- XQuery Update Facility 1.0 is a candidate recommendation
- XQuery 1.1 is in the making (working draft), work items include
  - value-based and positional grouping
  - outer join support
  - windowing
  - date and numeric value formatting
- Additional ongoing work
  - XQuery and XPath Full Text 1.0 (candidate recommendation)
    - adds support for text retrieval in XQuery
  - XQuery Scripting Extensions 1.0 (working draft)
    - adds procedural features
Transforming XML Data: XSLT

- A **stylesheet** stores formatting options for a document, usually separately from document
  - E.g. HTML style sheet may specify font colors and sizes for headings, etc.
- The **XML Stylesheet Language (XSL)** was originally designed for generating HTML from XML
- XSLT is a general-purpose transformation language
  - Can translate XML to XML, and XML to HTML
- XSLT transformations are expressed using rules called **templates**
  - Templates combine selection using XPath with construction of results
Understanding A Template

- Most templates have the following form:
  
  ```xml
  <xsl:template match="emphasis">
    <i><xsl:apply-templates/></i>
  </xsl:template>
  ```

- The whole `<xsl:template>` element is a **template**
- The **match pattern** determines where this template applies
  - XPath pattern
- **Literal result element(s)** come from non-XSL namespace(s)
- XSLT elements come from the XSL namespace
SQL and XML

- Use existing (object-)relational technology?
  - Large Objects: granularity understood by DBMS may be too coarse!
    - search/retrieval of subsets, update of documents
  - Decompose into tables: often complex, inefficient
    - mapping complexity, especially for highly "denormalized" documents
  - Useful, but not sufficient
    - should be standardized as part of SQL
    - but needs further enhancement to support "native" XML support in SQL

- Enable "hybrid" XML/relational data management
  - supports both relational and XML data
    - storage, access
    - query language
    - programming interfaces
  - ability to view/access relational as XML, and XML as relational
  - all major relational DBMS vendors are moving into this direction
SQL/XML Big Picture

XML, XQuery client

enhanced SQL client

SQL client

storage

client view

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Two major goals:
- "Publish" SQL query results as XML documents
- Ability to store and retrieve XML documents

- Rules for mapping SQL types, SQL identifiers and SQL data values to and from corresponding XML concepts
- A new built-in type XML
- A number of built-in operators that produce values of type XML

**recent additions for SQL200n:**
- Integration of the XQuery Data Model
- Additional XML Constructor Functions
- Querying XML values
### XML Publishing Functions - Example

```sql
CREATE VIEW XMLDept (DeptDoc XML) AS (
SELECT    XMLELEMENT ( NAME "Department",
    XMLATTRIBUTES ( e.dept AS "name" ),
    XMLATTRIBUTES ( COUNT(*) AS "count",
    XMLAGG (XMLELEMENT (NAME "emp",
        XMLELEMENT(NAME "name", e.lname)
        XMLELEMENT(NAME "hire", e.hire)
    ) AS "dept_doc"
FROM employees e GROUP BY dept) ;

==>

department_doc

<table>
<thead>
<tr>
<th>Department name</th>
<th>count</th>
<th>Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accounting</td>
<td>2</td>
<td>Yates, Smith</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2005-11-01, 2005-01-01</td>
</tr>
<tr>
<td>Shipping</td>
<td>2</td>
<td>Oppenheimer, Martin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2002-10-01, 2005-05-01</td>
</tr>
</tbody>
</table>
```

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Manipulating XML Data

- Constructor functions
  - focus on publishing SQL data as XML
  - no further manipulation of XML
- More requirements
  - how do we select or extract portions of XML data (e.g., from stored XML)?
  - how can we decompose XML into relational data?
  - both require a language to identify, extract and possibly combine parts of XML values

SQL/XML utilizes the XQuery standard for this!
XMLQUERY

- Evaluates an XQuery or XPath expression
  - returns a sequence of XQuery nodes

XMLQUERY – Example

SELECT XMLQUERY('for $e in $dept[@count > 1]/emp
    where $e/hire > 2004-12-31 return $e/name'
    PASSING BY REF DeptDoc AS “dept”
    RETURNING SEQUENCE) AS “Name_elements”

FROM XMLDept

=>

<table>
<thead>
<tr>
<th>Name_elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;name&gt;Yates&lt;/name&gt;</td>
</tr>
<tr>
<td>&lt;name&gt;Smith&lt;/name&gt;</td>
</tr>
<tr>
<td>&lt;name&gt;Martin&lt;/name&gt;</td>
</tr>
</tbody>
</table>
JDBC-Support for SQLXML

- New methods to create and retrieve SQLXML
  - Connection.createSQLXML()
  - ResultSet.getSQLXML()
  - PreparedStatement.setSQLXML()

- SQLXML interface supports methods for accessing its XML content
  - getString()
  - getBinaryStream(), get CharacterStream()
    - obtain a Java stream/reader that can be passed directly to an XML parser
  - getSource()
    - obtain a source object suitable for XML parsers and XSLT transformers
  - corresponding setXXX() methods to initialize newly created SQLXML objects
Summary: XML Advantages

- Integrates data and meta-data (tags)
  - Self-describing
- XMLSchema, Namespaces
  - Defining valid document structure
  - Integrating heterogeneous terminology and structures
- XML can be validated against schema (xsd, dtd) outside the application
- Many technologies exist for processing, transforming, querying XML documents
  - DOM, SAX, XSLT, XPath, XQuery
- XML processing can help handle schema heterogeneity, schema evolution
  - Focus on known element tags, attributes, namespaces ...
  - Powerful filter and transformation capabilities
- XML is independent of platforms, middleware, databases, applications ...
Summary: XML and Data Management

- Increasing importance of XML in combination with data management
  - flexible exchange of relational data using XML
  - managing XML data and documents
  - trend towards "hybrid" approaches for relational DBMS

- SQL/XML standard attempts to support the following
  - "Publish" SQL query results as XML documents
  - Ability to store and retrieve (parts of) XML documents with SQL databases
  - Rules and functionality for mapping SQL constructs to and from corresponding XML concepts

- XQuery standard
  - XML data model
  - queries over XML data

- Broad support by major SQL DBMS vendors

- Additional standards to further extend and complete the "big picture"!
  - XQJ: XML queries in Java
  - Grid Data Access Services (GGF): web/grid services to access DBs using SQL, XQuery