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Technische Universität Kaiserslautern

Chapter 10 - XML

Digital Libraries and Content Management

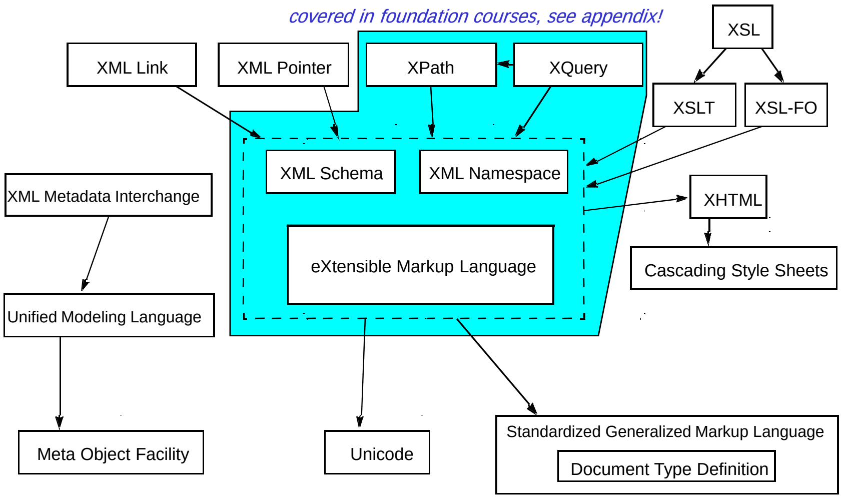
Forces Driving XML

- 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 and CM/DL

- XML can be used to represent documents and data
  - content and structure
- XML is a text-oriented language
  - not really suitable for multimedia content
- Multi-media content can be referenced in XML documents
  - URI, XLink, XPointer, XPath
  - Synchronized Multimedia Integration Language (SMIL)
- Multi-media content can be encoded in a text-based format
  - Scalable Vector Graphics (SVG)
- XML processing standards support flexible generation of different layout
  - XML Style Sheets Transformations
- XML for meta-data representation
  - RDF
  - Meta-data standards (e.g., Dublin Core)
    - Representation in XML

XML Language Specifications (W3C)



covered in foundation courses, see appendix!

XSL

XML Link

XML Pointer

XPath

XQuery

XSLT

XSL-FO

XML Schema

XML Namespace

XML Metadata Interchange

XHTML

eXtensible Markup Language

Cascading Style Sheets

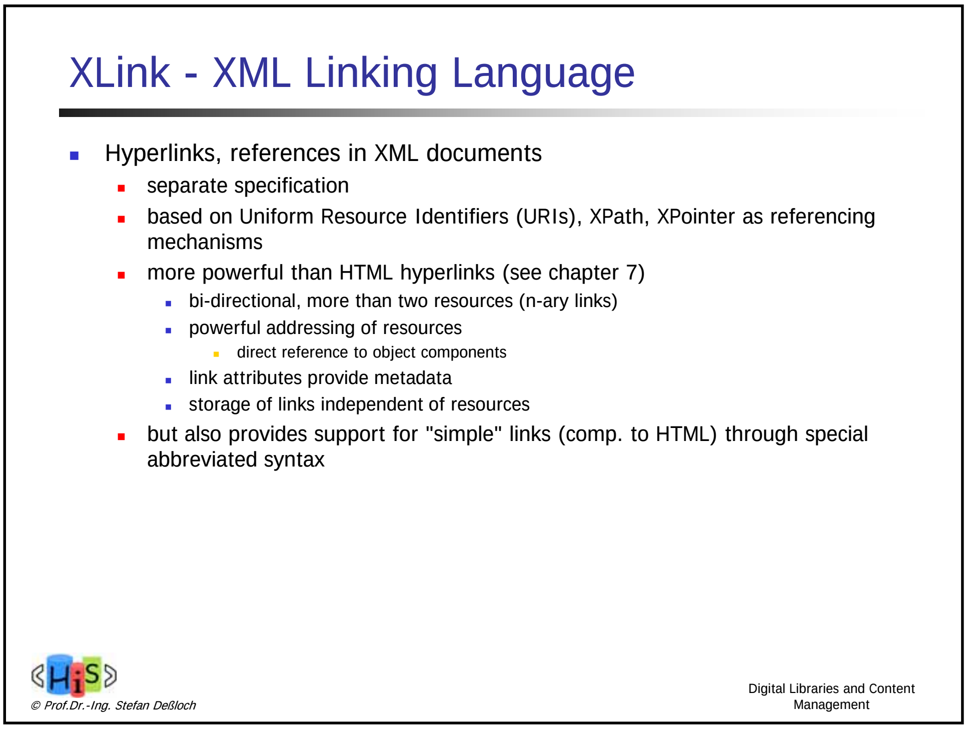
Unified Modeling Language

Meta Object Facility

Unicode

Standardized Generalized Markup Language

Document Type Definition



XLink - XML Linking Language

- Hyperlinks, references in XML documents
  - separate specification
  - based on Uniform Resource Identifiers (URIs), XPath, XPointer as referencing mechanisms
  - more powerful than HTML hyperlinks (see chapter 7)
    - bi-directional, more than two resources (n-ary links)
    - powerful addressing of resources
      - direct reference to object components
    - link attributes provide metadata
    - storage of links independent of resources
  - but also provides support for "simple" links (comp. to HTML) through special abbreviated syntax

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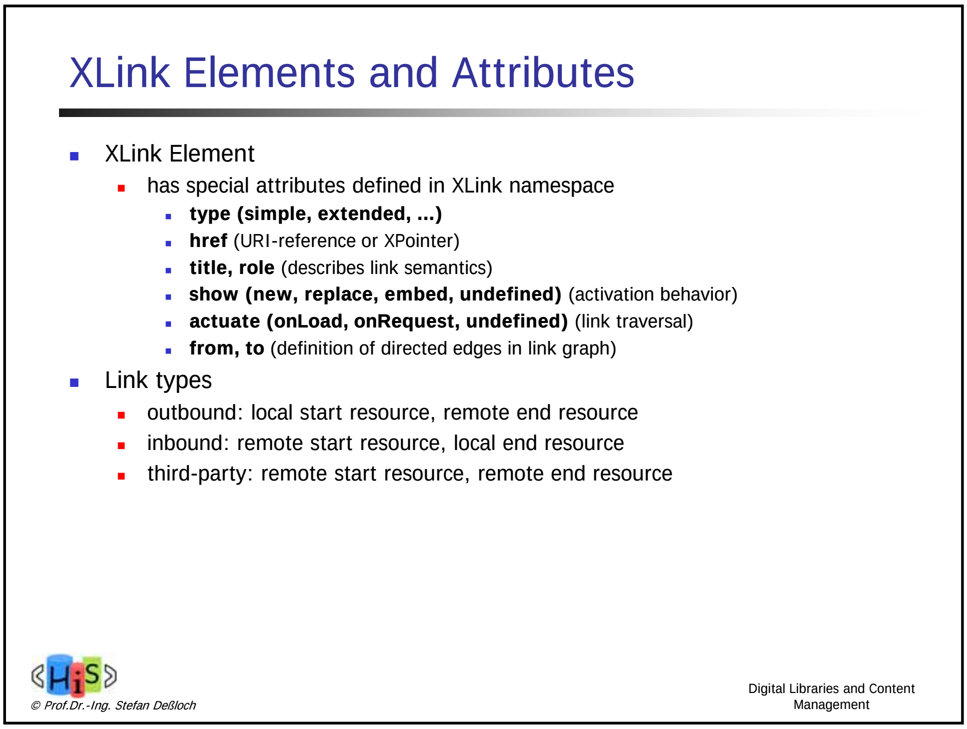

XLink Elements and Attributes

- XLink Element
  - has special attributes defined in XLink namespace
    - **type (simple, extended, ...)**
    - **href** (URI-reference or XPointer)
    - **title, role** (describes link semantics)
    - **show (new, replace, embed, undefined)** (activation behavior)
    - **actuate (onLoad, onRequest, undefined)** (link traversal)
    - **from, to** (definition of directed edges in link graph)
- Link types
  - outbound: local start resource, remote end resource
  - inbound: remote start resource, local end resource
  - third-party: remote start resource, remote end resource

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XLink - Example

- in DTD:

```
<!ELEMENT Player ANY>
<!ATTLIST Player
                    xlink:type  (simple)   #FIXED     "simple"
                    xlink:href  CDATA   #REQUIRED
                    xlink:role   NMTOKEN  #FIXED "http://www.fck.com/links/spieler"
                    xlink:title   CDATA    #IMPLIED
                    xlink:show    (new|embed|replace)   "replace"
                    xlink:actuate (onLoad|onRequest)   "onRequest"
         >
```

- in document instance:

```
< Player xlink:href="http://www.fck.de/Spielerliste.xml"
                    xlink:title="List of all FCK players"
                    xlink:show="new">
                    Here's a list of all FCK players.
</Player>
```

XSL – Transformation and Layout

- **XSL**: *Extensible Stylesheet Language*
  - formatting engine for XML
  - XML markup is presentation/layout-independent
- **XSLT**: *XSL Transformation Language*
  - stylesheet
  - transformation rules
    - consisting of a pattern and a template
    - usage of XPath
  - input tree
  - output tree
- **XSL-FO**: *XSL Formatting Objects*
  - vocabulary for the specification of formatting rules
    - reuse of complex formatting definitions
  - transformation into arbitrary formats (PDF, RTF, PostScript, ...)

Principles of XSLT

- XSL processor
  - element-by-element processing of input tree, starting with the root
  - looks for applicable XSLT rule
- XSLT rule defines
  - template: for which element, in which relationship context does the rule apply
  - action:
    - what should be generated as output
      - reference to document content using 'select'-expressions
    - what elements should be processed next by the processor
      - <xsl:apply-templates/> - continue with child elements
      - extended syntax supports selection of specific elements, order restrictions, etc.
- Default rules (if no other rule is matched)
  - for all elements (incl. root), process the children
  - for all text nodes and attributes, use their value as output

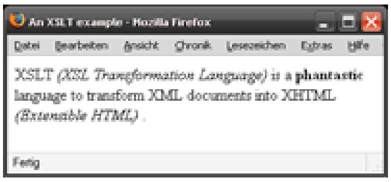
XSL - Example

- a fragment of an XML document:

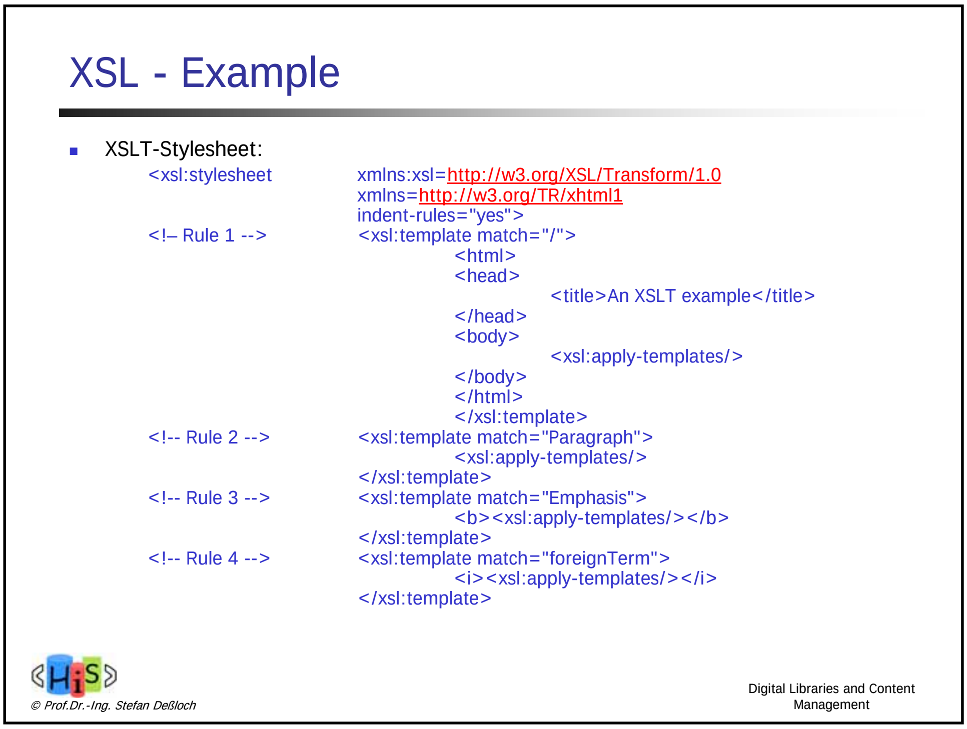
```
<Content>
<Paragraph>XSLT <foreignTerm> (XSL Transformation Language) </foreignTerm >
is a <Emphasis> phantastic</Emphasis> language to transform XML documents into
XHTML <foreignTerm> (Extensible HTML) </foreignTerm>.
</Paragraph>
</Content>
```

- result document:

```
<html>
  <head>
        <title>An XSLT example</title>
  </head>
  <body>
        XSLT <i>(XSL Transformation Language)</i>
         is a <b> phantastic </b> language to
        transform XML documents into XHTML
        <i> (Extensible HTML) </i>.
        </body>
</html>
```



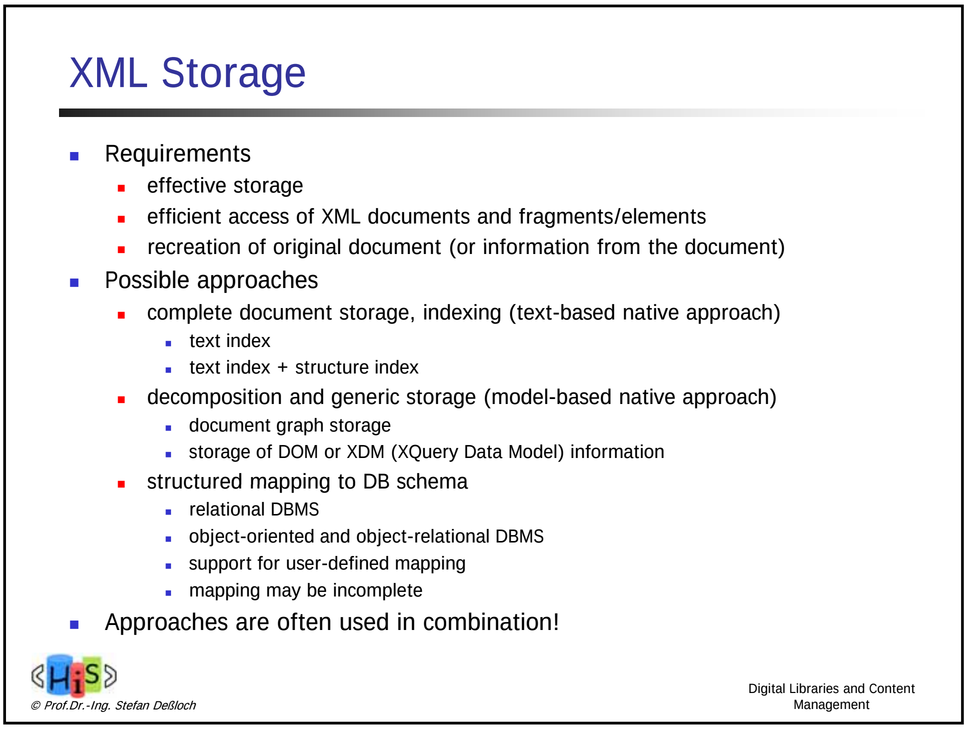
XSLT *(XSL Transformation Language)* is a **phantastic** language to transform XML documents into XHTML *(Extensible HTML)* .



XSL - Example

- XSLT-Stylesheet:

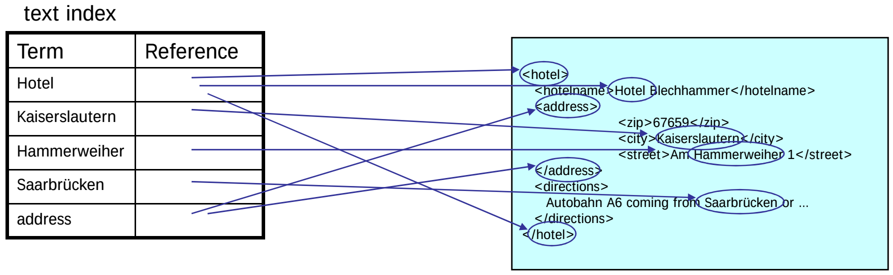
```
<xsl:stylesheet        xmlns:xsl=http://w3.org/XSL/Transform/1.0
                       xmlns=http://w3.org/TR/xhtml1
                       indent-rules="yes">
<!– Rule 1 -->         <xsl:template match="/">
                               <html>
                               <head>
                                       <title>An XSLT example</title>
                               </head>
                               <body>
                                       <xsl:apply-templates/>
                               </body>
                               </html>
                               </xsl:template>
<!-- Rule 2 -->        <xsl:template match="Paragraph">
                               <xsl:apply-templates/>
                       </xsl:template>
<!-- Rule 3 -->        <xsl:template match="Emphasis">
                               <b><xsl:apply-templates/></b>
                       </xsl:template>
<!-- Rule 4 -->        <xsl:template match="foreignTerm">
                               <i><xsl:apply-templates/></i>
                       </xsl:template>
```



XML Storage

- Requirements
  - effective storage
  - efficient access of XML documents and fragments/elements
  - recreation of original document (or information from the document)
- Possible approaches
  - complete document storage, indexing (text-based native approach)
    - text index
    - text index + structure index
  - decomposition and generic storage (model-based native approach)
    - document graph storage
    - storage of DOM or XDM (XQuery Data Model) information
  - structured mapping to DB schema
    - relational DBMS
    - object-oriented and object-relational DBMS
    - support for user-defined mapping
    - mapping may be incomplete
- Approaches are often used in combination!

Complete XML Document Storage



text index

Term	Reference
Hotel	
Kaiserslautern	
Hammerweiher	
Saarbrücken	
address	

```
<hotel>
  <hotelname>Hotel Blechhammer</hotelname>
  <address>
         <zip>67659</zip>
         <city>Kaiserslautern</city>
         <street>Am Hammerweiher 1</street>
  </address>
  <directions>
    Autobahn A6 coming from Saarbrücken or ...
  </directions>
</hotel>
```

- XML document is stored "as is" (e.g., in its textual form)
  - content (including whitespace) is completely preserved
- in addition: text index (e.g., inverted word list)
  - text retrieval cannot differentiate markup (e.g., element names) from text content
  - no structural information
    - search for "hotel" AND "Saarbrücken" will return the above document!
    - result is always the full document

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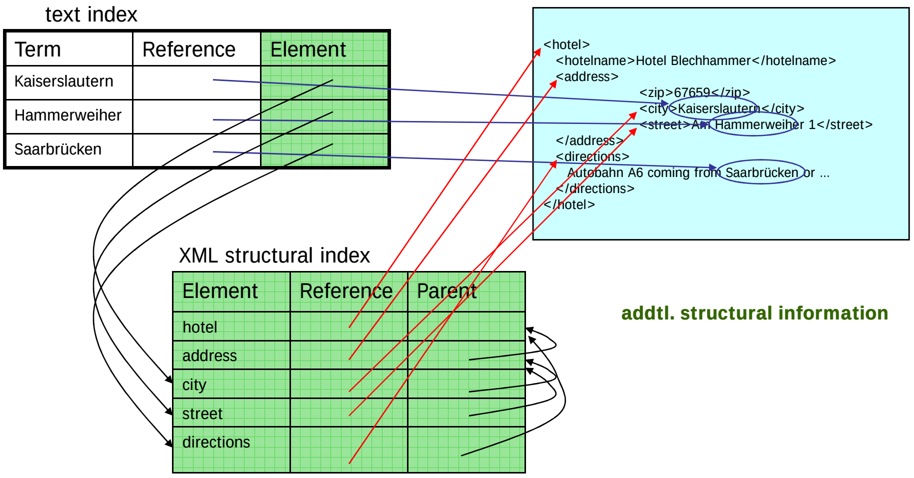
Document Storage With Structural Index



text index

Term	Reference	Element
Kaiserslautern		
Hammerweiher		
Saarbrücken		

```
<hotel>
  <hotelname>Hotel Blechhammer</hotelname>
  <address>
         <zip>67659</zip>
         <city>Kaiserslautern</city>
         <street>Am Hammerweiher 1</street>
  </address>
  <directions>
    Autobahn A6 coming from Saarbrücken or ...
  </directions>
</hotel>
```

XML structural index

Element	Reference	Parent
hotel		
address		
city		
street		
directions		

addtl. structural information

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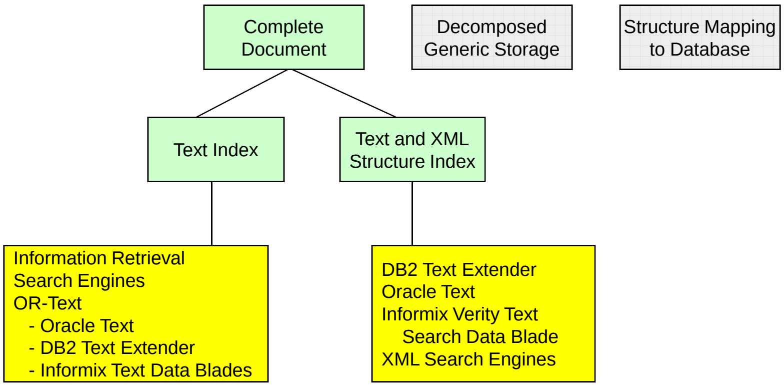
Digital Libraries and Content Management

Properties

schema definition	not required
document reconstruction	not needed (original document is preserved)
queries	information retrieval exploitation of markup (structure) possible XML queries supported
additional comments	fulltext functionality (SQL-MM)
usage	document-centric or semi-structured

Complete Document Storage


Complete Document
Decomposed Generic Storage
Structure Mapping to Database
Text Index
Text and XML Structure Index
Information Retrieval Search Engines
OR-Text
- Oracle Text
- DB2 Text Extender
- Informix Text Data Blades
DB2 Text Extender
Oracle Text
Informix Verity Text Search Data Blade
XML Search Engines

Decomposition and Generic Storage

- Storage of document graph structure
  - nodes: elements and attributes
  - edges: child/attribute relationship
  - RDBMS can be used as infrastructure, based on generic schema
    - table **ELEMENTS** with columns DOCID, ELEMENTNAME, ID, PARENT, POSITION, VALUE
    - table **ATTRIBUTE** with columns DOCID, ATTRIBUTNAME, ELEMENTID, VALUE

Elemente

docID	Elementname	ID	Parent	Position	Value
H0001	hotel	001		1	
H0001	hotelname	002	001	1	Hotel Blechhammer
H0001	address	003	001	1	

- Storage of Document Object Model (DOM) or XQuery Data Model (XDM) information
  - generic storage schema follows node types
    - Document, Element, Attribute, ….
  - RDBMS can be used as infrastructure as well

DOM

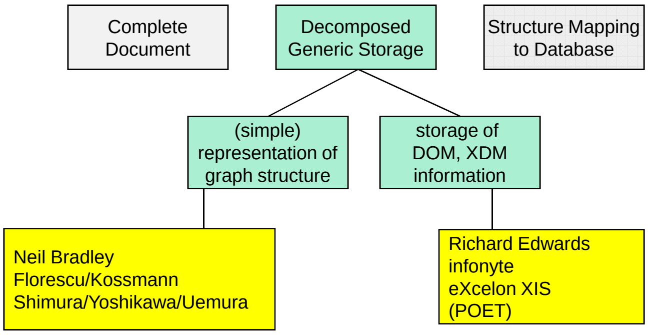
- DOM structure is a tree structure with different node types

Node type	Contains
Document	Element (maximum of one), ProcessingInstruction, Comment, DocumentType
DocumentFragment	Element, ProcessingInstruction, Comment, Text, CDATASection, EntityReference
DocumentType	no children
EntityReference	Element, ProcessingInstruction, Comment, Text, CDATASection, EntityReference
Element	Element, Text, Comment, ProcessingInstruction, CDATASection, EntityReference
Attr	Text, EntityReference
ProcessingInstruction	no children
Comment	no children
Text	no children
CDATASection	no children
Entity	Element, ProcessingInstruction, Comment, Text, CDATASection, EntityReference
Notation	no children

Properties

schema definition	not required
document reconstruction	possible ("equivalent" document), but expensive
queries	XML queries DB-queries (need to be adjusted to the storage schema used)
additional comments	queries over many elements/attributes become expensive DOM, XDM: standardised and accepted models
usage	data-, document-centric, or semi-structured

Generic Storage


Complete Document
Decomposed Generic Storage
Structure Mapping to Database
(simple) representation of graph structure
storage of DOM, XDM information
Neil Bradley
Florescu/Kossmann
Shimura/Yoshikawa/Uemura
Richard Edwards
infonyte
eXcelon XIS
(POET)

Systems

Infonyte-DB

- uses a persistent Document Object Model (PDOM) for XML storage
- doesn't use existing DBMS, but provides its own components for physical storage, optimized for XML documents
- query language: XQuery

Tamino

- model-based storage of XML documents
- query language: XPath/XQuery

eXcelon

- uses Document Object Model as a basis for generic storage
- all information supported for DOM nodes is stored in the OODBMS ObjectStore
- query language: OQL

Structured Storage Mapping to Databases

- XML document structure is reflected at the schema level
  - prerequisite: explicit XML schema exists
- Mapping to DB schema
  - default mapping by system
  - user-defined (application-specific) mapping
- Mapping definition for
  - transformation of query results
  - DB schema generation
- Example (for object-relational DBMS):

Hotel

id	hotelname	address			...
		zip	city	street	
0001	Hotel Blechhammer	67659	Kaiserslautern	Am ...	

Pros and Cons

Advantages: when storing structured data

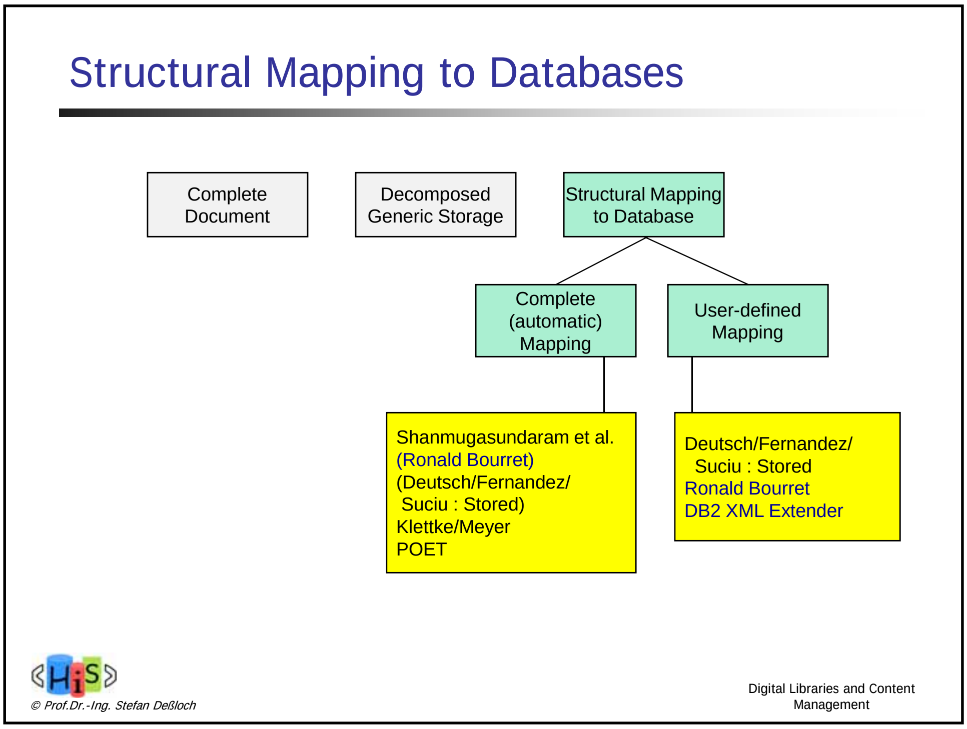
- Queries, data types, aggregate functions, views, ...
- Integration into/with existing databases

Disadvantages: when storing semi- and unstructured data

- large schema, sparsely populated, many null values
- no/restricted data type flexibility, problems with storing alternatives
- no/weakly integrated information/text retrieval support

Properties

schema definition	required
document reconstruction	usually not possible (unless mapping is complete and complete mapping process is "logged")
queries	- data base queries - XML queries possible (translation)
additional comments	- supports integration with existing data sources - XML documents and DB "independent from each other" (keeping the original document)
usage	data-centric applications



Structural Mapping to Databases

Complete Document

Decomposed Generic Storage

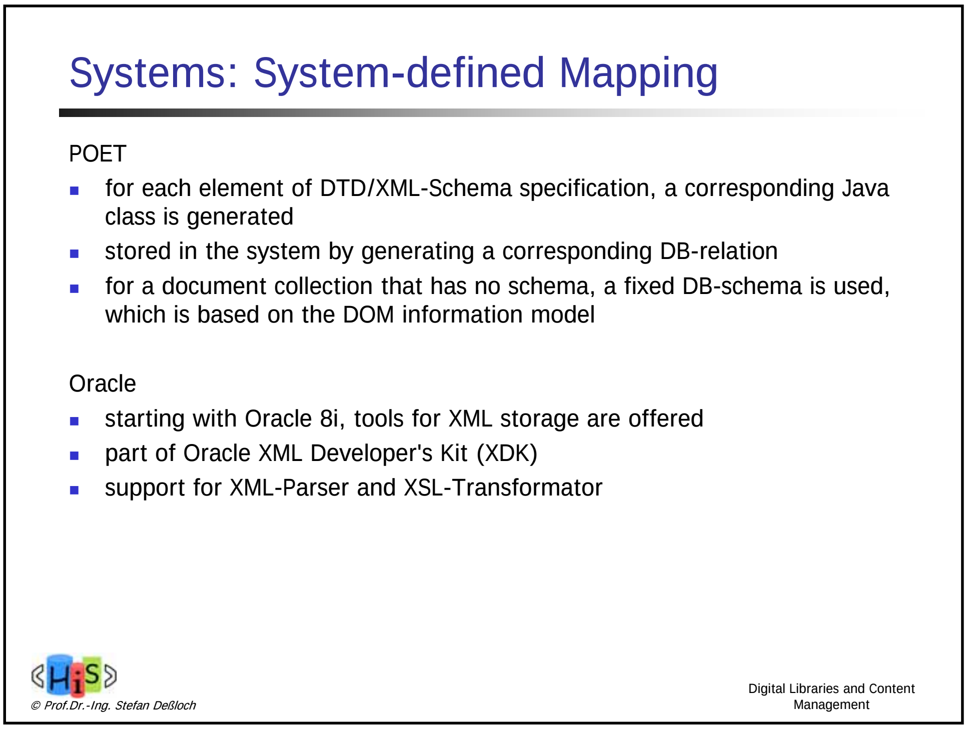
Structural Mapping to Database

Complete (automatic) Mapping

User-defined Mapping

Shanmugasundaram et al.
(Ronald Bourret)
(Deutsch/Fernandez/ Suciu : Stored)
Klettke/Meyer
POET

Deutsch/Fernandez/ Suciu : Stored
Ronald Bourret
DB2 XML Extender



Systems: System-defined Mapping

POET

- for each element of DTD/XML-Schema specification, a corresponding Java class is generated
- stored in the system by generating a corresponding DB-relation
- for a document collection that has no schema, a fixed DB-schema is used, which is based on the DOM information model

Oracle

- starting with Oracle 8i, tools for XML storage are offered
- part of Oracle XML Developer's Kit (XDK)
- support for XML-Parser and XSL-Transformator

Systems: User-defined Mapping

IBM DB2 XML-Extender

- storage of XML documents in DB2 DBMS
- based on user-defined mapping definition file (DAD - Data Access Definition)

Oracle

- object-relational storage of XMLType
- storage mapping using XMLSchema annotations
- XML document access using XPath or SQL

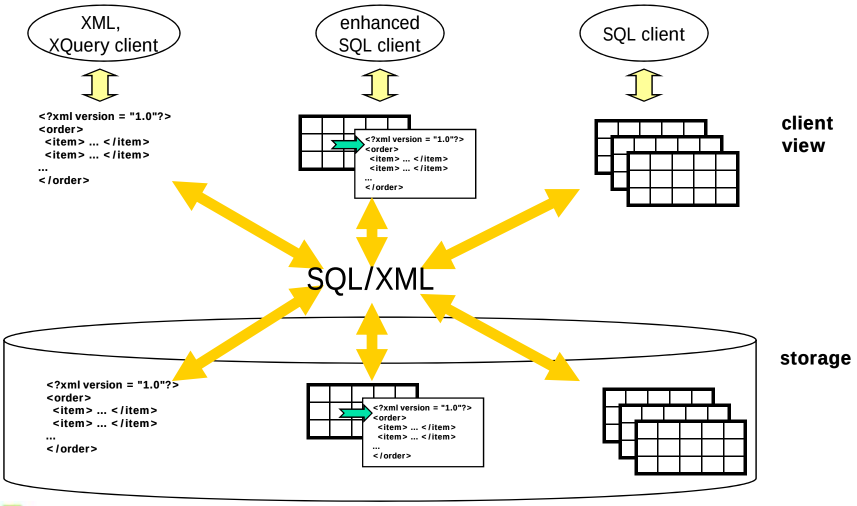
Microsoft SQL-Server

- annotated XDR Schema for user-defined mapping
  - sql:relation, sql:field, ...

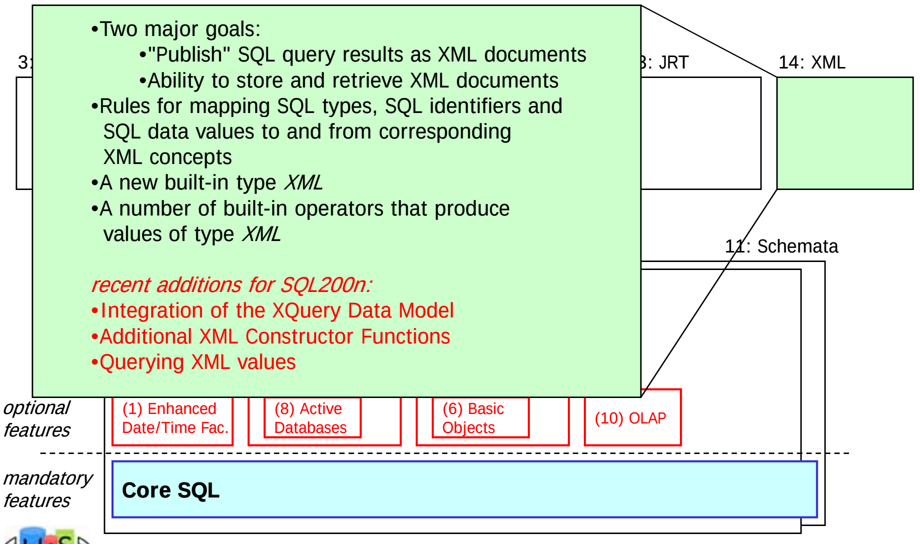
SQL and XML

- 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



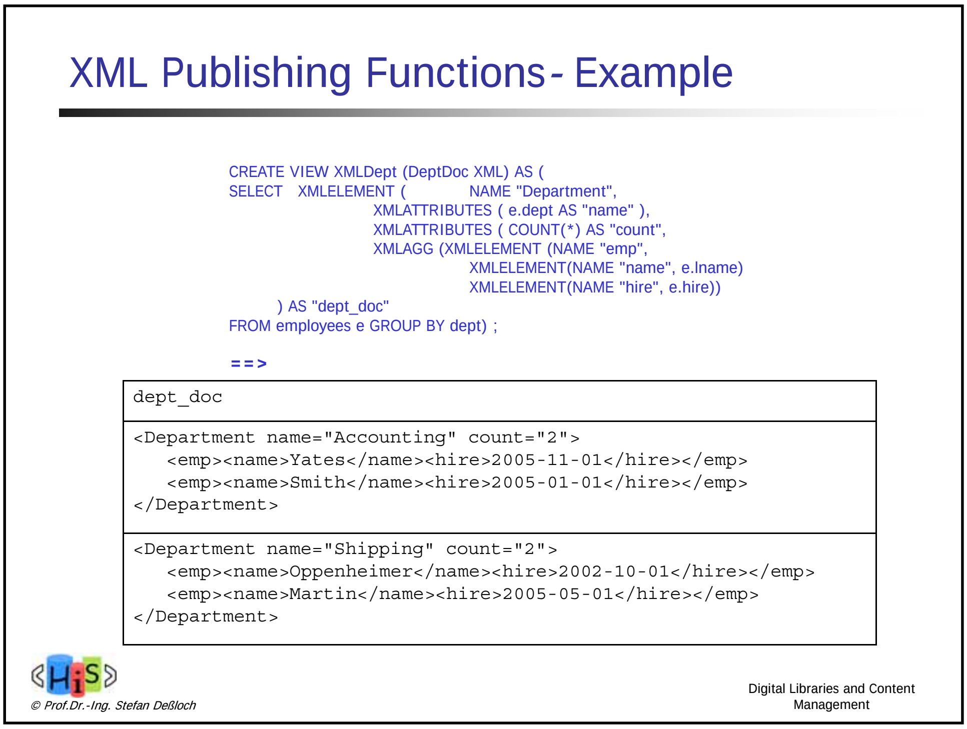
SQL:2003 Parts and Packages



- 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

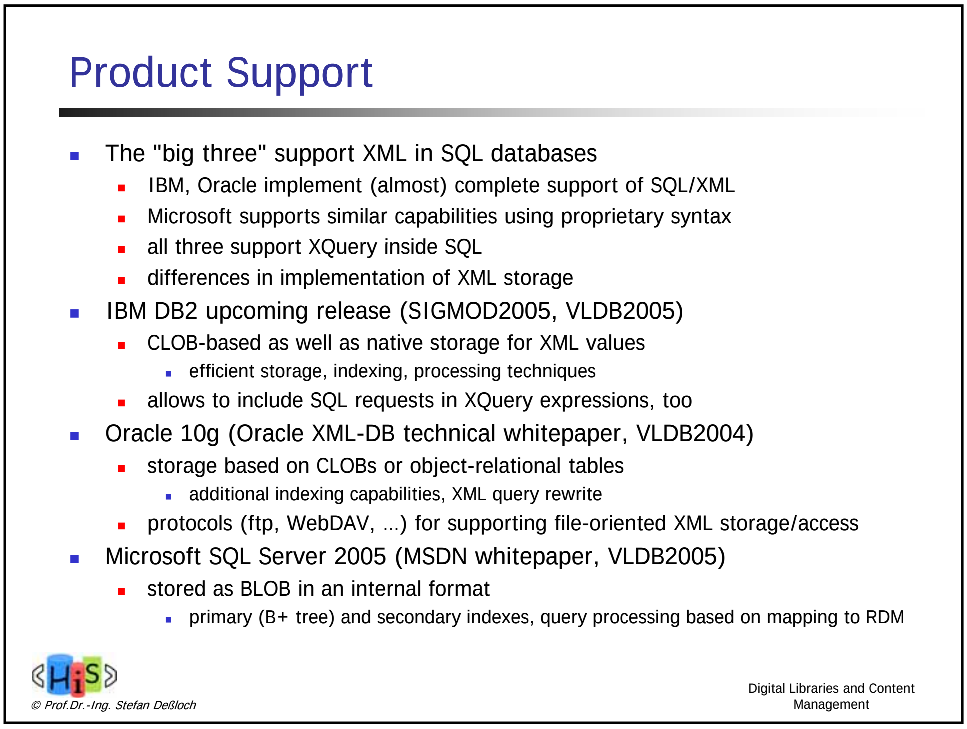
```
CREATE VIEW XMLDept (DeptDoc XML) AS (
SELECT   XMLELEMENT (          NAME "Department",
                    XMLATTRIBUTES ( e.dept AS "name" ),
                    XMLATTRIBUTES ( COUNT(*) AS "count",
                    XMLAGG (XMLELEMENT (NAME "emp",
                              XMLELEMENT(NAME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

==>
```

dept_doc

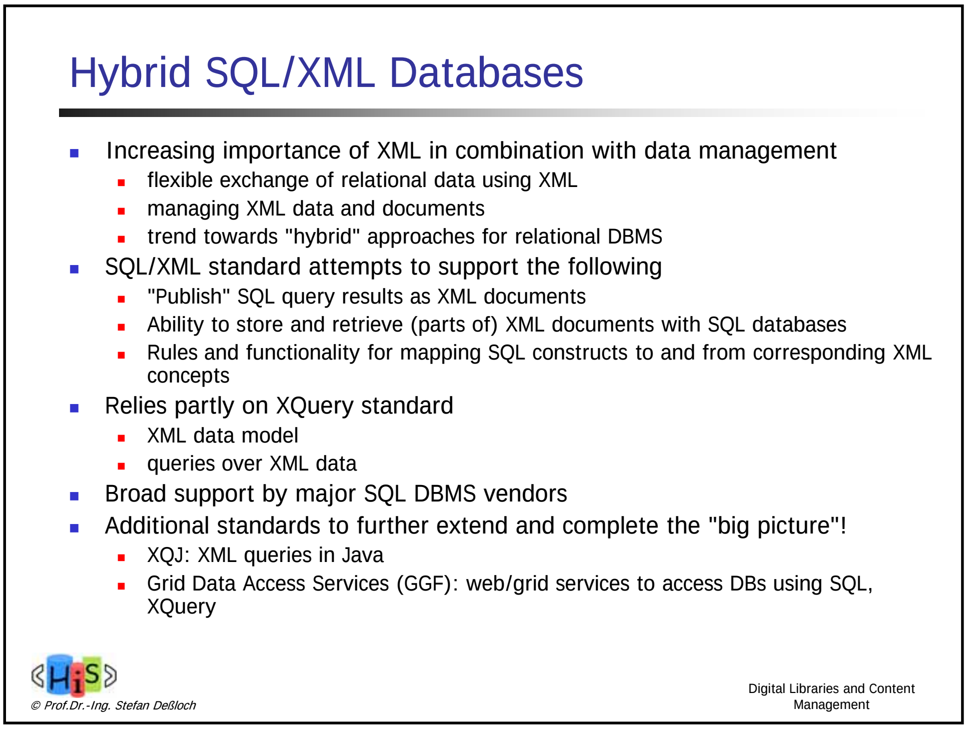
`<Department name="Accounting" count="2">`
`<emp><name>Yates</name><hire>2005-11-01</hire></emp>`
`<emp><name>Smith</name><hire>2005-01-01</hire></emp>`
`</Department>`

`<Department name="Shipping" count="2">`
`<emp><name>Oppenheimer</name><hire>2002-10-01</hire></emp>`
`<emp><name>Martin</name><hire>2005-05-01</hire></emp>`
`</Department>`



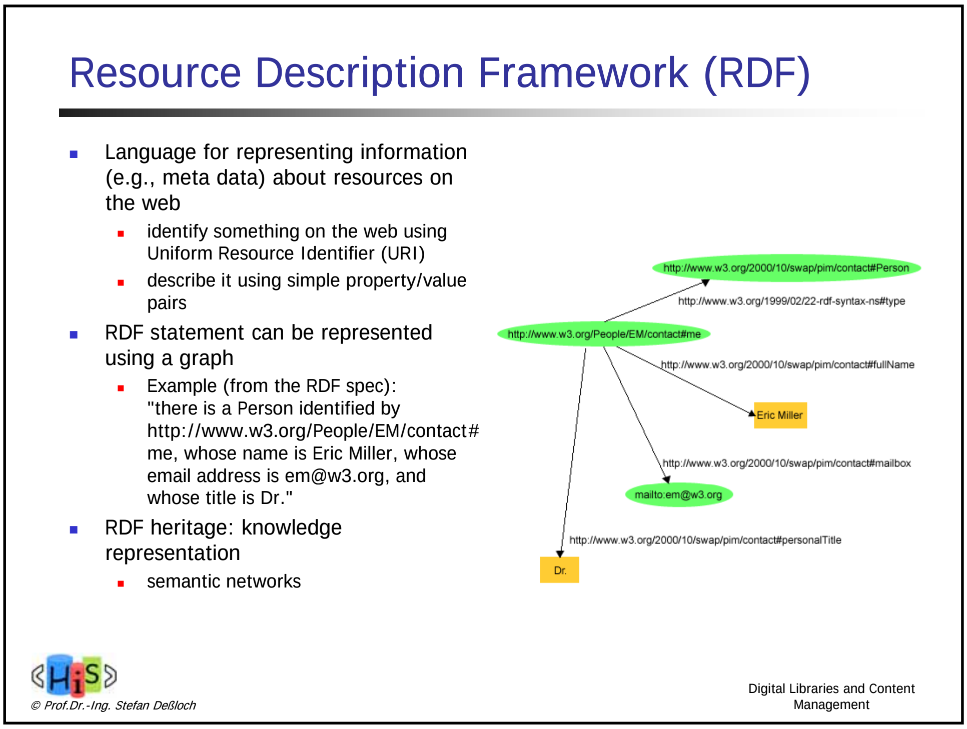
Product Support

- The "big three" support XML in SQL databases
  - IBM, Oracle implement (almost) complete support of SQL/XML
  - Microsoft supports similar capabilities using proprietary syntax
  - all three support XQuery inside SQL
  - differences in implementation of XML storage
- IBM DB2 upcoming release (SIGMOD2005, VLDB2005)
  - CLOB-based as well as native storage for XML values
    - efficient storage, indexing, processing techniques
  - allows to include SQL requests in XQuery expressions, too
- Oracle 10g (Oracle XML-DB technical whitepaper, VLDB2004)
  - storage based on CLOBs or object-relational tables
    - additional indexing capabilities, XML query rewrite
  - protocols (ftp, WebDAV, ...) for supporting file-oriented XML storage/access
- Microsoft SQL Server 2005 (MSDN whitepaper, VLDB2005)
  - stored as BLOB in an internal format
    - primary (B+ tree) and secondary indexes, query processing based on mapping to RDM



Hybrid SQL/XML Databases

- 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
- Relies partly on 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



Resource Description Framework (RDF)

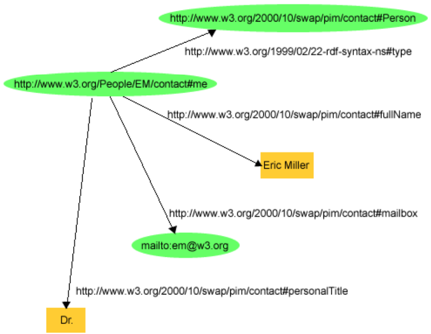
- Language for representing information (e.g., meta data) about resources on the web
  - identify something on the web using Uniform Resource Identifier (URI)
  - describe it using simple property/value pairs
- RDF statement can be represented using a graph
  - Example (from the RDF spec): "there is a Person identified by http://www.w3.org/People/EM/contact#me, whose name is Eric Miller, whose email address is em@w3.org, and whose title is Dr."
- RDF heritage: knowledge representation
  - semantic networks

http://www.w3.org/2000/10/swap/pim/contact#Person
http://www.w3.org/1999/02/22-rdf-syntax-ns#type
http://www.w3.org/People/EM/contact#me
http://www.w3.org/2000/10/swap/pim/contact#fullName
Eric Miller
http://www.w3.org/2000/10/swap/pim/contact#mailbox
mailto:em@w3.org
http://www.w3.org/2000/10/swap/pim/contact#personalTitle
Dr.

RDF/XML

- XML-based syntax for encoding and exchanging RDF statements
  - Example

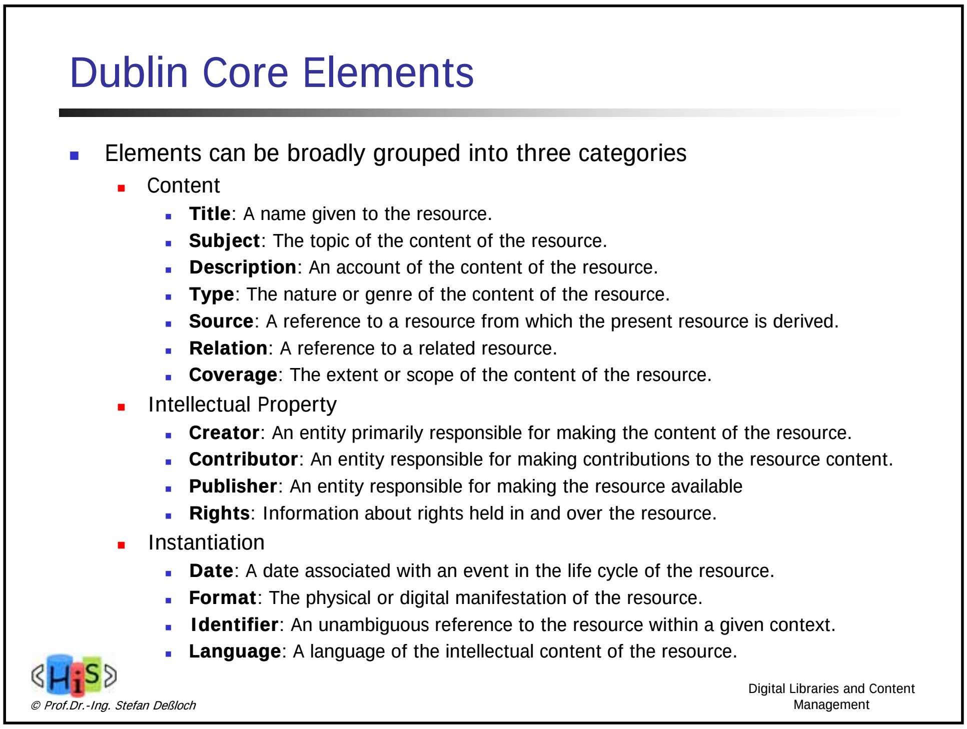
```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf=...>
<contact:Person
   rdf:about=
   "http://www.w3.org/People/EM/contact#me">
    <contact:fullName>
                Eric Miller
    </contact:fullName>
    <contact:mailbox
      rdf:resource="mailto:em@w3.org"/>
   <contact:personalTitle>
                Dr.
   </contact:personalTitle>
</contact:Person>
</rdf:RDF>
```


http://www.w3.org/2000/10/swap/pim/contact#Person
http://www.w3.org/1999/02/22-rdf-syntax-ns#type
http://www.w3.org/People/EM/contact#me
http://www.w3.org/2000/10/swap/pim/contact#fullName
Eric Miller
http://www.w3.org/2000/10/swap/pim/contact#mailbox
mailto:em@w3.org
http://www.w3.org/2000/10/swap/pim/contact#personalTitle
Dr.

- Could be used to provide semantic markup for XHTML documents
  - extension of the HTML META tag

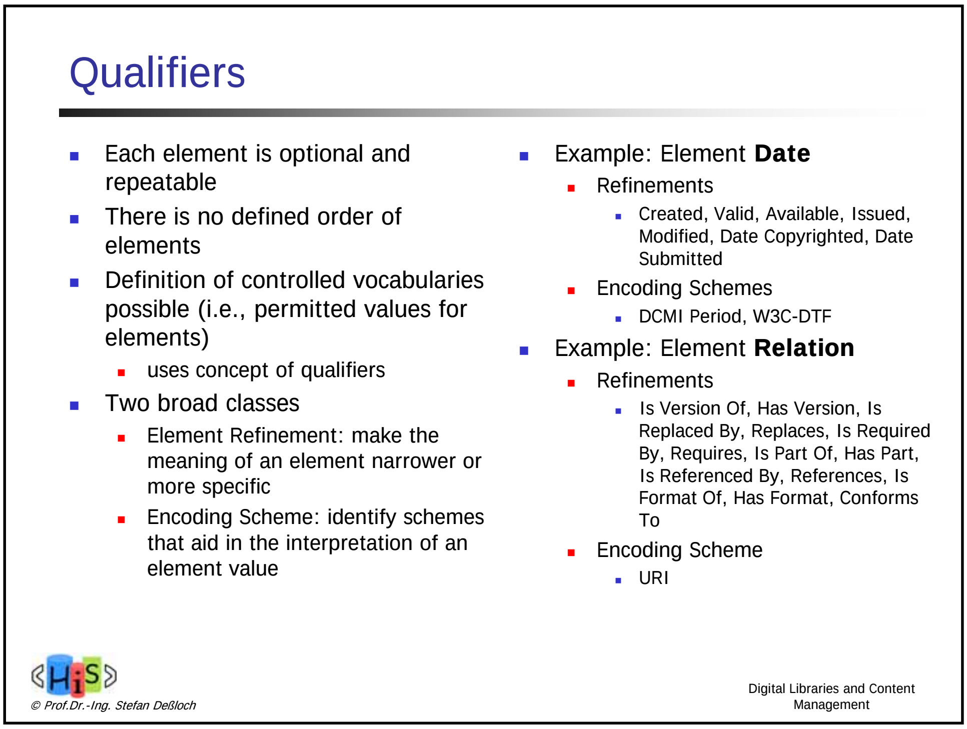
Dublin Core

- Meta-data standard for describing networked resources
  - established by international, cross-disciplinary group of professionals from librarianship, computer science, text encoding, the museum community, and other related fields
  - major goal: help improve resource discovery
  - also used in closed environments, for other purposes(e.g., meta-data exchange)
- Meta-data description
  - uses a set of common meta data elements (nouns) and qualifiers (adjectives)
    - can be embedded in the resource (e.g., as HTML meta tags)
    - can be contained in a separate record/description of a resource (e.g., in a meta-data catalog file or database)
- Dublin Core defines
  - a vocabulary for meta data
    - simple to use, based on commonly used semantics, international, extensible,
  - best practices of how to use the language in various formats
    - HTML, XML, RDF



Dublin Core Elements

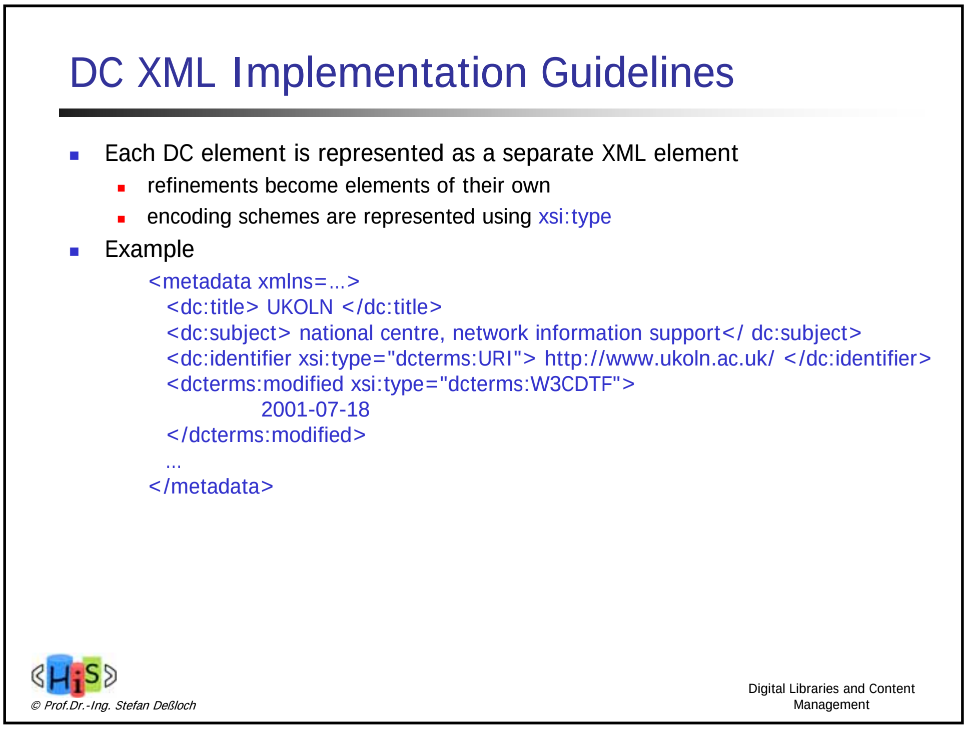
- Elements can be broadly grouped into three categories
  - Content
    - **Title**: A name given to the resource.
    - **Subject**: The topic of the content of the resource.
    - **Description**: An account of the content of the resource.
    - **Type**: The nature or genre of the content of the resource.
    - **Source**: A reference to a resource from which the present resource is derived.
    - **Relation**: A reference to a related resource.
    - **Coverage**: The extent or scope of the content of the resource.
  - Intellectual Property
    - **Creator**: An entity primarily responsible for making the content of the resource.
    - **Contributor**: An entity responsible for making contributions to the resource content.
    - **Publisher**: An entity responsible for making the resource available
    - **Rights**: Information about rights held in and over the resource.
  - Instantiation
    - **Date**: A date associated with an event in the life cycle of the resource.
    - **Format**: The physical or digital manifestation of the resource.
    - **Identifier**: An unambiguous reference to the resource within a given context.
    - **Language**: A language of the intellectual content of the resource.



Qualifiers

- Each element is optional and repeatable
- There is no defined order of elements
- Definition of controlled vocabularies possible (i.e., permitted values for elements)
  - uses concept of qualifiers
- Two broad classes
  - Element Refinement: make the meaning of an element narrower or more specific
  - Encoding Scheme: identify schemes that aid in the interpretation of an element value

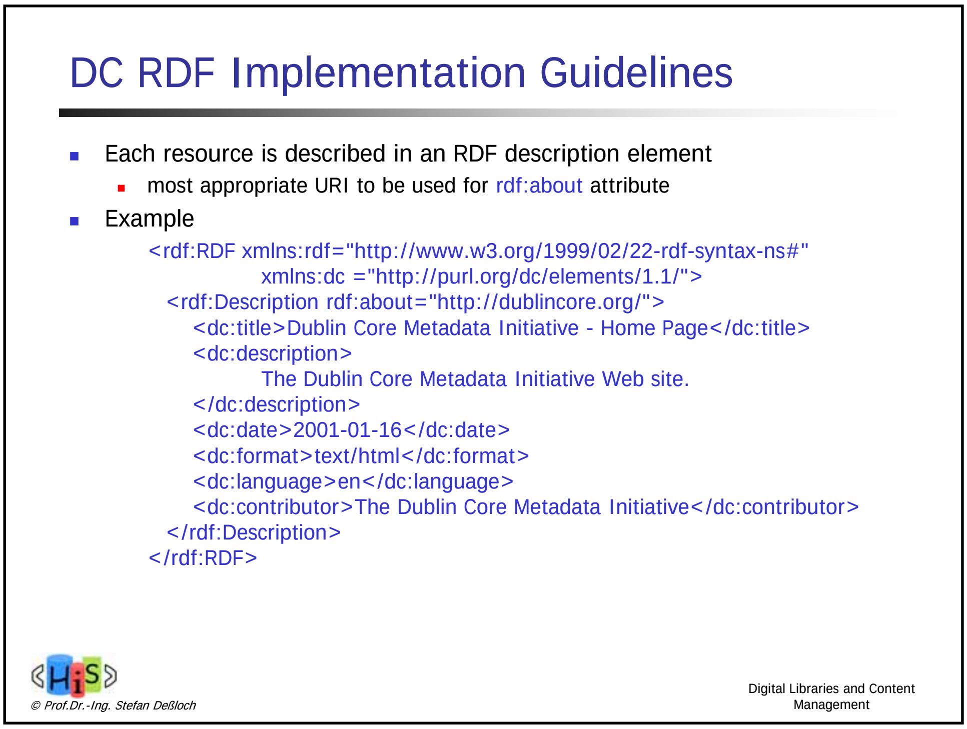
- Example: Element **Date**
  - Refinements
    - Created, Valid, Available, Issued, Modified, Date Copyrighted, Date Submitted
  - Encoding Schemes
    - DCMI Period, W3C-DTF
- Example: Element **Relation**
  - Refinements
    - Is Version Of, Has Version, Is Replaced By, Replaces, Is Required By, Requires, Is Part Of, Has Part, Is Referenced By, References, Is Format Of, Has Format, Conforms To
  - Encoding Scheme
    - URI



DC XML Implementation Guidelines

- Each DC element is represented as a separate XML element
  - refinements become elements of their own
  - encoding schemes are represented using xsi:type
- Example

```
<metadata xmlns=...>
  <dc:title> UKOLN </dc:title>
  <dc:subject> national centre, network information support</ dc:subject>
  <dc:identifier xsi:type="dcterms:URI"> http://www.ukoln.ac.uk/ </dc:identifier>
  <dcterms:modified xsi:type="dcterms:W3CDTF">
             2001-07-18
  </dcterms:modified>
  ...
</metadata>
```



DC RDF Implementation Guidelines

- Each resource is described in an RDF description element
  - most appropriate URI to be used for rdf:about attribute
- Example

```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
             xmlns:dc ="http://purl.org/dc/elements/1.1/">
  <rdf:Description rdf:about="http://dublincore.org/">
     <dc:title>Dublin Core Metadata Initiative - Home Page</dc:title>
     <dc:description>
             The Dublin Core Metadata Initiative Web site.
     </dc:description>
     <dc:date>2001-01-16</dc:date>
     <dc:format>text/html</dc:format>
     <dc:language>en</dc:language>
     <dc:contributor>The Dublin Core Metadata Initiative</dc:contributor>
  </rdf:Description>
</rdf:RDF>
```

Appendix

- XML Documents
- Schema support in XML
- Path Expressions
- XQuery
- XML APIs

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:
    [<declaration>] [<dtd>] [<comment-or-PI>] <element> [<comment-or-PI>]
    - (optional) XML declaration (XML version, encoding, ...)
    - (optional) schema (DTD)
    - single root element (possibly nested)
    - comments
    - processing instructions
      - example: reference to a stylesheet, used by a browser
  - additional requirements on the structure and content of <element>

XML Documents: Elements

- **Tag:** label for a section of data
- **Element**:
  - start tag <*tagname*>
  - content: text and/or nested element(s)
    - may be empty, alternative syntax: <*tagname*/>
  - end tag </*tagname*>
- Elements must be properly **nested** for the document to be **well-formed**
  - 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 (mixed content) is legal in XML
  - Example:

```
<account>
   This account is seldom used any more.
    <account-number> A-102</account-number>
    <branch-name> Perryridge</branch-name>
    <balance>400 </balance>
</account>
```

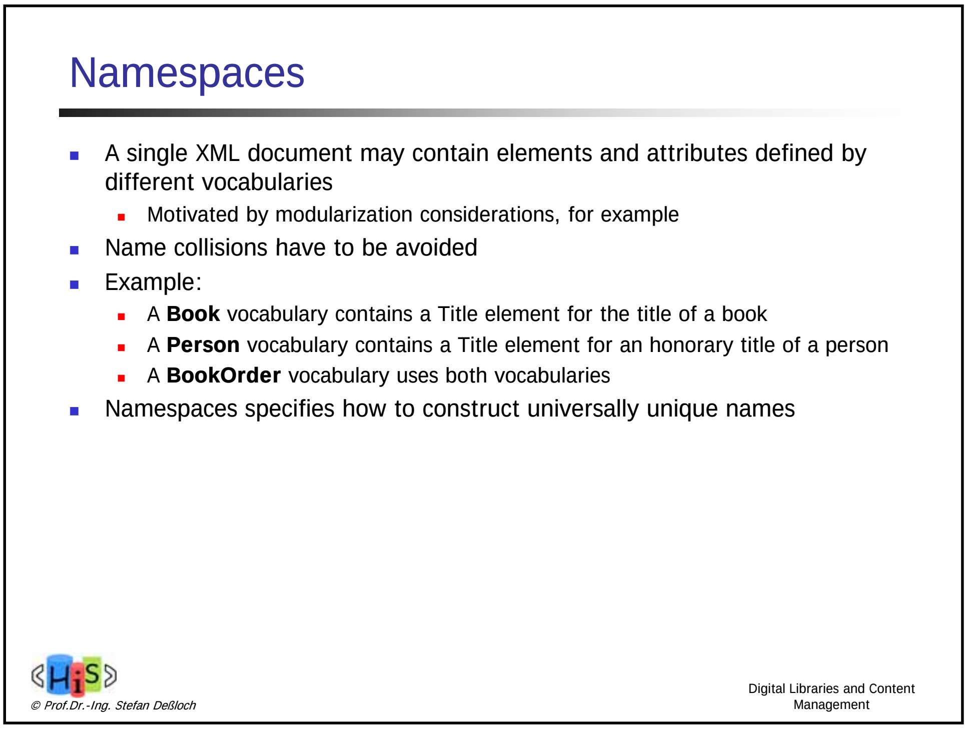
  - Useful for document markup, but discouraged for data representation
- Element content (i.e., text and nested elements) is ordered!

XML Documents: Attributes

- **Attributes:** can be used to further describe elements
  - attributes are specified by *name="value"* pairs inside the starting tag of an element
  - value is a text string
    - no further structuring of attribute values
  - attributes are not ordered
- Example:

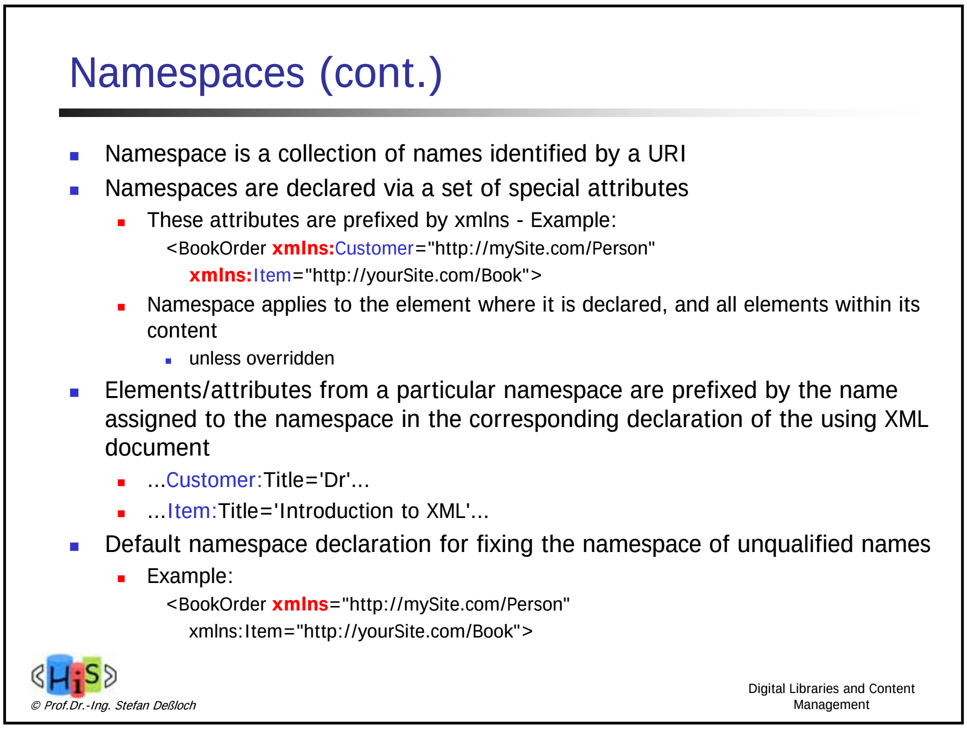
```
<account acct-type = "checking" >
        <account-number> A-102 </account-number>
        <branch-name> Perryridge </branch-name>
        <balance> 400 </balance>
</account>
```

- Well-formed documents:
  - attribute names must be unique within the element
  - attribute values are enclosed in single or double quotation marks



Namespaces

- A single XML document may contain elements and attributes defined by different vocabularies
  - Motivated by modularization considerations, for example
- Name collisions have to be avoided
- Example:
  - A **Book** vocabulary contains a Title element for the title of a book
  - A **Person** vocabulary contains a Title element for an honorary title of a person
  - A **BookOrder** vocabulary uses both vocabularies
- Namespaces specifies how to construct universally unique names

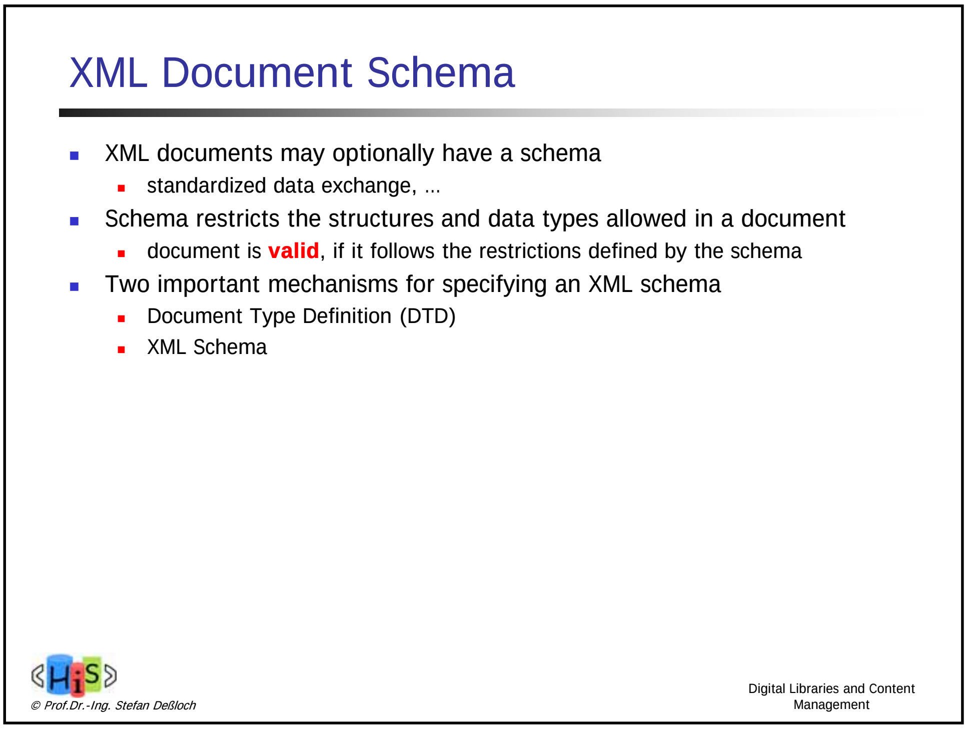


Namespaces (cont.)

- Namespace is a collection of names identified by a URI
- Namespaces are declared via a set of special attributes
  - These attributes are prefixed by xmlns - Example:

    ```
    <BookOrder xmlns:Customer="http://mySite.com/Person"
       xmlns:Item="http://yourSite.com/Book">
    ```
  - Namespace applies to the element where it is declared, and all elements within its content
    - unless overridden
- Elements/attributes from a particular namespace are prefixed by the name assigned to the namespace in the corresponding declaration of the using XML document
  - ...Customer:Title='Dr'...
  - ...Item:Title='Introduction to XML'...
- Default namespace declaration for fixing the namespace of unqualified names
  - Example:

    ```
    <BookOrder xmlns="http://mySite.com/Person"
       xmlns:Item="http://yourSite.com/Book">
    ```



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)
  - XML Schema

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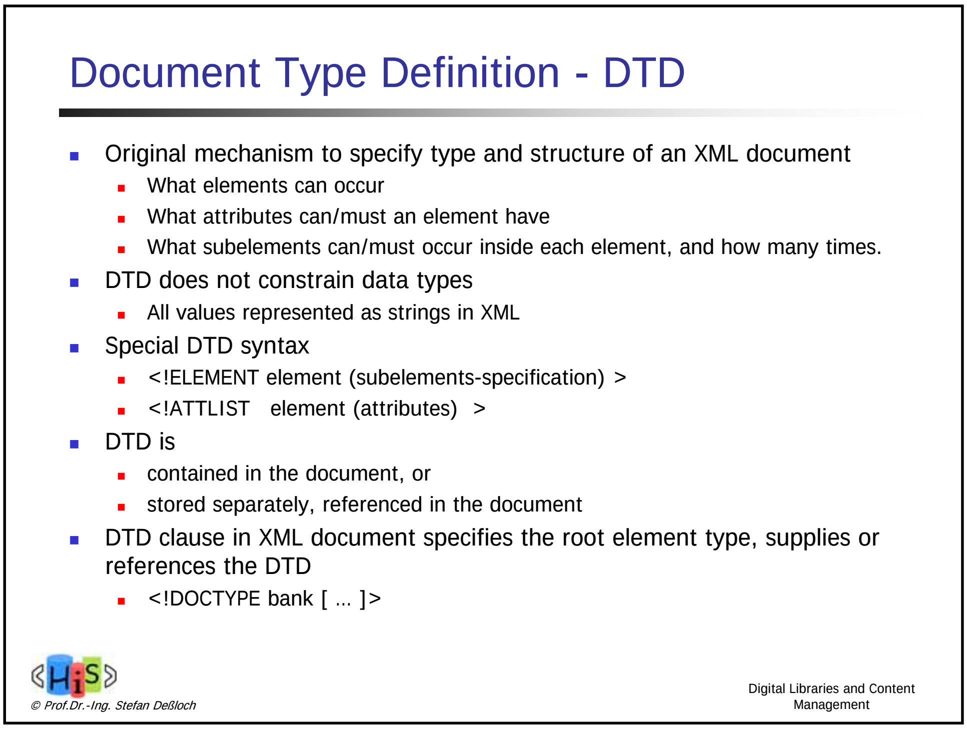

Document Type Definition - DTD

- 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) >
- DTD is
  - contained in the document, or
  - stored separately, referenced in the document
- DTD clause in XML document specifies the root element type, supplies or references the DTD
  - <!DOCTYPE bank [...]>

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Schema Definition with XML Schema

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

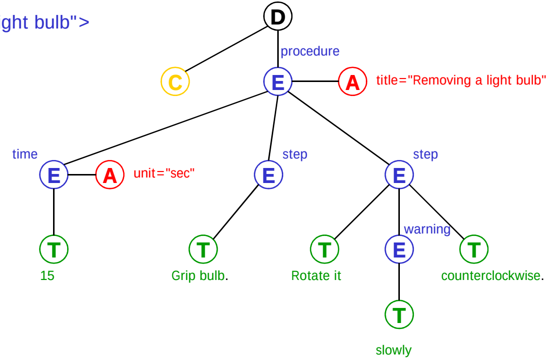
XQuery

- XQuery is a general purpose query language for XML data
- Standard developed by the World Wide Web Consortium (W3C)
  - W3C Recommendation since January 23rd, 2007
- 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

Tree Model of XML Data

- Query and transformation languages are based on a **tree model** of XML data
- An XML document is modeled as a tree, with **nodes** corresponding to elements, attributes, text, etc.
- Example:

```
<?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>
```



XQuery Data Model (XDM)

- Builds on a tree-based model, but extends it to support sequences of items
  - represent collections of documents and complex values
  - reflect (intermediate) results of query evaluation
  - closure property
    - XQuery queries and expressions operate on/produce instances of the XDM
- Based on XML Schema for precise type information
- XDM **instance**
  - ordered **sequence** of zero or more **items**
  - can contain heterogenous values
  - cannot be nested – all operations on sequences automatically "flatten" sequences
    - no distinction between an item and a sequence of length 1
  - may contain duplicate nodes (see below)
- An **item** is a **node** or an **atomic value**
- **Atomic values** are typed values
  - XML Schema simple types
  - important for representing results of intermediate expressions in the data model

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:

```
<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 { }

```
<book isbn = "{$x}">
   {$b/title }
</book>
```

- FLWOR - Expressions

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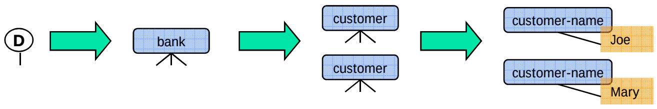
Path Expressions in XQuery

- An XPath expression maps a node (the context node) into a sequence of nodes
  - consists of one or more steps separated by “/”
  - e.g.: return the names of all customers in bank
    /child::bank/child::customer/child::name
- Evaluation of path expression
  - step by step, from left to right
  - starting from an externally provided context node, or from document root
  - each step works on a sequence of nodes
    - for each node in the sequence, look up other nodes based on step expression
    - eliminate duplicates from result sequence
    - sort nodes in document order
  - empty result sequence does not result in an error



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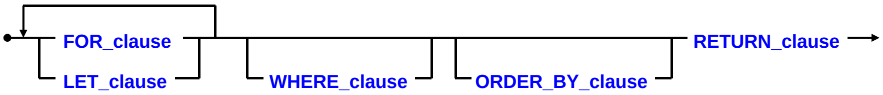
XQuery: The General Syntax Expression FLWOR



- FOR clause, LET clause generate list of tuples of bound variables (order preserving) by
  - iterating over a set of nodes (possibly specified by a path 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 ⇔ SQL from
  where ⇔ SQL where
  order by ⇔ SQL order by
  return ⇔ SQL select
  let allows temporary variables, and has no equivalent in SQL

FLWOR - Examples

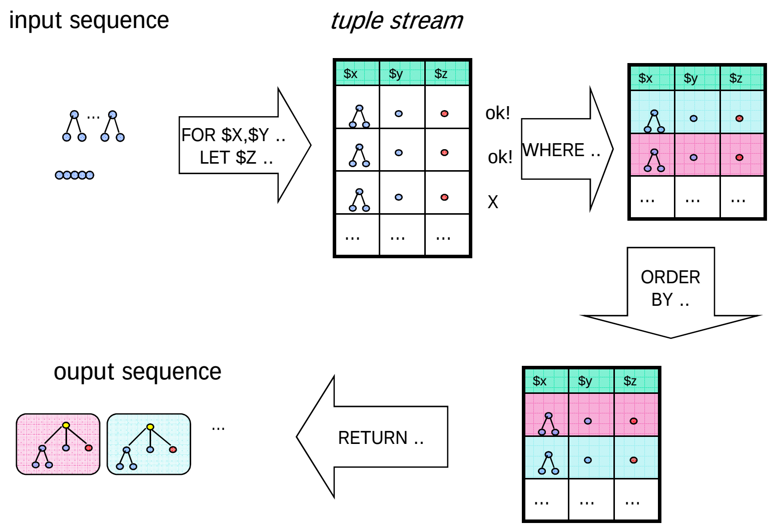
- Simple FLWR expression in XQuery
  - Find all accounts with balance > 400, with each result enclosed in an <account-number> .. </account-number> tag

```
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:

```
for       $x in /bank-2/account[balance>400]
return <account-number> {$x/@account-number}
                                        </account-number>
```

Evaluating FLWOR Expressions



input sequence

tuple stream

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

$x	$y	$z
…	…	…

ok!

ok!

X

WHERE ..

$x	$y	$z
…	…	…

ORDER BY ..

$x	$y	$z
…	…	…

RETURN ..

ouput sequence

…

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)