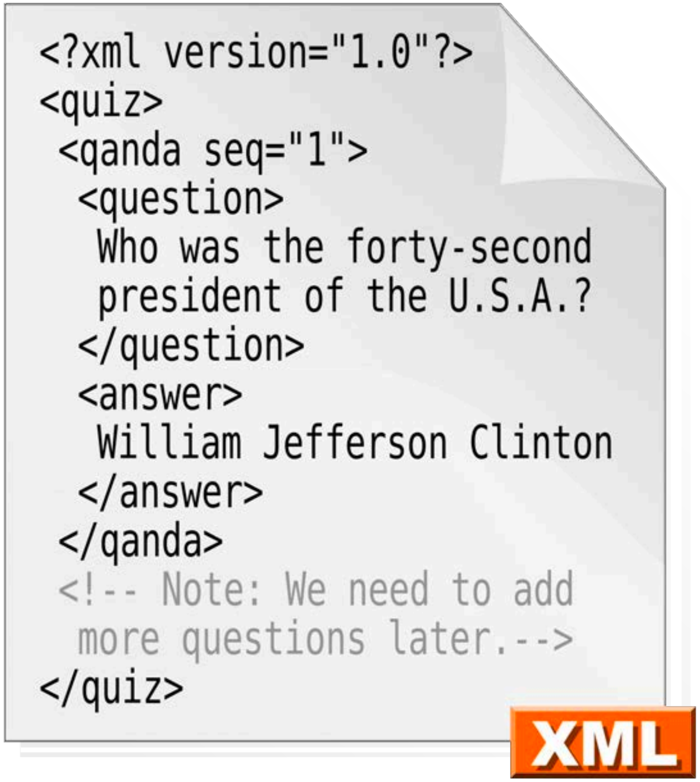

```
<?xml version="1.0"?>
<quiz>
 <qanda seq="1">
  <question>
   Who was the forty-second
   president of the U.S.A.?
  </question>
  <answer>
   William Jefferson Clinton
  </answer>
 </qanda>
 <!-- Note: We need to add
  more questions later.-->
</quiz>
```

Structured Web Documents in XML (a)

Adapted from slides from Grigoris
Antoniou and Frank van Harmelen

Outline

(1) Introduction

(2) XML details

(3) Structuring

- DTDs
- XML Schema

(4) Namespaces

(5) Accessing, querying XML documents: XPath

(6) Transformations: XSLT

Role of XML in the Semantic Web

- The Semantic Web involves ideas and languages at a fairly abstract level, e.g.: for defining ontologies, publishing data using them
- XML is a
  - Source of many key SW concepts & technology bits;
  - Potential alternative for sharing data that newer schemes must improve on; and
  - Common serialization for SW data

To paraphrase Jamie Zawinski

Some people, when confronted with a problem, think, "I know, I'll use XML."

Now they have two problems.

“Some people, when confronted with a problem, think "I know, I'll use regular expressions." Now they have two problems.”
-- Wikiquote

History

- XML's roots are in SGML
  - Standard Generalized Markup Language
  - A *metalanguage* for defining document markup languages
  - Extensible, but complicated, verbose, hard to parse, …
- HTML was defines using SGML, ~1990 by TBL
  - A markup language, not a markup *metalanguage*
- XML proposal to W3C in July 1996
  - Simplified SGML to greatly expand power and flexibility of Web
- Evolving series of W3C recommendations
  - Current recommendation: XML 5 (2008)

An HTML Example

```
<h2>Nonmonotonic Reasoning: Context-
   Dependent Reasoning</h2>
<i>by <b>V. Marek</b> and
   <b>M. Truszczynski</b></i><br>
Springer 1993<br>
ISBN 0387976892
```

The Same Example in XML

```
<book>
   <title>Nonmonotonic Reasoning: Context-Dependent Reasoning</title>
   <author>V. Marek</author>
   <author>M. Truszczynski</author>
   <publisher>Springer</publisher>
   <year>1993</year>
   <ISBN>0387976892</ISBN>
</book>
```

HTML versus XML: Similarities

- Both use **tags** (e.g. <h2> and </year>)
- Tags may be nested (tags within tags)
- Human users can read and interpret both HTML and XML representations “easily”

… **But how about machines?**

Problems Interpreting HTML Documents

Problems for a machine trying to get the author names of the book

- Authors' names could appear immediately after the title
- or immediately after the word *"by"* (or *"van"* if it's in Dutch)
- Are there two authors or just one, called *"V. Marek and M. Truszczynski*"?

```
<h2>Nonmonotonic Reasoning: Context-
Dependent Reasoning</h2>
<i>by <b>V. Marek</b> and <b>M.
Truszczynski</b></i><br>
Springer 1993<br>
ISBN 0387976892
```

HTML vs XML: Structural Information

- HTML documents don’t carry **structured information**: pieces document and their relations
- XML more easily accessible to machines since
  - Every piece of information is described
  - Relations defined through nesting structure
  - E.g., **<author>** tags appear within **<book>** tags, so they describe properties of a particular book

HTML vs XML: Structural Information

- A machine processing the XML document can assume (deduce/infer) that
  - **author** element refers to enclosing **book** element
  - Without using background knowledge, *proximity* or other heuristics
- XML allows definition of constraints on values
  - E.g., a year must be a integer of four digits

HTML vs. XML: Formatting

- HTML representation provides more than XML representation:
  - Formatting of the document is described
- Main use of an HTML document is to display information: it must define formatting
- **XML: separation of content from display**
  - same information can be displayed in different ways
  - Presentation specified by documents using other XML standards (CSS, XSL)

HTML vs. XML: Another Example

In HTML

```
<h2>Relationship matter-energy</h2>
<i> E = M × c^2 </i>
```

In XML

```
<equation>
    <gloss>Relationship matter energy </gloss>
    <leftside> E </leftside>
    <rightside> M × c^2 </rightside>
</equation>
```

HTML vs. XML: Different Use of Tags

- All HTML documents use the **same tags**
  - HTML tags come from a finite, pre-defined collection
  - Define properties for display: font, color, lists …
- XML documents can use completely different tags
  - XML tags not fixed: user definable tags
  - XML is a *meta markup language*, i.e., a language for defining markup languages

XML Vocabularies

- Applications must agree on common vocabularies to communicate and collaborate
- Communities and business sectors define their specialized vocabularies
  - mathematics (MathML)
  - bioinformatics (BSML)
  - human resources (HRML)
  - Syndication (RSS)
  - Vector graphics (SVG)
  - …

Outline

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(2) Description of XML

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The XML Language

An XML document consists of

- A **prolog**
- A number of **elements**
- An optional **epilog** (not discussed, not used much)

XML documents are tree data structures

Prolog of an XML Document

The prolog consists of

- An XML declaration and
- An optional reference to external structuring documents

```
<?xml version="1.0" encoding="UTF-16"?>
```

```
<!DOCTYPE book SYSTEM "book.dtd">
```

XML Elements

- Elements are the *things* the XML document talks about
  - E.g., books, authors, publishers, …
- An element consists of:
  - An opening tag
  - The content
  - A closing tag

<lecturer> David Billington </lecturer>

XML Elements

- Tag names can be chosen almost freely
- First character must be a letter, underscore, or colon
- No name may begin with the string “xml” in any combination of cases
  - E.g. “Xml”, “xML”

Content of XML Elements

- Content is what’s between the tags
- It can be text, or other elements, or nothing

```
<lecturer>
  <name>David Billington</name>
  <phone> +61 – 7 – 3875 507 </phone>
</lecturer>
```

- If there is no content, then element is called empty; it can be abbreviated as follows:

```
<lecturer/>  =  <lecturer></lecturer>
```

XML Attributes

- An empty element isn’t necessarily meaningless
  - It may have properties expressed as ***attributes***
- An **attribute** is a name-value pair inside the opening tag of an element

```
<lecturer
  name="David Billington"
  phone="+61 – 7 – 3875 507" />
```

XML Attributes: An Example

```
<order  orderNo="23456“
        customer="John Smith"
        date="October 15, 2017" >
  <item itemNo="a528" quantity="1" />
  <item itemNo="c817" quantity="3" />
</order>
```

The Same Example without Attributes

```
<order>
  <orderNo>23456</orderNo>
  <customer>John Smith</customer>
  <date>October 15, 2017</date>
  <item>
       <itemNo>a528</itemNo>
       <quantity>1</quantity>
  </item>
  <item>
       <itemNo>c817</itemNo>
       <quantity>3</quantity>
       </item>
</order>
```

XML Elements vs. Attributes

- Attributes can be replaced by elements
- When to use elements and when attributes is a mostly matter of taste
- **But attributes cannot be nested**

Further Components of XML Docs

- **Comments**
  - A piece of text that is to be ignored by parser

  <!-- This is a comment -->

- **Processing Instructions (PIs)**
  - Define procedural attachments

  **<?stylesheet type="text/css“
    href="mystyle.css"?>**

Well-Formed XML Documents

Constraints on syntactically correct documents:

- Only one outermost element (**root element**)
- Each element contains opening and corresponding closing tag (except self-closing tags like <foo/>)
- Tags may not overlap

  <author><name>Lee Hong</author></name>
- Attributes within an element have unique names
- Element and tag names must be permissible

  e.g.: can’t use strings beginning with digit "2ndbest"

The Tree Model of XML Docs

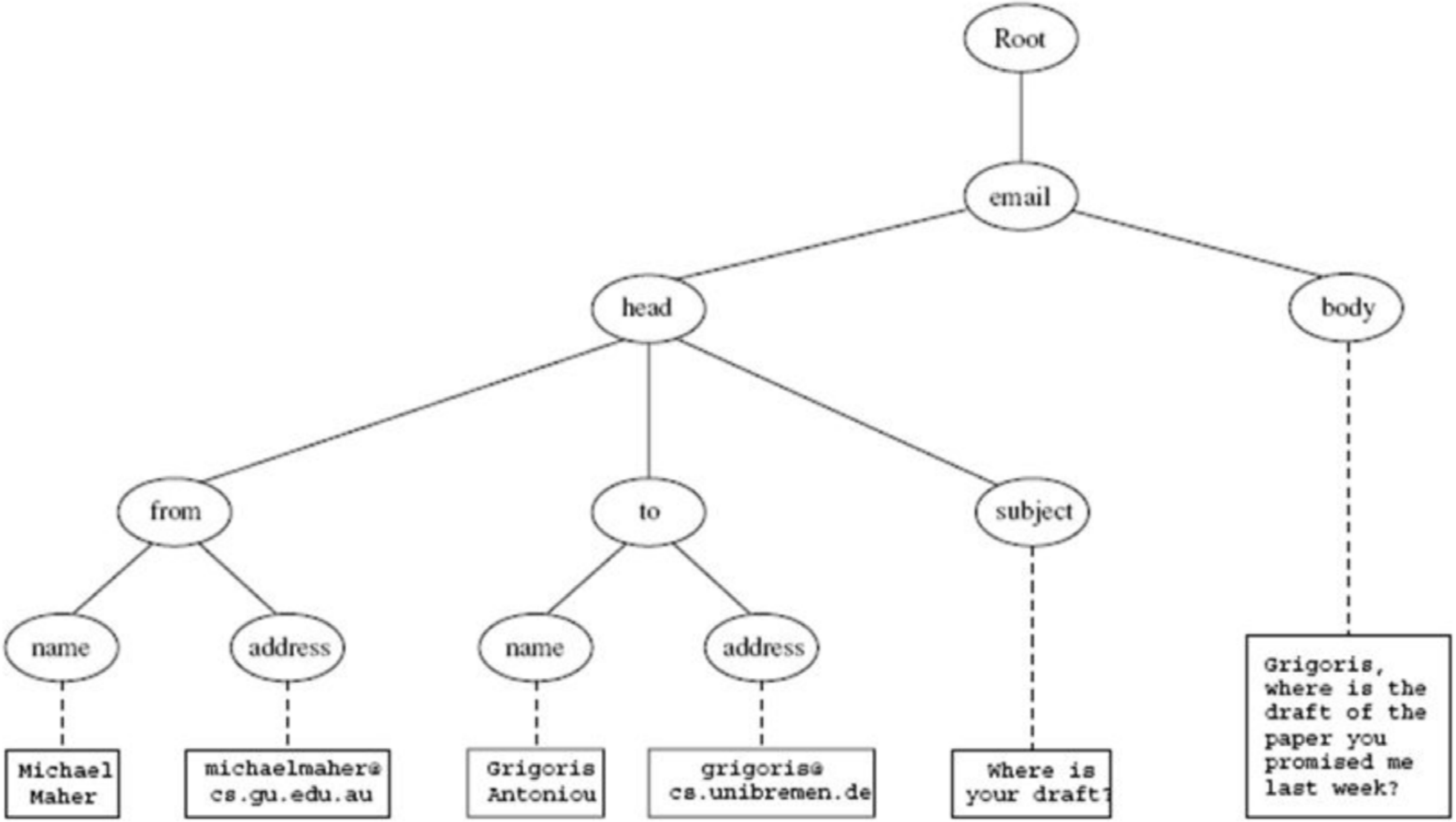
The tree representation of an XML document is an **ordered** labeled tree:

- Exactly one root
- No cycles
- Each non-root node has exactly one parent
- Each node has a label
- Order of elements is important
- … but order of attributes is not

Tree Model of XML Documents

```
<email>
  <head>
      <from name="Michael Maher"
            address="michaelmaher@cs.gu.edu.au" />
      <to name="Grigoris Antoniou"
            address="grigoris@cs.unibremen.de" />
      <subject>Where is your draft?</subject>
  </head>
  <body>
      Grigoris, where is the draft of the paper you
     promised me last week?
  </body>
</email>
```

Tree Model of XML Documents


Root
email
head
body
from
to
subject
name
address
name
address
Michael Maher
michaelmaher@ cs.gu.edu.au
Grigoris Antoniou
grigoris@ cs.unibremen.de
Where is your draft?
Grigoris, where is the draft of the paper you promised me last week?

Outline

(1) Introduction

(2) Description of XML

(3) **Structuring**

- **DTDs**
- XML Schema

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Structuring XML Documents

- Some XML documents must follow constraints defined in a “template” that can…
  - define the *element* and *attribute names* that may be used
  - define the *structure*
    - what values an attribute may take
    - which elements may or must occur within other elements, etc.
- If such structuring information exists, the document can be **validated**

Structuring XML Documents

- An XML document is **valid** if
  - it is well-formed XML
  - respects the structuring information it uses
- Ways to define structure of XML documents:
  - **DTDs** (*Document Type Definition*) came first, was based on SGML's approach
  - **XML Schema** (aka *XML Schema Definition*, XSD) is more recent and expressive
  - RELAX NG and DSDs are two alternatives

DTD: Element Type Definition

```
<lecturer>
        <name>David Billington</name>
        <phone> +61 – 7 – 3875 507 </phone>
</lecturer>
```

DTD for above element (and all **lecturer** elements):

```
<!ELEMENT lecturer (name, phone) >
<!ELEMENT name (#PCDATA) >
<!ELEMENT phone (#PCDATA) >
```

The Meaning of the DTD

```
<!ELEMENT lecturer (name, phone) >
<!ELEMENT name (#PCDATA) >
<!ELEMENT phone (#PCDATA) >
```

- The element types **lecturer**, **name**, and **phone** may be used in the document
- **lecturer** elements contain a **name** element and a **phone** element, in that order (*sequence*)
- **name** and **phone** elements may have any content

In DTDs, **#PCDATA** is the only atomic element type; stands for "*parsed character data*"

Disjunction in Element Type Definitions

- We say that **lecturer** elements contains *either* a **name** *or* a **phone** element like:

```
<!ELEMENT lecturer ( name | phone )>
```

- A **lecturer** element contains a **name** element and a **phone** element in *any order*

```
<!ELEMENT
   lecturer((name,phone)|(phone,name))>
```

- Do you see a problem with this approach?

Example of an XML Element

```
<order orderNo="23456"
       customer="John Smith"
       date="October 15, 2017">
   <item itemNo="a528" quantity="1” />
   <item itemNo="c817" quantity="3” />
</order>
```

Corresponding DTD

```
<!ELEMENT order (item+)>
<!ATTLIST order
   orderNo      ID        #REQUIRED
   customer     CDATA     #REQUIRED
   date         CDATA     #REQUIRED >

<!ELEMENT item EMPTY>
<!ATTLIST item
     itemNo        ID       #REQUIRED
     quantity      CDATA      #REQUIRED
     comments    CDATA      #IMPLIED >
```

Comments on the DTD

- The **item** element type is defined to be empty
  - i.e., it can contain no elements
- **+** (after **item)** is a **cardinality operator**:
  - It specifies how many item elements can be in an order
  - **?**: zero times or once
  - *****: zero or more times
  - **+**: one or more times
  - No cardinality operator: once

```
<!ELEMENT order (item+)>
<!ATTLIST
   order orderNo ID #REQUIRED
   customer CDATA #REQUIRED
   date CDATA #REQUIRED >
<!ELEMENT item EMPTY>
<!ATTLIST
    item itemNo ID #REQUIRED
    quantity CDATA #REQUIRED
    comments CDATA #IMPLIED >
```

Comments on the DTD

- In addition to defining elements, we define attributes
- Done in an **attribute list** containing:
  - Name of element type to which list applies
  - List of triples of attribute name, attribute type, and value type
- *Attribute name*: name that may be used in an XML document using a DTD

DTD: Attribute Types

- Similar to predefined data types, but limited …
- The most important types are
  - **CDATA**, a string (sequence of characters)
  - **ID**, a name that is *unique* across the entire XML document (~DB key)
  - **IDREF**, reference to another element with ID attribute carrying same value as IDREF attribute (~ DB foreign key)
  - **IDREFS**, a series of IDREFs
  - **(v1| . . . |vn)**, an enumeration of all possible values
- Limitations: no dates, number ranges, etc.

DTD: Attribute Value Types

- **#REQUIRED**
  - Attribute must appear in every occurrence of the element type in the XML document
- **#IMPLIED**
  - The appearance of the attribute is optional
- **#FIXED "value"**
  - Every element must have this attribute
- **"value"**
  - This specifies the default value for the attribute

Referencing with IDREF and IDREFS

```
<!ELEMENT family (person*)>
<!ELEMENT person (name)>
<!ELEMENT name (#PCDATA)>
<!ATTLIST person
    id          ID        #REQUIRED
    mother      IDREF     #IMPLIED
    father      IDREF     #IMPLIED
    children    IDREFS    #IMPLIED >
```

An XML Document Respecting the DTD

```
<family>
    <person id="bob" mother="mary" father="peter">
        <name>Bob Marley</name>
    </person>
    <person id="bridget" mother="mary">
        <name>Bridget Jones</name>
    </person>
    <person id="mary" children="bob bridget">
        <name>Mary Poppins</name>
    </person>
    <person id="peter" children="bob">
        <name>Peter Marley</name>
    </person>
</family>
```

Email Element DTD 1/2

```
<!ELEMENT email (head,body)>
<!ELEMENT head (from,to+,cc*,subject)>
<!ELEMENT from EMPTY>
<!ATTLIST from
   name       CDATA   #IMPLIED
   address    CDATA   #REQUIRED>
<!ELEMENT to EMPTY>
<!ATTLIST to
   name     CDATA  #IMPLIED
   address  CDATA  #REQUIRED>
```

Email Element DTD 2/2

```
<!ELEMENT cc EMPTY>
<!ATTLIST cc
        name      CDATA     #IMPLIED
        address   CDATA     #REQUIRED>
<!ELEMENT subject (#PCDATA) >
<!ELEMENT body (text,attachment*) >
<!ELEMENT text (#PCDATA) >
<!ELEMENT attachment EMPTY >
<!ATTLIST attachment
        encoding   (mime|binhex)      "mime"
        file           CDATA        #REQUIRED>
```

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XML Schema (XSD)

- XML Schema is a significantly richer language for defining the structure of XML documents
- Syntax based on XML itself, so separate tools to handle them not needed
- Reuse and refinement of schemas => can expand or delete existing schemas
- Sophisticated set of **data types**, compared to DTDs, which only supports strings
- XML Schema recommendation published by W3C in 2001, version 1.1 in 2012

XML Schema

- An XML schema is an element with an opening tag like

  <schema
  "http://www.w3.org/2000/10/XMLSchema"
  version="1.0">

- Structure of schema elements
  - Element and attribute types using data types

Element Types

```
<element name="email"/>
<element name="head“
    minOccurs="1“
    maxOccurs="1"/>
<element name="to" minOccurs="1"/>
```

Cardinality constraints:

- **minOccurs="x"** (default value 1)
- **maxOccurs="x"** (default value 1)
- Generalizations of *,?,+ offered by DTDs

Attribute Types

```
<attribute name="id" type="ID“ use="required"/>
<attribute name="speaks" type="Language"
    use="default" value="en"/>
```

- Existence: **use="x",** where **x** may be **optional** or **required**
- Default value: **use="x" value="..."**, where **x** may be **default** or **fixed**

Data Types

- Many **built-in data types**
  - Numerical data types: **integer**, **short,** etc.
  - String types: **string**, **ID**, **IDREF**, **CDATA,** etc.
  - Date and time data types: **time**, **month,** etc.
- Also **user-defined data types**
  - **simple data types**, which can’t use elements or attributes
  - **complex data types**, which can use them

Complex Data Types

Complex data types are defined from existing data types by defining some attributes (if any) and using:

- **sequence**, a sequence of existing data type elements (order is important)
- **all**, a collection of elements that must appear (order is not important)
- **choice**, a collection of elements, of which one will be chosen

XML Schema: The Email Example

```
<element name="email" type="emailType"/>

<complexType name="emailType">
    <sequence>
        <element name="head" type="headType"/>
        <element name="body" type="bodyType"/>
    </sequence>
</complexType>
```

XML Schema: The Email Example

```
<complexType name="headType">
    <sequence>
        <element name="from" type="nameAddress"/>
        <element name="to" type="nameAddress"
                minOccurs="1" maxOccurs="unbounded"/>
        <element name="cc" type="nameAddress"
                minOccurs="0" maxOccurs="unbounded"/>
        <element name="subject" type="string"/>
    </sequence>
</complexType>
```

XML Schema: The Email Example

```
<complexType name="nameAddress">
            <attribute name="name" type="string"
              use="optional"/>
            <attribute name="address"
             type="string" use="required"/>
</complexType>
```

- Similar for bodyType

Next

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