Structured Web Documents in XML

CSE 595 – Semantic Web

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http://www3.cs.stonybrook.edu/~pfodor/courses/cse595.html

Lecture Outline

- Introduction
- Detailed Description of XML
- Structuring
  - DTDs
  - XML Schema
- Namespaces
- Accessing, querying XML documents: XPath
- Transformations: XSLT

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 quite easily
- … But how about machines?

Problems with Automated Interpretation of HTML Documents

- An intelligent agent trying to retrieve the names of the authors of the book
- Authors' names could appear immediately after the title or immediately after the word by
- Are there two authors?
  - Or just one, called "V. Marek and M. Truszczynski"?

HTML vs XML: Structural Information

- HTML documents do not contain structural information, i.e., pieces of the document and their relationships.
  - HTML has only presentation
- XML more easily accessible to machines because
  - Every piece of information is described
  - Relations are also defined through the nesting structure.
    - E.g., the **`<author>`** tags appear within the **`<book>`** tags, so they describe properties of the particular book.

HTML vs XML: Structural Information

- A machine processing the XML document would be able to deduce that
  - the **`author`** element refers to the enclosing **`book`** element
  - rather than by proximity considerations
- XML allows the definition of constraints on values
  - E.g. **`year`** must be a number of four digits

HTML vs XML: Formatting

- The HTML representation provides more presentation than the XML representation:
  - The formatting of the document is also described
- The main use of an HTML document is to display information, therefore, it must define formatting
- XML: separation of content from display
  - same information can be displayed in different ways

HTML vs XML: Another Example

- In HTML

```
<h2>Relationship force-mass</h2>
<i> F = M × a </i>
```

- In XML

```
<equation>
    <meaning>Relationship force-
        mass</meaning>
    <leftside> F </leftside>
    <rightside> M × a </rightside>
</equation>
```

HTML vs XML: Different Use of Tags

- In both previous HTML docs we have the same tags
- In XML completely different (for different meanings)
- HTML tags define display: color, lists …
- XML tags not fixed: user definable tags
- XML is a meta markup language: language for defining markup languages

XML Vocabularies

- Web applications must agree on common vocabularies to communicate and collaborate
- Communities and business sectors are defining their specialized vocabularies
  - mathematics (MathML)
  - bioinformatics (BSML)
  - human resources (HRML)
  - …

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The XML Language

- An XML document consists of
  - a prolog
  - a number of elements
  - an optional epilog

Prolog of an XML Document

- The prolog consists of
  - an XML declaration

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

  - an optional reference to external structuring documents

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

Prolog of an XML Document

- The XML declaration

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

  - It specifies that the current document is an XML document, and defines the version and the character encoding used in the particular system (such as UTF-8, UTF-16, and ISO 8859-1).
  - The character encoding is not mandatory, but its specification is considered good practice.
  - Sometimes we also specify whether the document is self-contained – that is, whether it does not refer to external structuring documents:

```
<?xml version="1.0" encoding="UTF-16" standalone="no"?>
```

Prolog of an XML Document

- The optional reference to external structuring documents

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

  - Here the structuring information is found in a local file called **`book.dtd`**
  - Instead, the reference might be a URL.
  - If only a locally recognized name or only a URL is used, then the label **`SYSTEM`** is used.
  - If, however, one wishes to give both a local name and a URL, then the label **`PUBLIC`** should be used instead.

XML Elements

- 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>Paul Fodor</lecturer>
```

XML Elements

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

Content of XML Elements

- Content may be text, or other elements, or nothing

```
<lecturer>
	<name>Paul Fodor</name>
	<phone> +1 (123)456-7890 </phone>
</lecturer>
```

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

```
<lecturer/>
	for
<lecturer></lecturer>
```

XML Attributes

- An empty element is not necessarily meaningless
  - It may have some **<u>properties</u>** in terms of attributes
- An attribute is a **<u>name-value pair</u>** inside the opening tag of an element

```
<lecturer name="Paul Fodor"
          phone="+1 (123)456-7890"/>
```

XML Attributes: An Example

```
<order orderNo="23456"
         customer="John Smith"
         date="January 1, 2020">
    <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>January 1, 2020</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 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)
  - provide a mechanism for passing information to an application about how to handle elements.
  - The general form is: `<?target instruction?>`
  - Define procedural attachments

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

  - PIs offer procedural possibilities in an otherwise declarative environment.

Well-Formed XML Documents

- An XML document is well-formed if it is syntactically correct.
- Some syntactic rules:
  - Only one outermost element (called root element)
  - Each element contains an opening and a corresponding closing tag
  - Tags may not overlap

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

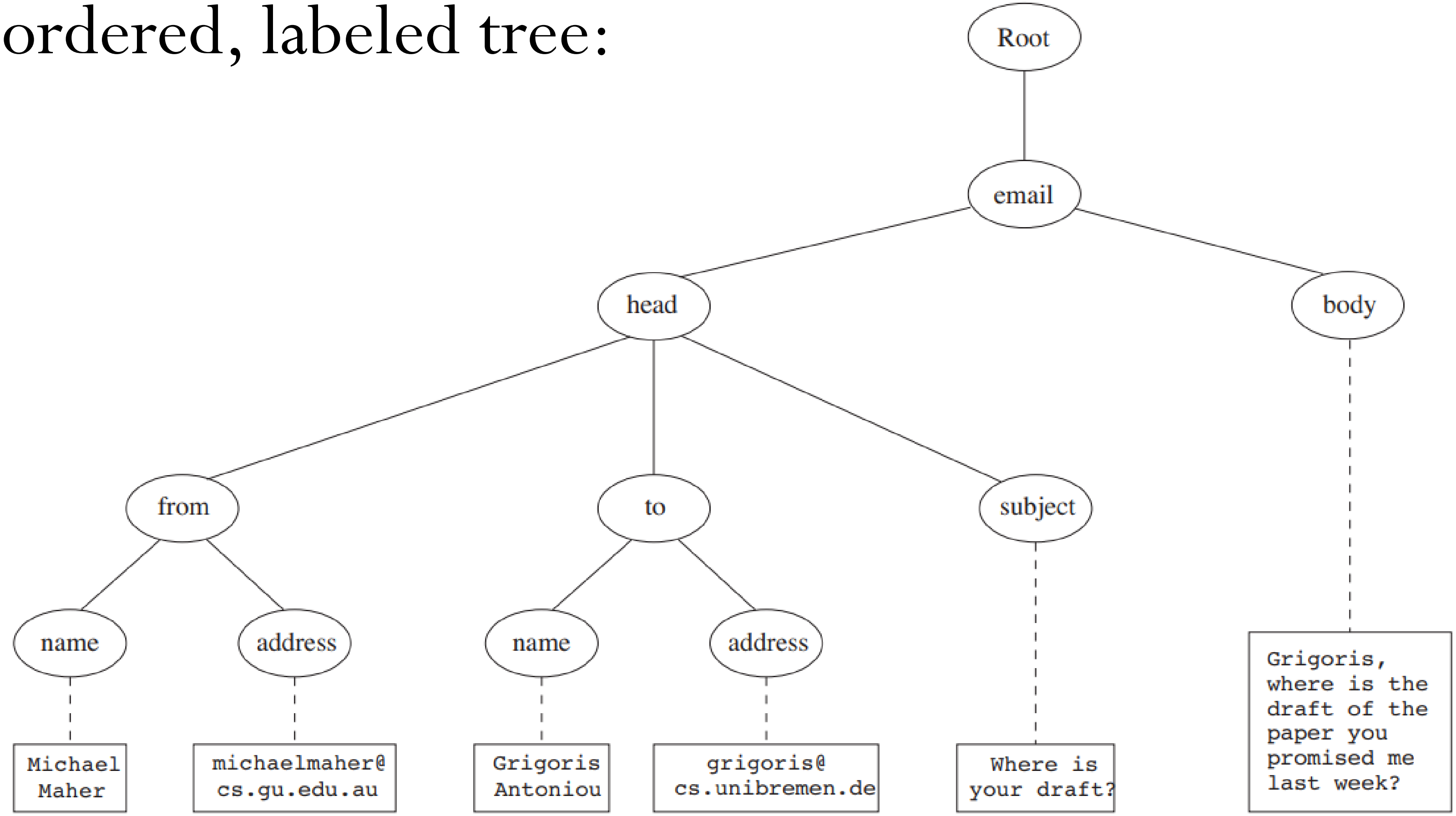
The Tree Model of XML Documents: An Example

- An XML document is well-formed if it is syntactically correct.

```
<?xml version="1.0" encoding="UTF-16"?>
<!DOCTYPE email SYSTEM "email.dtd">
<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>
```

The Tree Model of XML Documents: An Example

- The tree representation of this XML document is an ordered, labeled tree:


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?

@ Semantic Web Primer

The Tree Model of XML Docs

- The tree representation of an XML document is an ordered labeled tree:
  - There is exactly one root
  - There are no cycles
  - Each non-root node has exactly one parent
  - Each node has a label.
  - The order of elements is important
  - … but the order of attributes is not important

The Tree Model of XML Docs

- The order of attributes is not important:
  - the following two elements are equivalent:

```
<person lastname="Woo" firstname="Jason"/>
<person firstname="Jason" lastname="Woo"/>
```

  - This aspect is not represented properly in the tree.
    - In general, we would require a more refined tree concept; for example, we should also differentiate between the different types of nodes (element node, attribute node, etc.).

The Tree Model of XML Docs

- The figure also shows the difference between the root (representing the XML document), and the root element, in our case the **`email`** element
  - This distinction will play a role in addressing and querying XML documents

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Structuring XML Documents

- An XML document is well-formed if it respects certain syntactic rules.
  - However, those rules say nothing specific about the structure of the document.
- Imagine two applications that try to communicate, and that wish to use the same vocabulary.
  - For this purpose it is necessary to define all the element and attribute names that may be used.
  - The structure should also be defined: what values an attribute may take, which elements may or must occur within other elements, and so on

Structuring XML Documents

- Define all 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
  - We say that an XML document is ***valid*** if it is well-formed, uses structuring information, and respects that structuring information.

Structuring XML Documents

- An XML document is valid if
  - it is well-formed
  - respects the structuring information it uses
- There are two ways of defining the structure of XML documents:
  - DTDs (the older and more restricted way)
  - XML Schema (offers extended possibilities)

External and Internal DTDs

- Document Type Definition (DTD) is a set of markup declarations that define a document type
- The components of a DTD can be defined in a separate file (*external DTD*) or within the XML document itself (*internal DTD*).
  - Usually it is better to use external DTDs, because their definitions can be used across several documents; otherwise duplication is inevitable, and the maintenance of consistency over time becomes difficult.

DTD: Element Type Definition

```
<lecturer>
    <name>Paul Fodor</name>
    <phone> +1 (123)456-7890 </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

- The meaning of this DTD is as follows:
  - The element types **`lecturer`**, **`name`**, and **`phone`** may be used in the document
  - A **`lecturer`** element contains a **`name`** element and a **`phone`** element, in that order (sequence)
  - A **`name`** element and a **`phone`** element may have any content
    - In DTDs, **`#PCDATA`** is the only atomic type for elements

DTD: Disjunction in Element Type Definitions

- We express that a lecturer element contains either a name element or a phone element as follows:

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

- It gets more difficult when we wish to specify that a lecturer element contains a name element and a phone element in any order. We can only use the trick:

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

  - However, this approach suffers from practical limitations (imagine ten elements in any order).

Example of an XML Element

- Attributes: Consider the element:

```
<order orderNo="23456"
        customer="John Smith"
        date="January 1, 2020">
    <item itemNo="a528" quantity="1"/>
    <item itemNo="c817" quantity="3"/>
</order>
```

The Corresponding DTD

- A DTD for it looks like this:

```
<!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

- Compared to the previous example, a new aspect is that the **`item`** element type is defined to be **`EMPTY`**.
- Another new aspect is the appearance of **`+`** after **`item`** in the definition of the **`order`** element type.
  - It is one of the cardinality operators:
    - **`?`**: appears zero times or once
    - **`*`**: appears zero or more times
    - **`+`**: appears one or more times
    - No cardinality operator means exactly once

Comments on the DTD

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

DTD: Attribute Types

- Similar to predefined data types, but limited selection
- The most important types are
  - **`CDATA`**, a string (sequence of characters)
  - **`ID`**, a name that is unique across the entire XML document
  - **`IDREF`**, a reference to another element with an **`ID`** attribute carrying the same value as the **`IDREF`** attribute
  - **`IDREFS`**, a series of **`IDREF`**s
  - **`(`*`v1`*`|...|`*`vn`*`)`** , an enumeration of all possible values
- Limitations: no dates, number ranges etc.
  - for example, dates have to be interpreted as strings (**`CDATA`**); thus their specific structure cannot be enforced.

DTD: Attribute Value Types

- There are four value types:
  - **`#REQUIRED`**
    - Attribute must appear in every occurrence of the element type in the XML document
      - In the previous example, itemNo and quantity must always appear within an item element.
  - **`#IMPLIED`**
    - The appearance of the attribute is optional
      - In the example, comments are optional.
  - **`#FIXED "`*`value`*`"`**
    - Every element must have this attribute, which always has the value given after **`#FIXED`** in the DTD.
      - A value given in an XML document is meaningless because it is overridden by the fixed value.
  - **`"`*`value`*`"`**
    - This specifies the default value for the attribute
    - If a specific value appears in the XML document, it overrides the default value.

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>
```

XML Entities

- An *XML entity* can play the role of
  - a placeholder for repeatable characters
  - a section of external data
  - a part of a declaration for elements
- We can use the entity reference &thisyear instead of the value "**`2018`**"

```
    <!ENTITY thisyear "2018">
```

  - At each place the current year needs to be included, we can use the entity reference **`&thisyear;`** instead.
  - This way, updating the year value to "**`2019`**" for the whole document will only mean changing the entity declaration.

A DTD for an Email Element

```
<!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>
```

A DTD for an Email Element

```
<!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>
```

Interesting Parts of the DTD

- A **`head`** element contains (in that order):
  - a **`from`** element
  - at least one **`to`** element
  - zero or more **`cc`** elements
  - a **`subject`** element
- In **`from`**, **`to`**, and **`cc`** elements
  - the **`name`** attribute is not required
  - the **`address`** attribute is always required

Interesting Parts of the DTD

- A **`body`** element contains
  - a **`text`** element
  - possibly followed by a number of **`attachment`** elements
- The encoding attribute of an **`attachment`** element must have either the value "**`mime`**" or "**`binhex`**"
  - "**`mime`**" is the default value

Remarks on DTDs

- A DTD can be interpreted as an Extended Backus-Naur Form (EBNF)

```
<!ELEMENT email (head,body)>
```

is equivalent to

```
email -> head body
```

- Recursive definitions possible in DTDs

```
<!ELEMENT bintree
    ((bintree root bintree)|emptytree)>
```

A binary tree is the empty tree, or consists of a left subtree, a root, and a right subtree.

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XML Schema

- Significantly richer language for defining the structure of XML documents
- Its syntax is based on XML itself
  - not necessary to write separate tools
- Reuse and refinement of schemas
  - Expand or delete already existent schemas
- Sophisticated set of data types, compared to DTDs (which only supports strings)

XML Schema

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

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

  - The element uses the schema of XML Schema found at the W3C website
  - It is the foundation on which new schemas can be built
  - The prefix **`xsd`** denotes the namespace of that schema
  - If the prefix is omitted in the **`xmlns`** attribute, then we are using elements from this namespace by default

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

XML Schema

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

Element Types

- The syntax of element types is

```
<element name="..."/>
```

and they may have a number of optional attributes, such as types

```
type="..."
```

or cardinality constraints

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

Element Types

- Examples:

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

Attribute Types

- The syntax of attribute types is:

```
<attribute name="..."/>
```

and they may have a number of optional attributes, such as types

```
type="..."
```

or existence (corresponds to **`#REQUIRED`** and **`#IMPLIED`** in DTDs)

`use="x"`, where **`x`** may be **`optional`** or **`required`** or **`prohibited`**,

or a default value (corresponds to **`#FIXED`** and default values in DTDs).

Attribute Types

- Examples:

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

Data Types

- There is a variety of built-in data types
  - Numerical data types: **`integer, short, Byte, long, float, decimal`**
  - String types: **`string, ID, IDREF, CDATA, language`**
  - Date and time data types: **`time, date, gMonth, gYear`**

Data Types

- There are also ***user-defined data types***
  - ***simple data types***, which cannot use elements or attributes
  - ***complex data types***, which can use these

  - We discuss complex types first, deferring discussion of simple data types until we talk about restrictions.

Data Types

- ***Complex data types*** are defined from already 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

A Data Type Example

- Example:

```
<complexType name="lecturerType">
      <sequence>
            <element name="firstname" type="string"
                  minOccurs="0" maxOccurs="unbounded"/>
            <element name="lastname" type="string"/>
      </sequence>
      <attribute name="title" type="string"
            use="optional"/>
</complexType>
```

- The meaning is that an element in an XML document that is declared to be of type **`lecturerType`** may have a **`title`** attribute; it may also include any number of **`firstname`** elements and must include exactly one **`lastname`** element.

Data Type Extension

- Already existing data types can be extended by new elements or attributes. Example:

```
<complexType name="extendedLecturerType">
      <extension base="lecturerType">
            <sequence>
                  <element name="email" type="string"
                        minOccurs="0" maxOccurs="1"/>
            </sequence>
            <attribute name="rank" type="string"
                  use="required"/>
      </extension>
</complexType>
```

Resulting Data Type

- The resulting data type looks like this:

```
<complexType name="extendedLecturerType">
      <sequence>
            <element name="firstname" type="string"
                  minOccurs="0" maxOccurs="unbounded"/>
            <element name="lastname" type="string"/>
            <element name="email" type="string"
                  minOccurs="0" maxOccurs="1"/>
      </sequence>
      <attribute name="title" type="string"
            use="optional"/>
      <attribute name="rank" type="string"
            use="required"/>
</complexType>
```

Data Type Extension

- A hierarchical relationship exists between the original and the extended type
  - Instances of the extended type are also instances of the original type
  - They may contain additional information, but neither less information, nor information of the wrong type

Data Type Restriction

- An existing data type may be ***restricted*** by adding constraints on certain values
- Restriction is not the opposite from extension
  - Restriction is not achieved by deleting elements or attributes
- The following hierarchical relationship still holds:
  - Instances of the restricted type are also instances of the original type
  - They satisfy at least the constraints of the original type

Example of Data Type Restriction

```
<complexType name="restrictedLecturerType">
      <restriction base="lecturerType">
            <sequence>
                 <element name="firstname" type="string"
                       minOccurs="1" maxOccurs="2"/>
            </sequence>
            <attribute name="title" type="string"
                 use="required"/>
      </restriction>
</complexType>
```

Restriction of Simple Data Types

- Simple data types can also be defined by restricting existing data types
  - For example, we can define a type **`dayOfMonth`** that admits values from 1 to 31 as follows:

```
<simpleType name="dayOfMonth">
    <restriction base="integer">
        <minInclusive value="1"/>
        <maxInclusive value="31"/>
    </restriction>
</simpleType>
```

Data Type Restriction: Enumeration

- It is also possible to define a data type by listing all the possible values - example: data type **`dayOfWeek`**:

```
<simpleType name="dayOfWeek">
     <restriction base="string">
          <enumeration value="Mon"/>
          <enumeration value="Tue"/>
          <enumeration value="Wed"/>
          <enumeration value="Thu"/>
          <enumeration value="Fri"/>
          <enumeration value="Sat"/>
          <enumeration value="Sun"/>
     </restriction>
</simpleType>
```

XML Schema: The Email Example

- Here we define an XML schema for email, so that it can be compared to the DTD provided earlier:

```
<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>
```

- Similar for **`bodyType`**

XML Schema: The Email Example

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

XML Schema: The Email Example

- Some data types can be defined anonymously (the types for the attachment element and the encoding attribute).
- In general, if a type is used only once, it makes sense to define it anonymously for local use.

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Namespaces

- One of the main advantages of using XML as a universal (meta) markup language is that information from various sources may be accessed
  - An XML document may use more than one DTD or schema
- Since each structuring document was developed independently, name clashes may appear
- The solution is to use a different prefix for each DTD or schema

```
prefix:name
```

An Example

- Example, consider an (imaginary) joint venture (**`vu`** for virtual university) of an American university (say, Stony Brook University, **`sbu`**), and, an Australian university (say, Griffith University, **`gu`**), to present a unified view for online students

An Example

```
<?xml version="1.0" encoding="UTF-16"?>
<vu:instructors
    xmlns:vu="http://www.vu.com/empDTD"
    xmlns:sbu="http://www.stonybrook.edu/empDTD">
    xmlns:gu="http://www.gu.au/empDTD"

    <sbu:faculty
          sbu:title="assistant professor"
          sbu:name="John Smith"
          sbu:department="Computer Science"/>

    <gu:academicStaff
          gu:title="lecturer"
          gu:name="Mate Jones"
          gu:school="Information Technology"/>
</vu:instructors>
```

Namespace Declarations

- Namespaces are declared within an element and can be used in that element and any of its children (elements and attributes)
- A namespace declaration has the form:

  `xmlns:prefix="location"`

  - **`location`** is the address of the DTD or schema
- If a **prefix** is not specified: **`xmlns="location"`** then the location is used by default

An Example

```
<?xml version="1.0" encoding="UTF-16"?>
<vu:instructors
    xmlns:vu="http://www.vu.com/empDTD"
    xmlns="http://www.sbu.edu/empDTD">
    xmlns:gu="http://www.gu.au/empDTD"

    <faculty
          title="assistant professor"
          name="John Smith"
          department="Computer Science"/>

    <gu:academicStaff
          gu:title="lecturer"
          gu:name="Mate Jones"
          gu:school="Information Technology"/>
</vu:instructors>
```

Lecture Outline

- Introduction
- Detailed Description of XML
- Structuring
  - DTDs
  - XML Schema
- Namespaces
- Accessing, querying XML documents: XPath
- Transformations: XSLT

Addressing and Querying XML Documents

- In relational databases, parts of a database can be selected and retrieved using SQL
  - Same necessary for XML documents
  - Query languages: XQuery, XQL, XML-QL
- The central concept of XML query languages is a ***path expression***
  - Specifies how a node or a set of nodes, in the tree representation of the XML document can be reached

XPath

- XPath is core for XML query languages
  - Language for addressing parts of an XML document
    - It operates on the tree data model of XML
    - It has a non-XML syntax

Types of Path Expressions

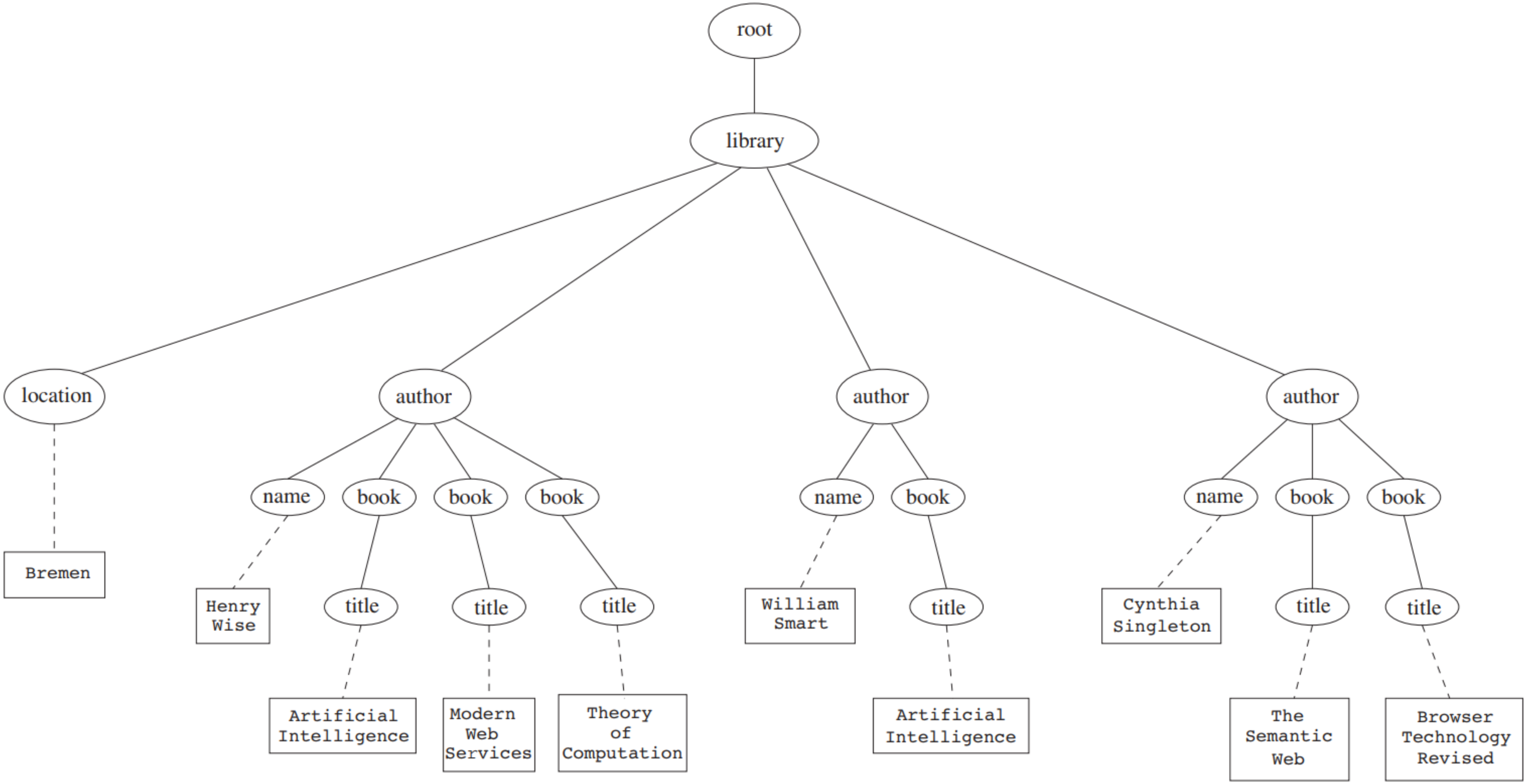
- Absolute (starting at the root of the tree)
  - Syntactically they begin with the symbol /
  - It refers to the root of the document (situated one level above the root element of the document)
- Relative to a context node

An XML Example

- Consider the following XML document:

```
<library location="Bremen">
      <author name="Henry Wise">
            <book title="Artificial Intelligence"/>
            <book title="Modern Web Services"/>
            <book title="Theory of Computation"/>
      </author>
      <author name="William Smart">
            <book title="Artificial Intelligence"/>
      </author>
      <author name="Cynthia Singleton">
            <book title="The Semantic Web"/>
            <book title="Browser Technology Revised"/>
      </author>
</library>
```

Its Tree Representation



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Examples of Path Expressions in XPath

- Address all author elements

```
/library/author
```

  - Addresses all **`author`** elements that are children of the **`library`** element node, which resides immediately below the root

- Absolute path expression general form:
  - $\mathtt{/t_1/.../t_n}$, where each $\mathtt{t_{i+1}}$ is a child node of $\mathtt{t_i}$, is a path through the tree representation

Examples of Path Expressions in XPath

- An alternative solution for the previous example is

```
//author
```

  - Address all author elements
  - Here `//` says that we should consider all elements in the document and check whether they are of type **`author`**
  - This path expression addresses all **`author`** elements anywhere in the document
    - this expression and the previous one lead to the same result in our example; however, they may lead to different results, in general

Examples of Path Expressions in XPath

- Address the **`location`** attribute nodes within **`library`** element nodes

```
/library/@location
```

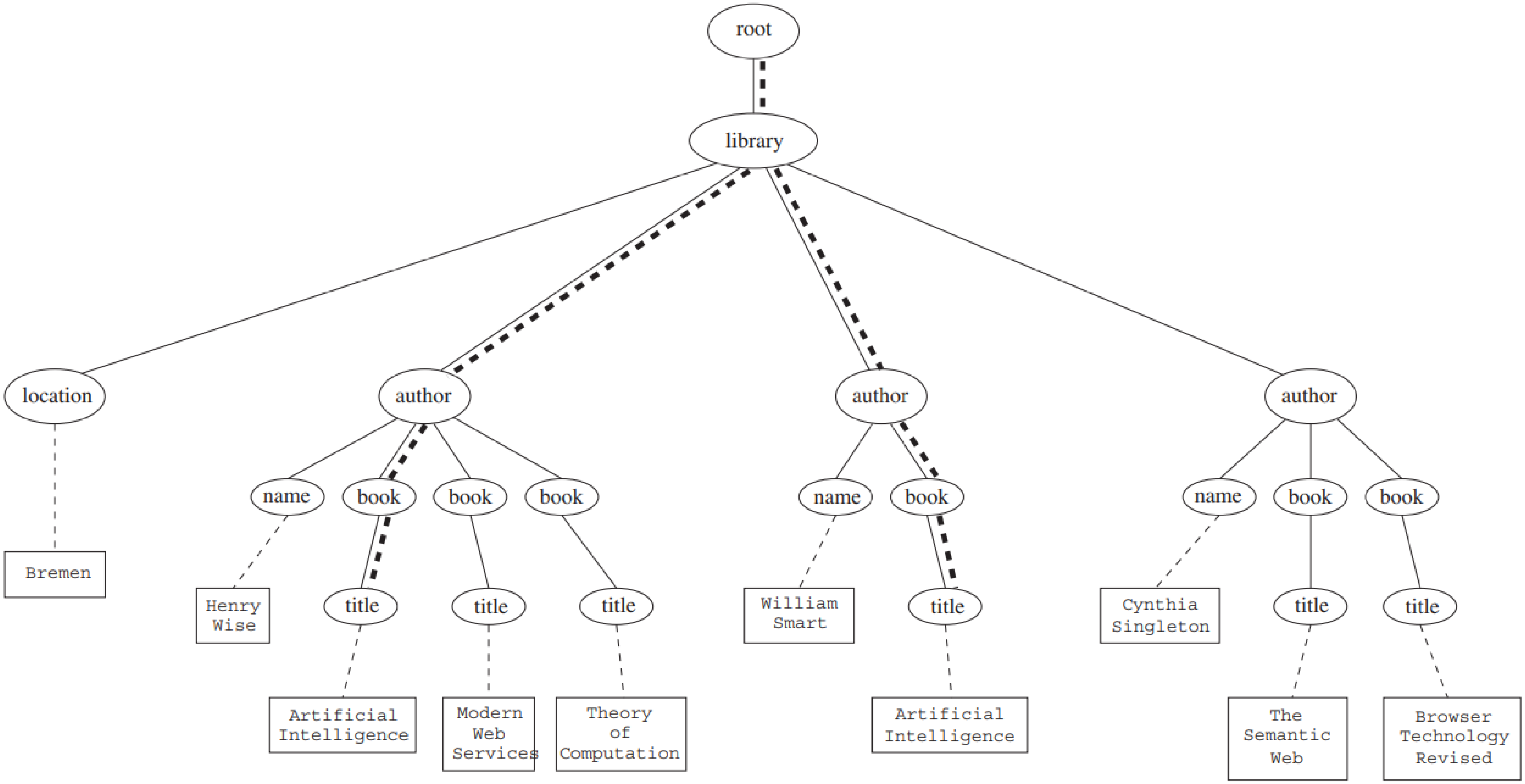
  - The symbol **`@`** is used to denote attribute nodes

Examples of Path Expressions in XPath

- Address all **`title`** attribute nodes within **`book`** elements anywhere in the document, which have the value “Artificial Intelligence”

```
//book/@title="Artificial Intelligence"
```

Tree Representation of Query



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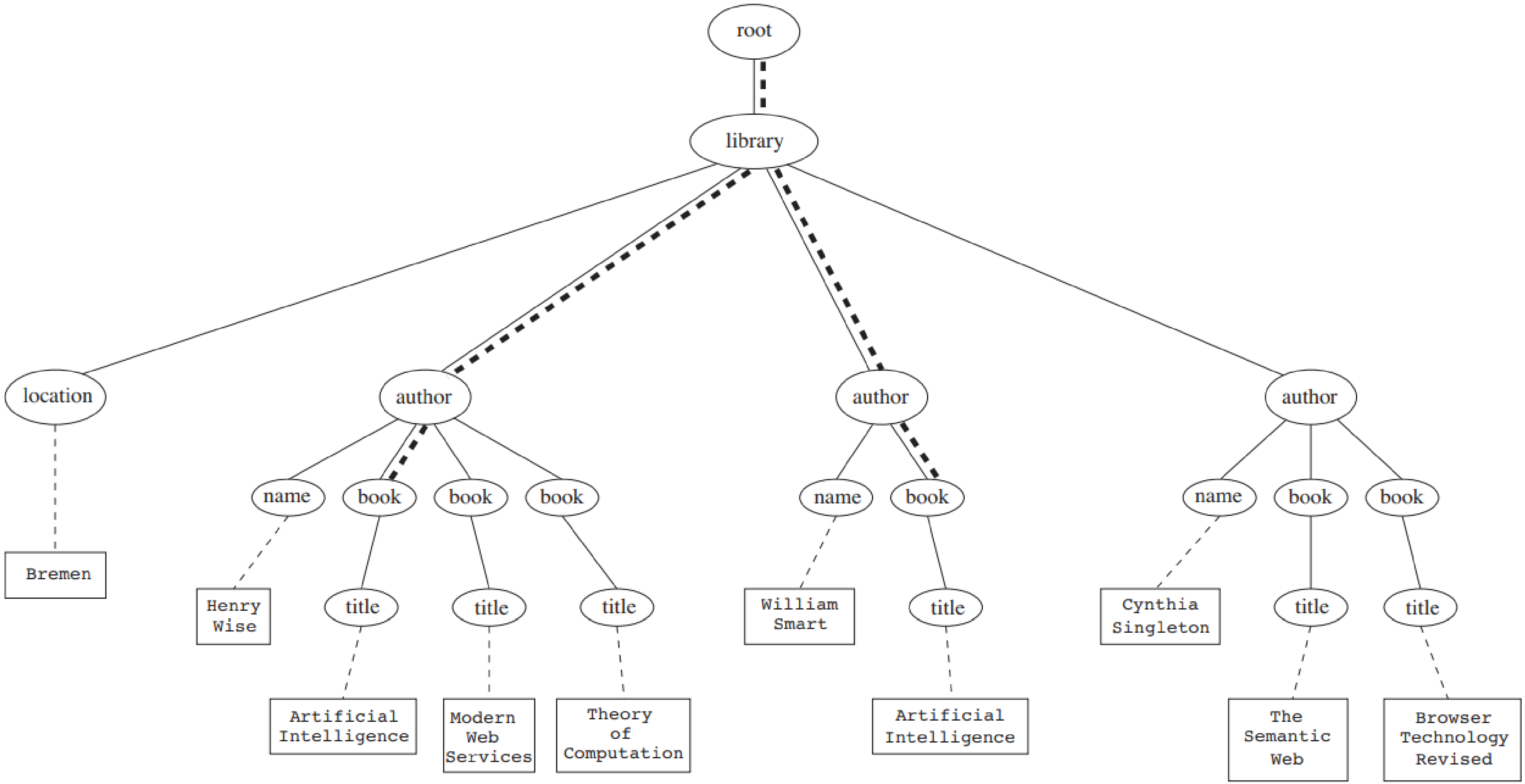
Examples of Path Expressions in XPath

- Address **all books** with title “Artificial Intelligence”

```
//book[@title="Artificial Intelligence"]
```

- Test within square brackets: a filter expression
  - It restricts the set of addressed nodes.
- Difference with the previous query
  - Previous Query collects **`title`** attribute nodes of **`book`** elements
  - This Query addresses **`book`** elements, the **`title`** of which satisfies a certain condition

Tree Representation of Query



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Examples of Path Expressions in XPath

- Address the first **author** element node in the XML document:

```
//author[1]
```

- Address the last **book** element within the first **author** element node in the document:

```
//author[1]/book[last()]
```

- Address all **book** element nodes without a **title** attribute:

```
//book[not @title]
```

General Form of Path Expressions

- A *path expression* consists of a series of steps, separated by slashes
- A *step* consists of
    - An axis specifier,
    - A node test, and
    - An optional predicate

General Form of Path Expressions

- An *axis* specifier determines the tree relationship between the nodes to be addressed and the context node
  - E.g. parent, ancestor, child (the default), sibling, attribute node
    - `//` is such an axis specifier: it denotes descendant or self

General Form of Path Expressions

- A *node test* specifies which nodes to address
  - The most common node tests are **element names**
  - E.g., * addresses all element nodes
  - **`comment()`** addresses all comment nodes

General Form of Path Expressions

- *Predicates* (or *filter expressions*) are optional and are used to refine the set of addressed nodes
  - E.g., the expression `[1]` selects the first node
  - `[position()=last()]` selects the last node
  - `[position() mod 2 =0]` selects the even nodes
- XPath has a more complicated full syntax
  - We have only presented the abbreviated syntax for path expressions

Lecture Outline

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Displaying XML Documents

- So far we have not provided any information about how XML documents can be displayed
  - Such information is necessary because unlike HTML documents, XML documents do not contain formatting information.

```
<author>
      <name>Grigoris Antoniou</name>
      <affiliation>University of Bremen</affiliation>
      <email>ga@tzi.de</email>
</author>
```

- may be displayed in different ways:

Grigoris Antoniou
University of Bremen
ga@tzi.de

Grigoris Antoniou
University of Bremen
ga@tzi.de

Style Sheets

- The advantage is that a given XML document can be presented in various ways when different style sheets are applied to it.
- Style sheets can be written in various languages, e.g.:
  - CSS2 (cascading style sheets level 2)
  - XSL (extensible stylesheet language)
- XSL includes
  - a transformation language (XSLT)
  - a formatting language
  - Both are XML applications

XSL Transformations (XSLT)

- XSLT specifies rules with which an input XML document is transformed to:
  - another XML document,
  - an HTML document, or
  - plain text
- The output document may use the same DTD or schema, or a completely different vocabulary
  - Generally XSLT is chosen when applications that use different DTDs or schemas need to communicate
- One way of defining the presentation of an XML document is to transform it into an HTML document

XSLT

- Move data and metadata from one XML representation to another
- XSLT can be used for machine processing of content without any regard to displaying the information for people to read.
- In the following we use XSLT only to display XML documents

XSLT Transformation into HTML

```
<?xml version="1.0" encoding="UTF-16"?>
<xsl:stylesheet version="1.0"
       xmlns:xsl="http://www.w3.org/1999/XSL/Transform">
  <xsl:template match="/author">
       <html>
             <head><title>An author</title></head>
             <body bgcolor="white">
                    <b><xsl:value-of select="name"/></b><br />
                    <xsl:value-of select="affiliation"/><br />
                    <i><xsl:value-of select="email"/></i>
             </body>
       </html>
  </xsl:template>
</xsl:stylesheet>
```

Style Sheet Output

- The output of this style sheet, applied to the previous XML document, produces the following HTML document (which now defines the presentation):

```
<html>
      <head><title>An author</title></head>
      <body bgcolor="white">
            <b>Grigoris Antoniou</b><br>
            University of Bremen<br>
            <i>ga@tzi.de</i>
      </body>
</html>
```

Observations About XSLT

- XSLT documents are XML documents
    - XSLT resides on top of XML
- The XSLT document defines a template
    - In this case an HTML document, with some placeholders for content to be inserted
- xsl:value-of retrieves the value of an element and copies it into the output document
    - It places some content into the template

Auxiliary Templates

- Suppose we have an XML document with details of several authors
- It is a waste of effort to treat each author element separately
- In such cases, a special template is defined for author elements, which is used by the main template

Example of an Input Document

```
<authors>
        <author>
                <name>Grigoris Antoniou</name>
                <affiliation>University of Bremen</affiliation>
                <email>ga@tzi.de</email>
        </author>
        <author>
                <name>David Billington</name>
                <affiliation>Griffith University</affiliation>
                <email>David@gu.edu.net</email>
        </author>
</authors>
```

XSLT document

```
<?xml version="1.0" encoding="UTF-16"?>
<xsl:stylesheet version="1.0"
      xmlns:xsl="http://www.w3.org/1999/XSL/Transform">

   <xsl:template match="/">
      <html>
          <head><title>Authors</title></head>
          <body bgcolor="white">
            <xsl:apply-templates select="authors"/>
            <!-- Apply templates for AUTHORS-->
          </body>
      </html>
   </xsl:template>
```

Example of an Auxiliary Template

```
    <xsl:template match="authors">
        <xsl:apply-templates select="author"/>
    </xsl:template>

    <xsl:template match="author">
        <h2><xsl:value-of select="name"/></h2>
        Affiliation:<xsl:value-of
            select="affiliation"/><br>
        Email: <xsl:value-of select="email"/>
        <p>
    </xsl:template>

</xsl:stylesheet>
```

Multiple Authors Output

- The output produced is:

```
<html>
      <head><title>Authors</title></head>
      <body bgcolor="white">
            <h2>Grigoris Antoniou</h2>
            Affiliation: University of Bremen<br>
            Email: ga@tzi.de
            <p>
            <h2>David Billington</h2>
            Affiliation: Griffith University<br>
            Email: David@gu.edu.net
            <p>
      </body>
</html>
```

Explanation of the Example

- **`xsl:apply-templates`** element causes all children of the context node to be matched against the selected path expression
  - E.g., if the current template applies to **`/`**, then the element **`xsl:apply-templates`** applies to the root element
    - i.e. the **`authors`** element (**`/`** is located above the root element)
  - If the current context node is the **`authors`** element, then the element **`xsl:apply-templates select="author"`** causes the template for the **`author`** elements to be applied to all author children of the **`authors`** element

Explanation of the Example

- It is good practice to define a template for each element type in the document
  - Even if no specific processing is applied to certain elements, the **`xsl:apply-templates`** element should be used
- In this way, we work from the root to the leaves of the tree, and all templates are applied

Processing XML Attributes

- Suppose we wish to transform to itself the element:

```
<person firstname="John" lastname="Woo"/>
```

- Let us attempt the easiest task imaginable, a transformation of the element to itself. One might be tempted to write:

```
<xsl:template match="person">
      <person firstname="<xsl:value-of select="@firstname">"
            lastname="<xsl:value-of select="@lastname">"/>
</xsl:template>
```

  - However, this is not a well-formed XML document because tags are not allowed within the values of attributes.

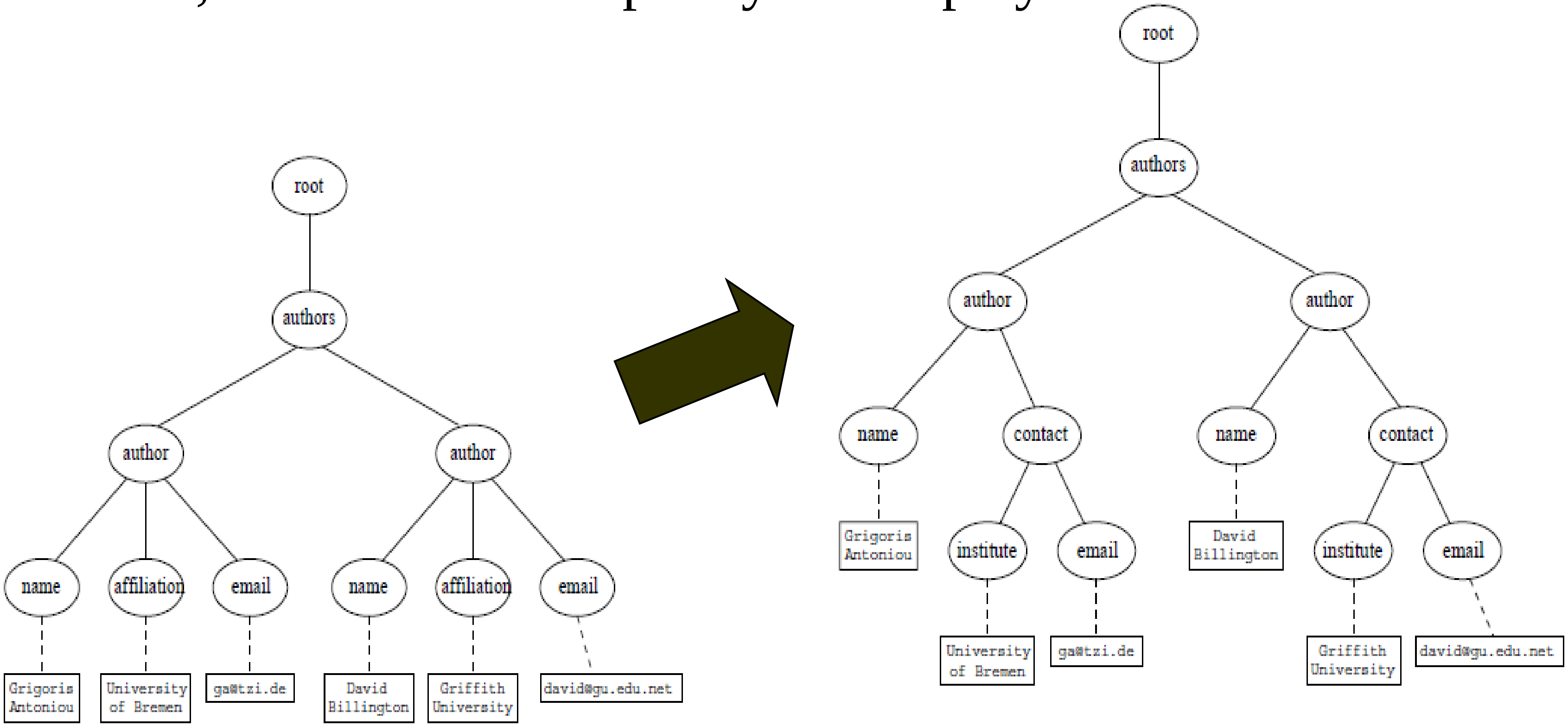
Processing XML Attributes

- We wish to add attribute values into template
- In XSLT, data enclosed in curly brackets take the place of the **`xsl:value-of`** element
- The correct way to define a template for this example is

```
<xsl:template match="person">
    <person
        firstname="{@firstname}"
        lastname="{@lastname}"/>
</xsl:template>
```

Transforming an XML Document to Another

- Finally, we give a transformation example from one XML document to another, which does not specify the display.



Transforming an XML Document to Another

```
<?xml version="1.0" encoding="UTF-16"?>
<xsl:stylesheet version="1.0"
      xmlns:xsl="http://www.w3.org/1999/XSL/Transform">

   <xsl:template match="/">
      <?xml version="1.0" encoding="UTF-16"?>
      <authors>
            <xsl:apply-templates select="authors"/>
      </authors>
   </xsl:template>

   <xsl:template match="authors">
      <author>
            <xsl:apply-templates select="author"/>
      </author>
   </xsl:template>
```

Transforming an XML Document to Another

```
   <xsl:template match="author">
      <name><xsl:value-of select="name"/></name>
      <contact>
            <institution>
                  <xsl:value-of select="affiliation"/>
            </institution>
            <email><xsl:value-of select="email"/></email>
      </contact>
   </xsl:template>

</xsl:stylesheet>
```

Summary

- XML is a metalanguage that allows users to define markup
- XML separates content and structure from formatting
- XML is the de facto standard for the representation and exchange of structured information on the Web
- XML is supported by query languages

Summary

- The nesting of tags does not have standard meaning
- The semantics of XML documents is not accessible to machines, only to people
- Collaboration and exchange are supported if there is underlying shared understanding of the vocabulary
- XML is well-suited for close collaboration, where domain- or community-based vocabularies are used
  - It is not so well-suited for global communication.