Database Management Systems

Course 236363

Lecture 8:
Extensible Markup Language (XML)
Motivation

• Applications consume and transfer data
  – Software libraries require files
  – Communication between online services
  – *How to represent such data usefully?*

• Option 1: every app defines its *own syntax*
  – For example, many of the UNIX programs
  – Requires specialized language design and parsers

• Option 2: use a *common “extensible” syntax*
  – But which one? The *relational model?*
    • Allows for software reuse, but often introduces significant challenges: proper decomposition, nulls due to fixed attributes, etc.
    • Often, translation into relations is unnatural and problematic
What is XML?

• Depending on who you're asking

• **Answer 1:** Rich documents that enrich text with markup
  – Markup captures mainly formatting, meta data (e.g., title) and links

• **Answer 2:** A hierarchical data model
  – Elegantly generalizes the relational model, object model
  – Most prominent model of semistructured data
**Document: Relations vs. XML**

### Haifa

Technion City generally refers to the 1.2-square-kilometer site located on the pine-covered north-eastern slopes of Mount Carmel. The campus comprises 100 buildings, occupied by thousands of people every day.

The Technion has two additional campuses. Its original building in midtown Haifa, in use by the Technion until the mid-1980s, now houses the **Israel National Museum of Science, Technology and Space**. The **Rappaport Faculty of Medicine** is located in the neighborhood of **Bat Galim**, adjacent to **Rambam Hospital**, the largest medical center in Northern Israel.

---

**XML**

```xml
<h3>Haifa</h3>
<p>Technion City generally refers to the 1.2-square-kilometer site located on the pine-covered north-eastern slopes of Mount Carmel. The campus comprises 100 buildings, occupied by thousands of people every day.</p>
<p>The Technion ... houses the <a href="http://...">Israel National Museum of Science</a>, <a href="...">Technology and Space</a>. The <a href="...">...</a> Northern Israel.</p>
```

---

**Relations**

<table>
<thead>
<tr>
<th>number</th>
<th>tag</th>
<th>content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>header</td>
<td>Haifa</td>
</tr>
<tr>
<td>2</td>
<td>normal</td>
<td>Technion ... the</td>
</tr>
<tr>
<td>3</td>
<td>link</td>
<td>Israel ... Space</td>
</tr>
</tbody>
</table>

---

**Link**

<table>
<thead>
<tr>
<th>number</th>
<th>URL</th>
</tr>
</thead>
</table>
Objects: Relations vs. XML

Faculty: Computer Science
Building: Taub

Member: Orna Grumberg
Office: Taub 620
Phone: 4327

Member: Irad Yavneh
Office: Taub 618, Taub 537
Phone: 4261, 4262

<faculty name="CS" building="Taub">
  <member name="Orna Grumberg">
    <office>Taub 620</office>
    <phone>4327</phone>
  </member>
  <member name="Irad Yavneh">
    <office>Taub 618</office>
    <office>Taub 537</office>
    <phone>4261</phone>
    <phone>4262</phone>
  </member>
</faculty>
Standardization Organizations

• ISO
  – International Organization for Standardization
  – Founded in 1947 to promote global commerce
    • In fact, UN backed reform of the 1926 “ISA”
  – Representatives from 162 countries

• W3C
  – World Wide Web Consortium
  – International standardization for the Web
  – Founded in 1994, by Tim Berners-Lee, supported by MIT, European Commission, and DARPA
    • Berners Lee is still heading W3C
  – Sponsored by industrial companies
  – Offices all around the world
XML History

• **1986**: SGML ISO standard for sharing documentation readable by machines
  – Stands for *Standard Generalized Markup Language*
  – Considered highly complicated, expensive to support
  – *Extensible* data model
    • Can be extended to many special cases using schemas

• **1991**: Tim Berners-Lee proposes the first version of **HTML** as an instantiation of SGML
  – Much simpler than SGML; restricted to Web pages

• **1998**: **XML** 1.0 released by W3C
  – Extensible and clean like SGML, but things stripped off to get the simplicity of HTML
XML vs. HTML

<table>
<thead>
<tr>
<th>HTML</th>
<th>XML</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed set of tags</td>
<td>Definable set of tags</td>
</tr>
<tr>
<td>Tags imply visual layout</td>
<td>No visual association</td>
</tr>
<tr>
<td>Loose format</td>
<td>Rigid format</td>
</tr>
</tbody>
</table>
XML-Based Technologies

- RDF (format for the Semantic Web)
- WSDL (Web-service protocol)
- SOAP (object communication)
- RSS (Web-feed format)
- SVG (graphics)
- MathML (format for math notation)
More XML-Based Formats

- Application Vulnerability Description Language (AVDL)
- Bank Internet Payment System (BIPS)
- Banking Industry Technology Secretariat (BITS)
- Common Business Library (xCBL)
- Connexions Markup Language (CNXML) for Modular Instructional Materials
- Electronic Business XML Initiative (ebXML)
- Extensible Access Control Markup Language (XACML)
- Financial Exchange (IFX)
- Financial Information eXchange protocol (FIX)
- Financial Products Markup Language (FpML)
- Genealogical Data Communication (GEDCOM)
- Geography Markup Language (GML)
- Global Justice’s Justice XML Data Dictionary (JXDD)
- Human Resources Background Checks and Payroll Deductions Language (HR-XML)
- Product Data Markup Language (PDML)
- Schools Interoperability Framework (SIF)
- Telecommunications Interchange Markup (TIM)
- The Text Encoding Initiative (TEI)
- Windows Rights Management Services (RMS) by Microsoft
- XML Common Biometric Format (XCBF)
- XML Process Definition Language (XPDL) for workflow management
• **XML Schemas** strengthen the typing and schema capabilities (compared to built-in DTDs)

• **XPath** is a language for querying and accessing XML elements

• **XSLT** is a language for transforming XML documents into other XML documents
  – Including XHTML for displaying XML files

• **XQuery** is a query language for XML

• **XLink** and **Xpointer** provide a rich support for cross-references among XML documents/elements
Outline

• Introduction

• XML Syntax

• DTD
  ▪ Element Declaration
  ▪ Attribute Declaration
  ▪ Entities
  ▪ Validity

• XPath
  ▪ Axes
  ▪ Predicates
  ▪ Examples of XPath Uses

• Namespaces
<?xml version="1.0"?>
<!DOCTYPE countries SYSTEM "world.dtd">
<countries>
  <country continent="Asia">
    <name>Israel</name>
    <population year="2001">6199008</population>
    <city capital="yes"><name>Jerusalem</name></city>
    <city><name>Ashdod</name></city>
  </country>
  <country continent="Europe">
    <name>France</name>
    <population year="2004">60424213</population>
  </country>
</countries>
XML Declaration

<?xml version="1.0" standalone="yes/no" encoding="enc"?>

• With standalone="no" we mean that we allow an external DTD
  – Default is "no"

• Default encoding is UTF-8
  – Good for Arabic, Armenian, Cyrillic, Greek, Hebrew, Latin, ...

• The entire declaration is optional
  – But it is pretty conventional to include it
Document Type Definition (DTD)

- Defines a schema
  - What sequences of elements can each element have as children?
  - For a given element name, which attributes are required? allowed?
  - We will study DTD in depth later

- Can be:
  - Internal (inside the XML document) or
  - External (in an external URL)
<?xml version="1.0"?>
<!DOCTYPE note [ 
  <!ELEMENT note (to,from,heading,body)> 
  <!ELEMENT to (#PCDATA)> 
  <!ELEMENT from (#PCDATA)> 
  <!ELEMENT heading (#PCDATA)> 
  <!ELEMENT body (#PCDATA)> 
]> 
<note> 
<to>Tove</to> 
<from>Jani</from> 
<heading>Reminder</heading> 
<body>Don't forget me this weekend</body> 
</note>
External DTD Example

```xml
<?xml version="1.0"?>
<!DOCTYPE countries SYSTEM "world.dtd">
<countries>
  <country continent="Asia">
    <!-- Israel. Note: 2001 population -->
    <name>Israel</name>
    <population year="2001">6199008</population>
    <city capital="yes"><name>Jerusalem</name></city>
    <city><name>Ashdod</name></city>
  </country>
  <country continent="Europe">
    <name>France</name>
    <population year="2004">60424213</population>
  </country>
</countries>
```

File world.dtd
XML Elements

• Structure:
  – Opening tag: `<name attribute_1="v_1", ..., attribute_k="v_k">`
  – Closing tag: `</name>`

• Proper nesting is required
  – `proper-nesting ::= <tag ...> proper-nesting </tag>`
  – Example of illegal XML: `<i><b>Hello</i></b>`
    • (Web browsers will accept it as legal HTML)

• Useful abbreviation for empty elements:
  – `<e ...></e> → <e .../>`
  – Examples in XHTML: `<br/> <hr/>`

• The entire document must be nested within a single element, denoted as the root
Attributes

• Restriction: An element *cannot* have two occurrences of the same attribute
  – For example, this is not allowed:
    \[
    <\text{person} \text{name}="\text{bill}" \text{name}="\text{william}">
    \]

• Design: not always clear whether an information item should be an *element* or an *attribute*
  – \[
    <\text{country} \text{population}="7M"/>\]
  – \[
    <\text{country}><\text{population}>7M</\text{population}></\text{country}>\]

• If an attribute should have its own attributes (e.g., year), then it should be an element
XML has a single primitive type: *text*
- Always nested within an element
- Some special characters (e.g., <, >, ", ; ...) are disallowed – encoded as *entity references*
  - ... which leads to new disallowed characters
  - `<eq>a > y</eq>  \(\rightarrow\)  `<eq>a &gt; y</eq>

**Encoding examples:**  `<\(\rightarrow\)&lt; \(\rightarrow\)&gt; \(\&\rightarrow\)&amp; \(\'\rightarrow\)&apos; \(\"\rightarrow\)&quot;*

- Textual elements are termed **PCDATA**
  - Parsed Character Data (parsed = entities resolved)
  - Name originated in SGML
<message>
<head>
   Entering a Kennel Club Member
</head>
<description>
   Enter the member by the name on his or her papers. Use the NAME tag.
The NAME tag has two attributes. Common (all in lowercase, please!) is
the dog's call name. Breed (also in all lowercase) is the dog's breed. Please
see the breed reference guide for acceptable breeds. Your entry should
look something like this:
</description>
<example>
   <![CDATA[<NAME common="freddy" breed="springer-spaniel">Sir
   Fredrick of Ledyard's End</NAME>]]>
</example>
</message>
Nesting Provides Flexibility

<person>
  <name>Lisa Simpson</name>
  <tel>02-828-1234</tel>
  <tel>054-470-777</tel>
  <email>lisa@cs.huji.ac.il</email>
</person>

record (tuple)

<addresses>
  <person>...</person>
  <person>...</person>
  <person>...</person>
  <person>...</person>
  <person>...</person>

...</addresses>

list (relation)
XML Must be Well Formed

• An XML document is **well-formed** if
  – Tags are syntactically correct
  – Every start tag has an end tag
  – Tags are properly nested
  – There is a root tag
  – A start tag does not have two occurrences of the same attribute

• When a DTD is specified, a document must be both **well formed** and **valid**
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  ▪ Validity
• XPath
  ▪ Axes
  ▪ Predicates
  ▪ Examples of XPath Uses
• Namespaces
Motivation

• A DTD adds syntactical requirements in addition to the well-formed requirement

• Why is it useful?
  – The usual “why schema” arguments
    • Helps avoiding errors when creating/editing XML
    • Facilitates communication via XML
    • Allows processing programs to make assumptions
  – Macros for constants/includes (entities)
Example Revisited

```xml
<?xml version="1.0"?>
<!DOCTYPE countries SYSTEM "world.dtd">
<countries>
  <country continent="Asia">
    <!-- Israel. Note: 2001 population -->
    <name>Israel</name>
    <population year="2001">6199008</population>
    <city capital="yes"><name>Jerusalem</name></city>
    <city><name>Ashdod</name></city>
  </country>
  <country continent="Europe">
    <name>France</name>
    <population year="2004">60424213</population>
  </country>
</countries>
```

File world.dtd
Example: An Address Book

<person>
  <name> Homer Simpson </name>  \{\text{Exactly one name per person}\}
  <greet> Dr. H. Simpson </greet>  \{\text{At most one greeting}\}
  <addr> 1234 Springwater Road </addr>  \{\text{As many address lines as needed (in order)}\}
  <addr> Springfield USA, 98765 </addr>
  <tel> (321) 786 2543 </tel>
  <fax> (321) 786 2544 </fax>  \{\text{Mixed telephones and faxes}\}
  <tel> (321) 786 2544 </tel>
  <email> homer@math.springfield.edu </email>  \{\text{As many as needed}\}
</person>
The Address Book DTD

```xml
<!ELEMENT addressbook (person*)>
<!ELEMENT person (name, greet?, address*, (fax | tel)*, email*)>
<!ELEMENT name (#PCDATA)>
<!ELEMENT greet (#PCDATA)>
<!ELEMENT address (#PCDATA)>
<!ELEMENT tel (#PCDATA)>
<!ELEMENT fax (#PCDATA)>
<!ELEMENT email (#PCDATA)>
```
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Forms of Element Definitions

• A regular expression
  – (name, greet?, address*, (fax | tel)*, email*)

• EMPTY
  – The element has no content
  – Example: <!ELEMENT br EMPTY> (in XML: <br/>)

• ANY
  – Mixture of PCDATA and elements defined in the DTD

• Mixed content
  – (#PCDATA)
  – (#PCDATA | address | name)*
  – (#PCDATA | italic | bold)*
### DTD Regular Expressions

<table>
<thead>
<tr>
<th>Format</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>name, tel, ...</strong></td>
<td>Element name</td>
</tr>
<tr>
<td>$e_1, e_2$</td>
<td>$e_1$ followed by $e_2$</td>
</tr>
<tr>
<td>$e^*$</td>
<td>Zero or more occurrences of $e$</td>
</tr>
<tr>
<td>$e?$</td>
<td>Zero or one occurrences of $e$</td>
</tr>
<tr>
<td>$e+$</td>
<td>One or more occurrences of $e$</td>
</tr>
<tr>
<td>$e_1</td>
<td>e_2$</td>
</tr>
<tr>
<td>(e)</td>
<td>Grouping</td>
</tr>
</tbody>
</table>

(Note: an inductive definition)
Restriction on Regular Expressions

• DTD standard does not allow every regular expression; only ones that can be “efficiently verified” in the following sense:
  – *We can determine whether a string $s$ matches the regex by scanning $s$ left to right; on every symbol we will know which regex symbol it matches without looking ahead in the string*

• Such a string is called **1-unambiguous**

• Example:
  – $(a|b)^*$, $a$ is not 1-unambiguous
  – $b^*$, $a$, $(b^*, a)^*$ is 1-unambiguous
    • Note: the two express the same language (string set)
Left-to-Right Scanning

(a|b)*,a

b*,a,(b*,a)*

not 1-unambiguous

1-unambiguous
Slightly More Precisely: Glushkov Automata

- **Glushkov automaton** of a regex [1961]:
  - Preprocessing: replace each \( a^+ \) with \( aa^* \)
  - State = symbol occurrence + init state
  - Transition \( a \rightarrow b \) whenever \( b \) is a possible follower of \( a \) in the left-to-right parse
  - Accepting states = possible last symbols

![Diagram showing Glushkov automaton with states and transitions labeled with symbols a and b.](image)

![Diagram showing a nondeterministic and deterministic automaton for (a|b)*,a and b*,a,(b*,a)*.](image)
The requirement states (or can be formalized as):

*Every regular expression has a deterministic Glushkov automaton*
The requirement states (or can be formalized as):

*Every regular expression has a deterministic Glushkov automaton*

This is a violation of the DTD recommendation:

```xml
<!ELEMENT filming ((movie|director)*,(movie|director))>
```
Mixed Content

- Described by a *repeatable OR group*
  
  $$(#\text{PCDATA} \mid \text{element}_1 \mid \cdots \mid \text{element}_k)^*$$

- Rules:
  - This is *the only regular expression allowed*
  - #PCDATA must be first
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**Attributes**

```xml
<!ELEMENT height (#PCDATA)>
<!ATTLIST height
    unit CDATA "cm" default value
    accuracy CDATA #IMPLIED >
```

```xml
<!ATTLIST element-name attribute-name attribute-type attribute-behavior>
    CDATA ID #REQUIRED
    IDREF #IMPLIED
    IDREFS #FIXED "value"
    ENTITY "default-value"
    ENTITIES (value_1 | ... | value_k)
```
Attribute Types

• **CDATA:** General text

• **ID:** Unique identifier
  – At most one ID attribute per element
  – No two elements can have the same identifying attribute values

• **IDREF:** ID value of an element in the document
  – Can be any element (not typed)

• **IDREFS:** A list of IDREFs (separated by space)

• **ENTITY:** A declared entity (later)

• **ENTITIES:** A list of ENTITYs (separated by space)

• \((value_1|\cdots|value_k):\) One of \(value_1, \ldots, value_k\)
Attribute Behavior

• **#REQUIRED:** Attribute must occur
  - name CDATA #REQUIRED : <person name="Alma">

• **#IMPLIED:** Optional
  - spouse CDATA #IMPLIED : <person>

• **#FIXED:** Has a predefined value (in the DTD)
  - genus CDATA #FIXED "Panthera" : <lion genus="Panthera">

• Default value: implied unless the attribute is given (with a different value)
  - unit "cm" : <length>
Example of Recursive XML

```
<!ELEMENT people (person*)>
<!ELEMENT person (name, dateOfBirth, person?, person?)>
```

*Problem: not satisfiable by any finite XML document*

```
<!ELEMENT people (person*)>
<!ELEMENT person (name, dateOfBirth, person, person?)>
```

*Problem: illegal (not 1-unambiguous)*

*Problem: if there is one parent, is it the mother of the father?*

*Problem: we need to replicate parents for siblings*
<people>
    <person id="lisa" mother="marge" father="homer">
        <name> Lisa Simpson </name>
    </person>
    <person id="bart" mother="marge" father="homer">
        <name> Bart Simpson </name>
    </person>
    <person id="marge" children="bart lisa">
        <name> Marge Simpson </name>
    </person>
    <person id="homer" children="bart lisa">
        <name> Homer Simpson </name>
    </person>
</people>
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XML Entities (Macros)

• Used for:

1. Referring to special characters
   • Seen in action, e.g., &lt;

2. Defining shared global constants (user defined) – these are named entities
   • Example follows

3. Including (embedding) external XML
   • Example follows

4. Defining DTD macros
   • Not discussed
Named Entities

• Syntax: `<ENTITY name "value">`
• Reference an entity by `&name;`
• Examples:
  – `<!ENTITY d "Donald">`
  – `<!ENTITY dd "&d; Duck">`
    • In XML: `<name>Mr. &dd;</name>`
  – `<!ENTITY eu "Europe">`
    • In XML: `<country continent="&eu;">`
Including External Files

```xml
<!DOCTYPE jokes [ 
<!ELEMENT jokes (joke)>*>
<!ELEMENT joke (#PCDATA)>
<!ENTITY joke.1 SYSTEM "http://j.com/joke1.txt">
<!ENTITY joke.2 SYSTEM "http://j.com/joke2.txt">
<!ENTITY joke.3 SYSTEM "http://j.com/joke3.txt">
]>
<jokes>
  <joke>&joke.1;</joke>
  <joke>&joke.2;</joke>
  <joke>&joke.3;</joke>
</jokes>
```
Even Better

```xml
<!DOCTYPE jokes [
<!ELEMENT jokes (joke)>
<!ELEMENT joke (#PCDATA)>
<!ENTITY joke.1 SYSTEM "http://j.com/joke1.txt">
<!ENTITY joke.2 SYSTEM "http://j.com/joke2.txt">
<!ENTITY joke.3 SYSTEM "http://j.com/joke3.txt">
]>
<jokes>
  <joke><![CDATA[&joke.1;]]></joke>
  <joke><![CDATA[&joke.2;]]></joke>
  <joke><![CDATA[&joke.3;]]></joke>
</jokes>
```

Why CDATA?
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Valid Documents

A well-formed XML document is *valid* if it conforms to its DTD:

- The sequence of names of the children of each element $e$ matches the regex of $\text{name}(e)$
- The types and values of attributes are correct
- IDs are unique
- IDREF attributes point to identifier values
DTDs vs. Schemas

• DTDs are rather weak specifications by DB & PL standards
  – Only one base type – PCDATA
    • No numbers, Booleans, dates, etc.
  – IDREFs are untyped
    • That is, the type of the object referenced is not known
  – No constraints beyond parent/child
    • For example, child is inverse of parent
  – No inheritance
  – Context-free element definitions
    • For example, <role> in a <movie> or a <play>?

• A much richer notion of a schema is XML Schema, which we do not study here
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<?xml version="1.0"?>
<!DOCTYPE countries SYSTEM "world.dtd">

<countries>
  <country continent="&as;">
    <name>Israel</name>
    <population year="2001">6199008</population>
    <city capital="yes"><name>Jerusalem</name></city>
    <city><name>Ashdod</name></city>
  </country>
  <country continent="&eu;">
    <name>France</name>
    <population year="2004">60424213</population>
  </country>
</countries>
<!ELEMENT countries (country*)>
<!ELEMENT country (name, population?, city*)>
<!ATTLIST country continent CDATA #REQUIRED>
<!ELEMENT name (#PCDATA)>
<!ELEMENT city (name)>
<!ATTLIST city capital (yes | no) "no">
<!ELEMENT population (#PCDATA)>
<!ATTLIST population year CDATA #IMPLIED>

<!ENTITY eu "Europe">
<!ENTITY as "Asia">
<!ENTITY af "Africa">
<!ENTITY am "America">
<!ENTITY au "Australia">

world.dtd
The root is implicit
(Does not appear in the text of the XML document)

Why?
The XPath Language

/countries/country[population>10000000]

• **XPath** expressions are used for referencing elements (nodes) of an XML document

• Used in **XSLT** (next subject today) and in **XQuery** (a query language for XML)
  – We will see examples in the end

• The syntax resembles that of the Unix file system
<?xml version="1.0"?>
<!DOCTYPE countries SYSTEM "world.dtd">
<countries>
  <country continent="&as;">
    <name>Israel</name>
    <population year="2001">6199008</population>
    <city capital="yes"><name>Jerusalem</name></city>
    <city><name>Ashdod</name></city>
  </country>
  <country continent="&eu;">
    <name>France</name>
    <population year="2004">60424213</population>
  </country>
</countries>
<?xml version="1.0"?>
<!DOCTYPE countries SYSTEM "world.dtd">
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  <country continent="&as;">
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    <population year="2001">6199008</population>
    <city capital="yes"><name>Jerusalem</name></city>
    <city><name>Ashdod</name></city>
  </country>
  <country continent="&eu;">
    <name>France</name>
    <population year="2004">60424213</population>
  </country>
</countries>
An XPath expression (or just XPath for short) matches paths in the XML tree.

An absolute path begins at the root of the document:
- Starts with / or //
- For example, /countries/country/city, //city

A relative path begins with a context node that is defined by the application that uses the XPath:
- For example, city/name, or ./name
Applying XPath to XML

- Applying an XPath expression $e$ to a context node $v$ results in the list of all nodes $u$, such that $e$ matches the path from $v$ to $u$
- Applying an XPath expression $e$ to a document $d$ means applying $e$ to $\text{root}(d)$
- The order in the list is the one induced by the preorder of the nodes in the DOM tree
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 XPath Steps and Axis

• An XPath describes a sequence of *steps* that together characterize a path

• A step is defined by an *axis* that specifies a binary relationship between nodes
  – The axis describes how to get from the current node to the next one
  – For example, *parent-child*, *child-parent*, *ancestor-descendant*, etc.

• Consecutive steps are separated by /
A child axis has the simple form `tagName`
- Go to an element child with the tag `tagName`

For example,
- `/tagName` matches the `tagName` child of root
- `city/name`
- `/countries/country/city`

The child axis `*` matches every tag
- For example: `/*/*/city`, `*/name`
Child-Axis Examples

countries

document root

countries

country

continent name population city city

Asia Israel year 6199008 name capital name capital

2001 Jerusalem yes Ashdod no
Child-Axis Examples

/countries/country/city

document root

countries

country

continent name population

Asia Israel year 6199008

2001 Jerusalem yes Ashdod no

city
city

name capital name capital
Child-Axis Examples

**Document Root**

- **countries**
  - **country**
    - **continent**
      - Asia
    - **name**
      - Israel
    - **population**
      - 6199008
    - **city**
      - name: Jerusalem, capital: no
      - name: Ashdod, capital: yes
    - **year**
      - 2001
An attribute is not an element child!
Self and Descendant-or-Self

- The **self** axis “.” denotes the **identity** relationship
  - That is, the step “remain in the current node”
  - `/countries/country/. ≡ /countries/country`
  - `country/.city` ≡ `country/city`
- The **descendant-or-self** axis means: either stay in the current node or go to some descendant of the current node
  - `descendant-or-self:node()`
- `//` is a shorthand for `/descendant-or-self:node/`
  - For example, `country//name`
Descendant Examples

//country/*

document root

countries

country

continent name population city city

Asia Israel year 6199008 name capital name capital

2001 Jerusalem yes Ashdod no
Descendant Examples

//country//.
Descendant Examples

```
./*
```

document root

countries

country

Contex

continent name population

Asia Israel year 6199008

2001

name capital

Jerusalem yes

Ashdod no

city
Other Axis Types

- The *parent* axis “..” denotes the parent relationship
  - “Go to the parent of the current node”
  - For example, `//name/..//population`

- XPath has more axis types (denoted by a different syntax from the ones shown earlier); examples:
  - descendant
  - ancestor
  - ancestor-or-self
  - following-sibling
  - preceding-sibling
Referring Attributes

• The *attribute* axis is written as @attName
  – That is, “go to the attribute attName of the current node”
• The operator @* matches every attribute
Attribute Examples

//country/@continent

document root

countries

country

continent

city

name

population

year

6199008

name

capital

city

name

capital

Asia

Israel

Jerusalem

Ashdod

2001

yes

no
Attribute Examples

@continent

document root

countries

country

continent
name
population
city
city

Asia
Israel
year
6199008
name
capital
name
capital

2001
Jerusalem
yes
Ashdod
no
Attribute Examples

document root

countries

country

continent
name
population
city
city

Asia
Israel
year
6199008
name
capital
name
capital

2001
Jerusalem
yes
Ashdod
no
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• Namespaces
XPath Predicates

• Predicates are used for filtering steps out
  – For example, `//city[@captial="yes"]` will match only capital cities

• Formally, given a predicate `[P]`:
  – `P` evaluated over target node `→` true/false
  – The step is taken iff the value is `true`
  – The node reached in the last step is the context node

• XPath has a rich logic for predicates; we demonstrate only the common ones
<?xml version="1.0"?>
<!DOCTYPE countries SYSTEM "world.dtd">
<countries>
  <country continent="&eu;">
    <name>France</name>
    <population year="2004">60424213</population>
  </country>
</countries>

//country[./population>10000000]

- The XPath ./population is transformed into a number by taking its embedded text
- The XPath ./population is relative to the current node (i.e., country) in the path
- Equivalent to //country[population>10000000]
- Semantics: ∃ [population>10000000]
<?xml version="1.0"?>
<!DOCTYPE countries SYSTEM "world.dtd">

<countries>
  <country continent="&as;">
    <name>Israel</name>
    <population year="2001">6199008</population>
    <city capital="yes"><name>Jerusalem</name></city>
    <city><name>Ashdod</name></city>
  </country>

  <country continent="&eu;">
    <name>France</name>
    <population year="2004">60424213</population>
  </country>
</countries>
An XPaths evaluates to **true** if and only if its result is **not empty**
<!DOCTYPE countries SYSTEM "world.dtd">

<wx:country continent="&as;">
  <name>Israel</name>
  <population year="2001">6199008</population>
  <city capital="yes"><name>Jerusalem</name></city>
  <city><name>Ashdod</name></city>
</wx:country>

<wx:country continent="&eu;">
  <name>France</name>
  <population year="2004">60424213</population>
</wx:country>

<wx:countries>“Why?"</wx:countries>
<?xml version="1.0"?>
<!DOCTYPE countries SYSTEM "world.dtd">
<countries>
  <country continent="&as;">
    <name>Israel</name>
    <population year="2001">6199008</population>
    <city capital="yes"><name>Jerusalem</name></city>
    <city><name>Ashdod</name></city>
  </country>
  <country continent="&eu;">
    <name>France</name>
    <population year="2004">60424213</population>
  </country>
</countries>
<?xml version="1.0"?>
<!DOCTYPE countries SYSTEM "world.dtd">
<countries>
  <country continent="&as;">
    <name>Israel</name>
    <population year="2001">6199008</population>
    <city capital="yes"><name>Jerusalem</name></city>
    <city><name>Ashdod</name></city>
  </country>
  <country continent="&eu;">
    <name>France</name>
    <population year="2004">60424213</population>
  </country>
</countries>
<?xml version="1.0"?>
<!DOCTYPE countries SYSTEM "world.dtd">
<countries>
  <country continent="&as;">
    <name>Israel</name>
    <population year="2001">6199008</population>
    <city capital="yes"><name>Jerusalem</name></city>
    <city><name>Ashdod</name></city>
  </country>
  <country continent="&eu;">
    <name>France</name>
    <population year="2004">60424213</population>
  </country>
</countries>
<?xml version="1.0"?>
<!DOCTYPE countries SYSTEM "world.dtd">
<countries>
  <country continent="&as;">
    <name>Israel</name>
    <population year="2001">6199008</population>
    <city capital="yes"><name>Jerusalem</name></city>
    <city><name>Ashdod</name></city>
  </country>
  <country continent="&eu;">
    <name>France</name>
    <population year="2004">60424213</population>
  </country>
</countries>

//country/city[2]

• A number acts as an index
• That is, the number n evaluates to true iff n is the position of the node among all those reached in the last step (city)
• Inside XPath predicates, you can use predefined functions

• Examples:
  – `last()` – returns the number of nodes obtained from the last axis step
  – `position()` – returns the position of the node in the list of nodes from the last axis step
  – `name()` – returns the tag of the current node
  – `count(XPath)` – returns the number of nodes satisfying `XPath`
<?xml version="1.0"?>
<!DOCTYPE countries SYSTEM "world.dtd">
<countries>
  <country continent="&as;">
    <name>Israel</name>
    <population year="2001">6199008</population>
    <city capital="yes"><name>Jerusalem</name></city>
    <city><name>Ashdod</name></city>
  </country>
  <country continent="&eu;">
    <name>France</name>
    <population year="2004">60424213</population>
  </country>
</countries>
<?xml version="1.0"?>
<!DOCTYPE countries SYSTEM "world.dtd">
<countries>
    <country continent="&as;">
        <name>Israel</name>
        <population year="2001">6199008</population>
        <city capital="yes"><name>Jerusalem</name></city>
        <city><name>Ashdod</name></city>
    </country>
    <country continent="&eu;">
        <name>France</name>
        <population year="2004">60424213</population>
    </country>
</countries>
<?xml version="1.0"?>

<!DOCTYPE countries SYSTEM "world.dtd">

<countries>
  <country continent="&as;">
    <name>Israel</name>
    <population year="2001">6199008</population>
    <city capital="yes"><name>Jerusalem</name></city>
    <city><name>Ashdod</name></city>
  </country>
  <country continent="&eu;">
    <name>France</name>
    <population year="2004">60424213</population>
  </country>
</countries>
<?xml version="1.0"?>
<!DOCTYPE countries SYSTEM "world.dtd">

<!--*[starts-with(name(),'"c"')]-->

<!DOCTYPE countries SYSTEM "world.dtd">

<countries>
  <country continent="&as;">
    <name>Israel</name>
    <population year="2001">6199008</population>
    <city capital="yes">
      <name>Jerusalem</name>
    </city>
    <city>
      <name>Ashdod</name>
    </city>
  </country>

  <country continent="&eu;">
    <name>France</name>
    <population year="2004">60424213</population>
  </country>
</countries>
<countries>
    <country continent="&as;">
        <name>Israel</name>
        <population year="2001">6199008</population>
        <city capital="yes">
            <name>Jerusalem</name>
        </city>
        <city>
            <name>Ashdod</name>
        </city>
    </country>
    <country continent="&eu;">
        <name>France</name>
        <population year="2004">60424213</population>
    </country>
</countries>
Final Remarks on XPath

• We presented the abbreviated (sugared) syntax syntax of Xpath
• For example, \texttt{city/../@name} is an abbrv. of \texttt{child::city/parent::node() /attribute::name}

• More details on XPath:
  – XPath tutorial in W3Schools
  – XPath W3C Recommendation
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XPath in XQuery

```xml
<?xml version="1.0" encoding="ISO-8859-1"?>
<catalog>
  <cd country="UK">
    <title>Dark Side of the Moon</title>
    <artist>Pink Floyd</artist>
    <price>10.90</price>
  </cd>
  <cd country="UK">
    <title>Space Oddity</title>
    <artist>David Bowie</artist>
    <price>9.90</price>
  </cd>
  <cd country="USA">
    <title>Aretha: Lady Soul</title>
    <artist>Aretha Franklin</artist>
    <price>11.90</price>
  </cd>
</catalog>
```

```xquery
<cdpairs> {
  for $c1 in catalog/cd, $c2 in catalog/cd
  let $t1 := $c1/title
  let $t2 := $c2/title
  where $c1/@country = $c2/@country
    and $t1 != $t2
  return <pair>
    { $t1 }
    { $t2 }
  </pair>
}
</cdpairs>
```

**FLWOR expressions:**

**For Let Where Order by Return**
XPath in XSLT Example

```xml
<?xml version="1.0" encoding="ISO-8859-1"?>
<?xml-stylesheet type="text/xsl" href="catalog1.xsl"?>
<catalog>
  <cd country="UK">
    <title>Dark Side of the Moon</title>
    <artist>Pink Floyd</artist>
    <price>10.90</price>
  </cd>
  <cd country="UK">
    <title>Space Oddity</title>
    <artist>David Bowie</artist>
    <price>9.90</price>
  </cd>
  <cd country="USA">
    <title>Aretha: Lady Soul</title>
    <artist>Aretha Franklin</artist>
    <price>11.90</price>
  </cd>
</catalog>
```

```
xsl:template match="/"
  <xsl:apply-templates
    select="catalog/cd[@country='UK']"/>
</xsl:template>

<xsl:template match="cd">
  <h2>A cd of price <xsl:value-of select="./price"/></h2>
  <p>Cool!</p>
</xsl:template>
```

Result:

```
A cd of price 10.90
Cool!
A cd of price 9.90
Cool!
```
Web Pages – The Whole Picture

Knowledge → XML → XHTML → XSL → Presentation

Data → Structure → Style → JavaScript → Dynamics
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1. `<table>`
   - `<tr>`
     - `<td>`Apples</td>`
     - `<td>`Bananas</td>`
   - `</tr>`
   - `</table>`

2. `<table>`
   - `<name>`African Coffee Table</name>`
   - `<width>`80</width>`
   - `<length>`120</length>`
   - `</table>`

`</root>`
XML Namespaces

• A mechanism for creating intuitive unique names (for elements and attributes)
  – Those can be used all over the Web, cf. RDF

• Semantically, a namespace is *a collection of names that were created for a specific domain of applications*

• We will see namespaces in action when we learn RDF
Adding Namespaces

```xml
<root
xmlns:h="http://www.w3.org/TR/html4/"
xmlns:f="http://www.w3schools.com/furniture">

<h:table>
  <h:tr>
    <h:td>Apples</h:td>
    <h:td>Bananas</h:td>
  </h:tr>
</h:table>

<f:table>
  <f:name>African Coffee Table</f:name>
  <f:width>80</f:width>
  <f:length>120</f:length>
</f:table>

</root>
```
<root
    xmlns:h="http://www.w3.org/TR/html4/"
    xmlns:f="http://www.w3schools.com/furniture">
<h:table>

<table>
<thead>
<tr>
<th>prefix</th>
<th>h</th>
</tr>
</thead>
<tbody>
<tr>
<td>local name</td>
<td>table</td>
</tr>
<tr>
<td>qualified name</td>
<td>h:table</td>
</tr>
<tr>
<td>namespace URI</td>
<td><a href="http://www.w3.org/TR/html4/">http://www.w3.org/TR/html4/</a></td>
</tr>
<tr>
<td>expanded name</td>
<td><a href="http://www.w3.org/TR/html4/table">http://www.w3.org/TR/html4/table</a></td>
</tr>
</tbody>
</table>
<root>

<table xmlns="http://www.w3.org/TR/html4/">
  <tr>
    <td>Apples</td>
    <td>Bananas</td>
  </tr>
</table>

<table xmlns="http://www.w3schools.com/furniture">
  <name>African Coffee Table</name>
  <width>80</width>
  <length>120</length>
</table>

</root>
Scope of Namespaces

• The scope of a namespace declaration is the element containing the declaration and all descendant elements

• More than one namespace can be declared in the same scope
  – At most one can be the default namespace
  – All others must have unique prefixes