XML

MPRI 2.26.2: Web Data Management

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[a] Based on slides from the Webdam book by Serge Abiteboul, Ioana Manolescu, Philippe Rigaux, Marie-Christine Rousset, Pierre Senellart
`https://webdam.inria.fr/Jorge/files/sldatamodel.pdf`

Preliminaries

The role of XML

We have seen how Web pages use HTML:

- HTML is appropriate for humans: allows sophisticated output and interaction with textual documents and images;
- HTML falls short when it comes to software exploitation of data.

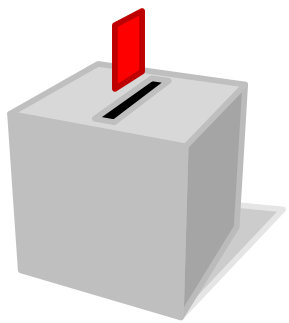
XML describes content, and promotes machine-to-machine communication and data exchange

- XML is a generic data format, and can be specialized for a wide range of fields,
  $\Rightarrow$ (X)HTML is a specialized XML dialect for data presentation
- XML simplifies data integration, since data from different sources now share a common format;
- XML comes equipped with many software products, APIs and tools.

POLL: XML and HTML

Is is true than an HTML page is an XML document

- **A**: Yes of course
- **B**: Normally yes, unless when it is invalid
- **C**: No, there is no connection
- **D**: It's complicated



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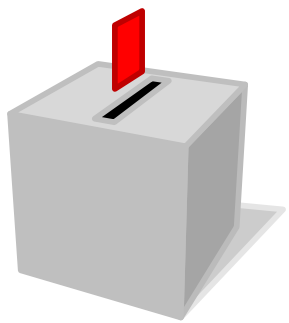


Semi-structured data model

A data model to represent both regular and irregular data.

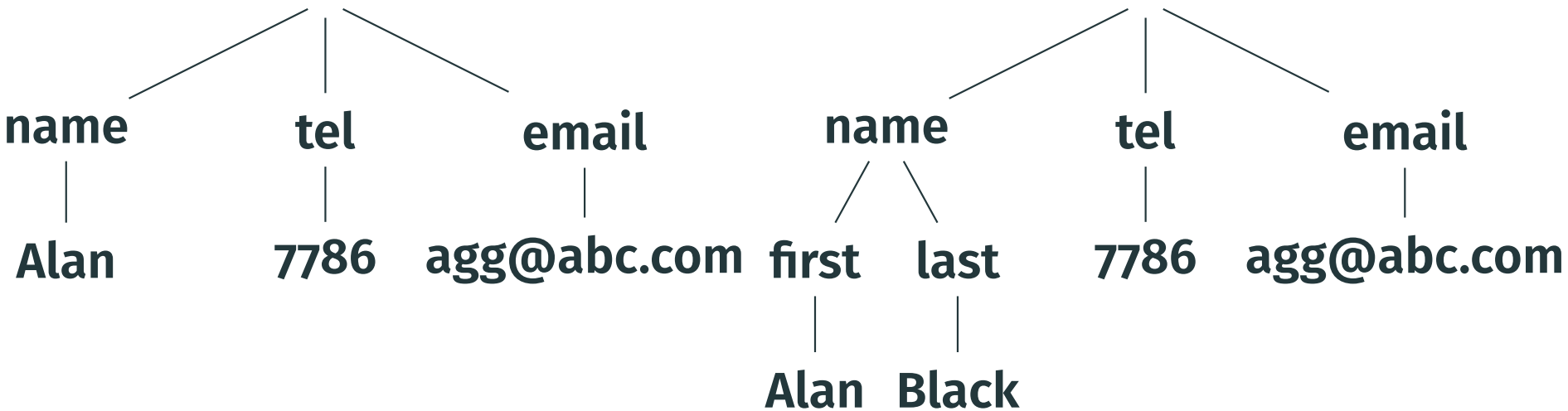
Self-describing data. The content comes with its own description;
$\Rightarrow$ contrast with the relational model, where schema and content are represented separately.

Flexible typing. Data may be typed (i.e., "such nodes are integer values" or "this part of the graph complies to this description"); often no typing, or a very flexible one

Serialized form. The XML document is serialized as text, that can be conveniently stored and exchanged.

Tree-based representation

An XML document is represented as a tree with both labels and values as vertices



Representation of regular data

The syntax makes it easy to describe sets of tuples as in:

```
{ person: {name: "alan", phone: 3127786, email: "alan@abc.com"},
  person: {name: "sara", phone: 2136877, email: "sara@xyz.edu"},
  person: {name: "fred", phone: 7786312, email: "fd@ac.uk"} }
```

→ Relational data can be represented

→ For regular data, the semi-structured representation is highly redundant

Representation of irregular data

The structure is not fixed and allows missing values, duplicates, etc.

```
{person: {name: "alan", phone: 3127786, email: "agg@abc.com"},
 person: {id: 314,
          name: {first: "Sara", last: "Green" },
          phone: 2136877,
          email: "sara@math.xyz.edu",
          spouse: 443                                    },
 person: {id: 443,
          name: "fred", Phone: 7786312, Height: 183,
          spouse: 314                                    }}
```

- Like for relational data, we can use IDs to refer to values elsewhere in the document

XML documents

An XML document is a labeled, unranked, ordered tree:

Labeled means that each node has a label

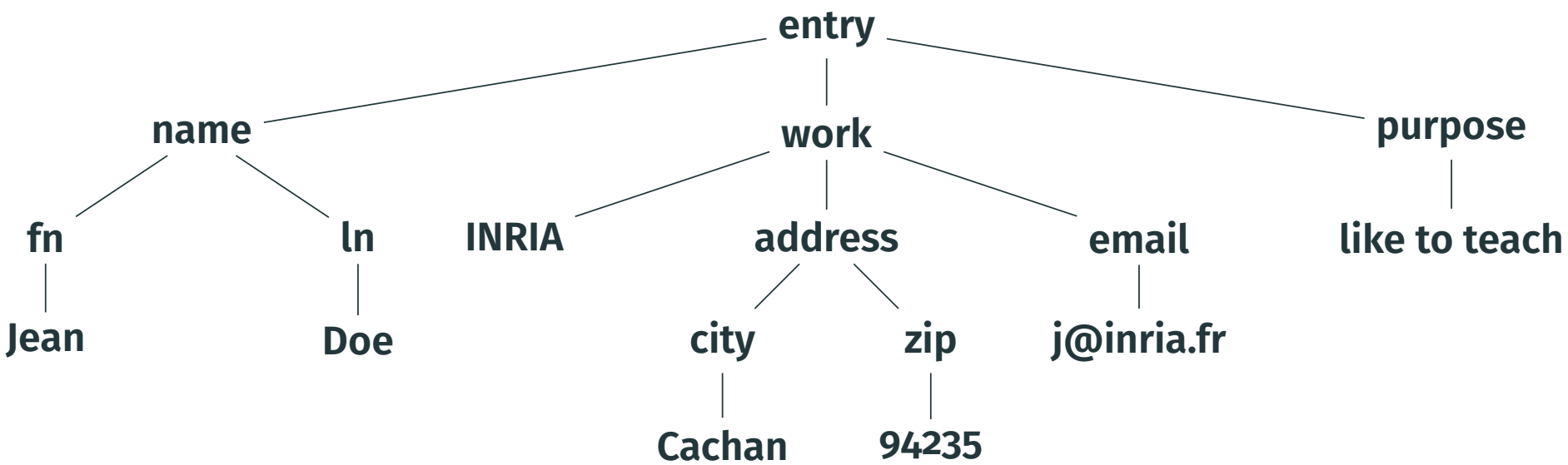
Unranked means that the number of children of a node is unbounded

Ordered means that there is an order between the children of each node.

XML specifies nothing more than a syntax: no meaning is attached to the labels.

A dialect, on the other hand, associates a meaning to labels (e.g., `title` in XHTML).

XML documents are trees



Serialized representation of XML documents

Documents can be serialized, such as, for instance:

```
<entry><name><fn>Jean</fn><ln>Doe</ln></name><work>INRIA
<email>j@inria.fr</email></work></entry>
```

or with pretty-printing as:

```
<entry>
  <name>
    <fn>Jean</fn>
    <ln>Doe</ln>
  </name>
  <work>
    INRIA
    <email>j@inria.fr</email>
  </work>
</entry>
```

Use `xmllint --format` and `pygmentize -l xml`

Serialized form, tree form

Typically, an application gets a document in *serialized form*, parse it in *tree form*, and *serializes* it back at the end.

- The serialized form is the textual, linear representation of the tree
- Standardized object-oriented model for the tree form: the *Document Object Model* (DOM) which we saw last week. Also standardizes things relevant to Web browsers.

XML basic syntax

Four examples of XML documents (separated by blank lines) are:

```
<document/>
```

```
<document>Hello World!</document>
```

```
<document>
  <salutation>Hello World!</salutation>
</document>
```

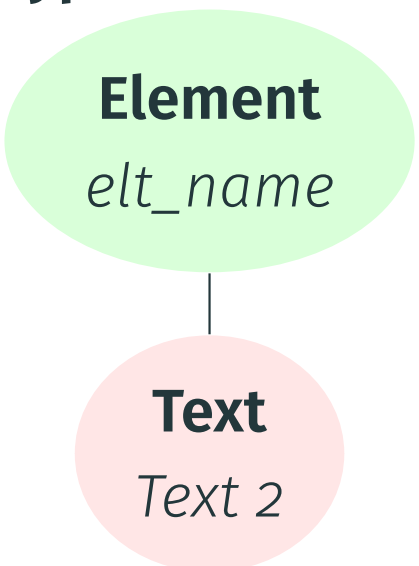
```
<?xml version="1.0" encoding="utf-8" ?>
<document>
  <salutation color="blue">Hello World!</salutation>
</document>
```

From serialized to tree form: text and elements

The basic components of an XML document are element and text.
Here is an element, whose content is a text.

```
<elt_name>
  Textual content
</elt_name>
```

The tree form of the document, modeled in DOM: each node has a **type**, either **Element** or **Text**.



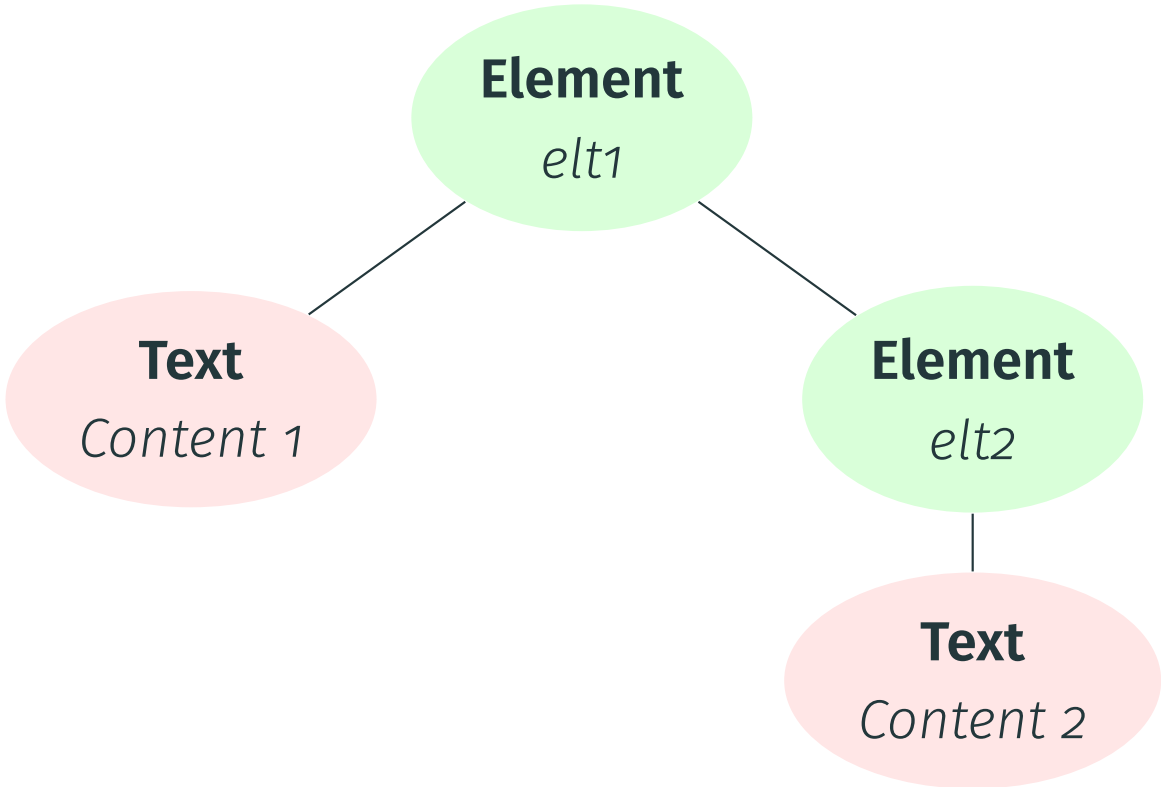
From serialized to tree form: nesting elements

The content of an element is

1. the part between the opening and closing tags (in serialized form),
2. the subtree rooted at the corresponding **Element** node (in DOM).

Example of an element nested in another element.

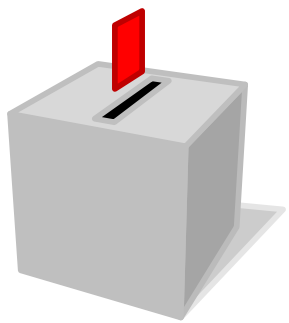
```
<elt1>
  Textual  content
  <elt2>
    Another content
  </elt2>
</elt1>
```



POLL: XML attributes

The attributes of an XML element are

- **A**: An ordered dictionary
- **B**: An unordered dictionary
- **C**: An ordered multi-dictionary
- **D**: An unordered multi-dictionary



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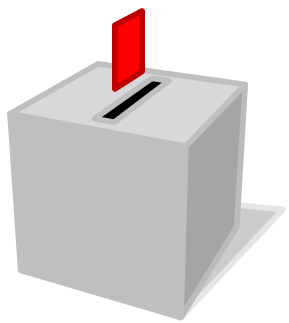


From serialized to tree form: attributes

Attributes are pairs of name/value attached to an element.

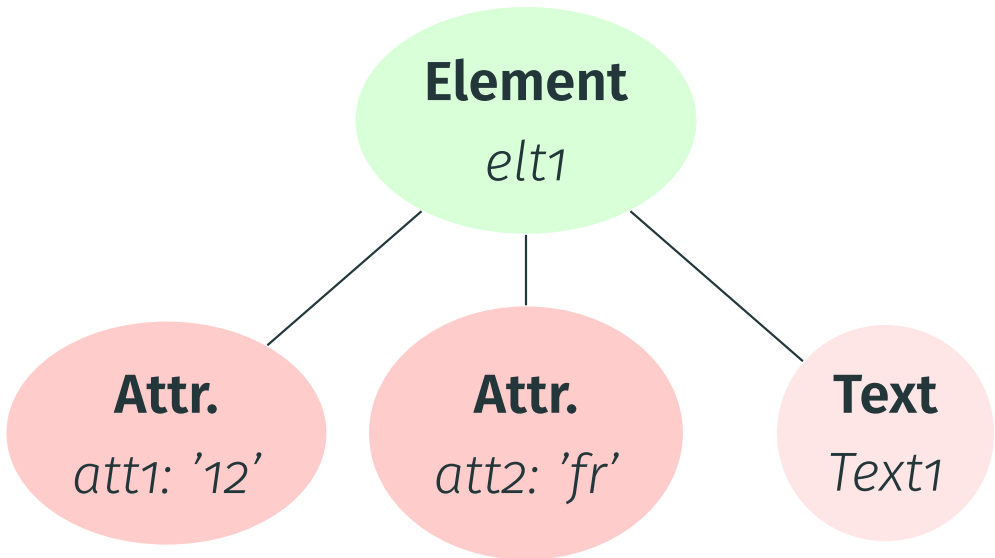
1. as part of the opening tag in the serialized form,
2. as special child nodes of the **Element** node (in DOM).

The content of an attribute is always text (no nesting).

An element with two attributes.

```
<elt1 att1='12' att2='fr'>
  Textual content
</elt1>
```

Attributes are *not* ordered, and no element can have two attributes with the same name.



From serialized to tree form: the document root

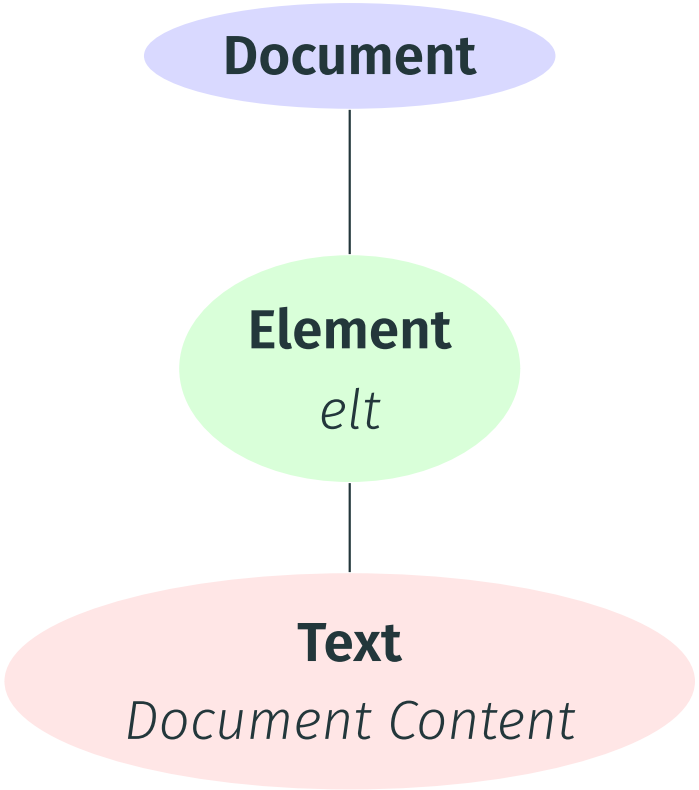
There may be a **prologue**, in which case it is the first document line:

```
<?xml version="1.0" encoding="utf-8" ?>
```

The document must **always** be enclosed in one single **element root** (= a **tree**, not a **forest**)

```
<?xml version="1.0"
    encoding="utf-8" ?>
<elt>
  Document content.
</elt>
```

Note: there may be other syntactic objects after the prologue (e.g., processing instructions).



Summary: syntax and vocabulary

Serialized form

- A document may begin with a prologue;
- It has a single root element;
- Each opening tag `<name>` has a corresponding closing tag `</name>`; everything between is either text or properly enclosed tag content.

Tree form

- A document is a tree with a root node (**Document** node in DOM),
- The root node has exactly one element child (**Element** node), called the element root)
- Each element node is the root of a subtree

Entities and references

Entities are used for the physical organization of a document.

An entity is declared (in the document type), then referenced.

```
<?xml version="1.0" encoding="ISO-8859-1"?>

<!DOCTYPE a [
  <!ENTITY  myName "John Doe">
  <!ENTITY  mySignature SYSTEM "signature.xml">
]>

<a>
  My name is &myName;.

  &mySignature;
</a>
```

Predefined entities

Five predefined entities, which in particular allow escaping:

Declaration	Reference	Symbol
`<!ENTITY lt "&#60;">`	`&lt;`	<
`<!ENTITY gt "&#62;">`	`&gt;`	>
`<!ENTITY amp "&#38;">`	`&amp;`	&
`<!ENTITY apos "&#39;">`	`&apos;`	’
`<!ENTITY quot "&#34;">`	`&quot;`	"

Also numeric character references based on Unicode codepoints:

- `&#42;` (decimal),
- `&#x2A;` (hexadecimal).

Problem with entities: XML external entity attack

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<!DOCTYPE foo [
  <!ELEMENT foo ANY >
  <!ENTITY xxe SYSTEM "file:///etc/passwd" >]>
<foo>&xxe;</foo>
```

→ On badly configured systems, this can exfiltrate `/etc/passwd` to an attacker

Problem with entities: Billion laughs attack

```
<?xml version="1.0"?>
<!DOCTYPE lolz [
 <!ENTITY lol "lol">
 <!ELEMENT lolz (#PCDATA)>
 <!ENTITY lol1 "&lol;&lol;&lol;&lol;&lol;&lol;&lol;&lol;&lol;&lol;">
 <!ENTITY lol2 "&lol1;&lol1;&lol1;&lol1;&lol1;&lol1;&lol1;&lol1;&lol1;&lol1;">
 <!ENTITY lol3 "&lol2;&lol2;&lol2;&lol2;&lol2;&lol2;&lol2;&lol2;&lol2;&lol2;">
 <!ENTITY lol4 "&lol3;&lol3;&lol3;&lol3;&lol3;&lol3;&lol3;&lol3;&lol3;&lol3;">
 <!ENTITY lol5 "&lol4;&lol4;&lol4;&lol4;&lol4;&lol4;&lol4;&lol4;&lol4;&lol4;">
 <!ENTITY lol6 "&lol5;&lol5;&lol5;&lol5;&lol5;&lol5;&lol5;&lol5;&lol5;&lol5;">
 <!ENTITY lol7 "&lol6;&lol6;&lol6;&lol6;&lol6;&lol6;&lol6;&lol6;&lol6;&lol6;">
 <!ENTITY lol8 "&lol7;&lol7;&lol7;&lol7;&lol7;&lol7;&lol7;&lol7;&lol7;&lol7;">
 <!ENTITY lol9 "&lol8;&lol8;&lol8;&lol8;&lol8;&lol8;&lol8;&lol8;&lol8;&lol8;">
]>
<lolz>&lol9;</lolz>
```

→ This can **crash** a badly configured XML parser

Comments and instructions

Comments can be put at any place in the serialized form.

```
<!-- This is a comment -->
```

They appear as **Comment** nodes in the DOM tree (they are typically ignored by applications).

Processing instructions: specific commands, useful for some applications, simply ignored by others.

The following instruction requires the transformation of the document by an XSLT stylesheet

```
<?xml-stylesheet href="prog.xslt" type="text/xslt"?>
```

Literal sections

Problem: what if we do *not* want the content to be parsed?

```
<?xml version='1.0'?>
<program>
if ((i < 5) && (j > 6))
   printf("error");
</program>
```

Solution: use entities to escape, or use a literal section.

```
<?xml version='1.0'?>
<program>
<![CDATA[if ((i < 5) && (j > 6))
           printf("error");
]]>
</program>
```

Interpreting labels: Namespaces

A particular label, e.g., *job*, may denote different notions in different contexts, e.g., a hiring agency or a scheduler.

The notion of **namespace** is used to distinguish them.

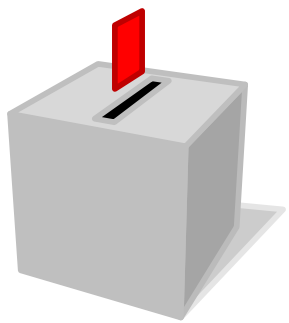
```
<doc xmlns:hire='https://a.hire.com/schema'
     xmlns:sched='https://b.scheduler.com/schema'>
  ...
  <hire:job> ... </hire:job> ...
  <sched:job> ... </sched:job> ...
</doc>
```

XML dialects and standards

POLL: Validity and well-formedness

The HTML page `<html><head>a</head></html>` is:

- **A**: Not well-formed and not valid
- **B**: Not well-formed, but valid
- **C**: Well-formed, but not valid
- **D**: Well-formed and valid



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The HTML page `<html><head>a</head></html>` is:

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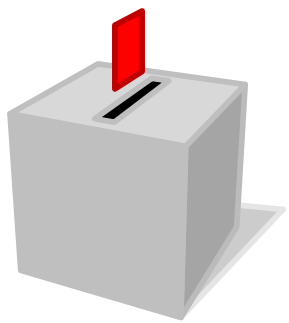


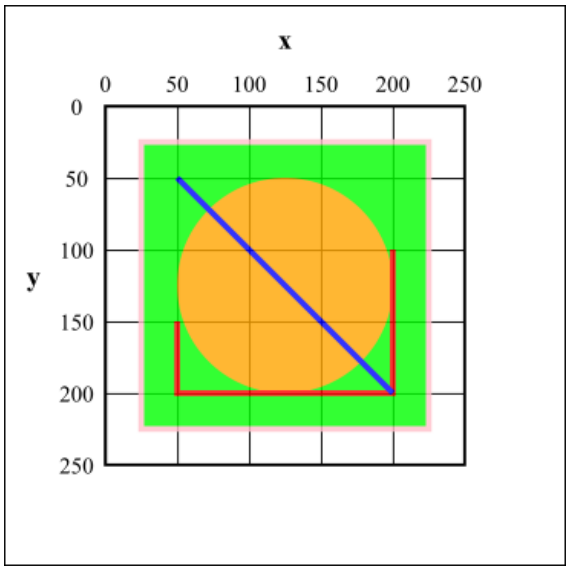
Dialects

- XML is just an **abstract syntax** with no specific **meaning**
- An XML **dialect** specifies the **syntax** (which elements, attributes, etc.) and gives it a **semantics**
- Distinguish:
  - **Well-formedness**: an XML document is **well-formed** if it conforms to the XML spec (dialect-independent)
  - **Valid**: an XML document is correct relative to the syntax of a dialect (as specified, e.g., by a DTD, Schema, etc.)

Popular XML dialects: SVG

An XML dialect for two-dimensional vector graphics:

```
<?xml version="1.0" encoding="UTF-8" ?>
<svg xmlns="http://www.w3.org/2000/svg"
     version="1.1">
  <rect x="25" y="25" width="200" height="200"
        fill="lime" stroke-width="4"
        stroke="pink" />
  <circle cx="125" cy="125" r="75" fill="orange" />
  <polyline points="50,150 50,200 200,200 200,100"
        stroke="red" stroke-width="4" fill="none" />
  <line x1="50" y1="50" x2="200" y2="200"
        stroke="blue" stroke-width="4" />
</svg>
```



Popular XML dialects: DocBook

An XML dialect for technical documentation:

```
<?xml version="1.0" encoding="UTF-8"?>
<book xml:id="simple_book"
    xmlns="http://docbook.org/ns/docbook" version="5.0">
  <title>Very simple book</title>
  <chapter xml:id="chapter_1">
    <title>Chapter 1</title>
    <para>Hello world!</para>
    <para>I hope that your day is proceeding
    <emphasis>splendidly</emphasis>!</para>
  </chapter>
  <chapter xml:id="chapter_2">
    <title>Chapter 2</title>
    <para>Hello again, world!</para>
  </chapter>
</book>
```

Popular XML dialects: RSS

An XML dialect for **articles** to subscribe to websites (also **Atom**):

```
<?xml version="1.0" encoding="UTF-8" ?>
<rss version="2.0">
<channel>
  <title>RSS Title</title>
  <description>This is an example of an RSS feed</description>
  <link>http://www.example.com/main.html</link>
  <lastBuildDate>Mon, 06 Sep 2010 00:01:00 +0000 </lastBuildDate>
  <pubDate>Sun, 06 Sep 2009 16:20:00 +0000</pubDate>
  <ttl>1800</ttl>

  <item>
    <title>Example entry</title>
    <description>Here is some description.</description>
    <link>http://www.example.com/blog/post/1</link>
    <guid isPermaLink="false">7bd204c6-1655-4c27-aeee-53f933c5395f</guid>
    <pubDate>Sun, 06 Sep 2009 16:20:00 +0000</pubDate>
  </item>
</channel>
</rss>
```

Popular XML dialects: OpenDocument and OpenXML

- XML-based **open standards** for office documents
- OpenXML is used by **LibreOffice** and **OpenXML** by **Microsoft Office**
- A LibreOffice file (e.g., **.odt**) is actually a **zip archive** of several files, including XML documents

Popular XML dialects: MathML

An XML dialect to describe the semantics and display of mathematical equations. Example for $ax^2 + bx + c$:

```
<math>
    <apply>
        <plus/>
        <apply>
            <times/>
            <ci>a</ci>
            <apply>
              <power/> <ci>x</ci> <cn>2</cn>
            </apply>
        </apply>
        <apply> <times/> <ci>b</ci> <ci>x</ci> </apply>
        <ci>c</ci>
    </apply>
</math>
```

Popular XML dialects: SSML

Speech Synthesis Markup Language: annotate text for text-to-speech

```
<!-- ?xml version="1.0"? -->
<speak version="1.0" xmlns="http://www.w3.org/2001/10/synthesis"
       xmlns:dc="http://purl.org/dc/elements/1.1/">
  <metadata>
    <dc:title xml:lang="en">Telephone Menu: Level 1</dc:title>
  </metadata>
  <p>
    <s xml:lang="en-US">
      <voice name="David" gender="male" age="25">
        For English, press <emphasis>one</emphasis>.
      </voice>
    </s>
    <s xml:lang="es-MX">
      <voice name="Miguel" gender="male" age="25">
        Para español, oprima el <emphasis>dos</emphasis>.
      </voice>
    </s>
  </p>
</speak>
```

Many more dialects

See `https://en.wikipedia.org/wiki/List_of_XML_markup_languages`

Example of XML data dumps

- OpenStreetMap: As a Protocolbuffer dump or as XML in a custom OSM dialect
- Wikimedia: As a Mediawiki dump in XML, with schema `https://www.mediawiki.org/xml/export-0.10.xsd`
- Stack Exchange: As a dumb XML encoding of relational data
- data.gouv.fr: 1 347 datasets are in XML (out of 37 147)
- arXiv: The arXiv dump provides metadata information in XML
- DBLP: The DBLP dump is in XML

XML Ecosystem

XML standards

SAX (Simple API for XML) gives an API for XML documents seen as a sequence of tokens (its serialization).

DOM (Document Object Model) gives an API for the tree representation of HTML and XML documents (independent from the programming language)

Schema languages Specify the structure of documents in a dialect (DTD, XML Schema, Relax-NG, etc.) (more to come)

XPath (XML Path Language) is a language for addressing portions of an XML document (more to come)

XQuery is a query language to extract information from collections of XML documents

XSLT (Extensible Stylesheet Language Transformations), to specify how to transform XML documents into other documents

Lesser-known XML standards

XLink Link to other XML documents

XPointer Refer to a specific point in an XML document

XInclude Include XML documents in other documents

XProc Language to define pipelines of XML content

XSL-FO Markup language for documents to be rendered as paginated documents

Generic XML tools

- **API**: XML or SAX
- Parsers and type checkers, e.g., `xmllint`
- GUI (Graphical User Interfaces)
- Editors
- XML diff
- Etc.

Parsing XML in Python (DOM)

```
import requests
from defusedxml import ElementTree

url = 'https://dblp.uni-trier.de/db/conf/icdt/icdt2021.xml'
r = requests.get(url)
t = ElementTree.fromstring(r.content)
for n in t.findall('.//inproceedings/author'):
    print(n.text)
```

Parsing XML in Python (SAX)

```
# would need to use an actual stream...
from io import BytesIO
import requests
from defusedxml import ElementTree

url = 'https://dblp.uni-trier.de/db/conf/icdt/icdt2021.xml'
r = requests.get(url)
for evt, element in ElementTree.iterparse(BytesIO(r.content)):
    if element.tag == 'author':
        print (element.text)
    # would need to clear up memory...
```

Dirty tools to work with XML

- `xmlstarlet`: dirty way to process XML on the command line, uses `libxml`

```
curl -s 'https://dblp.uni-trier.de/db/conf/icdt/icdt2021.xml' |
  xmlstarlet sel -t -m '//inproceedings/author/text()' -c . -n
```

  → Find elements with the XPath `//inproceedings/author` and copy their value followed by a newline

  → Actually producing XSLT under the scenes

- `xml2` and `2xml`: Convert XML to a text-based format and back: useful to work with CLI utilities

XML summary

JSON and XML: Dispassionate assessment

- XML has mostly **failed** on the Web (XHTML, AJAX)
- **Overengineered** ecosystem with many **dusty** technologies: XQuery, XLink, XPointer, XInclude, XSL-FO, RDDL...
- However, XML is still widely used as an **exchange format**
- JSON does not replace all XML uses, e.g., **mixed content**
- Still, if your data is **easy to represent** as JSON and you don't need **fancy tools** (schemas, etc.), use JSON

Research about XML

- XML has inspired much **theoretical research** in the database theory community
  - → E.g., **test-of-time** award at the PODS conference in 2015 and 2016
- Natural **practical applications** for **theoretical research**
- For instance, **tree automata** (cf later) for validation, querying...
  - → See **survey** by Schwentick, *Automata for XML–A survey*, JCSS 2007[1]
- Study of **query languages** such as **XPath**
  - → E.g., Benedikt and Koch, *XPath Leashed*, ACM Comput. Surv., 2009[2]
- Also other query languages, e.g., **tree pattern queries**
- A bit **out of fashion** in favor, e.g., of queries on **graph data**

[1] `https://www.sciencedirect.com/science/article/pii/S0022000006001085`

[2] `https://infoscience.epfl.ch/record/166852/files/25-leashed.pdf`

Bibliography

Specifications from the World Wide Web Consortium, `w3.org`:

- Document Object Model. `w3.org/DOM`.
- Extensible Markup Language. `w3.org/XML`.
- XML Schema. `w3.org/XML/Schema`.
- XML Query (XQuery). `w3.org/XML/Query`.
- Extensible Stylesheet Language. `w3.org/Style/XSL`.

Books:

- S. Abiteboul, I. Manolescu, P. Rigaux, M.-C. Rousset, P. Senellart. *Web Data Management*. Cambridge University Press, 2011. `http://webdam.inria.fr/Jorge/`
- S. Abiteboul, P. Buneman, and D. Suciu. *Data on the Web: From Relations to Semistructured Data and XML*. Morgan-Kaufman, 1999.

Sources

- Slide 21: https://en.wikipedia.org/wiki/XML_external_entity_attack
- Slide 22: https://en.wikipedia.org/wiki/Billion_laughs_attack
- Slide 28: https://en.wikipedia.org/wiki/File:SVG_example_markup_grid.svg
- Slide 29: https://en.wikipedia.org/wiki/DocBook
- Slide 30: https://en.wikipedia.org/wiki/RSS
- Slide 32: https://en.wikipedia.org/wiki/MathML
- Slide 33: https://en.wikipedia.org/wiki/Speech_Synthesis_Markup_Language