TDDD43 Advanced Data Models and Databases

XML (Extensible Markup Language)

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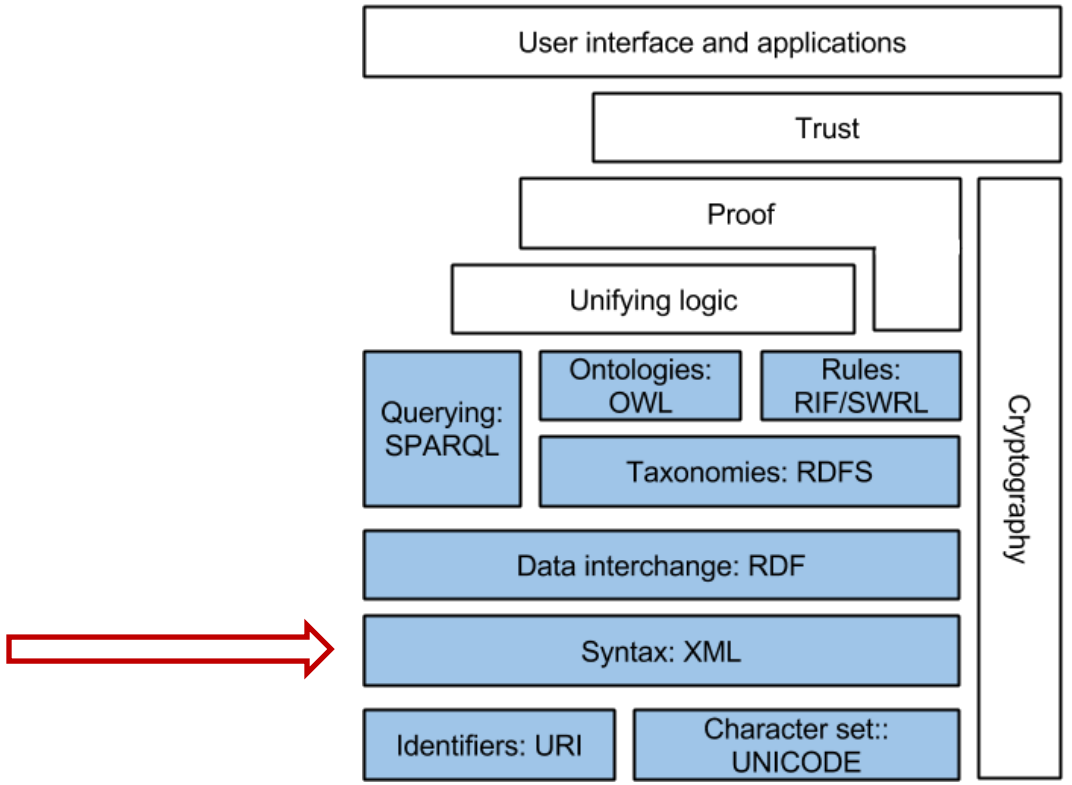
Recap

➢ Semantic Web

… to put machine-understandable data on the Web…
… data can be shared and processed by automated tools as well as by people…



Aims

- Data representation in different (common and standardized) formats
  - Underlying data models for different formats
  - Data schemas that data can/has to follow
  - Query languages
- E.g., relational data
  - relational data, tables (rows, columns)
  - relational schema (key/foreign key references)
  - SQL (Structured Query Language)

Outline

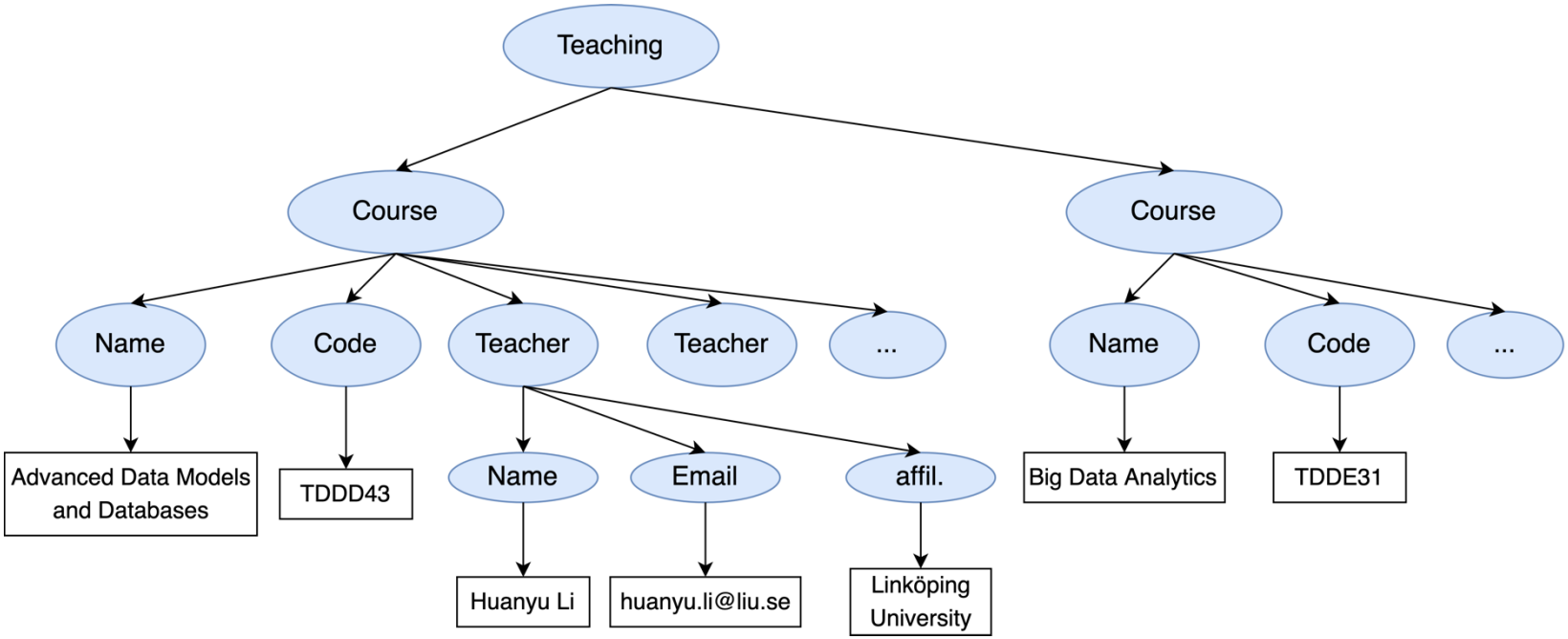
- XML
- Schema for XML
- Query languages for XML
- JSON and GraphQL

Extensible Markup Language

- *A language and a file format for storing data, in an exchangeable (sharable, interoperable) way…*
- *One of many standardized formats recommended by W3C (World Wide Web Consortium)*
- *https://www.w3schools.com/xml/default.asp*

XML Building Blocks - Elements

- Organizes data as a tree
- Special markups to indicate different elements of the data
- Tags to annotate elements and hierarchy, with one root element



XML – Tags and Content

```
<Teaching>
    <Course>
        <Name>Advanced Data Models and Databases</Name>
        <Code>TDDD43</Code>
        <Teacher>
            <Name>Huanyu Li</Name>
            <Email>huanyu.li@liu.se</Email>
            <Affiliation>Linköping University</Affiliation>
        </Teacher>
        <Teacher>
            <Name>Patrick Lambrix</Name>
            <Email>patrick.lambrix@liu.se</Email>
            <Affiliation>Linköping University</Affiliation>
        </Teacher>
    </Course>
    <Course>
        <Name>Big Data Analytics</Name>
        <Code>TDDE31</Code>
    </Course>
</Teaching>
```

Start tag

Content

End tag

XML – Tags and Content

```
<Teaching>
    <Course>
        <Name>Advanced Data Models and Databases</Name>
        <Code>TDDD43</Code>
        <Teacher>
            <Name>Huanyu Li</Name>
            <Email>huanyu.li@liu.se</Email>
            <Affiliation>Linköping University</Affiliation>
        </Teacher>
        <Teacher>
            <Name>Patrick Lambrix</Name>
            <Email>patrick.lambrix@liu.se</Email>
            <Affiliation>Linköping University</Affiliation>
        </Teacher>
    </Course>
    <Course>
        <Name>Big Data Analytics</Name>
        <Code>TDDE31</Code>
    </Course>
</Teaching>
```

Start tag

Content

End tag

XML – Attributes

- Elements can have attibures
- Attributes contain data that relates to an element
  - Listed in element's start tag
  - Value must be quoted


```
<Course id="1">
    <Name>Advanced Data Models and Databases</Name>
    <Code>TDDD43</Code>
    <Teacher>
        <Name>Huanyu Li</Name>
        <Email>huanyu.li@liu.se</Email>
        <Affiliation>Linköping University</Affiliation>
    </Teacher>
</Course>
```

XML – Empty Elements

- XML allows empty elements that may not have content

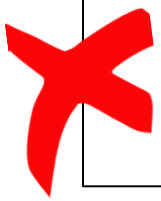
```
<Course id="1">
    <Name>Advanced Data Models and Databases</Name>
    <Code>TDDD43</Code>
    <Teacher/>
</Course>
```

- But an empty element can have attributes

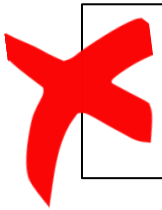
```
<Course id="1">
    <Name>Advanced Data Models and Databases</Name>
    <Code>TDDD43</Code>
    <Teacher id="t1"/>
</Course>
```

XML – Well-formed Documents

- An XML document must meet some rules to be valid
  - Correct nesting
  - Each start tag has its corresponding end tag
  - Elements don't have an attribute multiple times
  - Etc…



```
<Course id="1">
        <Name>Advanced Data Models and Databases</Name>
        <Code>TDDD43</Course>
</Code>
```



```
<Course id="1">
        <Name>Advanced Data Models and Databases</CourseName>
</Course>
```

```
<Course id="1">
        <Code>TDDD43</Code>
        <Teacher id="huali12" id="huali123"/>
</Course>
```

Outline

- ✓ XML
- ➢ Schema for XML
- ➢ Query languages for XML
- ➢ JSON and GraphQL

Document Type Definition (DTD)

- A DTD defines the document structure with a list of legal elements and attributes of an XML document
  - Elements – XML elements
  - Attributes – XML attributes
  - Entities – shortcuts to special characters
  - PCDATA – parsed character data
  - CDATA – character data

- A standard for defining structures or rules about XML data

- https://www.w3schools.com/xml/xml_dtd_intro.asp

Document Type Definition (DTD)

- !DOCTYPE is used to define what is the root element of the XML data
- Syntax:

```
<!DOCTYPE root-element [element-declarations]>
```

```
<!DOCTYPE Teaching [
    ...
]>
```

```
<Teaching>
    <Course>
        <Name>Advanced Data Models and Databases</Name>
        <Code>TDDD43</Code>
        <Teacher>
            <Name>Huanyu Li</Name>
            <Email>huanyu.li@liu.se</Email>
            <Affiliation>Linköping University</Affiliation>
        </Teacher>
        <Teacher>
            <Name>Patrick Lambrix</Name>
            <Email>patrick.lambrix@liu.se</Email>
            <Affiliation>Linköping University</Affiliation>
        </Teacher>
    </Course>
</Teaching>
```

Document Type Definition (DTD)

- !ELEMENT is used to define what are the composing elements of a nested element, or the type of a simple element
- Syntax: (declaring elements)

```
<!ELEMENT element-name (element-content)>
```

Examples:

```
<!ELEMENT element-name EMPTY>
<!ELEMENT element-name (child1, child2)>
<!ELEMENT element-name (#CDATA)>
<!ELEMENT element-name ANY>
```

Document Type Definition (DTD)

```
<!ELEMENT Teaching (Course+)>
<!ELEMENT Course (Name, Code, Teacher+)>
<!ELEMENT Teacher (Name, Email?, Affiliation*)>
<!ELEMENT Name (#PCDATA)>
<!ELEMENT Code (#PCDATA)>
<!ELEMENT Email (#PCDATA)>
<!ELEMENT Affiliation (#PCDATA)>
```

```
<Teaching>
    <Course>
        <Name>Advanced Data Models and Databases</Name>
        <Code>TDDD43</Code>
        <Teacher>
            <Name>Huanyu Li</Name>
            <Email>huanyu.li@liu.se</Email>
            <Affiliation>Linköping University</Affiliation>
        </Teacher>
    </Course>
</Teaching>
```

Document Type Definition (DTD)

- The content of the Teaching element contains 1 or more Course elements (+)
- The content of the Teacher element can contain 0 or more Affiliation elements (*), 0 or 1 Email elements (?)

```
<!ELEMENT Teaching (Course+)>
<!ELEMENT Course (Name, Code, Teacher+)>
<!ELEMENT Teacher (Name, Email?, Affiliation*)>
```

Document Type Definition (DTD)

- The content of the Name, Code, Email, Affiliation elements are defined as Parsed Character Data
  - PCDATA: usually used for content that should be parsed, special characters must be escaped, e.g., '&lt' for '<', '&gt' for '>'
  - CDATA: content is not parsed by XML parser rules; plain text

```
<!ELEMENT Name (#PCDATA)>
<!ELEMENT Code (#PCDATA)>
<!ELEMENT Email (#PCDATA)>
<!ELEMENT Affiliation (#PCDATA)>
```

Document Type Definition (DTD)

- Attribute content should be CDATA instead PCDATA
  - E.g., the value of the id attribute of the Teacher element must be Character Data
- Declare whether an attribute is required or optional
  - #REQUIRED, #IMPLIED
- Syntax: (declaring attributes)
  - Different options for attribute-type and attribute-value
    - https://www.w3schools.com/xml/xml_dtd_attributes.asp

```
<!ATTLIST element-name attribute-name attribute-type attribute-value>
```

```
<!ATTLIST Teacher id CDATA #REQUIRED>
```

Document Type Definition (DTD)

- External Declaration
  - Located in an external file, so that can be used by several XML files
  - Reference a dtd in the header of the XML file
  - Syntax:

```
<!DOCTYPE root-element SYSTEM "file_name">
```

```
<xml version="1.0"?>
<!DOCTYPE Teaching "teaching.dtd">
```

external

```
<xml version="1.0"?>
<!DOCTYPE Teaching [
    <!ELEMENT Teaching (Course+)>
    <!ELEMENT Course (Name, Code, Teacher+)>
    <!ELEMENT Teacher (Name, Email*, Affiliation?)>
    <!ATTLIST Teacher id CDATA #REQUIRED>
    <!ELEMENT Name (#PCDATA)>
    <!ELEMENT Code (#PCDATA)>
    <!ELEMENT Email (#PCDATA)>
    <!ELEMENT Affiliation (#PCDATA)>
]>
<Teaching>…</Teaching>
```

internal

XML Schema Definition (XSD)

- An XML schema also defines the structure of an XML document, like DTD (as a standard for defining structures or rules about XML data)
- An XML schema also written in XML, with specific markups
- Aims:
  - To define allowed elements/attributes in a XML document
  - Number/order of child elements
  - Data types, default values, fixed values for elements/attributes
- https://www.w3schools.com/xml/schema_intro.asp

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified">
  <xs:element name="Teaching">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="Course">
          <xs:complexType>
            <xs:sequence>
              <xs:element name="Name" type="xs:string"/>
              <xs:element name="Code" type="xs:string"/>
              <xs:element name="Teacher" maxOccurs="unbounded">
                <xs:complexType>
                  <xs:sequence>
                    <xs:element name="Name" type="xs:string"/>
                    <xs:element name="Email" type="xs:string"/>
                    <xs:element name="Affiliation" type="xs:string"/>
                  </xs:sequence>
                </xs:complexType>
              </xs:element>
            </xs:sequence>
          </xs:complexType>
        </xs:element>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
</xs:schema>
```

XML Schema (XSD) Elements and Attributes

- An XSD element can be of type simpleType, complexType or anyType
  - simpleType contains only text (no attributes or child elements)
  - complexType can contain text, elements or attributes
  - anyType specifies that any well-formed XML is allowed in its place in XML instance

- XSD attributes are always of type simpleType

XSD Elements, Attributes Definition

Element	Syntax	Explanation
element	<xs:element>	Defines an element
attribute	<xs:attribute>	Defines an attribute
complexType	<xs:complexType>	Defines a complex type element
all	<xs:all>	Specifies that child elements can appear in any order, each child element occur 0 or 1 time
sequence	<xs:sequence>	Specifies that child elements can appear in a sequence, each child element occur from 0 to any number of times
choice	<xs:choice>	Specifies only one of the elements contained in the declaration to be present within the containing element
restriction	<xs:restriction>	Defines restrictions on a SimpleType, simpleContent or a complexContent
any	<xs:any>	Enables the author to extend the XML document with elements not specificed by the schema

https://www.w3schools.com/xml/schema_elements_ref.asp

XML Schema (XSD) – Simple Element definition

- A simple element only contain text. It cannot contain any other elements or attributes.

```
<xs:element name="Name" type="xs:string"/>
<xs:element name="Birthday" type="xs:date"/>
```

- Fixed value or default value for simple elements

```
<xs:element name="Affiliation" type="xs:string" fixed="Linköping University"/>
<xs:element name="Affiliation" type="xs:string" default="Linköping University"/>
```

- XML schema has built-in datatypes
  - xs:string, xs:decimal, xs:integer, xs:boolean, xs:date, xs:time

XML Schema (XSD) – Complex definition

- A complex element contains other simple elements or attributes

```
<xs:element name="Teacher">
    <xs:complexType>
        <xs:all>
            <xs:element name="Name" type="xs:string"/>
            <xs:element name="Email" type="xs:string"/>
        </xs:all>
    </xs:complexType>
</xs:element>
```

Any order of its nexting elements

```
<xs:element name="Teacher">
    <xs:complexType>
        <xs:sequence>
            <xs:element name="Name" type="xs:string"/>
            <xs:element name="Email" type="xs:string"/>
        </xs:sequence>
    </xs:complexType>
</xs:element>
```

The order must be Name, Email

XML Schema (XSD) – Complex definition

- A complex element definition can be used by multiple elements in XML data

```
<xs:element name="Teacher" type="personinfo"/>
<xs:element name="Student" type="personinfo"/>

<xs:complexType name="personinfo">
  <xs:all>
    <xs:element name="Name" type="xs:string"/>
    <xs:element name="Email" type="xs:string"/>
  </xs:all>
</xs:complexType>
```

XML Schema (XSD) – Attribute definition

- An attribute definition is similar to a simple element definition

```
<xs:element name="Teacher">
    <xs:complexType>
        <xs:all>
            <xs:element name="Name" type="xs:string"/>
            <xs:element name="Email" type="xs:string"/>
            <xs:element name="Affiliation" type="xs:string"/>
        </xs:all>
        <xs:attribute name="employeeID" type="xs:string"/>
    </xs:complexType>
</xs:element>
```

XML Schema (XSD) – Restrictions

- Define acceptable values for XML elements or attributes
  - Value range, a set of values
  - Etc.

```
<xs:element name=”faculty" type="xs:string”/>
```

```
<xs:element name="faculty">
    <xs:simpleType>
        <xs:restriction base="xs:string">
            <xs:enumeration value="Arts and Sciences"/>
            <xs:enumeration value="Medicine and Health Sciences"/>
            <xs:enumeration value="Science and Engineering"/>
            <xs:enumeration value="Educational Sciences"/>
        </xs:restriction>
    </xs:simpleType>
</xs:element>
```

XML Schema (XSD) – Indicators

- To indicate
  - Order indicator
  - Occurrence indicator
  - Etc.

```
<xs:complexType>
        <xs:all>
                <xs:element name="Name" type="xs:string"/>
                <xs:element name="Email" type="xs:string"/>
        </xs:all>
</xs:complexType>
```

```
<xs:complexType>
        <xs:sequence>
                <xs:element name="Name" type="xs:string"/>
                <xs:element name="Email" type="xs:string"/>
        </xs:sequence>
</xs:complexType>
```

```
<xs:element name="Teacher" minOccurs="1" maxOccurs="unbounded">
```

Why use DTD or XML Schema?

- Disadvantages:
  - Rules and structures can be very complicated and cumbersome for a specific modeling scenario
  - An overhead on validations

- Advantages:
  - Facilitate information exchange and improve the interoperability
  - Guards against errors and malformed data

Outline

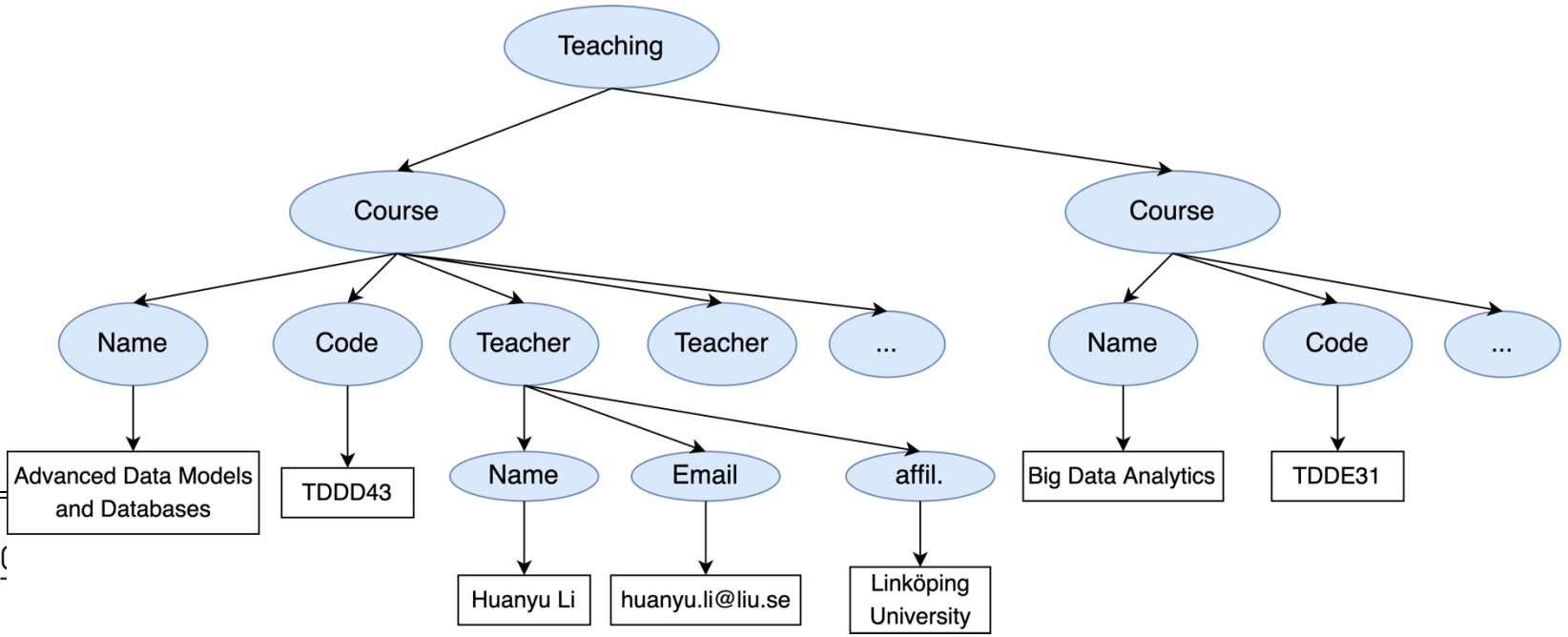
- ✓ XML
- ✓ Schema for XML
- ➢ Query languages for XML
- ➢ JSON and GraphQL

Query Language for XML

- Option 1: XPath
  - https://www.w3schools.com/xml/xpath_intro.asp
- Option 2: XQuery
  - https://www.w3schools.com/xml/xquery_intro.asp

XPath (XML Path Language)

- XPath specifies path expressions to match XML data by navigating down (occasionally up and across) in XML documents
- W3C recommendation
- Looks very much like the path expressions in computer file systems
- Nodes: element, attribute, text, namespace, comment, root, etc.
- Relationship of Nodes
  - Parent, Children, Siblings, Ancestors, Descendants



XPath Constructors

Basic Expression and Operation – Selecting nodes

Expression	Operation
elementName	Selects all nodes with the tag named “elementName”
/	Selects from the root node
//	Selects nodes in the document from the current node that match the selection no matter where they are
.	Selects the current node
..	Selects the parent of the current node
@	Selects attributes
*	Matches any element
@*	Matches any attribute
node()	Matches any node of any kind

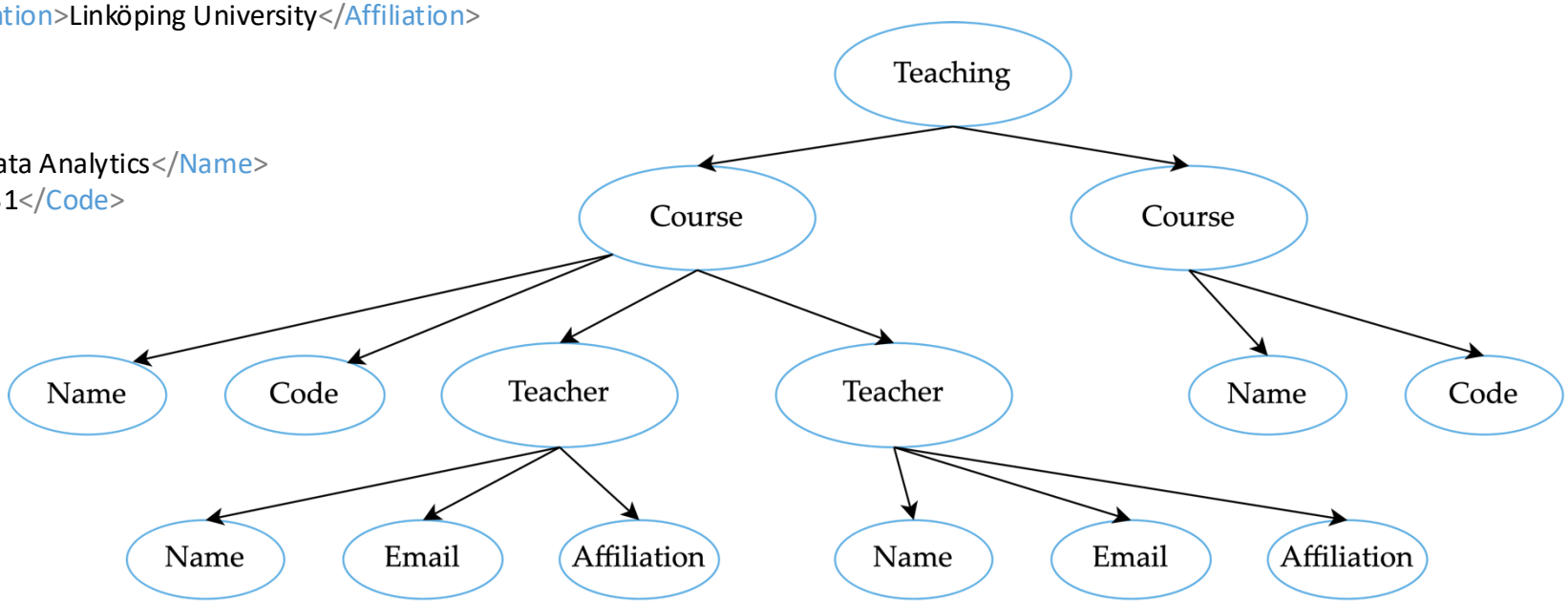
XPath - Constructors

- Predicates – finds a specific node or a node that contains a specific value, always embedded in square brackets
- [condition] matches the “current” element if condition evaluates to true on the current element

Predicate	Operation
[n]	Selects the nth child element
[last()]	Selects the last child element
[last()-1]	Selects the second-to-last child element
[position()<11]	Selects the first 10 children elements
[@attr]	Selects children elements with attribute attr
[@attr=val]	Selects children elements with value val in attribute attr
[@attr<n]	Selects children elements with a value for attribute attr less than n
[p or q]	Disjunction of predicates p or q
[p and q]	Conjunction of predicates p and q
[not (p)]	Negation of predicate p
[n][@attr]	Selects the nth child if it has attribute attr
[@attr][n]	Selects the nth child from those that have an attribute attr

XPath functions

```
<Teaching>
    <Course>
        <Name>Advanced Data Models and Databases</Name>
        <Code>TDDD43</Code>
        <Teacher id="t1">
            <Name>Huanyu Li</Name>
            <Email>huanyu.li@liu.se</Email>
            <Affiliation>Linköping University</Affiliation>
        </Teacher>
        <Teacher id="t2">
            <Name>Patrick Lambrix</Name>
            <Email>patrick.lambrix@liu.se</Email>
            <Affiliation>Linköping University</Affiliation>
        </Teacher>
    </Course>
    <Course>
        <Name>Big Data Analytics</Name>
        <Code>TDDE31</Code>
    </Course>
</Teaching>
```



XPath examples

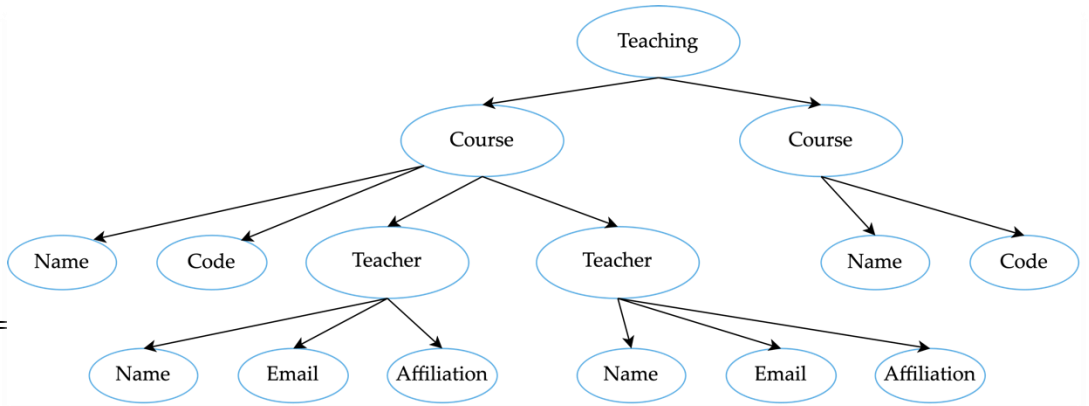
- To get all courses:

/Teaching/Course

- alternative:

//Course

  - Returns a set of elements with the tag <Course>, node-set



XPath examples

- To access an attribute:

//Teacher/@id

```
<Teaching>
    <Course>
        <Name>Advanced Data Models and Databases</Name>
        <Code>TDDD43</Code>
        <Teacher id="t1">
            <Name>Huanyu Li</Name>
            <Email>huanyu.li@liu.se</Email>
            <Affiliation>Linköping University</Affiliation>
        </Teacher>
        <Teacher id="t2">
            <Name>Patrick Lambrix</Name>
            <Email>patrick.lambrix@liu.se</Email>
            <Affiliation>Linköping University</Affiliation>
        </Teacher>
    </Course>
    <Course>
        <Name>Big Data Analytics</Name>
        <Code>TDDE31</Code>
    </Course>
</Teaching>
```

XPath examples

- To get affiliation information of a specific teacher (using predicates)

//Teacher[@id="t1"]/Affiliation[1]

//Teacher[@id="t1"]/Affiliation[last()]

```
<Teaching>
        <Course>
                <Name>Advanced Data Models and Databases</Name>
                <Code>TDDD43</Code>
                <Teacher id="t1">
                        <Name>Huanyu Li</Name>
                        <Email>huanyu.li@liu.se</Email>
                        <Affiliation>Linköping University</Affiliation>
                    <Affiliation>Swedish e-Science Research Centre</Affiliation>
                </Teacher>
                <Teacher id="t2">
                        <Name>Patrick Lambrix</Name>
                        <Email>patrick.lambrix@liu.se</Email>
                        <Affiliation>Linköping University</Affiliation>
                        <Affiliation>Swedish e-Science Research Centre</Affiliation>
                </Teacher>
        </Course>
</Teaching>
```

XPath - Functions

Function	Operation
contains(x, y)	Checks if string x contains string y
count(node-set)	Returns the number of elements in the node-set
name()	Returns the name of an element
starts-with(string,x)	Checks if string starts with the character sequence x
ends-with(string,x)	Checks if string ends with the character sequence x
substring(string,start,length)	Obtains a sub-sequence of string starting at the given position, optional length can be provided
normalize-space()	Removes trailing whitespaces
string-length(string)	Returns the length of string

XPath examples

- To get courses with more than 1 teacher

```
//Course[count(Teacher)>1]
```

- To get courses whose names contain “Data”

```
//Course[contains(Name, “Data”)]
```

```
<Teaching>
    <Course>
        <Name>Advanced Data Models and Databases</Name>
        <Code>TDDD43</Code>
        <Teacher id=“t1”>
            <Name>Huanyu Li</Name>
            <Email>huanyu.li@liu.se</Email>
            <Affiliation>Linköping University</Affiliation>
          <Affiliation>Swedish e-Science Research Centre</Affiliation>
        </Teacher>
        <Teacher id=“t2”>
            <Name>Patrick Lambrix</Name>
            <Email>patrick.lambrix@liu.se</Email>
            <Affiliation>Linköping University</Affiliation>
            <Affiliation>Swedish e-Science Research Centre</Affiliation>
        </Teacher>
    </Course>
</Teaching>
```

XPath - Axes

- An axis represents a relationship to the current node
- Used to locate nodes relative to that node on the tree
- Syntax: axis-name::element-name or attribute-name

Axis	Operation
child::	Selects all children of the current node
attribute::	Selects all attributes of the current node
descendant::	Selects all descendants of the current node
descendant-or-self::	Selects all descendants of the current node and the current node itself
parent::	Selects the parent of the current node
ancestor::	Selects all ancestors of the current node
ancestor-or-self::	Selects all ancestors of the current node and the current node itself
following-sibling::	Selects all siblings after the current node
preceding-sibling::	Selects all nodes appearing before the current node
self::	Selects the current node

XPath - Axes

- Examples: (select all course ancestors of the Teacher node whose id is “t1”)
- What courses does the teacher teach?

//Teacher[@id=“t1”]/ancestor::Course

```
<Teaching>
    <Course>
        <Name>Advanced Data Models and Databases</Name>
        <Code>TDDD43</Code>
        <Teacher id=“t1”>
            <Name>Huanyu Li</Name>
            <Email>huanyu.li@liu.se</Email>
            <Affiliation>Linköping University</Affiliation>
            <Affiliation>Swedish e-Science Research Centre</Affiliation>
        </Teacher>
        <Teacher id=“t2”>
            <Name>Patrick Lambrix</Name>
            <Email>patrick.lambrix@liu.se</Email>
            <Affiliation>Linköping University</Affiliation>
            <Affiliation>Swedish e-Science Research Centre</Affiliation>
        </Teacher>
    </Course>
    <Course>
        <Name>Big Data Analytics</Name>
        <Code>TDDE31</Code>
        <Teacher id=“t1”/>
    </Course>
</Teaching>
```

ancestor

ancestor

Query Language for XML

- Option 1: XPath
  - https://www.w3schools.com/xml/xpath_intro.asp
- Option 2: XQuery
  - https://www.w3schools.com/xml/xquery_intro.asp

XQuery

- XQuery is built on XPath expressions
  - Path matching
  - FLWOR expressions
    - FOR-LET-WHERE-ORDER BY-RETURN
  - Aggregation, functions
- W3C recommendation

XQuery – FLWOR Expressions

- For: selects a sequence of nodes/elements
- Let: binds a sequence to a variable
- Where: filters the nodes
- Order by: sorts the nodes
- Return: what to return

FLWOR Expressions

```
<result>{
        for $c in doc("teaching_data_1.xml")//Course
        let $t := $c/Teacher
        where $t/Affiliation = "Linköping University"
        return
                <selected_course>
                        {$c/Name}
                        {$c/Code}
                        {$t}
                </selected_course>
}
</result>
```

for/in – iterate over elements
let – value assignment
where – filter condition
return – construct a result

XQuery - Joins

```
<result>{
        for $c1 in doc("teaching_data_1.xml")//Course
        for $c2 in doc("teaching_data_2.xml")//Course
        let $t1 := $c1/Teacher
        let $t2 := $c2/Teacher
        where $c1/Teacher/Name = $c2/Teacher/Name
        return
                <selected_course>
                        {$c1}
                        {$c2}
                </selected_course>
}
</result>
```

XQuery - Joins

```
<result>{
      for $c1 in doc("teaching_data_1.xml")//Course
      for $c2 in doc("teaching_data_2.xml")//Course[Teacher/Name = $c1/Teacher/Name]
      return
            <selected_course>
                  {$c1}
                  {$c2}
            </selected_course>
}
</result>
```

XQuery – User-Defined functions

```
declare function prefix:function_name($paremeter as datatype) as returnDatatype
{
        …function code …
}
```

Outline

- ✓ XML
- ✓ Schema for XML
- ✓ Query languages for XML
- ➢ JSON and GraphQL

JSON – Javascript Object Notation

- Also a standardized format for exchanging data, based on key/value pairs
  - Keys must be strings, written with double quotes
  - Values can be in a string, a number, an object, an array, a Boolean, null

```
{
  "Teachers":
  [{
    "Name": "Huanyu Li",
    "Email": "huanyu.li@liu.se",
    "Affiliation": "Linköping University"
  },
  {
    "Name": "Patrick Lambrix",
    "Email": "patrick.lambrix@liu.se",
    "Affiliation": "Linköping University"
  }
  ]

}
```

JSON Schema

- A standard for defining structures or rules about JSON data
  - type: restrictions on specific types
  - properties: properties of an object and their corresponding schemas
  - required: properties that must exist
  - Etc.

  - JSON schema doc: https://www.learnjsonschema.com/2020-12/

```json
{
    "first_name": "Huanyu",
    "last_name": "Li",
    "address": {
        "street_address": "Mäster Mattias väg 7",
        "post_code": "583 30",
        "city": "Linköping",
        "state": "Östergötland",
        "country": "Sweden",
        "latitude": 58.397362,
        "longitude": 15.576967
    }
}
```

=

```json
{
    "type": "object",
    "properties": {
        "first_name": { "type": "string" },
        "last_name": { "type": "string" },
        "address": {
            "type": "object",
            "properties": {
                "street_address": { "type": "string" },
                "post_code": { "type": "string" },
                "city": { "type": "string" },
                "state": { "type": "string" },
                "country": { "type" : "string"},
                "latitude": { "type": "number", "minimum": -90, "maximum": 90 },
                "longitude": { "type": "number", "minimum": -180, "maximum": 180 }
            },
            "required": ["street_address", "city"]
        }
    }
}
```

Query JSON data

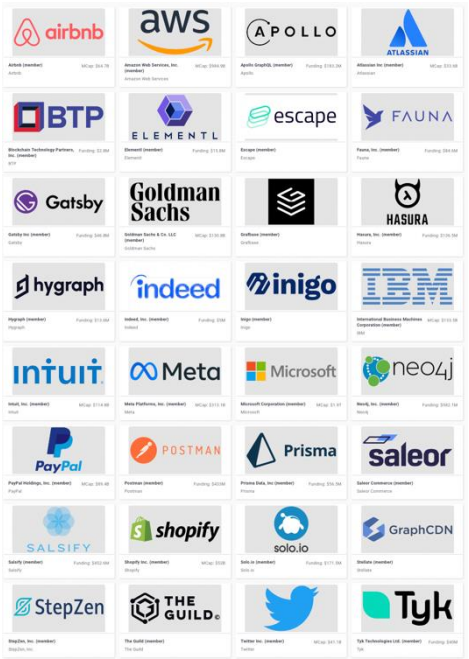
- XQuery 3.1 supports querying JSON data
  - https://www.w3.org/TR/xpath-functions-31/#json-functions

Function	Meaning
fn:parse-json	Parses a string supplied in the form of a JSON text, returning the results typically in the form of a map or array.
fn:json-doc	Reads an external resource containing JSON, and returns the result of parsing the resource as JSON.
fn:json-to-xml	Parses a string supplied in the form of a JSON text, returning the results in the form of an XML document node.
fn:xml-to-json	Converts an XML tree, whose format corresponds to the XML representation of JSON defined in this specification, into a string conforming to the JSON grammar.

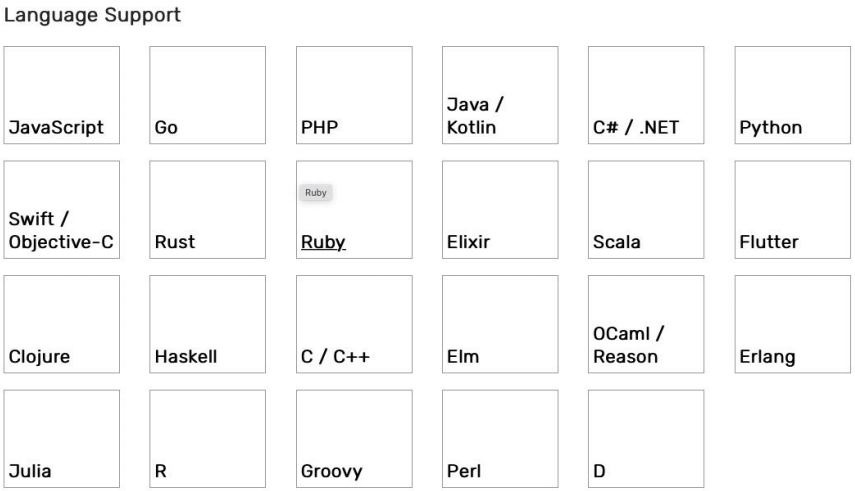
- JSON Path- XPath for JSON
  - https://goessner.net/articles/JsonPath/

GraphQL

- GraphQL is a conceptual framework for building web APIs
- The framework introduces GraphQL schema, resolver function and a query language (query, mutation, etc.)
- A GraphQL schema tells users how underlying data can be accessed



GraphQL landscape: https://landscape.graphql.org



GraphQL code: https://graphql.org/code/

GraphQL

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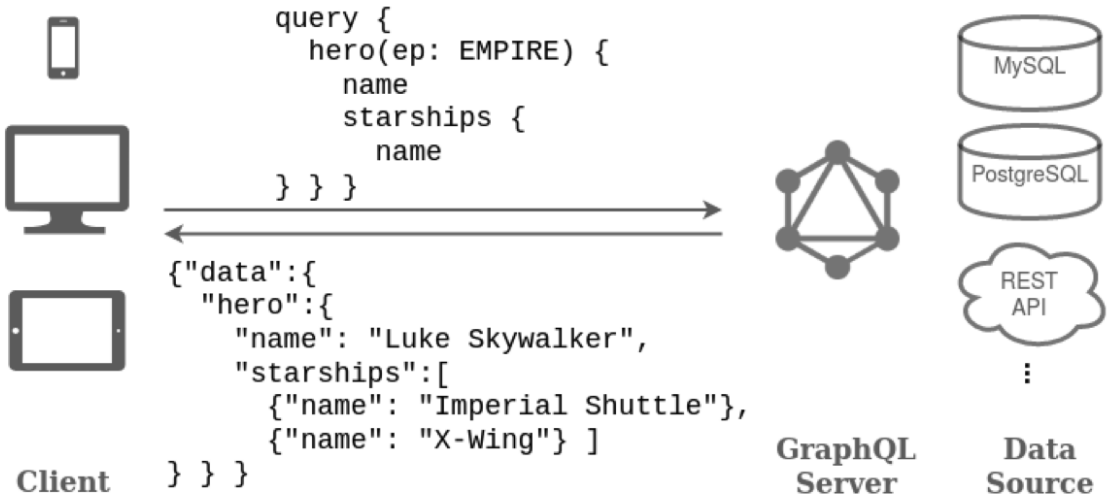

GraphQL querying scenario [1]

[1] Sijin Cheng and Olaf Hartig: **LinGBM: A Performance Benchmark for Approaches to Build GraphQL Servers**.

GraphQL Schema

- Object type, Query type, Input type, Interface, etc.
- ID, String, Float, Int, Boolean
- Field declaration
- GraphQL specification: https://spec.graphql.org

```
type University{
  UniversityID: String
  departments: [Department]
}
type Department{
  DepartmentID: String
  head: String
}
interface Author{
  AuthorID: String
}
type Professor implements Author{
  AuthorID: String
  doctoralDegreeFrom: [University]
}
input UniversityFilter{
  UniversityID: StringFilter
  departments: DepartmentFilter
  _and: [UniversityFilter]
  _or: [UniversityFilter]
  _not: UniversityFilter
}
```

```
input DepartmentFilter{
  DepartmentID: StringFilter
  head: StringFilter
  _and: [DepartmentFilter]
  _or: [DepartmentFilter]
  _not: DepartmentFilter
}
input StringFilter{
  _eq: String
  _in: [String]
  _neq: String
  _nin: [String]
  _like: String
}
type Query{
  UniversityList(filter: UniversityFilter): [University]
  DepartmentList(filter: DepartmentFilter): [Department]
  AuthorList: [Author]
  ProfessorList: [Professor]
}
```

GraphQL Query, Response, Resolver Function

GraphQL Query and Response

```
{
   UniversityList(
      filter:{
         UniversityID:{
           _eq:"u1"}
      }){
      departments{
         head
      }
   }
}
```

```
{
  "data":{
    "UniversityList":[
    {
     "departments":[
      {"head":"Harry,Potter"},
      {"head":"Sheldon,Cooper"}
     ]
    }]
  }
}
```

```
type University{
  UniversityID: String
  departments: [Department]
}
type Department{
  DepartmentID: String
  head: String
}
interface Author{
  AuthorID: String
}
type Professor implements Author{
  AuthorID: String
  doctoralDegreeFrom: [University]
}
input UniversityFilter{
  UniversityID: StringFilter
  departments: DepartmentFilter
  _and: [UniversityFilter]
  _or: [UniversityFilter]
  _not: UniversityFilter
}
```

```
input DepartmentFilter{
  DepartmentID: StringFilter
  head: StringFilter
  _and: [DepartmentFilter]
  _or: [DepartmentFilter]
  _not: DepartmentFilter
}
input StringFilter{
  _eq: String
  _in: [String]
  _neq: String
  _nin: [String]
  _like: String
}
type Query{
  UniversityList(filter: UniversityFilter): [University]
  DepartmentList(filter: DepartmentFilter): [Department]
  AuthorList: [Author]
  ProfessorList: [Professor]
}
```

```
const UniversityList = (university_id) => {
  let data = db_conection.select().from('university')
             .where('id', university_id);
  let allUniversities = data.then(rows => new University(rows[0]));
  return allUniversities;
};
```

Resolver function

Summary

- Data representation in different (common and standardized) formats
  - Underlying data models for different formats
  - Data schemas that data can/has to follow
  - Query languages

- XML
  - DTD, XSD, XQuery, XPath
- JSON
  - JSON Schema, XQuery 3.1, JSON Path
- GraphQL
  - GraphQL schema, GraphQL Query

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