DSD: A Schema Language for XML

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Connections between XML and Formal Methods

XML: a notation for labeled trees,
a lot of technologies built on top

Formal Methods: notations and reasoning principles for complex systems at an abstract level

Our aim: *show that proven FM technologies are applicable to the world of XML*

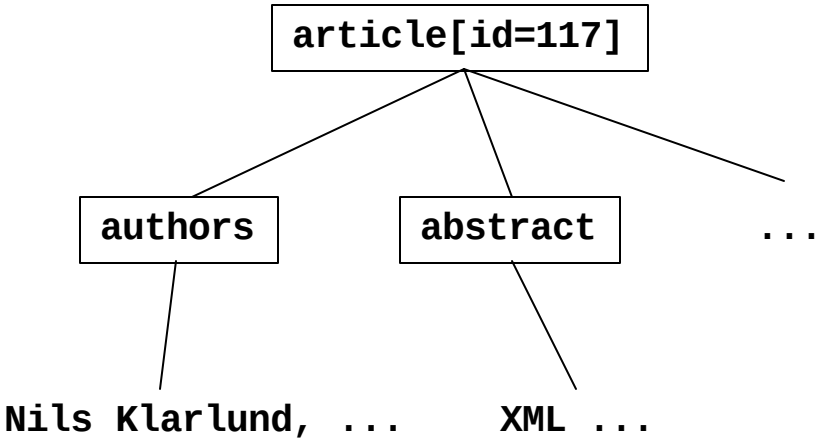
- expressiveness
- simplicity
- efficiency
- elegance

The ideas behind XML

- Textual notation for hierarchically structured information
- Built-in internationalization and platform independence

```
<?xml version="1.0"
      encoding="iso-8859-1">
<article id="117">
  <authors>
    Nils Klarlund, ...
  </authors>
  <abstract>
    XML (eXtensible Markup Language)
    is a linear syntax for ...
  </abstract>
  ...
</article>
```

concrete, textual representation



abstract, tree representation

Central technologies building on top of XML

- Schema languages (grammar notations)
  e.g. DTD, **DSD**, XML Schema, ...
- Transformation languages
  e.g. XSLT, XDuce, ...
- Query languages
  e.g. XML-QL, Quilt, ...
- ...

All could benefit from Formal Methods!

Our DSD proposal: ***a schema language with a CS foundation***.
Each DSD document defines (essentially) a ***regular tree language***.

DSD: Document Structure Description

What schemas can do for you

- Formalize your notion of “articles” by making a DSD description
- Check validity of your article XML documents using a DSD processor

Example:

1. Insert `<?dsd URI=”article.dsd”>` in the article header
2. Run the DSD processor: `dsd article.xml`
   The result might be:

```
Error in ’article.xml’ line 17: attribute ’font’ has illegal
value ’ttt’ (checking attribute in ’article.dsd’ line 84)
```

In order to be useful, the schema notation must

- have enough **expressive power**
- be **efficiently implementable**
- be **easily understandable**

Design goals

DSD must

- allow **linear-time** processing
- be 100% **self-describing**
- subsume the **expressive power** of DTD
- contain a **default mechanism** for attributes, elements, and text
- support **modularization**, **evolution**, and **reuse**
- be able to express **semi-structured data**
- handle **syntax for attributes and text**
- support **context dependencies**
- support **conditional constraints**

A quick tour of DSD

Processing model: like a ***deterministic top-down automaton***,
but extended with

- default insertion
- a sophisticated transition function with context sensitivity

(A top-down approach complies with the recursive structure of typical XML languages!)

Each node is associated a **state** called an "**Element Definition ID**", referring to a description in the DSD of a particular kind of element.

If the top-down traversal succeeds, the document "**conforms**" to the DSD.

An example: a DSD for XML “business cards”

An application document:

```
<card type=”simple”>
  <name>John Doe</name>
  <title>CEO, Widget Inc.</title>
  <email>john.doe@widget.com</email>
  <phone>(202) 456-1414</phone>
</card>
```

A part of a DSD for business-card XML documents:

```
<DSD IDRef=”card-element”>
  <Title>This is a DSD for XML business cards</Title>
  <ElementDef ID=”card-element” Name=”card”>
    <AttributeDecl Name=”type” Optional=”yes”>
      <Union><String Value=”simple”/><String Value=”complex”/></Union>
    </AttributeDecl>
    <Element Name=”name”><StringType/></Element>
    <If><Attribute Name=”type” Value=”simple”/><Then> ... </Then></If>
    ...
  </ElementDef>
  ...
</DSD>
```

Element constraints

The central DSD construct:

```
<ElementDef ID="Element ID" Name="element name">
  constraint
</ElementDef>
```

It associates an **element name** and a **constraint** to an **Element Definition ID**.

A **constraint** declares and constrains *attributes* and *content* of the element.

Constraints can be made **conditional** on attributes and context.

Attribute declarations

In a constraint,

- element attributes can be **declared hierarchically**
- their allowed **values** can be constrained

String types

We use standard **regular expressions** to define valid values for **element attributes** and **text**.

All well-known data types can be described by regular expressions:

- URLs
- email addresses
- ZIP codes
- ISBN numbers
- ...

– and they can be processed efficiently using automata techniques.

Other schema notations rely on fixed sets of data types.

Content expressions

Content of an element: its sequence of child nodes

Obvious choice for specifying valid content: ***regular expressions***

However:

- that would conflict with default insertion
- not obvious how to assign a single Element Definition ID to each child element

The DSD solution: a notation resembling regular expressions, but

- having a **direct operational semantics**
- support for both **ordered** and **unordered** contents
- each child node is **matched exactly once**

Context patterns

In practice, many validity constraints on an element depend on its **context**. (Same for Cascading Style-Sheets.)

Element context: the sequence of elements above it in the tree

DSD constraints can

- be conditional on the context
- impose requirements of the context

Default insertion

Insertion of defaults

- is very useful
- must be part of the validation process!

The DSD default mechanism is **declarative**; each default consists of

  - an applicability expression (probing context etc.)
  - an XML fragment

Defaults are inserted “upon request” during the top-down traversal.

ID attributes and Points-to requirements

– going slightly beyond regularity

Special attributes:

ID attributes: their values must be **unique** in the document

IDRef attributes: their values must be that of some **ID** attribute

– i.e., they can be seen as internal **definitions** and **references**

Additionally, **points-to** requirements can be imposed on ID attributes. This allows ***semi-structured data*** to be expressed.

Redefinitions and evolving DSDs

Modification, **extension**, and **reuse** is crucial.

The DSD solution:

- document inclusion (allows reuse)
- selective redefinitions (for modification and extension)

DSD highlights

- Large class of tree languages, handling almost all syntactic constraints of boolean or regular nature
- Grammar modifications: abstraction, restriction, extension
- Context dependencies, semi-structured data description, and defaults

Related work

- **DTD** (part of XML 1.0 spec.)
  - general agreement that it is much too simple
- **RELAX** (by Makato Murata)
  - elegantly characterizes the set of all regular tree languages
  - uses bottom-up approach
- **XML Schema** (draft specification, by W3C WG)
  - much more complex than other proposals
  - significantly less expressive: no boolean dependencies, schema evolution, context sensitivity, declarative default insertion, semi-structured data, ... (but supports namespaces, inheritance, and uniqueness)
  - has been receiving harsh comments for being convoluted and incomprehensible

Conclusion

XML represents an excellent opportunity to promote formal descriptions.

Future work:

- minor extensions to DSD
- simplify DSD even further, and obtain a cleaner semantics
- apply Formal Methods to other areas of XML

http://www.brics.dk/DSD