XML framework for concept description and knowledge representation

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Abstract

An XML framework for concept description is given, based upon the fact that the tree structure of XML implies the logical structure of concepts as defined by attributional calculus. Especially, the attribute-value representation is implementable in the XML framework. Since the attribute-value representation is an important way to represent knowledge in AI, the framework offers a further and simpler way than the powerful RDF technology.

ACM: I.7.2 XML, E.2 Object Representation, H.1.1 Information Theory, G.2.3

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1 Introduction

Knowledge representation is an important and wide area of Artificial Intelligence. The simplest way to represent knowledge of an object is the attribute-value representation. Here an object is characterized by its attributes, each of which having a fixed range of value. A concept then is a category of objects specified by a logical combination of attribute values.

On the other hand an XML document consists of elements specified by attribute-value pairs and nested in a hierarchical tree structure. Hence the idea to apply XML to knowledge representation via the attribute-value representation is straightforward. The logical notions of rules and concepts are rather naturally mapped into the XML framework, which to demonstrate is the major intention of this paper.

The application of XML to concept description has a lot of advantages. Since XML is a universal and web-based data format, it is appropriate for platform-independent and world-wide use. XML nowadays has become a widely accepted standard data interchange technology so that its general usability is guaranteed for a long time.

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Another aspect is the power of XML to let check data consistency of instance documents against the corresponding XML schema. This tears consistency checks apart from the applications processing the data.

The new XML framework supplements different approaches towards knowledge representation using RDF technology to build a Semantic Web \[1\] \[4\] \[5\] \[6\] \[7\] \[8\] \[9\] \[12\] \[13\]. But whereas RDF is the more powerful technology enabling semantic links by an entity-relationship implementation, the XML framework is simpler and more appropriate to a description of concepts based upon attribute-value representation as well as to their storage and to data interchange. The framework enables and simplifies worldwide data access for subsequent applications, e.g. machine learning programs.

The present paper is organized as follows. In section 2 a sketchy overview of XML is given, followed by a short introduction to knowledge representation and attributional calculus in section 3. The core of the paper is section 4 modelling concept description in XML, section 5 provides Emerald’s world as an example of this model. A short discussion concludes the paper.

2 XML

Among other purposes, XML has been constructed as a data interchange format. By definition it is a textual markup language consisting of elements which are organized in a tree structure. Syntactically, each element name is opened by a start tag, <name>, and closed by an end tag, </name>. To reflect the tree structure, any element opened after the start tag of a previous element must be closed before the previous element is closed.

Any element can have m children as well as n attributes, m, n ∈ \(\mathbb{N}_0\) (both m and n may vanish). An attribute is written in the start tag of the element with its value in quotation marks ("), i.e.

\[
<\text{name attribute="value"}> \ldots </\text{name}>
\]

If an element in an XML document has no child, it can be written as <name/>, i.e. <name> </name> = <name/>. The possible elements of an XML document are declared in its DTD (document type definition) or, more generally, in its XML schema. An XML schema by itself is an XML document with a predefined element set. In particular, the root element of an XML schema is <xsd:schema> ... </xsd:schema>. Here xsd denotes the XML namespace (xmlns) of the W3C consortium,

\[
\text{xmlns:xsd="http://www.w3.org/2001/XMLSchema".}
\]

A typical XML schema looks like the following source code.

<?xml version="1.0"?><xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"targetNamespace="..."> ...
</xsd:schema>

For details see \[3\] \[4\].
3 Knowledge representation and attributional calculus

Attributional calculus \[11\] is a simple description language whose representational power is between propositional calculus and first order predicate logic. It serves as a technique for knowledge representation. In the sequel a set-theoretic version of attributional calculus is presented, briefly compared to the standard VL1 notation.

Let \( X \) be a given finite set of objects. An attribute then is a mapping \( a : X \rightarrow W \), \( x \mapsto a(x) \), where \( W \) is a given finite set, the range of the attribute values of the objects \( x \) in \( X \). Therefore, \( a(x) \) is the value of the attribute that object \( x \) possesses. Let the objects \( x \) in \( X \) be uniquely characterized by a finite set of attributes \( A = \{a_1, \ldots, a_n\} \), where each attribute \( a_i \) has a fixed finite range \( W_i = a_i(X), i = 1, \ldots, n \). Then each attribute can be written as \( a_i : X \rightarrow W_i, x \mapsto a_i(x) \) \((i = 1, \ldots, n)\) (1)

Thus by this choice of attributes an object \( x \) is well distinguishable from the others by all its attribute values \( a_1(x), \ldots, a_n(x) \). In other words, each object \( x \) corresponds uniquely to a vector of attribute values \( w_1, \ldots, w_n \), \( x \cong (w_1, \ldots, w_n) \in W_1 \times \ldots \times W_n. \) (2)

The attribute-value representation formalizes the information that we have about the object set \( X \) and its objects. Hence it is a precise notion for (one kind of) knowledge representation.

The basic construct of attributional calculus is the elementary selector \( S(a, w) \) given for an attribute-value pair \( (a, w) \) by \( S : \mathcal{D} \rightarrow 2^X, (a, w) \mapsto S(a, w) \), with \( S(a, w) = \{ x \in X : a(x) = w \}. \) (3)

Here \( 2^X \) denotes the potential set of \( X \), and \( \mathcal{D} \) is the attribute-value set, \( \mathcal{D} = \bigcup_{i=1}^{n} \{a_i\} \times W_i \). In other words, \( S(a, w) \) selects all objects whose attribute \( a \) has value \( w \). Of course, this set might be empty. An empty selector corresponds to a “don’t care.” Often, a selector \( S \) is written a bit sloppily as \( S = \{a = w\}. \) (4)

This is justified by Boole’s second law \[2 \] §XII.1. In VL1 notation \[10\], a general selector is written as \( [a \mapsto w] \), where \( \mapsto \) is a relation satisfying \( \mapsto \in \{=, \neq, \geq, >, \leq, <\} \). Since the range \( W \) is finite, a general selector is a disjunction of elementary selectors. For instance, if \( W = \{w_1, w_2, \ldots, w_m\} \), the selector \( [a \neq w_1] \) is equivalent to \( [a = w_2] \lor [a = w_3] \lor \ldots \lor [a = w_m] \).

A rule \( R \) is an intersection of selectors \( S_1, \ldots, S_m \), \( R = S_1 \cap \ldots \cap S_m \) (5)

where selector \( S_i \) corresponds to attribute \( a_i \). Note that a selector may be empty and can be omitted in this case. A concept \( C \) is a union of rules \( R_1, \ldots, R_k \), \( C = R_1 \cup \ldots \cup R_k \). (6)
In VL1 notation, an intersection corresponds to a conjunction, and a union corresponds to a disjunction. Analogously to the context of Boolean functions, we call this representation the disjunctive normal form [2 §III.5] of a concept. In the next section it will be worked out that this simple structure of concepts is naturally represented in XML.

4 XML model of concepts

The XML model of concepts relies on the fact that the structure of XML implies the structure of attributional calculus. Three implications are immediately observed:

1. a selector is representable by an attribute-value pair, cf. eq. [1];
2. the intersection (conjunction) of selectors corresponds to a list of attribute-value pairs in a single element;
3. the union (disjunction) of rules corresponds to the creation of children to a parent element.

Thus the XML model of concepts is straightforwardly achieved: A concept can be considered as an element which has either no, one, or more rules as child elements; a selector is simply an attribute-value pair of a rule element. For instance, a concept may be given as

```
<concept>
  <rule a_i="w_{ij}" ... a_k="w_{kl}"/>
  <rule a_m="w_{mn}" ... a_p="w_{pq}"/>
</concept>
```

Here \( a_i \) is attribute number \( i \), \( W_i \) is its range, and \( w_{ij} \in W_i \) is one of its possible values. Hence a concept can be graphically represented by the following diagram.

```
concept
  /   \
rule 1
    /   \
  selector S_{11}  ...  selector S_{1n_1}

...  ...  ...

rule k
    /   \
  selector S_{k1}  ...  selector S_{kn_k}
```

To enable this construct, the corresponding XML schema for a concept has to be given as in the following source code.

```
<?xml version="1.0"?>
<xsd:schema
  xmlns:xsd="http://www.w3.org/2001/XMLSchema"
  targetNamespace= 
    "http://www.math-it.org/xml/2002/concept.xsd"
  xmlns="http://www.math-it.org/xml/2002/concept.xsd"
  elementFormDefault="qualified"
>
  <xsd:element name="concept">
```

The names for the attributes, e.g. attribute_1, as well as for the ranges (data types) of the values, e.g. W_1, have to be adjusted appropriately.

This XML model can be easily extended to enable naming of concepts or rules by adding another child to the concept element, or the rule element, respectively.

5 An example: Emerald’s robots

To illustrate the notion of the concept and its implementation in XML, let us consider exemplarily the world of Emerald’s robots. It is a software system consisting of objects called “robots.” Each robot is described by the values $w_1, \ldots, w_6$ of six attributes, $w_i \in W_i$. The attributes with their ranges are listed in table 1. A concept now is a specific description of a robot category. For

| attributes | range of values |
|------------|----------------|
| headShape  | $W_1 = \{\text{’round’}, \text{’square’}, \text{’octagon’}\}$ |
| bodyShape  | $W_2 = \{\text{’round’}, \text{’square’}, \text{’octagon’}\}$ |
| isSmiling  | $W_3 = \{\text{’true’}, \text{’false’}\}$ |
| holding    | $W_4 = \{\text{’sword’}, \text{’balloon’}, \text{’flag’}\}$ |
| jacketColor| $W_5 = \{\text{’red’}, \text{’yellow’}, \text{’green’}, \text{’blue’}\}$ |
| hasTie     | $W_6 = \{\text{’yes’}, \text{’no’}\}$ |

Table 1: The robots’ attributes and their ranges.

[1] EMERALD = Experimental Machine Example-based Reasoning And Learning Disciple, see www.mli.gmu.edu; at this URL you also find Java-based animations illustrating the system.
instance,

\[ C = \text{“head is round and jacket is red, or head is square and is holding a balloon”} \]

is a concept. There are \(3 \cdot 3 \cdot 2 \cdot 3 \cdot 4 \cdot 2 = 432\) different robot objects in this world, 84 of which belong to the category \(C\). In our XML framework, the concept \(C\) is implemented as

\[
\begin{align*}
\text{<concept>}
\text{ <rule headShape="round" jacketColor="red"/>}
\text{ <rule headShape="square" holding="balloon"/>}
\text{ </concept>}
\end{align*}
\]

The corresponding XML schema is given in the appendix; it can also be found in the WWW at the URL

http://www.math-it.org/xml/2002/emerald.xsd

It defines the concept structure as well as the attribute ranges of the robots.

6 Discussion

In this paper an XML framework for concept description is proposed. Concepts are expressed with the aid of attributional calculus as set-theoretic combinations of rules and selectors. An important observation is that the structure of concepts is implied by the structure of an XML document. In particular, a selector is representable by an attribute-value pair, a rule as an intersection (conjunction) of selectors by a list of attribute-value pairs in a single element, and a union (disjunction) of rules by a generation of children of a parent element. In this way, the XML framework for concept descriptions can be developed in a straightforward manner.

As a consequence, the attribute-value representation in this XML framework offers a route to represent knowledge, distinct from similar but more powerful approaches based, e.g., on the RDF technology \([1, 4, 5, 6, 7, 8, 9, 12, 13]\). Since the framework refers to concepts in the sense of attributional calculus, it cannot represent all possible logical connectives. For instance, it does not provide recursive structures (the mainstay of RDF where, e.g., the object of an RDF property can itself have arbitrary properties) or express inductive concepts which have only necessary conditions (cf. the concept “human” and the classical “featherless biped” example due to Aristotle). In addition, it has no quantification, negation, etc., although this could be implemented easily in a richer schema for concept definitions, as is done in a wide range of web-based knowledge representation languages such as OKBC \([12]\), DAML+OIL \([9]\), OWL \([13]\), or full FOL \([7]\).

Moreover, the attribute-value representation on which the XML framework is based upon is only applicable to knowledge systems consisting of solely finite ranges of attribute values.

However, the framework is still rich enough to tackle problems of machine learning. Here the emphasis is laid upon the representation of learning examples, which are completely determined by their attributes as well as an additional Boolean flag indicating whether they are positive or negative. Thus the
framework enables to store concepts in XML documents and to let them be further processed by concept learning algorithms. Reconciliation of a concept document with its corresponding XML schema by standard XML parsers can be used as a data consistency check, independently from subsequent processing programs. The example of Emerald’s robots indicates a perspective how this can be done.

Since moreover XML is a universal data interchange format, a web-based storage of concepts could serve as a germ of a standardized world-wide knowledge database platform.

Appendix: XML schema of Emerald’s world

```xml
<?xml version="1.0"?>
<xsd:schema
 xmlns:xsd="http://www.w3.org/2001/XMLSchema"
 targetNamespace="http://www.math-it.org/xml/2002/emerald.xsd"
 xmlns="http://www.math-it.org/xml/2002/emerald.xsd"
 elementFormDefault="qualified"
 >
 <xsd:element name="emerald">
  <xsd:complexType>
   <xsd:sequence minOccurs="0" maxOccurs="unbounded">
    <xsd:element name="concept" minOccurs="0" maxOccurs="unbounded">
     <xsd:complexType>
      <xsd:sequence>
       <xsd:element name="rule" minOccurs="0" maxOccurs="unbounded">
        <xsd:complexType>
         <xsd:attribute name="headShape" type="HeadShape"/>
         <xsd:attribute name="bodyShape" type="BodyShape"/>
         <xsd:attribute name="isSmiling" type="IsSmiling"/>
         <xsd:attribute name="holding" type="Holding"/>
         <xsd:attribute name="jacketColor" type="Color"/>
         <xsd:attribute name="hasTie" type="HasTie"/>
        </xsd:complexType>
       </xsd:element>
      </xsd:sequence>
     </xsd:complexType>
    </xsd:element>
   </xsd:sequence>
  </xsd:complexType>
 </xsd:element>
</xsd:schema>
```

```xml
<xsd:simpleType name="HeadShape">
 <xsd:restriction base="xsd:string">
  <xsd:enumeration value="round"/>
  <xsd:enumeration value="square"/>
  <xsd:enumeration value="octagon"/>
 </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="BodyShape">
 <xsd:restriction base="xsd:string">
  <xsd:enumeration value="round"/>
  <xsd:enumeration value="square"/>
 </xsd:restriction>
</xsd:simpleType>
```
<xsd:enumeration value="octagon"/>
</xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="IsSmiling">
  <xsd:restriction base="xsd:boolean">
    <xsd:pattern value="true"/>
    <xsd:pattern value="false"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="Holding">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="sword"/>
    <xsd:enumeration value="balloon"/>
    <xsd:enumeration value="flag"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="Color">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="red"/>
    <xsd:enumeration value="yellow"/>
    <xsd:enumeration value="green"/>
    <xsd:enumeration value="blue"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="HasTie">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="yes"/>
    <xsd:enumeration value="no"/>
  </xsd:restriction>
</xsd:simpleType>
</xsd:schema>

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