XML Processing and Term Rewriting

Martin Bravenboer

martin@cs.uu.nl

Institute of Information and Computing Sciences, University Utrecht, The Netherlands

contents

monday

- relate xml and aterms
- impression of xml processing methods and languages
  - mainstream oriented

    - text/api based
    - xpath, xslt, xquery
  - research oriented

    - xen, xduce, xtatic, cduce
    - generic haskell

wednesday

- how to connect xml and aterm tools
- how to apply stratego for xml processing

why discuss xml processing

- *stratego*: program transformation
- transform *aterm* representations of the source code of programs
- why not *structured data* in general?
- that's the topic of my master's thesis:

connecting *xml processing* and *term rewriting*
using tree grammars

xml and aterm concepts

xml and aterm: concepts

- *xml web-services*
  - independent software tools
  - working together by exchanging xml

- *stratego/xt*
  - component-based transformation systems
  - exchanging program representations
  - in the aterm format

exchange of structured, tree-like data between
software components

xml and aterm: contribution

enables ‘generic’:

- *tools and libraries*
  parsers, pretty-printers, well-formedness checkers, validators, editors, browsers, . . .
- *languages*
  schema, query, transformation, style, dedicated, general purpose, . . .

xml syntax for tree-like data is

- platform,
- language,
- culture,
- and application independent.

xml and aterm: similarities and differences

similarities

- xml element $\sim$ aterm application
- xml character data $\sim$ aterm string
- xml attribute $\sim$ aterm annotation

differences

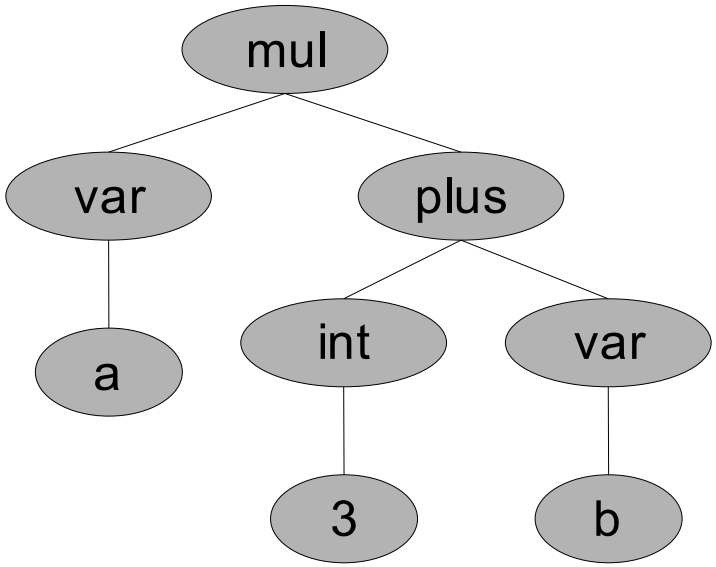
- aterm has:
  - explicit structure
  - primitive data types
  - structured annotations
- formalisms:
  - aterm format $\sim$ tree languages
  - xml $\sim$ hedge languages

xml and aterm: concepts

- an xml document is not a tree
- an aterm is not a tree

$\Rightarrow$ generic *syntax* for tree-like data

```
<mul>
  <var>a</var>
  <plus>
    <int>3</int>
    <var>b</var>
  </plus>
</mul>
```




```
mul(
   var("a")
,  plus(
      int(3)
   ,  var("b")
   )
)
```

xml processing in practice

text based xml processing

- xml in string literals
- xml in templates with embedded variables

```
sw.WriteLine("<?xml version=\"1.0\" encoding=\"Windows-1252\"?>");
sw.WriteLine("<configuration>");
sw.WriteLine("\t<appSettings>");
sw.WriteLine("\t\t<add key=\"Main.ConnectionString\" value=\""
                                  + m_sConnectionString + "\" />");
sw.WriteLine("\t</appSettings>");
sw.WriteLine("</configuration>");
sw.Close();
```

(fragment of LLBLGen)

text based xml processing

- xml in string literals
- xml in templates with embedded variables

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- xml in ‘concrete syntax’
- easy to start with

-

- no syntax checking: well formedness
- no transformation: requires interpretation

api based

produce or consume xml with a dom, sax or pull api

```
Element report = new Element("exception-report");

Element topic   = new Element("topic");
topic.setText(_exception.getTopic());
report.addContent(topic);

Element userinfo = new Element("user-info");
userinfo.setText(_message.getBackgroundValue().getContent());
report.addContent(userinfo);

createExceptionElement(report, _exception.getException());

StringWriter writer = new StringWriter();
XMLOutputter outputter = new XMLOutputter("\t", true);
outputter.output(report, writer);
```

api based

produce or consume xml with a dom, sax or pull api

```
void serialize(Date time, ContentHandler h) {
  _calendar.setTime(time);
  intElement(h, "day-of-month", _calendar.get(Calendar.DAY_OF_MONTH));
  intElement(h, "month",        _calendar.get(Calendar.MONTH) + 1);
  intElement(h, "year",         _calendar.get(Calendar.YEAR));
}

void intElement(ContentHandler handler, String elem, int val) {
  textElement(handler, elem, String.valueOf(val));
}

void textElement(ContentHandler handler, String elem, String text) {
  startElement(handler, elem);
  characters(handler, text);
  endElement(handler, elem);
}
```

api based

produce or consume xml with a dom, sax or pull api

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- guarantees for well-formedness (not always)
- transformation possible if api allows

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- verbose: does not scale to large fragments
- no xml specific language facilities

how to improve?

- *embed the xml syntax* in general purpose language
  - syntax for api calls or data
  - not (yet) applied in practice
  - tiger, java, c# with xml syntax

- *xml data binding*
  - natural representation of xml data
  - jaxb, castor, dtd2haskell
  - applied in practice

- *dedicated xml language*
  - built-in support for xml
  - xpath, xslt, xquery, xslt, xduce, cduce
  - applied in practice

xpath: succesful mini language

- select nodes in an xml document
- no variable binding

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- easy to use syntax, based on a set of axes
- can be reused in many languages

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- verbose pattern matching

```
BinOp[PLUS and *[position() = 3 and name(.) = 'BinOp']/PLUS ]
```

- lack of variable binding sometimes annoying

xslt: xml transformation language

- *templates rewrite* a node that matches an xpath
- *recursively apply templates* to nodes selected by and xpath
- stateless ‘functional’ language

```
<xsl:template match="category">
  <li>
    <h2><xsl:value-of select="@name"/></h2>
    <ul><xsl:apply-templates/></ul>
  </li>
</xsl:template>

<xsl:template match="link">
  <li>
    <a href="{@url}" alt="{@name}">
      <xsl:value-of select="@name"/>
     </a>
  </li>
</xsl:template>
```

xslt: xml transformation language

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- easy to use if you know xpath
- most widely applied functional language!

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- limited set of functions (use EXSLT)
- difficult to create abstraction
- transformation of ‘results’ not allowed (EXSLT, XSLT 2.0)
- abused to generate ‘plain text’

- compared to stratego
  - no separation of rules and strategies
  - no first class pattern matching
  - no support for implementing full xml applications

xquery: xml query langage

FLOWR expressions

- *for* - select nodes using xpath
- *let* - bind nodes to variables
- *where* - apply conditions
- *order by* - sort the results
- *return* - construct new nodes

- very easy to learn
- more declarative, not operational

  like Java, XSLT, Stratego, Haskell
- less convenient for transformations (duh)

xml processing in research

research xml processing languages

focus of research:

- *type systems*
  $\Rightarrow$ xduce, xtatic, xquery, xen, cduce
- *performance*
  $\Rightarrow$ pattern matching compilation

limited research:

- *generic programming*
  $\Rightarrow$ focus on getting a basic type system right
- *traversals*
  $\Rightarrow$ xml data is not typical data in functional languages
- *composition and interaction*

xen

- Microsoft Webdata, Research / Cambridge
- extension of C#: more general data model
  - streams: $T?, T!, T, T*, T+$
  - tuples: $sequence$
  - unions: $choice$
- xml is object literal syntax for this extended data model
- more operations: filter, apply to all

read the articles for more info:

- unifying tables, objects and documents
- programming with circles, triangles and rectangles

generic haskell

- generic extension of haskell
- type-safe access to the structure of data
- xml programming is xml data binding to haskell data types
- subject of *generic programming* course

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- amazing abstraction and reuse

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- data structures must be known at compile time
  $\Rightarrow$ generic programming, but not ‘any’ data
- no dedicated features for xml like data

more info: *http://www.generic-haskell.org*

cduce

- designed at two universities in France
- typed, xml-oriented, functional language
- goal: develop more complex applications completely in cduce

main areas of interest:

- type system: structural typing
  - type: set of values
  - t_1 subtype t_2 if e_1 subset of e_2
- type-based pattern matching
- generic programming

cduce: type system

- universal type: Any
- native scalar types: Int (infinite), $Char$ (Unicode), $Atom$
- constructed types
  - product type: (t_1, t_2)
  - open record type: $\{a_1 = t_1, \ldots, a_n = t_n\}$
  - closed record type: $\{|a_1 = t_1, \ldots, a_n = t_n|\}$
  - xml type: $< t_1\ t_2 > t_3$
  - functional type: $t_1 \rightarrow t_2$
- boolean operations on types
  - union: $t_1|t_2$
  - intersection: $t_1 \& t_2$
  - difference: $t_1 \setminus t_2$
- singleton types: a scalar or constructed value is a type

cduce: type system

- encoded types
  - sequence: $[v_1, v_2, \ldots, v_n]$ is $(v_1, (v_2, (\ldots, (v_n, `nil))))$
  - strings are sequences of chars

- overloaded functions

$$
\begin{array}{l}
let\ fun\ f(t_1 \rightarrow s_1;\ \ldots\ ; t_n \rightarrow s_n) \\
\quad \mid p_1 \rightarrow e_1 \\
\quad \mid \ldots \\
\quad \mid p_m \rightarrow e_m
\end{array}
$$

cduce: patterns

- pattern-matching expression

$$
\begin{array}{l}
match\ e\ with \\
\quad \mid p_1 \ \rightarrow \ e_1 \\
\quad \mid \ \ldots \\
\quad \mid p_n \ \rightarrow \ e_n
\end{array}
$$

- $let\ p = e_1\ in\ e_2$ is defined as $match\ e_1\ with\ p \ \rightarrow \ e_2$
- _ refers to Any
- matching must be exhaustive
- exceptions can be used to make 'dynamic type errors' *explicit* in the code

  (compare to Maybe and NullPointerException)

cduce: pattern variables

- capture variables: bind values
- multiple occurrences of a variable: multiple values
- $x \ \& \ t_1$ adds type constraint t_1 to capture variable x.
- $p_1 \mid p_2$ matches p_1 or p_2.
- $x \ := \ c$ sets a default value for a capure variable.
- $x \ :: \ R$ sequence capture variable for regular expression R.
- recursive patterns
  - $P \ where \ P = (\_, P) \mid (x \ \& \ Int, \_)$
  - $P \ where \ P = (x \ \& \ Int, \_) \mid (\_, P)$
  - $P \ where \ P = (x \ \& \ Int, P) \mid (\_, P) \mid (x := \text{`}nil)$

cduce: exceptions

- raise an exception:
  $raise\ e$
- catch an exception:

$$
\begin{array}{l}
try\ e\ with \\
\quad \mid p_1 \rightarrow e_1 \\
\quad \mid \ldots \\
\quad \mid p_n \rightarrow e_n
\end{array}
$$

application: loading an xml file

```
let e : Exp =
  match load_xml "program.xml" with
       x & Exp -> x
    |  _ -> raise "program.xml is not of type Exp"
```

cduce: map and (x)transform

currently cduce does not support parametric polymorphism

or in other words: you cannot define a foldr, map, etc.

(that preserves the type of the expression)

- $map\ e\ with$
  $p_1 \rightarrow e_1 \mid \ldots \mid p_n \rightarrow e_n$
- $transform\ e\ with$
  $p_1 \rightarrow e_1 \mid \ldots \mid p_n \rightarrow e_n$
  $\sim filter(\ldots); concat$
- $xtransform\ e\ with$
  $p_1 \rightarrow e_1 \mid \ldots \mid p_n \rightarrow e_n$
  $\sim alltd(\ldots)$

cduce: generic programming

- cduce provides access to the structure of an xml element
- function can accept Any type and constructed types containing Any
- implement the operation for the possible constructed and scalar types.

more info: *http://www.cduce.org*

xml processing in stratego

xml, terms and stratego: why?

exchange

- → from *xml* systems invoke *term* tools
- ← invoke *xml* tools from *term* systems

implement

more complex xml transformations using

- strategic rewriting
- dynamic rules
- general traversals
- concrete object syntax

what representation to transform?

- every application has its own essence of xml
- different needs, different representations
  - *xml-doc*
  - *xml-info*
  - *implictly structured aterm*
  - *explicitly structured aterm*
- issues
  - namespace notation
  - character data constructs
  - empty elements
  - comments, processing instructions
  - ‘meta’ and default attributes

levels of representation

- *xml-doc*

  actual syntax of an xml document

- *xml-info*

  relevant informatie of an xml document

- *implictly structured aterm*

  drop xml, no explicit structure

- *explictly structured aterm*

  natural data of an xml document

  $\Rightarrow$ what is natural?

xml-doc in Stratego

- xml is a concrete syntax for xml-doc
- embed the xml syntax in stratego

meta programming with concrete object syntax

```
module tom
imports xml-doc options
strategies

  main =
    output-wrap(title)

  title =
    !%><title>Tom Bombadil</title><%
```

```
Meta([Syntax("Stratego-xml")])
```

xml-info in Stratego

- information oriented transformations
- same syntax of xmlin stratego
- process xml-doc fragments to xml-info
- allows declaration of module namespaces

```
parse-stratego-xml-info -i select-bars.str
  | process-stratego-xml-doc
  | process-stratego-xml-info
  | meta-explode
  | stratego-desugar -o select-bars.rtree
```

does this scale to real programs?

- *XDoc* – Rob Vermaas
  - exendible documentation generator
  - instantions for stratego, java, sdf
- *XWeb* – Niels Janssen
  - transformation tool demo
  - uses xml-info in Stratego
- Relation algebra to *MathML* – Martin Bravenboer
- Misc. *small tools* – Martin Bravenboer
  - samples package
  - daily build system overview
  - xml-tools themselves!

structured aterm in Stratego

- make structure explicit
- should be nothing special to tell about
- little experience; applied to
  - java
  - lecture results
  - xml-rpc
  - svn log