An XML-Based Standard for Representing Linear Programming Problem Instances

Robert Fourer

Industrial Engineering & Management Sciences
Northwestern University, Evanston, IL, USA

4er@iems.northwestern.edu

Leo Lopes

Systems & Industrial Engineering Department
University of Arizona, Tucson, AZ, USA

leo@sie.arizona.edu

Kipp Martin

Graduate School of Business
University of Chicago, Chicago, IL, USA

kipp.martin@gsb.uchicago.edu

APMOD 2004

Brunel University, London — Tuesday, June 22, 2004 — TB32

XML-Based Standard Formats

Motivation

- for any standard format
- for an XML-based format

Proposals (*see* `http://senna.iems.nwu.edu/xml/`)

- OptML
- SNOML
- LPFML . . .

Aspects of LPFML

- Examples
- Schemas
- Libraries
- Compression

XML Means "Tags" . . .

Example: html for a popular home page

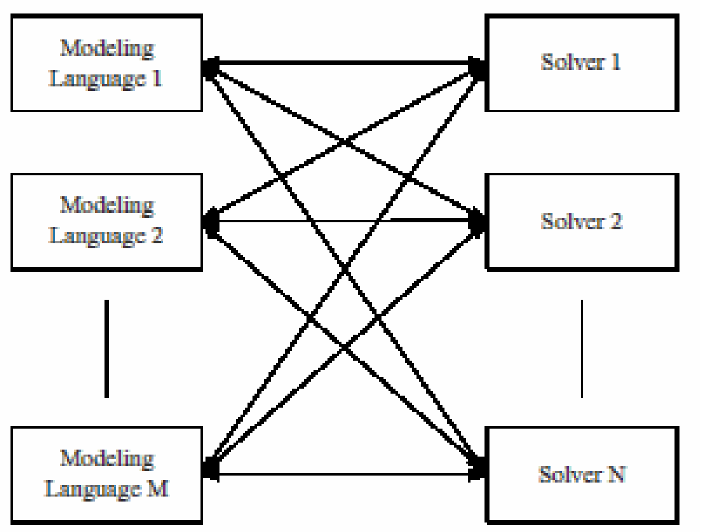
```
<html><head><meta http-equiv="content-type" content="text/html;
charset=UTF-8"><title>Google</title><style><!--
body,td,a,p,.h{font-family:arial,sans-serif;}
.h{font-size: 20px;}
.q{text-decoration:none; color:#0000cc;}
//-->
</style>
</head><body bgcolor=#ffffff text=#000000 link=#0000cc
vlink=#551a8b alink=#ff0000 onLoad=sf()><center><table border=0
cellspacing=0 cellpadding=0><tr><td><img src="/images/logo.gif"
width=276 height=110 alt="Google"></td></tr></table><br>
.......
<font size=-2>&copy;2003 Google - Searching 3,307,998,701 web
pages</font></p></center></body></html>
```

. . . a collection of XML tags is designed for a special purpose

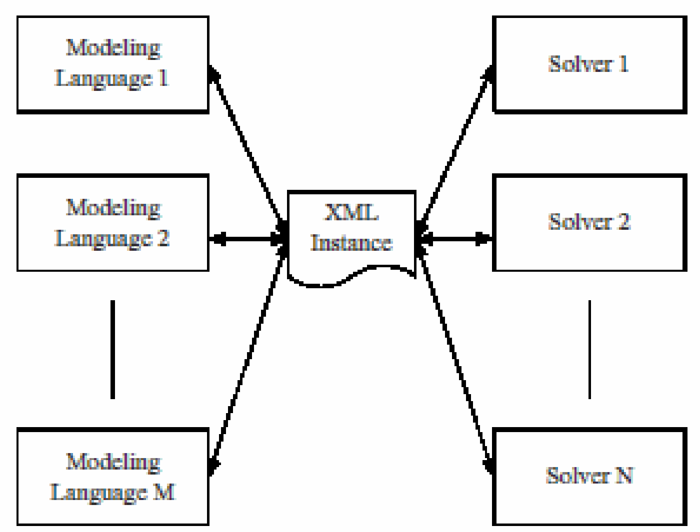
*. . . by use of a **schema** written itself in XML*

Advantage of any standard

MN drivers without a standard



M + N drivers with a standard



Advantages of an XML Standard

Specifying it

- Unambiguous definition via a *schema*
- Provision for *keys* and *data typing*
- Well-defined expansion to new *name spaces*

Working with it

- Parsing and validation via standard *utilities*
- Amenability to *compression* and *encryption*
- Transformation and display via XSLT *style sheets*
- Compatibility with *web services*

What about "MPS Format"?

Weaknesses

- Standard only for LP and MIP, not for
  nonlinear, network, complementarity, logical, . . .
- Standard not uniform (especially for extensions)
- Verbose ASCII form, with much repetition of names
- Limited precision for some numerical values

Used for

- Collections of (mostly anonymous) test problems
- Bug reports to solver vendors

Not used for

- **Communication between modeling languages & solvers**

Example: AMPL Model and Data

```
set RES;  # resources
set PRD;  # products

param hrs {RES};      # hrs of resource i available
param prf {PRD};      # profit per unit of product j
param act {RES,PRD};  # res i consumed by 1 unit if product j

var Make {PRD} >= 0;  # units of product j to be made

maximize TotPrf:
   sum {j in PRD} prf[j] * Make[j];

subject to HrsAvl {i in RES}:
   sum {j in PRD} act[i,j] * Make[j] <= hrs[i];
```

```
param: RES: hrs := cutdye 630 sew 600 finish 708 pack 135 ;

param: PRD: prf := RC 10 LFA 9 ;

param act (tr): cutdye  sew  finish  pack :=
            RC    0.7   0.5  1.0     0.1
            LFA   1.0   0.0  0.6667  0.25 ;
```

Example: MPS Format

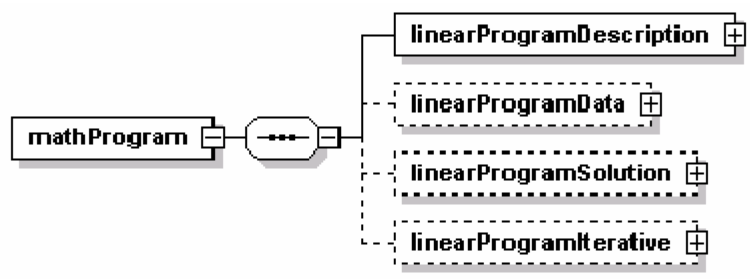
```
NAME          PRODMIX
ROWS
 N  TOTPROF
 L  HRAV1
 L  HRAV2
 L  HRAV3
 L  HRAV4
COLUMNS
    MAKE1     TOTPROF   10
    MAKE1     HRAV1     0.7            HRAV2     0.5
    MAKE1     HRAV3     1              HRAV4     0.1
    MAKE2     TOTPROF   9
    MAKE2     HRAV1     1              HRAV2     0.8333
    MAKE2     HRAV3     0.6667         HRAV4     0.25
RHS
    RHS1      HRAV1     630
    RHS1      HRAV2     600
    RHS1      HRAV3     708
    RHS1      HRAV4     135
ENDATA
```

Example: AMPL's "nl" Format

```
g3 2 1 0
 2 3 1 0 0
 0 0
 0 0
 0 0 0
 0 0 0 1
 0 0 0 0 0
 6 2
 0 0
 0 0 0 0 0
C0
n0
C1
n0
C2
n0
O0 1
n0
                    ----->
```

```
r
1 630
1 708
1 135
b
0 0 1200
2 0
k1
3
J0 2
0 0.7
1 1
J1 2
0 1
1 0.6667
J2 2
0 0.1
1 0.25
G0 2
0 10
1 9
```

Example: LPFML



First we'll show . . .

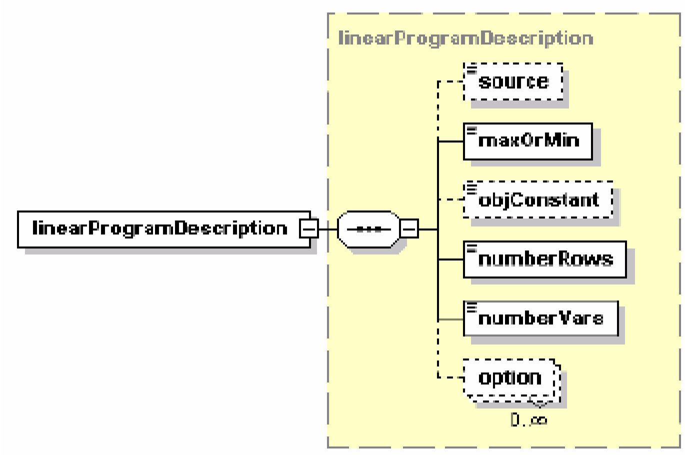
- Diagrams of parts of the LPFML schema
- Corresponding XML for the example

Then we'll see . . .

- Actual schema files

Standard formats

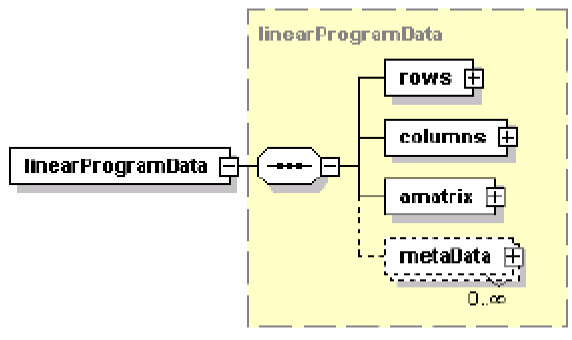
linearProgramDescription




```
<linearProgramDescription>
   <source>Par Inc. Problem from Anderson, Sweeny,
      and Williams </source>
   <maxOrMin>max</maxOrMin>
   <numberRows>4</numberRows>
   <numberVars>2</numberVars>
</linearProgramDescription>
```

Standard formats

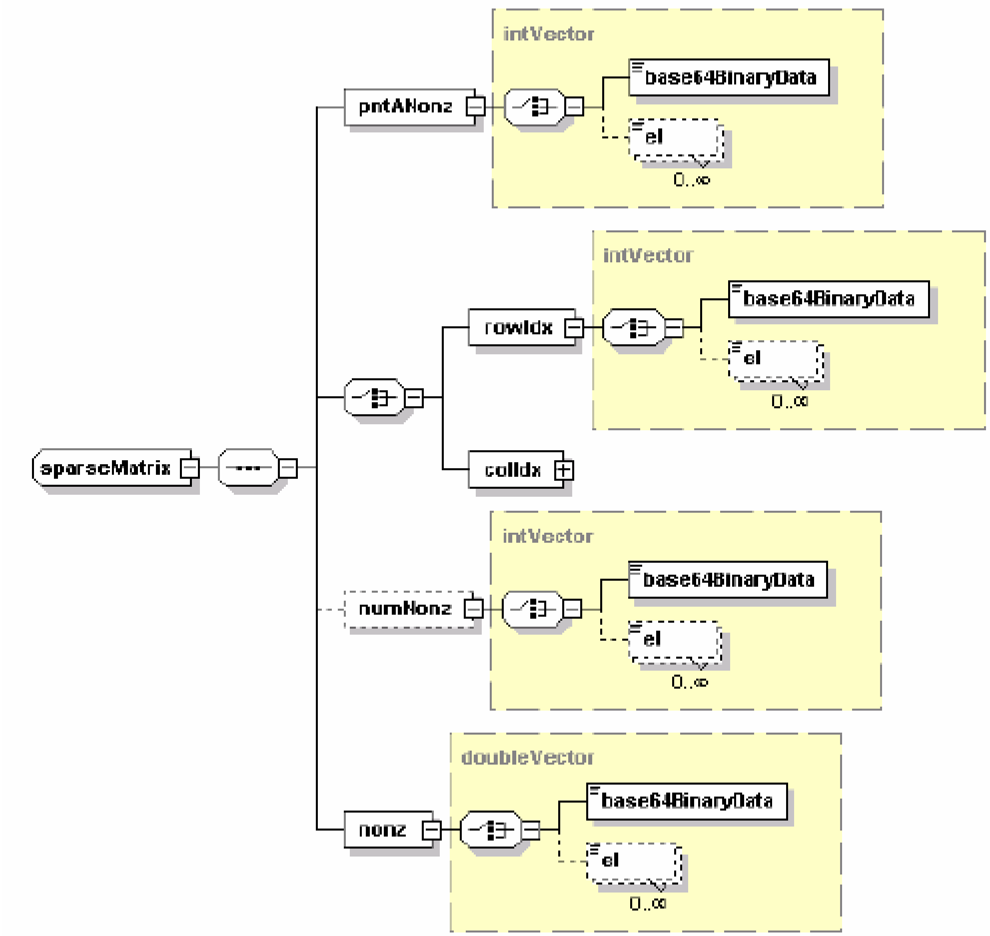
linearProgramData




```
<rows>
   <row rowName="HrsAvl[cutdye]" rowUB="630"/>
   <row rowName="HrsAvl[sew]" rowUB="600"/>
   <row rowName="HrsAvl[finish]" rowUB="708"/>
   <row rowName="HrsAvl[pack]" rowUB="135"/>
</rows>

<columns>
   <col objVal="10" colName="Make[RC]"  colType="C" colLB="0.0"/>
   <col objVal="9"  colName="Make[LFA]" colType="C" colLB="0.0"/>
</columns>
```

amatrix

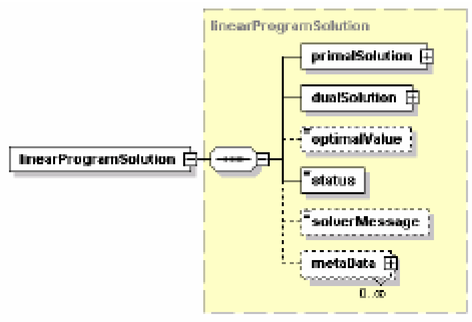



```xml
<sparseMatrix>
  <pntANonz>
    <el>4</el><el>7</el>
  </pntANonz>
  <rowIdx>
    <el>0</el><el>1</el>
    <el>2</el><el>3</el>
    <el>0</el><el>2</el>
    <el>3</el>
  </rowIdx>
  <nonz>
    <el>.7</el><el>.5</el>
    <el>1.0</el><el>0.1</el>
    <el>1.0</el>
    <el>0.66666667</el>
    <el>0.25</el>
  </nonz>
</sparseMatrix>
```

. . . optional base-64 encoding of vectors

Standard formats

linearProgramSolution




```
<linearProgramSolution>
   <primalSolution>
      <sol idx="1" name="Make1" val="540"/>
      <sol idx="2" name="Make2" val="252"/>
   </primalSolution>
   <dualSolution>
      <sol idx="1" name="cutdye" val="4.37457"/>
      <sol idx="3" name="finish" val="6.9378"/>
   </dualSolution>
   <optimalValue>7667.94</optimalValue>
   <status statusId="optimalSolutionFound">maximum
      primal infeas 1.3e-7 dual infeas 2.7e-6</status>
   <solverMessage>XPLEX 14.7
      dual simplex optimizer with superpivot</solverMessage>
</linearProgramSolution>
```

Schema for <rows> Element

```
<xs:element name="rows">
  <xs:complexType>
    <xs:sequence>
    <xs:element name="row" minOccurs="0" maxOccurs="unbounded">
      <xs:complexType>
        <xs:attribute name="rowName" type="xs:string“ use="optional"/>
        <xs:attribute name="rowUB" type="xs:double“ use="optional"/>
        <xs:attribute name="rowLB" type="xs:double“ use="optional"/>
        <xs:attribute name="mult" type="xs:int“ use="optional"/>
      </xs:complexType>
    </xs:element>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

Schema for <intVector> Type

```
<xs:complexType name="intVector">
  <xs:choice>
    <xs:element name="base64BinaryData“ type="base64BinaryData"/>
    <xs:element name="el" minOccurs="0“ maxOccurs="unbounded">
      <xs:complexType>
        <xs:simpleContent>
          <xs:extension base="xs:int">
            <xs:attribute name="mult" type="xs:int“ use="optional"/>
            <xs:attribute name="incr" type="xs:int“ use="optional"/>
          </xs:extension>
        </xs:simpleContent>
      </xs:complexType>
    </xs:element>
  </xs:choice>
</xs:complexType>
```

Schema for <colType> Simple Type

```
<xs:simpleType name="colType">
   <xs:restriction base="xs:string">
      <xs:enumeration value="C"/>
      <xs:enumeration value="B"/>
      <xs:enumeration value="I"/>
   </xs:restriction>
</xs:simpleType>
```

Libraries

Read and write LP instances in LPFML format

- Allow format to be used immediately
- Hide all parsing code
- Allow for future changes and extensions without rewriting code

. . . ***major contribution of this work***

Parsing Library

FMLHandler class

- Aggregate data from LPFML
  into rows, columns, and other LP components
- Methods startElement, endElement, etc.

FMLParser class

- Virtual methods for setting up LP components
- Derived class for each solver
- For each LP component, derived methods
  implement LPFML input to individual solvers
- *Event driven:* Derived method only called
  after component has been parsed

. . . also derived methods for starting solver & writing solution

Parsing Library *(cont'd)*

Example

- Class FMLLINDOParser derived from FMLParser
- Virtual methods such as **`onObjectiveSense`**, **`onConstraints`**, etc. replaced by LINDO-specific routines

Advantages of event-driven approach

- Avoid searching the LPFML file
- Reduce number of copies of data that must exist at one time

Current Parsing Library

Classes inheriting from FMLParser

- FMLCOINParser
  - Creates CoinPackedMatrix data structure
- FMLOSIParser
  - Connects to any solver that has an Open Solver Interface implementation
- FMLLINDOParser
  - Supports data structures of the LINDO API

Utilities

- nl2fml
- FMLCOINMPSToXML
- FMLLINDOToXML

. . . implement interface between AMPL and any solver that supports the Open Solver Interface

Communicating Instances

Tightly coupled environments

- Modeling system & solver
  communicating directly on the same machine
- *Parsing time* is the primary concern

Loosely coupled environments

- Modeling system & solver
  reside on different machines and networks
- *File size* is the primary concern

. . . tests on 15 largest netlib problems

Compression

LPFML-specific space-saving features

- Collapse sequences of row/column numbers
- Collapse repeated element values
- Base-64 representation of arrays

Comparisons without compression

- MPS > LPFML > base-64 LPFML >> AMPL nl

Comparisons with compression

- gzipped MPS $\approx 2 \times$ gzipped LPFML
- gzipped LPFML $\approx 1.5 \times$ bzipped LPFML
  - bzip2 reorders file before searching for patterns
- gzipped LPFML $\approx 1.65 \times$ xmilled LPFML
  - xmill uses XML-specific compression techniques

Parsing Time

File-based using base-64 encoding

- Specialized LPFML ≈ COIN MPS
- Generic Xerces LPFML ≈ 3-4 × COIN MPS

In-memory using base-64 encoding

- Generic Xerces LPFML ≈ COIN MPS

Extensions to Come

Quadratic

- Matrix of coefficients for each quadratic objective or constraint

Stochastic

Nonlinear

- Algebraic expressions
- Logical expressions

Distribution

Open source

- Source code available without additional charge
- License does not require that modifications or redistributions be open source

Availability

- Download from **`gsbkip.uchicago.edu/fml/fml.html`**
- Available for Windows and Linux