# Optimization Services Modeling Language (OSmL)

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# Introduction and Motivation

**The Objective: A native XML modeling language**

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  1. take a general infix notation
  2. support sets and subscripts
  3. have looping capability
  4. support logical conditions
  5. allow for user-defined functions
  6. allow for sparse sets, union, intersection, etc.

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- Store model instances internally as an OSInstance object
- Also function as a matrix generator

# Introduction and Motivation

XML is a key technology in industry

- XML is rapidly becoming an accepted format for transferring/storing data. This is where the data is! Think Willie Sutton and Sam Savage.
- People in IT use XML. Perhaps OR people should use IT tools, rather than having IT people use OR tools.
- Numerous open-source. tools exist for manipulating XML files

# Introduction and Motivation

There are four ways to incorporate XML in the mathematical modeling process:

- Use XML to represent the instance of a mathematical program
- Develop an XML modeling language dialect
- Enhance modeling languages with XML features such as XPath
- Use XML technologies to transform XML data into a problem instance

# Introduction and Motivation

**Strategy 1:** Use XML to represent the instance of a mathematical model: e.g. LPFML and OSiL (Fourer, Kristjansson, Lopes, Ma, Martin, etc.).

If there are N modeling languages and M drivers you can go from $M \times N$ drivers to $M + N$ drivers.

**Strategy 2:** Use XML to represent the mathematical model, e.g. Ezechukwu and Maros (AML  Algebraic Markup Language)

- With this approach we use XML tags to represent the algebraic model NOT the instance.
- This is a high level approach.
- Have tags for model constructs such as sets, variables, parameters, etc.

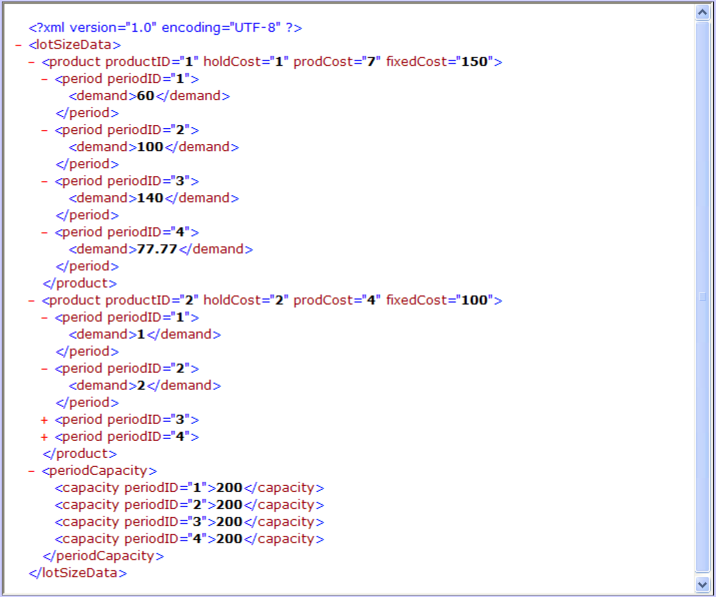
# Introduction and Motivation

**Strategy 2 (Continued):** Use XML to represent the mathematical model, e.g. Ezechukwu and Maros (AML  Algebraic Markup Language)

**Potential Problems:**

- How do we get everyone to agree? Witness the proliferation of modeling languages.
- XML is wordy and would lead to a very verbose language.

# Introduction and Motivation



```
  <?xml version="1.0" encoding="UTF-8" ?>
– <lotSizeData>
  – <product productID="1" holdCost="1" prodCost="7" fixedCost="150">
    – <period periodID="1">
        <demand>60</demand>
      </period>
    – <period periodID="2">
        <demand>100</demand>
      </period>
    – <period periodID="3">
        <demand>140</demand>
      </period>
    – <period periodID="4">
        <demand>77.77</demand>
      </period>
    </product>
  – <product productID="2" holdCost="2" prodCost="4" fixedCost="100">
    – <period periodID="1">
        <demand>1</demand>
      </period>
    – <period periodID="2">
        <demand>2</demand>
      </period>
    + <period periodID="3">
    + <period periodID="4">
    </product>
  – <periodCapacity>
      <capacity periodID="1">200</capacity>
      <capacity periodID="2">200</capacity>
      <capacity periodID="3">200</capacity>
      <capacity periodID="4">200</capacity>
    </periodCapacity>
  </lotSizeData>
```

# Introduction and Motivation

**Dynamic Lot Size Model:**

$$\min = \sum_{i=1}^{N} \sum_{t=1}^{T} (h_{it} I_{it} + f_{it} y_{it})$$

$$\begin{aligned} I_{i,t-1} + x_{it} - I_{it} &= d_{it}, \quad i = 1, \ldots, N, \quad t = 1, \ldots, T \\ \sum_{i=1}^{N} x_{it} &\leq c_t, \quad t = 1, \ldots, T \\ x_{it} &\leq c_t y_{it}, \quad i = 1, \ldots, N, \quad t = 1, \ldots, T \end{aligned}$$

# Introduction and Motivation

**Strategy 3:** Enhance current modeling languages with XML features such as XPath.

With **XPath** we can query an XML file and return a node set as an ordered sequence.

In AMPL we declare sets such as:

```
set PROD;
set LINKS = {PROD, 1..numPeriods};
param HC {PROD} ;
param FXC {PROD} ;
param CAP {1..numPeriods} ;
param DEM {LINKS};
```

Lets look at equivalent in XPath.

# Introduction and Motivation

**Strategy 3:** Enhance current modeling languages with XML features such as XPath.

```
set PROD;
set LINKS = {PROD, 1..numPeriods};
param HC {PROD} ;
param FXC {PROD} ;
param CAP {1..numPeriods} ;
param DEM {LINKS};
```

Key Analogy: Create a built-in XPath Handler much like ODBC

table FXC IN `XPath lotsizedata.xml`
`/lotSizeData/product/@fixedCost`

# The OSmL Philosophy: All X all the time!

**Key Premise**: OSmL is based on **XQuery**. Think of XQuery as a much more powerful SQL applied to XML data rather than relational data.

SQL:

- SELECT
- FROM
- WHERE

XQuery (FLWOR  flower):

- For
- Where
- Let
- Order by
- Return

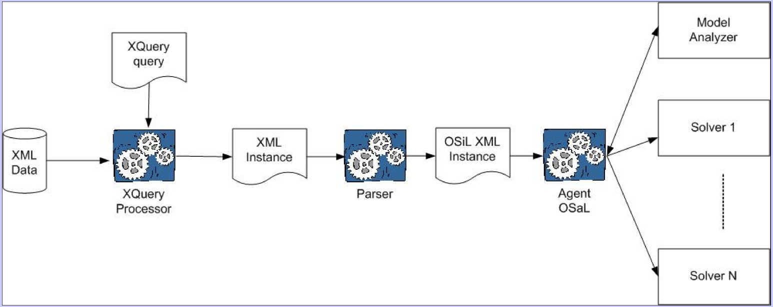
# The OSmL Philosophy: All X all the time!

**Key Premise**: XQuery (an extension of XPath) is a very powerful modeling language for mathematical optimization. It is (See Fourer 1983):

- symbolic
- general
- concise
- understandable

We can build a modeling language using existing W3C standards!

# The OSmL Philosophy



# The OSmL Philosophy

Advantages of using XQuery:

- XQuery and XPath have very powerful algebraic modeling features, e.g. sets, for loops, if-then, union, intersection, library modules
- These are already accepted W3C standards
- Allow for concise model representation
- Lots of open source software tools are being written
- XQuery and XPath very amenable to distributed computing
- Easy problem analysis on OSrL

# OSmL Syntax

**First Requirement:** Take a model in infix format without any set notation.

```
return
<mathProgram>
<obj maxOrMin="min" name="Rosenbrock">
100*(x2 - x1^2)^2 + (1 - x1)^2
</obj>
<constraints>
<con>
x1 + x2 <= 100
</con>
</constraints>
</mathProgram>
```

# OSmL Syntax

Of course work with sets:

Here is some AMPL

```
param HC {PROD} ;
param FXC {PROD} ;
param CAP {1..numPeriods} ;
```

Here is some XQuery

```
let $HC := $products/@holdCost
let $FXC := $products/@fixedCost
let $CAP := $time/text()
```

# OSmL Syntax

We can point to any number of data sets:

```
let $products :=
doc("/Users/kmartin/temp/osml/lotsizedata.xml")
/lotSizeData/product[ (1, 2, 5, 11, 17)]
```

```
let $products :=
doc("http://128.135.124.10/Users/kmartin/  ...")
```

We can also define variables:

```
let $N := count($products)
let $T := count($time)
```

# OSmL Syntax

We can do looping:

Here is AMPL

```
subject to demand {i in PROD, t in 1..numPeriods}:
    X[i, t] + I[i, t - 1] - I[i, t] = DEM[i, t];
```

Here is XQuery

```
for $i in PROD, $t in (1 to $T)
let $demand :=
$products[$i]/period[@periodID=$t]/demand/text()
   return
<con name="demand[{$i},{$t}]>
X({$i},{$t }) + I({$i},{$t - 1}) - I({$i},{$t}) =
{$demand}
</con>
```

# OSmL Syntax

An AMPL and XQuery analogy:

```
AMPL:   subject to
XQuery:   <con>

AMPL:   demand
XQuery:   name="demand[{$i},{$t }]"
AMPL: {i in PROD, t in 1..numPeriods}
XQuery:   for $i in (1 to $N),  $t in (1 to $T)
let $demand :=
data($products[$i]/period[@periodID=$t]/demand)

AMPL: X[i, t] + I[i, t - 1] - I[i, t] = DEM[i, t]

XQuery:   X({$i},{$t }) + I({$i},{$t - 1}) - I({$i},{$t}) =
{$demand}
```

# OSmL Syntax

XQuery evaluates what is in {. . .} and the $ tells XQuery you have a variable.

```
{
for $i in $PROD,  $t in (1 to $T)
let $demand :=
($products[$i]/period[@periodID=$t]/demand/text())
   return
<con name="demand[{$i},{$t}]">
X[{$i},{$t}] + I[{$i},{$t - 1}] - I[{$i},{$t}] =
{$demand}
</con>  }
```

# OSmL Syntax

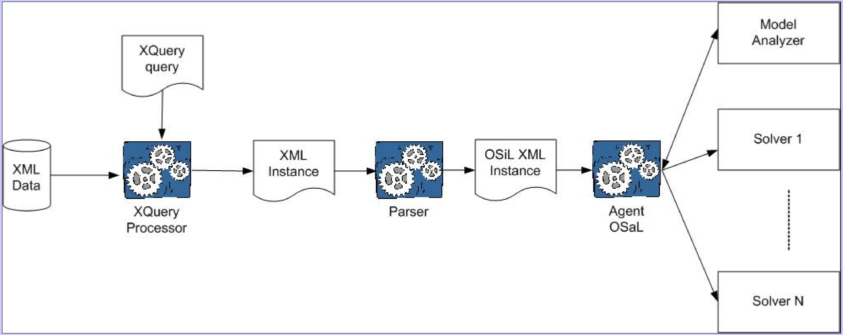
The XQuery results is:

```
<!-- DEMAND CONSTRAINTS -->
<con name=demand[1,1]>
   X(1,1) + I(1,0) - I(1,1) = 60
</con>
<con name=demand[2,1]>
   X(2,1) + I(2,0) - I(2,1) = 1
</con>

Etc
```

We then parse this and transform into OSiL.

# OSmL Syntax


XQuery query
XML Data
XQuery Processor
XML Instance
Parser
OSiL XML Instance
Agent OSaL
Model Analyzer
Solver 1
Solver N

# OSmL Syntax

Other features:

- Use `if-then` logic
- We can use built-in Java functions. For example:

  ```
  declare namespace math="java:java.lang.Math";
  ```
- We can define our own functions
- Use XQuery and XPath to display results
- Define sparse sets, intersection, union

```
let $products := /lotSizeData/product[ (1, 2, 11, 19)]
```

```
for (1 to 100)[mod 2  eq 0]
```

# Data and XML

**Point 1:** It is getting easy to get data in XML format from traditional sources

- Can export to XML from desktop software (Microsoft Office)
- Can query an enterprise database in SQL and get result as XML

**Point 2:** There is even a trend toward native XML databases

- Total XML  Cincom
- Tamino  Software AG
- Apache  Xindice
- Cognetic Systems' solutions
- Ipedo

# Hybrid Approaches

**Possibilities:**

- Make XQuery/XPath equivalent to ODBC/SQL
- Introduce the concept of a node set (as an alternative) to a table in algebraic modeling languages
- What about adding XQuery syntax to the an algebraic modeling language?

**Perhaps all algebraic modeling languages could have a common underlying syntax based upon XQuery/XPath?**

# OSmL GUI

The current implementation of OSmL is in OSmL GUI. It can be used in three ways:

- A simple agent to send OSiL to a Web server.
- Use XQuery and our parser to turn OSmL into OSiL
- With the OSInstance class as a matrix generator

# OSmL GUI

The OSInstance class is used to access the problem data or create/modify the problem. For example, accessing a problem for the solver

```
m_mdVarLB = osinstance->getVariableLowerBounds();
m_mdVarUB  = osinstance->getVariableUpperBounds();
solver->assignProblem(m_,  m_mdVarLB,  m_mdVarUB,
m_mmdObjDenseCoefValue,  m_mdConLB,  m_mdConUB);
```

or creating a problem

```
instanceData.linearConstraintCoefficients.start.el
= A_colstarts;
instanceData.linearConstraintCoefficients.value.el
= A_vals;
instanceData.linearConstraintCoefficients.rowIdx.el
= A_rownos;
```

*Key Idea:* It maps to the OSiL Schema.