Towards Declarative Scripting Combining CP and Analytics

CP 2015 Panel on CP and Analytics

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And so. . .

Purpose of this (short) presentation

Disclaimer: What this talk is not about...

It is:

- not a complete survey (of Analytics nor CP!)
- not a report of research/experimental results

This presentation's (hopeful) **objective**:

- high-level **glance at current trends** in the Analytics and CP landscape (the forest rather than the trees)
- speculate and **extrapolate some perspectives** therefrom (*i.e.*, what seems to be needed)

So what is this presentation about?

rapid overview of current trends in:

- the state of the art in **Statistical and Predictive Analytics**
- how it can leverage **CP technology**
- and ***vice versa!***

- **Analytics**—quick look at popular tools and trends in Statistics and OR
- **Synthesis**—CP meets Analytics
- **Prognosis**—declarative scripting?
- **Discussion**—recapitulation and requirements

And so. . .

Analytics

with

Statistical Analysis

Statistical Analytics

Used in **Decision Science** for:

computing/plotting probabilistic measures of data (moments—mean, variance, *etc.*), scatter-diagrams, trends, rates-of-change

drawing inference by correlation, regression, Bayes Law, *etc.*, in (discrete or continuous) autoregressive stochastic processes

- **not new**—has been around in varied forms since antiquity
  modern mathematical formulation due to Galton and Pearson (late 1800s–early 1900s)
- practical **computational tools for systematic data analysis**
  e.g., developed by the RAND Corporation since its inception
- **invaluable for data-driven decision-making**
  e.g., trend analysis forecasting (business and social sciences)

And so. . .

Analytics

Some popular statistical analytics tools

Some tools used for statistical analytics

- **some have been around for a while**; *e.g.*:
  - SPSS (at least since I was a grad student!)
  - SAS
  - Stata
  - S
- **new systems surf the Big Data wave**; *e.g.*:
  - R
  - Apache Spark (Hadoop)
  - RapidMiner (Radoop)
  - KMINE
  - Datameer's JSON Array Analytics

Most started as academic systems then went private (bought off or going corporate); most remain open-source

Current usage trends of statistical analytics tool

Top 10 tools by share of users: (KDNuggets, May 2015)

System	2015 % share	2014 % share	up down	2014–2015 % change
R	46.9	38.5	↗	+8.4
RapidMiner	31.5	44.2	↘	−12.7
SQL	30.9	25.3	↗	+5.6
Python	30.3	19.5	↗	+10.8
Excel	22.9	25.8	↘	−2.9
KNIME	20.0	15.0	↗	+5.0
Hadoop	18.4	12.7	↗	+5.7
Tableau	12.4	9.1	↗	+3.3
SAS	11.3	10.9	↗	+0.4
Spark	11.3	2.6	↗	+8.7

And so. . .

Analytics

with

CP/OR

Constraint Programming and Operations Research

Constrained Optimization and Operations Research

Formal models expressing (linear or quadratic) objective functions to min/max/imize subject to (linear) constraints over reals (LP/QP) or integers (IP) or both (MIP)

- **not new**—has been around for a while, but took off since Dantzig's Simplex algorithm (1940's)
- **practical**—*e.g.*, as used by the RAND Corporation, esp. since Dantzig created its OR Dept (1952)
- invaluable **for strategic decision-making** (esp. military and business)
- **new (non-classical OR) CP techniques have emerged** (*e.g.*, arc consistency, *all-different*, SAT, BDDs, symmetry, *etc.*)

And so. . .

What is “scripting?”

Isn’t it programming?

What is *scripting*?...

Isn't writing a JavaScript or Python script the same as writing a C, C++, C#, or Java program?

Or is it?

Yes and **no**:

- **Yes**: **scripting** is indeed a form of software programming in the sense that it is writing an executable coded specification of instructions; it **is the *glue* connecting application modules and actual data**.
- **No**: **scripting is not for high-performance static software development** producing well-honed blackboxes implementing the best-known *algorithms*.

What is *scripting*?...

- scripting programs are not statically compiled then executed: they are dynamically interpreted text-based source code (in particular, they can be put together as strings of text and executed on the fly)
- scripting specifies how to orchestrate several interacting static program apps into a coherent whole
- scripting may be seen as "light-weight" programming where the focus is not on the use of complex algorithms, with the use of a very large pool of tool libraries: both public, *etc.* and private.

Hence, **scripting is** more useful for application deployment as dynamic jigsaw puzzle construction **using pre-built construction blocks and building new ones to be (re-)used as libraries**.

And so. . .

Some popular scripting tools

why they are more or less popular

(pros and cons)

Scripting tools

- Programming languages can be used for scripting; *e.g.*:
  - Java
  - Scala
  - Rust

But scripting is a specific kind of programming:

- Popular scripting tools; *e.g.*:
  - JavaScript
  - Python
  - IPython Notebook

Can be used in such systems as Apache Spark and Apache Flink

And so. . .

New Trends

Functional Scripting

(pros and cons)

Apache Spark:

Declarative notation for multithreaded MapReduce?

Quoting from their site, Spark. . . "***is a fast and general engine for large-scale data processing***." It offers:

- **Speed**: run programs up to 100x faster than Hadoop MapReduce in memory, or 10x faster on disk
- **Ease of use**: applications in Java, Scala, Python, R

  Word count using Spark's Python API:

```
text_file = spark.textFile("hdfs://...")
text_file.flatMap(lambda line:  line.split())
         .map(lambda word:  (word, 1))
         .reduceByKey(lambda a, b:  a+b)
```

- **Generality**: complex analytics on data accessed with SQL, streaming, *etc.*

Apache Spark

Pros:

- ↗ **light-weight and fast**
- ↗ **industrial strength**
- ↗ **declarative functional style** for massive Hadoop/MapReduce computation
- ↗ **syntax-interfaced** with most popular scripting and analytics systems (Python, Java, Scala, R)
- ↗ is **gaining rapid popularity** in the Analytics tools landscape

Cons:

- ↘ still **relatively young**
- ↘ **no CP integration** (yet?)

And so...

Synthesis

Constraints meet Analytics:

GREAT IDEA!

What's the best way?

And so. . .

CP meets Analytics—Use Cases

IBM ILOG Solver + IPython Notebook Mixing CP/OR tools

(pros and cons)

Google OR Tools

(pros and cons)

Scripting CP and Analytics

- **Use case 1**

  IBM ILOG Optimization Decision Manager Enterprise

  Using IPython Notebook for analytics script with distributed multithreaded CP with IBM Solver

  (JF Puget, IBM)

  - *"IT Best Kept Secret Is Optimization"*
  - Solving Optimization Problems on the Cloud with Python

    (Apr 13, 2015)
  - A Sudoku Web App Based On DOcloud and Python

    (Apr 27, 2015)

- **Use case 2**

  Google OR tools

  OR models scripted with Python/Java/C/C++/C#

  (Laurent Perron, Google) – CP 2013

IBM ILOG Optimization Decision Manager Enterprise

Pros:

- ↗ **fastest existing CP/OR solvers** (ILOG/CPLEX)
- ↗ **industrial strength**
- ↗ uses IPython Notebook to **leverage Python for scripting CP with Analytics**

Cons:

- ↘ uses relatively **low-level tooling** for distributed concurrency management (Boot2Docker) (would prefer generic reusable higher-level declarative utilities for multithreaded concurrency)

Google OR Tools

Pros:

- ↗ **industrial strength** (load and time)
- ↗ scripting (Python, Scala, C#) makes up **4/5 of the code** for orchestrating C++-compiled solving modules **at 1/20 of the cost** of dedicated CP systems such as OPL or AMPL
- ↗ **full interfaces** with Python, Java/Scala (JVM), and C#

Cons:

- ↘ **no high-level** OR **model management** (Minizinc/Flatzinc to parse models and display existing solutions)
- ↘ **limited dynamicity** (relies on static presolving)
- ↘ **limited search control** adaptability (esp. local search)

And so. . .

Prognosis

CLP Declarative Scripting

Does it makes sense?

Leverage C(L)P: declarative scripting for CP/OR Analytics?

Two-way street:

1. Analytics extended with CP
2. CP extended with Analytics

- CP libraries for procedural languages
  - **Exemplar**: Python-CP libraries
- CLP scripting languages
  - **Exemplar**: Picat scripting

And so. . .

Declarative scripting for analytics

Where are we today?

(pros and cons)

Python-CP libraries

Pros:

- ↗ **no need for new syntax**—Python
- ↗ **light-weight**, dynamically typed and interpreted
- ↗ **flexible style** complete Python's already varied styles (procedural, functional, object-oriented) with CP style
- ↗ **full access to** Python **libraries**

Cons:

- ↘ **scripting itself is not declarative** nor generic (need to program an explicit solver + search interpreter per app)

Picat

- **P**attern-matching

  Predicates and functions are defined with pattern-matching rules

- **I**mperative

  Assignments, loops, list comprehensions

- **C**onstraints

  CP, SAT and LP/MIP

- **A**ctors

  Action rules, event Action rules, event-driven programming, actor driven programming, actor-based concurrency

- **T**abling

  Memoization, dynamic programming, planning, model-checking

Picat scripting

Picat script for traversing a directory tree:

```
import os.

traverse(Dir), directory(Dir) =>
    List = listdir(Dir),
    printf("Inside %s%n",Dir),
    foreach(File in List)
        printf(" %s%n",File)
    end,
    foreach(File in List, File != ".", File != "..")
        FullName = Dir ++ [separator()] ++ File,
        traverse(FullName)
    end.

traverse(_) => true.
```

Picat

Picat Sudoku solver—courtesy of Hakan Kjellerstrand

```
sudoku(N, Board) =>
    N2 = N*N,
    Vars = Board.vars(),
    Vars ::  1..N2,
    foreach(Row in Board)
        all_different(Row)
    end,
    foreach(Column in transpose(Board))
        all_different(Column)
    end,
    foreach(I in 1..N..N2, J in 1..N..N2)
        all_different([Board[I+K,J+L] : K in 0..N-1, L in 0..N-1])
    end,
    solve([ffd,down], Vars).    % ffd+down fastest var ordering
```

Picat

Pros:

- ↗ **light-weight**, dynamically typed and interpreted
- ↗ **flexible style** as appropriate: procedural (*if-then-else, looping, destructive assignment*) ***as well as*** functional, and constraint logic programming
- ↗ **terse**, clear, and easily reusable CP
- ↗ **most script-like** among CLP languages (unique in enhancing CP with built-in procedural scripting)

Cons:

- ↘ still **young**
- ↘ **unfamiliar syntax** (to majority of users)
- ↘ **needs** more **tools** (libraries)
- ↘ **needs** more **interfaces** (IPicat Notebook?)

And so. . .

Discussion

Declarative Scripting, CP/OR, Analytics?

Discussion

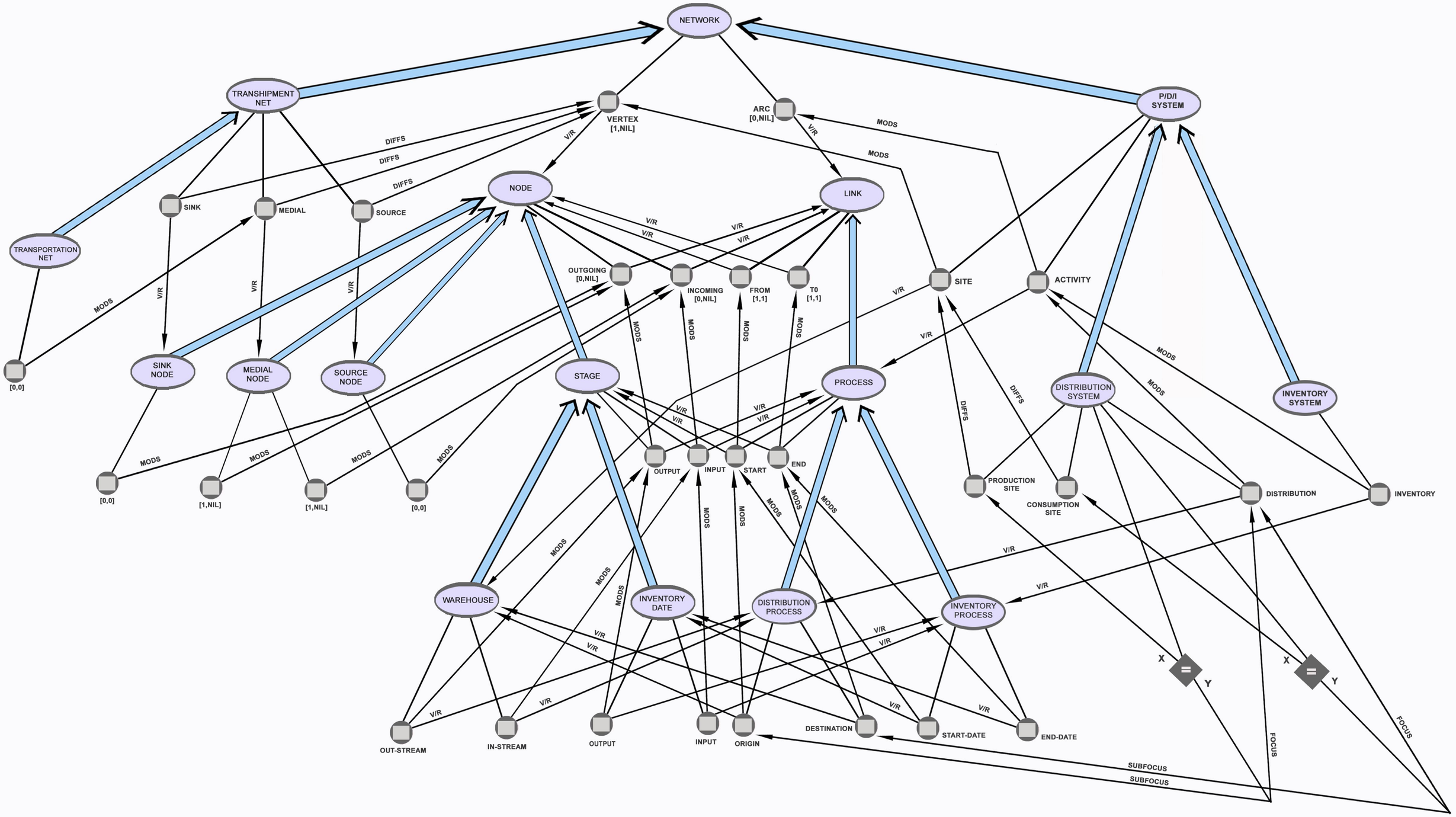
Mimimum Requirements

- **Industrial strength** (cloud-aware, large-scale concurrency)
- **Ease of use** (portability, graphing, reporting)
- **Immediate payoff** (notation, flat learning curve, instant compatibility with familiar tools)
- **Libraries** (provide a large varied pool of app-specific reusable tools)
- **Interfaces** (open up to the rest of the world)
- **Ontologies** (encode knowledge for models, solvers, search)

Discussion

Challenges for CP-based **declarative analytics**:

- **need standard interfaces** with easy-to-plug-in modules providing **syntax-independent constructs for solving & search heuristics** (libraries with standard interfaces in most popular languages)
- need **analytics scenario libraries** for reusable configurations (statistical *cum* CP/OR)
- need **ontologies for models, use scenarios, and search** to enable **knowledge-based model-building** (*e.g.*, PDI-net example)


NETWORK
TRANSHIPMENT NET
VERTEX [1,NIL]
ARC [0,NIL]
P/D/I SYSTEM
TRANSPORTATION NET
SINK
MEDIAL
SOURCE
NODE
LINK
OUTGOING [0,NIL]
INCOMING [0,NIL]
FROM [1,1]
TO [1,1]
SITE
ACTIVITY
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SINK NODE
MEDIAL NODE
SOURCE NODE
STAGE
PROCESS
DISTRIBUTION SYSTEM
INVENTORY SYSTEM
[0,0]
[1,NIL]
[1,NIL]
[0,0]
OUTPUT
INPUT
START
END
PRODUCTION SITE
CONSUMPTION SITE
DISTRIBUTION
INVENTORY
WAREHOUSE
INVENTORY DATE
DISTRIBUTION PROCESS
INVENTORY PROCESS
X
=
Y
X
=
Y
OUT-STREAM
IN-STREAM
OUTPUT
INPUT
ORIGIN
DESTINATION
START-DATE
END-DATE
DIFFS
MODS
V/R
FOCUS
SUBFOCUS

Discussion

So what about **"declarative scripting for CP/Analytics?"**

- **CP/OR constraint-based analytics scripting has become essential** in actual field deployment for decision-making (it connects models with actual data, carries out statistical, "what-if," and sensitivity analyses, produces reports, plots, justifications, *etc.* . . .)

- **C(L)P can simplify formal specification** as its style enhances expressive power (high-level, declarative); it also enables reasoned data-backed Decision Making to complement Data Processing with Analytics

  though still needs work to reach popularity

Discussion

But what about existing scripting languages?

Many, many, "scripting" languages are used in Analytics, but most essentially provide similar **homomorphic syntax** for:

- **data types**
  (monoid comprehensions, esp., collections, arrays, tables)
- **functional computation over collections**
  great for concurrency (MapReduce, multi-D array algebra)
- even **"procedural" iteration with assignment** can be cast as a monoid comprehension

Discussion

Rather than **many-to-many *ad hoc* interfaces**, it makes more sense to agree on **one** essential canonical (abstract) structure and operations (*e.g.*, comprehension syntax)

It is easier to have n (homomorphic) interfaces than n^2 *ad hoc* translators; and only one canonical representation to conform to than n *ad hoc* ones

Work such as Bistarelli/Rossi makes CP based on semi-rings (which BTW extend collection monoids) a "natural" canonical algebra for "soft" CP (including Fuzzy Sets, Bayesian, GDL, Rough Sets, etc., ...) So one could argue that **CP has the means to make such "non-crisp" analysis possible** by setting the CP solving in the appropriate algebra(s).

Discussion—Recapitulation

- **Where we are**:
  - silo-ed CP systems are dead: too hard to interface with GP middleware, analytics, graphing, and reporting (*e.g.*, OPL, AMPL)
  - flexible Analytics combines CP/OR and Statistical Analysis via light-weight orchestrating scripts
  - *Ergo*: scripting is *the* key for orchestrating CP apps
- **What we need**:
  - **disciplined scripting** (not for just CP): simple, terse, and easy to (re)use
  - **knowledge-based scripting** for Analytics: ontologize collection algebras and statistics
  - **declarative scripting** for CP/Analytics: ontologize models, solving, and search

Discussion—Conclusion

This last item—**ontologizing CP/OR—is the most sensible way** IMHO; *i.e.*,

The Global Constraint Catalog as an *attributed ontology* à *la* FCA to be used operationally for declarative scripting as *"OntoLogic" Programming* (*e.g.*, CLP *à la* LIFE)

And BTW: ontological reasoning itself *is* CP!

Lest the cobbler's children stay the worst shod. . .

Thank You For Your Attention !