Considering Feedback Loops in Constraint Programming Methodology

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Based on work with...

- Current and past staff at Insight
- ICON project partners
- TASC team in Nantes
- Constraint team in Uppsala
The Conventional Story

1. Problem
2. Human
3. Model
4. Constraint Solver/Search
5. Solution
A Slightly More Accurate Picture
Key Points

• This is not a realistic model
• Definitely not for industrial work
• Nobody knows what the problem is
• The problem keeps changing
• The process is a set of nested feedback loops, all influencing each other
Focus on Benchmarking Hides This Issue

• Work on clearly defined problem
• Solutions may already exist for comparison
• Quality is easily defined
  • Better objective value
  • Faster than previous approaches
• Only run-time counts
• Should be:
  • Overall development time until first usable solution
  • Including design, revision, training
Some Real-World Examples

- Based on recent projects at Insight
- Not in production use
Example: Datacenter Management

- Electricity Price
- Weather Forecast
- Virtual Machines
- Demand Forecast
- Current Assignment
- VM Allocator
- Resources
- VM Allocation
- Management Platform
- Running VM
Example: Transport

- Expected Travel Times
- Transport Requests
- Transport Solver
- Work Rules Preferences
- Customers
- Manager
- Planned Tours
- Fleet Operation
- Actual Tours
- Current Location
- Agents
Example: Personnel Rostering

- Unplanned Unavailability Emergencies
- Demand Plan
- Rostering Solver
- Work Rules Preferences
- Planned Schedule
- Operations
- Actual Schedule
- Manager
- Staff
The General Scheme

Exogenous Data

Decision Variables

Current State

Constraint Model

Constraints Preferences Objectives

Plan

Realization

Actuals
The ICON Loop

1. **World** produces **Observations**
2. **World-to-ML**
3. **ML**
   - L=(E,H,t,loss)
   - Xlearn
4. **Patterns**
5. **World-to-CP**
6. **CP**
   - N=(X,D,C,f)
   - xsolve
7. **Apply-to-World**
8. **Solutions**
9. **CP-to-ML**

The cycle continues in a feedback loop.
A Blueprint for Interaction

- Developed in the European ICON project
- Partners KU Leuven, Montpellier, Pisa, UCC
- Ways of combining Machine Learning with CP
Machine Learning fuels Decision Making

(Outside) World

Decide
- Optimization
- Rules
- ...

Sense
- Machine Learning
- Natural Language Processing
- ...

Interpret / Predict
- Machine Learning
- Rules
- Knowledge Mgt
- ...

Structured data

Unstructured data

Actions

Structured insights

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Example: Intra-City Transport

- Optimization only as good as data feeding into it
Feedback May Lead to More Traffic

- The “world” reacts to changes
- That may be difficult to predict
Reacting to Real-time Electricity Prices

- Good way to optimize cost individually
- May lead to oscillation if everybody does it
Feedback Loops in Modelling

- Problem
- User
- Modeler
- Model
- Solver
- Proposed Solution
- Designer
- Constraint Bias

Integration

- (Informal) Description
The Future: Automated Modelling

- Problem
  - Sample/Historical Solutions
  - ModelSeeker
    - Model Elements
  - User/Modeler
    - Model
    - Solver
    - Constraint Bias
    - Solver Generator
    - Proposed Solution

Integration
ModelSeeker

- Learn elements of constraint models from positive examples
- Highly stuctured problems
  - Essentially matrix models
  - Conjunctions of global constraints
  - Based on global constraint catalog
- System suggests sets of constraints
- Relies on user to select meaningful subset
• Generate constraints for families of constraints automatically
• Currently being developed for time-series
• No limit on number of different constraints needed to model problem
• Also generate implied constraints for conjunction of basic constraints
Conclusions

- Very little work on methodology
- CHIC-II project
- Not the linear model often presented
- Feedback loops are everywhere
- Impact little understood