Centre for
Data Analytics

Insight

Constraint Programming Methodology

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CRT-AI CP Week 2025

Constraint Programming Methodology

Licence

Acknowledgments

This publication has emanated from research conducted with the financial support of Science Foundation Ireland under Grant number 12/RC/2289-P2 at Insight the SFI Research Centre for Data Analytics at UCC, which is co-funded under the European Regional Development Fund.
A version of this material was developed as part of the ECLiPSe ELearning course:
`https://eclipseclp.org/ELearning/index.html`.
Support from Cisco Systems and the Silicon Valley Community Foundation is gratefully acknowledged.

What we want to introduce

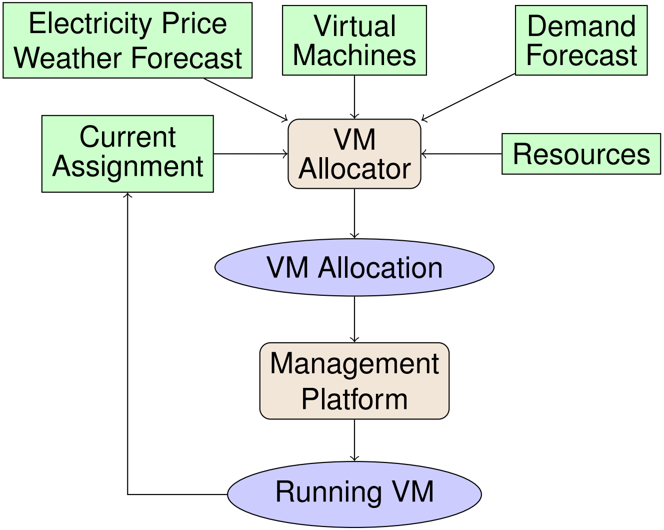
- How does a Constraint Model fit into a bigger system
- Interaction with stakeholders
- You define what the problem is
- 12 Steps to success

Outline

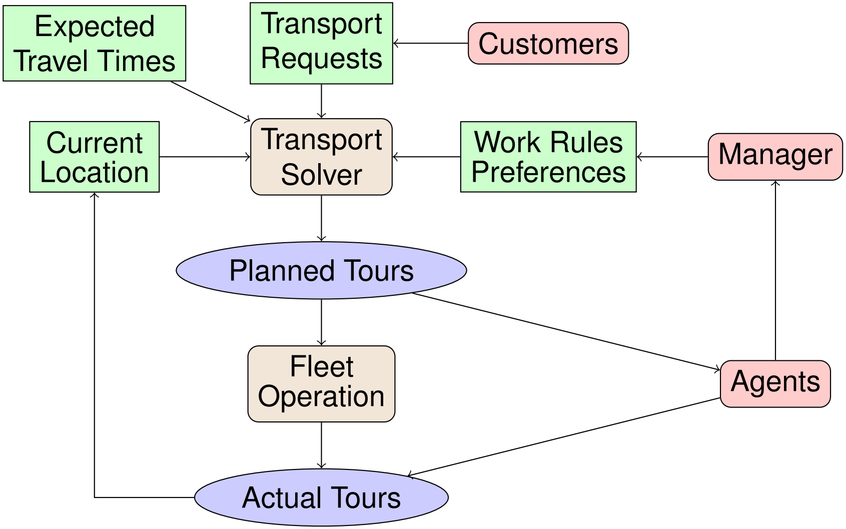
CP Model is Part of a Larger System

- Where do data come from?
- Control over data
- Generated plan
- Externalized representation of constraints
- Implementation of plan
- Feedback from previous runs

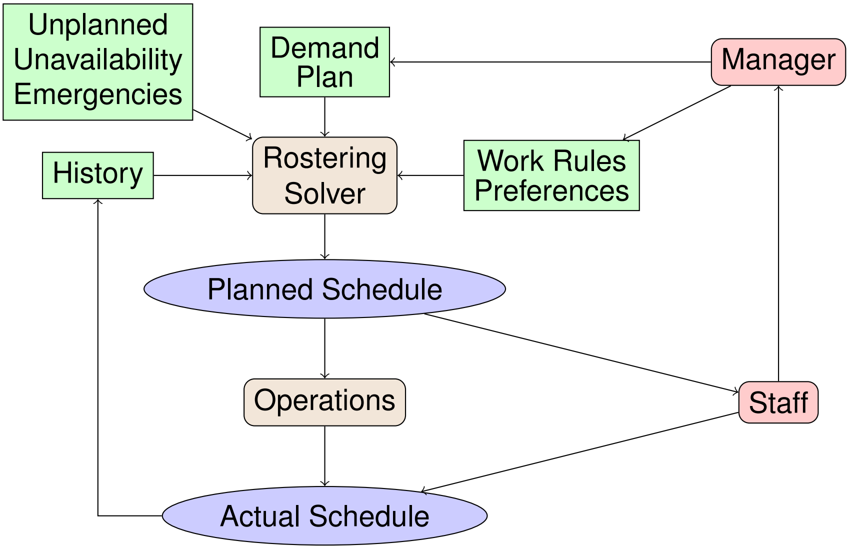
Example: Datacenter Management



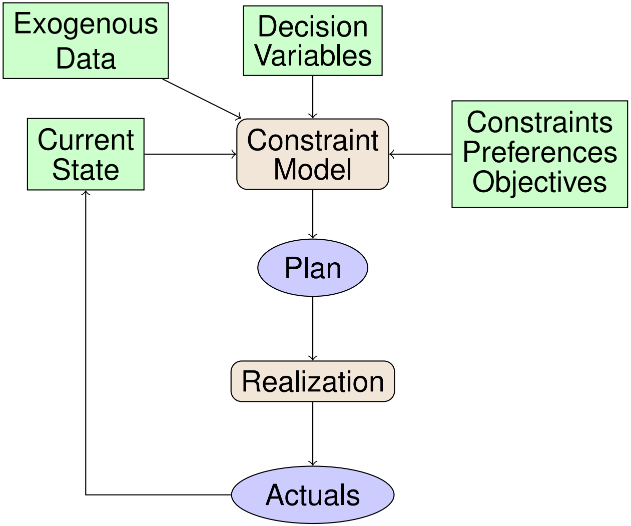
Example: Transport



Example: Personnel Rostering



The General Scheme



Key Questions: How? Who? When? Where?

- (How is work done?)
- Who performs work?
- When is it performed?
- (Where is it performed?)

Outline

Step 1: Literature Review

- Which problem are other people solving?
- What are the favourite tecniques, why?
- What tools are used?
- Learn the domain specific language

Step 2: Description of Problem

- Clearly defined use cases, ranked by importance
- Textual description of problem before math
- Important: Involve all stakeholders
- Important: Identify champions and their benefits
- State what is outside the scope

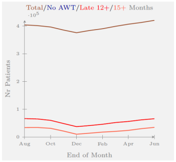
Step 3: Example Data and Solution

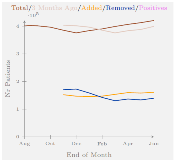
- Best is years of existing data and solutions
- Important: Set with manageable problem size
- Independent checker of solutions
- Possible: Trivial problem example for manual exploration

Step 4: Visualizing Results

- Develop before solver
- Visualize existing solutions
- Perhaps end-users have existing visualizations
- Generic views for classes of problems (global constraints)
- Helps to understand poor performance
- Also: Compute KPI (Key Performance Indicators)

Example Dashboard: Patient Waitlists





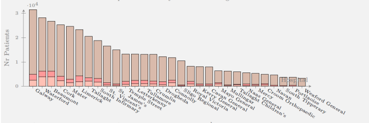
3 Month Cohort Changes

Date	Added	0-3 ↓ 3-6	3-6 ↓ 6-9	6-9 ↓ 9-12	9-12 ↓ 12-15	12-15 ↓ 15-18	15-18,18+ ↓ 18+	Removed	Changed
30-11-2015	152294	-65995	-26658	-13937	-19270	-20573	-24296	-170729	-18435
31-12-2015	146984	-61886	-25250	-15200	-15377	-25957	-29039	-172709	-25717
31-1-2016	145800	-61092	-24275	-13897	-13271	-20504	-25548	-158587	-12787
29-2-2016	147095	-63521	-22644	-12972	-12677	-15298	-15408	-142520	4575
31-3-2016	153534	-63074	-24024	-13808	-12772	-13078	-3763	-130519	23105
30-4-2016	159832	-63769	-25898	-15315	-14835	-11920	-5077	-136814	23018
31-5-2016	158239	-62651	-25506	-15649	-14368	-10780	-4552	-133506	24733
30-6-2016	160906	-66237	-24605	-15887	-15695	-12175	-5079	-139678	21138

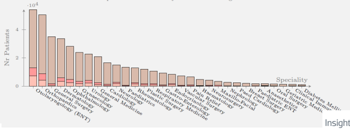
Type	Value	Min	local previous months/selected national	Max
Patients Waiting	420545.00	0.00		420545.00
Waiting 15+ Months	34674.00	0.00		34674.00
Added in 3 Months	160906.00	0.00		160906.00
Total Changed	21138.00	-25717.00		24733.00
Percent 12+ Months	15.66	0.00		29.43
Percent Added	38.26	0.00		100.00

Type	Value	Min	local previous months/selected national	Max
Waiting 12+ Months	65863.00	0.00		66369.00
Total Wait Years	265084.77	0.00		265084.77
Removed in 3 Months	- 139678.00	- 172709.00		0.00
Est. Avg Wait Time	230.07	0.00		302.56
Percent 15+ Months	8.25	0.00		22.64
Percent Removed	-33.21	-177.78		0.00

Hospitals Ranked by Patients Waiting



Specialities Ranked by Patients Waiting



OWL2 (Ireland on 30-6-2016): Created Tuesday 2nd August, 2016, at 11:24

Step 5: Implement Core Model

- One constraint type at a time
- Start with finding feasible, good solutions
- Find lower/upper bounds to estimate solution quality
- Start with basic search strategy

Step 6: Feedback from Domain Experts

- Are you solving the right problem?
- Are all stakeholders happy with solution and objectives?

Step 7: Study Obvious Alternatives

- If you have time (PhD students have time)
- Is there a straight-forward MIP/SAT model of problem?
- Do they work on small scale, large scale problems?
- Can you come up with good, feasible heuristics?

Step 8: Solve Integration Issues

- Not too early, time wasted if solver does not work
- Not too late, without integration solver is just a demonstrator

Step 9: Performance Engineering

- Problem specific search strategies
- Parallelism
- Improved model
- Improved solver
- Parameter tuning

Step 10: Fight Feature Creep

- If it works, then people want more
- Not in first release
- Implement core use case, nothing more
- Exception: Allow all constraints to be optional

Step 11: Improve Stability

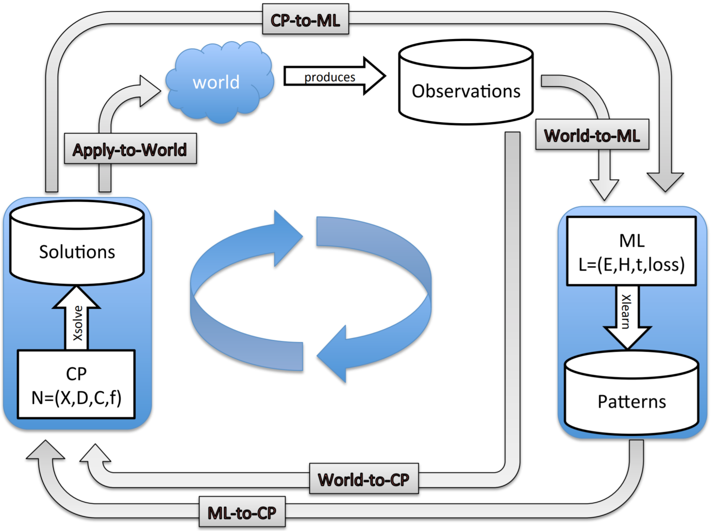
- What is really required?
- Remove experimental code
- How far can we push model?
- Code review against model description
    - Allow changes in description

Step 12: Tell the World

- Dozens of good CP applications hidden from view
- Consider writing application paper
    - Involve end-users and stakeholders
    - Describe problem from their perspective
    - If possible, publish data set and constraint description
- Submit instances to solver competitions
    - Other people will work on improved performance of your model

Outline

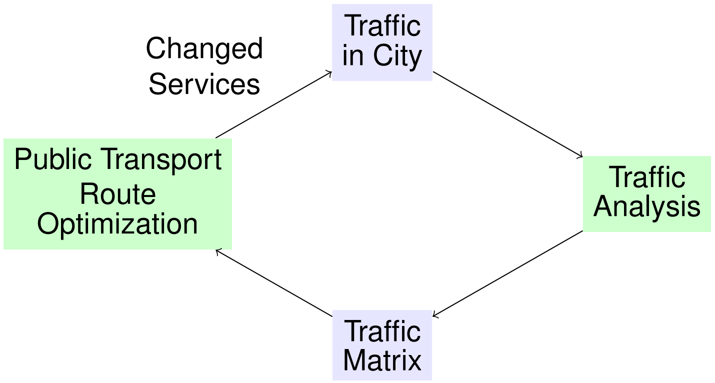
The ICON Loop



A Blueprint for Interaction

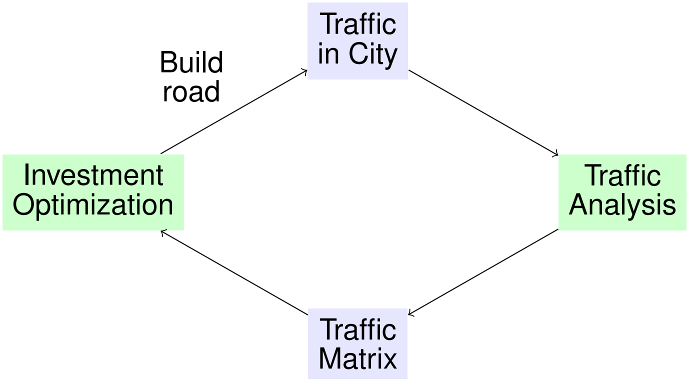
- Developed in the European ICON project
- Partners KU Leuven, Montpellier, Pisa, UCC
- Ways of combining Machine Learning with CP

Example: Intra-City Transport



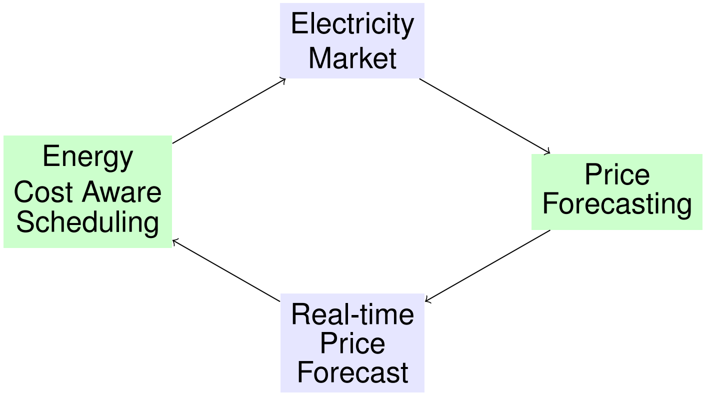
- Optimization only as good as data feeding into it

Feedback May Lead to More Traffic



- The "world" reacts to changes
- That may be difficult to predict

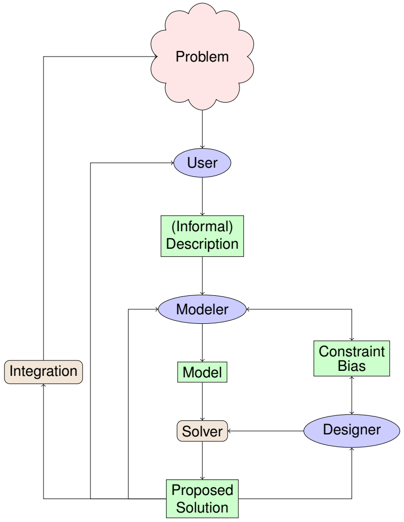
Reacting to Real-time Electricity Prices



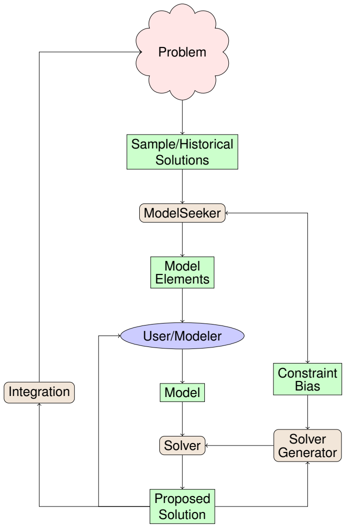
- Good way to optimize cost individually
- May lead to oscillation if everybody does it

Outline

Feedback Loops in Modelling



The Future: Automated Modelling



Outline

Points to Remember

- A CP application is part of a larger system
- CP Model is rarely cause of project failure
    - No clear champion
    - No clear use case
    - Data not available/data quality
- Every problem is different, you decide what to model
- Understand the interaction between tools and problem