CP in Practice



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Who am I? And why would you want to listen to me?

- Doctoral studies in constraint programming at KTH
 - Architecture for constraint programming systems
- Co-created and maintains Gecode
- More than a decade in industry using CP and related technologies
 - Packing for laser cutting at Tomologic
 - Scheduling for cancer treatment at RaySearch
 - Consulting in scheduling and configuration
 - Co-founded Optischedule, a scheduling start-up together with Magnus Rattfeldt





Todays plan

- Challenges and opportunities in using CP for real
- "War stories" cases where I've used CP
 - Tomologic and cut path planning
 - Building custom solvers for fun and profit problems
 - Creating shift schedules at Optischedule
- This will be more fun if you ask questions

Many companies have CP systems in disguise

- Typically "that complicated piece of critical code" May require experienced eye to see isomorphism to CP
- system
- Delivers real business value
 - But often without optimality being of utmost importance
- Inexperience leads to convoluted design



Biggest opportunities for CP AKA: When should you remember this course

- A method for solving problems
- The "right" mental models
 - Separation of Representation, Rules, Solution method, Heuristics
- Turn-key method for simple problems
- Key to building highly customised solutions
 - Might not look like a classical CP problem

Your time to shine! Remember that CP exists and know that there is a better way!

But what about Al/Machine Learning/Neural Networks? Won't ChatGPT solve all my problems?

- Machine learning and CP/Optimization are complementary
- Machine learning is great for generating new information
 - Predictions, classification, identification
- CP and Optimization is great for using information
 - Combining information
- Predict + Optimize is getting a lot of interest
- "Optimisation is the Intelligence in Artificial intelligence" Peter Stuckey



Tomologic Laser cutting path planning

- Special rules enables better packing
- Huge industrial impact
- Key idea common cuts between parts



- Base problem is geometric packing
- Clusters of parts needs a special cutting path
- Without special cutting paths, parts would not be usable

TOMOlogic







Tomologic Laser cutting path planning

- First approach assumed a cutting path solution was easy to find
- Turns out, we were wrong
- CP model was crucial to understand the structure of the problem
- Actual solution in production used custom algorithms in Java & Scala
- Reported in Laser Cutting Path Planning Using CP, Lagerkvist, Rattfeldt & Nordkvist, CP 2013

TOMOLOGIC



• A new detailed model in Gecode, with many custom search heuristics



Custom solvers for scheduling Fun, obvious, tricky, and with surprising depth

- What to do when your boss tells you that your team needs to solve a scheduling problem?
 - Remember something about backtracking search from school
- Build algorithms close to the style of the rest of the system
 - Maintenance and institutional knowledge is super important
- At some point, realise that you are stuck
- I've seen and worked with more than one home-grown CP-like system

Custom solvers for scheduling The good parts

- Fun to build
- Easy integration into rest of system
- Lots of focus on business heuristics
 - In many cases there is no clear objective to optimise
 - Solutions must be constructed to feel right
- Debugging similar to rest of system
- Flexible when done right

Custom solvers for scheduling The bad parts

- Hard to build and ensure correctness
 - If anyone was an expert, a CP system would probably have been used
- Decades of experience in CP systems required to get right
 - Separation of variables, propagators, search methods, heuristics
- Very common to mix the concepts
 - variables that propagate, "propagators" with own variables, no pluggable parts, no structured propagation loop, search and heuristic intertwined...
- State restoration and efficient updates are tricky

Optischedule Specialised in solving complicated scheduling and rostering problems

- There are many problems to solve for personnel scheduling Shift design, work rotation, shift assignment, vacation
 - planning, contract balancing, ...
- Multiple goals
 - Productivity, sustainable staffing, adaptable planning
- Our customers often use home-grown Excel systems
- New company, but a lot of experience www.optischedule.ai







Retail Staff Optimization



Optischedule Shift Design, the problem

- Very common in retail, warehouses, and many other cases
- Given requirements, create shifts for employees
- Fixed and floating requirements from demand curves
- Competencies, task ordering, coordinated tasks, resource limits, ...
- Lunch breaks and coffee breaks very important to get right
- Sometimes minute resolution, often 5/15/30 minute blocks
- Goal is nice shifts with 8 hours of work and reasonable breaks



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Warehouse Staff Planning



Retail Staff Optimization



Optischedule Technologies

- Custom CP-like solver
 - Used for shift design. Enables detailed control
 - A lot of code to build almost right solution from the start
 - MiniZinc model also in the works
- Custom local search system
 - Used for work rotation
- CP based model for shift assignment and contract mix
 - LNS used for search, very large instances





Warehouse Staff Planning



Retail Staff Optimization



Summary What to remember in 2033

- CP can be very useful in many areas
 - As a technology and as an idea
- Look for use cases, but don't assume CP is the right choice
 - Experimentation, evaluation, and experience required
- A home-grown solution has positive and negative sides
 - Beware of solutions with idiosyncratic and unusual architectures