CP in Practice

Scheduling, configuration, and packing

Optischedule

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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
    - Configuration consulting
    - Building custom solvers for fun and ~~profit~~ problems
    - Creating shift schedules at Optischedule
- This will be more fun if you ask questions

Biggest challenges for CP

AKA: What does Pierre *not* tell you?

- Most of the time, it is not needed
    - Sad reality is that most code requires few to no advanced algorithms
- Most developers are not aware of the existing tools
    - Some developers might know some mathematical optimisation or algorithms
- Developing production ready CP-based solutions is hard
    - Debugging and testing is lacking
- Robustness (similar solutions for similar input) and business driven heuristics

Biggest opportunities for CP

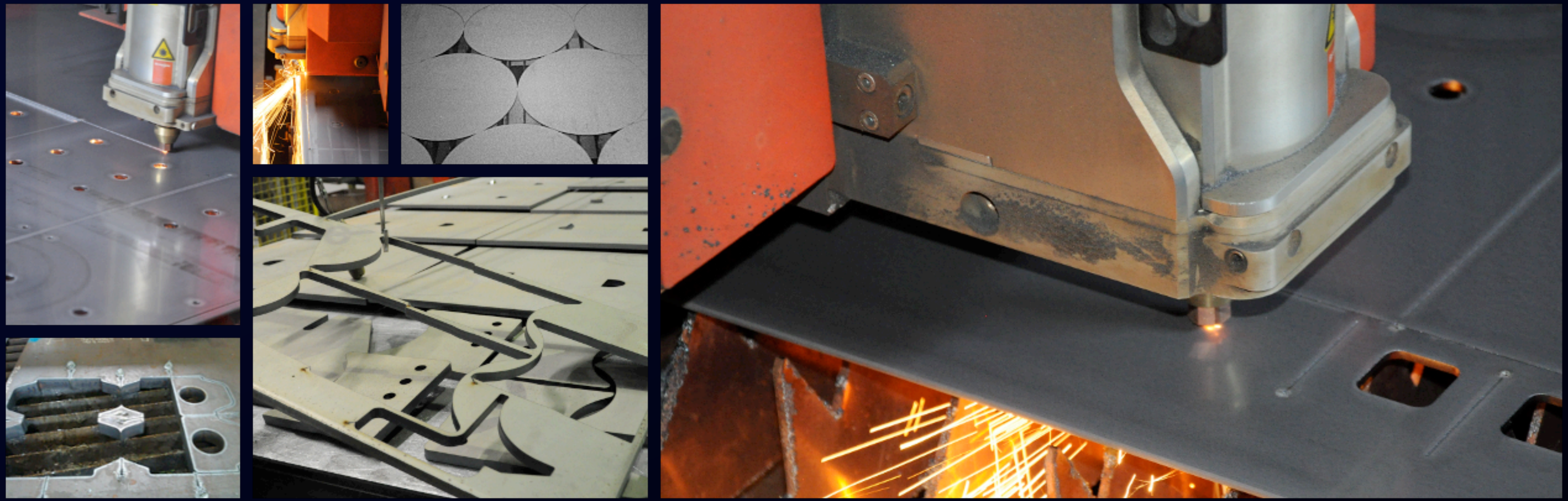
AKA: When should you remember this course

- 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
- Optimal is often not a requirement, rather good enough with heuristic control
- Your time to shine! Remember that CP exists and know that there is a better way!

Tomologic

Laser cutting path planning

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

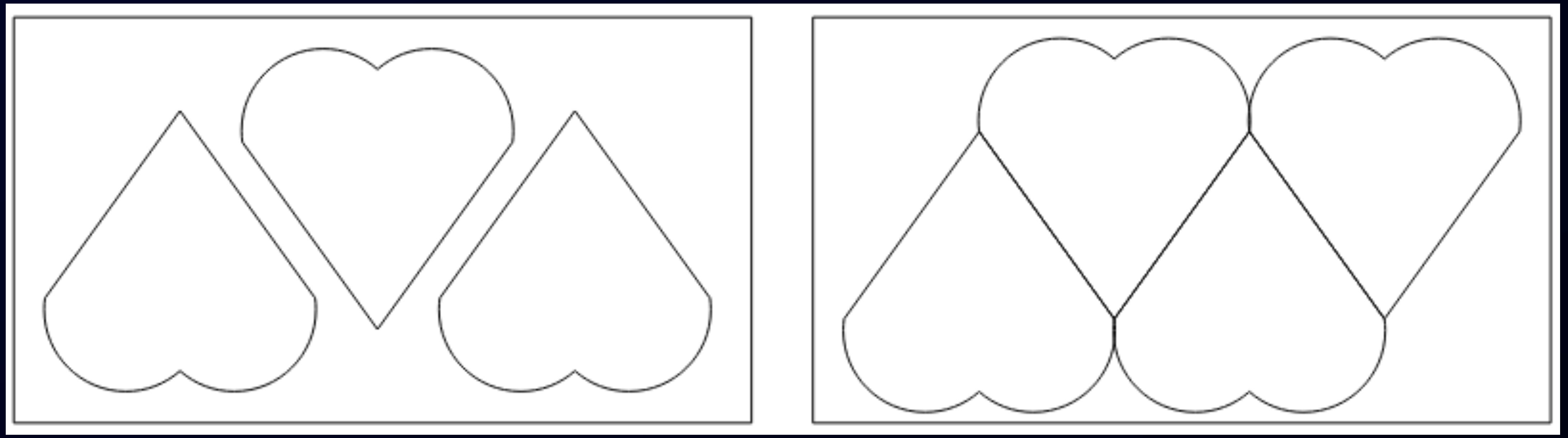


- Base problem is geometric packing
- Clusters of parts needs a special cutting path
- Without special cutting paths, parts would not be usable

Tomologic

Laser cutting path planning

TOMOlogic



- First approach assumed a cutting path solution was easy to find
- Turns out, we were wrong
- A new detailed model in Gecode, with *many* custom search heuristics
- 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

Configuration systems

CP in an alternative setting

- Configuring technical systems and products
  - Cars, assembly lines, kitchens, warehouses
- Many companies around the world build general systems
  - Tacton, Configura, ConfigIT, SAP S4/Hana, …
- Using CP is a common strategy
  - Goal is to find what choices are still valid
  - Essentially global consistency for problem with some assignments made

Configuration systems

CP in an alternative setting

- Worked with a client that had advanced general configuration system
  - Based on generate and test
  - Mostly efficient, but some cases tricky (billions of solutions)
- Built prototype using CP as a building block
  - Gecode used as a propagation engine and for short easy searches
- Could handle complex scenarios with good performance

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 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

Airport & Catering Logistics

Warehouse Staff Planning

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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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

Airport & Catering Logistics

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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

Master Thesis proposals

- Incremental FlatZinc checker for WebAssembly in Rust
  - Given FlatZinc constraints and repeated instance data, check validity incrementally and explain errors
- Modern IntVar representation in Gecode
  - The current representation uses xor-linked lists, a compact array-representation is probably much better for cache locality
- A new smarter default search in Gecode for MiniZinc
  - Gecode has all the tools needed for a smart default search, but it needs to be researched, engineered, and evaluated