

A World
Leading SFI
Research
Centre



Applications, Real World Examples and Success Stories

ACP Summer School 2026

Insight

SFI RESEARCH CENTRE FOR DATA ANALYTICS

Helmut Simonis
Jilin, August 2026

HOST INSTITUTIONS



NUI Galway
O'Gaillimh



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Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin



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Insight is was one of the largest data research and innovation centres in Europe...



4
Co-Lead Universities
9 partner institutions

Built on **20** years of
research in Data
Analytics and AI

450+
Academics, Postdocs, PhDs,
RAs

3400+
Scientific conference
and journal papers

175+
Funded collaborations
with industry partners

350+
Research Awards

16
Spin out companies
72 license agreements

135+
H2020 consortia, 500+
collaborations, 40+
countries

1,137+ school
visits, 28,000 students

276
PhDs graduated

Rinn Artificial Intelligence: Research & Innovation in Data Science and AI

Rinn Artificial Intelligence is designed to serve as a national hub for research and innovation in data science and AI. The programme has two overarching goals: (i) to advance foundational cutting-edge research in Data Science and AI, and (ii) to pursue open, international, and inter- and transdisciplinary research aimed at studying, designing, and implementing strategies to address societal challenges.



Background

- Mathematics @ TH Darmstadt
- 1986-1990 ECRC GmbH, Munich
- 1990-2000, Technical Director, Cosytec SA, Orsay
- 2000-2005, Imperial College London, Parc Technologies Ltd
- 2013-2014, President, Association for Constraint Programming
- Best Application Paper Awards, CP 2009, CP 2013
- Program Chair, CP 2020, CPAIOR 2014
- Distinguished Service Award, ACP
- Editor in Chief, Constraints, 2026



Applications are important

- Provide motivation for basic research
 - Which constraints, methods are needed
- Provide realistic benchmark problems
 - Easy to optimize for pointless results
- Shows that research has potential benefits
 - Much easier to convince funding agencies
- Typically much easier to explain than solver internals
 - Adds motivation, helps with outreach

Structure of Presentation

- Application areas
- Real-world examples
 - Work in Cork
- Success stories
 - Based on impact
- Methodology
 - How to develop applications, do's and don'ts
- Additional resources

Part I

Application Areas for CP

Main Application Areas for CP

- Scheduling
- Product Configuration
- Rostering and Assignment
- Software/Hardware Design and Testing
- Transportation

Outline

Scheduling

Configuration

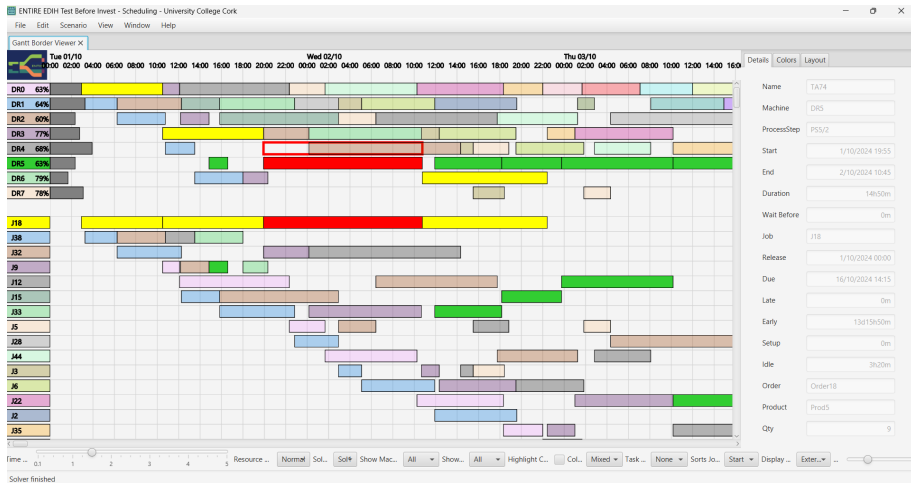
Rostering

Timetabling

Test/Verification

Transportation

Scheduling Demo



More on Scheduling

- Later in this presentation
- One hour talk in the **Scheduling Seminar** series
- Video https://www.youtube.com/embed/6fSRT64XE9w?si=B-hcivmO__q9fapD
- Slides https://schedulingseminar.com/presentations/schedulingseminar_helmutsimonis.pdf

Outline

Scheduling

Configuration

Rostering

Timetabling

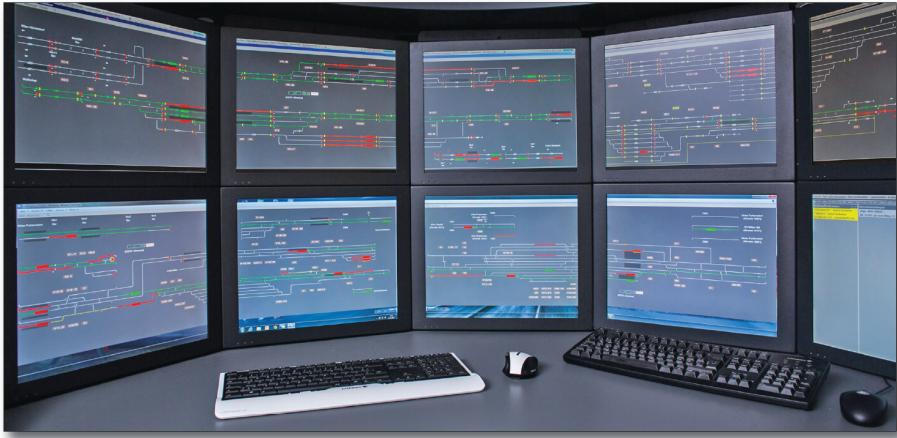
Test/Verification

Transportation

Product Configuration

- Used for semi-custom products
- Product consist of many different components
- Many choices for each component type from a catalog
- Strong constraints between different components
 - Power
 - Bandwidth
 - Space
 - Thermal limits
- Overall objectives: cost, power, space

Configuration Example: Railway Signalling (Siemens Austria)



from Falkner et al, 2016

Configuration Example: Configurable Hardware (Siemens Austria)



from Falkner et al, 2016

Configuration Modelling

- Variables describing alternative component choices
- Properties of components described by `table` constraints
- Linear constraints for global properties
- `bin-packing` constraints for rack space
- `diffrn` constraint for non-overlap in 3D space
- Multi-objective optimization

To learn more

- Falkner et al, 2016: Twenty-Five Years of Successful Application of Constraint Technologies at Siemens
- Erik Cervin-Edin, 2025: Lessons Learnt from Developing & Maintaining the World's Largest CP Model Using MiniZinc
- Ulrich Junker, Chapter 24: Configuration, Handbook of Constraint Programming

Outline

Scheduling

Configuration

Rostering

Timetabling

Test/Verification

Transportation

Rostering Demo

ENTIRE EDIH Test Before Invest - Rostering - University College Cork

File Edit Scenario View Window Help

Solution Assignment Matrix X

Row	Mon Day 0 26/11/9/6/14 26/11/9/6/0	Tue Day 1 24/8/9/7/16 24/8/9/7/0	Wed Day 2 22/9/7/6/18 22/9/7/6/0	Thu Day 3 27/10/9/8/13 25/10/9/6/0	Fri Day 4 24/10/8/6/16 23/10/8/5/0	Sat Day 5 16/7/5/4/24 15/6/5/4/0	Sun Day 6 14/5/5/4/26 14/5/5/4/0	Mon Day 7 26/10/9/7/14 26/10/9/7/0	Tue Day 8 27/12/8/7/13 23/8/8/7/0	Wed Day 9 25/9/10/6/15 25/9/10/6/0	Thu Day 10 23/9/7/7/17 23/9/7/7/0	Fri Day 11 25/11/9/5/15 24/10/9/5/0	Sat Day 12 18/9/5/4/22 15/6/5/4/0	Sun Day 13 20/11/5/4/20 15/6/5/4/0	M
Full 0 20/13/2/5/8	M	R✓	R✓	N	M	N	A	R✓	M	M	R	M	M	M	M
Full 1 20/12/4/4/8	R✓	R✓	N	N	N	N	R	M	M	M	R✓	A	R✓	M	M
Full 2 20/11/5/4/8	M	A	R✓	N	N	N	A	R✓	M	M	R✓	A	R✓	M	M
Full 3 20/11/5/4/8	A	R	M	M	R	M	R	M	N	N	A	M	R	M	M
Full 4 20/14/4/2/8	R✓	A	M	N	R	M	M	R	M	M	M	A	M	R	N
Full 5 20/9/4/7/8	M	A	M	N	R	M	R✓	A	M	R✓	N (1)	A	R	N	M
Full 6 20/9/4/7/8	M	N	N	N	N	A	R	R✓	A	N	N	R✓	M	M	A
Full 7 20/12/0/8/8	M	M	N	R	N	N	N	R	N	N (3)	R✓	M	M	R✓	M
Full 8 20/8/4/8/8	N	A	R	N	R	N	N	A	N	A	R✓	N	N	R	R
Full 9 20/7/6/7/8	N	R	M	R	M	A	R	M	M	M	N	A	R	A	M
Full 10 20/10/4/6/8	N	A	M	N	N	R	R	M	M	M	M	R	N	R✓	M
Full 11 20/11/4/5/8	N	A	M	M	M	R	R✓	M	M	M	M	M	R	M	M
Full 12 20/12/5/3/8	R✓	M	R✓	N (2)	N	R	A	M	R✓	M	R✓	A	M	M	M
Full 13 20/13/2/5/8	M	M	M	R✓	M	R	A	N	N	R	M	A	R	M	M
Full 14 20/12/6/2/8	R✓	M	M	R✓	M	M	R	M	N	A	A	R✓	M	A	M
Full 15 20/7/7/6/8	M	A	A	M	M	R	R✓	N	N	A	M	N	R	M	M
Full 16 20/9/7/4/8	M	N	A	M	M	R	A	A	R✓	M	M	M	A	R✓	M
Full 17 20/4/10/6/8	A	N	A	A	R✓	N	N	N	R✓	A	N (5)	A	A	R	R
Full 18 20/1/17/2/8	A	N	R✓	A	A (5)	A	R✓	A	A	A	A	R✓	A	R✓	M
Full 19 20/4/13/3/8	A	R	N	A	M	R	R	N	A	A	A	A	R	M	M
Full 20 20/3/13/4/8	A	R✓	N	A (7)	A (5)	R✓	A	R	A	A	N	R	M	M	M
Full 21 20/1/13/6/8	A	A	R	M	A	R	A	N	R	N	N	R	A	N	M
Full 22 20/1/14/5/8	A	N	A	A	A	R	N	N	A	R	A	M	A	N	M
Full 23 20/1/11/8/8	A	N	A	A	A	R	R	A	A	N	R	N	N	R	M
Full 24 20/0/12/8/8	A	N	A	R✓	A	N	R✓	A	A (4)	N	R✓	N	N (1)	A	M
Part 25 12/0/9/3/16	R✓	R✓	R✓	A	A	R	R	R	A	A	A	R✓	R	A	M
Part 26 12/9/2/1/16	N	R✓	R✓	R	M	R✓	R	R	R	M	M	R✓	M	R	M

- State-of-the-art: Klapperstueck et al, CP 2026: CrewAId: Interactive Optimisation for Human-In-The-Loop Crew Rostering and Rerostering
- Older: Ernst et al, EJOR 2004: Staff scheduling and rostering: A review of applications, methods and model

Outline

Scheduling

Configuration

Rostering

Timetabling

Test/Verification

Transportation

Timetabling Demo

ENTIRE EDIH Test Before Invest - Timetabling - University College Cork (csData.json, Solved)

File Edit Scenario View Window Help

Module Solution DrawingArea X

Resources

- Modules
- Lecturers
 - B O'Sullivan
 - G Russell
 - J Morrisson
 - J Doherty
 - S Prestwich
 - K Brown
 - J Bowen
 - D Bridge
 - C McCormack
 - K Herley
 - M Van Dongen
 - H Sorensen
 - F Boehme
 - J Vaughan
 - C Sreenan
 - D Grigoras
 - I Pitt
 - E Healy/ C Mc Cormack
 - E Healy
 - M Schellekens
 - S Foley
 - S Tabirca
 - J O'Mullane
 - G Provan
 - J Herbert

	TP1 Mon	TP1 Tue	TP1 Wed	TP1 Thu	TP1 Fri
08-09					
09-10		P CS1106B (56) WGBG24 [75]			
10-11					
11-12		L CS1106 (112) WGBG09 [117]			
12-13			L CS6403 (17) WGBG09 [40]		
13-14			Barry O'Sullivan	Staff Meeting	
14-15	L CS6403 (17) WGBG16 [39]		L CS1106 (112) WGBG03 [117]		
15-16					
16-17			P CS1106A (56) WGBG20 [80]		
17-18					

Details Interaction Display Colors

Color By: None

Box Display: PencilMarks

Box Size: [Slider]

Background Alpha: [Slider]

Constraint Alpha: [Slider]

Foreground Alpha: [Slider]

Explanation Alpha: [Slider]

Labels: ☒ Show Row/Column Labels ☐ Show Cell Labels

Solution Sol1 Teaching Period TP1 Teaching Method All Resource First Previous Next Last Snapshot Color By Preference

Timetabling

- School timetabling
 - Start with Demirović, E., Stuckey, P.J. (2018). **Constraint Programming for High School Timetabling: A Scheduling-Based Model with Hot Starts**. CPAIOR 2018.
- University timetabling
 - Classic: H.J. Goltz, 1999: University Timetabling using Constraint Logic Programming
- Exam timetabling
 - Good introduction: S. Hamilton, MSc Thesis 2022: Constraint Programming Models For Real-World Examination Scheduling

Outline

Scheduling

Configuration

Rostering

Timetabling

Test/Verification

Transportation

Test/Verification

- Not my area of expertise
- Specialised CP solvers
 - New domain types, e.g. uint32
 - New constraints, e.g. integer overflow arithmetic
- To learn more: Arnaud Gotlieb video

<https://www.youtube.com/watch?v=E1Seayx3eXU>

Outline

Scheduling

Configuration

Rostering

Timetabling

Test/Verification

Transportation

Transport Example: TACT

- Transporting chickens and turkeys from farms to factory
 - Source of Chicken McNuggets in UK
- Sun Valley Food (Cargill), Hereford, UK
- Primary objective: Keep factory supplied with birds
- Multi-resource transport problem
 - Catching teams
 - Drive to farm, catch birds, put in cages, put cages on trucks, go to next farm
 - Drivers
 - Drive to farm, load truck with forklift, drive to factory, unload, clean truck, next trip
 - Trucks
 - Different vehicle sizes/capacity depends on temperature

Producer/Consumer Constraint for Factory

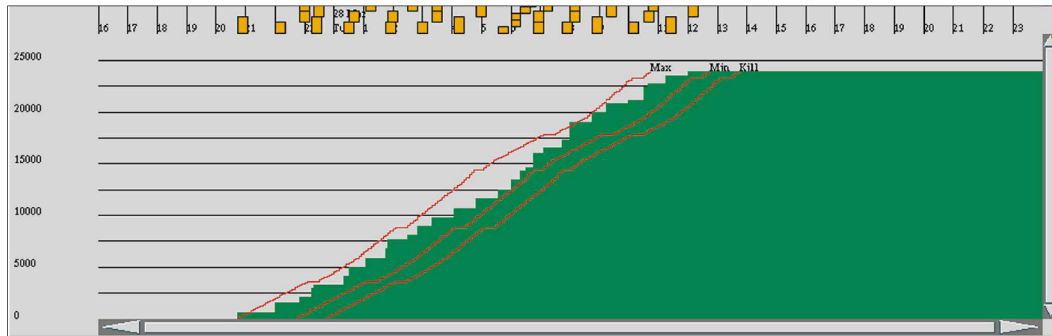
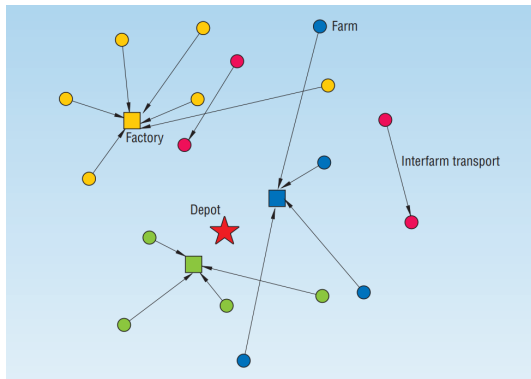


Figure 3. Producer and consumer constraint for factory intake. The x-axis indicates time; the y-axis indicates the number of birds processed. The red line shows the factory's bird consumption during the day, with minimal and maximal stock levels also indicated. The green curve shows the actual arrivals at the factory. Each arrival is marked by a yellow square in the time square, which allows you to access more information about the delivery if required.

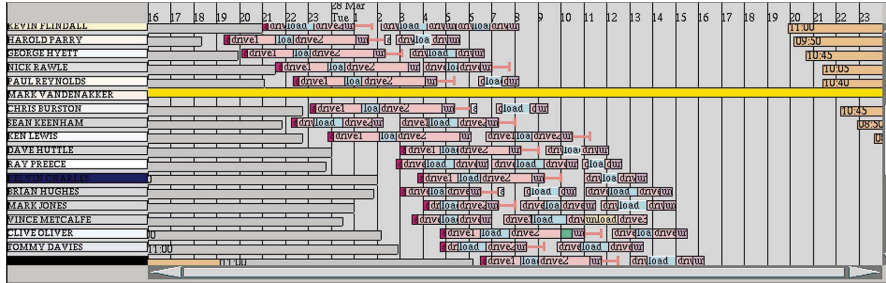
- Do not run factory out of birds!
- Do not deliver birds too early

Order Book

- All trucks/drivers start/end at depot
- Schedule multiple trips to farms
 - Plan correct number of trips to get all birds from farm
 - Number of trip depends on lorries used
- Transport birds to factory
- Some transfers between farms

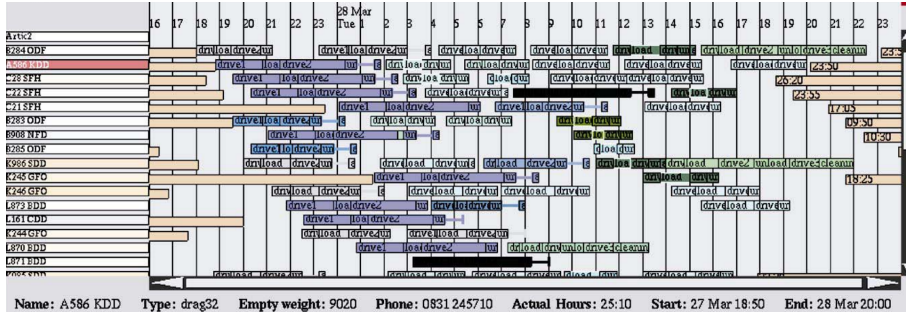


Driver Assignment



- Drivers make 2-4 round trips per day
- Extra truck/drivers needed for peak demand (cost!)
- Schedule of one day influences next day (legal rest periods)

Truck Assignment



- Restrictions of lorry size on certain farms
- Provide correct transport capacity to get all birds from farms
- Transport of fork-lifts on truck

- Developed by COSYTEC with CHIP
- GUI connected to solver and commercial systems
- Turn-key solution for manager
- Flexible interactive tool for scheduling expert
- To learn more: Simonis et al, 2000: Constraint Handling in an Integrated Transportation Problem.
- More modern solver: Delecluse et al., CP 2022, [Sequence Variables for Routing Problems](#)

Part II

Real World Examples

More Detailed Example Applications

- Flexible Flow-Shop with Transportation Times
 - J&J, studies future factory design
- Production Planning and Scheduling
 - Multi-year capacity planning
 - For Siemens Energy, part of ASSISTANT project
- Elevator Maintenance Planning and Scheduling
 - Importance of decomposition
 - Combination with simulation
- Selection of other problem types
 - Only summary slides shown

Outline

Hybrid Flexible Flowshop with Transportation Times

ASSISTANT SE Use Case

Elevator Maintenance Planning and Scheduling

Other Applications

Joint work with

- Michele Garraffa
- Barry O'Sullivan
- Eddie Armstrong (J&J Research, Limerick)

Real-World Problem

- Manufacturing Industry
- Move away from dedicated, high volume standard production
- Allow for increasing customization of product to customer needs
- Take advantage of more flexible, universal machines
- Decentralize production

Research Challenges

- Consider transport time in flowshop scheduling
- Choose appropriate technology to solve problem
- Study realistic scenarios at scale

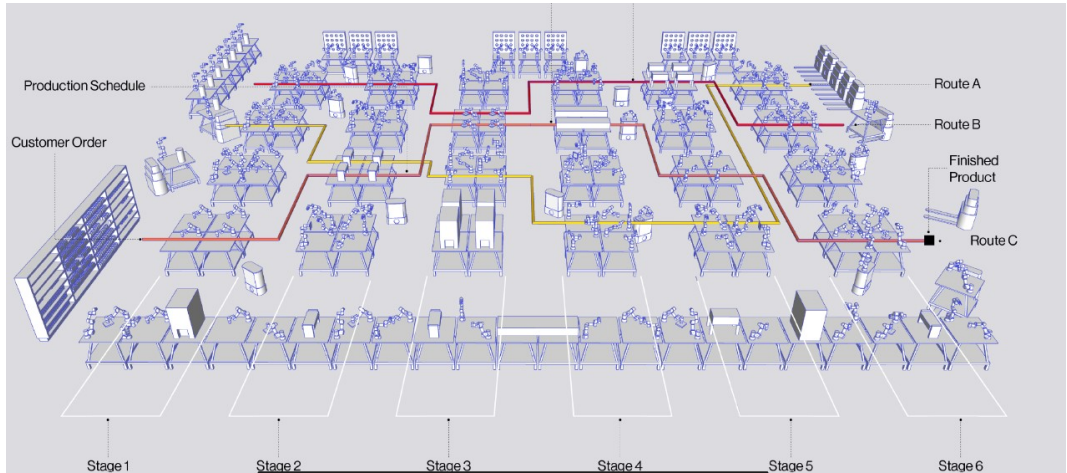
A bit of Background

- Johnson&Johnson is a large multi-national company
 - Strong production and research presence in Ireland
 - Focus on consumer health, medical devices, pharmaceuticals
- Confirm
 - Irish National SFI Centre focussed on Manufacturing
 - Includes groups from multiple universities
 - Our focus is on analytics/optimization
 - Complements our work in the Insight SFI Centre for Data Analytics

Johnson & Johnson

Confirm
Smart Manufacturing

Flexible Factory Structure (Including Transport Between Machines)



Main Elements of Problem

- Flow shop
 - Jobs run through production in the same sequence
- Hybrid
 - Multiple, identical machines available in each stage
- Flexible
 - Some production stages may be skipped for certain jobs
- Transportation Time
 - Time for transport between stage is significant, but not a resource limit
 - Many robots to handle transport tasks
 - Typical machine layout in lanes
- Objective makespan
 - Production not driven by due dates

Objectives of Project

- Identify best tools to schedule new plant
 - Explore variety of different approaches and techniques
 - Do not just focus on your preferred solution method/solver
- Answer some design questions before committing to one approach
 - Is it better to have one or multiple facilities?
 - How far should the transport reach between lanes?
 - How can we exploit flexibility in new machines to offer better products?
 - Semi custom production
- Provide some quantitative comparison based on typical production data
 - Not currently for operational scheduling

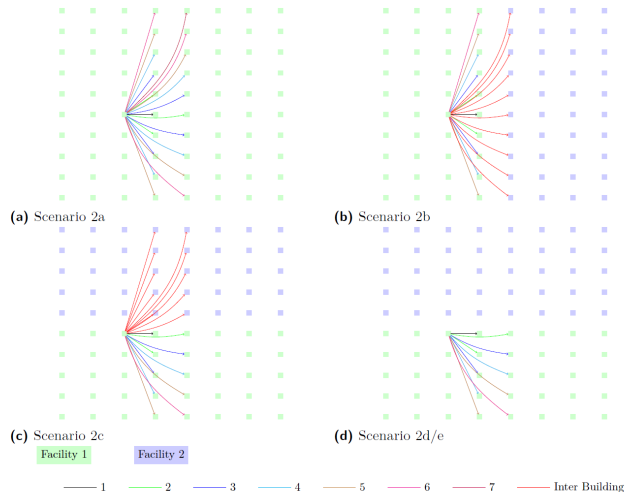
Cmax Results with Different Models (average over 25 instances, 300s timeout)

Size	Lower Bound	Upper Bound	CP Opt	Chuffed Free	Chuffed Priority	Dispatch Rule	Local Search	SICStus
20	61.88	63.56	62.72	63.48	63.04	63.28	63.20	62.72
25	62.84	65.96	64.24	-	64.76	65.20	64.84	64.16
30	64.12	70.24	66.68	-	68.44	69.16	68.24	66.84
40	65.32	77.36	72.56	-	75.40	76.08	75.28	73.28
50	67.24	84.52	78.40	-	82.24	83.16	82.24	79.40
100	94.72	120.12	115.16	-	116.96	118.28	118.92	113.04
200	153.08	185.16	180.48	-	181.32	182.80	184.76	176.72
300	214.96	249.12	248.96	-	248.76	246.96	248.88	240.96
400	275.36	311.60	311.28	-	-	308.76	311.40	303.16

Comments

- CP Optimizer and SICStus perform best
 - CP Optimizer better for small/medium instances
 - SICStus does scale better
 - Note: SICStus uses hand made search routine
 - Chuffed free search does not scale at all
 - Very poor improvements on makespan
 - Chuffed priority search: good initial solutions only
- Dispatch Rule and Local Search perform quite well
 - Further development potential
- MIP does not work at all
 - Limited to smaller instances not shown here

Four Layout Alternatives (One or Two Locations)



Five Scenarios Tested

- 2a Single facility organized in lanes
- 2b Two facilities in sequence (sequential for all jobs)
- 2c Two facilities in parallel with transport between facilities allowed
- 2d Two facilities in parallel, transport only within each facility
- 2e Two factories in parallel, with 80% of jobs preassigned to a factory

Summary

- New variant of known scheduling problem
 - Arising from flexible new factory design
 - Transportation between machines/locations important element of schedule
 - Good solutions are obtained with CP for large problem instances
 - Not all CP models achieve the same solution quality
 - MIP results weak
 - Remaining, open gap between best lower bound and best solution found
- Scheduling model used for factory design study
 - Which layout gives the best overall results?
 - Explores four design alternatives

Results Scale to Hundreds of Jobs (shown: SICStus 1000 jobs, 80 machines)



Outline

Hybrid Flexible Flowshop with Transportation Times

ASSISTANT SE Use Case

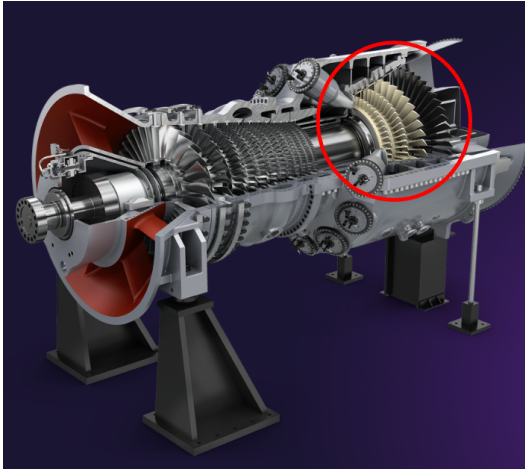
Elevator Maintenance Planning and Scheduling

Other Applications

An Industrial Example

- ASSISTANT project Siemens Energy use case
- Mid/Long-term scheduling/production planning
- Realistic/not real data
- Rather complex constraint model
 - Multi-stage BOM
 - Alternative Process Paths
 - Alternative machines
 - Quality/cost based routing preferences
 - Potential outsourcing of certain steps
 - Machine specific calendars
 - Infeasible release/due date pairs
 - Calendar dependent speed reduction
 - Complex manpower constraints

Assistant Siemens Energy Use Case



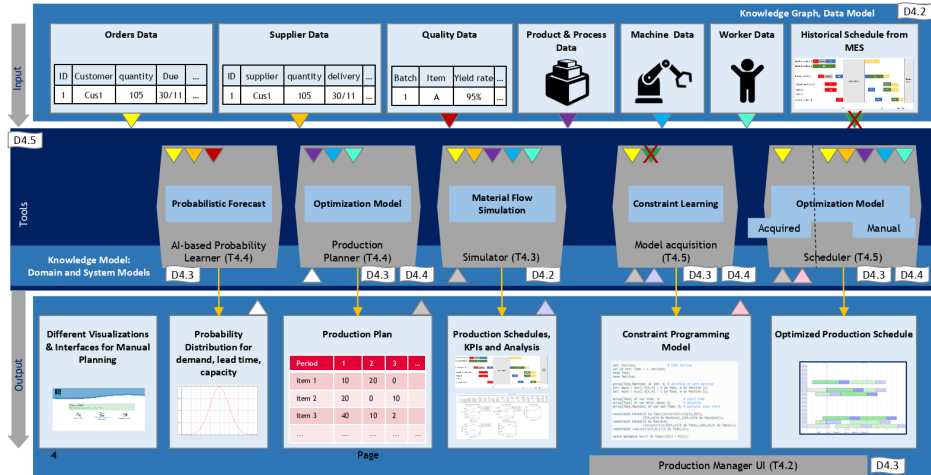
Use Case Scenarios

- Schedule *validation* of gas turbine blades and vanes manufacturing operations in Berlin plant
- Schedule *optimization* to manage short-term, mid-term and long-term load fluctuations
- Generate *Make-or-Buy proposals* for workload balancing within the manufacturing network

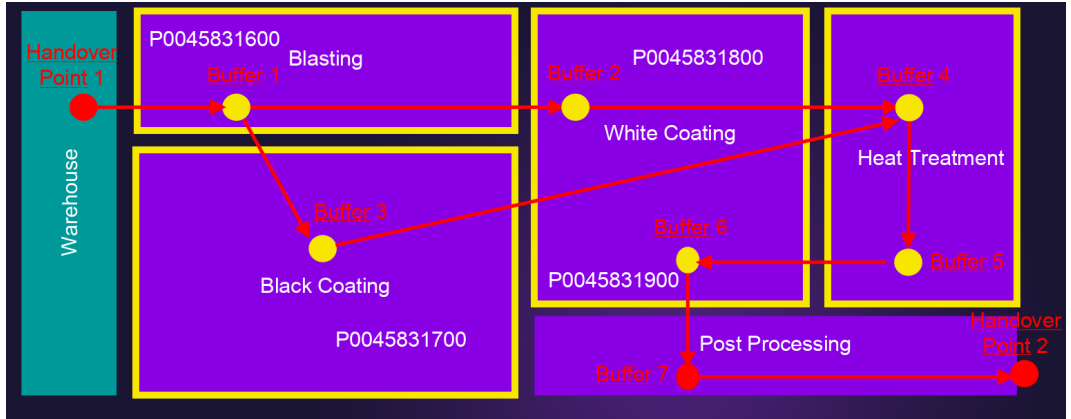
Digital Twin

Intelligent digital twin for process planning and scheduling

ASSISTANT



SE Product Routing



Datasets

Full Scale Datasets

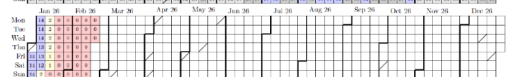
Berlin06: 96 orders, 9 months horizon,
previous review



Berlin07: 450 orders, 4 years horizon

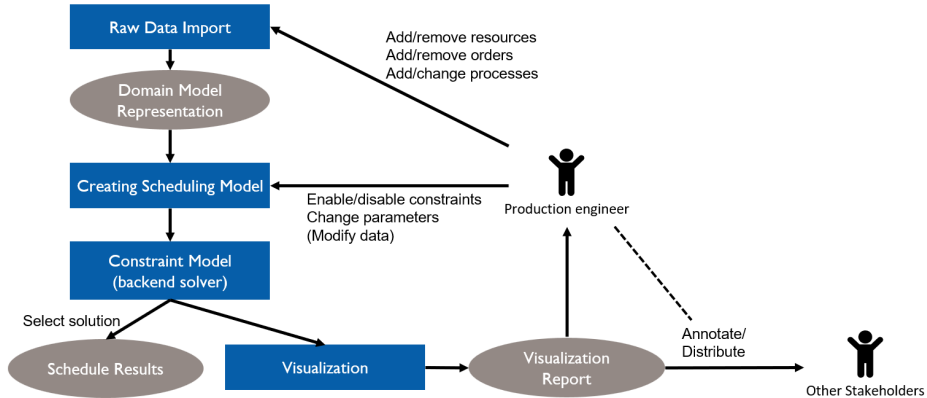
Berlin08: 559 orders, Christmas gap added

Berlin08a: 670 orders, filling gaps



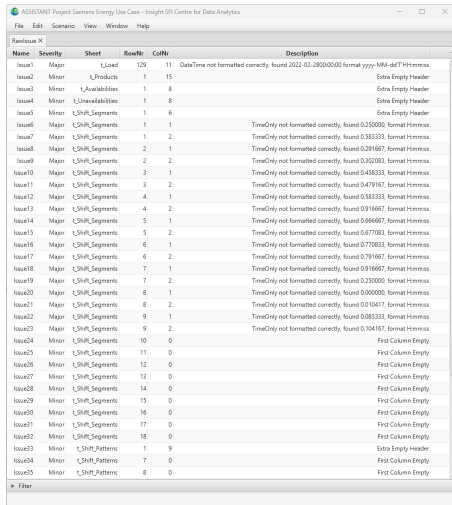
Value in cell indicates active orders
Yellow and red colors indicate low order
volume

Optimizer High Level Structure



Raw Data - Manual Data Entry Causes Problems

- Raw data come from spreadsheet
 - 20 tabs
- Excel is a particularly bad input data format
- Realistic, not real data
- Created by hand/automatically from existing test scenarios
- Series of files Berlin01 - Berlin05 were too inconsistent to run
- Berlin06 still contains some errors
- Optimizer explains all issues that it finds

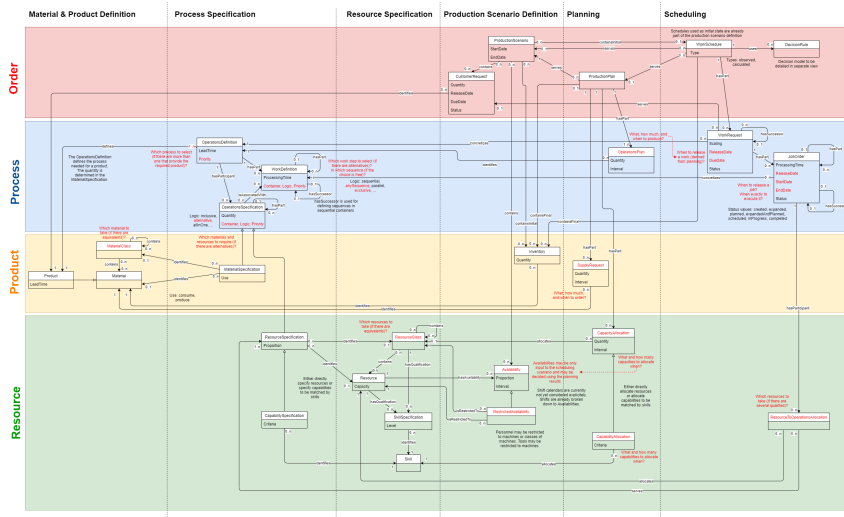


ASSISTANT Project Siemens Energy Use Case - Insight SRI Centre for Data Analytics

Name	Severity	Sheet	RowNr	ColNr	Description
Issue1	Major	t_Load	129	11	DateTime not formatted correctly, found 2022-02-280000:00 format yyyy-mm-ddTHH:mm:ss
Issue2	Minor	t_Products	1	15	Extra Empty Header
Issue3	Minor	t_Availability	1	8	Extra Empty Header
Issue4	Minor	t_Unavailability	1	8	Extra Empty Header
Issue5	Minor	t_Shift_Segments	1	6	Extra Empty Header
Issue6	Major	t_Shift_Segments	1	1	TimeOnly not formatted correctly, found 0.250000, format H:mm:ss
Issue7	Major	t_Shift_Segments	1	2	TimeOnly not formatted correctly, found 0.583333, format H:mm:ss
Issue8	Major	t_Shift_Segments	2	1	TimeOnly not formatted correctly, found 0.291667, format H:mm:ss
Issue9	Major	t_Shift_Segments	2	2	TimeOnly not formatted correctly, found 0.302083, format H:mm:ss
Issue10	Major	t_Shift_Segments	3	1	TimeOnly not formatted correctly, found 0.458333, format H:mm:ss
Issue11	Major	t_Shift_Segments	3	2	TimeOnly not formatted correctly, found 0.479167, format H:mm:ss
Issue12	Major	t_Shift_Segments	4	1	TimeOnly not formatted correctly, found 0.583333, format H:mm:ss
Issue13	Major	t_Shift_Segments	4	2	TimeOnly not formatted correctly, found 0.916667, format H:mm:ss
Issue14	Major	t_Shift_Segments	5	1	TimeOnly not formatted correctly, found 0.666667, format H:mm:ss
Issue15	Major	t_Shift_Segments	5	2	TimeOnly not formatted correctly, found 0.677083, format H:mm:ss
Issue16	Major	t_Shift_Segments	6	1	TimeOnly not formatted correctly, found 0.770833, format H:mm:ss
Issue17	Major	t_Shift_Segments	6	2	TimeOnly not formatted correctly, found 0.791667, format H:mm:ss
Issue18	Major	t_Shift_Segments	7	1	TimeOnly not formatted correctly, found 0.916667, format H:mm:ss
Issue19	Major	t_Shift_Segments	7	2	TimeOnly not formatted correctly, found 0.250000, format H:mm:ss
Issue20	Major	t_Shift_Segments	8	1	TimeOnly not formatted correctly, found 0.000000, format H:mm:ss
Issue21	Major	t_Shift_Segments	8	2	TimeOnly not formatted correctly, found 0.010417, format H:mm:ss
Issue22	Major	t_Shift_Segments	9	1	TimeOnly not formatted correctly, found 0.083333, format H:mm:ss
Issue23	Major	t_Shift_Segments	9	2	TimeOnly not formatted correctly, found 0.104167, format H:mm:ss
Issue24	Minor	t_Shift_Segments	10	0	First Column Empty
Issue25	Minor	t_Shift_Segments	11	0	First Column Empty
Issue26	Minor	t_Shift_Segments	12	0	First Column Empty
Issue27	Minor	t_Shift_Segments	13	0	First Column Empty
Issue28	Minor	t_Shift_Segments	14	0	First Column Empty
Issue29	Minor	t_Shift_Segments	15	0	First Column Empty
Issue30	Minor	t_Shift_Segments	16	0	First Column Empty
Issue31	Minor	t_Shift_Segments	17	0	First Column Empty
Issue32	Minor	t_Shift_Segments	18	0	First Column Empty
Issue33	Minor	t_Shift_Patterns	1	9	Extra Empty Header
Issue34	Minor	t_Shift_Patterns	7	0	First Column Empty
Issue35	Minor	t_Shift_Patterns	8	0	First Column Empty

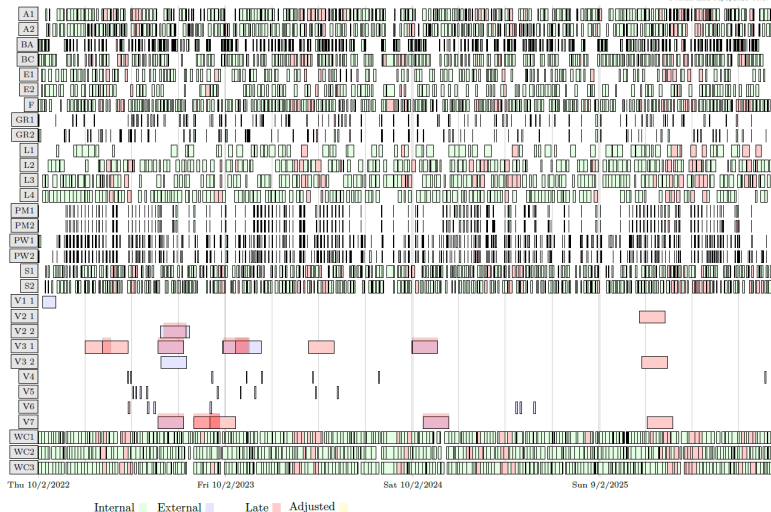
Filter

Domain Model - Knowledge Graph



Single Solution for Berlin 08a - Shows Only 20% of Tasks in Model

Overall End 14/1/2026 06:37

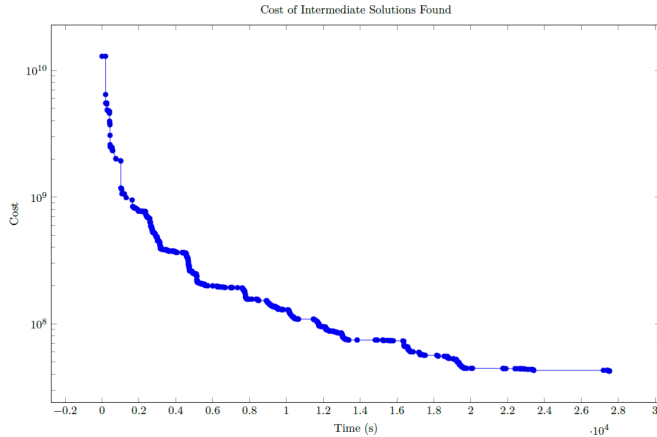


Implementation

- Requirement capture done inside project
- Data checking/cleaning most time consuming aspect
- Some specified functionality was rejected by Betriebsrat
- Built in Java
- Uses IBM's CPO back-end
- 120k LoC, 110k generated, 3k solver
- Outperforms both
 - Current in-house tool
 - Simulation based tool based on commercial simulator
- System installed at SE site, but not in daily use

CPO Keeps on Trucking

Figure 23: Evolution of Intermediate Solution Cost over Time, Dataset08, Pref 2 Options, time limit 8 hours



Conclusion

“Within less than eight hours the ASSISTANT tools provided us thousands of manufacturing scenarios including different make-or-buy recommendations for making deliberate decisions on the way to proceed for strategic planning.”

Siemens SE final project review assessment

Outline

Hybrid Flexible Flowshop with Transportation Times

ASSISTANT SE Use Case

Elevator Maintenance Planning and Scheduling

Other Applications

Elevator Maintenance Planning and Scheduling

- Project with UTRC (Ireland, US) and Otis (Canada)
- Plan and schedule maintenance of elevators/lifts/escalators
- Shows importance of overall problem decomposition

Joint work with...

- Mark Antunes, Vincent Armant, Kenneth N. Brown, Gabriel G. Castane, Daniel Desmond, Guillaume Escamocher, Michele Garraffa, Anne-Marie George, Diarmuid Grimes, Mike O'Keefe, Yiqing Lin, Barry O'Sullivan, Cemalettin Ozturk, Luis Quesada, Mohamed Siala, Helmut Simonis and Nic Wilson

Real World Problem

- Manufacturing Industry, after sales support
- Maintenance is crucial for safety/availability of product
- Preventive/Predictive/Reactive Maintenance influence each other
- How to organize service, what to do?

Research Challenge

- How to plan/schedule if events interrupt planned work
- How to use predictive maintenance to avoid problems before they occur
- What is the right problem decomposition?

Travelling Repair Person (TRP)

- Providing service for devices at customer premises
- Planned preventive maintenance and testing, regular visits
- Technicians travel to multiple, but few customers per day
- Unplanned repair work after faults, response-time critical
- Service times quite variable
- Impact of skills and local knowledge

Why is this important? (1)



South China Morning Post

Connecting quality brands in *different industries* with *educated and affluent* readers.

Law and Crime

Lift firm Otis fined HK\$320,000 over Hong Kong mall escalator accident that injured 18

Company, which pleaded guilty to four summonses, could have discovered safety issues with escalator three months before malfunction, court told



Jasmine Siu

Published: 8:15pm, 9 Mar, 2018

Why is this important? (2)

BIG STORY 10 APRIL 5, 2016 / 6:40 AM / 3 YEARS AGO

Schindler sells Japanese business to Otis after accident

2 MIN READ



ZURICH (Reuters) - Elevator maker Schindler is selling its Japanese business to United Technologies' Otis unit after its new installations in the country were halted following a 2006 accident.

Source:  REUTERS

Why is this important? (3)

Elevator at one of Chicago's tallest skyscrapers plunges 84 floors after hoist rope breaks

NOVEMBER 19, 2018 / 10:47 AM / CBS NEWS



Source: By Chris6d - Own work, CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=78201640>

High-level View

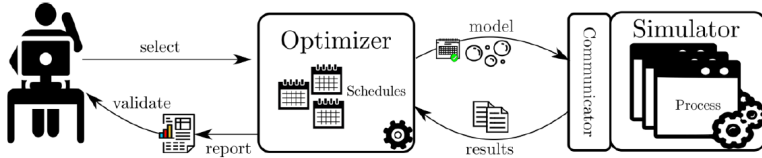


Figure 1 High level overview of the framework

- Optimizer deals with planning, load balancing, efficient schedules
- Simulator explores how to react to changes
- Simulator also provides one result as assumed reality

Optimizer Design

- Infeasible to build homogenous model for complete problem
- Added business process constraint
 - Technicians should be responsible for “their” buildings
 - Improves service quality
 - Customers see familiar face
- All work in one building should be performed by the same engineer, if possible
- Engineers should be assigned compact areas of work
- Balanced workload within the same depot

Optimizer Decomposition

Clustering

Route Generation

R_1

R_2

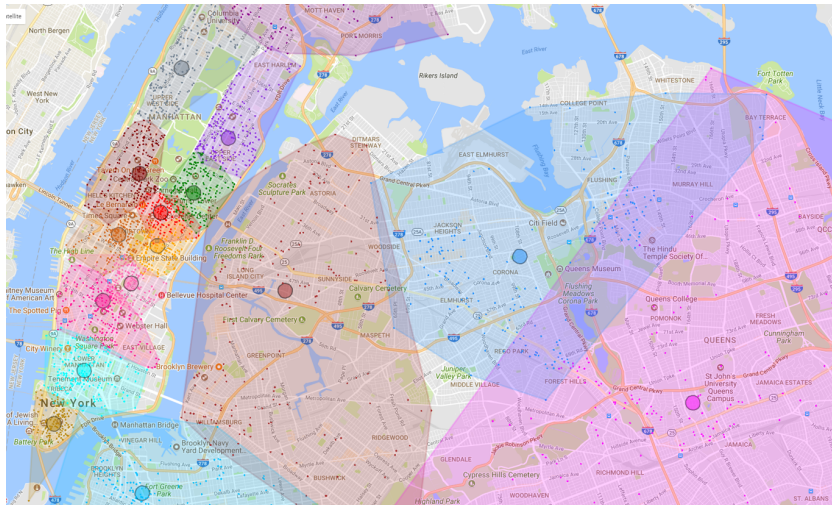
Monthly
Schedule

R_{n-1}

R_n

Daily Schedule

Clustering and Depot Assignment



Scheduling: One Day of Monthly Plan



Methods Used

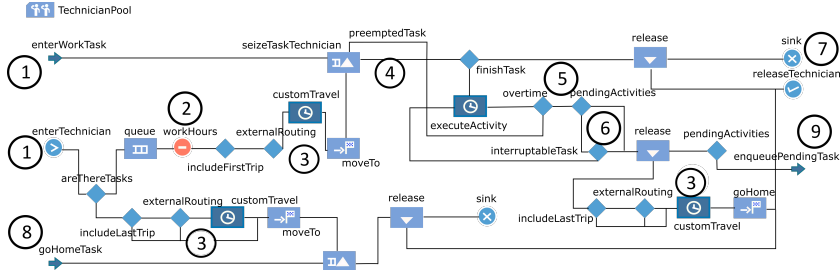
Clustering Connected components on generated graph

Routing Which places to visit in one trip

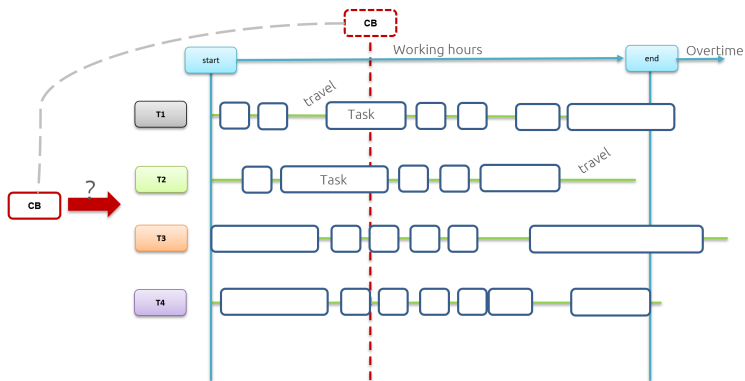
- Core MIP Model
- Iterative MIP inside Clustering
- Two stage grouping of locations to reduce expected travel
- Local Search

Scheduling Dynamic Programming and Set Partitioning

Simulator Process Modelling



Dealing with Unplanned Callbacks



- Who is dealing with the callback?
- How to adjust the schedule after callback?

Use Cases

- Compare variants of problem to understand impact of changes
- Examples
 - Where to place depots and their area?
 - How many technicians are needed in which depots?
 - Should technicians do both planned and unplanned work?
 - When is overtime the better choice?

Challenges: Data

- We need company internal data to understand problem
- Problem for publication, for continued work
- Open data as alternatives
 - New York City
 - 76,000 elevators with locations
 - Toronto, ON
 - 40,000 elevators
 - Inspection dates, outcomes
 - Accident and injury reports

What I did not talk about

- Preferences and Incentives
 - Retention of personnel
 - Optimize while taking preferences into account
- Elevator health
 - If you don't do the maintenance, then elevators will fail
- Condition Based Maintenance
 - You can predict some of the failures and prevent them

Conclusions

- We presented the Travelling Repair Person Problem
- Important as an industrial problem
- Interesting as a research challenge
- We use combination of optimization and simulation to deal with novel properties of problem
- System transferred to customer in 2019

Outline

Hybrid Flexible Flowshop with Transportation Times

ASSISTANT SE Use Case

Elevator Maintenance Planning and Scheduling

Other Applications

Other Noteworthy Applications

- NVD LoadBuilder
- Boliden Tara Mines Dewatering
- Dental School Timetabling
- Irish Naval Service Rostering
- Data Centre Load Consolidation
- Scheduling with Time Variable Energy Prices
- Characterizing EDF Power Plants with Timeseries Constraints
- Optical Network Design
- Supplier Selection Problem
- Optimizing UCC's CHP Plant Operation
- CP Conference Paper Assignment Tool

NVD LoadBuilder

- Real-World Problem
 - Deliver cars/vans from factory/ports to dealers
 - Group cars into loads for joint delivery
 - Using specialized transporters with complex configurations
 - Balance distance travelled, utilization of fleet, priority of orders
- Status
 - Operational at customer starting in 2020
 - Start-up company CMC to further develop tool



- Research Challenges
 - Vehicle routing problem with complex capacity constraints
 - Decide which cars to deliver today
 - What impact does this have tomorrow
 - Explaining solutions to end-user
- Solution Approach
 - Decomposition
 - MIP, Constraint Programming, Local Search, Data Analytics

Boliden Tara Mines Dewatering



- Real-World Problem

- When/how to pump water out of mine
- Multiple pumps, reservoirs
- Electricity cost major cost factor
- Safe operation of mine paramount

- Status

- Student-led project with DCU
- Paper at AAAI 2016
- Major flooding event in 2021

- Research Challenges

- Scheduling with uncertain energy prices (real-time tariff)
- Uncertain water ingress depends on operations
- Capacity (min/max) constraints for storage

- Solution Approach

- Electricity price prediction
- Optimization

Dental School Timetabling

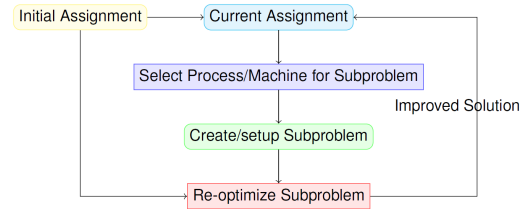
- Real-World Problem
 - Change time table during period of teaching capacity increase
 - Previous schedule no longer feasible
 - Multiple courses share same lab space (dental chairs) at the same time
 - Hard capacity limits on available resources and time slots
- Status
 - Used by dental school during transition period
 - Paper in IAAI 2013, AI Mag 2014



- Research Challenges
 - Very different from standard timetabling problem
 - Hard/soft capacity constraints
 - Tool cleaning setup time constraints
- Solution Approach
 - Optimization
 - Flexible prioritization of constraints

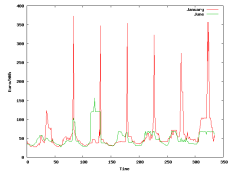
Data Centre Load Consolidation

- Real-World Problem
 - Move virtual machines between servers in a data centre
 - Balance/concentrate workload on multiple resource types
 - Extend to multiple data centres across world
- Status
 - 2nd place in Google Roadef/Euro Challenge 2012
 - Multiple papers



- Research Challenges
 - Reassignment problem
 - Multi-bin packing constraints
 - Large neighbourhood search to deal with problem size
- Solution Approach
 - Optimization
 - New tools/propagators

Scheduling with Time Variable Energy Prices



- Real-World Problem

- How do time-variable electricity prices affect scheduling of use
- Uncertainty of prices, sudden peak prices common in Ireland
- In most cases, we have to commit to production before price is known
- Deal with risk/possible rewards

- Status

- Multiple papers
- Continued work on price prediction with industry

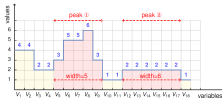
- Research Challenges

- Can we use time variable electricity prices to our advantage?
- Which properties should a price prediction model have to help with scheduling?
- Can we tune price prediction for the use case it is intended for?

- Solution Approach

- Machine Learning
- Optimization

Characterizing EDF Power Plants



- Real-World Problem

- Unit Commitment Model for electricity supply
- Decide which units to run when to satisfy demand/minimize cost
- Change of production for different units is limited over time
- Very error-prone integration into global model

- Status

- Joint work with IMT-Atlantique, EDF Research
- Series of papers on time-series constraints, Volume II of Global Constraint Catalog

- Research Challenges

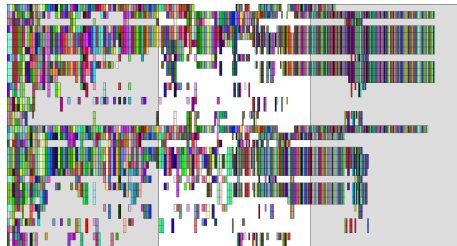
- Can we characterize the production limits of power plants as time-series constraints?
- Learn constraints from historical data (planned/actual)
- Create model of individual plants to describe their capabilities
- Find redundant constraints to overcome limits of propagation

- Solution Approach

- Machine Learning
- Automata constraints
- Generated code for propagators

Optical Network Design

- Real-World Problem
 - Core optical network design
 - Different from traditional IP network design
 - Define paths from source to sink
 - Use multiple frequency (light) bands over same fibre
- Status
 - Paper ICTAI 2014



- Research Challenges
 - Modelling Choices
 - Amount of propagation achieved
 - Scalability of methods
- Solution Approach
 - Global Constraints

Supplier Selection Problem

Texas Instruments  **SN7400N** €0.631 [Add to BOM](#) [Datasheet at TI.com](#) [CAD Models](#) 19

Logic IC Operating temperature: 0...70°C Series: SN7400 Function: Quad / 2 Input / NAND Manufacturer: Texas Instruments Package: D6: 14 Technology: TTL

Distributor	SKU	Stock	MOQ	Pkg		1	10	100	1,000	10,000
• Digi Key	296-146451-5-ND	3,644	1	Tube	EUR	1.39	1.24	0.967	0.631	0.559
• Verical	SN7400N	9,975	525		EUR				0.564	0.564
• Amnet	SN7400N	513	1		EUR*	1.34	1.15	0.884	0.684	0.684
• Farnell	1102927	874	1		EUR	1.32	1.32	0.893	0.617	0.549
• Tistore	SN7400N	5,787	1	Tube	EUR*	1.26	1.12	0.886	0.478	0.478

[Show All](#) [Specs](#) [Descriptions](#) [Manufacturer Page](#)

- Real-World Problem

- Which suppliers to select to provide list of components
- Limit number of suppliers by ordering multiple items from same supplier
- Price/lead time/quality of service are competing objectives

- Status

- Work with industry partner
- Paper in Annals of Operations Research

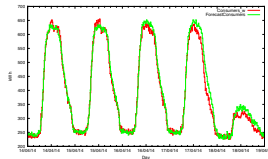
- Research Challenges

- How do we learn which choices are preferred
- Difficult to assign fixed weights to different aspects of solution quality
- Iterative, interactive learning of preferences

- Solution Approach

- Preference Learning
- Optimization

Optimizing UCC's CHP Plant Operation



- Real-World Problem

- When to run UCC's CHP plant to create electricity/heat on-site
- Needs demand forecast for heat and electricity
- Uncertain Real-time grid electricity price
- Heat and electricity demand of campus not in sync

- Status

- Tested for several weeks with operator of plant
- Part of EU Campus21 project

- Research Challenges

- Heat and Electricity Demand prediction for campus
- Price prediction for real-time grid price
- Integration of plant operational constraints
- Wider impact of heating strategy on campus

- Solution Approach

- Machine Learning
- Optimization



- Real-World Problem
 - Which reviewers to assign to papers
 - Consider bids by reviewers, avoid assigning unwanted papers
 - Deal with reviewers shared between multiple tracks
 - Balance assignment between reviewers
 - Allow pre-assignment, specific capacity constraints
- Status
 - Joint work with Data61, INRA
 - Used in 2020, 2021
 - Paper at ModRef 2020

- Research Challenges
 - Fair treatment of papers and reviewers
 - Finding mechanisms to allow Program Chair to control process
 - Not a black-box assignment
 - Integration with easychair
- Solution Approach
 - Optimization

Part III

Success Stories

Success Stories

- Some examples which show impact of CP
- Not just a nice model or a novel constraint
- Impact of solution
- Recognition of CP as best tool for the job

Rosetta/Philae Mission Scheduling, LAAS-CNRS

Unison Compiler, SICS, KTH, Ericsson, 2010-2018

Scheduling of Data Transfer on Philae Lander

- Rosetta/Philae Mission 2004-2014
- Land on a comet
- Perform experiments
- How do the data get back to earth?

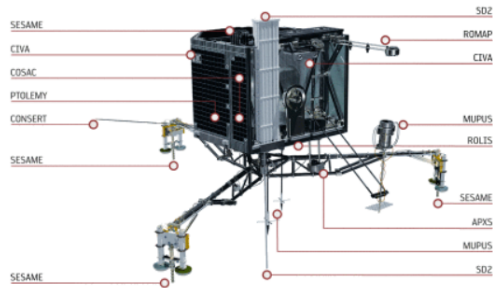


Figure 1. Philae's instruments (© ESA/AOES Medialab)

CP on a Comet?

- Constraint model schedules data transfers between Rosetta (orbiter) and Philae (lander)
- Part of the software suite controlling the lander
- Developed by LAAS-CNRS, Toulouse
 - Running on earth, not in the lander!
- Written in Ilog Scheduler
- To learn more: Simonin et al, 2015: Scheduling scientific experiments for comet exploration
- Also: ACP Website <https://www.a4cp.org/node/1058>

Global Constraint Model

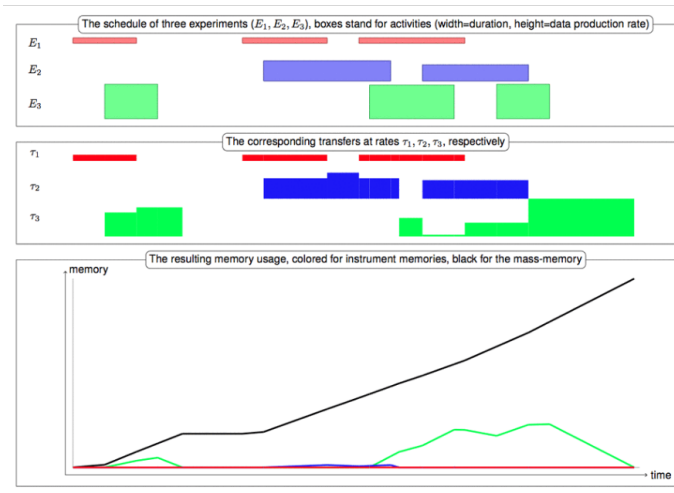
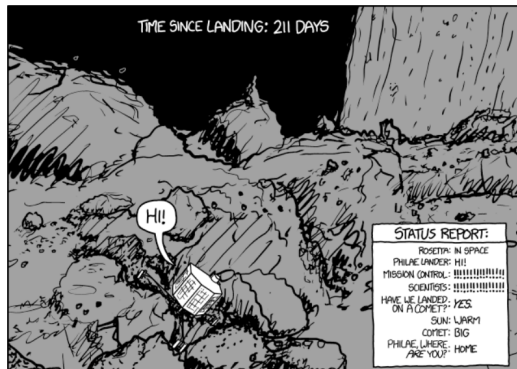


Figure 3. Illustration of the data transfers onboard Philae.

Rosetta/Philae in popular culture

LANDING

|< < PREV RANDOM NEXT > >|



|< < PREV RANDOM NEXT > >|

PERMANENT LINK TO THIS COMIC: [HTTPS://XKCD.COM/1446/](https://xkcd.com/1446/)

Rosetta/Philae Mission Scheduling, LAAS-CNRS

Unison Compiler, SICS, KTH, Ericsson, 2010-2018

- Long-term project to develop CP Based optimising compiler
 - Instruction selection
 - Register allocation
 - Instruction scheduling
- Integrates in **LLVM** toolchain
- Targeted for embedded systems processors

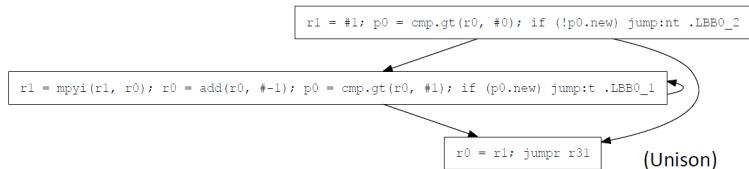
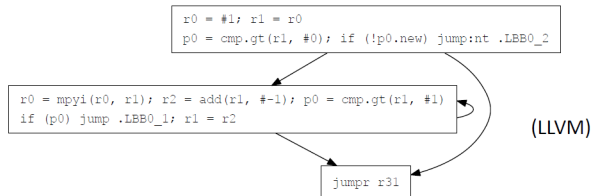
What is the problem?

- Translate high-level language into assembly code
- Map variables to registers and memory
- Map statements to instruction sequences
- Modern processors are powerful, but complicated!
- Complex resource allocation and scheduling problem
- Most compact/ most performant code?
- Must work all the time
- Improvements are shared by all users (huge impact)

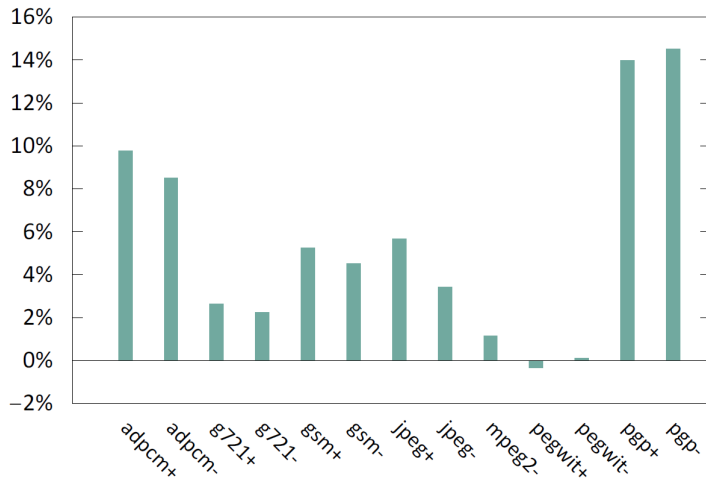
Example High-level Program

```
int fac(int n) {  
    int f = 1;  
    while (n > 0) {  
        f = f * n;  
        n--;  
    }  
    return f;  
}
```


Generated Code Comparison (subtle)



Unison Speedup Compared to LLVM



Conclusions

- State-of-the-art compiler
- Multiplier effect of improvements, everybody wins!
- Significant number of publications outside CP domain
- To learn more: Roberto Castaneda Lozano, NordConsNet 2025: Working in Unison with Mats <https://pierre-flener.github.io/research/NordConsNet/NordConsNet25/>

Part IV

Methodology

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

The Bigger Picture

12 Steps to Success

Constraints in an Uncertain World

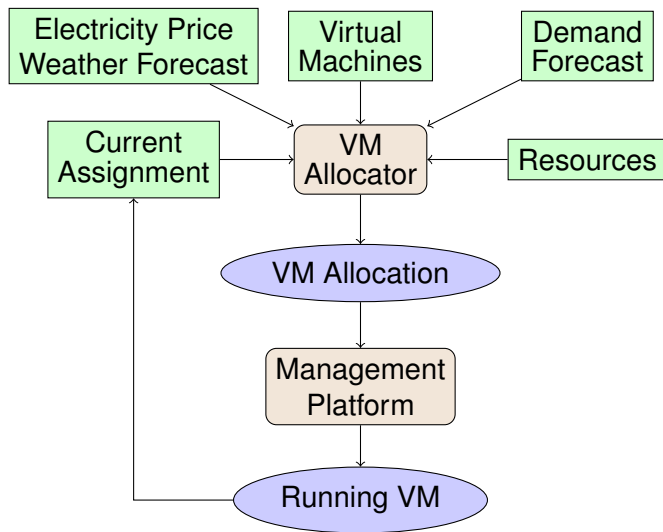
There is no “The Model”

Conclusion

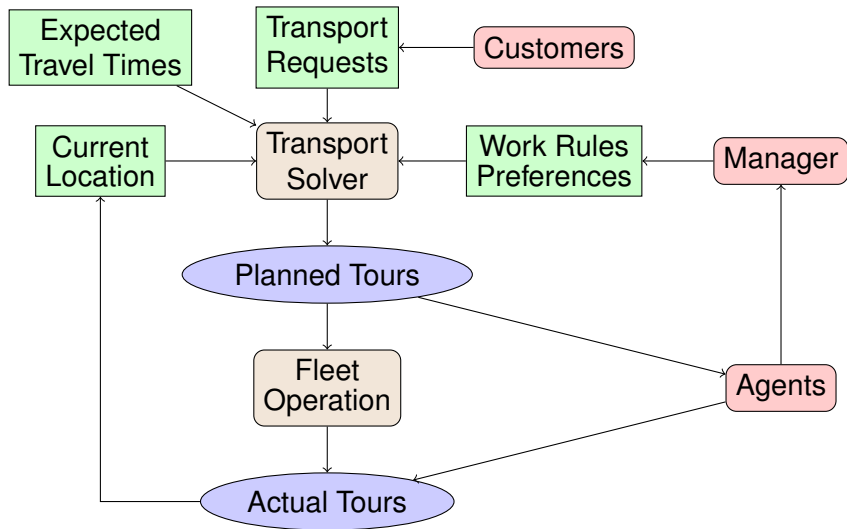
CP Model is Part of a Larger System

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

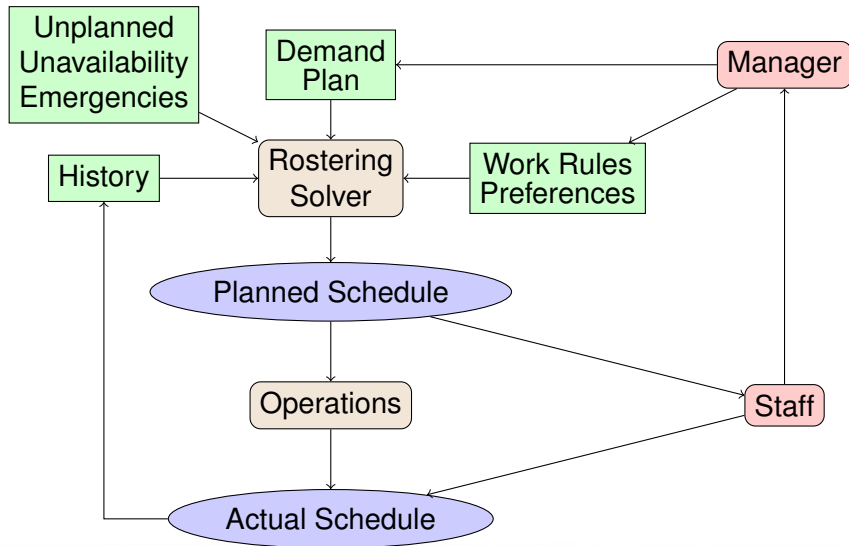
Example: Datacenter Management



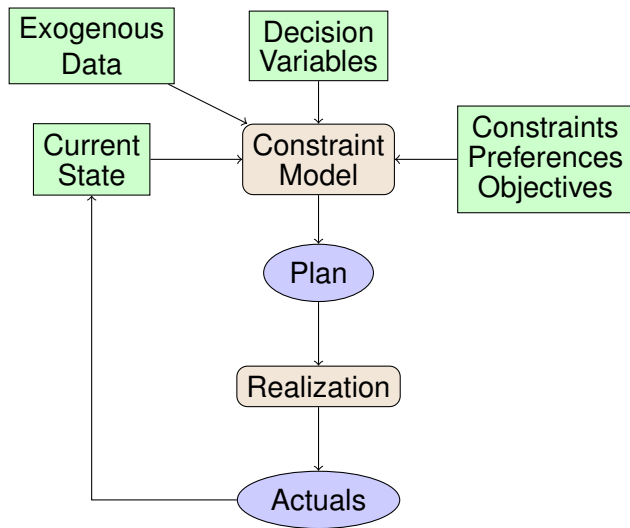
Example: Transport



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

The Bigger Picture

12 Steps to Success

Constraints in an Uncertain World

There is no “The Model”

Conclusion

Step 1: Literature Review

- Which problem are other people solving?
- What are the favourite techniques, 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

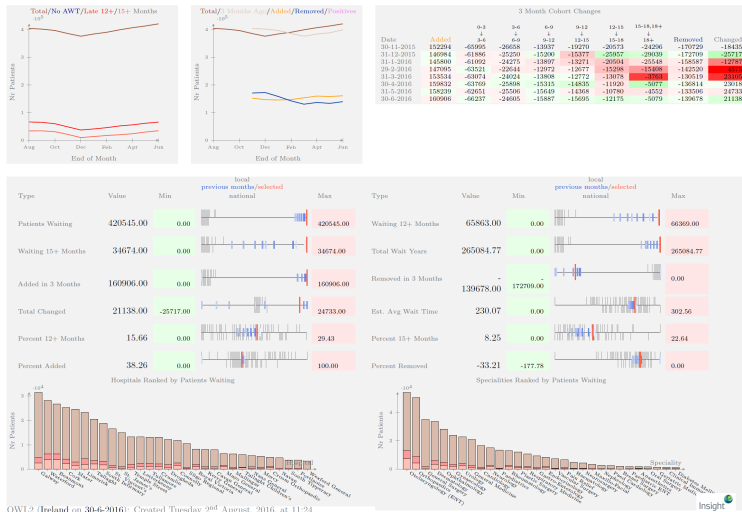
Step 3: Example Data and Solution

- 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



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 Bigger Picture

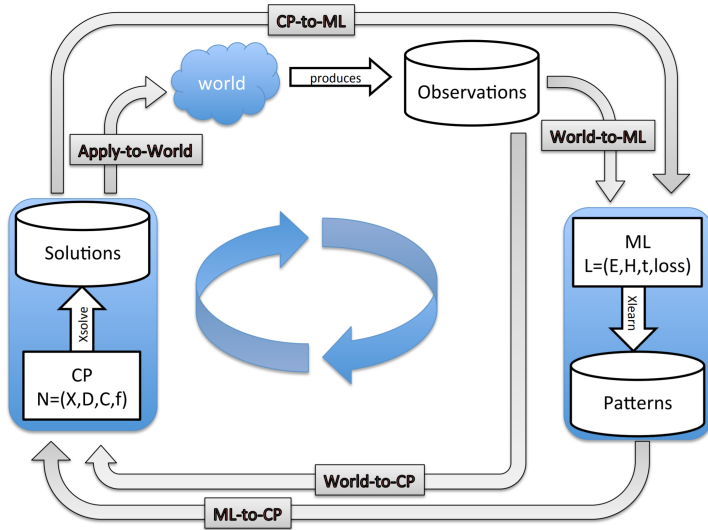
12 Steps to Success

Constraints in an Uncertain World

There is no “The Model”

Conclusion

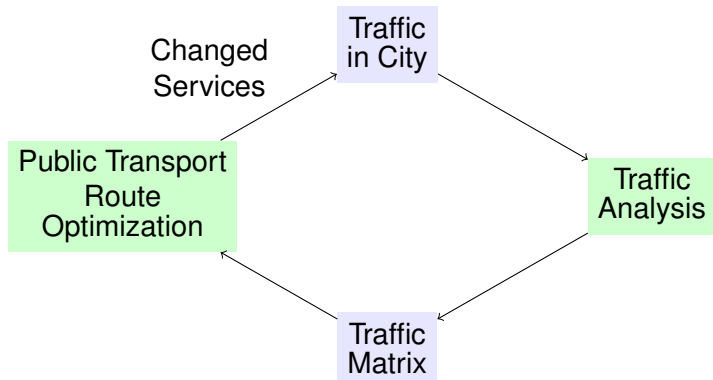
The ICON Loop



A Blueprint for Interaction

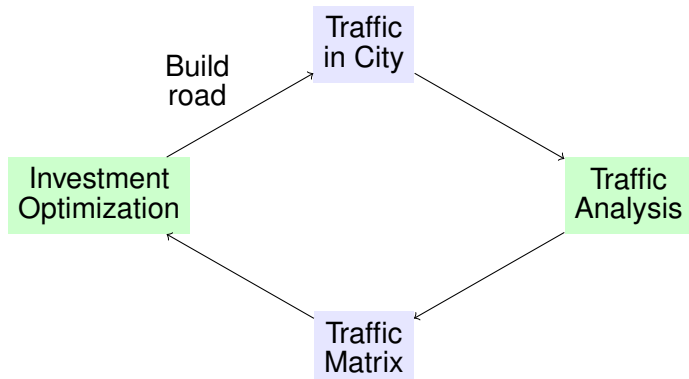
- Developed in the European ICON project
- Partners KU Leuven, Montpellier, Pisa, UCC
- Ways of combining Machine Learning with CP

Example: Intra-City Transport



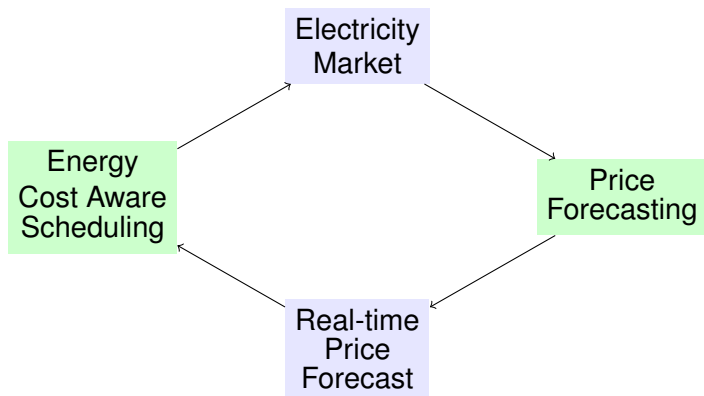
- Optimization only as good as data feeding into it

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

The Bigger Picture

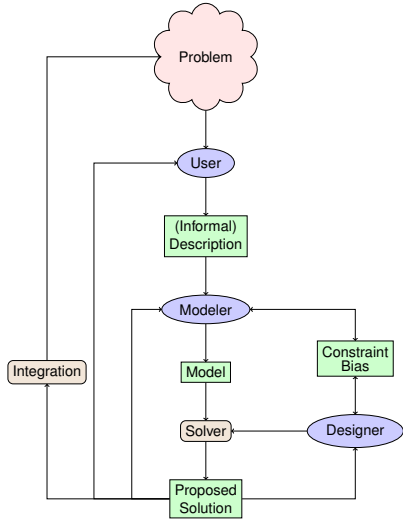
12 Steps to Success

Constraints in an Uncertain World

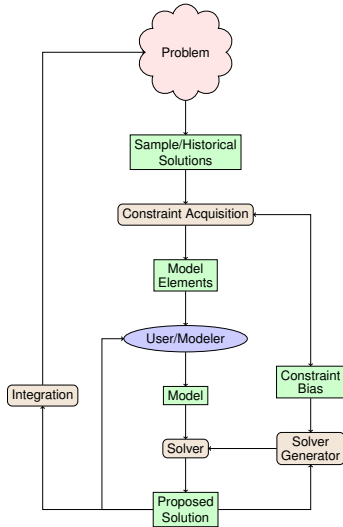
There is no “The Model”

Conclusion

Feedback Loops in Modelling



The Future: Automated Modelling



Outline

The Bigger Picture

12 Steps to Success

Constraints in an Uncertain World

There is no “The Model”

Conclusion

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

Part V

Additional Resources

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Tools already discussed in Summer School

- MiniZinc
- CPMpy
- Glasgow Constraint Solver

Other Academic Solvers

- Gecode (KTH, Sweden)
- Choco-solver (IMT Atlantique, France)
- MiniCP (Louvain, U Conn, Georgia Tech)
- MaxiCP (Louvain, U Conn, Georgia Tech)
- SICStus Prolog (RISE, Sweden)

Commercial Tools

- **CP Optimizer**
 - P. Laborie et al, 2018: IBM ILOG CP optimizer for scheduling 20+ years of scheduling with constraints at IBM/ILOG
- **CP-Sat**
 - L. Perron et al, Invited Talk, CP 2023: The CP-SAT-LP Solver
 - [Video in Scheduling Seminar](#)
- **OptalCP**
 - P. Vilim, Invited Talk, CP 2023: CP Solver Design for Maximum CPU Utilization
 - [Video in Scheduling Seminar](#)
- **Hexaly**
 - T. Benoist, Tutorial at CP 2026
 - [Video in Scheduling Seminar](#)

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- Workshops on Teaching CP at CP 2015, CP 2023
<https://hsimonis.github.io/WTCP2023/index.html>
- Survey of teaching materials with Tejas Santanam (Georgia Tech)
- Available at <https://arxiv.org/abs/2403.12717>

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IBM and Constraint Programming

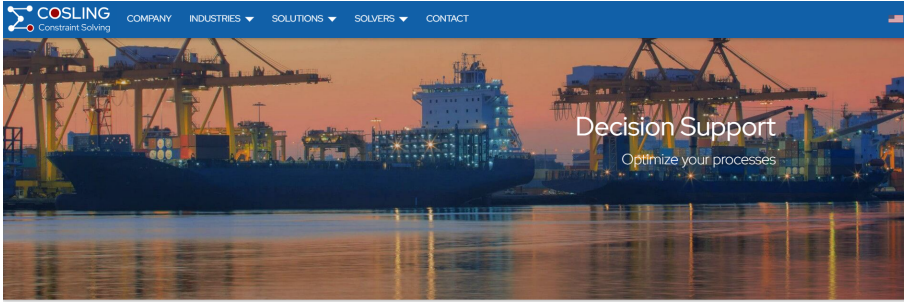
Constraint programming technology is used to find solutions to scheduling and combinatorial optimization problems. It is based primarily on computer science fundamentals, such as logic programming and graph theory, in contrast to mathematical programming, which is based on numerical linear algebra.

Constraint programming is invaluable when dealing with the complexity of many real-world sequencing and scheduling problems.

IBM (<https://ibmdecisionoptimization.github.io/docplex-doc/cp.html>)

Examples

- Cosling, France
- OptalCP, France, Czech Republic
- Hexaly, France
- Keelvar, Ireland
- Opturion, Australia
- Optix Solutions, Hong Kong



Choco Solver within our applications

 OptalCP

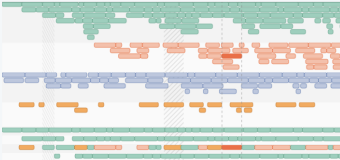
[Quick Start](#) [Guide](#) [Reference ▾](#) [Benchmarks](#)

[Blog](#) [What's New](#) [Resources](#) [Team](#) 

The **scheduling** engine for complex operations.

A modern Constraint Programming engine for real factories, warehouses, and crews. Benchmarked against CP Optimizer and winning.

[Quick Start →](#) [View Benchmarks](#)



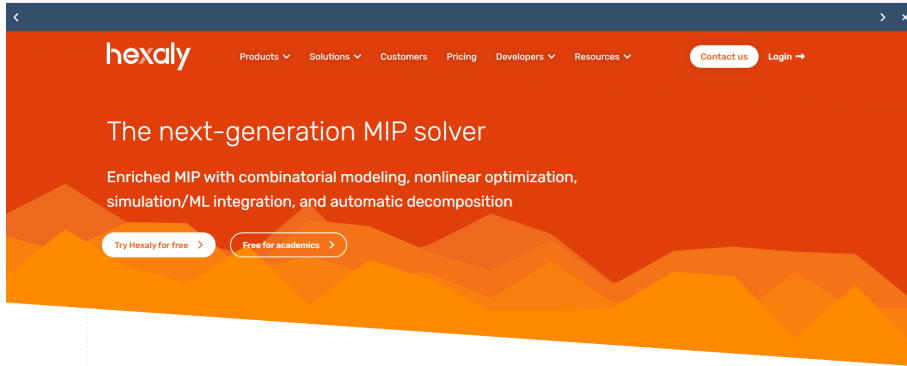
01 · ENGINE

Why OptalCP?

 Industrial

 Fast

 Familiar

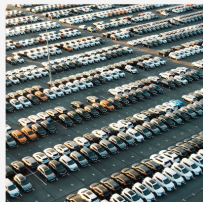


DISCOVER OUR CUSTOMERS

Trusted by 400 companies



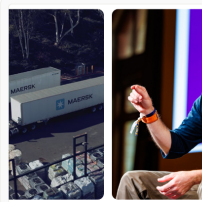
Newport Tank Containers Frees Up 200+ Hours in Ocean Freight Sourcing with Keelvar + Xeneta



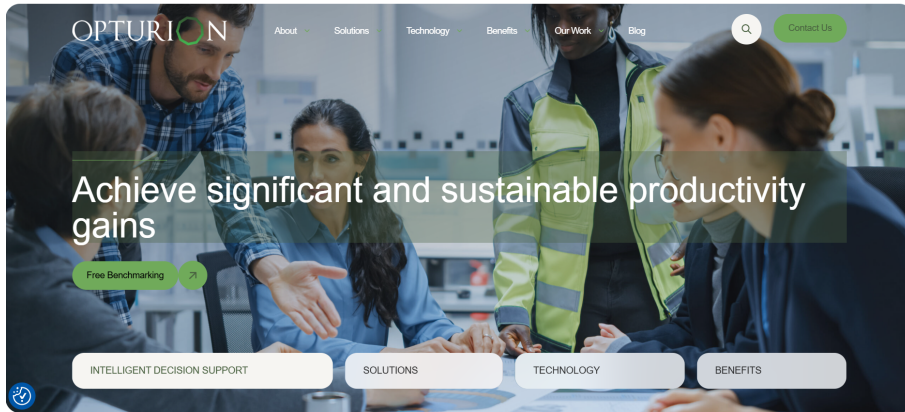
Nissan Scales Sourcing Excellence with Keelvar Sourcing Optimizer & Autonomous Sourcing



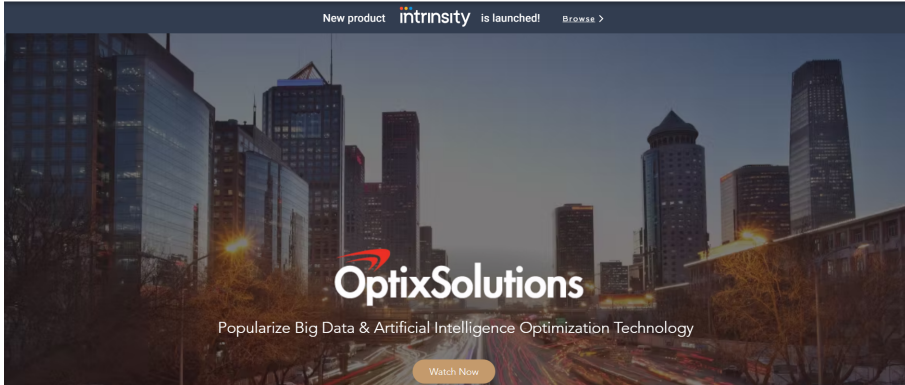
ABF Transforms Freight & Logistics Procurement with Keelvar



Maersk Scales Sourcing Excellence with Keelvar Sourcing Optimizer & Autonomous Sourcing



Optix Solutions



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- Getting started in field can be overwhelming
- A lot of work has been done
- What is most relevant?
- What is most related to what I want to do?
- Where should I publish?
- Getting to know the community

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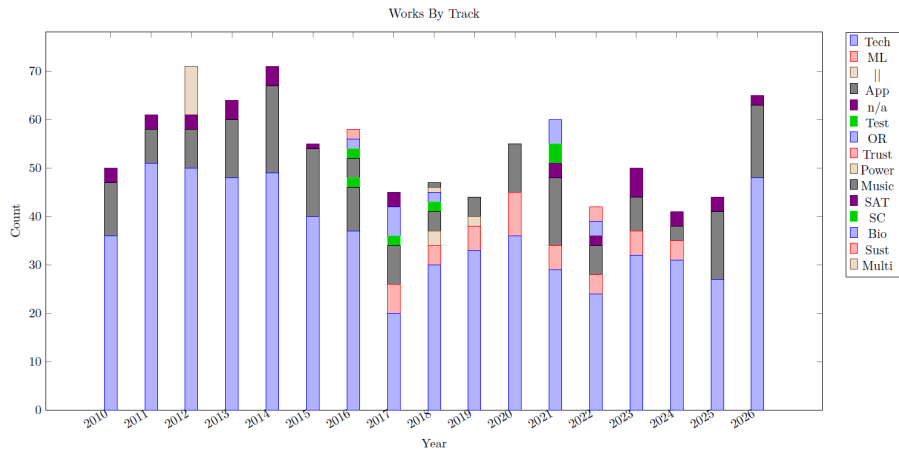
Constraints Journal

CP and Scheduling

Summary

- Organised by Association for Constraint Programming (ACP)
- Yearly since 1995
- Special application track since 2002
- CP 2027 will be here in Jilin
- Survey of all papers since 2010
- Online version at
<https://hsimonis.github.io/pthg24/cpconference.pdf>

CP Conference Papers by Track



CP Conference Award Winning Papers

Key Source	Authors	Title (Colored by Open Access)	Details LC	Cite	Year	Conference /Journal /School /SubType /Award	Pages /Linked /Topical	Relevance	Cites OC XR SC	Refs OC XR	Links Cites Refs
SchausAG17 SchausAG17*	P. Schaus, J. O. R. Aaga, T. Guns	CoverSize: A Global Constraint for Frequency-Based Itemset Mining*	Details Yes	764	2017	CP 2017 ML	18 1.00 1.00 18.70		16 14 30	28 39	8 4 4
BoothNB16 BoothNB16*	K. E. C. Booth, G. Nejat, J. C. Beck	A Constraint Programming Approach to Multi-Robot Task Allocation and Scheduling in Retirement Homes*	Details Yes	137	2016	CP 2016 App	17 2.00 2.00 20.70		25 24 36	24 31	0 0 0
Carbonnel16 Carbonnel16*	C. Carbonnel	The Dichotomy for Conservative Constraint Satisfaction is Polynomially Decidable*	Details Yes	160	2016	CP 2016 Student	17 2.00 2.00 23.30		3 3 6	15 19	0 0 0
DvijothamCHVM17 Dvijotham-CHVM17*	K. Dvijotham, M. Chertkov, P. V. Hentenryck, M. Vuffray, S. Misra	Graphical models for optimal power flow*	Details Yes	289	2016	Constraints An Int. J.	26 0.00 0.00 11.50		16 14 13	15 29	1 0 1
ManloveMT17 ManloveMT17*	D. F. Manlove, I. McBride, J. Trimble	"Almost-stable" matchings in the Hospitals / Residents problem with Couples*	Details Yes	608	2016	Constraints An Int. J.	23 0.00 0.00 14.40		17 15 26	24 42	0 0 0
PapadopoulosRP16 PapadopoulosRP16*	A. Papadopoulos, P. Roy, F. Pachet	Assisted Lead Sheet Composition Using FlowComposer*	Details Yes	688	2016	CP 2016 Music	17 0.00 0.00 7.50		32 29 45	9 15	1 0 1
CofrinHH15 CofrinHH15*	C. Cofrin, H. L. Hijazi, P. V. Hentenryck	Strengthening Convex Relaxations with Bound Tightening for Power Network Optimization*	Details Yes	201	2015	CP 2015	19 0.00 0.00 16.00		37 34 51	30 41	2 2 0
Hooker16a Hooker16a*	J. N. Hooker	Projection, consistency, and George Boole*	Details Yes	421	2015	Constraints An Int. J.	18 0.00 0.00 22.40		5 5 6	35 48	1 0 1
IvriiMMV16 IvriiMMV16*	A. Ivrii, S. Malik, K. S. Meel, M. Y. Vardi	On computing minimal independent support and its applications to sampling and counting*	Details Yes	447	2015	Constraints An Int. J. Student	18 0.00 0.00 7.50		36 37 56	18 33	3 1 2
KilbyU16 KilbyU16*	P. Kilby, T. Urii	Fleet design optimisation from historical data using constraint programming and large neighbourhood search*	Details Yes	493	2015	Constraints An Int. J. App	20 2.00 2.00 15.00		8 8 8	17 20	1 1 0
CooperMTZ14 CooperMTZ14*	M. C. Cooper, A. E. Mouelhi, C. Terrioux, B. Zanuttini	On Broken Triangles*	Details Yes	221	2014	CP 2014	16 0.00 0.00 10.40		9 8 22	9 12	3 3 0
MartinsJML14 MartinsJML14*	R. Martins, S. Joshi, V. Manquinho, F. Lynce	Incremental Cardinality Constraints for MaxSAT*	Details Yes	616	2014	CP 2014	18 1.00 2.00 27.00		42 42 87	0 0	9 9 0
MossigeGM14 MossigeGM14*	M. Mossige, A. Gottlieb, H. Meling	Using CP in Automatic Test Generation for ABB Robotics' Paint Control System*	Details Yes	651	2014	CP 2014 App	17 1.00 1.00 11.50		12 12 13	10 16	3 2 1
NguyenL14 NguyenL14*	T. Nguyen, A. Lallouet	A Complete Solver for Constraint Games*	Details Yes	667	2014	CP 2014	17 1.00 1.00 15.10		2 2 6	2 0	1 1 0
OztokD14 OztokD14*	U. Oztok, A. Darwiche	On Compiling CNF into Decision-DNNF*	Details Yes	681	2014	CP 2014 Student	16 0.00 0.00 0.60		14 15 31	0 0	2 2 0
CambazardMOS13 CambazardMOS13*	H. Cambazard, D. Mehta, B. O'Sullivan, H. Simonis	Bin Packing with Linear Usage Costs - An Application to Energy Management in Data Centres*	Details Yes	153	2013	CP 2013 App	16 0.00 0.00 9.60		14 13 16	16 20	1 0 1

CP Conference Most Cited Papers

Table 124: Most Cited Works (Total 30)

Key Source	Authors	Title (Colored by Open Access)	Details LC	Cite	Year	Conference /Journal /School /SubType /Award	Pages /Linked /Topical	Relevance	Cites OC XR SC	Refs OC XR	Links Cites Refs
DaviesB11 DaviesB11	J. Davies, F. Bacchus	Solving MAXSAT by Solving a Sequence of Simpler SAT Instances	Details Yes	241	2011	CP 2011	15	1.00 1.00 13.10	73 61 144	8 15	19 18 1
KadiogluMSSS11 KadiogluMSSS11*	S. Kadioglu, Y. Malitsky, A. Sabharwal, H. Samulowitz, M. Sellmann	Algorithm Selection and Scheduling*	Details Yes	175	2011	CP 2011	16	0.00 0.00 8.70	72 65 131	15 41	5 5 0
ChakrabortyMV13 ChakrabortyMV13*	S. Chakraborty, K. S. Meel, M. Y. Vardi	A Scalable Approximate Model Counter*	Details Yes	174	2013	CP 2013	17	0.00 0.00 4.00	70 69 127	23 37	2 2 0
BeldiceanuS12 BeldiceanuS12	N. Beldiceanu, H. Simonin	A Model Seeker: Extracting Global Constraint Models from Positive Examples	Details Yes	87	2012	CP 2012	17	2.00 2.00 23.90	56 47 112	21 31	13 12 1
MorgadoDM14 MorgadoDM14	A. Morgado, C. Dodaro, J. Marques-Silva	Core-Guided MaxSAT with Soft Cardinality Constraints	Details Yes	649	2014	CP 2014 ShortPaper	10	2.00 2.00 15.20	45 41 102	19 22	11 9 2
MartinsJML14 MartinsJML14*	R. Martins, S. Joshi, V. Manquinho, L. Lynce	Incremental Cardinality Constraints for MaxSAT*	Details Yes	616	2014	CP 2014	18	1.00 2.00 27.00	42 42 87 0 0	9 9 0	
Gelder12 Gelder12	A. V. Gelder	Contributions to the Theory of Practical Quantified Boolean Formula Solving	Details Yes	346	2012	CP 2012	17	0.00 0.00 8.50	47 45 78 23 28	2 1 1	
AudemardS12 AudemardS12*	G. Audemard, L. Simon	Refining Restarts Strategies for SAT and UNSAT*	Details Yes	62	2012	CP 2012 ShortPaper	9	1.00 1.00 7.90	33 39 77 7 13	5 5 0	
HodaHH10 HodaHH10*	S. Hoda, W. J. van Hoeve, J. N. Hooker	A Systematic Approach to MDD-Based Constraint Programming*	Details Yes	417	2010	CP 2010	15	3.00 3.00 28.80	49 50 73 6 8	10 10 0	
ReginRM13 ReginRM13	J.-C. Regin, M. Rezagui, A. Malapert	Embarrassingly Parallel Search	Details Yes	740	2013	CP 2013	15	0.00 0.00 4.60	42 38 67 9 18	6 5 1	
DaviesB13 DaviesB13	J. Davies, F. Bacchus	Postponing Optimization to Speed Up MAXSAT Solving	Details Yes	242	2013	CP 2013	16	0.00 0.00 6.60	33 27 63 14 17	7 5 2	
Demeule-naereHLP16 Demeule-naereHLP16	J. Demeule-naere, R. Hartort, C. Lecoutre, G. Perez, L. Perron, J.-C. Regin, P. Schaus	Compact-Table: Efficiently Filtering Table Constraints with Reversible Sparse Bit-Sets	Details Yes	262	2016	CP 2016	17	1.00 1.00 12.10	23 20 60 20 35	8 5 3	
IgnatievPLM15 IgnatievPLM15	A. Ignatiev, A. Previti, M. H. Liffitoy, J. Marques-Silva	Smallest MUS Extraction with Minimal Hitting Set Dualization	Details Yes	434	2015	CP 2015 ShortPaper	10	0.00 0.00 3.50	29 27 60 16 19	6 5 1	
NagarajanLYB16 NagarajanLYB16	H. Nagarajan, M. Lu, E. Yamangil, R. Bent	Tightening McCormick Relaxations for Nonlinear Programs via Dynamic Multivariate Partitioning	Details Yes	657	2016	CP 2016	19	0.00 0.00 6.70	40 43 56 23 25	1 0 1	
IvritMMV16 IvritMMV16*	A. Ivrit, S. Malik, K. S. Meel, M. Y. Vardi	On computing minimal independent support and its applications to sampling and counting*	Details Yes	447	2015	Constraints An Int. J. Student	18 CP 2015	0.00 0.00 7.50	36 37 56 18 33	3 1 2	

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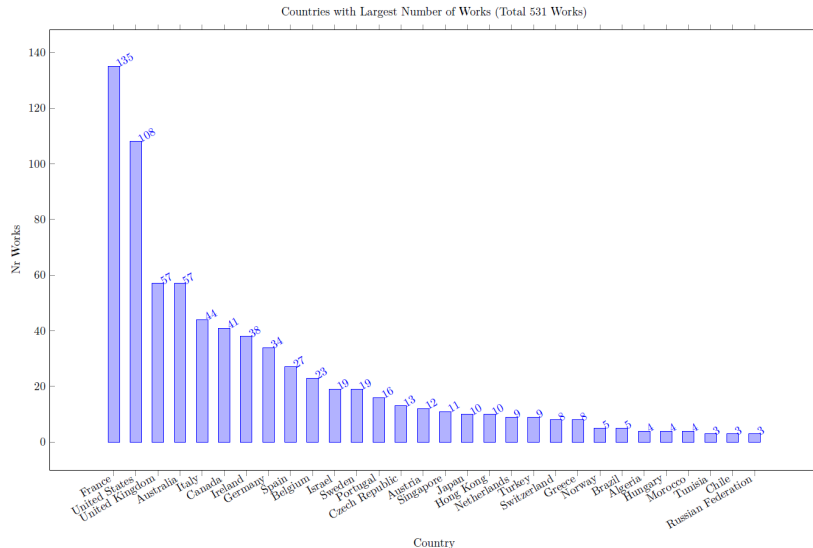
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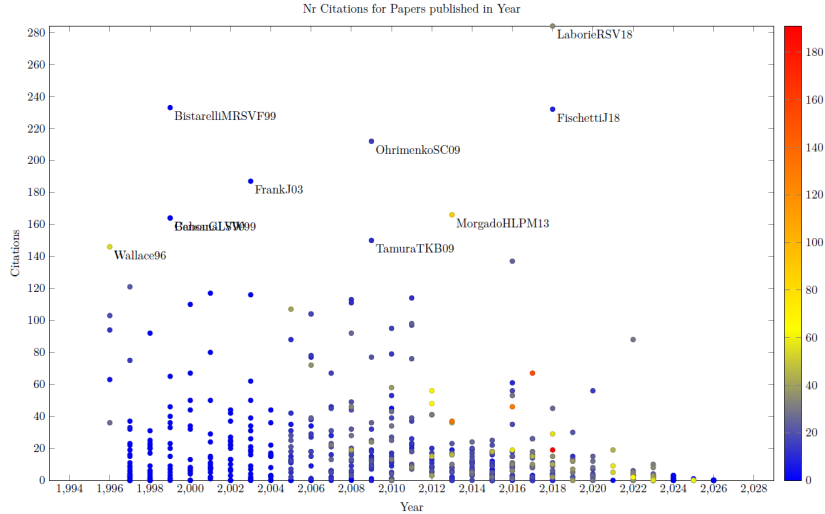
Constraints Journal

- Shameless plug by EiC (me)
- Published by Springer
- 30 years, started in 1996
- Often publishes extended versions of CP/CPAIOR conference papers
- Also longer form original articles
- Submissions welcome!
- Survey online version at
<https://hsimonis.github.io/pthg24/constraints.pdf>
- A data analysis at
<https://hsimonis.github.io/pthg24/slidescp2026.pdf>

Constraints Journal Articles by Country



Constraints Journal Citations



Constraints Journal Special Issues

Table 55: Special Issues (Total 43)

Name	Short Name	Topic	Based on Conference	Nr Articles
Special1	30th Anniv.	30th Anniversary Issue	false	13
Special2	CPAIOR 2020	Special Issue on Fast Track CPAIOR 2020	true	5
Special3	CPAIOR 2018	Special Issue on Fast Track CPAIOR 2018	true	4
Special4	CPAIOR 2017	Special Issue on Fast Track CPAIOR 2017	true	5
Special5	20th Anniv.	20th Anniversary Issue	false	5
Special6	CPAIOR 2016	Fast track issue for CPAIOR 2016	true	4
Special7	CP 2016	Fast track issue for CP 2016	true	5
Special8	CP 2015	CP 2015	true	7
Special9	CPAIOR 2015	Fast track issue for CPAIOR 2015	true	6
Special10	CSP in AI	CSP technologies in artificial intelligence	false	5
Special11	Future	Looking into the crystal-ball: a bright future for CP	false	7
Special12	ModRef	Special issue on constraint modelling and reformulation	false	6
Special13	Plan/Schedule	Constraint satisfaction for planning and scheduling problems	false	5
Special14	Preferences	Special issue on Constraint-based approaches to Preference Modelling and Reasoning	false	6
Special15	CP 2007	Special issue on CP 2007	true	5
Special16	CP 2008	Special issue on CP 2008	true	6
Special17	QCSP	Special issue on quantified CSPs and QBF	false	6
Special18	Modelling	Special Issue on Abstraction and Automation in Constraint Modelling	false	6
Special19	Bio	Special Issue on Bioinformatics and Constraints	false	8
Special20	Global	Special Issue on Global Constraints	false	4
Special21	Local Search	Special Issue on Local Search Techniques in Constraint Satisfaction	false	6
Special22	CPAIOR 2005	Special Issue on CPAIOR 2005	true	6
Special23	CP 2005	Special Issue on CP 2005	true	6
Special24	CP 2002	Special Issue on CP 2002	true	5
Special25	CP 2003	Special Issue on CP 2003	true	5
Special26	CP 2004	Special Issue on CP 2004	true	6
Special27	Interaction	Special Issue on User-Interaction in Constraint Satisfaction	false	5
Special28	Soft	Soft Constraints	false	5
Special29	Agents	Special Issue on Constraint Agents	false	4
Special30	CP 1998/99	CP 1998, CP 1999	true	10
Special31	CP 2000	CP 2000	true	6
Special32	Planning	Special Issue on Planning	false	4
Special33	Bio	Special Issue on Bioinformatics	false	8
Special34	Multimedia	Special Issue on Constraints for Multimedia Artistic Applications	false	6
Special35	Scheduling	Special Issue on Industrial Constraint-Directed Scheduling	false	4
Special36	CP 1997	CP 1997	true	7
Special37	CLP	Constraint Logic Programming	false	5
Special38	CP 1996	CP 1996	true	5
Special39	Graphics	Constraint-based graphics and visualization	false	5
Special40	Temporal	Constraints on Spatial and Temporal Reasoning	false	10
Special41	Interval	Interval Constraints	false	6
Special42	Databases	Constraints and Databases	false	6
Special43	Strategic	Strategic Directions for Computing Science	false	14

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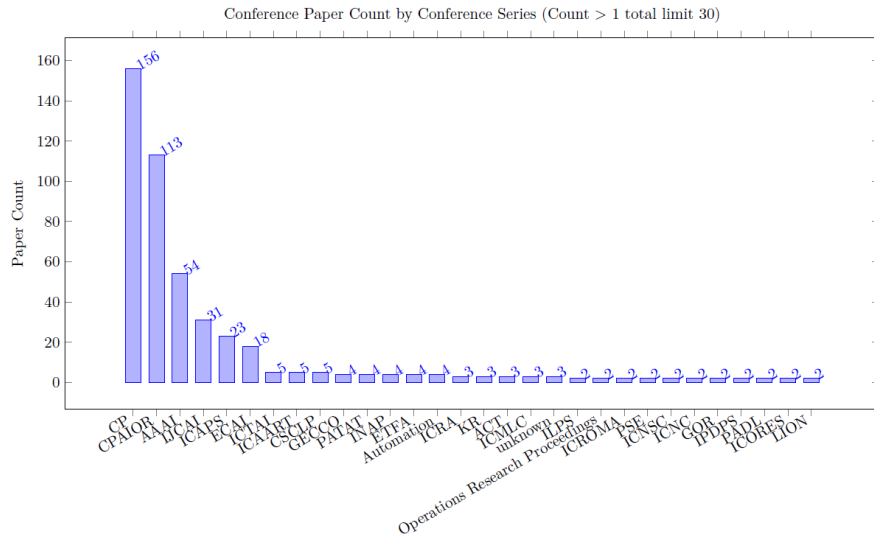
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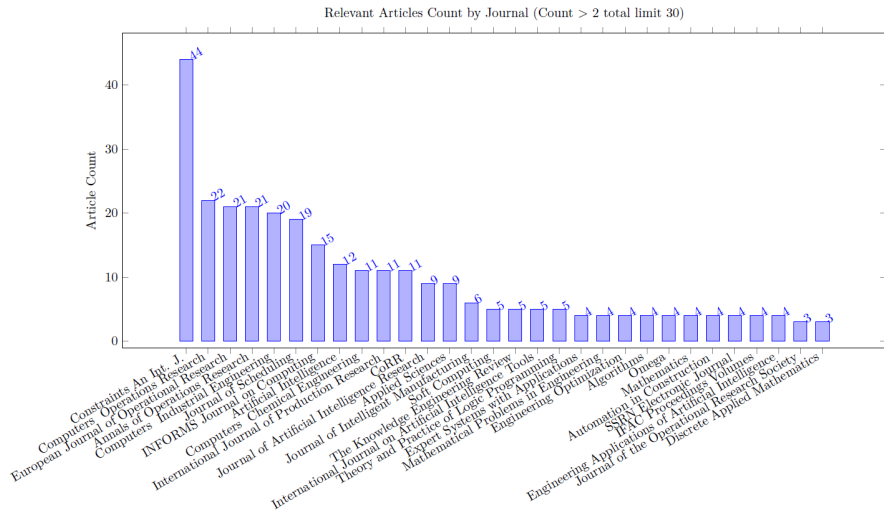
- Joint work with Cemal Ozturk (MTU)
- Overview of works combining CP with scheduling
- Works since 1980
- Survey online at

<https://hsimonis.github.io/pthg24/scheduling.pdf>

CP & Scheduling Conferences



CP & Scheduling Journals

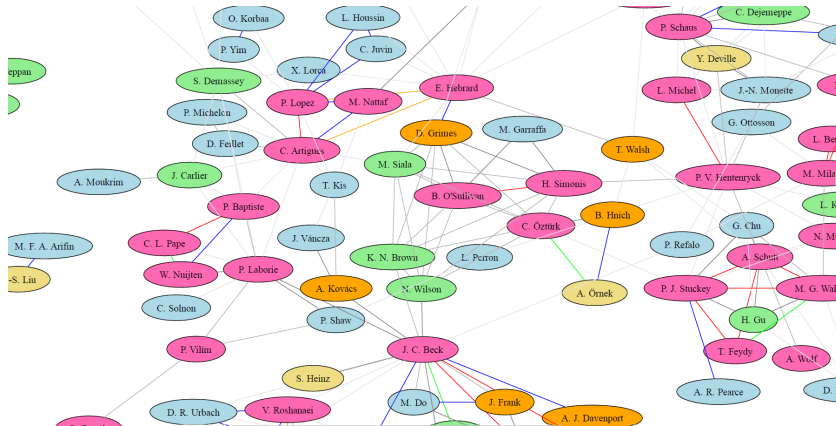


CP & Scheduling Prolific Authors

Table 6: Co-Authors of Articles/Papers (Total 2104 Names)

Author	Nr Works	Nr Cites	Entries
J. Christopher Beck	61	959	Zhang2025, Green24, LuoB22, ZhangBB22, TangB20, RoshanaeiBAUB20, SenderovichBB19, TranPZLDB18, TranVNB17, TranVNB17a, CohenHB17, BoothNB16, KuB16, TranAB16, TranWDKFOVB16, LuoVLBM15, TranDRFNOVB15, BoothFN15, BajestaniB15, KoschB14, BeckhoerT14, LouiVNB14, LetortBC13, IsjostenB13, HeintzB12, TravelleyDOB12, TranB12, TranB12, ZarembkiB12, KovacsB11, BeckFW11, HeckmanB11, BajestaniB11, Beck10, WBB99, BidotVLB09, CarcinacB09, WatsonB08, KovacsB08, BeckW07, Beck07, KovacsB07, BidotVLB07, Beck06, Bidot2006, CarcinacB05, WuB05, BeckW05, BeckW04, BeckR03, BeckP503, BeckF00, BeckF00a, Beck59, BeckP99, BeckF98, BeckDDF98, BeckDF97, BeckDSF97, BeckDSF97a
Michela Milano	36	365	BorghesiBLMB18, BonfiettiLBM16, BridiBLMB16, BridiLBBM16, LombardiBM15, BartoliniBBLM14, BonfiettiLM14, BonfiettiLBM14, Reale2014, BonfiettiLM13, LombardiM13, LombardiMB13, LombardiM12, BonfiettiLBM12, LombardiM12a, BonfiettiLM12, BonfiettiLBM11, LombardiBMB11, BeniniLMR11, Milano11, LombardiM10, LombardiM10a, LombardiMRB10, LombardiM09, RuggieroBDBM09, MilanoW09, BeniniLMR08, BeniniLMR08a, BeniniLMR06, BeniniLMR05, BeniniRM05, BeniniBGM05, BeniniZOR102, BeniniM01, LammaMM07, BrusoniCLM196
Michele Lombardi	27	240	BorghesiBLMB18, CauvelierLS18, BridiBLMB16, BridiLBBM16, LombardiBM15, CauvelierLS15, BartoliniBBLM14, BonfiettiLM14, BonfiettiLBM14, BonfiettiLM13, LombardiM13, LombardiMB13, LombardiM12, BonfiettiLBM12, LombardiM12a, BonfiettiLBM11, LombardiBMB11, BeniniLMR11, BeniniLMR11a, LombardiM10, LombardiM10a, LombardiM10, LombardiMRB10, LombardiM09, BeniniLMR08, BeniniLMR08a, HoeveGSL07
Andreas Schutt	27	369	YangSS19, KreterSSZ18, GoldwasserS18, MusluSS18, KreterSS17, YoungFS17, GoldwasserS17, SchuttS16, SzecediS16, KreterSS15, EvenSH15, EvenSH15a, SchuttFSW15, ThiruvadyWGS14, GuSSWC14, SchuttFS13, SchuttFS13a, GuSS13, SchuttFSW13, ChuGNSW13, SchuttCSW12, SchuttFSW11, Schutt11, SchuttW10, abs-1099-0347, SchuttFSW09, SchuttW305
John N. Hooker	25	1783	ElGHO22, Hooker19, HechingHK19, Hooker17, HookerH17, HechingH16, CireCHI16, HarjunokoskiMBC14, CireCH13, CobanH11, CobanH10, Hooker10, Hooker07, Hooker06, Hooker06a, Hooker05, Hooker05a, Hooker05b, Hooker04, Hooker003, HookerY02, Hooker02, Hooker00, HookerOTK00, HookerO99
Peter J. Stuckey	25	517	GokGSTO20, YangSS19, DemirovicS18, KreterSSZ18, MusluSS18, KreterSS17, SchuttS16, BlomPS16, KreterSS15, BartLPS15, SchuttFSW15, BlomBPS14, LipovetzkyBPS14, GuSSWC14, SchuttFS13, SchuttFS13a, GuSS13, SchuttFSW13, SchuttCSW12, GuSW12, SchuttFSW11, Ban-tesC11, abs-1009-0347, SchuttFSW09, OrlinenskoSC09
Nysret Muslu	24	76	Danzinger2024, GeibingerMM24, LacknerMMW23, Danzinger2023, Eiter2023, WinterMMW22, LacknerMMW22, GeibingerKMMW21, GeibingerMM21, KletzanderMH21, Mischek2021, Mischek2021a, Eiter2021, KletzanderM20, Danzinger2020, GeibingerMM19, abs-1911-04766, Geiger2019, MusluSS18, KletzanderM17, ErkinerM17, Trieka2011, Muslu05
Pierre Lopez	23	232	Rouzo2025, JuvinHHL23, JuvinHL23a, JuvinHL23, HebrardALLCMR22, JuvinHL23, Polo-MejiaALB20, NattaHKA19, NattaAL17, NattaALR16, SimoninAHL15, NattaAL15, ArtiguesL14, ArtiguesLH13, SimoninAHL12, BillautHL12, LahimerLH11, TrojetHL11, Artigues2011, BriandHHL08, EsquiroLH2008, LopezAKYG00, TorresL00
Christian Artigues	22	410	Rouzo2025, PovedaA23, PotlAK22, HebrardALLCMR22, ArtiguesHQT21, Polo-MejiaALB20, NattaHKA19, NattaAL17, NattaALH16, SimoninAHL15, NattaAL15, SlaiaAH15, ArtiguesL14, ArtiguesLH13, SimoninAHL12, Artigues2011, Mat2011, ArtiguesP07, NeronABCD06, De-mauesAM09, ArtiguesBF04, ArtiguesR00
Mark G. Wallace	22	554	WallaceY20, HeGOLDW18, SchuttFSW15, ThiruvadyWGS14, GuSSWC14, SchuttFSW13, SchuttCSW12, GuSW12, SchuttFSW11, abs-1009-0347, SchuttFSW09, MilanoW09, MilanoW06, Wallace06, AjiliW04, EreminW01, SakountW00, RodosekWH99, RodosekV98, SakountRW98, Wallace64, Wallace64a
Emmanuel Hebrard	21	77	Antuori2025, Hebrard2025, Luchterhand2025, Rouzo2025, JuvinHHL23, HebrardALLCMR22, AntuoriIHEN21, ArtiguesHQT21, GodetLHS20, AntuoriIHEN20, HebrardHMV19, SimoninAHL15, SlaiaAH15, GrimesH15, BensierHMQW14, SimoninAHL12, BillautHL12, GrimesH11, GrimesH10, GrimesM09, HebrardTWO9
Pascal Van Hentenryck	18	329	KotaryPH22, KletzanderMH21, FontaineMH16, EvenSH15, EvenSH15a, Michel2012, SchausHMCMD11, PacinoH11, MonetteDH09, Michel2009, DoomsH08, HentenryckM08, MercierH08, MercierH07, HentenryckM04, Michel2004, Hentenryck2000, DincheasSH90
Philippe Laborie	18	633	LunardiBLR20, LaborieFSV18, Laborie18a, Laborie2017, MelgarejoLS15, VilimLS15, LaborieR14, Laborie2011, Laborie09, BidotVLB09, BidotVLB07, BapstisteLPN06, NeronABCD06, Bidot2006, GodardLN05, Laborie05, Laborie03, FocacciaLN00
Pierre Schaus	18	102	Legrand2025, Thomas2024, CauvelierDS20, ThomasK20, HompsSW19, CappartFSR18, CauvelierLS18, CappartS17, CauvelierDMS16, De-mauesAM15, CayHLS15, CayHLS15a, CauvelierLS15, HompsSW14, CaySS14, SchausHMCMD11, SchausD08
Helmut Simonin	18	168	Carrafin2025, ArmstrongOS22, ArtiguesGOS21, ArtiguesAHD20, ArtiguesABD18, HubyOS16, KinsellaSOS16, GrimesOS14, IfrimOS12, SimoninH11, Simonin07, SimoninK06, SimoninC95, Simonin95, Simonin95a, DincheasS91, DincheasH90
Mats Carlsson	17	182	PrimodigECM23, WessenCSFP22, WessenCS20, Lozano2019, MossigeGSMC17, CarlssonJL17, LetortCB15, LarsonJC14, Lozano2014, LetortCB13, LetortBC12, LozanoCS21, BeldiceanuCPD11, BeldiceanuCP08, BeldiceanuC02, BeldiceanuC01, CarlssonKA96
Philippe Baptiste	16	523	BaptisteB18, Baptiste09, BaptisteLPN06, NeronABCD06, ArtiguesHQB05, Baptiste02, BaptistePN01, Baptiste2001, BaptisteP00, BaptistePN99, PapaB98, Baptiste1998, BaptisteP97, PapaB97, PapaB96, BaptisteP96

CP & Scheduling Co-Author Graph (Excerpt)



CP & Scheduling Concept Matching

Table 18: Works for Concepts of Type ApplicationAreas (Total 72 Concepts, 71 Used)

Keyword	Weight	High	Medium	Low
satellite	1.00	Rouza2025, Antuori2025, Xu2024, Le24, SquillaciPR23, Squillaci2022, Godet21a, GodetLHS20, KucukY19, He2019, LaborieRSV18, HebrardHJMPV16, FrankDT16, Maillard15, PraletLJ15, KelarevaTK13, ReddyFIBKAJ11, Verfaillie2010, Johnston05, BarbulescuWH04, GlobusCLP04, Younes2003, VerfaillieL11, BensanaV99, PembertonG98, MengLZ021, ZarandiASC20, MoapertN19, NattaDYW19, Ham18a, HamFC17, ZebastaniB15, NovasH12, Pinto2012, ZaballosCM10, Wang2007, Bixby2006	Green24, Komatsovs2024, Laborie2017, AlesioBNG15, Alesio2013, OddiPCC05, JussienL02	Le2025, WessenCSFPM23, EfthymiouY23, FouatBT22, Astrand21, AstrandOF21, Zahout21, ZarandiASC20, FachiniA20, Hooker19, Pralet17, TranVNB17, Froger16, TranWDRFOVB16, SimoninAHL15, BessiereHMOW14, LaborieR14, HeinzSB13, SimoninAHL12, GuyonLPR12, RuggieroBBMA06, Rodriguez07, OddiPCC03, Larrosa2002, NuijtenP98
semiconductor	1.00	MengLZ021, ZarandiASC20, MoapertN19, NattaDYW19, Ham18a, HamFC17, ZebastaniB15, NovasH12, Pinto2012, ZaballosCM10, Wang2007, Bixby2006	PenzDN23, Tassel22, QinWLSL21, Tang2020, Ham20, GokgurHO18, HamC16, FriedrichFMRST14, Davenport10, LombardiMRB10, KrogLPHJ07, JainM59	Terbrack2025, Sun2024, Ziadlou2024, LacknerMMWW23, Oujana2023, Fatemi-AnarakiTFV23, Eiter2023, Hajji2023, abe-2211-14492, El-Kholany2022, MengGRZSC22, EmdeD22, YuraszekMPV22, MullerMKP22, ColT22, ZhangJZ122, FanXG21, LacknerMMWW21, HamP21, Ham18, GrimesH15, Sahraeian2015, TerekhovTDB14, KoschB14, HarjunkoskiMBC14, MalapertGR12, Malapert11, Lombardi10, AchterbergBKW08 (Total: 43)
shipping line	1.00			QinDCS20, LaborieRSV18, KelarevaTK13
sports scheduling	1.00	Weidmann2025, NaqviAIAA22, LarsonJC14, SuCC13, Ribeiro12, KendallKRU10, RasmussenT09, RasmussenT07, RasmussenT06, Simonis07, ChunCTY99, DincbaeS91	Kuramata2022, LiuLH18, CarlssonJL17, ZengM12, Perron05, Trick03, ElJR03	BulkG22, ZarandiASC20, Watermeyer2020, Hooker19, LiuLH19a, GedikKEK18, HookerH17, QinDS16, RiiseML16, CobanH11, RussellU06, DilkinaH04, EastonNT02, SchaeP96, FalqueALM24, Ruixin2018, Salido2008, Darby-DowmanLMZ97, SimonisC95, Simonis95a, AalianPG23
stand allocation	1.00		Simonis99	
steel cable	1.00			
steel mill	1.00	GaySS14, Letort13, HeinzSSW12, SchausHMCMD11, HentenryckM08, GarganiR07		abe-2312-13682, PerezGSL23, LiuLH19a, DoulabiRP16, MenciasSV13, MenciasSV12, Frisch2006, LuoB22, Lozano2019a, GaleguilloKSB19, Tang2018, Dejemeppe16, HurleyOS16
super-computer	1.00	BorghesiBLMB18, BridiBLMB16, BartoliniBBLM14		ForbesHJST24, AlfieriGPS23, NaderiBZR23, NaderiBZ23, Oujana2023, NaderiBZ23, ElciOH23, Lemos21, FrimodigS19, Filho2012, MeskensDHG11
surgery	1.00	GurPAE23, Tayyab2023, Lyons2023, ChandelariK22, FarisTM22, RoshanaeiN21, RoshanaeiBAUB20, Schwarz2019, GurEA19, YounespourAKE19, Elkhyari2017, RoshanaeiLAU17, RiiseML16, DoulabiRP16, WangMD15, ZhaoL14, DoulabiRP14, MeskensDL13, Wolf11, Wolf09, Elkhyari2006, Prumm2025, FrankK05, FrankK03, MintonJPL92, MintonJPL90	FrimodigECM23, ZarandiASC20, TopalogluO11	
telescope	1.00	CatusseCBL16, Johnston05, FoxS90		He2019, AlesioBNG15, Maillard15, Alesio2013, ReddyFIBKAJ11, BidotVLB09, BeckW07, GlobusCLP04, Beck99, BeckDDF98, PembertonG98, Wallace96, Wallace94, SmithC93, Hooker19
torpedo	1.00	Geiger2019, GoldwasserS18, KletzanderM17, GoldwasserS17	AntuoriHHEN20	
tournament	1.00	Weidmann2025, NaqviAIAA22, Kuramata2022, BulkG22, FanXG21, ZarandiASC20, Lunardi20, LiuLH18, CarlssonJL17, LarsonJC14, SuCC13, ZengM12, Ribeiro12, KendallKRU10, RasmussenT09, RasmussenT07, RasmussenT06, RussellU06, HenzMT04, GlobusCLP04, Trick03, ElJR03, EastonNT02, Henz01, SchaeP97, SchaeP96	CuiKLO22, Koriche2022, QinWLSL21, Hosseiniian2019, HookerH17, Sahraeian2015, StidsenKM56	Nguyen2024, Xu2024, abe-2402-00459, Gao2022, Ortiz-Bayliss2021, Lemos21, HubnerGSV21, Hosseiniian2021, Hooker19, LiuLH19a, LiuLH19, Gonzalez2017, GedikKBRI17, Froger16, Dejemeppe16, Li2014b, Li2014a, RendPHPR12, Pessan2012, CobanH11, Coelho2011, LAW08, Terashima-Marn2008, SureshMOK06, Perron05, KanetAG04, DilkinaH04, Demasey03, EreminW01
train schedule	1.00	Bansal2024, LuZZYW24, MarliereSPR23, Lemos21, CappartS17, Mladenovic2017, Rodriguez2009, Rodriguez07b, Mladenovic2007, Geske05, MurphyRFS97	Ma2025, Eiter2021, ZarandiASC20, Acuna-Agost2011, LammaMM97, BrusoniCLMMT96	Cherif24, abe-2312-13682, Eiter2023, SvancaraB22, GebingerMM21, Wang2021, Novas19, AgussurjaKL18, Froger16, LiuW11, Salido2008a, Rodriguez07, RodriguezDG02, MartinPY01, Wallace96

Outline

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Summary

Summary

- Overview of applications and methodology
- Highlights on success stories
- Research can have a real impact
- Your application could be next!
- Provided details on some application work in Cork
- Shows the impact of practical problems on basic research
- It takes time to do application based research
- Time well spent!