

Christian Doppler Laboratory: Artificial Intelligence and Optimization for Planning and Scheduling

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Research in Christian Doppler Laboratories



Application-orientated basic research
Cooperation between science and business

“A research group elaborates fundamental knowledge that flows into the development of new products and processes at commercial partners”

Industrial partners of our Christian Doppler Laboratory **ARTIS**



It offers software and consulting services
for workforce/working hours issues

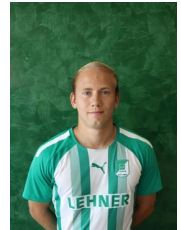
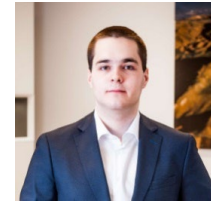


Its core expertise is capacity and
production planning and scheduling



Leading global supplier of
technology and services

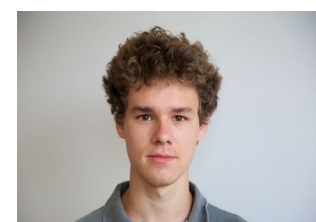
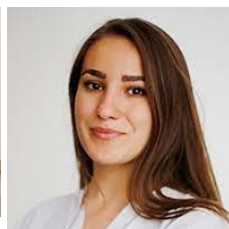
Team (CD Lab employees and associated PhD students)



Lukas Frühwirth



Patrick Malik



Research work in the CD Lab ARTIS

Existing problems

New challenging problems provided by the industry

- Formal mathematical formulations
- Identification of related problems in the literature
- Complexity analysis
- General variants of problems
- New problem instances provided to the literature

- **Novel modeling**
- **AI solving techniques**
- **New (hybrid) algorithms**
- **Hyper-heuristics**
- **Algorithm selection and instance space analysis**

Decision support systems

-
- Research in Christian Doppler Laboratories
 - **Real-life Application Domains**
 - Machine learning for automated algorithm selection and heuristic algorithms design
 - Industrial AI based decision support systems
 - Conclusions

Investigated Applications in our Lab

Rotating Workforce Scheduling

Shift Design

Break Scheduling

Nurse Rostering

Torpedo Scheduling

Electric Vehicle Charging

Tourist Trip Planning

Social Golfer Problem

High School Timetabling

Production Leveling Problem

Parallel Machine Scheduling

Industrial Oven Scheduling

Physician Scheduling During a Pandemic

...

Unicost Set Covering

(Hyper)tree Decomposition

Graph Coloring

Traveling Salesman Problem

Facility Location

Vehicle Routing

Sudoku

Bus Driver Scheduling

Test Laboratory Scheduling

Artificial Teeth Production
Scheduling

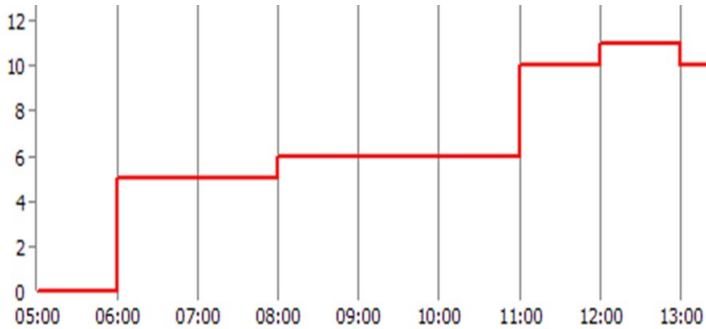
Project Scheduling

Paint Shop Scheduling Problem

Curriculum-based Course
Timetabling

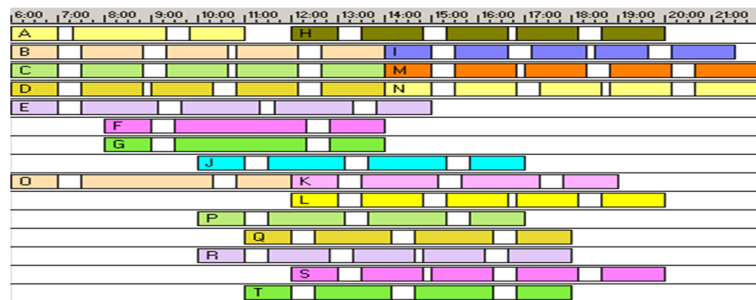
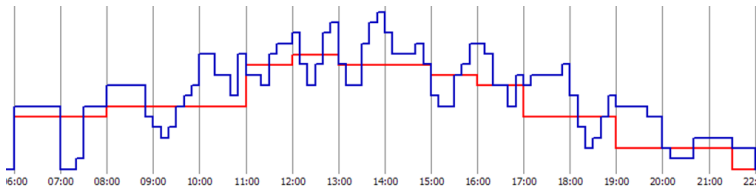
Employee Scheduling Problems

Phase 1: Workforce requirements



<https://www.ximes.com/>

Phase 2: Shift Design/Break Scheduling



Phase 3: Assignment of shifts

	Mo	Di	Mi	Do	Fr	Sa	So
A	F	F	F	S	S		
B		N	N	N	N		
C		F	F	N	N	N	N
D			S	S	S	N	N
E	N			F	F	S	S
F	S			F	F	F	F
G	S	S				F	F
H	F	S	S			S	S
I	N	N	N				

Work schedules influence the lives of employees

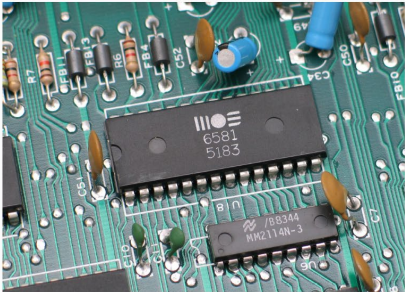
Organizations in the commercial and public sector must meet their workforce requirements and ensure the quality of their services and operations

Production Planning and Scheduling

- In these applications it is important to
 - Reduce resource consumption, including energy
 - Increase production efficiency...



	<i>R1</i>	<i>R2</i>	<i>R3</i>	...
1	A	A	C	...
2	A	A	C	...
3	A	C	C	...
4	B	B	B	...
5	B	B	B	...



https://commons.wikimedia.org/wiki/File:M0S6581_1_1htaube061229.jpg, Christian Taube
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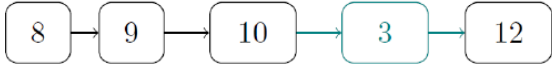


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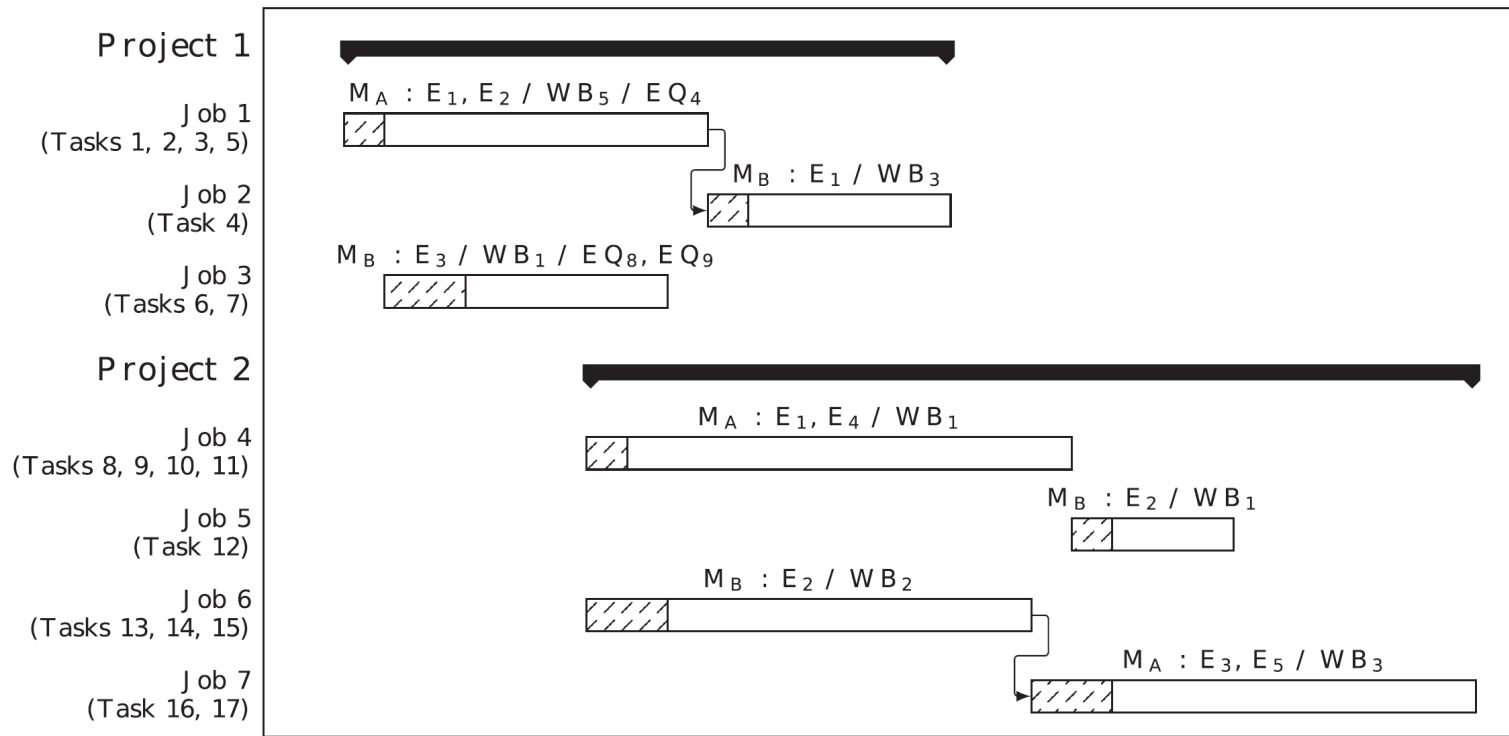
Machine 1:



Machine 2:



Test Laboratory Scheduling/Project Scheduling



More examples in health care, production, education, public transport, ...

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AI and optimization methods

Complete approaches

Constraint programming
Answer set programming
SAT/SMT
Mathematical programming
...

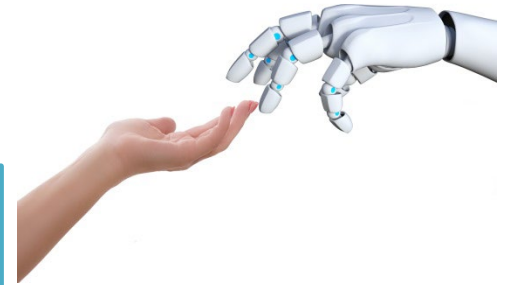
Metaheuristic techniques

Tabu search
Simulated annealing
Evolutionary strategies
Memetic algorithms
...

Hybrid methods

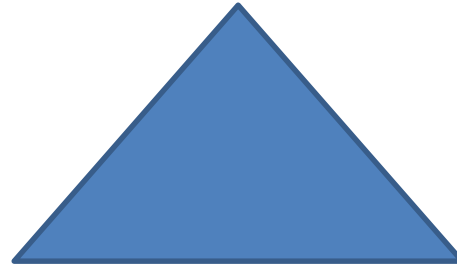
Large neighborhood search
Hyper-heuristics
Machine learning based approaches
...

Hybrid techniques



*Methods of Artificial Intelligence
(Machine Learning, Heuristics...)*

Methods of Logic



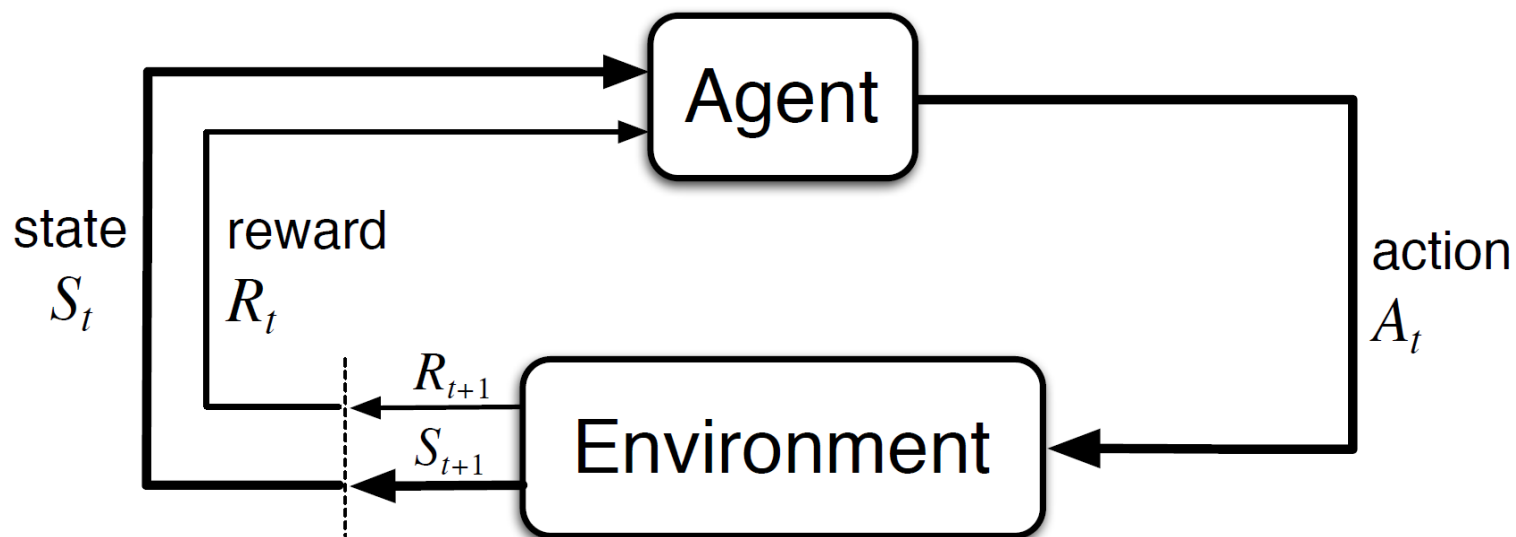
Mathematical Optimization

$$S_{i,d,t} \Leftrightarrow \bigwedge_{x=1}^{sl_t} U_{i,d,x} \bigwedge_{y=sl_t}^{sl_{max}} \neg U_{i,d,y}$$

...

$$\begin{aligned} \text{minimize } f = & 30 * \sum_{\substack{s \in S \\ k \in K \\ d \in \{1 \dots 7\}}} C_{skd}^{S1} \\ & + 15 * \sum_{\substack{n \in N \\ s \in S \\ d \in \{1 \dots 7\}}} (C_{nsd}^{S2a} + C_{nsd}^{S2b}) \\ & + 30 * \sum_{\substack{n \in N \\ d \in \{1 \dots 7\}}} (C_{nd}^{S2c} + C_{nd}^{S2d}) \end{aligned}$$

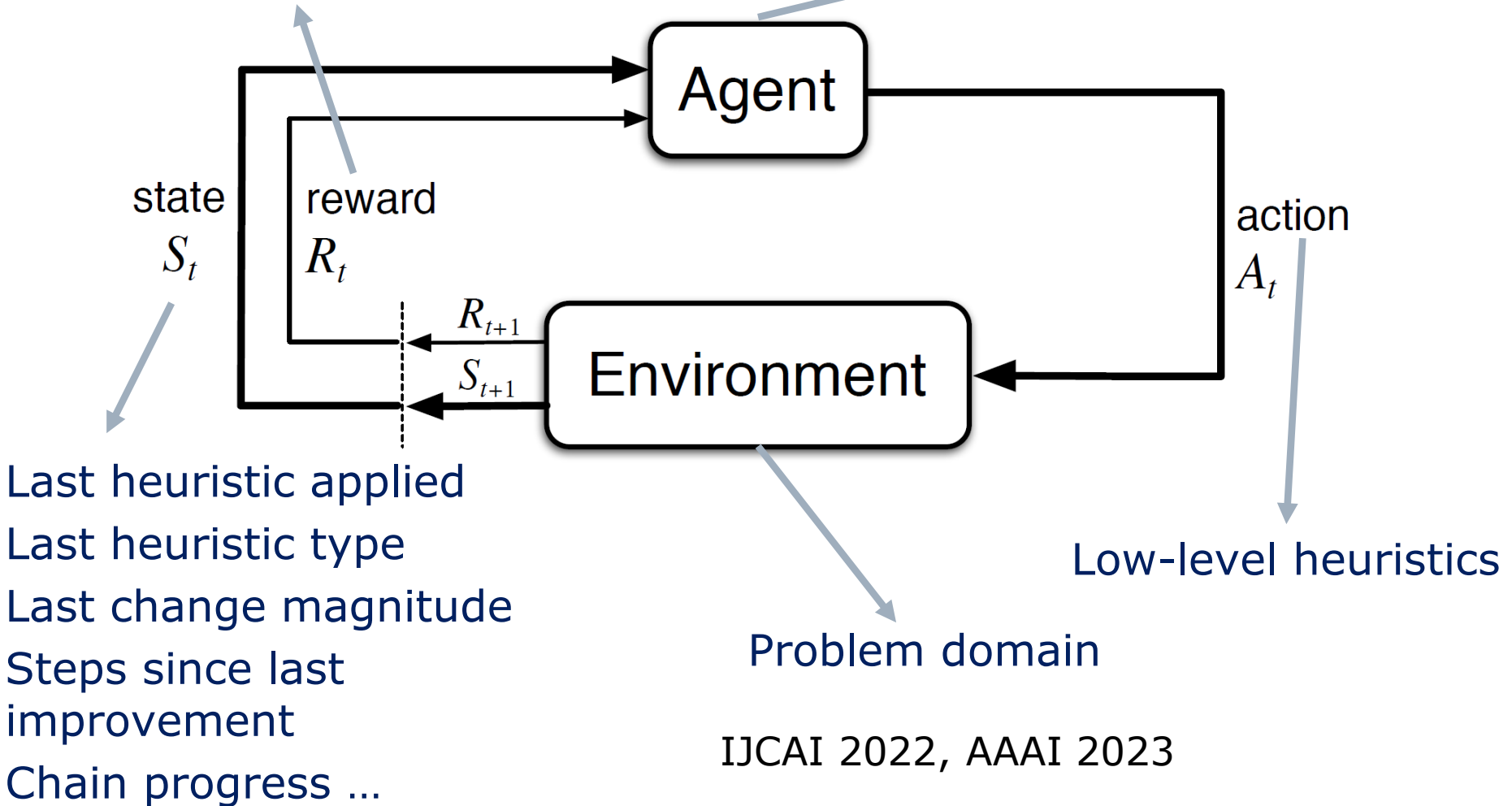
Reinforcement learning for Hyper-heuristics



Sutton and Barto. Reinforcement Learning, 2018

Reinforcement learning for Hyper-heuristics

Based on objective value difference and time

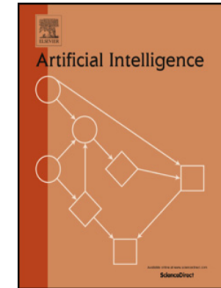




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Artificial Intelligence

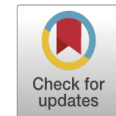
journal homepage: www.elsevier.com/locate/artint



Hyper-heuristics for personnel scheduling domains

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Combinatorial optimization

ABSTRACT

In real-life applications problems can frequently change or require small adaptations. Manually creating and tuning algorithms for different problem domains or different versions of a problem can be cumbersome and time-consuming. In this paper we consider several important problems with high practical relevance, which are Rotating Workforce Scheduling, Minimum Shift Design,

Best Industry and Applications Track Paper Award, ICAPS 2022

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 - **Industrial AI based decision support systems**
 - Conclusions

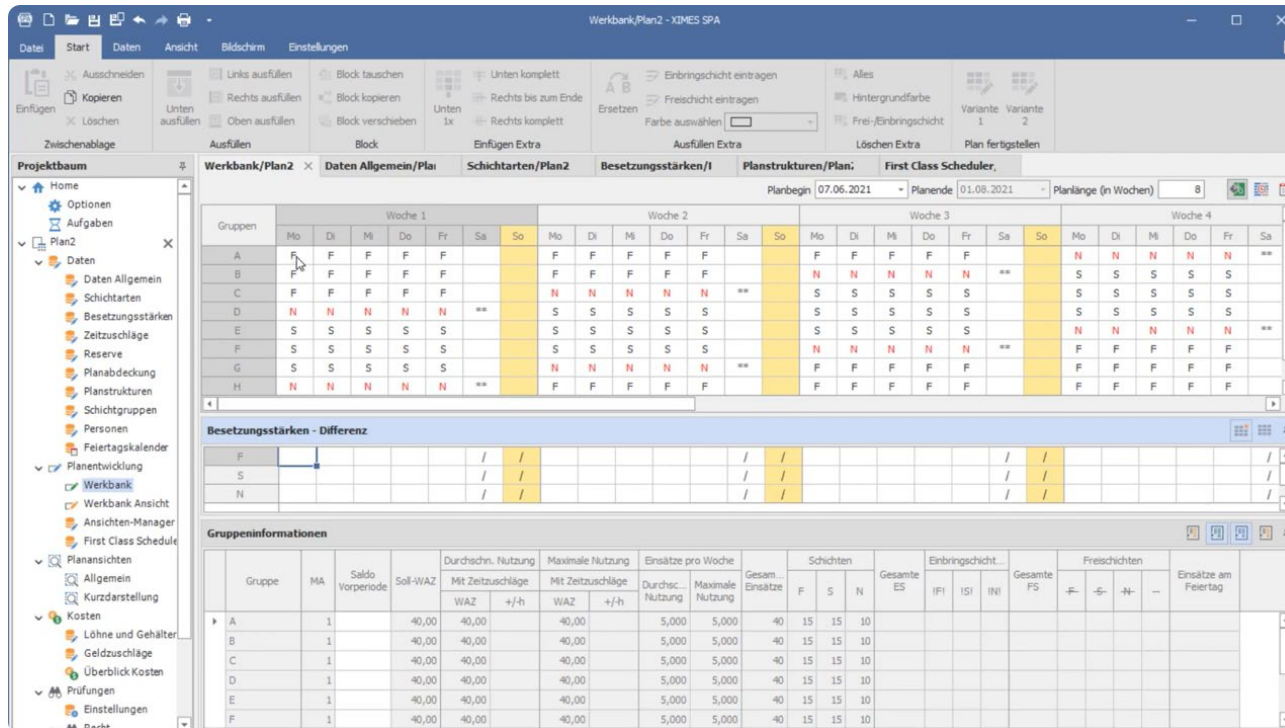
Exact Methods for Extended Rotating Workforce Scheduling Problems

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A System for Automated Industrial Test Laboratory Scheduling

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DAVID JANNEAU, Robert Bosch AG, Austria

FLORIAN MISCHKEK and NYSRET MUSLIU, Christian Doppler Laboratory for Artificial Intelligence and Optimization for Planning and Scheduling, DBAI, TU Wien, Austria

CHRISTIAN POSCHALKO, Robert Bosch AG, Austria

ACM Transactions on Intelligent Systems and Technology, Vol. 14, No. 1, 2023.

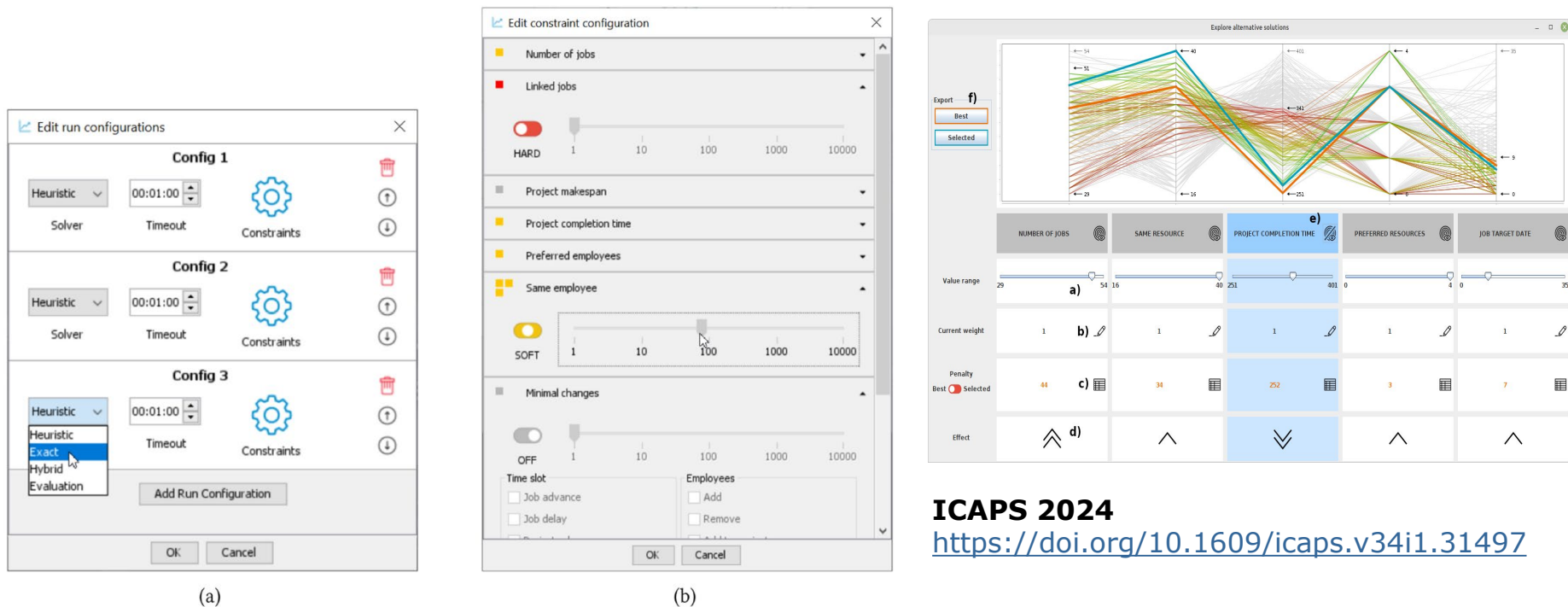


Fig. 7. Dialogs for editing run and constraint configurations.

ICAPS 2024

<https://doi.org/10.1609/icaps.v34i1.31497>

Conclusions

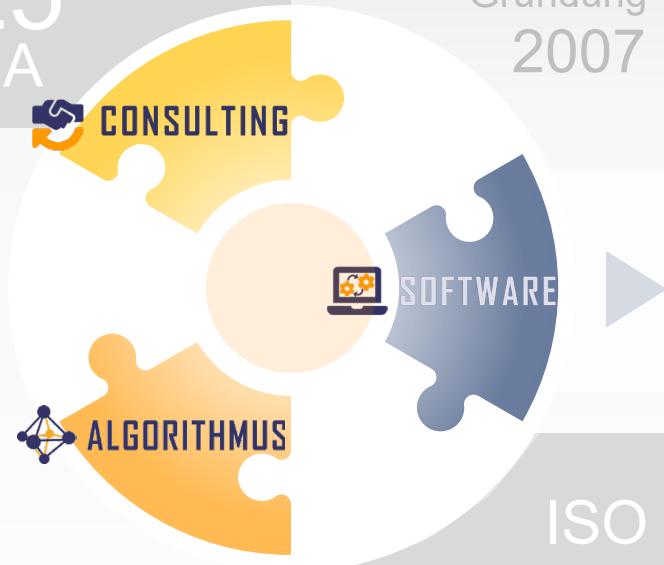
- Many optimization problems in industry are still solved manually
- AI and optimization offer tremendous potential for further improving solutions in these domains
- Using of machine learning improves results on several real-life domains
- Additional features very important for decision support systems in practice
 - Explanations
 - Guidance for setting weights...

CD Lab awards: Two Ressel Awards (2022, 2023), Sub Auspiciis Promotion, Best Industry and Applications Paper Award at the A* conference ICAPS, the Master Thesis Prize from the Austrian Society for Artificial Intelligence, the “Würdigungspreis” for an outstanding master’s thesis in Austria, and the Best Doctoral Consortium Poster Award at ICAPS 2019

Publications: <https://cdlab-artis.dbai.tuwien.ac.at/publications/>

25
MA

Gründung
2007



ISO
27001



PRODUKTION OHNE VERSCHWENDUNG: ”

Sales & Operations Planning

Demand & Supply

Advanced Planning & Scheduling
Integrierte
Energieplanung

Masterplanung

Feinplanung

Workforce Management

Personaleinsatzplanung

Referenzbeispiele:

SIEMENS VIESSMANN HUBER+SUHNER beyondgravity WACKER



Spezialisierung auf das
Themenfeld der
Produktionsplanung

1

2

3

4

Gründung als
Unternehmensberatung für
Prozessoptimierung

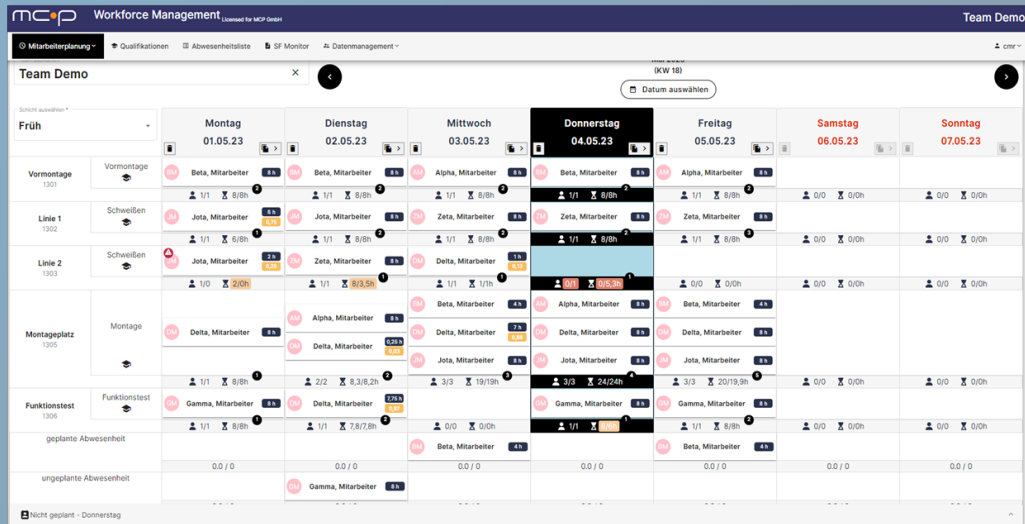


Beschäftigung mit
Algorithmen auf Basis von
Einzelproblemen aus der
Industrie



Grundlagenforschung &
strukturierte Entwicklung
algorithmischer Produkte





Automatische PLANUNG

- ✓ Automatische Einsatzplanung auf Basis tatsächlicher Bedarfe
- ✓ Flexible Einstellung von Optimierungszielen
- ✓ Berücksichtigung von Qualifikationen der Mitarbeiter

PLANUNGSASSISTENT

- ✓ Intelligente Planungshilfe bei Reaktion auf Änderungen (Umplanung, Krankenstand)
- ✓ Schrittweise und nachvollziehbare Optimierung des Plans

- ✓ All-in-One-Lösung für bedarfsgerechte Mitarbeiterereinsatzplanung
- ✓ Schnelle Kommunikation und Reaktionsfähigkeit auf Änderungen
- ✓ Transparenz und automatische Berücksichtigung von An- / Abwesenheiten sowie Qualifikationen



MCP stellt den Planungsalgorithmus als Azure Function App zur Verfügung:

Kundensystem

INPUT

DATA PROCESSING

OUTPUT

- Auftragsdaten
- Maschinen & Ressourcen
- Rüstmatrizen
- Zwischenlagerdaten

- Erstellung Produktionsplan unter Einhaltung von Restriktionen
- Optimierungsziel: Minimierung von Verspätungen und Rüstaufwänden
- Optimierung der Nutzung von Zwischenspeichern

- Detaillierte Produktionspläne, einschließlich Rüst-/Start-/Endzeiten und Maschinenzuweisungen
- Zuweisung von Zwischenlagern, Transportstrecken, Mitarbeiter

Integration von externen Solvern (z.B. Google OR-Tools) ist möglich.

as a Service

Bisherige Anwendungsfelder:

- ✓ Mitarbeiter-Einsatzplanung
- ✓ Food Production
- ✓ Rüstoptimierung
- ✓ Batchoptimierung

Kurz über XIMES



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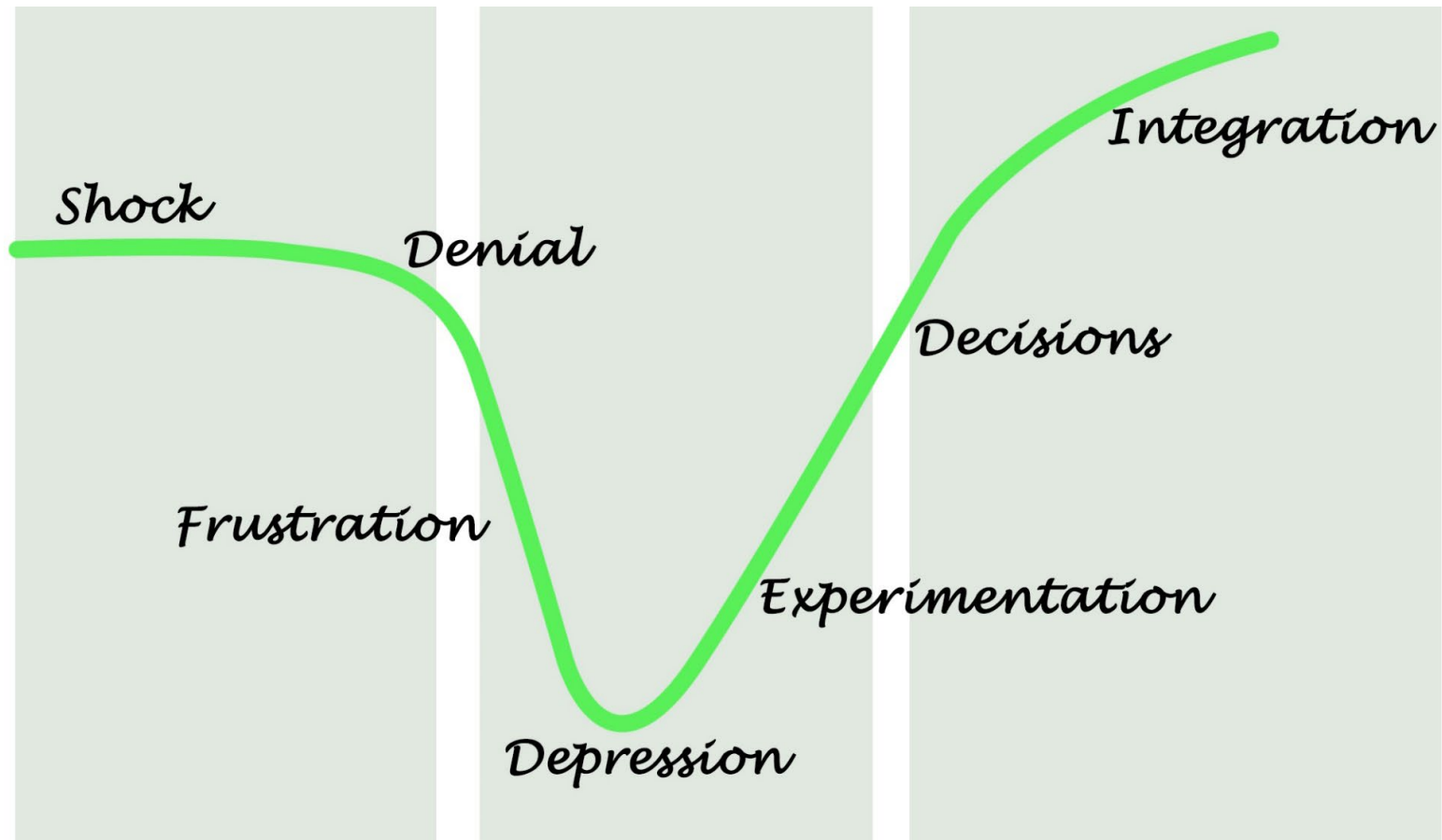
+43 676 973 21 72

www.ximes.com/page/team

XIMES Unternehmensprofil

- Gegründet **1997** als „Spin-off“ der TU Wien.
- **Personalbedarf und Arbeitszeitgestaltung.**
- Ca. **20 Berater und Software-Experten** in Österreich.
- **International tätig.** Ca. 50% des Umsatzes werden außerhalb Österreichs erwirtschaftet.
- **Hohe Diversität** der Kunden. Verschiedene Branchen und Betriebsgrößen.
- **Arbeitsweise:** methodisch-analytisch, Wissenschaft-basiert, Einsatz moderner IT-Werkzeuge.
- **Beratende Begleiter** in fachlich, sachlich orientierten Change-Prozessen.

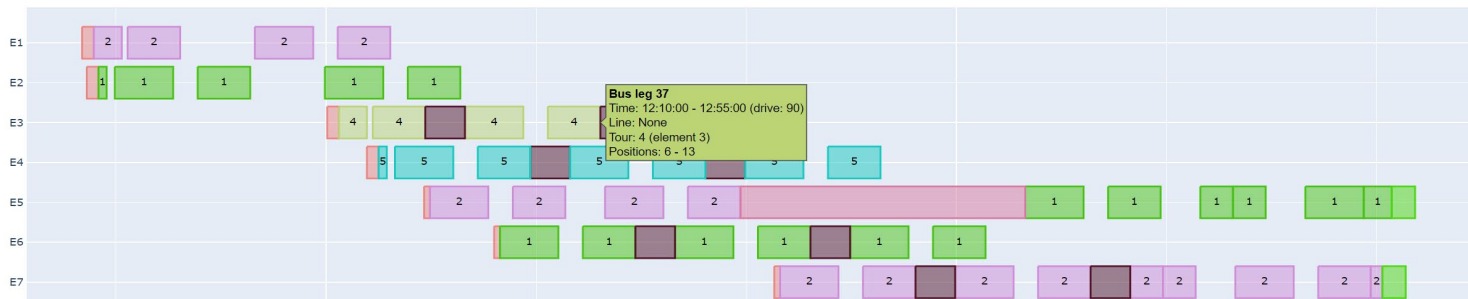
Change Prozess



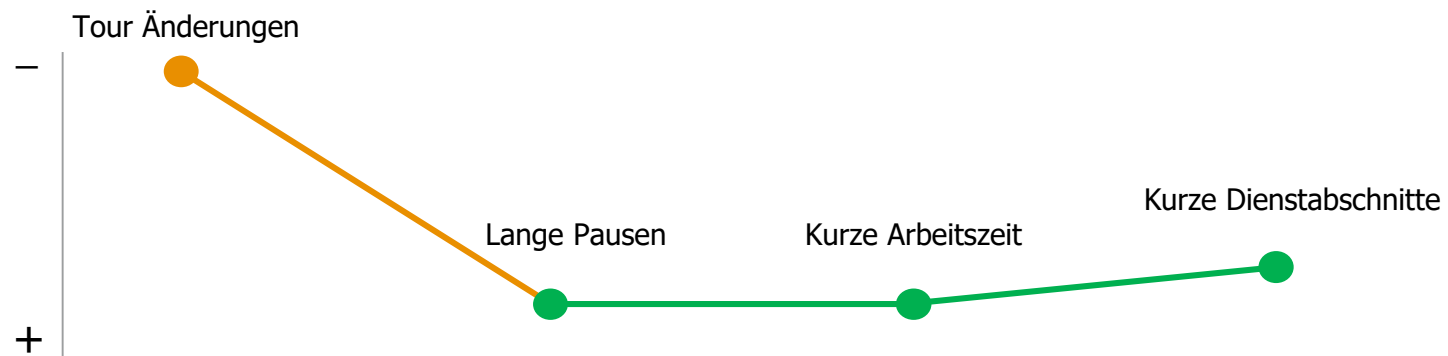
Stock-Image, <https://www.istockphoto.com/>, ID:825911996

Wie unterstützt KI im Change Prozess?

➔ State-of-the-art Methoden



➔ Nachvollziehbare und kommunizierbare Ergebnisse



Vielen Dank für die tolle Unterstützung!

- ➔ Langfristige Stärkung der **Wettbewerbsfähigkeit**.
- ➔ Verbesserung die **Arbeitsqualität** für die Betroffenen.
- ➔ Arbeit **wirtschaftlich und fair** gestalten. Auch dann wenn es schwierig ist!

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