ESTEP SPRING DISSEMINATION EVENT

5-6 JUNE 2025 KRAKOW (POLAND)

Enhanced Steel Production Efficiency Through Fuzzy Logic Aided Genetic Algorithms

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Outline



- The problem of **coil-order alloation** (COA) lacksquare
 - A real world case study from TKS Rasselstein within the DynReact project
- COA solution by using **Genetic Algorithms** (GA) •
- Embedding human reasoning via **fuzzy logic** •
- Results, comparison and discussion •
- The future





Introduction: coil order allocation



Main issues

- dimension, provenience, mill, ...)
- Orders have a due date
- associate to an order

What do we look for

- - Respect constraints
 - Respect due dates
- \bullet



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Orders require coils with specific characteristics (grade,

Coils in stock may nedd some adjustments to be

Efficient method to allocate available coils in order to

Limit adjustments and reduce work, waste, energy,... Complex task due to all constraints and dynamic stock



The DynReAct_PDP case study – TKS Rasselstein



- TKS Rasselstein (Andernach, Germany) is the world's largest tinplate production site, with an annual capacity of 1.5 million tonnes
- Specializes in high-quality tinplate and chrome-coated steel coils **for packaging** (food cans, steel boxes, twist-off caps, closures, etc.) • Supplies over 400 customers in more than 80 countries worldwide
- High daily production volume creates complex operational challenges, especially in coil allocation to customer orders. • Some coils are rejected during production due to quality issues (e.g., surface defects), requiring manual allocation by experienced
- personnel.





The DynReAct_PDP case study - Challenges



objectives

This task is critical to ensure order fulfillment while minimizing waste and optimizing production efficiency.



Constraints

- Steel grade
- Dimensions
- Coil weight
- Hot-Rolling Mill
- Provenance

Objectives

lacksquare

ullet



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Manual or automatic COA requires navigating a complex decisionmaking process that involves balancing multiple constraints and

Minimize discrepancy between requested and allocated material (optimize resource use) Meet order delivery deadlines (prioritize urgent orders)



Case study – Available data

Orders and Coils backlog provided by RAS (with a looong tutorial for data ingestion)



В
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Number of orders: 726 Orders total required weight: 74839



Not all orders can be fulfilled **Priority** used

Number of coils: 3753 Available steel weight in coils: 69124







Optimization approach





		Order 1	Order 2	Order 3	Order 4	Order 5
-	Coil 1					
	Coil 2					
	Coil 3					
	Coil 4					
	Coil 5					
	Coil 6					
	Coil 7					
	Coil 8					
	Coil 9					
	Coil 10					
	Coil 11					
	Coil 12					
	Coil 13					
	Coil 14					
	Coil 15					



Genetic Algorithms for COA

Combinatorial problem with high dimensionality and non linear constraints

- GAs performs well on these problems finding in reasonable time an optimal solution \bullet
- GAs operate by mimicking natural evolution principles such as selection, crossover, and mutation lacksquareto evolve solutions to complex problems
- Solution coded and evolved in compliance with COBAM lacksquare







Objective function (*minimization***)**

$$D_{j} = \frac{\left| \left(\sum_{c_{i} \mid (c_{i}, o_{j}) \in S} W(a_{i}) \right) \right|^{2}}{RW(a_{i})}$$

$$fitness(S) = \sum_{o_{j} \in O} D_{j} \cdot P_{j}$$

$$P_{j} = \left(\frac{max(DDS) - DI}{\sum_{j} DDS_{j}} \right)$$











Curious about the results? Wait, we have something else to show





Embedding human reasoning with fuzzy reasoning

Crisp GA achieves good results but it misses the smoothness of human reasoning

- **Fuzzy inference** can embed human knowledge, experience and uncertainties management through the use of smooth (fuzzy) concepts
- A Fuzzy Inference System (FIS) exploits a set of rules expressed by human operators via natural language. Qualitative concepts are modeled as fuzzy sets via membership functions
- COA objective function components have been translated into fuzzy sets









Embedding human reasoning with fuzzy reasoning





GA and fuzzy logic enhanced coil-order allocation, Marco Vannucci ESTEP Spring Dissemination event 2025 – Krakow, Poland, June 5-6th AND DDS is INTIME THEN EVAL is H, THEN EVAL is L,

- AND DDS is INTIME THEN EVAL is A,
- AND DDS is INTIME THEN EVAL is H,
- AND DDS is DELAY THEN EVAL is L,
- AND DDS is EARLY THEN EVAL is A,



Embedding human reasoning with fuzzy reasoning



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$$ss(S) = 100 - \frac{\sum_{o_j \in O} FIS(Alloc_j)}{N}$$



Experimental set-up



- Adaptive GA framework adopted for faster convergence and low risk of local minimum
 - Genetic recombination rates dinamically adjusted during optimization
 - Hyper-parameters empirically determined (accuracy-speed tradeoff)
- 100 chromosomes, 500 max generations with early stopping





Results

	Baseline	GA-Standard
Completed orders, $\%$	54	69
Ave. discrepancy, $\%$	4.7	3.2
Ave. discrepancy, tons	3.5	2





GA-Fuzzy
69
3.8
2.3



Results



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Conclusions and a sight on the future



- ulletof production
- ulletthe end of the project
- Integration I/O with MES



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Extend to include **long term** and **mid term planning**

Stronger embedding of FIS with more rules, criteria Within the **DynReAct_PDP** project, COA is part of a common open-source framework to be released at



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https://dynreact.eu/

DynReAct	ABOUT OBJECTIVES SOLUTION CONSORTIUM WORK PROGRAMME NEWSLETTER PUBLICATIONS PROJECT BRIEF	×
	DYNREACT PDP	DynReAct PDP Research Services Refinement of production sche
	Roll-out refinement of production scheduling through dynamic product routing, considering real-time plant n	Follow
	Today an optimized and target-oriented use of resources is mandatory, and a major objective of advanced production lack the flexibility to deal with unforeseeable events frequently appearing in real industrial.	
	Within the DynReAct PDP an open-source platform for dynamic production planning will be realized comprising the full in coming free plant involved to generate resource-optimized production plans for products of the highest reachable quality. The bar system developed in the former RFCS project DynReAct (2019-2023) combining three different planning horizons to planning), while continuing to consider optimized mid-term and long-term planning strategies.	About us
	To improve the planning precision as well as the useability of the platform three further components will be implemented based on the DynReAct platform services.	
	 A Recommender system providing recommendations in-case of suboptimal planning situations. 	Within the DynRe
	A Coil-order-allocation system providing optimized allocations of raw material to orders.	realized comprising the ful
	• A plant performance modelling system providing real-time estimations of plant performances concerning multiple aspects as use of resources or product quality	generate resource-optimiz
	An industrial DynReAct prototype for production scheduling will be realized at Rasselstein to demonstrate the applicability of the DynReAct platform in industrial practise should reach TRL 7-8 at the end of the DynReAct PDP.	

Website

Linked in

DynReAct

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Jhank you for your attention.



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