‘Algorithms for dynamic scheduling in manufacturing, towards digital factories’ applied on:

Flexible Job Shop Problems with **no-wait** and **general time lag** constraints

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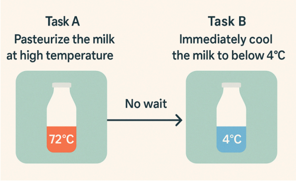
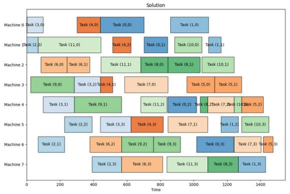
1. Motivation & Introduction

- **Smart Manufacturing & Industry 4.0 [1]** - shift to smart, digital factories, where **adaptive** scheduling algorithms are crucial for managing **uncertain task durations** and **dynamic operations** in **real-time**.
- **Real-Time Adaptability** with **STNUs[2]** compared to **Proactive**, **Reactive** methods - explore use of **temporal networks** for **dynamic scheduling** targeting **FJSP[4]** with **generalized time-lags** and **no-wait** constraints

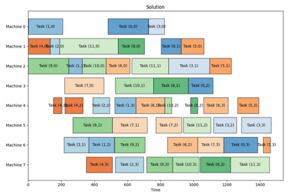


2. Background

- **FJSP** - **F**lexible **J**ob **S**hop **P**roblems → scheduling problem where tasks can be assigned to multiple machines → flexibility in task allocation and machine utilization



→ Flexible Job-Shop Problem with No-Wait constraints

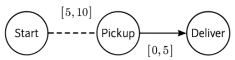


→ Flexible Job-Shop Problem with general time lag constraints

- **STN/STNU** - **S**imple **T**emporal **N**etwork/with **U**ncertainty → framework for scheduling tasks, where temporal constraints are represented between events or tasks.

Example: Robot delivering medicine in a hospital
- arrives at pickup in around 5-10 min; has to deliver medicine in under 5 min after pickup

Nodes: Start, Pickup, Deliver
Edges: - **contingent(uncertain)** start → pickup ~ 5-10 min
- **requirement(controllable)** pickup → deliver - imposed under 5 min



- **RTE*[5]** - **R**eal-**T**ime **E**xecution with **Earliest start times** - simulates execution of a dynamically controllable STNU with earliest feasible start times for tasks under uncertain durations, respecting constraints.

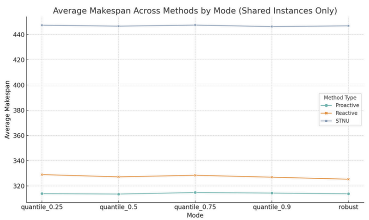
3. Research Question

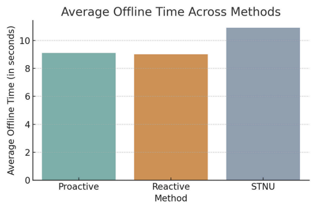
How do **hybrid scheduling strategies** based on **STNUs** compare to **proactive** and **reactive methods** and how do they influence the **feasibility** and **performance** of **FJSPs** with **generalized time-lags** and **no-wait constraints** under **stochastic task durations**?
→ **Subquestion**: Investigate results given different modes and noise factors for duration distributions

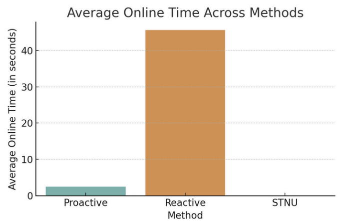
4. Contribution

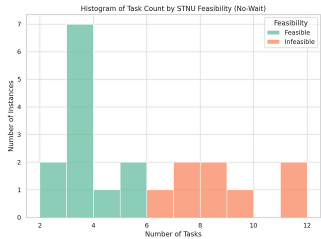
- **Research FJSP** incorporating **generalized time-lags** and **no-wait constraints** under **stochastic task durations**
- **Build** upon the **PyJobShop** platform → **extend** its **modeling capabilities** to support **no-wait** & **general time lag** constraints
- Adapt **proactive, reactive and hybrid scheduling strategies** from previous codebase to **FJSP** and ensure compatibility with **PyJobShop[3]**
- **Generate pipeline** and **run experiments:** use **standard FJSP datasets** and model **generalized lags** and **no-wait constraints**, followed by **performance evaluation** having as **objectives:** makespan, run time online/offline and feasibility

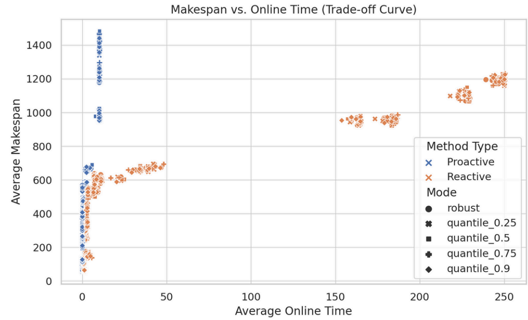
5. Results











6. Conclusions

- **Fully proactive** approach is completely **infeasible** for **no-wait** and **tight** temporal constraints
- **STNU hybrid** approach performs worse in terms of **makespan** than **proactive** and **reactive** approaches when applied to **FJSP** with afore mentioned constraints → opts for **robustness over objective performance**
- **Hybrid** approach has **lower feasibility** (around 60-65% on average) than other two approaches → due to complex **schedules** with **high number of tasks** failing **dynamic controllability** test
- **Noise factors** (tested for noise factor 1.0, 2.0) and **duration distribution modes** have **little** to **no impact** on results → difference in makespan appears to come mainly from difference in duration since there is no variable lags in between tasks for no-wait constraints

7. Recommendations

- Consider analyzing the transition from no-wait constraints to tight general time lags that transition into more relaxed lags and compare feasibility during the transition

References

[1]https://www.tno.nl/en/digital/smart-manufacturing/digitalising-smarter-production/
[2] Kim van den Houten, K., Planken, L., Freydell, E., Tax, D. M., & de Weerdt, M. (2024). Proactive and Reactive Constraint Programming for Stochastic Project Scheduling with Maximal Time-Lags. *arXiv e-prints*, arXiv-2409.
[3] Lan, L., and Berkhout, J. (2025). PyJobShop: Solving scheduling problems with constraint programming in Python. https://arxiv.org/abs/2502.13483
[4] Chaudhry, I. A., & Khan, A. A. (2016). A research survey: review of flexible job shop scheduling techniques. International Transactions in Operational Research, 23(3), 551-591.
[5]Luke Hunsberger and Roberto Posenato. Foundations of dispatchability for simple temporal networks with uncertainty. In Proceedings of the 16th International Conference on Agents and Artificial Intelligence (ICAART2024), volume 2, pages 253–263, 2024.