Multi-model Maintenance Scheduling

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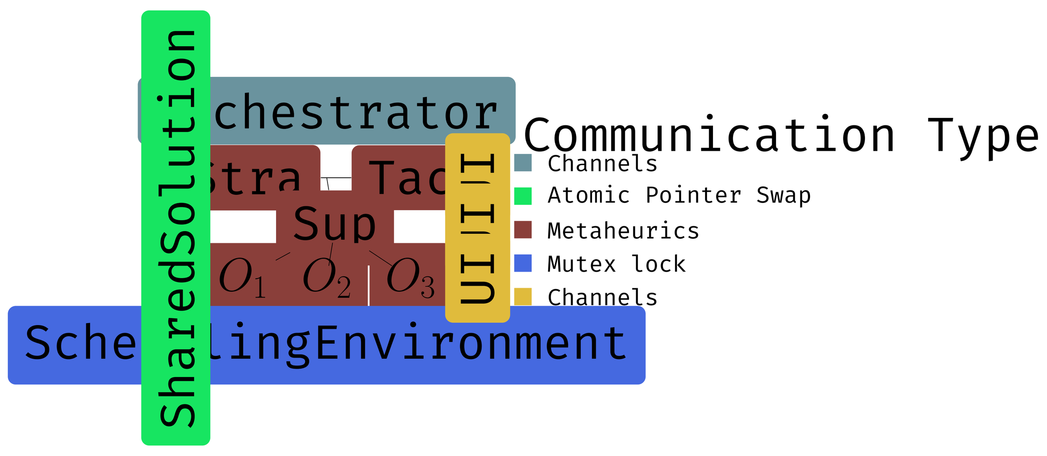
Introduction

Operation

Research Questions

1. How to implement a scheduling system that can coordinate in real-time
2.
3. Can you coordinate metaheuristics based on different mathematical models in real-time

Solution Method



Case Study: Total Energies

The proposed system has been developed in collaboration with Total Energies to help optimize there maintenace scheduling operations.

Future Work

- Extend the approach to international supply chains.
- Incorporate real-time data analytics for dynamic decision-making.
- Explore applications in other sectors like healthcare and transportation.

Results

- **Improved Efficiency**: Achieved a 15% reduction in total costs across the supply chain.
- **Stakeholder Satisfaction**: Increased satisfaction scores among all actors by 20%.
- **Collaborative Strategies**: Developed joint policies that benefit all parties.

Conclusion

Methodology

1 Strategic

Meta variables:

$$s \in S \tag{1}$$
$$\tau \in [0, \infty] \tag{2}$$

Minimize:

$$\sum_{w \in W(\tau)} \sum_{p \in P(\tau)} \mathit{strategic\_value}_{wp}(\tau) \cdot \alpha_{wp}(\tau) + \sum_{p \in P(\tau)} \sum_{r \in R(\tau)} \mathit{strategic\_penalty} \cdot \epsilon_{pr}(\tau) + \sum_{p \in P(\tau)} \sum_{w1 \in W(\tau)} \sum_{w2 \in W(\tau)} \mathit{clustering\_value}_{w1,w2} \cdot \alpha_{w1p}(\tau) \cdot \alpha_{w2p}(\tau) \tag{3}$$

Subject to:

$$\sum_{w \in W(\tau)} \mathit{work\_order\_work}_{wr} \cdot \alpha_{wp}(\tau) \leq \mathit{resource}_{pr}(\tau, \beta(\tau)) + \epsilon_{pr}(\tau) \quad \forall p \in P(\tau) \quad \forall r \in R(\tau) \tag{4}$$
$$\sum_{w \in W(\tau)} \alpha_{wp}(\tau) = 1 \quad \forall p \in P(\tau) \tag{5}$$
$$\alpha_{wp}(\tau) = 0 \quad \forall (w, p) \in \mathit{exclude}(\tau) \tag{6}$$
$$\alpha_{wp}(\tau) = 1 \quad \forall (w, p) \in \mathit{include}(\tau) \tag{7}$$
$$\alpha_{wp}(\tau) \in \{0, 1\} \quad \forall w \in W(\tau) \quad \forall p \in P(\tau) \tag{8}$$
$$\epsilon_{pr}(\tau) \in \mathbb{R}^+ \quad \forall p \in P(\tau) \quad \forall r \in R(\tau) \tag{9}$$

2 Tactical

Meta variables:

$$s = S \tag{10}$$
$$\alpha(\tau) \tag{11}$$
$$\tau \in [0, \infty] \tag{12}$$

Minimize:

$$\sum_{o \in O(\tau, \alpha(\tau))} \sum_{d \in D(\tau)} \mathit{tactical\_value}_{do}(\tau) \cdot \beta_{do}(\tau) + \sum_{r \in R(\tau)} \sum_{d \in D(\tau)} \mathit{tactical\_penalty} \cdot \mu_{rd}(\tau) \tag{13}$$

Subject to:

$$\sum_{o \in O(\tau, \alpha(\tau))} \mathit{work}_o(\tau) \cdot \beta_{do}(\tau) \leq \mathit{tactical\_resource}_{dr}(\tau) + \mu_{rd}(\tau) \forall d \in D(\tau) \quad \forall r \in R(\tau) \tag{14}$$
$$\sum_{d = \mathit{earliest\_start}_o(\tau)}^{\mathit{latest\_finish}_o(\tau)} \sigma_{do}(\tau) = \mathit{duration}_o(\tau) \quad \forall o \in O(\tau, \alpha(\tau)) \tag{15}$$
$$\sum_{d^* \in D_{\mathit{duration}_o(\tau)}(\tau)} \sigma_{d^*o}(\tau) = \mathit{duration}_o(\tau) \cdot \eta_{do}(\tau) \quad \forall o \in O(\tau, \alpha(\tau)) \quad \forall d \in D(\tau) \tag{16}$$
$$\sum_{o \in O(\tau, \alpha(\tau))} \eta_{do}(\tau) = 1, \quad \forall d \in D(\tau)$$
$$\sum_{d \in D(\tau)} d \cdot \sigma_{do1}(\tau) + \Delta_o(\tau) = \sum_{d \in D(\tau)} d \cdot \sigma_{do2}(\tau) \quad \forall (o1, o2) \in \mathit{finish\_start}_{o1,o2} \tag{17}$$
$$\sum_{d \in D(\tau)} d \cdot \sigma_{do1}(\tau) = \sum_{d \in D(\tau)} d \cdot \sigma_{do2}(\tau) \quad \forall (o1, o2) \in \mathit{start\_start}_{o1,o2} \tag{18}$$
$$\beta_{do}(\tau) \leq \mathit{number}_o(\tau) \cdot \mathit{operating\_time}_o \quad \forall d \in D(\tau) \quad \forall o \in O(\tau, \alpha(\tau)) \tag{19}$$
$$\beta_{do}(\tau) \in \mathbb{R} \quad \forall d \in D(\tau) \quad \forall o \in O(\tau, \alpha(\tau)) \tag{20}$$
$$\mu_{rd}(\tau) \in \mathbb{R} \quad \forall r \in R(\tau) \quad \forall d \in D(\tau) \tag{21}$$
$$\sigma_{do}(\tau) \in \{0, 1\} \quad \forall d \in D(\tau) \quad \forall o \in O(\tau, \alpha(\tau)) \tag{22}$$
$$\eta_{do}(\tau) \in \{0, 1\} \quad \forall d \in D(\tau) \quad \forall o \in O(\tau, \alpha(\tau)) \tag{23}$$
$$\Delta_o(\tau) \in \{0, 1\} \quad \forall o \in O(\tau, \alpha(\tau)) \tag{24}$$

3 Supervisor

Meta variables:

$$z \in Z \tag{25}$$
$$\alpha(\tau) \tag{26}$$
$$\theta(\tau) \tag{27}$$
$$\tau \in [0, \infty] \tag{28}$$

Maximize:

$$\sum_{a \in A(\tau, \alpha(\tau))} \sum_{t \in T(\tau)} \mathit{supervisor\_value}_{at}(\tau, \lambda_t(\tau), \Lambda_t(\tau)) \cdot \gamma_{at}(\tau) \tag{29}$$

Subject to:

$$\sum_{a \in A_o(\tau, \alpha(\tau))} \rho_a(\tau) = \mathit{work}_o(\tau) \quad \forall o \in O(\tau, \alpha(\tau)) \tag{30}$$
$$\sum_{t \in T(\tau)} \sum_{a \in A_o(\tau, \alpha(\tau))} \gamma_{at}(\tau) = \phi_o(\tau) \cdot \mathit{number}_o(\tau) \quad \forall o \in O(\tau, \alpha(\tau)) \tag{31}$$
$$\sum_{o \in O_w(\tau, \alpha(\tau))} \phi_o(\tau) = |O_w(\tau, \alpha(\tau))| \quad \forall w \in W(\tau, \alpha(\tau)) \tag{32}$$
$$\sum_{a \in A_o(\tau, \alpha(\tau))} \gamma_{at}(\tau) \leq 1 \quad \forall o \in O(\tau, \alpha(\tau)) \quad \forall t \in T(\tau) \tag{33}$$
$$\gamma_{at}(\tau) \leq \mathit{feasible}_{at}(\theta(\tau)) \quad \forall o \in O(\tau, \alpha(\tau)) \quad \forall t \in T(\tau) \tag{34}$$
$$\gamma_{at}(\tau) \in \{0, 1\} \quad \forall o \in O(\tau, \alpha(\tau)) \quad \forall t \in T(\tau) \tag{35}$$
$$\rho_a(\tau) \in [\mathit{lower\_activity\_work}_a(\tau), \mathit{work}_a(\tau)] \quad \forall a \in A(\tau, \alpha(\tau)) \tag{36}$$

4 Operational

Meta variables:

$$t \in T(\tau) \tag{37}$$
$$\alpha(\tau) \tag{38}$$
$$\gamma(\tau) \tag{39}$$
$$\tau \in [0, \infty] \tag{40}$$

Maximize:

$$\sum_{a \in A(\tau, \gamma_t(\tau))} \sum_{k \in K(\gamma(\tau))} \delta_{ak}(\tau) \tag{41}$$

Subject to:

$$\sum_{k \in K(\gamma(\tau))} \delta_{ak}(\tau) \cdot \pi_{ak}(\tau) = \mathit{activity\_work}_a(\tau, \rho(\tau)) \cdot \theta \quad (\tau) \forall a \in A(\tau, \gamma_t(\tau)) \tag{42}$$
$$\lambda_{a21}(\tau) \geq \Lambda_{a1last(a1)}(\tau) + \mathit{preparation}_{a1,a2} \quad \forall a1 \in A(\tau, \gamma_t(\tau)) \quad \forall a2 \in A(\tau, \gamma_t(\tau)) \tag{43}$$
$$\lambda_{ak}(\tau) \geq \Lambda_{ak-1}(\tau) - \mathit{constraint\_limit} \cdot (2 - \pi_{ak}(\tau) + \pi_{ak-1}(\tau)) \quad \forall a \in A(\tau, \gamma_t(\tau)) \quad \forall k \in K(\gamma(\tau)) \tag{44}$$
$$\delta_{ak}(\tau) = \Lambda_{ak}(\tau) - \lambda_{ak}(\tau) \quad \forall a \in A(\tau, \gamma_t(\tau)) \quad \forall k \in K(\gamma(\tau)) \tag{45}$$
$$\lambda_{ak}(\tau) \geq \mathit{event}_{ie} + \mathit{duration}_{ie} - \mathit{constraint\_limit} \cdot (1 - \omega_{akie}(\tau)) \quad \forall a \in A(\tau, \gamma_t(\tau)) \quad \forall k \in K(\gamma(\tau)) \quad \forall i \in I(\tau) \quad \forall e \in E(\tau) \tag{46}$$
$$\Lambda_{ak}(\tau) \leq \mathit{event}_{ie} + \mathit{constraint\_limit} \cdot \omega_{akie}(\tau) \quad \forall a \in A(\tau, \gamma_t(\tau)) \quad \forall k \in K(\gamma(\tau)) \quad \forall i \in I(\tau) \quad \forall e \in E(\tau) \tag{47}$$
$$\lambda_{a1}(\tau) \geq \mathit{time\_window\_start}_a(\beta(\tau)) \quad \forall a \in A(\tau, \gamma_t(\tau)) \tag{48}$$
$$\Lambda_{alast(a)}(\tau) \leq \mathit{time\_window\_finish}_a(\beta(\tau)) \quad \forall a \in A(\tau, \gamma_t(\tau)) \tag{49}$$
$$\pi_{ak}(\tau) \in \{0, 1\} \quad \forall a \in A(\tau, \gamma_t(\tau)) \quad \forall k \in K(\gamma(\tau)) \tag{50}$$
$$\lambda_{ak}(\tau) \in [\mathit{availability\_start}(\tau), \mathit{availability\_finish}(\tau)] \quad \forall a \in A(\tau, \gamma_t(\tau)) \quad \forall k \in K(\gamma(\tau)) \tag{51}$$
$$\Lambda_{ak}(\tau) \in [\mathit{availability\_start}(\tau), \mathit{availability\_finish}(\tau)] \quad \forall a \in A(\tau, \gamma_t(\tau)) \quad \forall k \in K(\gamma(\tau)) \tag{52}$$
$$\delta_{ak}(\tau) \in [0, \mathit{work}_{a\_to\_o(a)}(\tau)] \quad \forall a \in A(\tau, \gamma_t(\tau)) \quad \forall k \in K(\gamma(\tau)) \tag{53}$$
$$\omega_{akie}(\tau) \in \{0, 1\} \quad \forall a \in A(\tau, \gamma_t(\tau)) \quad \forall k \in K(\gamma(\tau)) \quad \forall i \in I(\tau) \quad \forall e \in E(\tau) \tag{54}$$
$$\theta_a(\tau) \in \{0, 1\} \quad \forall a \in A(\tau, \gamma_t(\tau)) \tag{55}$$