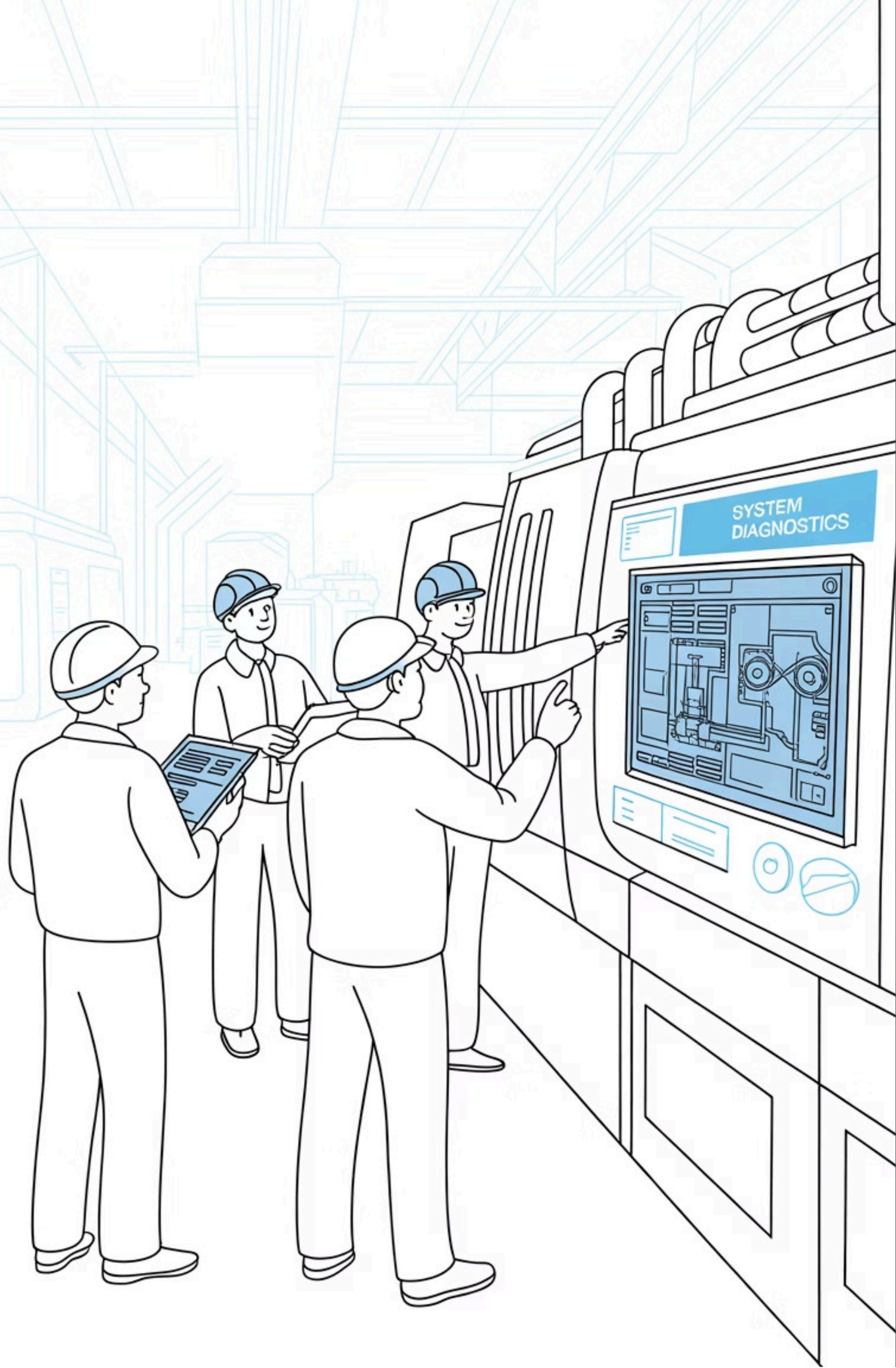

8.4.1 Exemple of algorithm usein MODAPTO:

Dynamic Grouping in Maintenance Planning and Optimization: An Industrial Perspective

This presentation examines the innovative approach of dynamic grouping for maintenance optimization, based on the work by Van-Thai Nguyen, Phuc Do, Chiara Franciosi, Alexandre Voisin, Benoît Iung, et al.. "Dynamic grouping in maintenance planning and optimization: An industrial application." 18th IFAC Symposium on Information Control Problems in Manufacturing, INCOM 2024, Aug 2024, Vienne, Austria.

Fundamentals of Maintenance Optimization

Definition & Core Principles

Maintenance encompasses all technical, administrative, and managerial actions during an asset's life cycle intended to retain or restore it to a state where it can perform its required functions (EN 13306). In industrial settings, this translates to a delicate balance between:

- Preventive vs. corrective maintenance approaches
- Optimal resource allocation across multiple assets
- Minimizing downtime while controlling maintenance costs
- Ensuring compliance with safety and regulatory requirements

Evolution of Maintenance Strategies

Traditional maintenance approaches have evolved from reactive to increasingly sophisticated models:

1. **Run-to-failure**: Simplistic but costly in critical systems
2. **Time-based maintenance**: Regular intervals regardless of condition
3. **Condition-based maintenance**: Monitoring-driven interventions
4. **Reliability-centered maintenance**: Prioritizing critical components
5. **Dynamic grouping strategies**: Holistic system-level optimization accounting for interdependencies and constraints

The increasing complexity of modern industrial systems has revealed significant limitations in component-level maintenance models, which often fail to address system-wide interactions and dependencies. This has created the need for more sophisticated approaches that consider the entire system's operational context.

Industrial Maintenance Challenges

Increasing System Complexity

Modern industrial equipment like the Combiline Machine at Continental Sarreguemines features thousands of interconnected components with complex failure dependencies. When one component deteriorates, it often accelerates the degradation of adjacent or functionally connected components, creating cascading failure patterns that are difficult to predict using traditional component-level models.

Operational Constraints

Manufacturing environments face stringent production schedules, with limited maintenance windows available. Equipment may only be accessible during planned shutdowns, creating temporal constraints for intervention. Additionally, safety protocols and regulatory compliance requirements may restrict when and how maintenance can be performed, particularly in hazardous environments or with specialized equipment.

Logistical Limitations

Maintenance operations face resource constraints including limited spare parts inventory, specialized tooling availability, and qualified technician shortages. Many facilities struggle with budget restrictions while facing pressure to maximize equipment availability. These logistical factors significantly impact maintenance decision-making and must be incorporated into optimization models.

Limitations of Classical Strategies

Treating each component separately often leads to sub-optimal system performance in several ways:

- Excessive system downtime due to frequent individual interventions
- Increased setup and teardown costs from multiple maintenance events
- Missed opportunities for economic grouping of related activities
- Potential introduction of new failures during maintenance activities
- Inefficient resource utilization across maintenance tasks
- Degraded overall system reliability despite component-level optimization

Dynamic Grouping Methodology

Conceptual Framework

Dynamic grouping represents a paradigm shift in maintenance planning by considering interdependencies between components and optimizing maintenance activities at the system level rather than the component level. This approach aims to identify optimal groupings of maintenance tasks that minimize overall cost while satisfying both operational and logistical constraints.

Mathematical Formulation

The core of dynamic grouping involves a cost function optimization that balances:

- **Direct maintenance costs**: Labor, parts, and materials for each intervention
- **Setup costs**: Preparation, shutdown, and restart costs per maintenance event
- **Downtime costs**: Production losses during maintenance periods
- **Risk costs**: Expected failure costs when deferring maintenance

This is subject to constraints including resource availability, production schedules, and component reliability thresholds. The mathematical model employs stochastic processes to model component degradation with time-dependent hazard functions.

Key points in the proposed approach

The methodology introduced in the reference paper offers several significant advances:

1. Integration of both structural (physical) and functional dependencies between components
2. Incorporation of economic dependencies in setup and intervention costs
3. Dynamic adjustment of grouping decisions based on updated condition monitoring data
4. Explicit modeling of resource constraints including spare parts availability and technician skills
5. Consideration of opportunistic maintenance during unplanned downtime events