MODAPTO [101091996]: Modular Manufacturing and Distributed Control via Interoperable Digital Twins

3.2.2. Comparing Setups for Optimal Performance

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Comparing Setups for Optimal Performance

Comparing different manufacturing setups to identify optimal configurations is a critical capability in modular manufacturing. The MODAPTO project has developed sophisticated approaches for evaluating alternative setups based on multiple criteria, enabling informed decision-making for production design and reconfiguration.

Simulation-Based Comparison Approaches

Simulation serves as the foundation for comparing different manufacturing setups. By creating virtual representations of alternative configurations, organizations can evaluate performance without disrupting actual production operations.

SEW Pilot Implementation

In the SEW pilot, a co-simulation approach is utilized to compare different manufacturing setups. SEW currently uses FlexSim, a commercially available simulation system, to evaluate initial production sequences and various parameters. The AUEB simulator was developed within MODAPTO to support daily decision-making in production.

The comparison process follows a defined protocol:

1. The same dataset of orders is fed into both FlexSim and AUEB simulators
2. Key indicators are measured and compared, including:
    - Complete time to produce the set of orders
    - Timestamps for each order at each production stage

This approach ensures a consistent basis for comparison, allowing meaningful evaluation of different simulation approaches and configuration options.

Performance Metrics and Visualizations

Effective comparison of manufacturing setups requires appropriate metrics and visualizations to represent performance differences clearly. The SEW pilot uses several visualization techniques to compare different setups:

1. **Utilization Rate Visualizations**:
    - Cell-level utilization rates: Shows which production cells require the most operators and have the highest utilization rates
    - Step-level utilization rates: Provides a higher-level view of utilization across production steps
2. **Production Throughput Comparisons**:
    - Demonstrates the time required to produce a set of orders
    - Shows the resulting throughput under different configurations
3. **Buffer Occupation Rate Analysis**:
    - Critical for identifying potential bottlenecks

    - Shows when buffers are consistently full or empty

Through these comparisons, the system can evaluate whether a particular setup is optimized for operator utilization, lead time, or buffer management.

Key Performance Indicators for Comparison

The comparison of different setups relies on well-defined KPIs that reflect manufacturing objectives. For the SEW pilot, these include:

1. **Assembly Flow Lead-Time**:
    - Baseline: 1.72 days
    - Target: Less than 8 hours
    - Current result (from simulation): 0.42 days
2. **Productivity**:
    - Baseline: 9 gearmotors per operator per shift
    - Target: 12 gearmotors per operator per shift
3. **Flow Rate Stability**:
    - Target: ±10 gearmotors per hour
    - Current result (from simulation): ±9 gearmotors per hour
4. **Production Capacity**:
    - Baseline: 500 gearmotors/day
    - Target: 800 gearmotors/day
    - Current result (from simulation): 800 gearmotors/day
5. **Machine Utilization Rate**:
    - Target: >80%
    - Current result (from simulation): 89%

These KPIs provide a structured framework for comparing different setups and determining which configuration delivers optimal performance for specific objectives.

Optimization Services for Setup Comparison

Beyond simulation, the MODAPTO project implements optimization services that enhance the comparison of different setups:

1. **Planning Optimization Service 1**:
    - Assists decision-makers in estimating delivery dates for new orders based on the current production schedule
    - Enables comparison of how different configurations would affect delivery times
2. **Planning Optimization Service 2**:
    - Generates improved sequences before orders enter production
    - Allows for comparison of different priority rules and their impact on schedule completion time
3. **Scheduling Optimization Service 1**:
    - Provides assignments of jobs to cells with corresponding sequencing
    - Enables dynamic rescheduling when unexpected events occur
    - Allows comparison of different scheduling approaches

These services support more sophisticated comparison of manufacturing setups by optimizing parameters within each configuration, ensuring that each setup is evaluated at its best potential performance.

Robot Design Setup Comparison in FFT Pilot

In the FFT pilot, the comparison of robot design setups follows a different approach focused on sustainability and operational criteria:

1. **Operational Criteria**:
    - Reachability
    - Operation time
    - Quality specifications
2. **Sustainability Criteria**:
    - Energy consumption
    - Carbon footprint

The comparison workflow includes:

1. The user provides task specifications through the User Interface
2. The system identifies robot design setups that can perform the given task
3. Detailed information about each suitable design is fetched from the Digital Twin
4. Results are filtered based on ability to fulfill the task
5. The user selects the preferred robot design setup from the list

This approach enables comparison of different robot configurations based on both performance and sustainability metrics, supporting environmentally conscious decision-making.

Multi-Criteria Decision Making

Comparing manufacturing setups often involves multiple criteria with different priorities. The MODAPTO project supports multi-criteria decision making through:

1. **Weighted Criteria Evaluation**:
    - Assigning weights to different performance criteria
    - Calculating composite scores for each configuration
    - Ranking configurations based on overall performance
2. **Pareto Analysis**:
    - Identifying non-dominated configurations (those where no other configuration is better in all criteria)
    - Visualizing trade-offs between different criteria
    - Supporting decision-makers in understanding the implications of different choices
3. **Scenario Analysis**:
    - Evaluating configurations under different operational scenarios
    - Testing robustness against variations in demand, resource availability, etc.
    - Identifying configurations that perform well across multiple scenarios

Practical Implementation and Results

The practical implementation of setup comparison has shown promising results across the MODAPTO pilots:

SEW Pilot Results:

- Simulation results indicate that applying the MODAPTO system can significantly reduce the assembly flow lead time from 2 days to 0.42 days
- Production capacity increased from 500 to 800 gearmotors per day
- Cell utilization rates improved to 89%, exceeding the target of 80%
- Flow rate stability achieved ±9 gearmotors per hour, better than the target of ±10

CRF/ILTAR Pilot Results:

- Applying MODAPTO smart services improved the time required for kit holder preparation by 26%
- Optimization of picking sequences reduced movement time and energy consumption

FFT Pilot Results:

- Comparison of different robot configurations led to improvements in sustainability metrics:
    - Reduction of energy consumption by 10%
    - Reduction of carbon emissions by 5%
    - Incorporation of detailed energy and sustainability parameters for production modules

Best Practices for Comparing Manufacturing Setups

Based on the MODAPTO implementation, several best practices for effective comparison of manufacturing setups have emerged:

1. **Establish Clear Comparison Criteria**:
    - Define explicit KPIs for evaluation
    - Ensure metrics align with strategic objectives
    - Include both operational and sustainability criteria
2. **Use Consistent Datasets**:
    - Apply the same input data across all compared configurations
    - Ensure fair comparison by controlling variables
    - Validate results with historical data when available
3. **Implement Appropriate Visualizations**:
    - Design visualizations that highlight key differences
    - Use multiple views to represent different aspects of performance
    - Enable interactive exploration of results
4. **Consider Multiple Scenarios**:
    - Test configurations under varying conditions
    - Evaluate robustness to unexpected events
    - Consider long-term performance, not just optimal conditions
5. **Involve Stakeholders in Evaluation**:

- Include perspectives from different roles and departments
- Consider both technical and business implications
- Balance quantitative results with qualitative insights

Future Directions in Setup Comparison

The field of manufacturing setup comparison continues to evolve, with several promising directions for future development:

1. **AI-Enhanced Comparison**:
   - Machine learning algorithms to identify patterns in performance data
   - Automated generation and evaluation of alternative configurations
   - Predictive analytics for long-term performance
2. **Real-Time Comparison**:
   - Dynamic evaluation of configuration changes
   - Continuous optimization based on current conditions
   - Adaptive reconfiguration recommendations
3. **Extended Sustainability Metrics**:
   - More comprehensive environmental impact assessment
   - Life-cycle analysis of different configurations
   - Social sustainability considerations
4. **Integration with Digital Marketplaces**:
   - Comparison of configurations using components from different vendors
   - Cost-benefit analysis including procurement considerations
   - Supply chain resilience evaluation

Conclusion

The MODAPTO project demonstrates sophisticated capabilities for comparing different manufacturing setups to identify optimal configurations. Through a combination of simulation, optimization, and defined performance metrics, the system enables users to evaluate alternatives based on multiple criteria, including production time, throughput, resource utilization, and sustainability factors.

By implementing structured comparison methodologies and visualization techniques, manufacturing organizations can make more informed decisions about production design and reconfiguration, ultimately leading to improved performance, resource efficiency, and competitive advantage.

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