POPULAR SCIENTIFIC ABSTRACT

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Predictive Maintenance for Collaborative Robot Applications

In the era of Industry 4.0 (I4.0), collaborative robots (cobots) have become integral to manufacturing and automation processes, enhancing productivity and efficiency by working alongside humans. The reliability of cobots is crucial, as unplanned downtime can cause significant production losses and increased costs. Maintenance operations account for 15% to 60% of manufacturing expenses, underscoring the need for refined maintenance strategies to boost profitability and output.

This industrial PhD research project addresses these challenges through Predictive Maintenance (PdM) for cobot applications, a data-driven approach that predicts and prevents equipment failures, enhancing cobot reliability and efficiency. The project covers all phases of the cobot deployment life cycle, considering pre- and post-deployment factors, and reviews current maintenance methods and technologies.

Current cobot maintenance practices rely on condition-based management and diagnostics, lacking comprehensive estimates of remaining useful life (RUL). Additionally, data access is limited to frequency-based methods for state data. This project enables event-based interfaces for data access, allowing efficient and accurate process and event monitoring from the edge.

Furthermore, it introduces methods for estimating cobot wear and predicting RUL based on workload and context, with 90.3% worst-case accuracy. It proposes ways to visualize the data for debugging and cobot program optimization and develops methods to transfer the RUL models based on runtime data to work in the pre-deployment phase without access to telemetry, with 90.4% accuracy. This allows code to be evaluated on longevity before deployment, creating awareness and acknowledging that 60% to 80% of a system's budget is typically allocated to software maintenance. Finally, although diagnostics is a mature domain within PdM, the project proposes a set of efficiency and reliability metrics to identify poor program cycles and evaluate robot program implementations for robustness.

These contributions enable more reliable and efficient cobot operations, potentially reducing downtime and maintenance costs in the robot industry. They also suggest ways for future research to enhance PdM strategies further and develop more advanced tools.