OPTIMIZATION OF PREDICTIVE DIAGNOSTICS AND MAINTENANCE IN PCBA MANUFACTURING USING MACHINE LEARNING AND PROCESS MINING

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Abstract: Server diagnostics and debugging are critical components of maintaining operational efficiency in Printed Circuit Board (PCB) manufacturing and server assembly industries. However, traditional diagnostic processes face challenges such as extended Mean Time to Repair (MTTR), inefficiencies in resource utilization, and bottlenecks in the debug workflow. This thesis proposes a Machine Learning-based framework to optimize server diagnostics, leveraging data-driven insights and advanced modeling techniques to address these issues.

The study begins with an in-depth analysis of the current debug flow, identifying inefficiencies through process mining techniques. Event logs containing system alerts, error codes, timestamps, and technician response times were analyzed to map diagnostic workflows and uncover critical bottlenecks. These include delays caused by manual inspections, technician unavailability, and reliance on traditional fault-detection methods. To quantify these inefficiencies, the MTTR was calculated and analyzed, providing a measurable basis for evaluating the impact of the proposed improvements. At the core of this research is the application of machine learning models—Decision Trees, Random Forest, K-Nearest Neighbors (KNN), and Hierarchical Clustering. Among these, the Decision Tree model achieved the highest accuracy of 94%, demonstrating its effectiveness in predicting failure patterns and guiding efficient decision-making in the repair process. A weighted Tri-partite graph was utilized to visualize the relationships between failure symptoms, corrective actions and affected components, enabling a deeper understanding of diagnostic pathways and probabilities.

The results highlight significant improvements in diagnostic efficiency, including reduced MTTR and enhanced fault-detection accuracy. Comparative analyses reveal the superior performance of the Decision Tree model, making it a cornerstone of the proposed framework. This research provides a scalable, data-driven approach to server diagnostics and debugging, integrating machine learning and process mining techniques. It underscores the transformative potential of transitioning from manual processes to automated, predictive systems. The findings have broader implications for industries reliant on high-throughput testing and debugging, offering actionable insights and paving the way for future research to refine and expand the proposed methodologies.