Event Log-Driven Bottleneck Detection Using Quasi-Random Monte Carlo Methods in Discrete Event Simulation for PCBA Manufacturing

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Abstract:

In modern manufacturing, optimizing efficiency and minimizing delays are essential for meeting the demands of high-volume production. In electronics manufacturing, especially in Printed Circuit Board Assembly (PCBA), even minor inefficiencies can lead to substantial bottlenecks, impacting throughput and increasing operational costs. Traditional bottleneck analysis methods, such as Discrete Event Simulation (DES) and Monte Carlo simulations, often fail to comprehensively explore system configurations, leading to suboptimal solutions. This thesis introduces an advanced approach using Quasi-random Monte Carlo based Sobol sequences within a DES framework to improve bottleneck detection with precision. Quasi-random sequences ensure a more uniform distribution across potential configurations, unlike conventional Monte Carlo methods that may produce clustered results. Using event log (EL) data from five work orders, covering 20,948 PCBA assemblies with details like serial numbers, station transitions, timestamps, and operator identity. By integrating Quasi-random sequences with Event log data, this method aims to outperform traditional approaches to develop a Framework for Production Bottleneck Analysis which identifies bottlenecks related to resource allocation issues, manpower shortages, and specific station inefficiencies, such as machine overuse, production delays, and inefficient shift patterns. The method enables a thorough assessment of manufacturing limitations by categorizing bottlenecks into Primary, Secondary, and Minor groups across three scenarios: Ideal PTs (Optimistic), Event Log-based PTs (Realistic), and QMC Sobol Sequence-based PTs (Pessimistic), providing a scalable and systematic solution for effective bottleneck resolution in complex manufacturing systems.