Data-Driven Throughput Bottleneck Analysis in Production Systems

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Abstract

Manufacturing companies are increasingly adopting digital solutions to monitor and manage production systems. By adopting digital solutions, it has become possible for manufacturing companies to collect huge volumes of widely varying production system data. Alongside this, significant advances in recent years in machine learning and artificial intelligence fields have opened up opportunities to develop data-driven approaches for analyzing the huge emerging volumes of data, deriving insights, and using those insights to improve shop floor productivity. One way to increase shop floor productivity is to strive to achieve an even flow within production systems. However, even system flows may be disturbed by throughput bottlenecks. Throughput bottlenecks are a set of machines that constrain the system throughput. Quick and correct identification of throughput bottlenecks will help practitioners plan appropriate eliminating actions. Existing academic research efforts to investigate throughput bottlenecks have largely adopted analytical approaches (based on building explicit recursive equations) or discrete-event simulation-model-based ones. These approaches are better suited for static analysis and more useful for early configurations of the production systems. On the other hand, now that companies are collecting huge volumes of digital data, this data can be analyzed directly by developing data-driven approaches. This allows the derivation of insights into throughput bottlenecks in production systems. This doctoral thesis constructs a series of data-driven approaches to analyze throughput bottlenecks. Firstly, a data-driven approach is proposed to identify historical throughput bottlenecks in a production system. But merely identifying bottlenecks is not enough if informed actions are to be taken. Secondly, a data-driven approach is proposed for diagnosing historical throughput bottlenecks. Specifically, a diagnosis is made based on a maintenance perspective. Combined with identification and diagnosis, practitioners may then plan and execute different corrective actions. However, when such corrective actions are applied, the dynamics of the production system change. That means that bottlenecks will not act as bottlenecks in the future. Thirdly, to thus predict how the system dynamics will change (and thereby to predict future throughput bottlenecks), a data-driven approach is proposed to predict future throughput bottlenecks in a production system. Fourthly, to help practitioners plan for proactive actions on the predicted throughput bottlenecks, a further data-driven approach is proposed; one which prescribes actions to combat the bottlenecks. The different data-driven approaches proposed in this thesis have been tested using production system data sets extracted from different real-world production systems. The insights obtained from applying these approaches may help practitioners to better understand the dynamics of throughput bottlenecks and plan for specific actions to eliminate them. Such elimination helps achieve an even flow in production systems, thus increasing productivity. The research outcomes of this thesis were implemented in the real world. Two automotive manufacturing companies (one in Sweden and one in Germany) have implemented a datadriven approach to detect historical throughput bottlenecks. A US-based manufacturing analytics software provider has implemented the data-driven approach to detect historical bottlenecks into their package. They provide it directly to their different customers who are using their software.

Keywords
Throughput bottlenecks, Production System, Manufacturing system, Data-driven

Mukund Subramaniyan is a researcher in the intersection of manufacturing and artificial intelligence (AI). Mukund's PhD work has led to the development of data-driven algorithms using statistical and machine learning tools for throughput bottleneck management in production systems. The impact of the work is that it will help manufacturing companies produce more products within a specified time interval. Mukund's long term mission is to build AI technologies for routine diagnosis and prognosis of production systems dynamics to achieve higher shop floor productivity.