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Queueing network modelling of flexible manufacturing system using mean value analysis

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Abstract

In the present investigation, we develop queueing model for the performance prediction of flexible manufacturing systems (FMSs) with a multiple discrete material-handling devices (MHD). An iterative method has been suggested using mean value analysis (MVA) for the state-dependent routing. Two queueing network models are considered to determine the material-handling device interference. In the first one, we model the interference from the MHD by inflating the station service times but neglect queueing at the MHD. In another network, the queueing for the MHD is taken into consideration. The performance of FMS configuration is obtained by iterating between two networks. The suggested algorithms demonstrate better results than the algorithm used by earlier workers for single MHD. Some performance indices viz. throughput, mean service time, mean waiting time, etc. are obtained. Numerical results are provided to highlight the effect of the system parameters on performance indices, which are further evaluated by using neuro-fuzzy controller system to validate the tactability of soft computing approach.
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Keywords: Queueing networks; Flexible manufacturing system; Mean value analysis; Material handling; Adaptive neuro-fuzzy systems (ANFS); Throughput; Waiting time

1. Introduction

With the objective of minimizing the total cost after a long run, considerable interest has been focused on the flexible manufacturing systems having multi-functional machines united together by a material-handling system known as a flexible manufacturing system (FMS). FMS can be defined like a group of numerically controlled machine tools under central computer control. The machine tools are attached together by material-handling system (MHS). The major components of FMSs are computerized numerically controlled machines (CNCs). The set of machine groups wherein each group has one or more identical CNCs such

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as washing machines, unload/load stations and a transportation system, etc. has one or several vehicles giving the structure of flexible manufacturing system (FMS). In real life, production line plays an important role to fulfill a desired demand in due time. With the increased competition in the marketing world, flexibility is essential for a manufacturing company. Mostly manufacturing system managers do not understand the significance of FMSs with a discrete material-handling device (MHD). The success or failure of managers in directing the production rate depends largely on his ability to understand the financial aspects of their jobs.

Flexible manufacturing system (FMS) technology came into existence during the period of late 1960s to early 1970s. Its complexity has moved the Management Science/Operations Research/Engineering Science community by providing challenging new problems regarding the design, planning and control functions of the system. A large number of researchers have attempted to obtain explicit form solutions for general problems in FMS. Some queueing models for flexible manufacturing systems were developed by Dubois [1], Kim [2], Papadopoulos and Heavy [3], Buzacott [4] and many others. Co and Wysk [5] stated robustness of CAN-Q in modelling automated manufacturing systems. Discrete material-handling resources such as automated guided vehicles (AGVs) and central automated resources/retrieval system (AS/RS) were analyzed by Suri and Hildebrant [6] and Dallery and David [7]. Srinivasan et al. [8] searched out the probabilistic models that analyze AGV systems emphasizing more on the material-handling aspect and dispatching rules. A model of FMS with state-dependent routing wherein the job gets routed dynamically to the machine with the shortest queue was developed by Yao and Buzacott [9].

In flexible manufacturing systems for a minimum cost configuration problem, different algorithms are provided by Lee et al. [10], Lee and Kim [11], Choi and Lee [12], Kim et al. [13], etc. Design of manufacturing systems using queueing models was developed by Buzacott and Shanthikumar [14]. To improve manufacturing performance, capacity based order review/release strategies are given by Philipoon and Rry [15]. Stecke and Raman [16] suggested production-planning decisions in FMSs with random material flows. The robustness of using balanced part mix ratios to determine cyclic part input sequence into flexible flow systems was considered by Smith and Stecke [17]. Kim and Yano [18] gave an impact of throughput-based objectives and machine grouping decisions on the short-term performance of flexible manufacturing systems. Nam [19] introduced dynamic scheduling for a flexible processing network. Jain et al. [20] have done performance prediction of a flexible manufacturing system. Sharma et al. [21] gave a transient analysis for maintenance planning of material-handling system (MHS). Kianfar [22] considered the simultaneously planning of the production and the maintenance in a flexible manufacturing system and approximated the origin stochastic optimal control model by a discrete-time deterministic optimal control problem to find a sub-optimal control.

Neuro-fuzzy systems are employed to facilitate the soft computing approaches, which combine artificial neural networks (ANNs) and fuzzy systems (FS). These two soft computing techniques help in developing approximations for complex problems and work on the principle of supervised learning. Takagi [23] has done a survey on fusion of fuzzy technology and neural networks. Haykin [24] gave a comprehensive foundation of neural network. Jang and Sun [25] studied the learning algorithms of adaptive network-based fuzzy inference systems. More detailed descriptions of adaptive neuro-fuzzy systems can be found in Tettamanzi and Tomassini [26]. Kartalopoulos [27] published his work on various application concepts of neural network and fuzzy logic. Darus and Tokhi [28] presented modelling and control techniques based on soft computing methods including neural networks and fuzzy logic for vibration suppression of two-dimensional flexible plate structures.

In this paper, we develop queueing network model for a flexible manufacturing system in which parts are loaded onto finite number of pallets and transported from station to station by multiple MHD according to process plan or routing. The rest of the paper is organized as follows. The assumptions, notations and configuration of the model are described in Section 2. An algorithm for calculating throughput of the MHD based on MVA is given in Section 3. We give algorithm to calculate the waiting time of MHD in Section 4. By neuro-fuzzy approach, various performance measures of the present manufacturing system are discussed in Section 5. Numerical illustrations for comparing the analytical results with the neuro-fuzzy results are provided in Section 6. Finally, the conclusions are drawn in Section 7.

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