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Evaluation of entropy-based dispatching in flexible manufacturing systems

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Abstract

Traditionally, part dispatching has been done using static rules, rules that fail to take advantage of the dynamic nature of today's manufacturing systems. In modern manufacturing systems, machines carry multiple tools so parts have the option of being machined at more than one machine. This flexibility, termed routing flexibility in the literature, opens up new possibilities for shop floor planners for the scheduling and dispatching of parts.

In this paper, we give some background of manufacturing system flexibility, including its measurements. We also present quantifiable measures of flexibility and discuss part dispatching based on entropic measures of part routing flexibilities. Two rules for parts dispatching, namely 'least reduction in entropy' and 'least relative reduction in entropy' are presented. It is proposed that to take advantage of system flexibility, parts dispatching rules based on flexibility measures should be used, especially in systems with high breakdown rates. An extensive simulation study is conducted to evaluate the performance of the dispatching rules. The simulation study confirms that entropy-based dispatching rules out-perform traditional dispatching.

Keywords: Flexible manufacturing systems; Dispatching; Entropic measures of flexibility; Routing flexibility

1. Background

The need for improved product quality, reduced work-in-process (WIP) and lead times, and increased flexibility of operations cannot be over-emphasized. Modern computerized and flexible manufacturing

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systems play an increasingly important role towards this end. These manufacturing systems, with advances in computer control and machining technology, have been evolving continually, but the management of these systems has not kept pace with the advances in hardware. These modern computerized systems are still managed like their older counterparts such as job shops and flow lines.

Operational control of modern manufacturing systems concerns issues like part type selection (for current processing), part input into the system, routing of parts and material handling devices, and handling of unexpected events like machine breakdowns. In this research, we concentrate on the specific problem of parts dispatching, which refers to the selection of the next machine to which a part should be routed, upon completion of the current operation.

One way that modern manufacturing systems contribute towards reducing lead times and WIP is by means of versatile machines capable of performing multiple types of operations. Manufacturing systems consisting of such versatile machines are called flexible manufacturing systems (Talavage and Hannam, 1988). While many studies have been done on the impact of manufacturing flexibility on its performance (Tsubone and Horikawa, 1999; Mahmoodi et al., 1999), little research has looked at the development of scheduling strategies that exploit the flexibility inherent in these systems.

In this paper, we study dispatching strategies for flexible manufacturing systems. We introduce and define manufacturing system flexibility next (Section 2), followed by entropic measures of routing flexibility (Section 3). In Section 4, we present dispatching strategies based on routing flexibility. In Section 5, we discuss a simulation study conducted to evaluate the performance of the dispatching rules. Finally, we present a summary of the simulation results in Section 6 and some concluding remarks in Section 7.

2. Manufacturing system flexibility

The operational flexibility of a manufacturing system arises from the different processing alternatives that exist for processing a part through the system (Browne et al., 1984). Benjaafar (1992) refers to this operational flexibility as product flexibility, and subdivides it into task, sequence, and processing flexibilities. Task flexibility is defined as the availability of multiple machines capable of performing the task. Following Browne et al. (1984), Sethi and Sethi (1990), and Yao (1985), we use routing flexibility to define the availability of multiple machines capable of performing the task/operation.

Sequence flexibility is measured by the ease with which a subset of the operations required to produce a part can be interchanged in sequence. For an example of sequence flexibility, consider a prismatic part that requires two operations to complete it's processing. The first operation consists of milling a face, while second operation consists of drilling on another face of the part. Since the two operations can be carried out in any sequence, the part is said to have complete sequence flexibility (value of one). On the other hand, if it were required that the drilling operation be carried out only after the milling operation was completed, the part would have zero sequence flexibility. A sequence of more than two operations can have sequence flexibility values between zero and one.

Processing flexibility (also referred to as operation flexibility), on the other hand, is measured by the possibility of interchanging an operation (or a set of operations) with another operation (or a set of operations). In this research, we concentrate only on routing flexibility, and ignore sequence or operation flexibility of the parts.

3. Entropic measures of routing flexibility

Flexible manufacturing systems enable managers to cope with the uncertainties of a manufacturing environment (such as machine breakdowns and processing delays) by making use of any operational flexibility