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An intelligent hierarchical workstation control model for FMS

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Abstract

Hierarchical planning, scheduling and control in flexible manufacturing systems (FMS) provide a systematic way to effectively allocate resources along different time horizons. This paper describes the design and development of an intelligent hierarchical control model based on a proposed tool management method. The control model consists of four levels: the process plan selection, the master scheduling, the job sequencing and the control level. The model is developed to optimize the machine utilization and balance tool magazine capacity of a flexible machining workstation (FMW) in a tool-sharing environment. Problems are identified and modeled in the level of process plan selection, master scheduling, and job sequencing. A genetic-based algorithm was developed to solve the problem domains throughout the hierarchical planning and scheduling model. Fuzzy logic technique could also be incorporated into the master production schedule (MPS) level to allow for a more realistic result in the presence of uncertainty and impreciseness in order to fit the realistic nature of actual industrial environments.

Keywords: Flexible manufacturing system; Intelligent hierarchical planning and scheduling; Genetic algorithms

1. Introduction

In order to gain market competitiveness, manufacturers must be able to cope with rapid change in customer demands, reduce manufacturing costs while remaining the quality of products, and shorten the product cycle time. The design and implementation of flexible manufacturing system (FMS) has been one of the popular approaches to address these aspects. Other advantages which can be of benefit from FMS have also been discussed in [1]. The inherent flexibility of FMS, to a large extent, is brought about by computer numerical control (CNC) machines containing tool magazines with multiple tool slots. These machines are capable of performing various functions, for example, a CNC milling machine can also have boring and drilling functions so long as the appropriate tool is inserted in the tool magazine. Therefore, the number of different tools and the tool magazine size determine how flexible such a system can be. On the other hand, the more flexibly the machine can perform, the more expensive and difficult it is to maintain the machine. As a result, the FMS can produce parts that are in large variety and small batches. However, with the increase in part variety, the number of tool types and hence tool costs will also increase. According to Cumings [2] and Ayres [3], tool cost contributes to about 25–30% of the total fixed cost and variable cost in a FMS. One of the most common strategies to reduce this cost is tool sharing among machines in FMS. Gaalman et al. [4] conducted a feasibility study on a FMS in a tool-sharing environment and showed that tool sharing contributes significantly to savings in the overall cost of an FMS. To adopt a tool-sharing strategy, the benefit will be the reduction in tool inventory and improvement in tool utilization. On the other hand, because of the high versatility of the CNC machines and the complexity of tool-sharing strategy, careful planning, scheduling, and control must be in place to make the implementation of such a system justifiable.

This paper focuses on the development of an intelligent hierarchical model for the planning, scheduling and control of a flexible machining workstation (FMW) in such a tool-sharing environment. The FMW under investigation is located in the Industrial Center of the Hong Kong Polytechnic University where the research was carried out. The FMS consists of three CNC milling machines capable of performing boring and drilling processes besides milling functions. The only difference among the three machines is the size of tool magazine slots. Each machine is capable of processing all the operations of the same process types provided that the machine capacity and the necessary tools are available. Tools are centralized in a tool storage room and shared among the three CNC machines by an automatic

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tool-interchanging device that can carry a number of tools equal to the slots of total machine magazines. Apart from the three CNC milling machines, the FMW also consists of an I/O buffer storing pallets of parts, a robot for picking and placing of parts, a vision system for inspection, a washing machine, and a conveyor for the transfer of parts to enable standard inspection and cleaning functions to be performed.

The development of the intelligent hierarchical planning and scheduling model is composed of three levels: the process plan selection, the master scheduling, and the job sequencing level. A process plan conveys a large amount of the processing information of parts. Because of the inherit flexibility given by the FMW, alternative process plans are available for different parts. The constructed plan is composed of a set of features, of which the temporal precedence is represented as a non-linear feature graph in a form of an AND/OR graph. This representation provides a useful tool for the selection of a goal plan, recovery from executive errors, and opportunistic scheduling [5]. The function at the process plan selection level is to select a linear process plan with a set of appropriate tools according to a given criteria for every part. The master scheduling level specifies the production quantity of each part along the planning horizon taking into account the machine capacity and batch sizes. The master production schedule (MPS) must be accurate and realistic because this information will be passed down to the job sequencing level. Subsequent to this is the function of job sequencing. The job sequencing level can be split up into two separate tasks, namely, tool loading to the machine tool magazines and job–machine assignment. For each part, a set of tools must be loaded into the machine tool magazine before performing operations. Further, each machine is capable of performing the operations of each part, so that the problem becomes the assignment of the parts to the machines. This information will finally pass to the CNC machines for the machining of the parts. Due to the complexity of the planning and scheduling problems in the FMW, a genetic-based planning and scheduling algorithm is designed and developed to tackle the three problem domains of the three levels. It is elaborated and illustrated in the following sections.

2. The hierarchical intelligent workstation control model

The intelligent hierarchical control model is depicted in Fig. 1. As can be seen from the figure, the model comprises four levels: process plan selection, master scheduling, job sequencing, and control.

At the top level, the process plan selection level is informed as to which parts are to be processed and receives a set of alternative process plans in a form of non-linear AND/OR graphs. Through the genetic-based planning and scheduling algorithm, a set of efficient linear process plans for each part in the form of linear feature sequences in real

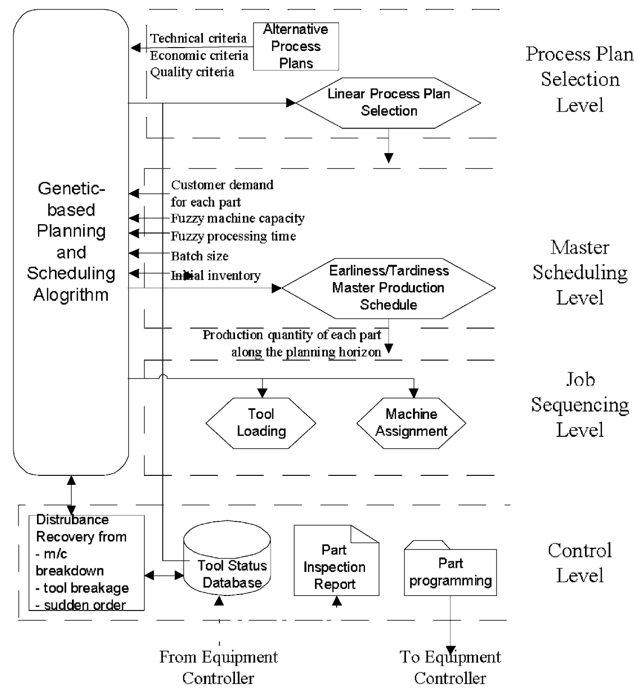

Fig. 1. The intelligent hierarchical control model.

time is determined according to the technical, economic and quality criteria. This information is delivered to the master scheduling level which specifies the production quantity of each product along the planning horizon taking into account the machine capacity and batch sizes. The MPS must be accurate and realistic because it will be downloaded each day to the lower level of the model. Fuzzy logic technique could be incorporated into the modeling of the master production problem in an attempt to make to solution more realistic to be robust in an industrial environment.

The output is then downloaded to the next level: job sequencing level. Job sequencing activities can be split up into two separate tasks, namely, tool loading to machine tool magazines and job–machine assignment. For each part, a set of tools must be loaded into the machine tool magazine before performing operations. Further, each machine is capable of performing the operations of each part, so that the problem becomes the assignment of the parts to the machines in order to minimize the number of tool switches and tool switching instants. Finally, the control level is responsible for interfacing with the equipment level controllers and executing commands from the job scheduling level. It is in charge of workstation start-up and shut-down, monitoring the tool status and the status of part inspection, downloading of part programming to equipment, and recovery from system disturbances such as tool breakage, machine break-down, and sudden orders. Due to the complexity of the planning and scheduling problems in this FMW, a genetic-based planning and scheduling algorithm is designed and developed to tackle the problems at all levels. It is elaborated and illustrated in the following sections.