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ON-LINE KNOWLEDGE-BASED SIMULATION FOR FMS: A STATE OF THE ART SURVEY

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ABSTRACT

Simulation modeling has been widely used to study many aspects of FMS design, planing and control. Yet, simulation modeling still offers other capabilities that are proven to be effective for the on-line control of FMS. An example of it is the training of neural nets off-line, so that it will later control the decision making process when the FMS is in operation. if the neural net runs out of knowledge, it turns back to a simulation model to learn new situations. In this paper, we review the various ways in which on-line knowledge-based simulation for FMS has been approached. This paper represents the early stages of on-going research efforts at Florida International University.

1 INTRODUCTION

A *flexible manufacturing system (FMS)* is a production system consisting of a set of identical and/or complementary numerically controlled machines, connected through an automated transportation system Tempelmeier (1993). FMSs have continuously gained importance not only in big factories but also in the small and medium serial production environments because in a properly organized FMS the production costs and delivery times are relatively low. However, the success of an FMS heavily depends on having effective real-time planning, scheduling, and control. Theoretically, "real-time" should mean providing a decision immediately. But, in practice, the speed at which the decision is needed is actually a function of various system parameters such as the magnitude of part processing times.

The design and operation of an FMS involve solving intricate operational problems in the areas of planning, scheduling, and control. These problems render real-time control of the system difficult to achieve. Some of the planning problems include the number part types to produce in the FMS, and the components and layout of the FMS itself. Scheduling problems include order releasing and sequencing, whereas control problems involve monitoring and controlling of machines. In addition, no two FMS are identical; thus, system decision making varies both in type and complexity Drake, et. al. (1995).

Computer-based simulation can be used in many parts of the life cycle of an FMS. Traditionally, simulation has been used for capacity planning, bottlenecks detection, and creating and testing manufacturing schedules. This means that the simulation modeling activity is done off-line. However, recent efforts have been geared towards using simulation for real-time decision making; thus, drifting from the conventional off-line approach. This new approach to using simulation for FMS analysis requires the handling of large amount of knowledge to prepare the simulation model and to evaluate its outputs. Thus, the combination of traditional simulation systems with knowledge-based systems seems to provide a feasible and effective approach to the decision making problem in an FMS environment. This combination has resulted in what has been called knowledge-based simulation Kopacsi et. al. (1993).

Section 2 provides a description of an architecture of a knowledge based, on-line simulation system. Section 3 survey the current status on the usage of knowledge-based on-line simulation systems as applied to an FMS scenario. This section also provides a review of recent developments in this field. Section 4 summarizes some of the areas and related issues that need further research, so as to fully exploit the use of knowledge based on-line simulation in the context of FMS.

2 STRUCTURE OF A KNOWLEDGE-BASED ON-LINE SIMULATION SYSTEM

On-Line simulation is a computerized system capable of performing both, deterministic and stochastic simulation in real-time (or quasi real-time) to monitor, control, and schedule parts and resources in a discrete part manufacturing system such as an FMS. The level of complexity of an on-line simulation system depends upon the following factors:

Freshness of Dynamic Data: Refers to the frequency by which data is collected from the FMS. This desired frequency level is determined by the elapsed time to conduct the simulation and the complexity of the simulation model.

Degree of Automation of Data Collection: Refers to the means of collecting the data from the FMS. This process could be fully automated or manual through the use of operators.

Degree of Reaction to Data from Shop-floor: Refers to those changes that would prompt a reaction in the on-line simulation system.

Frequency of Simulation: Refers to the frequency and number of times that a simulation would be conducted. This would depend upon the purpose for which the on-line simulation system has been implemented, for instance short-term planning.

Levels of Capability: Refers to the way the on-line simulation system is structured to handle the control decisions.

The Knowledge-based on-line simulation system provides the ability to control the FMS environment by integrating several knowledge-bases with a simulator and data communication software. This architecture can be used for modeling, simulating and analyzing several of the operational problems discussed in the previous section that characterize an FMS.

To integrate the on-line simulation principle and FMS, there are several means of interfacing the simulation model and the physical system. Figure 1 presents a typical viewpoint of this interfacing as given by Tayanithi, (1992) .

Figure 1 shows the major components of the knowledge-based on-line architecture: FMS emulation, nested databases. knowledge bases, on-line simulation (OLS), knowledge-based controller and supervisor interface.

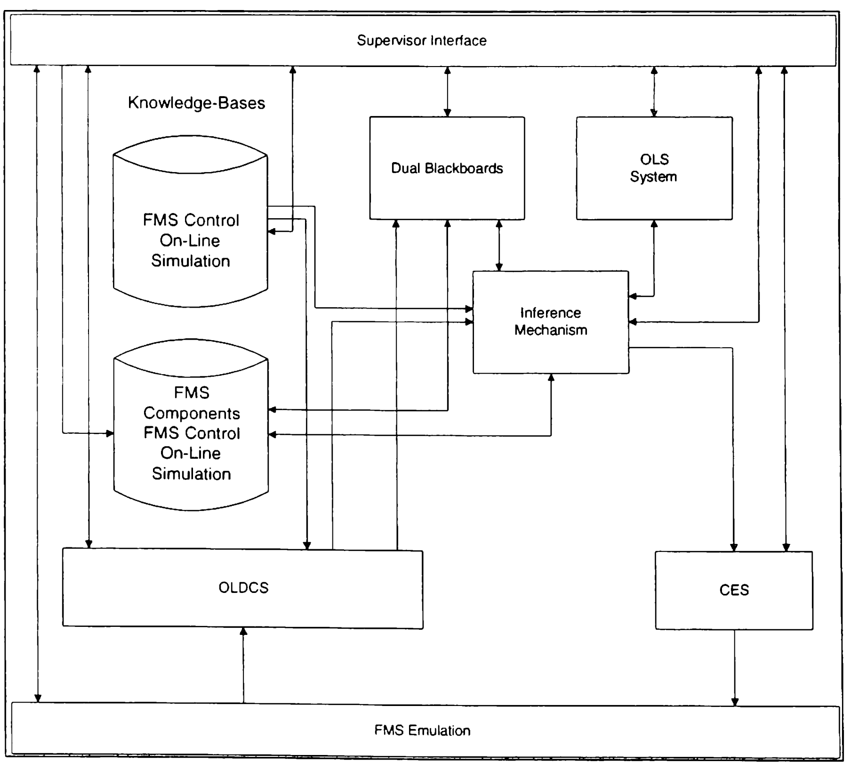

Figure 1: Knowledge-Based On-line Simulation Architecture

The emulated FMS is monitored by the knowledge-based controller; thus, detecting problem immediately when they occur. Upon detection, it would classify the control problems and check to see if a suitable solution resides in the KBs. In the event that no solution is found, alternative actions would be developed and evaluated using on-line simulation. The knowledge base would select the best alternative based on the results from the simulation.

The KB controller includes several inferential methods like forward chaining and blackboard architectures for storing data and improving the inferential process. It interacts with the emulated FMS, nested databases , knowledge bases, OLS, and supervisory interface. The emulated FMS and the KB controller are connected through an on-line data collection system (OLDCS) and a control execution system (CES), as depicted in Figure 1. The OLDCS collects information about the FMS status to allow the KB controller to monitor the system state variables, so as to make appropriate decisions. The CES executes the actions as described by the methods encapsulated in the control decision criteria Tayanithi et. al. (1992).

3 RELEVANT WORK

Many researchers have devoted considerable time to study and prototyping OLS systems in FMS scenarios. Tayanithi, et. al. (1992) presents a study regarding the complexity reduction during interruption analysis in a FMS using a knowledge-based on-line simulation system (KBOLS). Their effort focused on interruptions caused by machine breakdowns and rush orders. These interruptions prompt for changes in the loading scheduling decisions; thus, posing a high level of complexity in the decision making, even when the number of machines and part types in a FMS is small. They developed a new architecture that combines KB, simulation, and an on-line data acquisition techniques in order to perform the interruption analysis. Several experiments were conducted using this architecture to evaluate the improvements in terms of complexity reduction and response time. Results showed a significant reduction of complexity while making critical on-line decisions during the interruptions in a FMS. Another contribution of the study is that the developed architecture is capable of reducing the search space to only a few alternatives instead of evaluating every single one; thus, reducing the response time.

In a similar study done by Manivannan and Banks (1991), a framework for achieving real-time control was developed. The framework integrates data collection devices with a dynamic knowledge base and a simulation model. The framework is known as real-time knowledge-based simulation (RTKBS). The meaning of modeling control and analysis framework within the RTKBS is provided using a very abstract terminology. The problem of synchronizing various events within the FMS and their times of occurrence in both the simulation and the actual manufacturing cell is discussed. Response time reduction is accomplished by creating a dynamic knowledge base containing the results from previous simulations. The RTKBS system is applied to a manufacturing cell connected by a variety of material handling systems.

Szu-Yung David Wu et. al. (1988), proposes a control structure for flexible manufacturing cells that takes advantage of the Expert System technology and discrete event simulation. MPECS (Multi-pass Expert Control System) utilizes artificial intelligence and simulation in real-time control procedures to maximize the benefits provided by each method. The system breaks up a production cycle into various decision point periods. At each of these decision points, the current system status is assessed and simulations are conducted to test which control rule performs the best, among those alternatives generated by the expert system. One significant result from this study establishes that the performance of MPECS is considerably better than that of single-pass traditional methods that constantly use a single rule.

Smith et. al. (1994) examined the application of discrete event simulation for shop floor control of an FMS. In their architecture, namely RapidCIM, simulation is also used as a task generator to control the physical equipment of the shop floor. The way the system is configured provides for a clear separation of decision making and execution; thus, it introduces flexibility into the shop floor control system.

Harmonosky (1995) performed a very comprehensive review of recent developments in the field of knowledge based on-line simulation, focusing on those problems regarding real-time scheduling in an FMS. One of the studies reviewed is the one done by Krishnamurthi and Vasudevan (1991). In their work, they present a framework for a domain-based on-line simulation, which could be used as a general purpose decision support system. This indeed represents the biggest contribution of their study, since as the authors claim, the framework although domain-specific, is generic to all problems generated within such domain. The simulation continuously monitors the real systems so that it always reflects the current system state. This system constitutes an example of what Harmonosky identifies as continuos real-time scheduling, in which every decision regarding the task to be scheduled next is made as time moves forward in the physical system. This opposes the other type of real-time scheduling system, "exception", in which decisions are made whenever an event like a breakdown occurs.

Another study that Harmonosky discusses is the one performed by Duffe and Prabhu (1994). In their study, the authors exemplarize the use of simulation to evaluate local schedules generated by local controllers in an FMS environment. All entities in the system develop a local schedule, which is optimal among their alternatives. Furthermore, the best alternative among all local schedules is selected for execution posterior to the simulation evaluation of these optimal local alternatives. The authors sustain that this method of providing feedback to the entities, allowing them to select their own local schedule, provides faster scheduling decision making and evaluation, which in turns makes this method more attractive for real-time applications.

4 SUMMARY

It has been established that the complexity of the operational problems that characterize an FMS calls for an efficient tool that would facilitate decision making by providing a real-time control in a reasonable response time. A viable alternative to these problems has been the use of knowledge-bases in conjunction with on-line simulation implementations. Although a relevant amount of work has been undertaken in this regard, there are still areas for future research opportunities. One of the areas many of the reviewed authors have agreed on is the frequency by which data should be collected. This area is very important for the overall performance of the system since creating large databases has a negative effect in the response time.

In addition, another area for potential improvement involves simulation software developers. Simulation packages of the future should provide the programming capability to help resolve the issue of interfacing the simulation with the real system which is already being considered by commercial developers as per Harmonosky (1995).

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