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Agent-based FMS control

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ABSTRACT

Future manufacturing systems will be integrated into the networks of distributed resources, and at the same time, such systems will be capable of processing both knowledge and material. It will probably be required that manufacturing systems be agile, flexible, and fault-tolerant. Petri nets (PN) and object-oriented design (OOD) are used together in order to develop the integrated agent-based FMS control system. The flexible manufacturing system (FMS) consists of machines, workstations, and automated material handling system, distributed buffer storage sites and computer-based supervisory control, all which can be modeled as an agent in OOD with PN. This paper introduces the design of an agent-based FMS control system through PNs and evaluates the performance using timed placed Petri nets (TPPN). In order to do so, the agent control design, FMS structure has been evaluated in detail and the agent definitions have been submitted. The system includes the sharing and distribution of tasks among agents and the mentioned structure has been simulated by TPPN. The simulation procedure has been realized through Petri Net 2.0—MATLAB Demo Program [Mahulea CF, Motcovschi MH, Pastravanu O. Department of Automatic Control Industrial Informatics, Technical University "Gh. Asachi" of Iasi, Blvd., Mangeron 53A, 6600 Iasi, Romania, 〈http://www.ac.tuiasi.ro/pntool,pntool@ac.tuiasi.ro〉, 2004.]. Each case is modeled, and then the agent's machine processing time is considered in this program. As for the evaluation of the study, the system performance is assessed through the waiting time of the parts in queue and the task distributions.

1. Introduction

Agent-based flexible manufacturing system (FMS) control system is a mechanism in which status analysis and control of the system is performed by the agents. This control is performed by the Supervisor Agent. This is a mechanism, which continually monitors the system status and conditions and makes the production related decisions.

It is a mechanism where knowledge about the system status, and about which part will be processed in and how much time by use of which robot or AGV and in which frame is received and evaluated. The Supervisor Agent also makes decisions about which process plan is going to be implemented with which operation sequence, taking into consideration the system status. Supervisor Agent is a mechanism which endeavors to answer the questions such as what and how for the production of a part.

It has been aimed at reaching the more rapid and flexible control system that has a complex structure with factor-based FMS control model. For this procedure, firstly, the data and rule base are determined by taking into consideration in detail. The unified modeling language (UML) structure was used in modeling the factors. The UML structure was chosen because this structure shows the message stages particularly and clearly. The Petri net (PN) is preferred in the working style of the system as metaphor simulation. This paper represents the design of an agent-based FMS (ABFMS) control system through PNs and evaluates the performance with timed placed PNs (TPPN). In this study, PN model is designed by taking into account the event-state diagram and database; this program has been run, and its performance figures have been submitted as a conclusion.

It is obvious that artificial intelligence is concerned with intelligent actions in the system. The agent, which is a branch of artificial intelligence, is a task that perceives and acts in this situation. The agent is an autonomous, computational entity that can be viewed as perceiving its environment and acting upon it. It aims at reaching the more rapid and flexible control system, which has a complex structure with the factor-based FMS control model. For this procedure, firstly, the data and rule base are determined considering the components, which primarily comprise FMS for this procedure. Each of the FMS components is determined as factors; the styles of sending messages between the components are examined in detail. The UML structure was used in the modeling of the factors. The UML structure was chosen because this structure shows the message stages more obviously

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and clearly. Secondly, TPPN is used to evaluate the performance of the system components. The TPN is preferred because of the working style of the system and of the metaphor simulation.

In this paper, Section 2 represents literature review; Section 3 includes the explanation of the modeling formalism and simulation algorithm; Section 4 deals with the system design and modeling; and Section 5 covers the conclusion.

2. Literature review

Till now, the structure of FMS has been evaluated only as object-oriented in the previous studies. The other working style of FMS is both modeled and simulated only by PN. The performance evaluation has been preferred through timed PN, for dynamic systems and scheduling problems, which is used to introduce time delays associated with transitions and/or places in net models.

UML and object-oriented design (OOD) structures were used by modeling ABFMS structure to understand the system easily. System modeling and simulation activities are realized by using PN. The aim of this study is to take FMS into a multi-factored system structure and to build much simpler structure and to develop a quicker decision-making process with a complex structure. A widely accepted definition of FMS is as follows [1]: "an FMS is an integrated, computer-controlled complex of automated material handling devices and numerically controlled machine tools that can concurrently process medium-sized volumes of a variety of part types". This definition includes only system elements and physical activities automation and the processing of the parts. The suggested system has been designed to control the efficiency of a well-balanced machine, depending on the speed of the transfer lines, while utilizing the flexibility that shop floor have, in order, to concurrently machine-process the multiple part types. The system element behaviors are modeled in agent approach. An ABFMS is a production system consisting of several workstations linked by a material handling system capable of enabling jobs to follow various routes through the system, monitored and controlled by a network of linked computers, and data acquisition devices. Different parts can be processed simultaneously and with one setup of hardware system.

A descriptive model of sequence control by PN has become appealing due to its simplicity. PNs have a graphical feature that makes understanding the control flow easier. Furthermore, they offer the sequence control functions required to implement FMS. The related studies reviewed here include modeling of FMS control activities by using PN in general.

According to Cho [2], FMS cell activities were built as a model in PN, but they did not realize the simulation. Especially, the shop floor control system was evaluated during the production activities in factory level control systems. Deng and Yang [3] built an object-based architectural model on FMS, considering the detail system structure that resembles the structure of the above reference. They divided the system into various parts, and they called these 'system modules'. They constructed the design and model. Zhang et al. [4] reviewed the test process in FMS control software by using generic PN, but they did not apply it in the system. They have modeled the FMS software system and used the detailed structure and system behaviors. Huang et al. [5] evaluated the cell controller structure and built a cell controller model in PN. They reviewed the detailed system components and behaviors. Jain [6] acquired the system modeling, using the stochastic PN that was used in various manufacturing activities. Especially, the rule-based structure was proposed as a model. Tiwari et al. [7] modeled and evaluated the AGVs in FMS. Then, they obtained the optimum automated guide vehicles' (AGV) routine in manufacturing system via PN. Choi and Kim [8] developed FMS line using the IDEF0 (integrated definition method) modeling system. The developed architectural structure was simulated by using the Visual C++ and Oracle DBMS software. Shi-jin et al. [9] realized the dynamic scheduling and compared the dynamic and static scheduling. Lee and Korbaa [10] presented an analysis of the cyclic scheduling for the determination of the optimal cycle time and the minimization of the work in process (WIP). The product ratio-driven FMS cyclic scheduling problem using timed Petri nets (TPN) unfolding is described by them. Kim et al. [11] presented the scheduling for manufacturing system based on the timed PN model and a reactive fast graph search algorithm [21,24].

The theory of the PN was proposed by Petri in Germany in the 1960s [12]. The PN enables the modeling of synchronic and uncertain behaviors of a system. The graphical representation of a PN can express system behaviors, resources and constraints more easily than other methods [13,19,22,23,25].

As acknowledged, FMS is characteristically composed of: (i) several manufacturing machines such as computer numerical control (CNC) machining centers; (ii) material transport and handling equipment such as an AGV together with a material loading and unloading station, central material buffer, and local material buffer dedicated to an individual manufacturing machine to carry out efficient material-flow tasks within the system; and (iii) robots using the tool transport and exchange equipment. Multi-agent systems (MASs) offer modularity. If a problem domain is particularly complex, large or unpredictable, then the only way it can reasonably be addressed is to develop a number of functionally specific modular components (agents) that are specialized in solving a particular problem aspect [18,20].

Fig. 1 shows a typical structure configuration of an FMS, which was used as a testing case in this research. The operation information of the jobs and resources will be discussed below. The system contains four CNC machine, two robots, three AGV components that represent the ABFMS elements.

While there have been some programming tools developed for FMS control software in PNs, they are not sufficiently capable of FMS control involving complicated information processing. In this paper, a timed PN model is proposed for the development of the ABFMS control software, and an approach is developed to implement operation checks and software testing in an FMS. It consists of two phases: design and modeling. The simulation result of the system provides the optimum scheduling route for processing. A timed PN of FMS is first described as a kind of 'form'. The model of a particular FMS is then established as instances of the form.

PN is addressed for a given FMS, which is envisaged for the FMS control software testing. The key ideas leading to our objective include: (i) the modeled according to their activity characteristics in the FMS; (ii) the elements in sets of the places and the transitions are described via the general problem solving strategy in the agent base.

3. Agent-based FMS control

This section reviews the ABFMS mathematical formulation, design and simulation in the subsections. The process of designing includes the grouping and defining of the FMS components. The components making up FMS—machines, robots and AGVs—communicate with each other and optimize the dynamic operating of the system. Agent systems and components are described in a mathematical formulation through timed placed PN and then designed. In the process of simulation, the decision-making