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DYNAMIC CO-OPERATIVE SCHEDULING BASED ON HLA

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Abstract: In an advanced factory, higher and higher flexibility is required to meet a great variety of customers' requirements. In this environment, a dynamic management architecture is required for distributed production system. In this paper, a newly distributed simulation architecture called HLA (High Level Architecture) is utilized to achieve a distributed scheduling simulation for dynamic work assignment and flexible working group configuration in a distributed production system. It is verified that the distributed scheduling simulation based on HLA is effective to achieve higher flexibility for a distributed production system, by some case studies.

Key words: HLA, dynamic scheduling, distributed simulation, intelligent and distributed production system

1. INTRODUCTION

Because of the drastic change in computers and information technology, production systems have to be changed. Some mass production systems or transfer line production systems have become old fashioned, and YATAI production systems or cell production systems have been introduced to satisfy a great variety of customers' requirements[1]. In this environment, a dynamic management architecture is required for such distributed production systems to have and to maintain higher flexibility and agility.

In distributed systems, information processing in each subsystem can be reduced as compared with the centralized module in conventional systems.

However, the heavier load is imposed on the network because frequent information exchange among subsystems is needed. Furthermore, synchronization among subsystems is also required because information processing speed of subsystems are different from each other.

In this study, HLA (High Level Architecture)[2], which can realize effective communication and time management among subsystems, is applied to the distributed production system. Furthermore, cooperation methods among subsystems which do not need any centralized module are proposed in order to realize flexibility and agility of the whole system. Finally, the effectiveness of our developed system based on HLA is demonstrated with some case studies.

2. DISTRIBUTED PRODUCTION SYSTEM BASED ON HLA

HLA is an architecture in order to realize distributed simulation, which has been developed by the U.S. Department of Defense[2]. It has the following characteristics ;

- Reusability and interoperability of simulators
- Easy realizability of complex distributed/parallel processing

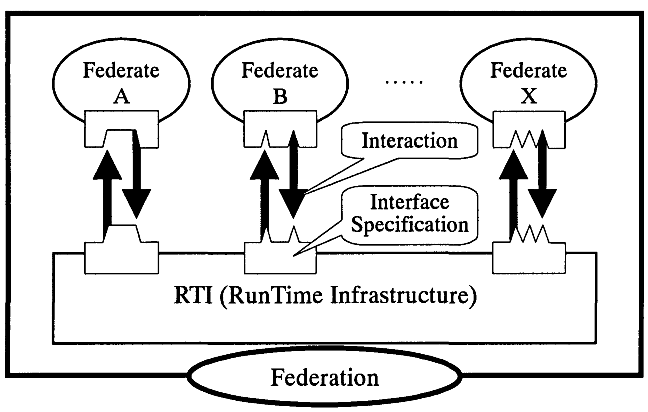

Figure 1. Conceptual diagram of HLA

Figure 1 shows the conceptual diagram of HLA. A federation is a simulation system which consists of several subsystem simulators referred to as federates. RTI (Run Time Infrastructure) is a software supporting communication among federates. Each federate can exchange only data which are defined by FOM (Federate Object Model) with others through RTI.

A new federate can be added to the federation at any time if it has only an adapter which satisfies interface specification in order to connect RTI.

Consequently, we apply HLA to the distributed production system architecture. Each cell/AGV then corresponds to a federate. They have the capability to estimate their processing/transporting time with respect to works and exchange only input/output of the estimation with each other through RTI. Furthermore, a cell/AGV can be attached/detached to the system at any time. This implies that the structural flexibility of the system can be realized.

We also provide a scheduler as one of federates. As a production system becomes large and complex, it takes a longer time to optimize a production schedule. However, the generated schedule may become null immediately if disturbances such as change of production requirements or breakdown of facilities occur frequently during production. Moreover, all processes for production must be stopped until rescheduling is finished. This inhibits the agility of the system as a result. Therefore, in our study, the scheduler has a quick scheduling method based on a simple rule without stop of the whole system. It is referred as to dynamic scheduling in this paper. Note that its result can be not optimal totally.

Our developed system consists of some cell groups, a storage, a scheduler, and RTI. Each cell group consists of some cells. Each cell has the capability to determine processability and to estimate operating time with respect to works. They can exchange such information with others in the same cell group. Cell groups exchange another information such as request of assistance with each other. A production schedule in a cell group is determined by a scheduler, but cooperation among cell groups is executed without any centralized function/module.

This system is similar to a centralized and distributed production system based on active database which we developed[3]. In this system, the active database of the previous system is replaced by RTI. Then, cell groups can be synchronized by RTI. A procedure to generate a master schedule in a cell group is equivalent to that in the active database system. Let us explain it briefly. Production requirements are transmitted to each cell group through RTI at first. Each cell in each cell group determines processability with respect to each work and estimates operating time of works if it can be processed by them. Estimation results from each cell are sent to a scheduler through RTI, then, the scheduler generates a master schedule. Note that scheduling is executed after the scheduler receives replies from all cells in this phase.

We explain the rescheduling flow of our developed system based on HLA in the next section.

3. DYNAMIC RESCHEDULING

In this paper, as disturbances of the system, the following events are considered ;

- Change of production requirements
- Change of properties of subsystems

The former includes change of the kind/number of parts to be manufactured, the latter includes change of functions/abilities of subsystems. Not only facilities but also human workers/craftsmen can be regarded as one of subsystems. When a disturbance occurs, our developed system tries dealing with it by rescheduling in each cell group. If it is impossible, that is, the final result of rescheduling can not satisfy due date, each cell group tries cooperating with others by reassigning works or facilities. Let us explain this procedure.

3.1 Rescheduling in One Cell Group

In this section, let us consider rescheduling in one cell group. When a disturbance occurs, only manufacturing operations which are being executed and can be continued are assigned to running cells until they are finished. The rest of operations should be cancelled and rescheduled. Information with respect to operations to be rescheduled is delivered to each cell and processability determination and operating time estimation are performed by each cell. Note that the current operation in each cell never be stopped during its processability determination and operating time estimation. After that, each cell replies a result of them to the scheduler.

As processability and operating time with respect to each operation, which are determined/estimated by each cell when a master schedule was generated, are stored in the scheduler, they are used for rescheduling without asking each cell about them again. Therefore, needless inquiries to cells can be omitted.

However, time needed for processability determination and operating time estimation by each cell is different because function, ability, and/or information processing capability of each cell is different. So, the scheduler can not receive replies from all cells at a time.

Moreover, when the number of operations increases, it takes much time for the scheduler to receive replies from cells because much time is needed for determination /estimation of each cell.

In our system, the scheduler repeats rescheduling whenever it receives a reply from a cell. This process flow is illustrated in Figure 2. In order to finish rescheduling with a short time, SPT (Shortest Processing Time) rule is adopted as a dispatching rule in the scheduler. Consequently, a new result by one rescheduling does not reflect all processability determination and operating time estimation with respect to operations which have not been executed yet. Furthermore, this system does not guarantee that the finishing time of all operations becomes earlier by repeating rescheduling. Therefore, the system repeats rescheduling with adopting only an improved rescheduling result on the previous one until the result reflects all processability determination and operating time estimation with respect to un-started operations.

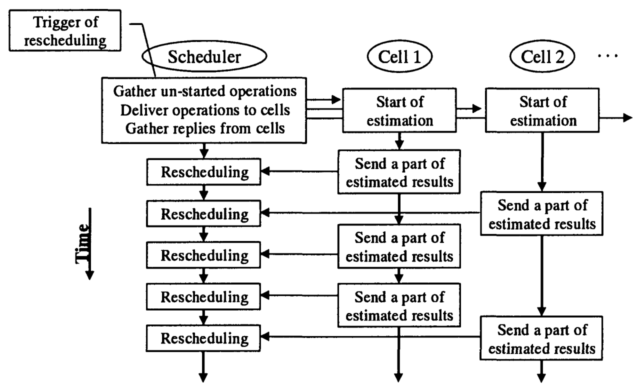

Figure 2. Rescheduling procedure in one cell group

3.2 Rescheduling among Cell Groups

In the previous section, we explained rescheduling in one cell group of our developed system. However, the result of rescheduling in the group may not satisfy its due date. Then, rescheduling among cell groups is needed so that all cell groups can satisfy their due dates. In this study, for such cooperation among cell groups, the following means are prepared ;

- Dynamic work assignment among cell groups
- Dynamic operator assignment among cell groups

First, let us explain dynamic work assignment. When disturbance such as breakdown of facilities occurs in one cell group, rescheduling mentioned in the previous section is executed at first. If the due date of this cell group is not satisfied in spite of rescheduling, the group asks for assistance, that is, taking on operations with respect to one lot to other groups. Other groups simulate rescheduling when they accept it, with executing their current operations. If their results satisfy their due dates, they inform that they can accept that request. Then, the lot is reassigned to the cell replied earliest. The asking cell reschedules again in order to check whether its due date is satisfied by assistance of another cell or not. If it is not satisfied yet, the cell continues to request assistance of another lot. Other cells also continue to determine its request and accept if possible. When the due date of all cell groups is satisfied, rescheduling of the whole system completes.

When we assume that cells are not fully automated facilities but machines controlled by human operators or human workers/craftsmen themselves, they can move around in a factory. This implies that dynamic reconfiguration of cell groups is possible. In such environment, dynamic operator assignment, one more cooperative scheduling method can be introduced.

A cell which becomes unable to satisfy its due date asks for sending of one operator to others. Other groups simulate rescheduling when one operator in them is sent to another group without stop of their operations. Note that which operator should be sent depends on each cell group. If their due dates are satisfied in spite of decrease of their operators, one operator is actually sent from the earliest responding cell group. After that, requests and acceptances/rejects are exchanged among cell groups until all due dates are satisfied.

Thus, by using two types of dynamic cooperative scheduling methods, our proposed system can deal with disturbances without any centralized module.

4. CASE STUDIES

In this section, the effectiveness of our developed system is demonstrated with some case studies. First, rescheduling in a cell group is shown. Next, two kinds of cooperative rescheduling among cell groups are shown.

4.1 Rescheduling among Cell Groups

Figure 3 shows an experimental rescheduling result of one cell group, which is a part of our developed system. This cell group consists of five machining cells. The first Gantt Chart in Figure 3 shows a master schedule. The finishing time of all operations is 21:08. If the ability of cell 1 descends at a certain time, the system generates the rescheduling result when cell 2 through cell 5 are used as shown the second chart in Figure 3. Because this result does not reflect an operation assigned to cell 1 and been executed and operations following it, the chart includes many blanks. The finishing time becomes 22:22. The scheduler reschedules whenever processability and operating time with respect to an operation been executed and not finished by cell 1 are sent from each cell. Incidentally, those with respect to other operations are stored in the scheduler. The finishing time reaches 24:33 temporally when processability and operating time of one cell are reflected. Whenever those of a cell are transmitted to the scheduler, rescheduling is executed and the more improved result, that is, the shorter one between a new one and the previous one is adopted. After replies from all cells are received, the finishing time becomes 22:13 as the result of final rescheduling.

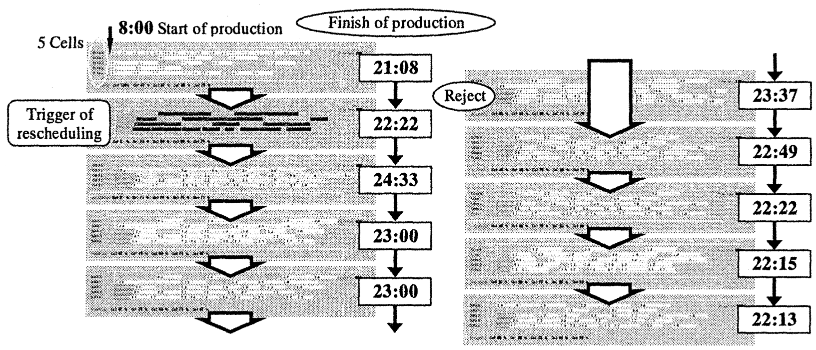

Figure 3. Experimental rescheduling result in one cell group

4.2 Rescheduling Among Three Cell Groups

Next, let us show examples of cooperation among cell groups. Our developed system consists of three cell groups. Cell group 1, 2, and 3 also consist of five, seven, and three machining cells, respectively.

Figure 4 shows an example of dynamic work assignment. At a certain time, cell group 1 becomes unable to satisfy its due date because the ability of one cell descends. Then, cooperative rescheduling mentioned in the previous section is started. After three lots and two lots are reassigned into cell group 2 and 3, respectively, the due date of cell group 1 is satisfied.

Figure 5 shows an example of dynamic operator assignment. When the due date of cell group 1 becomes unable to be satisfied, the group asks for sending of one operator to cell group 2 and 3. In this case, cell group 2 can accept this request but cell group 3 can not accept it as a result of rescheduling simulation. Therefore, cell group 2 sends one operator to cell group 1. By this assistance, cell group 1 can satisfy its due date.

Thus, our developed system can deal with some disturbances by rescheduling in each cell group in the first step, and by rescheduling among cell groups with two kinds of cooperation methods in the second step.

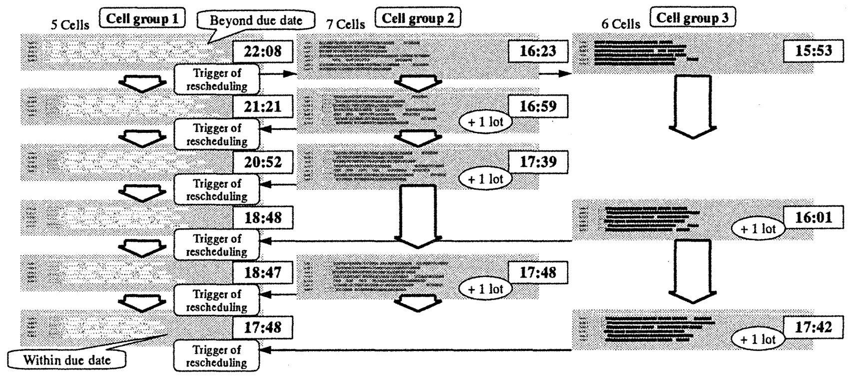

Figure 4. Rescheduling result of dynamic work assignment

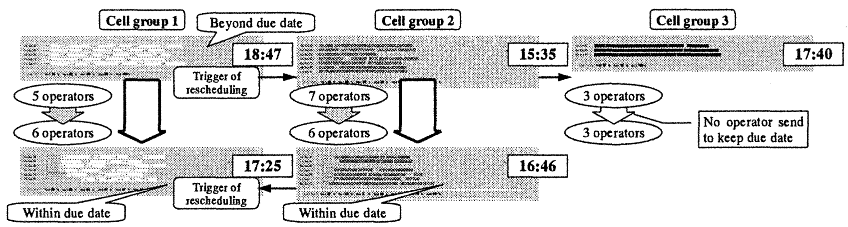

Figure 5. Rescheduling result of dynamic operator assignment

5. CONCLUSION

In this paper, a distributed production system based on HLA was proposed. It has a function of dynamic scheduling for flexibility and agility of the whole system. Furthermore, two kinds of cooperation methods, dynamic work assignment and dynamic operator assignment, were introduced in this system. Then, by cooperation among subsystems, the system can deal with disturbances without any centralized module.

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