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DEVELOPMENT OF INTEGRATED SCHEDULING SYSTEM FOR VIRTUAL MANUFACTURING SYSTEM

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Abstracts Virtual Manufacturing System(VMS) is an integrated computer based model which has physical, logical schema and behavior of real manufacturing system. In this paper, an integrated scheduling system is developed to simulate and control a Virtual Factory. A workflow model is constructed to define and analyze the structure of a VMS. On-line dynamic dispatching system is developed using MultiPass algorithm and scheduling system considering dynamic CAPP is carried out. Integrated scheduling system developed in this paper reduces the discrepancies between virtual model and real manufacturing system, and control of real shop floor is possible.

Keywords Virtual Manufacturing System, Scheduling, Modeling, Computer Aided Process Planning, Simulation

1. INTRODUCTION

As construction of information highway and wide distribution of internet, database integration and communication between each corporation in CALS(Commerce at the Light Speed) environment enable Virtual Corporation (VC).

Virtual Manufacturing System(VMS), which is one of the essential factors of VC, is the integrated computer based model contains all activities and decisions about real manufacturing system with database and networks. VMS can simulate the real plant with startling reality.

An integrated scheduling system is developed in this paper in order to construct and control VMS. This integration means concurrent development of dispatching and simulation module, and an integration with CAPP module.

First, an workflow model using IDEF0 for functional modeling and IDEF1X for information modeling is performed to analyze and define the structure of VMS. Second, an on-line dynamic dispatching system is developed using MultiPass algorithm as well as many previous dispatching rules. Third, scheduling system considering CAPP is carried out to integrate CAPP and scheduling system.

Expert system is used to construct the scheduling system because of the advantages for maintenance, easy modifications, and to prepare the dynamic characteristics of FMS.

2. WORKFLOW MODEL FOR VMS

2.1 Concept of VMS

VMS is an integrated computer based model which has physical, logical schema and behavior of real manufacturing system[3]. In CALS environment, construction of global computer network and integrated database is possible. VMS realizes VC in CALS environment.

Some advantages of VMS are summarized as follows:

- Many manufacturing processes are integrated and realized by unique system. So manufacturing cost and lead-time are reduced and productivity is improved.
- Abilities to cope with rapid changes of manufacturing environment and market are increased.
- Manufacturing time and employees which are needed to design products and prepare off-line processes and manufacture parts are dramatically reduced.
- VMS is the core technique to develop the open system integration, which enables VC.

2.2 Functional Analysis of VMS

VMS is seems to be one of the most challenging issues in manufacturing stage at present. Organized functional analysis and workflow modeling of VMS is needed.

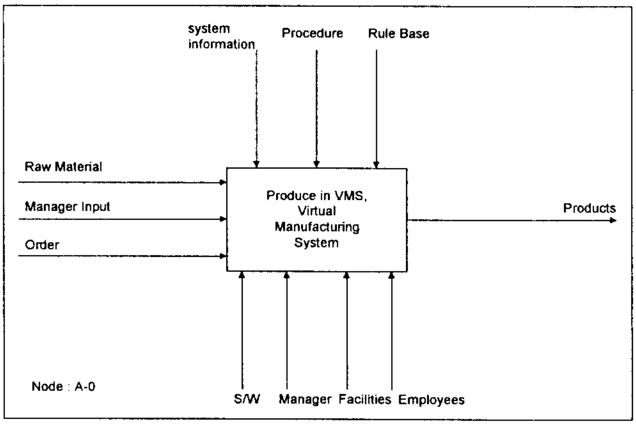


Figure 1. VMS IDEF0 diagram : Node A-0

The IDEF0 for functional modeling methodology which was developed by U.S.Air Force is used in this stage. The IDEF0 diagram that shows input (raw material, manager input, order), control (system information, procedure, rule base), mechanism (software, manager, facilities, employees) and output (products) of VMS at the highest level is given in Figure 1. Figure 2 shows A0 node, which the branch of top-level diagram A-0 node.

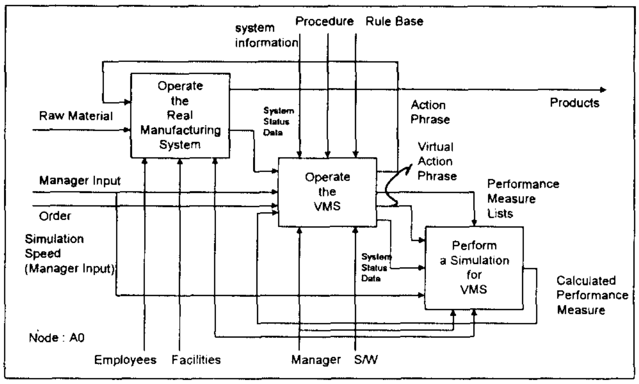


Figure 2. VMS IDEF0 diagram : Node A0

A whole workflow model for VMS is formulated, and it became a fundamental structure to construct Manufacturing Database(MDB), to perform object oriented analysis and to design an scheduling system with expert system.

3. INTEGRATED SCHEDULING SYSTEM

3.1 Integrated Scheduling System

The integration of scheduling system for VMS is performed by two steps as follows.

First, the simulation model of manufacturing system is integrated with VMS scheduling system. In stead of using commercial simulation package such as SIMAN, AUTOMOD, SIM-FACTORY, system imported simulator is developed by using an expert system shell. Generally, most off-line scheduling and simulation interface is performed by file interface. But the simulator which is proposed in this paper is developed with scheduling system simultaneously. So no file interfaces is needed and on-line dynamic simulation is possible.

Secondly, a scheduling system which considered dynamic CAPP system is developed. CAPP is the bridge process between design and scheduling by process selection, sequencing, machine allocation. Because of the machine selection of CAPP, integration of CAPP and manufacturing scheduling system is essential.

3.2 Construct Simulation Model using Expert System

As described above, a Virtual Factory simulator was imported to VMS scheduling system.

Generally, many established scheduling systems have off-line simulation to evaluate system with file I/O interface and on-line control of real manufacturing system is very hard to perform. In this paper, on-line simulation model to operate and test VMS or real manufacturing system was developed.

Object oriented technology was used to integrate simulation model and main scheduler. When the system state changes to predetermined state, main scheduler transfers a message and an object of action phrase to simulation model in real time. Then it receives a message containing some performance measures after simulation.

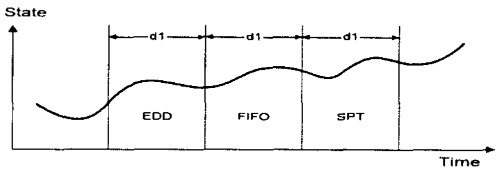
3.3 On-line Dynamic Scheduling System

(1) Scheduling Methodology : *MultiPass method.*

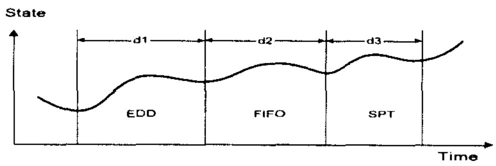
Many researchers have been studying dispatching rules since 1960s. As a result, more than one hundred dispatching rules such as SPT, FIFO, LIFO, EDD have been proposed. But no dispatching rule have been shown to consistently produce better results than all other rules under a variety of shop configuration and operating conditions. So Wu and Wysk[9] (1989) propose MultiPass method for this problem.

In this paper three MultiPass method which is described as follows is used.

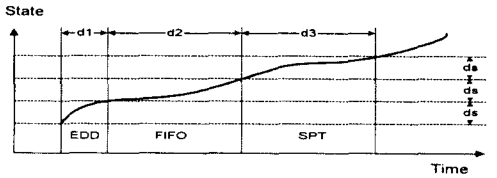
- Method of Wu, Wysk[9] : system state variable is constant time interval. Whenever the time interval reaches previously selected time interval, scheduling start simulation.
- Method of Ishi, Talavage[6] : system state variable is a user set state index function. Whenever state index function reaches transient state, scheduling start simulation.
- Method of Hong[4] : system state variable is the number of produced parts. Whenever the number of produced parts reaches previously set value, scheduling start simulation.



(a) Method of Wu, Wysk



(b) Method of Ishi, Talvage



(c) Method of Hong

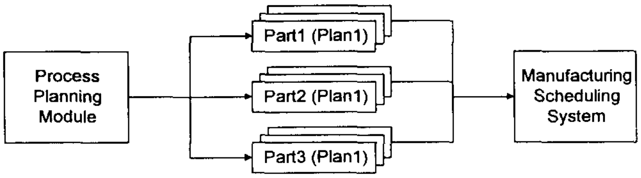
Figure 3. Characteristics of MultiPass Systems

To perform satisfactory on-line MultiPass scheduling, time is the most important factor to consider. So simulator and scheduling system integration without file interface is essential.

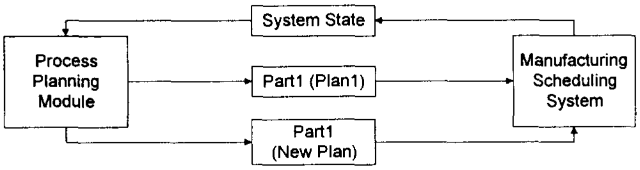
(2) CAPP Integration Methodology : *Closed Loop CAPP.*

Several Researches have been performed about the integration of CAPP and scheduling system to achieve totally integrated manufacturing operating system and dismiss the traditional sequential manufacturing system. Approaches about integration of CAPP and scheduling system can be categorized as following two phase.

- Open loop process planning (OLPP)[2] : This approach makes all possible alternative process plans(plans) before it enters into shop-floor. Each plan has priority and scheduler selects first priority. If the selected plan is not suitable the current status of shop-floor, next priority plan is selected.
- Closed loop process planning (CLPP)[2] : At this approach, CAPP perform a planning with initial system state before it enters shop-floor. If system state changes and plan is not suitable then some feedback to planner occurs and re-planning is performed with new system state.



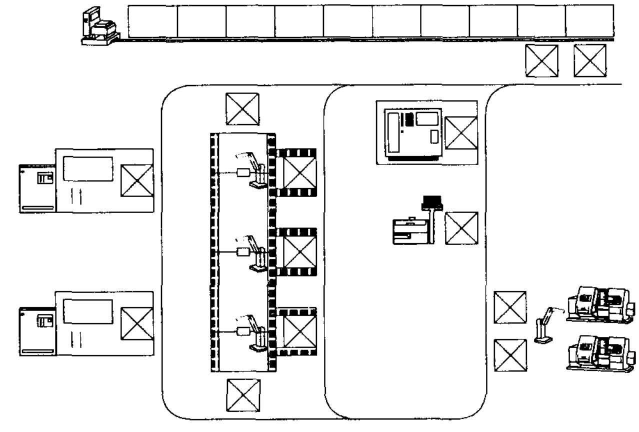
(a) Open Loop Process Planning



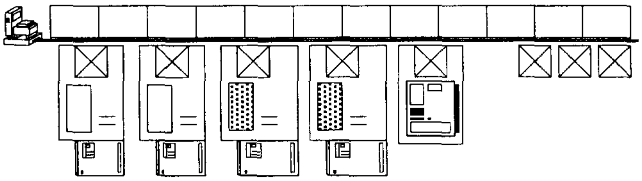
(b) Closed Loop Process Planning

Figure 4. Approaches of Integration of CAPP & Scheduling

In this paper, an integration of CAPP and scheduling system was developed based on CLPP approach.



(a) Virtual Factory 1.



(b) Virtual Factory 2.

Figure 5. Virtual Factory for implementation

4. IMPLEMENTATION

4.1 A VMS Model for Implementation

Two Virtual Factory(VF) were developed in this paper to apply VMS scheduling system. The layout of each VF is shown Figure 5. (a) VF1 and (b) VF2. VF1 produces and assembles three types of electronic motor with the number 200 small size, 150 medium size, 150 large size each month. VF2 produces some subparts of machining center and NC lathe like case, block, bed, housing. Table 1. shows an example of this products.

In this experiments, the performance of VMS is compared using following five criteria.

- Machine Utilization
  = Working Time / Machine Hours Available
- MLT (Manufacturing Lead Time)
- Average Tardness
  = The difference between due date and produced date
- Average Lateness = Max{0, Lateness}
- Productivity = The number of products each hour

Table 1. Example of Products : CAP (Lot size 4)

ID	Process Name	Machine	Process Time (min)		
			Small	Medium	Large
10	Set-up	SETUP	5:00	5:00	5:00
20	Facing, Drilling, Milling	MCT	160:00	200:00	240:00
30	Washing	WASH	3:00	3:00	3:00
40	Inspection	INSP	2:00	2:00	2:00
50	Set-up	SETUP	3:30	3:30	3:30
60	Turning, Boring	NCLT	72:00	84:00	96:00
70	Washing	WASH	5:00	5:00	5:00
80	Inspection	INSP	4:00	4:00	4:00
90	Set-down	SETDN	1:00	1:00	1:00

4.2 Simulation Parameters

In this paper the manufacturing simulator is integrated with VMS scheduling system. To evaluate the performance of this simulator, SIMAN which is known for manufacturing simulation package is selected. The same shop-floor simulation model with VMS simulator is constructed by SIMAN.

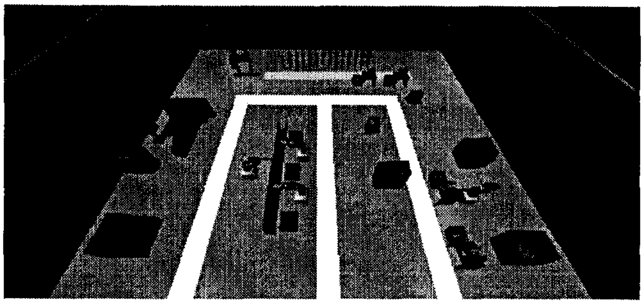
- Simulation Time : 1 week
- Number of replicates : 10

Three MultiPass Algorithm as shown Figure 3. is tested at this stage. Simulation window size have the same time value of simulation interval. Each MultiPass method described above has simulation interval as follows :

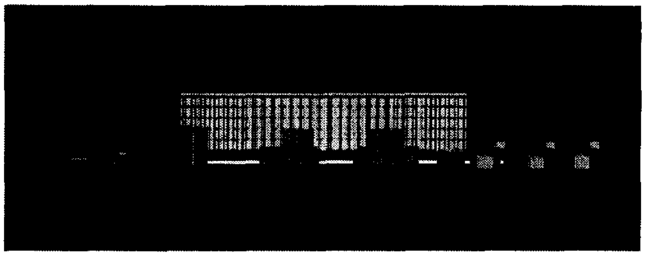
- Method of Wu, Wysk : 3 times of average process time.
- Method of Ishi, Talavage : index function.
- Method of Hong : each time of 6 parts produced.

4.3 Results of Implementation

An integrated scheduling system for VMS was developed by means of an expert system shell. First, a Virtual Factory was constructed to replace real shop-floor. Simulation model using object oriented technology was developed and imported to scheduling system. As well as simulator, every VMS module was developed by using the expert system shell with object oriented technology.



(a) Virtual Factory 1



(b) Virtual Factory 2

Figure 6. Implemented Virtual Factory.

Figure 6 shows a 3-Dimensional VRML model by VRML language for developed Virtual Factories. Developed scheduling system was tested to Virtual Factories of Figure 6. and the results is described at Table 2. and Table 3.

The performance of VMS simulator is evaluated by means of comparison with SIMAN.

Table 2. Result of Implementation 1 : Utilization

	Utilization
MCT1	0.893
MCT2	0.892
NCLT1	0.930
NCLT2	0.918
INSP1	0.212
WASH1	0.267
AGV1	0.684
SYSTEM	0.715

Table 3. Result of Implementation 2 : Produced Parts

	large motor	medium motor	small motor
Part Number	56	53	51

5. CONCLUSIONS

In this paper an integrated scheduling system which is designed for the operation of Virtual Manufacturing System was proposed.

A developed manufacturing simulator is integrated with VMS scheduling system. MultiPass scheduling methodology is applied to developed scheduling system of Virtual Factory.

Some important observations on integrated scheduling system is shown as follows :

- A systematic workflow model for VMS is formulated using IDEF0, IDEF1X, and it became a fundamental structure to construct MDB, to perform object oriented analysis and to design an scheduling system with expert system.
- By means of developed integrated scheduling system, some manufacturing paradigm such as MultiPass methodology was applied and tested to VMS. So manufacturing lead-time, cost and risk of applying new manufacturing strategy are reduced.
- Not off-line simulation to evaluate system by file I/O interface, but on-line simulation to operate and test VMS or real manufacturing system was developed.
- As well as SinglePass, MultiPass methodology was applied to VMS and system performance improvement of MultiPass methodology was shown.

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