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Integration of process planning and scheduling using simulation based genetic algorthms

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Abstract

Process planning and scheduling are traditionally regarded as separate tasks performed sequentially. But, if two tasks are performed concurrently, greater performance can be achieved. In this study, we propose new approach to integration of process planning and scheduling. We propose new process planning combinations selection method using simulation based genetic algorithms. Computational experiments show that proposed method yield better performance when compared with existing methods.

Keywords: Genetic algorithms , process planning , process plans , scheduling , simulation

1. Introduction

A process plan specifies what raw materials or components are needed to produce a product, and what processes and operations are necessary to transform those raw materials into the final product. Process planning is therefore the function which forms the link between design and manufacturing. Scheduling is another manufacturing system function which attempts to assign manufacturing resources to the operations indicated in the process plans in such a way that some relevant criteria, such as due date , are met. Although there is a strong relation between process planning and scheduling , conventionally two functions has been studied as independent ones. In the most of the current practice, process planning and scheduling are performed separately. The scheduling module assumes the process plan to be fixed, and attempts to allocate the resources and to sequence the operations such that the dictated plan is followed. Almost all of the CAPP systems assume that the shop floor is idle and there are unlimited resources on the shop floor. Therefore the process plans generated are somewhat unrealistic (cannot be readily executed on the shop floor) But, we can take much advantages by solving the two problems simultaneously. The integration of the two functions can introduce significant improvements to the efficiency of the manufacturing facilities through reduction in scheduling conflicts, reduction of flow time and work-in-process, increase of utilization of production resources and adaptation to irregular shop floor events[1][2][3][4].

In this paper, we suggest the framework for the integration of process planning and scheduling system, which takes advantages from other approach And, this paper describes a new method to select near optimal process plan combination.

2. Method to integrate process planning and scheduling

Several approaches have been proposed for the integration of process planning and scheduling. Larsen and Alting discussed three candidate approaches for the integration of process planning and scheduling : (1) Nonlinear Process Planning (NLPP) (2) Closed-Loop Process Planning (CLPP), and (3) Distributed Process Planning(DTPP)

The NLPP makes all possible plans for each part before it enters into shop floor. The NLPP still based on a static shop floor situation. All these possible plans are ranked according to process planning criteria and stored in process planning database. The first priority plan is always ready for submission when the job is required. The

scheduling makes real decision. If first priority plan is not suitable for the current status of the shop floor, the second priority plan will be provided to the scheduling. The CLPP generates plans by means of a dynamic feedback from production scheduling. The process planning mechanism generates process plans based on available resources. Production scheduling tells process planning what machines are available in the shop floor for the coming job, so that every plan is feasible with respect to the current availability of production facilities. Real time status is crucial for the CLPP. Since a real time dynamic feedback is required, it is also referred to as process planning or dynamic process planning. Distributed process planning performs both the process and production scheduling simultaneously. It divides the process planning and production scheduling tasks into two phases[5][6][7][8].
These three approaches have their advantages and disadvantage, so we can't say that any one outperforms the others.

3. Process plan combination selection using simulation based genetic algorithms

A CAPP system , which is capable of generating alternative plans, uses the parts scheduled in the part production schedule and their detailed design information as input to generate all the alternative process plans for each part. Because each part may have multiple process plans and there are possibly two or more parts scheduled during the same planning horizon, there might be some process plan combinations for these parts. For example, if there are four parts scheduled and each part has three alternative process plans, there will be 81 process plan combinations As problem size(number of part, number of alternative plans per part) is large , number of process plan combinations is getting larger exponentially. And, this paper uses genetic algorithm dealing with large problem.

Scheduling module uses only one of all possible process plan combinations. And, it is a crucial problem what process plan combination is selected as an input of scheduling module, because performance of scheduling system depends upon its input. This paper uses performance measure as criterion for selection of process plan combination.

There are a few papers which use other criterion such as the shortest machining time, machine load, similarity coefficient[9][10]. For example, it is assumed that process plan combination with the shortest machining time may have a good effect on performance of scheduling system. But, practically not one factor such as the shortest machining time, machine load but many factors might affect performance of scheduling system. And, to directly use performance measures is better than use only a few factors as criterion for selection of process plan combination, because performance measures reflect almost all factors connected with results of scheduling.
We propose a new method using simulation based genetic algorithms to select near optimal process plan combination. The method uses makespan as fitness function of genetic algorithms. And, a simulation model is used to get makespan, evaluate and select the best process plan combination.

Let us introduce the following notations.
There are n jobs, Jj (j = 1, ... , n)
For any specific schedule, each job Jj has the following associated with it.

Actual completion time = C_j
Makespan = C_{max} max Cj

Pi = part i (i = 1, ... , n)
Aj(k) = one of the process plans of part j (k = 1, ... , Tj)

For example, A1(1) means process plan of part 1 , and A1(2) does another process plan (alternative process plan) of part 1. The meaning of alternative plans could be alternative machining sequence or alternative machines for the same process.
Figure 1 shows overall flow chart, and overall procedure of genetic algorithms for process plan combination selection is as follows[11].
(1) Define string as vi = (A1(k1) , A2(k2), ... , An(kn))

Vi means one of the process plan combinations. For examples, (A1(2), A2(1), A3(4)) means process plan combination which describes that part 1 uses 2nd process plan , part 2 uses 1st process plan, and part 3 uses 4th process plan.

(2) Define population, probability of mutaion, probability of crossover
(3) Choose initial population
(4) Calculate total finess of population

$$F = \sum_{i=1}^{pop\_size} eval(vi)$$

In this paper, we use makespan as finess function. Makespan is the maximum completion time of all jobs. To calculate value of finess function for each string (process plan combination), we use simulation model. Simulation model takes process plan combination and other needed data as input. And it simulates scheduling using SPT (shortest processing time) rule. As a result of it, we can get makespan.

(5) Pi = eval(vi) /F
(6) Calculate cumulative probability

$$qi = \sum_{j=1}^{i} pj$$

(6) Generate random number between [0,1]
(8) If r<q1 , then select first string (vi) , otherwise, select j th string such that qj-1 <r <qj
(9) Generate random number between [0,1]
(10) If ri <Pc(probability of crossover) , then operate crossover
(11) Generate random number between [0,1] for each bit.
(12) If r <Pm(probability of mutation), then operate mutate for the bit.
(13) If stopping rule is not satisfied, go to (4)

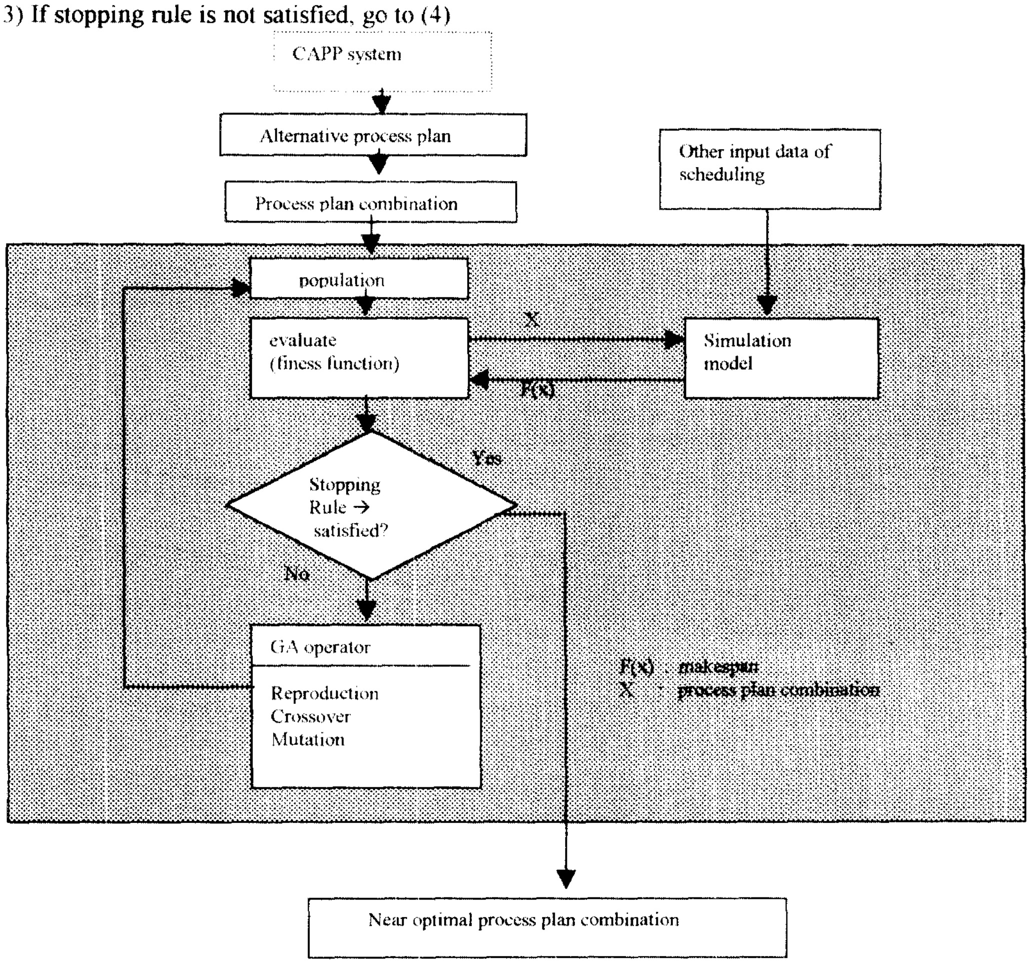

Figure 1 overall flow chart

4. Numerical Example and Results

In order to evaluate the performance of simulation based genetic algorithms as a process plans selection method, experiments are carried out. The following are the situation we assumed in the experiments.
(1) Number of part, number of alternative process plans per part, number of operation per part are same as table 1.
(2) Processing times are generated from the uniform distribution of (10,30)
(3) All the orders are processed by three machines .

The following three method are used for the comparison purpose.
Method 1: A process plan combination is selected randomly
Method 2: A Process plan combination with the least processing time is selected.
Method 3: Proposed method (Simulation based genetic algorithms)

The table 1 shows in what levels of variables experiments are carried out.
Experiments are carried out for each combination of levels. The performance was measured by the makespan.
In table2 , makespan are compared for three methods. As a whole, the new method outperforms the other methods. And the improved values, for makespan, are shown to be of statistical significance.

Table 1 levels of variables

Variables	Levels		
	#1	#2	#3
Number of parts	7 ,	15 ,	20
Number of altermative process plans per part	4 ,	8 ,	12
Number of operation per part	5 ,	10	

Table 2 result of experiments

Combination of levels	method		
	1	2	3
(7, 4, 5)	312	297(95.2%)	225(72.1%)
(15, 4, 5)	644	595(92.4%)	467(72.5%)
(20, 4, 5)	758	781(103.0%)	651(85.8%)
(7, 8, 5)	321	317(98.8%)	217(67.6%)
(15, 8, 5)	632	576(91.1%)	462(73.1%)
(20, 8, 5)	737	743(100.6%)	637(86.4%)
(7 ,12, 5)	315	353(113.1%)	215(68.2%)
(15 ,12 ,5),	647	613(94.7%)	459(70.9%)
(20,12,5)	746	732(98.1%)	629(84.3%)
(7 ,4,10)	591	567(95.9%)	496(83.92%)

(15,4,10) ,	1203	1217(101.2%)	1021(84.87%)
(20,4,10)	1566	1547(98.8%)	1336(85.3%)
(7, 8, 10)	565	578(102.3%)	476(84.2%)
(15, 8, 10)	1154	1179(102.1%)	998(86.5%)
(20, 8, 10)	1566	1621(103.5%)	1340(85.6%)
(7, 12, 10)	587	545(92.8%)	473(80.6%)
(15,12,10)	1161	1142(98.4%)	991(85.3%)
(20,12, 10)	1575	1611(102.3%)	1294(82.1%)
Average	100%	99.5%	82.1%

5. Summary and Conclusion

In the paper , we propose a new method, based on simulation based genetic algorithms, to select process plan combinations which is expected to have an good effect on scheduling performance. And this method is found to be more effective than the other methods in minimizing makespan. Proposed method is expected to apply to very large problem. This paper makes use of SPT rule to simulate and calculate finess, but other better heuristic algorithms can be used.

6. References

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