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Dynamic Rescheduling Expert System for Hybrid Flow Shop with Random Disturbance

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Abstract

For the problem of hybrid flow shop with random disturbance, a dynamic rescheduling expert system is established in the paper. As the core of the system, the rescheduling solver is detailed described and the heuristic algorithm is proposed on the base of random disturbance modeling. The system is developed on the platform of G2. The simulation and computational results given at last verified that the system proposed in the paper can well meet the requirements of both function and performance.

Keywords: Dynamic rescheduling; Hybrid Flow Shop ; expert system, time repair

1. Introduction

The key of dynamic rescheduling is to obtain the scheduling solution quickly that can satisfy the production constraints and minimize the production cost when workshop condition change. The key of dynamic rescheduling is to obtain the scheduling solution quickly that can satisfy the production constraints and minimize the production cost when workshop condition change. Usually, for the problem of dynamic rescheduling, the way is respectively to generate a totally new solution and on-line local

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modify the initial scheduling solution. Because of the practical use and its difficulty, the dynamic scheduling method has always been the focus of the academic research and enterprise application [1].

A great deal of efforts has been made to the rescheduling problems in recent years. Vieira et al. describe a framework of rescheduling system [2] and present an analytical model to predict the performance of one-machine systems under periodic and event-driven rescheduling strategies [3]. Guo et al. study the properties of a three-machine flow shop scheduling problem and present a trigger mechanism to instruct the rescheduling [4]. References [5]-[6] address rescheduling problem on single machine, parallel machines, flow shops and job shops, respectively. Though variations of existing methods improve the efficiency of dynamic rescheduling from different angles of view, the most difficulty point still lies in the contradiction between the real-time and stability of solution performance and the corresponding contradiction between the real-time ability and complexity of computation.

Focusing on these difficulties, this paper studies the hybrid flow shop scheduling (HFS) with the random disturbance which typically exists in the manufacture practice, such as machine failures, arrival of rush orders, material shortages, tool breakages and so on. The remainder of this paper is organized as follows: In next section, the dynamic rescheduling solver embedded in the expert system is introduced. Then, two heuristic algorithms for disturbance of processing abnormal and machine breakdown are proposed. The realization of dynamic rescheduling expert based on G2 and computational results are illustrated next after. We conclude at last.

Nomenclature

O_i^l	the No. i operation of job J_l, $l=1,2,...,n$
p_i^l	the normal processing time of O_i^l
$p_i^{l}{'}$	the abnormal processing time of O_i^l
st_i^l	the start time of O_i^l
et_i^l	the completion time of O_i^l
$Slack_i^l$	the slackness of O_i^l
t_{break}	the time of machine breakdown
$t_{recover}$	the time of machine repaired
cap_m	the remaining capacity of machine M_j, $j=1,2,...,m$
b_{kj}	the No. k breakdown of M_j
ro_{hj}	the processing time for emergency rush order h on the M_j
Δx_j	the processing time change of M_j

2. Design of dynamic rescheduling solver

2.1. The Semantic Network

As the core of the whole system, dynamic rescheduling solver consists of rules and processes and describes the problem of HFS with random disturbance. As shown in the Fig.1, there are six class definitions in the conceptual model, including schedule solution, job, operation, machine, constraint and random disturbance. On this basis, the knowledge network can be structured. The underline in the Fig.1 represents the key attributes of the class and the semantic network inference is realized by correlation, focus and multiple inheritances between different classes provided by G2.

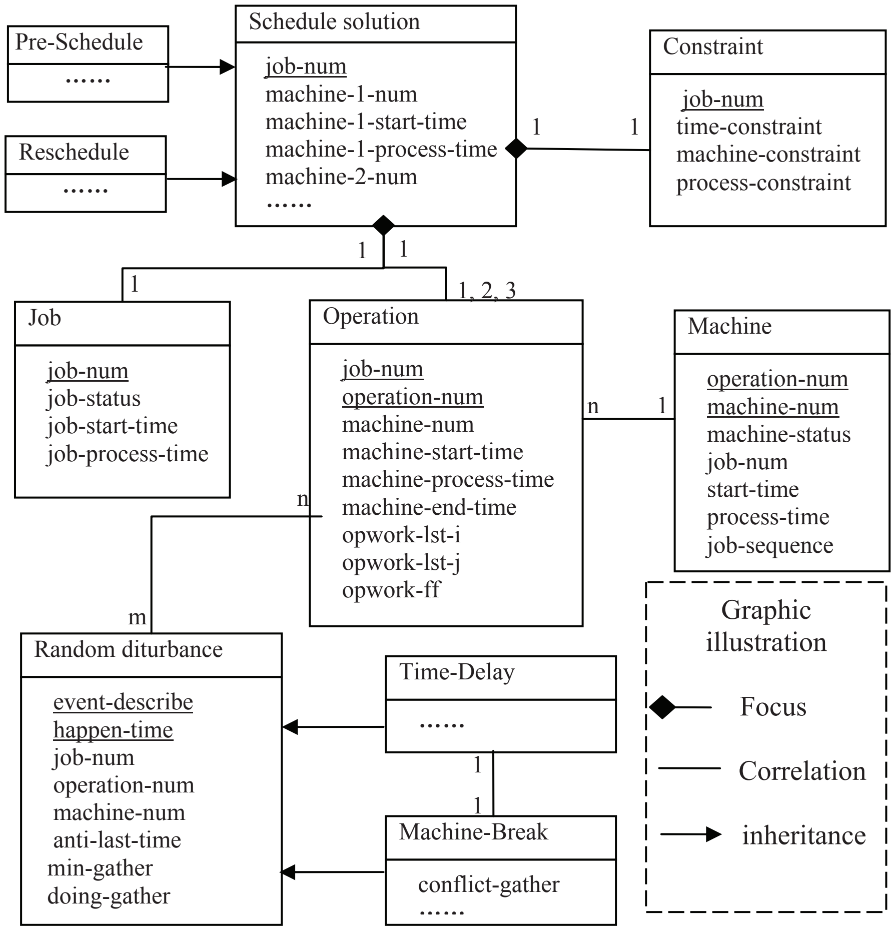

Fig.1 The semantic network of dynamic rescheduling solver

2.2. The Solving Procedure

The solving procedure of dynamic rescheduling:

1. *Initialization: Create entity* $J = \{J_1, J_2, ..., J_n\}$ *; input the initial scheduling solution* S^0*; Constraint check; initialize attribute value.*
2. *Real-time monitoring: Executing scheduling; monitoring the shop state; identifying the disturbance.*
3. *Choose proper program: If the disturbance belongs to processing abnormal, then call the heuristic algorithm of time parameter repair (**TPR**); if the disturbance belongs to machine breakdown or emergency rush order, then call the heuristic algorithm based on the remaining capacity of machine (**RCM**); else transfer to human-computer interaction (dynamic editor).*
4. *Constraint Check: If rescheduling solution is infeasible, then call the conflicts resolution program*
5. *Output the rescheduling solution.*

Considering the production requirement for both the real-time ability of rescheduling efficiency and stability of rescheduling quality, the strategy of local repair is adopted. We take the advantage of the powerful real-time capability and concurrent multi-thread capacity of G2 which is developed by the Gensym Corporation, USA. The solving procedure of dynamic rescheduling is shown as follows: According to different kinds of disruption, different heuristic algorithm is dynamically exploited.

The heuristic algorithm of time parameter repair (TPR):

1. *Calculate the minimum operation set as follows:*

$$A = \left\{O_i^l\right\} \cup \left\{ O_{i+1}^l \middle| O_i^l \in A\right\} \cup \left\{ O_j^k \middle| (O_j^k \parallel O_i^l) \vee (st_j^k > et_i^l), O_i^l \in A\right\} \quad (1)$$

2. *For* $\forall O_i^l \in A$, *Calculate the* $Slack_i^l$ *as follows:*

$$Slack_i^l = \min\left\{st_{i+1}^l - p_i^l - st_i^l, st_j^k - p_i^l - st_i^l\right\} \quad (2)$$

3. *If* $Slack_i^l < p'^l_i - p_i^l$, *then Calculate the start time as follows:*

For O_{i+1}^l, $st_{i+1}^l{}' = \max\left\{st_{i+1}^l, st_{i+1}^l + et_i^l{}' - st_{i+1}^l\right\}$ (3)

For O_j^k, $st_{i+1}^l{}' = \max\left\{st_j^k, st_j^k + et_i^l{}' - st_{i+1}^l\right\}$ (4)

4. *Constrain propagation and check.*

$A = A - \{O_i^l\}$, *if* $A = \varnothing$, *then stop; else, go to step 2.*

The heuristic algorithm based on the remaining capacity of machine (RCM):

1. *Calculate the minimum operation set as follows:*

$$A = \left\{ O_i^l \middle| \left(st_i^l \geq t_{break} \wedge st_i^l < t_{recover}\right) \vee \left(et_i^l > t_{break} \wedge et_i^l \leq t_{recover}\right)\right\} \quad (5)$$

2. *For* $\forall O_i^l \in A$, *calculate the* cap_m *of the other normal machine available as follows:*

$$cap_m = \left(et_i^l - st_i^l\right) - \sum_{M(O_j^k = m)} \max\left\{\left(\min\left\{et_j^k, et_i^l\right\} - \max\left\{st_j^k, st_i^l\right\}\right), 0\right\} \quad (6)$$

3. *Assign the machine of max* cap_m *to process* O_i^l, $A = A - \{O_i^l\}$, *if* $A = \varnothing$, *then go to step 4 ; else go to step 2.*

4. *Constrain propagation and check.*

5. *If conflict exists, TPR adopted to modify the time parameters of related rest operation; else stop.*

3. Experimental result

Table 1 The computation result of RCM

A	Initial solution	Rescheduling solution	Constrain propagation and check
O_1^9	CF-1	CF-1	Confict exists in O_1^9 and O_1^{13} on CF-1, $\Delta f = 35$
O_1^5	CF-3	CF-3	
O_1^{13}	CF-2	CF-1	

Random Create an entity of machine breakdown. Assign the attribute value as follows: event-describe=breakdown, job-num=13, operation-num=1, machine-num=2, happen-time = 125, anti-last-time=35. The rescheduling result is shown in table 1 and in table 2.

Table 2 The computation result of TPR

A	Operation	Rescheduling solution	Operation	Rescheduling solution
O_1^{13} , O_1^{14} , O_2^{13} ,	O_1^{13}	$st_1^{13}=160$	O_3^{14}	$st_3^{14}=265$
O_1^{15} , O_2^{14} , O_3^{13} ,	O_1^{14}	$st_1^{14}=195$	O_2^{6}	$st_2^{6}=255$
O_3^{14} , O_1^{12} , O_2^{15} ,	O_2^{13}	$st_2^{13}=195$	O_3^{6}	$st_3^{6}=300$
O_2^{6} , O_3^{15} , O_2^{12} ,	O_3^{13}	$st_3^{13}=225$	O_3^{15}	$st_3^{15}=305$
O_2^{16} , O_3^{6} , O_3^{16} ,	O_1^{15}	$st_1^{15}=230$	O_3^{16}	$st_3^{16}=345$
O_3^{12} , O_2^{18} , O_3^{17} ,	O_2^{14}	$st_2^{14}=230$	O_3^{17}	$st_3^{17}=375$
O_3^{18}	O_2^{15}	$st_2^{15}=265$	O_3^{18}	$st_3^{18}=405$

4. Summary

When scheduling solution executed in the workshop, dynamic disturbance often unpredictable occurs, such as task change, processing abnormal, machine breakdown and etc. These make rescheduling attach comprehensive attention to the solving mechanism, considering both the real-time ability and solution quality. Focus on this problem, the dynamic rescheduling solver is designed and developed on the platform-G2 in the paper, including the semantic network, the solving procedure and the heuristic algorithm of TPR and RCM. The simulation and computational results show that the system is efficient and effective.

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