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A Hybrid Pso Algorithm for Order Assignment Problem with Buffer Zone in Holonic Manufacturing System

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Abstract. In order to make the enterprise assessment system become more intelligent and efficient for the application and realization technology of advanced manufacturing technology, the enterprise alliance and its business reconfiguration model for Holonic Manufacturing System(HMS) are processed. The enterprise alliance with dynamic reconfiguration and Holon feature is established by constructing the information platform to Holonic Manufacturing system. The system can realize the informationize in enterprise and between enterprise. The cooperation between enterprises can also be supported. The task assignment problem in the enterprise with directed graph model is presented. Task assignment problem with buffer zone is solved via a hybrid PSO algorithm. Simulation result shows that the model and the algorithm are effective to the problem.

Keywords: Task assignment problem, Holonic Manufacturing System (HMS), Directed graph model, Particle swarm optimization (PSO)

1. Introduction

Agile Manufacturing[1] needs the production system having ability to reconfiguration by the separated unit and forming the manufacturing organizations which have no relevance with the production batch. All the processes are operated by the information flow to cope with the market requirement. There are also some new requirement for the manufacturing unit to simplify the hierarchy, realize the modular management and flexibility production, and work concurrently based on the actively response and innovation of the unit. That is mean to make all the manufacturing system to be more agility and immediately response. So it is important to build the manufacturing units which have agility ability to organize (1) all the production process (2) integrate the production process and the other part in the enterprise to a whole system (3) integrate the corresponding unit in different enterprise into a new system.

Manufacturing system evolve from hierarchy[2] to parallel, from center-control to distributed control[3]. All the change bring new requirement for the production management and control. The changes include how to divide the manufacturing unit, the manufacturing unit management style, control structure and corresponding control methods. The application of the manufacturing modular brings a new series problem. Main problem caused by the unit management include:

1. How to build a new production control structure and model to satisfy the organization and structure flexibility to suit the control of multi-unit enterprise production activity. From the point of the tendency of the manufacturing system development, cooperative and division are the first problem to be solved. It is necessary to change from the tradition hierarchical structure to ‘bio-manufacturing’ to realize the cooperation and responsibility from each other.

2. How to build the modular intelligent control system and corresponding operation style to not only satisfy the requirement from the top system, but also implement easily step by step. The decisive factors of the realization of system agility are the local decision ability and cooperative of each unit. So the operation environment must be provided for distributed production process.

3. How to realize the efficient production schedule and optimum process. The core of production control

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is to build high efficient and flexibility system to meet the requirement from the dynamic production schedule.

In order to make more intelligent and efficient for the application and realization technology of advanced manufacturing technology, the research on enterprise alliance and its business reconfiguration to Holonic Manufacturing system[4][5] is processed, by constructing the information platform to Holonic Manufacturing system, the enterprise alliance with dynamic reconfiguration and Holon feature is established, this system can realize the informationize within enterprise and among enterprise, then support the cooperation between enterprise.

This paper provides a dynamic re-configuration and order optimization model and optimization algorithm of holonic manufacturing systems (HMS). The paper is organized as follows. Section 2 provides a summary of the state of arts of Holonic Manufacturing Systems (HMS). In section 3, task assignment model based directed graph is applied to cooperative activity among orders in a community. A hybrid PSO algorithm for Order assignment problem with buffer zone is given in Section 4. Simulation result is given in section 5. Finally, Section 6 concludes the paper.

2. A Holonic Architecture For Manufacturing Systems

Holonic Manufacturing Systems is one of the Intelligent Manufacturing Systems (IMS) program's six major projects resulting from a feasibility study conducted in the beginning of the 1990's. The objective of the work of the HMS consortium is to "attain in manufacturing the benefits that holonic organisation provides to living organisms and societies, e.g., stability in the face of disturbances, adaptability and flexibility in the face of change, and efficient use of available resources." [6][7]

In the holonic manufacturing system, each holon cooperate with other holon and make use of extern resource to accomplish the task delivered by system. So the chains from customer requirement, through internal production planning holon and cooperative production task holon to supplier delivered task are established in the system. As showed in figure 1.

After analyzing the relationship and activity of each pair of entity do, we find that we can model the relation between each pair of entities as the connection of customer and supplier. The role of the initial planning holon is that of matching the task and resource capacity to accomplish the task that is fulfilled by the supplier. The decision processes are based on a supply and demand relationship and the outcomes are decided by selling and buying activity in respect of the resource and by market behavior. As shown in the figure 1. There are four basic elements in the market behavior: supplier, customer, item required and rules of transaction.

Suppliers are the holders of resource and the providers of the requirement of the project. The customer is the consumer of the requirement. Supplier and customer can be the rational entities of supplier, manufacturer, sub-seller, section in manufacturing enterprise and customer. The project requirement is the stuff which has value for the customer, including processed materials, semi finished articles, final product, services, and so on. Transaction rules are the criteria of transfer of project ownership from supplier to customer, That is to say, the rules for transaction and trade for resource capacity in different time.

In the application of the system, roles can change. For example, when one holon provides the resource to another holon, its role is as supplier. It will, however, play the customer role when capacity can not meet the requirement and it turns for help to another holon. In the market mechanism all we need to do is to define the connectivity and activity of the entities in the holonic manufacturing system. So when an enterprise holon lays out its production planning, it can use market mechanism method based on market equilibrium theory, and apply it to the modification feature that matches order/task to resource in the market, and consequently lay out the appropriate strategy, rule, or optimization method to realize the optimum allocation of resource. The production planning and control system can response to the market quickly through the holonic manufacturing system. The responsiveness can be seen at several points: 1) when the production task and resource experience changes, the system can reconfigure to set a new production planning and control system. 2) the system can collect, save, fetch and keep track of the information on-line. 3) it can respond quickly when the resource encounters any problems.

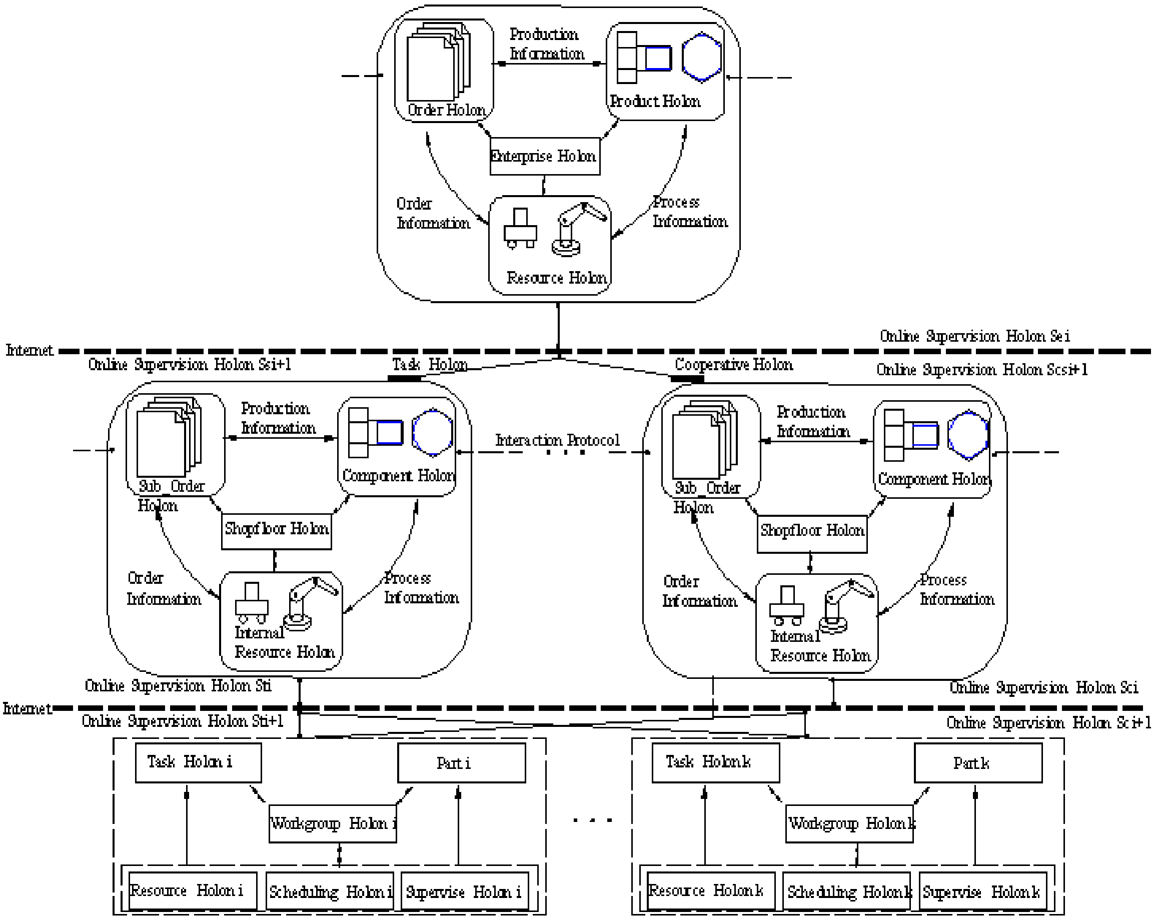

Figure 1. Holonic Manufacturing System

3. Task Assignment Problem

Task assignment problem can be depicted as: there are n orders $O = \{1,2,\cdots,n\}$ to be bidden by m holons $M = \{1,2,\cdots,m\}$, n orders assessed by m holons step by step. At certain time, each order can only be assessed by one holon, each holon can only process one order at the same time. The process time for order j on holon i is $d_{i,j}$. The buffer zone for holon i and $i+1$ is B_i. The optimum objective is minimize the whole assessment time for the whole order.

3.1. Mathematics Model

Let $O = \{o(1), o(2), \cdots, o(n)\}$ as the feasible order sequence for the order system, $S_{i,j}$ is the start time for order j to be processed on Holon i, then the mathematics model for the task allocation problem with some buffer zone can be depicted as

$$S_{i,O(j)} = \max\,(S_{i-1,O(j)} + d_{i-1,O(j)}, S_{i,O(j-1)}, S_{i+1,O(j-Di+1-1)}), i = 1,2,\cdots,m, j = 1,2,\cdots,n \quad (1)$$

$$D_{\max}(o) = S_{m,o(n)} + d_{m,o(n)} \quad (2)$$

$$T^* = \arg\{D_{\max}(o)\} \to \min, \forall o \in O \quad (3)$$

Where equation 3 is the maximum time model for all the orders to be processed on the task Holon evaluation system. In equation 1, the first part is the sequence of order passed by the system. The second part is the sequence of order processed by the system. The last part has relevance with the saving capability of limited buffer zone. The buffer zone will have no effect on the task allocation problem if $C_i \geq n-1$.

3.2. DIRECTED GRAPH MODEL

Directed graph[8][9] is the important tool to analyze the task allocation problem with buffer zone. For one feasible order process sequence o, the corresponding directed graph model is $G(o)=(N,A)$, the vertex is $N=M\times J$, connect arc is $Q=Q^V\cup Q^H\cup Q^S$, where

$$Q^V=\bigcup_{j=1}^{n}\bigcup_{i=2}^{m}\{((i-1,j),(i,j))\}$$

$$Q^H=\bigcup_{j=2}^{n}\bigcup_{i=1}^{m}\{((i-1,j),(i,j))\}$$

$$Q^S=\bigcup_{i=1}^{m-1}\bigcup_{j=B_{i+1}+2}^{m}\{((i+1,j-B_{i+1}-1),(i,j))\}$$

In the graph, vertex (i, j) is the operation of order $o(j)$ in holon i with the weight of $d_{i,o(j)}$. The arc ((i-1,j),(i,j)) is the process sequence constriction, that is $S_{i,o(j)}\ge S_{i-1,o(j)}+d_{i-1,o(j)}$. Arc ((i, j-1)(i,j)) is the order exchange constrict in aggregation Q^V which is the $S_{i,o(j)}\ge S_{i,o(j-1)}+d_{i-1,o(j-1)}$. Arc $((i+1,j-B_{i+1}-1),(i,j))$ is the buffer zone constriction in Q^S which is $S_{i,o(j)}\ge S_{i+1,o(j-B_{i+1}-1)}$. The arc weight in Q^V and Q^H are 0. The arc weight for ((a,b),(c,d)) is $-d_{a,o(b)}$.

For a certain order with process sequence o, lead time is the length of key path in $G(o)$ according to the graph knowledge. In figure 2, we use the directed graph model with $n=10,\ m=4,\ B_2=4,\ B_3=B_4=2$.

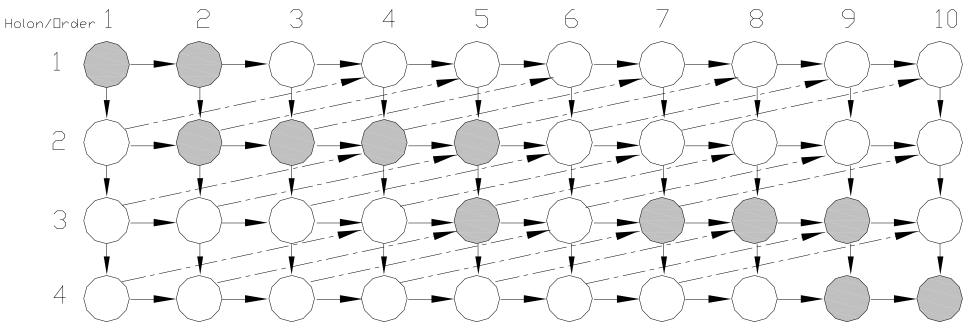

Figure 2. Orders assignment based on directed graph

4. A Hybrid Pso Algorithm For Order Assignment Problem With Buffer Zone

Assume a vertex sequence $o=(o_1,o_2,\cdots o_l)$ in $G(o)$, where l is the vertex number and $oi=(i[u],j[u])\in M\times J, 1\le u\le l$. The key path can be break down into several sub sequences $(g,h), 1\le g\le h\le l$. Each sub sequence is connected by the arc with same property which is belonging same group in Q^H or Q^S. Let $i[g_l]$ and $i[h_l]$ are the first and end segment, then $i[h_{l-1}]=i[g_l]$ and B_l is connected. For the i^{th} position aggregation there are

$$P_l=\begin{cases}\{o_{l-1},o_{l-1}+1,\cdots,o_{l-1}\}\ if\ \ Bl\ is\ connected\\ \{o_{l-1}+1,\cdots,o_{l-1}\}\ ,otherwise\end{cases},$$

Theorem 1: Let $o\in\prod$, $o=(o_1,o_2,\cdots,o_l)$ is a key path for $G(o)$, B_l is the block in key path, $1\le l\le k$. $C_{\max}(\sigma)\ge C_{\max}(o)$

1. σ is the random array in $\prod$, and $\sigma(j)=o(j), j\in J\setminus\bigcup_{l\in QH(i)}U_l$ or
2. each holon i and random array $\sigma\in\prod$, $\sigma(j)=o(j)$, $j\in J\setminus\bigcup_{l\in Q^H(i)}U_l$

According to the above theorem, we can see that it will no difference when the content in Q^H and Q^s exchange their sequences. So the array satisfies theorem should be deleted from the search space. The search process in its feasible space can be depicted as follow.

The order m in array o can be forward or backward one step $ST(m)$, $m < ST(m) \le n$ or $L(m), (1 \le L(m) < m)$. For each step m, $1 \le m < n$, the nearest right move is $r(m) = \min\{l : 1 \le l \le k, m < o_l\}$. For $m, 1 < m \le n$, the nearest left move is $l(m) = \max\{l : 1 \le l \le k, o_{l-1} < m\}$. The new position can be gotten according to following rules

$$R(m) = o_{r(m)}, 1 \le x < n$$

$$L(m) = \begin{cases} o_{b(m)-1} - 1, \text{ if } B_{b(m)} \text{ is connected and } m \ne o_{b(m)} \\ o_{b(m)-1}, \quad \text{otherwise} \end{cases} \quad 1 < m \le n$$

The move aggregations $M(o) = \bigcup_{m=1}^{n-1}\{(m, R(m))\} \cup \bigcup_{m=2}^{n}\{(m, L(m))\}$ have relevance with array with o. $M(o)$ include all the neighbor $N(o)$ with array o. The search algorithm based on separated block is search the neighbor around $N(o)$ to get new array o' as the best solution as shown in Table 1.

Table 1. The movement aggregation for the order path

m	1	2	3	4	5	6	7	8	9	10
$R(m)$	4	3	6	8	8	6	10	10	10	-
$L(m)$	-	1	3	2	5	6	7	7	6	7

The algorithm is shown is figure 3. The balance stragedy is the possibility for neighbor search based on Block.

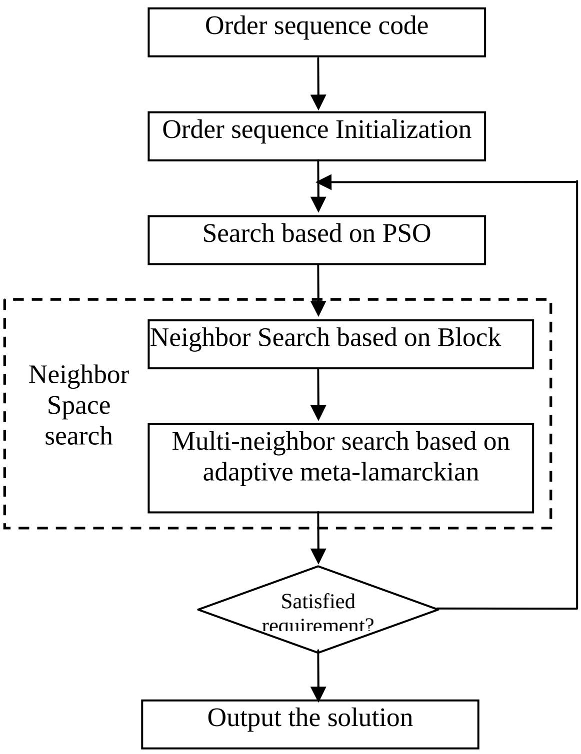

Figure 3. Neighbor Space search algorithm for the task assignment problem

5. Simulation Result

Firstly, one problem with buffer zone is solved in this part, meanwhile the influence of the size of buffer zone to the task allocation problem is studied. Secondly, the other performances in the PSO[10][11] have been compared with other method. Finally, the size of population and neighbor search possibility for the optimization performance and computation time have been studied .

The parameter for the PSO as follows. Population size $p_s = 20, B = 25$, $w = 1.414, c_1 = c_2 = 2.712, x_{\min} = 0, x_{\max} = 8.0, v_{\min} = -5.0, v_{\max} = 5.0$

The possibility to execute the block neighbor $p_{ls} = 0.1$, start temperature $T_0 = 5.0$, degrade velocity $\lambda = 0.85$, the step for selection is $n \times (n-1)$, keep the optimum $L = 10$ as the stop criteria. Each case is run 20 times. The result is shown in table 2.

Table 2. Information system levels

Holon/order	Lead time	Buffer=0			Buffer=3			Buffer=5		
		BRE	AVE	Tavg	BRE	AVE	Tavg	BRE	AVE	Tavg
5/5	3032	4.21	6.45	0.56	0	0	0.22	0	0	0.13
10/5	3161	5.80	6.90	0.64	0	0	0.29	0	0	0.15
15/10	3310	9.61	12.32	0.66	4.32	6.91	0.44	0	3.33	0.21
15/15	3996	14.21	17.33	1.81	5.12	11.03	0.67	3.11	5.78	0.31
20/5	3720	12.13	14,21	2.54	0	5.67	1.01	0	0	0.26
20/10	4331	12.44	17.65	3.39	4.33	5.45	1.86	3.56	4.12	0.18
20/15	5673	13.59	18.77	3.64	7.32	6.33	2.09	4.04	5.43	1.91
20/20	6005	9.48	10.32	5.11	5.89	6.71	3.09	4.45	5.01	1.21

Table 3. The result in different population

Swarm size	10	20	30	40	50	60	70	80	90	100
BRE	1.13	0.78	1.33	1.29	1.47	0.94	1.25	1.45	0.95	1.21
ARE	2.57	2.35	2.56	2.44	2.66	2.13	2.43	2.36	2.22	2.61
WRE	4.02	3.50	4.37	4.10	3.80	4.12	3.39	3.60	3.54	4.04
Tavg	23	27	26	25	29	32	31	33	38	35

With the increase of the population, the computation time is also increasing, but the quality of search changed in small scope. So the population size has little influence on the search quality for the task allocation problem. The suitable size for the middle and small problem is 20, but the size can also adjust according to the scale of the problem.

6. Conclusions

A Holonic Manufacturing architecture for manufacturing system to improve the response and efficient for the enterprise is presented and testified in this paper. The task allocation problem in this architecture is solved by directed graph based on PSO algorithm. The great benefit of a Holonic Architecture for dynamic response of manufacturing systems is the graphical and concise representation of activities, resources and constraints of a operation of task holon in a single coherent formulation, which is very helpful for designers to better understand and formulate scheduling problems.

7. Acknowledgement

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