A Hybrid Algorithm Based on PSO and GA to Dynamic Virtual Holon Mechanism and Negotiation Model

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Abstract

Nowadays, the change of marketplace require manufacturing system to diversify from mass customization style to step-mass customization style, thus lead to the manufacturing value orientation change from product oriented to custom oriented, main manufacturing strategy change from cost, quality etc. to deadline, manufacturing principle change from individual to cooperation, manufacturing direction change from technology-oriented to innovation and human centered. The proposed holonic control system for operating an automated material handling system attempts to combine both the advantages of hierarchical (global optimization) and heterarchical (real-time response when changing conditions occur) control architectures. Due to its architecture, the holonic system can work both as a hierarchical system, during normal operation when no disturbances are present, and as a heterarchical system, when facing sudden disturbances. In this paper, the negotiation Holon which is map to agent strategy is applied to cooperative activity among holons in a Holonic society. A novel algorithm based on PSO and GA for the order task Holon allocation problem is presented. Simulation results show that the architect and negotiation model is effective to the task allocation problem, the algorithm have good performance on settling task optimization problem.

Keywords: Holon, Particle swarm optimization, Genetic algorithm, Task allocation problem, Contract net protocol

1. Introduction

Nowadays, when we look into the global manufacturing, many transformation have taken place, there are more and more customization, more and more shorten the deadline of the product require the enterprise pay more on the optimization, adaptation, reliability of manufacturing system[1]. From the viewport of the change of marketplace requirement, manufacturing system have change from mass customization style to step-mass customization style, thus lead to the manufacturing value orientation change from product oriented to custom oriented, main manufacturing strategy change from cost, quality etc. to deadline, manufacturing principle change from individual to cooperation, manufacturing direction change from technology-oriented to innovation and human-centered, and so on[2].

The marking out and operation control of the new generation manufacturing control system should based on a available, configuration manufacturing control architecture, and need the corresponding guidance method. Based on the concept of the Holonic manufacturing system[3], the macro-flow manufacturing and the control system is depicted again, the communication mechanism, control strategy, algorithm the design method of the system and some key enable is studied thorough in this paper.

The paper is organized as follows. Section 2 provides some basic concept of HMS and its interaction mechanism. In section 3, the negotiation Holon which is map to agent strategy is applied to cooperative activity among holons in a Holonic society. Section 4 describes our novel algorithm based on PSO and GA algorithm for the order task Holon allocation problem. Simulation results are reported in Section 5. Finally, the concluding remarking is given out in Section 6.

2. Dynamic virtual holon mechanism

2.1. Task interaction mechanism

In cooperative processing, Holons as cohorts work together to solve a joint (i.e global) task, the task can be subdivided to lower-level tasks (T1 ... Tn) ,each task have executive sequence (Figure 1). One agent might act as the task agent or the coordinator, responsible for the global task.

Each task has both its own exclusive resources and some shared resources In addition, each task has a set of preferences as well as a set of other constraints. Dependencies exist among tasks, these dependencies can be task precedence, input, time, or resource dependencies. The global solution space (which must satisfy all the constraints) is the intersection of the local solution spaces, and may include more than one satisfactory global solution. In that case we accept the solution that preserves most preferences, we call this an acceptable solution.

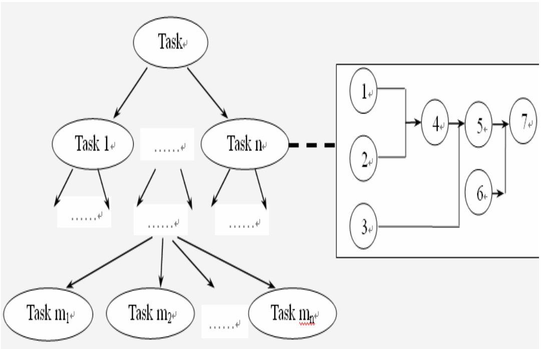

Fig.1: Task subdivision with some constriction.

2.2 Dynamic virtual holon mechanism

HMS is to strengthen autonomy and harmony for the basic unit, which is made up of basic Holon unit, the research areas covered enterprise, workshop supported mainly by information technology and standardization[4][5].

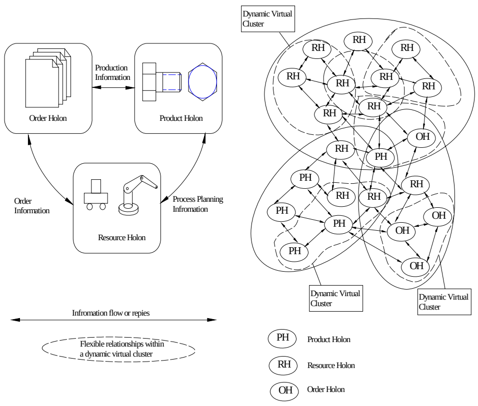

Fig.2: Holarchy of HMS.

Its topology structure is illustrated by figure 2, it has self-resemble topology structure. The topology relationship and function model is determined by fixed rules, the concreted action is determined by flexible strategy. Each Holon have tendency both integrated itself to Holon society and kept itself independence and individuality, former is the coordination character, latter is the self-discipline character, which are two basic quality for Holon System. Self-discipline character is the dynamic representation for integration attribute which means Holon having self perfect and self study ability according to capability and surrounding to fulfill the task. Coordination is the dynamic representation to self-discipline which means its self discipline is relatively, Holon would bring into play within constriction scope, accept direct command from top-level system, negotiate with other Holon to accomplish self task. So Holon is the self-discipline unit having certain independence, when met accidence, it can treat by itself and need not ask for instructions for top level unit, so it is a stable format and do not care with disturbance. The Holon System construction is shown as Fig.3.

In a word, Holon is a system construction unit, relative to top organization, it is a component with coordination quality, relative to bottom organization, it is a whole system with self-discipline attribute. Holon concept combined merits of hierarchy system and distribution system together. On the one hand, Holon unit collaborate each other to reach an whole object, on the other hand, Holon unit is the autonomy, distribute entity having intelligent and self-adaptation. For example, the cell in biology system, which have highly autonomy attribute and coordination with other cell to respond to top level cell.

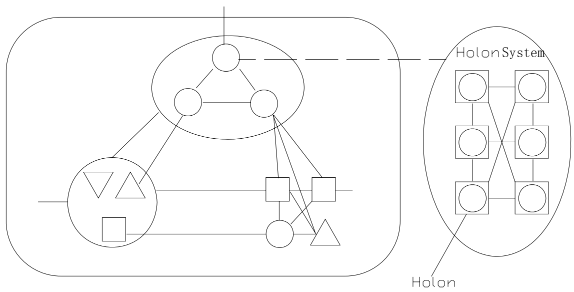

Fig.3: Holon System construction.

3. Modeling of dynamic virtual holon

In a HMS, holons may form holarchies whose members collaborate through Cooperation Domains. Using the mechanism of virtual clustering, holons can be dynamically involved in different holarchies and cooperate through a Cooperation Domain. The cluster exists for the duration of its cooperation tasks and disappears when the tasks are completed. A Cooperation Domain can be implemented and maintained through the creation of a mediator holon. An operational holon can be made of a set of several operational and/or supervisor holons, with the top supervisor holon acting as the logic component, and the several operational holons acting as the physical part of the holon [6]. This feature allows the structured development of manufacturing control applications through the encapsulation of functions or manufacturing components. As an example, illustrated in Fig. 4, a manufacturing cell can be represented by an operational holon that is constituted by several other operational holons, each one representing a manufacturing resource, and one supervisor holon representing the manufacturing cell controller. Additionally, each one of these operational holons could be constituted by other operational holons, representing the numerical control machine itself and the several tools stored in its tool magazine.

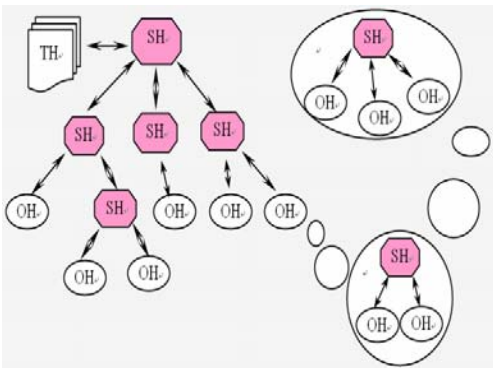

Fig. 4: Manufacturing cell controller.

Because basic holon in Holonic society is operating by marketing mechanism, their action is diversified by different task requirement, so the basic holon would cooperate in dynamic holonic manufacturing system, the system can efficiently accomplish production objection only when its own benefit met at the same time.

In dynamic holonic manufacturing system, basic holon can constitute into some dynamic virtual Holon cluster according to its own cooperation domain, by its own operation mechanism, the basic holon can take part in different holon cluster, these holon cluster in Dynamic Holonic Manufacturing Society could collaborate each other to finish task, then dismiss automatically. In the cooperation process, the collaboration are carry out and maintain by mediator Holon in on-line supervise Holon on different layer. Mediator Holon is established by one basic Holon dynamically, Mediator Holon has ability to search partner Holon and send invitation to the Holon which can solve the problem that system provided.

The process that generate one virtual cluster follow these steps.

(1) Basic Holon collect some or whole contract to form a new local task, after re-planning and analysis, cooperation task were listed wholly.

(2)collaboration Holon in on-line supervise Holon search subcontract Holon that having ability to solve system problem and send invitation for bid. Other Holon can also send bid to collaboration Holon to participant bid.

(3) Invited Holons decided automatically how to take part in bid and give bid value for its interested task.

(4) Collect all the bid and evaluate the bid value by Holon sent bid and collaboration Holon, after make certain that the optimum result for task allocation, basic Holon and subcontract Holon sign contract directly, the basic Holon and all subcontract Holon signed agreement form a virtual cluster.

(5)each Holon signed contract can also add some sub-Holon to finish subtask, which formed some new low degree sub virtual Holon cluster, each virtual Holon cluster having a dynamical collaboration mediator Holon.

(6) When the task finished, some related virtual Holon cluster dismissed, dynamic collaboration mediator Holon would send dismissed information and its function would disappear.

Every holon in Holon society can take part in the creation of different virtual Holon. In the evolvement of dynamic Holonic Manufacturing System, one holon can be comprised by different organization, a multi-dimension task driven virtual Holon is formed as figure 5 shows.

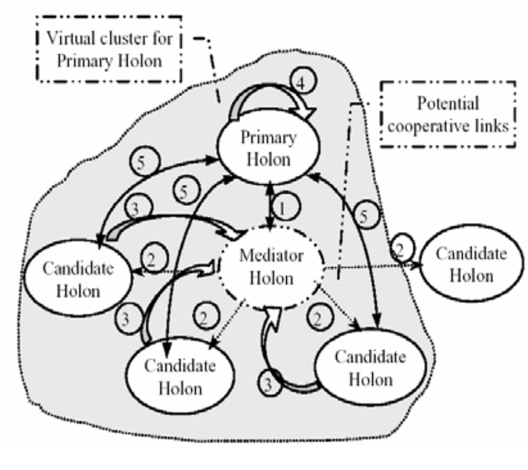

Fig.5: Multi-dimensional dynamic cluster space in a Holonic society.

In order to guarantee the cooperation of Holon under its own benefit to implement the production goal commonly, the negotiation mechanism and communication protocol that accorded with system feature should be build up. According to above feature, it is very suitably and effectively to adopt contract net protocol and control strategy to describe action of Holon in Holon society.

contract net protocol adopt task distribution model and introduce invite public bidding-tender-evulate bidding-win bidding mechanism, depend on compete and negotiate interactively to solve distribution and adaptation task allocation and construction reconfiguration problem, contract net suit to configure hiberarchy organization.contract net protocol is adopted in contract net model, that is used task distribution model and decision-making adaptively by invite public bidding-tender mechanism. Contract net protocol have some good feature, for example, the method is very simple, the optimum is very clear, the effect is also distinctness quietly. So we can make use of flexibility and adaption of system to satisfy the demand of order diversification. The negotiate process by contract net protocol is depicted as follows.

(1) Create mediator Holon: the basic Holon generate a dynamic collaboration Holon to accept subcontract information and send bid requirement for basic Holon.

(2) invite public bidding: mediator Holon release bidding task and send bidding invitation to related Holon. Task structure can be describe as{ task ID, task content, restriction condition, rewards and punishment condition, efficiency time and so on}

(3)tender: the basic Holon bid for some task according to itself condition, the computation of bidding content is determined intelligently by mediator Holon. Bid information structure can be described as{task ID, task content, processing time, delivery time, bid value and so on}

(4)evaluate bid value: task Holon evaluate the bid according to the bid information collected in effective period and acquire ultimately optimum schema. If all the bid can not meet the loose requirement of the system, the mediator holon would adjust the constitute structure of whole task and release task bid again, if necessary, the mediator would feed back to its top Holon organization or require for manpower intervene.

(5) sign contract: the bid process ended and contract is signed, the task begin to carry out.

(6) implementation: tender Holon dominate its performance situation automatically, if some disturbance occurred, the Holon society would perform inner adjustment firstly, then negotiate with some parallel units, if the disturbance still can not be settled, the Holon would feed back this situation to top level Holon cluster.

The negotiate process of virtual Holon cluster is showed as figure 5.

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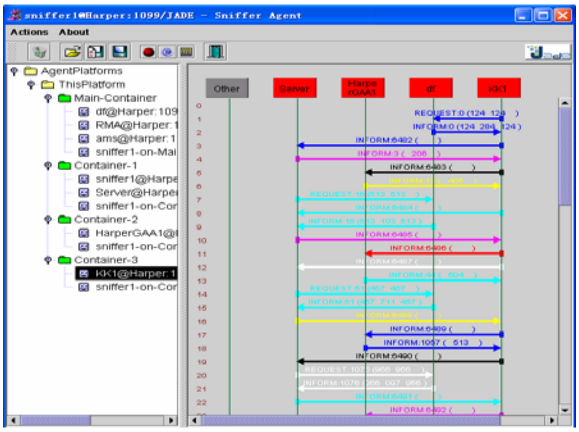

Fig.6: bid interaction process for one agent.

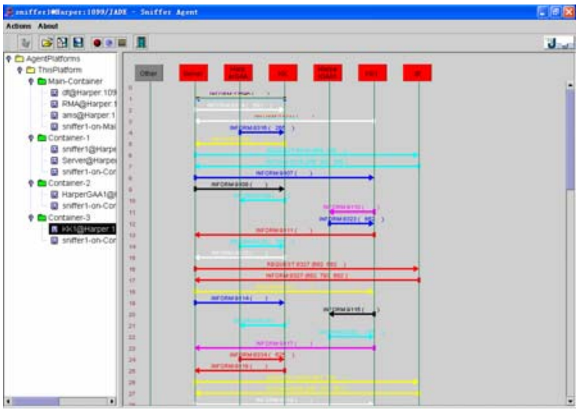

Fig.7: bid interaction process for Multi-agent system.

The negotiate process of virtual Holon cluster is showed as figure 5.

The establishment process for virtual Holon cluster based on contract net protocol have some good feature.

(1) from the viewport of the layer of virtual enterprise, the enterprise in internet can search manufacturing resource conveniently by the advantage of internet, which is easily to find perfect cooperation partner and enhance the efficency of whole process.

(2) the negotiate process is very similar to protocol process and very apt to accept.

(3) because each item is the combination of equipment, technology and human, every contractor bid for task after concerning all the resource, so the selection of resource and reconfiguration of task are not only reconfiguration of equipment and resource, but also human.

(4) the fourth step of the contract process is the selection of bid value by human and finish two non-linear decision, it is determined by decision function of people. It is also the combination of optimization selection to bidder, which is a quantitive optimization problem, the optimization problem can be solved by some optimum algorithm.

Bid interaction process for one agent as figure 8 shows, bid interaction process for Multi-agent system as figure 9 shows.

4. Hybrid algorithm based on PSO and GA

The basic PSO model is proposed by Kennedy and Eberhart.A standard textbook is introduced by them on PSO, including both the social and computational paradigms [7][8].

4. 1. Standard PSO algorithm

Suppose that the searching space is D-dimensional and m particles form the colony. The i th particle represents a D-dimensional vector $X_i(i=1,2,\cdots,m)$. It means that the i th particle locates at $X_i=(x_{i1},x_{i2},\cdots,x_{iD})$ $(i=1,2,\cdots,m)$ in the searching space. The position of each particle is a potential result. We could calculate the particle's fitness by putting its position into a designated objective function. When the fitness is higher, the corresponding X_i is "better". The i th particle's "flying" velocity is also a D-dimensional vector, denoted as $V_i=(v_{i1},v_{i2},\cdots,v_{iD})$ $(i=1,2,\cdots,m)$. Denote the best position of the i th particle as $Pi=(p_{i1},p_{i2},\cdots,p_{iD})$, and the best position of the colony as $P_g(P_{g1},P_{g2},\cdots,P_{gD})$, respectively. The PSO algorithm could be performed by the following equations

$$x_{id}=x_{id}+v_{id} \quad (1)$$

$$v_{id}=\chi(wv_{id}+c_1r_1(p_{id}-x_{id})+c_2r_2(p_{gd}-x_{id})) \quad (2)$$

Where

p_i P_{best} of agent i at iteration k;

p_g gbest of the whole group

χ compress factor

r_1,r_2 random numbers in (0,1)

c_1,c_2 weighting factor

ϖ inertia function, in this paper, the inertia weight is set to the following equation

$$\varpi=\varpi_{\max}-\frac{\varpi_{\max}-\varpi_{\min}}{I_{\max}}\times I$$

where $\varpi_{\max}$ Initial value of weighting coefficient

$\varpi_{\min}$ Final value of weighting coefficient

$I_{\max}$ Maximum number of iterations or generation

I current iteration or generation number

4.2. Hybrid adaptive mutation PSO with GA

Random parameter ϖ, c_1, c_2, as following equation ,

$$\frac{c_1 + c_2}{2} - 1 < \varpi < 1 \quad and \quad c_1 + c_2 > 0 \quad (3)$$

have a relation to guarantee the particle convergent to optimization result, but how to coordinate the above parameter to get a high convergence speed is another difficult matter, so we propose HAMPSO to coordinate the relationship of ϖ, c_1, c_2 to make the algorithm have a good performance.

Because ϖ, c_1, c_2 have a constriction as equation (3), the following objective function is introduced to evaluate the particle performance of HAMPSO.

$$q_k = \frac{Z_k}{S}, k = 1,2,\cdots,Q \quad (4)$$

$$E(t) = -\sum_{k=1}^{Q} q_k \ln q_k \quad (5)$$

Where $E(t)$ is the particle population distribution entropy to evaluate the population distribution performance.

PSO algorithm is problem-independent, which means little specific knowledge relevant to a given problem is required. What we have to know is just the fitness evaluation for each solution. This advantage makes PSO more robust than many other search algorithms. However, as a stochastic search algorithm, PSO is prone to lack global search ability at the end of a run. PSO may fail to find the required optima in case when the problem to be solved is too complicated and complex. We can avoid the problem of trapping to local minimum, firstly, to coordinate the relationship of ϖ, c_1, c_2 to make the algorithm have a good performance, then introducing the mechanism of mutation of GA, when the particle trapped to optimization result for a long time, the velocity $v(t)$ be given a disturbance mutation to keep the search process escape the local optimum more efficiently.

Thus, a hybrid algorithm of PSO and GA with self-adaptive velocity mutation, named HAMPSO, is presented as follows.

Begin
STEP 1 Initialization
Initialize swarm population, each particle's position and velocity;
Evaluate each particle's fitness;
Initialize gbest position with the lowest fitness particle in swarm;
Initialize pbest position with a copy of particle itself;
Initialize $\varpi_{\max}, \varpi_{\min}, c_1, c_2$,maximum generation, and generation=0.
Determine T_0, T_{end}, B.
STEP 2 Operation
For PSO
do {
generate next swarm by Eq.(1) and Eq.(2);
find new gbest and pbest;
update gbest of swarm and pbest of the particle;
For GA[9][10]
{
Initialize population n_p, crossover probability p_c ,mutation probability p_m, makespan T_G;
Generate the initialization population.
calculate fitness of GA by Equation (5);
selection the candidate according the fitness
crossover,mutation, then generate the next generation.
if ($T \geq T_G$),Accept ϖ, c_1, c_2 , otherwise continue GA
}
generation++;

$$if \ (v_{id} < v_T) \quad then \quad v_{id} = r.V\max \quad pBest(t) = x_{id}(t)$$

} while (generation<maximum generation)
STEP 3 Output optimization results.
END

From the chart, we can see that GA provides the optimization parameter of PSO to get a good performance during the hybrid search process. HAMPSO implements easily and reserves the generality of PSO and GA. Moreover, such HAMPSO can be applied to many combinatorial optimization problems by simple modification.

4.3. The procedure of hybrid algorithm

GA and PSO are much similar in their inherent parallel characteristics, whereas experiments show that they have their specific advantages when solving different problems. What we would like to do is to obtain both their excellent features by synthesizing the two algorithms. The performance of the algorithm is described as follows:

(1) Initialize GA and PSO sub-systems, respectively.

(2) Execute GA and PSO simultaneously.

one best fitness solution											Fitness
Solution6	3	9	2	5	6	8	15	12	1	10	55.866
Task No.	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	
olon No.	H3	H9	H2	H5	H6	H8	H4	H7	H1	H10	

(3) Memorize the best solution as the final solution and stop if the best individual in one of the two sub-systems satisfies the termination criterion.

(4) Perform hybrid process if generations could be divided exactly by the designated iterative times N .

Select P individuals from both sub-systems randomly according to their fitness and exchange. Go to step 2.

5. Numerical simulation

There are three main problems in designing a PSO-based optimization approach:

(1) How to convert an optimization problem into a string of symbols, called a particle in PSO. Each particle represents a possible solution and each bit of the particle represents the value of a problem variable.

(2) How to design the fitness function, which determines how well a particle fits the real problem. The design of fitness function should facilitate the optimization algorithm.

(3) How to select the operators of PSO algorithm. c1 and c2 are positive constant parameters called acceleration coefficients (which control the maximum step size the particle can do). The inertia weight, w is a user-specified parameter that controls, with c1 and c2, the impact of previous historical values of particle velocities on its current one. A larger inertia weight pressures towards global exploration (searching new area) while a smaller inertia weight pressures toward fine-tuning the current search area. Suitable selection of the inertia weight and acceleration coefficients can provide a balance between the global and the local search.

The main steps in the PSO-based optimization approach are:

(1) An initial population of particle is generated randomly.

(2) Each particle is assigned a fitness value through a fitness function, according to how well the particle solves the problem.

(3) The successive population is generated by operators and update mechanism by Eq.(1),(2) and evaluated by the fitness function.

(4) The last step is repeated until the best-so-far solution appears.

In our PSO algorithm, we map an M-task assignment instance into corresponding M-coordinate particle position. The algorithm starts by generating randomly as many potential assignments for the problem as the size of the initial population of the PSO. It then measures particles' fitness. We used Eq. (4) as our fitness function.

A test case is used to testify the effectiveness and performance of proposed algorithm in this paper, the task can be divided into 10 subtasks, the implementation system can be carried out by 15 Holon, the detail information for task is listed in table 1.

Task No.	Weight	Time	Priority	Cost
1	0.1	3	5	5
2	0.05	3	5	7
3	0.2	5	7	8
4	0.02	2	3	6
5	0.08	5	1	3
6	0.15	12	9	10
7	0.1	10	9	5
8	0.2	15	7	8
9	0.05	2	3	3
10	0.1	8	5	5

Table 1: Task detail information.

The optimization target is a minimal cost. Evaluated according to equation 1, after 20 times test, the best fitness are given in Table 2. Average of Fitness is 59.302, Maximum Fitness is solution 5 , its fitness is 63.221, Minimum Fitness is solution 5, its fitness is 55.866. in the random test after 50 times, the conclusion is same as the first 20 times run test, we assume solution 6 is the optimum task allocation with 250 generations. The task allocation schema is shown in Table 3. we also compute this test case by simple PSO and GA, the simulation result are shown in Table 4. The result show that our algorithm have good performance on convergence speed, in another word, the algorithm have better time complexity than simple PSO and GA.

Task / Solution	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	Fitness
1	3	9	2	5	13	6	8	1	15	10	59.328
2	3	9	2	7	10	6	8	15	1	12	60.663
3	5	7	8	6	11	14	1	15	12	9	59.430
4	5	2	3	6	1	8	7	4	9	15	56.234
5	4	5	1	3	11	8	7	12	10	6	63.221
6	3	9	2	5	6	8	15	12	1	10	55.866
7	1	10	9	5	6	8	15	12	3	2	60.126
8	3	15	7	8	6	12	2	10	1	5	58.423
9	3	2	6	5	9	15	12	1	8	10	59.403
10	3	8	5	6	9	12	1	15	10	2	60.325

Table 2: Task detail information.

Table 3:The task allocation schema for one solution.

Fitness	Best	Mean	Maximum	CPU time
GA	56.311	59.678	66.534	183”25
PSO	55.866	59.412	65.362	35”35
Hybrid Algorithm	55.866	59.302	63.211	31”12

Table 4: The comparison of different algorithm.

6. Conclusions

Whether the concepts of the HMS can be successfully implemented in practical manufacturing systems, depends on an effective mechanism for collaboration, re-organization, and optimization. The dynamic re-organization of holons is a key element of current research on HMS. Dynamic intelligent reconfiguration is important for holonic control. This paper extends the mechanism of virtual clustering to the reorganization of holons and uses Contract Net-based task allocation protocol to efficiently deal with the communication and coordination problems during task-oriented clustering. The PSO-based virtual clustering optimization algorithm described in this paper can solve the optimization problem of task allocation on the basis of global optimization. This provides a new approach for task allocation in an HMS and may also be an effective approach in other similar optimization situations.

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