Modeling and Simulation on Dynamic Allocation and Scheduling of Multi-resource problem

Wenbin HU[12] Zhengbing HU[3] Yuheng CHENG[1] Hai ZHANG[1] Wei SONG[1]
[1]Computer School, Wuhan University, Wuhan, 430079
[2]State Key Lab. For Novel Software Technology, Nanjing University, P.R.China)
[3]Department of Information Technology, Huazhong Normal University
Email: hwb@whu.edu.cn

Abstract— **Resource-constrained project scheduling and configuration determines the progress of the construction and quality. This paper proposes a simulation modeling method based on 0-1 variables according to multi-resource dynamic allocation and scheduling of discrete features, use digital circuit based simulation method to make a 0-1 variables model for multi-resource dynamic allocation and configuration problem. This paper constructs a model for dynamic resources allocation and scheduling based on priority and fuzzy theory. And use ant colony algorithm with trust mechanism to solve it. The algorithm simulates ant feeling of mutual trust and act and is subject to significant interaction between consciousness and unconsciousness in path selection, so that in the initial time to use their own experience, thereafter conditionally accept the trust mechanism for peers to influence the information volume, at the same time modify the amount of information on the path adaptively. In this way have good balance between accelerating the convergence and preventing early-maturing, stagnation. Each ant as an Agent, the autonomy of ant Agent shall be autonomous; each has some control of their own behavior. Through the port logistics scheduling system simulation applications, the results reflect the algorithm has good convergence and meet the actual production.**

Keywords-ACO; scheduling; multi-resource; port; model

I. Introduction

Modern production is becoming more variety, smaller batch and reducing inventory, the rational allocation and scheduling of enterprise and social resources attract more and more attention, how to allocate and schedule production equipment, manpower, capital and social public resources rationally directly affect the utilization efficiency of resources and effectiveness of production system. For previous static equipment configuration problems, in many cases we can create a mathematical model, but for the dynamic equipment configuration problem for discrete event system, we have to establish a simulation model first, run the simulation system for several times and get the system performance state in different configurations, through the comparison of the system state to determine the optimum equipment configuration, although this limited program selection method will not necessarily be the best configuration. Combining optimization and simulation models together, establishing the equipment configuration simulation optimization system structure can effectively optimize the equipment configuration problems. The current research on equipment configuration simulation optimization mainly focuses on improving the rationality of configuration and service level, the standards are within a fixed period of time's level assessment, instead of a dynamic, long-term targets, for general multi-resource dynamic allocation and scheduling problem, because of its large investment and long payback period, often through short-term, static indicators can not reflect the pros and cons of the system. Therefore, research in this topic, will address the characteristics of the system to improve the intelligent swarm optimization algorithm, and based on the current operating status of multi-resource dynamic configuration and scheduling, dynamically phased program for simulation and optimization is proposed to satisfy the equipment configuration and scheduling in different times and different operating conditions, reduce costs and improve operating efficiency. This paper proposes a simulation modeling method based on 0-1 variables according to multi-resource dynamic allocation and scheduling of discrete features, use digital circuit based simulation method to make a 0-1 variables model for multi-resource dynamic allocation and configuration problem, make improvement for the ant colony algorithm, propose an algorithm based on multi-Agent particle swarm and ant colony optimization algorithm for solving multi-resource allocation and scheduling problem.

II. RELATED WORKS

A. Modeling of multi-resource allocation scheduling

With the development of industrial control systems, the application of Petri net modeling increase, but it is a serious problem of how to describe, analyze and verify the system model when the researching object is becoming increasingly complex and large [1]. It is an effective method that combines Petri net modeling, invariant analysis and simulation, but there are some shortages as follows:

- It needs too much work to build a complex system model.
- It needs too much repetitive work to build a complex system model with Petri net [2].
- It has a high expectation of modeler to build a complex system model with Petri net.

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The modeler needs to discern the system in detail so as to make the model correctly reflect the actual production system and avoid deadlocks when modeling. And the method asks the modeler a certain degree of simulation modeling skills, professional knowledge and experience [3].

Is there an easy way that the modeler who is just familiar with the logical relationships between the modeling objects able to model? And we can do the dynamic performance analysis in that way?

In nature, many Physical quantities perceptible by human such as speed, pressure, temperature, sound, weight and location are converted into electric quantities such as current, voltage, resistance and the others in order to facilitate the analysis in engineering technology. In electronic technology, in order to facilitate the storage, analysis and transmission, analog signals are often converted into digital signals. Then using digital logic, analyze and design complex digital circuits or digital systems in order to store, analyze and transmit digital signals. In digital circuits, binary is often used to quantize continuous change analog signals, while the binary is just two values, 1 and 0. This will help to store, analyze and transmit signals with the complex digital system. In discrete event system, the state of the incident or not can be state of digital logic 1, 0 and the incident can be triggered by the trigger in digital circuit. So is it possible to analyze discrete event system even continuous system with digital circuit?

There is some far reaching significance as follows if it is successful to establish a digital circuit model of the discrete event system with digital circuit and analyze:

1) We can make use of the existing research results of the electric aspects when we analyze the digital circuit model of discrete event system model just like analyze other analog, such as speed, pressure. For example, simulation analyze the system digital circuit model and reveal the interaction of the system objects, the dynamic behavior and other important information in order to evaluate the system performance or show the improvement direction by the digital circuit simulation analyze software.

2) The digital circuit model can directly generate the circuit, and it is possible to provide a effective method for hardware and software co-design by combining with the existing technology, in order to shorten the design cycle.

Therefore, this paper does an attempt on 0-1 variables simulation modeling, taking dynamic multi-resource scheduling system as example. And then propose the theoretical methods of simulation modeling based on 0-1 digital circuits variables.

B. Simulation and optimization of multi-resource allocation scheduling

For multi-resource allocation and scheduling problems, you can first establish a system simulation model, run the simulation model repeatedly to obtain the different performance state in different configurations, and then determine the optimum equipment configuration by comparing the system state. Swisher [4] and others study the statistical method of sorting and comparison (R & S-MCP method) to choose the best solution from a group of simulation states. But this method getting best selection form the limited set will not necessarily generate the best configuration. It is effective to optimize the equipment configuration by combining the optimization and simulation models to establish the simulation structure. Leyuan Shi [5] and others apply the nest area method to the discrete resource allocation and optimization problem in supply chain. B. Joshi [6] and others study the production resource allocation problem through the discrete event simulation and apply the genetic algorithms to the production resource allocation problem. Those studies above are lack of the research of equipment configuration structure simulation and optimization and of the consideration to scheduling problems in the production system on the other hand.

For simulation and optimization, equipment configuration optimization and multi-resource scheduling, the research is still in its infancy, and there are many issues which need further study. Now the main research direction of simulation and optimization on the one hand is to establish and perfect the simulation and optimization system framework and to optimize in the simulation process to avoid the separation of simulation and optimization, on the other hand is to research the new simulation algorithm to improve the convergence speed and accuracy.

Ant colony algorithm has solved the TSP problem, and achieved very good result by making full use of the similarity between process of ant searching food and the traveling salesman problem (TSP). But multi-resource dynamic configuration and scheduling problem is not strictly the TSP problem, the traditional ant colony algorithm can converge to a result, but can not guarantee a global optimum. Thus, the traditional ant colony algorithm has a larger non-adaptive. And for the ant algorithm, ant always reinforcement learning relying on other ants feedback, rather than to consider their own accumulated experience, and this head behavior easily lead to early maturity, stagnation, so that the convergence slows down. In order to solve these problems, this paper proposes a multi-Agent ant colony algorithm with trust mechanism. The algorithm imitate the ants to select path, which the ants trust each other and feel each other and select the path by the interaction of consciousness and subconscious. The ants accept their own experience affection in the initial stage, then gradually accept other's information amount and then adaptively modify the information amount on the path. This can get a good balance between speeding up convergence, avoiding premature and stagnation.

III. MODEL OF THE DYNAMIC ALLOCATION AND SCHEDULING FOR MULTI-RESOURCES

A. Problem description

Because the fierce competition for survival has forced many enterprises to use some expensive renewable resources more effectively and rationally, such as the heavy allocation, Resource Constrained Project Dynamic

Scheduling and Allocation (RCPDSE) become more and more important and an important reason for this is that RCPDSE regard the rate of changing of using resources as a index of evaluation, that is, the more flat the contours of the balanced use of resources is, the better.

To establish the model of the dynamic allocation and scheduling for multi-resources, the following notations are used for the formulation:

t_i the scheduling decision variable of the activity a_i, if a_i can be implemented, then t_i=1, otherwise t_i=0;

P_i the priority of activity a_i, and $p_i \in \{p_{low}, \cdots, p_{high}\}$, $p_{low}, p_{up} \in N$;

d_i the duration of the activity a_i;

s_i the starting time of scheduling of activity a_i;

$x_{i,j}$ the choosing decision variable of resources, if choose the resource S_j to implement activity a_i, then $x_{i,j}$=1, otherwise $x_{i,j}$=0;

$TW_{i,j}$ the time, the amount and the constraint or priority of the resource i to activity j, $TW = \cup TW_{i,j}$, $TW_{i,j} = \{TW_{i,j}^1, TW_{i,j}^2, \cdots, TW_{i,j}^{|TW_{i,j}|}\}$, $|TW_{i,j}|$ is the number of dynamic constraints;

$STW_{i,j}^k$ the bound form of the *k*th dynamic constraints; $ETW_{i,j}^k$ the end time of the *k*th dynamic constraints;

$vtw_{i,j}^k$ the decision variable under dynamic constraints.

According to these constraints, we establish the initial model of the dynamic scheduling for multi-resources:

$$\max: \quad Q = \sum_{1 \le i \le m} t_i p_i$$

$$s.t. \quad t_i = \{0,1\}$$

$$p_i = \{p_{low}, \cdots, p_{high}\}, \quad p_i \in N$$

$$t_i = 1, \quad \bar{i} \in \overline{M}$$

(1)

$$t_i \ge 0, \quad i \in M\overline{M}$$

$$\sum_j \sum_k (x_{i,j} * vtw_{i,j}^k) = 1, \quad \bar{i} \in \overline{M}$$

(2)

$$t_i = \sum_j \sum_k (x_{i,j} * vtw_{i,j}^k), \quad i \in M\overline{M}$$

(3)

$$x_{i,j} * s_{i'} - x_{i',j} * s_{i'} \ge d_{i'}, \quad s_i > s_{i'}$$
$$i, i' \in M, 0 \le j \le s$$

(4)

$$x_{i',j} * s_{i'} - x_{i,j} * s_i \ge d_i, \quad s_i > s_{i'}$$
$$i, i' \in M, 0 \le j \le s$$

(5)

$$t_i * s_i \ge t_i * \sum_j (x_{i,j} * (\sum_{1 \le k \le |TW_{I,J}|} (vtw_{i,j}^k * STW_{i,j}^k))$$
$$i, j \in M, 0 \le j \le s$$

(6)

$$t_i * (s_i + d_i) \le t_i * \sum_j (x_{i,j} * (\sum_{1 \le k \le |TW_{i,j}|} vtw_{i,j}^k * STW_{i,j}^k))$$
$$i, j \in M, 0 \le j \le s$$

(7)

$$0 \le s_i \le T_{horizon}, \quad 0 \le s_i + d_i \le T_{horizon}, \quad i \in M$$

(8)

Description:

The objective function $\max: Q = \sum_{1 \le i \le m} t_i p_i$: scheduling program should make the sum of implemented activities' priority the largest. (1): all the activities must be completed for a specified subset of activities $\overline{M}$, and if there is no plan for any activity in the subset in the final scheduling program, the task scheduling program is not valid. This is the so-called hard constraints. (2): any activity of $\overline{M}$, the subset of activities and the implementation of activities is scheduled dynamically under the dynamic constraints. (3): the activity should be allocated some resources and meet the given dynamic constraints if it can be implemented. Constraint (4) and constraint (5) contain a conditional judgment that is when $s_i > s_{i'}$, the constraint $x_{i,j} * s_i - x_{i',j} * s_{i'} \ge d_i$ is activated. If the activity a_i's scheduling time starts after the activity $a_{i'}$, then a_i should be implemented after $a_{i'}$ completed; when $s_i < s_{i'}$, the constraint $x_{i,j} * s_{i'} - x_{i,j} * s_i \ge d_i$ is activated. If the activity a_i and $a_{i'}$ occupy the same resource and a_i's scheduling time starts after a_i, then $a_{i'}$ should be implemented after a_i completed. This constraint shows that any resources can only implement one activity at the same time. (6): the implementation of any activities can be completed must be in the case that the selected resources are available under the dynamic constraints. (7): any activities that can be completed must be completed before the limit time $T_{horizon}$.

B. Multi-resource dynamic configuration and scheduling modeling based on digital circuit

B.1 Multi-resource dynamic configuration and scheduling modeling

With the 0-1 variables model to analyze the dynamic performance of the discrete event system, digital circuit model must accurately reflect the running process of the discrete system, analyze the relations of discrete system's objects by model simulation. The container under-loading process below is to illustrate the procedure of multi-resource dynamic configuration and scheduling with 0-1 variables modeling:

①Analyze the logic relations of the system's running process

Analyze the relations between the system objects, determine the logic relations and the logic functions when the system state changes. The dynamic process of container unloading is: the quay crane (B) and crane vehicles (C) receive the unloading order (A), then enter the working state (D); After the quay crane unload containers from the ship to the vehicles (E), the crane vehicles enter the import container area, the yard crane (G) starts to work (F), unload containers from the vehicles to the yard, complete the container unloading process from the ship(Y).

② Obtain the logic relations from the origin state diagram

As the timing circuit output signal not only relates with the current input signal but also the origin state of the signal. Therefore, to design the sequential circuit, first must analyze the given logic function to find the corresponding truth table. Determine the input variables, output variables and states of the circuit with binary representation. Consider the corresponding output in each possible input and obtain the Truth Table 1 correspond to reality; the state that has nothing to do with the production is not listed in the table. In this paper the unfinished state of the quay crane (B), crane vehicle(C), the yard crane (G) is represented with a low level, the finished state is represented with a high level; Events not occurring represented with high level and events occurred with low level.

③Seek out the logic equation and draw the output logic circuit diagram.

From the truth table we can obtain the output logic equation: $Y=\overline{A}\cdot BC\cdot\overline{D}\cdot\overline{E}\cdot\overline{F}\cdot G$. Thus output the logic relations and get the circuit diagram in figure 1.

④Select the type of flip flop and draw the event-triggered relation circuit diagram.

According to the analysis in ①, select the proper type of flip flop, this paper choose the D Type Flip Flop, and according to the logic relations, design the logic circuit which reflects the events triggered process, shown in Figure 2.

⑤Use the circuit simulation software to implement this circuit to see if the simulation model can accurately express the logic process of the ship unloading process.

In this paper, we implement the circuit with the Electronics Workbench 5.0 software, and use its logic analyzer to obtain the logic changes of each variable. The logic analyzer is mainly used for high-speed digital signal acquisition and timing analysis, it can be used for simultaneously track and display multi-channel digital signal and complex digital circuit design and analysis.

Table 1 the truth table.

A	B	C	D	E	F	G	Y
1	1	1	0	0	0	1	0
0	0	0	1	0	0	1	0
0	1	0	0	1	0	1	0
0	1	0	0	0	1	0	0
0	1	1	0	0	0	1	1

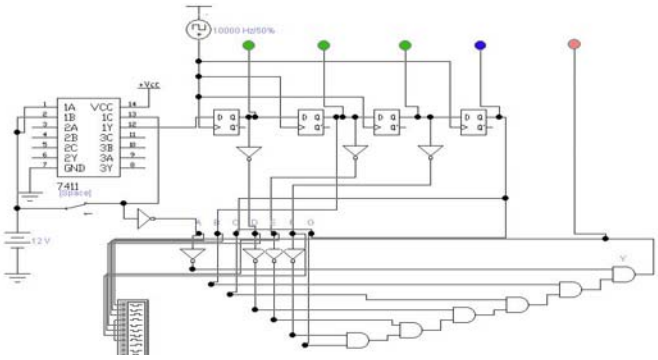

Figure 1 digital simulation model for the container unloading process

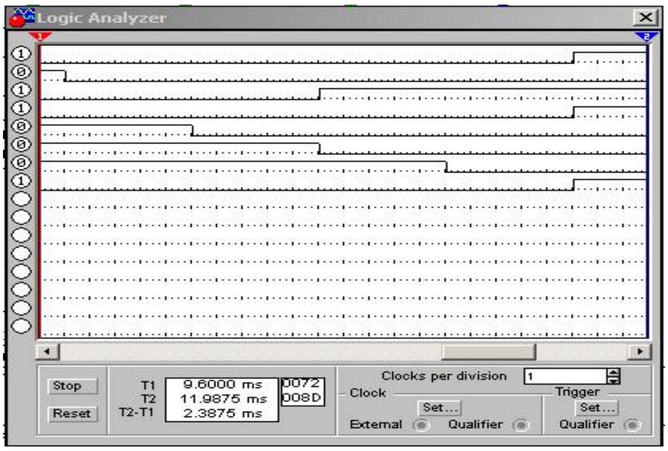

Figure 2 the logic analyzer

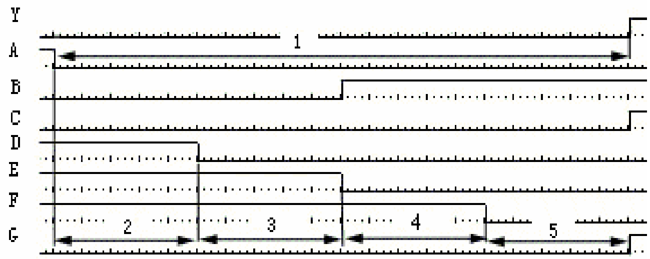

Figure 3 the waveform figure

To illustrate the meaning the simulation waveform expressed, this paper takes the waveform the analyzer obtained and adds comment, as shown in figure 3. In the figure B, C, G represent the working state of the quay crane, crane vehicle, yard crane; A represents the container unloading event; D, E, F represent the events that the container unloading from the ship, loading to the vehicle, unloading from the vehicle to the yard. The unfinished state of the ship (Y), quay crane (B), crane vehicle (C) and yard crane (G) is represented with low level, the finished state is represented with high level; Event not occurred with a high level and event occurred with a low level. 1 represents the process of unloading a container, 2 for the ordering and scheduling process, 3 for unloading container from the ship, 4 for transporting the container to the yard, 5 for unloading the container to the yard. When an unloading instruction is sent, A changes from high level to low level; B, C, G accept the task instruction to finish the process 2, when the unloading process start D changes from high level to low level; when the container is loading to the vehicle, E changes from high level to low level, while the quay crane complete the task, B changes from low level to high level to finish process 3, and go to process 4; the vehicle arrives the yard, starts to unload container to the yard, F changes from high level to low level; when the process 5 ends, the ship (Y), crane vehicle （C, yard crane(G) finish an unloading task, Y,C,G change from low level to high level.

Although this is only a simplified model of the container unloading process, from the above analysis we can draw this conclusion: using variable 0, 1 can describe the container unloading process.

B.2 The modeling ideas based on digital circuits

Taking into account the advantage that hardware description language can describe the behavior and the EDA technology design ideas, the design ideas of Seaport Container Logistics System simulating and modeling are as follows:

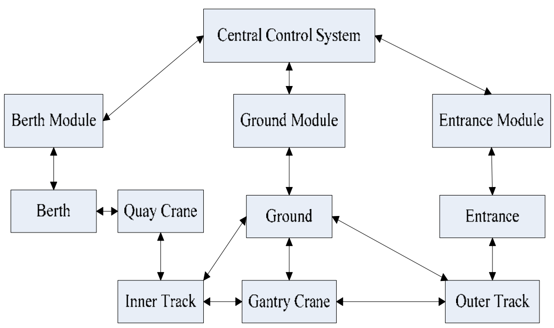

Figure 4 The design idea of Container Terminal structure

(1) The system structure shown in Figure 4 is formed by functional partition and structural design on the top of system ,using top-down hierarchical analysis and object-oriented method. Each module can be designed and implemented as a hardware design module in an integrated circuit design. And that structural design implies the successive decomposition idea of hardware design. Every module has at least one description at any level of the design process, which the description especially the behavior description is called behavior modeling. That can be implemented by the hardware description language. It is close to direct human thought to conceive from behavior of the design to be implemented rather than specific basic components. It is close to abstract thinking, and can achieve the specific performance requirements in the most direct way when implemented with HDL language.

(2) Code and implement some behavior modules such as berth, ground, entrance module in high levels. The aim of simulation verifying is to find errors of the structure design and to avoid the useless design rather than to implement the specific circuit by considering the system performance and target allocation of each module generally. Although no specific circuit implementation, the goals can be verified by analyzing the system logic waveform in EDA tools.

(3) Design the module in different levels in different ways. When the design level is close to the bottom level, the behavior description of the module often need to implemented by logic circuits, such as quay crane, yard crane and truck module. And the module needs to verify with simulation. Overall, the specific circuit designed in this part is implemented gradually from the bottom up. It can improve the design efficiency that take advantage of the two methods which EDA tools not only supports HDL description, but also supports circuit input.

There is a lot in common between the simulation modeling above and OPN modeling which first divides into module objects , then establishes the relationship between the objects and then describes and implements the internal behavior of each object according to the system feature and researching purpose. Therefore, a build OPN network model can be converted with the above method and do logical simulation to verify the correctness of OPN.

IV. THE ANT COLONY ALGORITHM BASED ON THE MULTI-AGENT

A. The structure of solution space

We can find that the allocation of resources is much more difficult than the TSP. In the TSP, the basic unit is “urban node” and nodes are the same so that ants can be randomly or evenly distributed to each city; but in resources allocation, the basic unit is “resource” and resources are not the same. Resources have both order constraints and non-blocking constraints so that a starting node V0 must be supposed to make all the ants start with this node.

In essence, the construction graph is a description of solution space, so we can use the construction graph to solve the allocation of resources. First of all, the solution of optimization problems should be divided into the set of every stage’s structure blocks according to the resources type, and then, make them mapped to the construction graph and map the set of each stage’s structure blocks to a layer node, so the entire construction graph is made of many layer nodes. In addition, in the ant colony algorithm, pheromone is connected to the nodes or arcs on the construction graph. Some researcher found that when the distribution of pheromone is associated with nodes, the performance of the ant colony algorithm is superior to the time that the distribution of pheromone associated with the arcs in some combinatorial optimization problems. So, we define a special construction graph, the layered construction graph based on the pheromone associated with nodes, to solve such combinatorial optimization problem.

Supposed that the resources allocation is described as the construction graph G = (V,A,Γ,Ω). V is the set of nodes in the graph and each node is the resource waiting for allocating; A is the set of both one-way arcs and two-way arcs in the graph and two nodes of the same type of resources are connected by two-way arcs while in the different type connected by a one-way arc. The feasible solution of the problem is the sequence of tasks' work (node). The constraint Ω is that each node appears only once in the sequence and Γ is the matrix of pheromone. It is as shown in Figure 5.

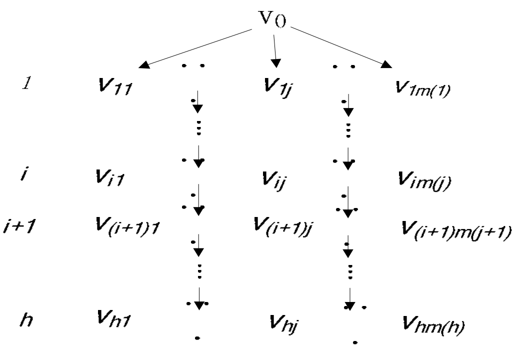

Figure 5 the layered construction graph

In the Figure 5, the pheromone in the layered construction graph is associated with nodes. Map every step (every type of resources) to a finite set of nodes in the layered construction graph and nodes distribute hierarchically except the virtual starting node V0. Each layer's nodes correspond to a set of a certain type of resources and every set's amount is m (i), which is not exactly the same. All the nodes in the same layer are connected by the two-way arcs and (…) in the graph stands for the two-way arc between nodes. The one-way arcs exist between the node *v* □*Ri* belonging to the *ith* layer and the node *w* □*Ri +1* belonging to the *(i+1)th* layer and the direction is from *v* □*Ri* to *w* □*Ri +1*. As a result of the sequence of resources allocation, constraints must be distributed according to layers and the arc connected to the starting node is one-way arc too. Label the nodes' pheromone belonging to the *ith* layer as *τij*, and label the set of these pheromones as *Γi*.

Each artificial ant begins with the virtual node (V0), and the ants must go though nodes in every layer. In every construction's step, if the ant moves from the node j to the adjacent node s in the same layer, then s □allowed k. The choice of s is in accordance with the rule that the state's migration is at the pseudorandom ratio and when the nodes in this layer have been met the task, it will turn to the next layer of resources. In this way, choose the needed node for the sequence of resource allocation π step by step. The Figure 6 shows one solution to the optimization problem in the construction graph. Besides, Vi stands for the set of nodes in the *ith* layer and *Vij* stands for the *jth* node in this layer.

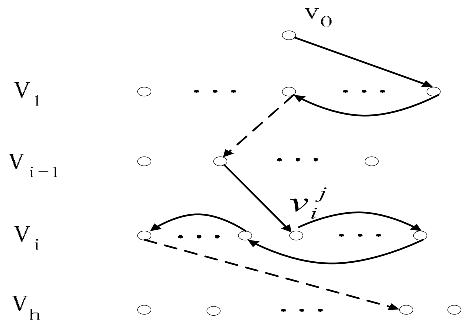

Figure 6 the solution to the optimization problem

B. The introduction of trust mechanism as heuristic information

In the ant colony algorithm, the factor that plays a decisive role is the heuristic information. *ηij* in that algorithm is the question-based heuristic information, it directly affects the results of the model of the algorithm, here we use trust of resources as the heuristic information [7].

At present, many researchers who study the ants' path choice, usually only consider the length of the path. However, the actual ants' path choices, not only have to consider the distance, but also will be affected by the blockage of the path and other conditions. For example, the existing two paths A and B, A is shorter than B, but A frequent blocks; B is longer, but in most cases more smooth. When A blocks, ants choose B instead of A and spend less time. Considering the distance and blockage of path, ants may choose the longer path B.

In the traditional ant colony optimization algorithm, the probability for ants to choose path is determined by the pheromone and heuristic information, which are affected by distance. Considering the effect of the blockage of path on ants to choose the path, this paper introduce the trust mechanism to indicate the trust of ants on whether the path is smooth or not, and we use trusted point to measure as heuristic information. Thus, the probability that for ants to choose path is constrained by the length (pheromone) of the path and the trust (heuristic information) of the path these two factors, it's more in line with the actual process of ant routing. Trusted point can be learned from the ants' prior experience of this path, the range is [0, 1]. In the basic ACO algorithm, each ant fully trusts all the paths that trusted point is 1. In resource allocation, taking into account the depreciation of resources and service levels, not all of the resources can be used to complete the task. Some resources are unable to be used to complete the task during the execution because of aging allocation or allocation failure, reducing the operating efficiency in the implementation. Thus, in the allocation of resources, in addition to consider the resources of the operating cost(pheromones) , the resources of depreciation, service capacity and other factors also have to be considered. It's similar to the trust on the path that is unobstructed during ants' path choosing process. We use trusted point to indicate the depreciation of resources and service capabilities. Resources with strong service capabilities is less prone to fail, the trusted point is higher; aging resources with weak service capabilities is easy to fail, the trusted value is lower.

Trusted point is related to tasks scheduling and resources allocation, which needs different setting for specific configuration problem. This paper gives a most simple method of calculating the trust value of resources: assume that allocate n jobs for resources I, in which the number of successfully completed jobs is m and the failed is n-m, the resource depreciation rate is k%, thus the trusted point $T_i = \frac{m}{n} \times (k\%)^{\alpha}$ (α is the depreciation rate).

C. Multi-node search strategy

For a particular task, when one resource can not meet the service, may need a variety of resources at the same time provide such services. For example, in port logistics, when a large ship arrives the port, one tugboat can't tug it to the berth, at this time more tugboats are needed to complete the task together. Using ant algorithm to solve general flow shop problem requires each machine can only process one job, that is one job can only be assigned to one machine at a time. If regard the resources to complete the same task as one machine to meet the service, then the resource allocation problem can be reduced to the general flow shop problem.

This paper regard the resources that the task need to allocate as a task group(node group),and set multiple ant subgroup for the task group, each subgroup is the same and has the same number of ants, each ant is a task of the task group. Multiple subgroups work in parallel, the ants interact within the subgroup but independent among different ants, the ant subgroup structure figure is below:

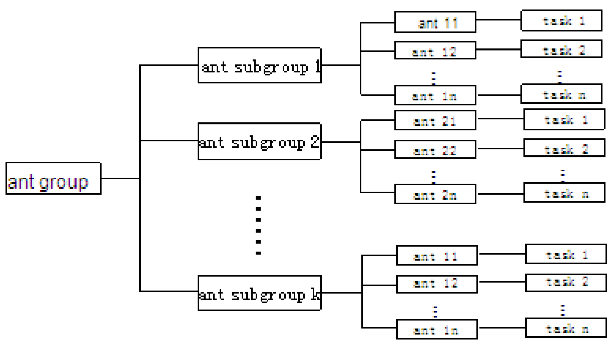

Figure 7 ant subgroup structure decomposition

In the process of each cycle, ants decide to shift the direction according to the pheromone concentration of each node, when arrive a node, add the resource that the node represents to the ants' task group, it's shown in figure 8. In the figure, there are ten same resources to be allocated, including the start node v0, respectively represented as node $(v_0, v_2, v_3, ..., v_9)$. When each cycle starts, all ants begin from node v_0 to set their task groups. Four ants build four resource groups {1, 4, 6}, {3,8}, {5,9}, {7} to complete four tasks, resource 2 is not allocated and remains idle. Resource group {1, 4, 6} has resource 1, resource 4 and resource 6, ants have left pheromone at node v1, v4,v6. In the moving process, ants decide to shift the direction according to the pheromone concentration of each edge, when arrive a node, add the resource that the node represents to the ants' task group.

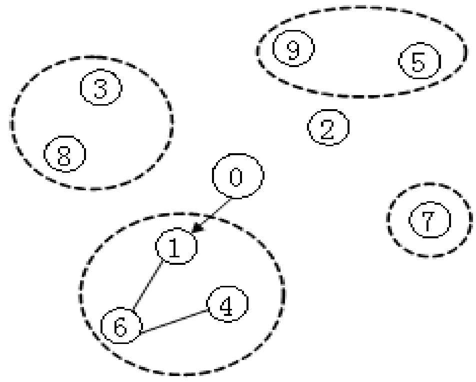

Figure 8 task group figure of multi-resource allocation

The resource configuration problem is converted to solving the solution on the structure map nodes in the group at all levels (task group）, in order to enhance ants' searching parallelism.

D. Description of the algorithm

Initialize pheromone vector Γ and parameters:

While (iteration times **t** *< max iteration times){*

Initialize multi-agent coalition, and generate ant , Agent and node Agent

For (ant (task) y = 1,...,Y){

Generate a multi-agent coalition according to the pseudo code

//ant Agent y starts the solution construction

make ant Agent y start at the virtual node V0;

Initialize ant Agent y's coalition sequence L = {V0};

For (construction graph layer x =1… X){

//starts from layer one

Ant Agent y choose a node Agent vxi in the layer according to the probability calculating by formula(4-6);

While((not satisfy service|| vxi□allowed(x))&&i< the number of nodes in the layer){

Ant Agent y choose the next node Agent vxi in the layer according to the probability calculating by formula(4-6);

Ant Agent y and node Agent's coalition added to the sequence L={ v0,…, vxi }；

Construct the coalition of the ant Agent and node Agent to accomplish the task.

Calculate the kth ant Agent coalition value $V(C_K)$ *, update the value of the sum coalition value and its coalition.*
If(max sum coalition value==max sum coalition value after N loops)
Update the trusted point of every node according to formula (2-11) and (2-12)
}
}
Pheromone vector Γ updates partially according to the rules of different types of resources;
}
//ant Agent y ends the solution construction
The feasible solution sty constructed by ant y is saved to set St⊆S;
}
If (the present solution is better than the optimal one){
Update the optimal solution;
Update the feasible solution globally constructed by ants;
}

V. EXAMPLE APPLICATIONS

Many matching problems exist in the operating process of port resources, for example, the length of the shoreline the ships docked at should meet the length of ship, between ships certain space should be left; Tugboats in port help one or more ships to dock at the port, different type and size of ships should be allocated with tugboats of different horsepower. In the container loading and unloading process [8], the quantity determines the length of time.

Table 2 Ship Record Sheet for a Port(partial data)

ship name	num	dock time (h)	ship length (m)	berth	tug	horse power	work time(h)
Kai Yue	17	0.67	72	4	No.7	2600	2.58
Jiang Peng No.5	50	1.42	154	2	No.6, No.1	5200	16.75
Ji Jing	32	0.58	62.48	4	No.16	1200	1.58
…	…	…	…	…	…	…	…
Hui Long No.7	294	.17	208	1	No.5 , No.3 , No.11	6600	7.83
…	…	…	…	…	…	…	…
An Hua No.3	114	1.08	84.6	3	No.14, No.2	1200	7

Table 2 is the ship record sheet docked at a certain port, some ships only need one tugboat, however, some need two or three. In order to avoid the case that"large tugboats drag small -tonnage ships" or "small tugboats can't drag large-tonnage ships", certain matching rules should be based on to choose the right tugboats.

Take a north port's ship work data as an example to simulate, set the single simulation time as 30 days. Its resources allocation options are shown in Table 2, the output of the simulation results of these options are shown in Table 3.

It can be seen through the analysis of simulation that: the utilization rates of 2600 PS's tugboat are much higher than other tugboats of different horsepower, the utilization rates of tugboats with different horsepower increase as the number of tugboats increase and the average waiting time and max queue length decrease. The allocation of port and crane resources directly affects the handling efficiency and service levels, considering the waiting time of ships are the sum of the time waiting for the berth and the time waiting for handling, thus appropriate increase in the number of crane is also necessary. In the allocation of port equipment, we need to receive higher equipment utilization rate and lower the ship waiting time with the least equipment.

Table 3 Resources Allocation Options for a North Port

resource	tugboat horsepower					port	crane
	1200	2600	3200	3400	4000		
1	1	6	2	2	1	4	4
2	1	7	2	3	1	4	4
3	0	6	3	3	1	4	5
4	1	7	3	3	1	4	6
5	0	7	3	3	1	4	6
6	0	7	3	3	2	4	6
7	0	8	3	2	3	4	6
8	0	7	3	3	3	4	6
9	2	8	2	2	1	4	5
10	2	7	3	3	2	4	5

Table 4 Simulation Results for Different Allocation

Project and result		1	2	3	4	5
Tug using rate(%)	1200PS	9.4	0	0	0	15.0
	2600PS	64.6	56.8	68.9	58.8	58.5
	3200PS	21	27.9	23.4	24.2	23.3
	3400PS	18.4	23.8	13.5	21.5	21.8
	4000PS	7.5	6.3	15.6	16.5	10.6
Tug average using rate(%)		20.5	28.7	30.6	30.3	25.8
Railway crane average using rate(%)		47.8	46.5	44.0	44.7	45.0
Tyre crane average using rate(%)		36.3	32.0	27.3	29.0	31.5
Total ship number		1525	1525	1525	1525	1525
Biggest waiting ship number		9	8	7	6	6
Average waiting ship number		0.44	0.018	0.013	0.017	0.014
Average waiting time of ship		5.987	3.380	1.860	3.494	2.767

Rational allocation of port resources can reduce the ships' queue length and waiting time, ships arrive at the port receive service in time; reduce the rotation cost of the goods at port and the time of ships that stay at port and attract more ships to dock at the port in order to promote the throughput of the port and the economic efficiency [9].

IV. CONCLUSION

Because the fierce competition for survival has forced many enterprises to use some expensive renewable resources more effectively and rationally, such as the heavy allocation, Resource Constrained Project Dynamic Scheduling and Allocation (RCPDSE) become more and more important and an important reason for this is that RCPDSE regard the rate of changing of using resources as a index of evaluation, that is, the more flat the contours of the balanced use of resources is, the better. Resource-constrained project scheduling and configuration determine the progress of the construction and quality. This paper constructs a model for dynamic resources allocation and scheduling based on priority and fuzzy theory. And use ant colony algorithm with trust mechanism to solve it. The algorithm simulates ant feeling of mutual trust and act and is subject to significant interaction between consciousness and unconsciousness in path selection, so that in the initial time to use their own experience, thereafter conditionally accept the trust mechanism for peers to influence the information volume, at the same time modify the amount of information on the path adaptively. In this way have good balance between accelerating the convergence and preventing early-maturing, stagnation. Each ant as an Agent, the autonomy of ant Agent shall be autonomous; each has some control of their own behavior. Through the port logistics scheduling system simulation applications, the results reflect the algorithm has good convergence and meet the actual production.

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Wenbin Hu. Associate professor worked in Wuhan University since 2006. He got his doctor degree in 2004.

His main research interests are intelligent simulation and optimization, multi-agent system and swarm intelligent algorithm.