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MULTI-AGV SCHEDULING OPTIMIZATION BASED ON NEURO-ENDOCRINE COORDINATION MECHANISM

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***Abstract:** To solve the problems of task scheduling and coordination control presented by a multi-AGV system, the mixed regional control model for the production task has been advanced. The architecture of multi-AGV task assignment and scheduling mechanism has been proposed by combining the mixed regional control model for the production task and the neuro-endocrine coordination mechanism. Hormones for manufacturing cell are secreted by the machine tool according to the information in the production task, and the task can be allocated to the most suitable machine according to the hormone concentrations of the manufacturing cell. The AGV's hormones are secreted according to the AGV's operation state. The AGV with the largest hormone concentration will be chosen to execute the transportation task, thus shortening the overall run time of the system. A series of scheduling simulation experiments are performed for some specific examples to demonstrate the feasibility and efficacy of the proposed approach. The results show that tasks can be allocated according to the current status of a machine tool and tasks can be scheduled according to the current state of the AGV system to maximize the efficiency of the AGVs as well as that of the overall system.*

Index terms: **multi-AGV, scheduling strategy, coordination control, neuro-endocrine coordination mechanism, scheduling simulation**

Ⅰ. INTRODUCTION

The rapid development of modern manufacturing systems has led to greater demands for flexibility and robustness in those systems[1]. As critical subsystems, automatic guided vehicles (AGVs) are increasingly being used in manufacturing scenarios, as they can greatly improve the productivity and robustness of the overall system, as well as reduce production costs due to their unique flexibility, efficiency, and other notable features[2]. The task scheduling, path planning, and coordination control problems presented by a multi-AGV installation have been the subject of several investigations in recent years. One of the basic problems presented by a multi-AGV system is the main settlement of task scheduling, and the distribution and portfolio optimization of the tasks to be processed when using multiple AGVs while considering the current constraints[3]. The settlement of path planning for a multi-AGV system involves determining a path from the start point of a task to the corresponding target point after receiving a new task, while considering the current environmental parameters. Coordination control is the most critical problem facing a multi-AGV system, for which the main settlement involves the collision and deadlock problems which may be presented by the system during real-time operation[4].

As a real-time concurrent system, satisfactory control of a multi-AGV system cannot be achieved owing to the long computation times and control lag problems associated with centralized online path planning and coordination control. However, organisms in complex and dynamic environments have a very strong resilience and resourcefulness, with which they can quickly coordinate their related functional activities to reach a new state of dynamic equilibrium, in response to changes in their internal and external environments. A neuro-endocrine coordination mechanism is an important physiological mechanism for maintaining biological environmental homeostasis, and involves rich and complex distributed information processing and coordination mechanisms, which make the organism highly adaptive and self-organizing[5]. Therefore, this study applied the outstanding properties of the neuro-endocrine coordination mechanisms of living organisms to task scheduling and the coordination of the control of a multi-AGV system. We went on to perform simulation experiments to prove the efficacy of this approach. To solve the task scheduling and coordination control problems of a multi-AGV system, we devised a hormone secretion model that combines the mixed regional control model for the tasks and manufacturing units, as well as the AGV control that was based on the neuro-endocrine coordination mechanism.

Based on this, we propose a multi-AGV task assignment and scheduling mechanism based on the neuro-endocrine coordination mechanism.

Ⅱ. NEURO-ENDOCRINE COORDINATION CONTROL MODEL

a. Neuro-endocrine regulation mechanism

The nervous system is a functional regulatory system which plays a dominant role in the human body, either directly or indirectly regulating the functions of the body's systems, organs, and physiological processes. The endocrine system is essential to regulating the functions and activities of the body, and consists of endocrine glands, endocrine cells, and hormones, which together regulate the body's tissues and organ functions by secreting said hormones. There is extensive contact and interaction between the nervous system and the endocrine system. Firstly, the nervous system accepts internal and external environmental stimuli, and transforms them to nerve impulses to stimulate the secretion of hormones by the endocrine system to regulate the endocrine system; moreover, the endocrine system can adjust its sensitivity to specific stimuli of the nervous system by secreting hormones, thus affecting the activity of the nervous system. The body's nervous system is primarily overseen by neural regulation. The structural basis of neural regulation is the reflex arc, which is a single electrical conductor, and can thus rapidly regulate the most important feature of neural regulation. Secondly, nerve impulses are transmitted directly from the reflex arc to effectors with an accurate adjustment range; finally, neurotransmitters are broken down immediately after they have completed their task. Endocrine regulation causes the transmission of hormones, CO2, and other chemicals to the tissues and organs of the body through the blood and tissue fluid, whereby the different physiological activities can be regulated over a fairly extensive range. A nerve-endocrine system could be simulated by mimicking each feature of neural and endocrine regulation, which play an important role in maintaining internal homeostasis. Maintaining a constant body temperature in a cold environment is a typical example of the nerve-endocrine coordination mechanisms interacting to maintain internal homeostasis. The hypothalamus can directly regulate the activity of the skeletal muscles, adrenal gland, etc. when the body senses cold, as well as controlling the secretion of hormones from the pituitary and other endocrine glands, thereby reducing the loss of heat from the body and increasing heat production to maintain a constant body temperature. The specific procedure is shown in Fig. 1.

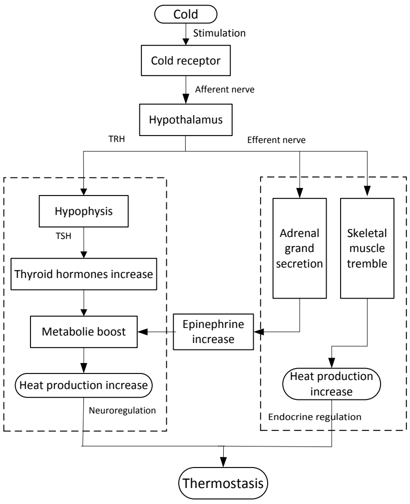

Fig. 1. Maintaining a constant body temperature in a cold environment

b. Analogy between Multi-AGV scheduling system and nerve-endocrine system

An AGV is an important item of logistics and transport equipment in a modern manufacturing system. It may be responsible for transporting materials between the individual tasks of an entire manufacturing system. Generally, multiple AGVs work together in a production process, such that the scheduling efficiency and robustness of the multi-AGV system affects the productivity of the entire manufacturing system. The nerve-endocrine system is capable of coordination, but is a highly complex distributed adaptive control system with complex information processing mechanisms. It is highly adaptive and capable of self-regulation in response to internal and external stimuli. The inherent characteristics of the nerve-endocrine system should provide a new basis for solving the scheduling problems presented by multi-AGV systems in modern manufacturing applications. Such a multi-AGV scheduling system would be able to learn from its nerve-endocrine-based coordination mechanism for scheduling. A multi-AGV scheduling system and the nerve-endocrine system analogy are presented in Table 1.

Table 1. Analogy between multi-AGV scheduling system and nerve-endocrine system

Multi-AGV scheduling system	**Neuro-endocrine system**
AGV, machine tools, and other manufacturing resources	Endocrine cells , endocrine glands
AGV, machine tools, and other states	Nerve stimulation, hormones
Manufacturing unit	Hypothalamus
Monitoring terminal	Central nervous system
CAN-Bus	Reflex arc, humor
Information and communication	Nervous-humoral regulation
Communication protocol	Neural regulation, humoral regulation rules

Ⅲ. MULTI-AGV SYSTEM SCHEDULING MODEL BASED ON NEURO-ENDOCRINE COORDINATION MECHANISM

a. AGV scheduling path planning based on mixed regional control model

Based on conventional control models for an organizational structure, control mechanisms, and operating mode, the mixed regional control model [6] was developed to make it better suited to distributed control. A multi-AGV scheduling system based on the path layout of a mixed regional control model is as shown in Fig. 2 In the mixing regional control model, a multi-AGV scheduling system is composed of several AGVs, each having the same structure and operating independently in a closely controlled manufacturing unit. The AGVs operating in each manufacturing unit are controlled by a controller linking the different areas so as to take advantage of the distributed control.

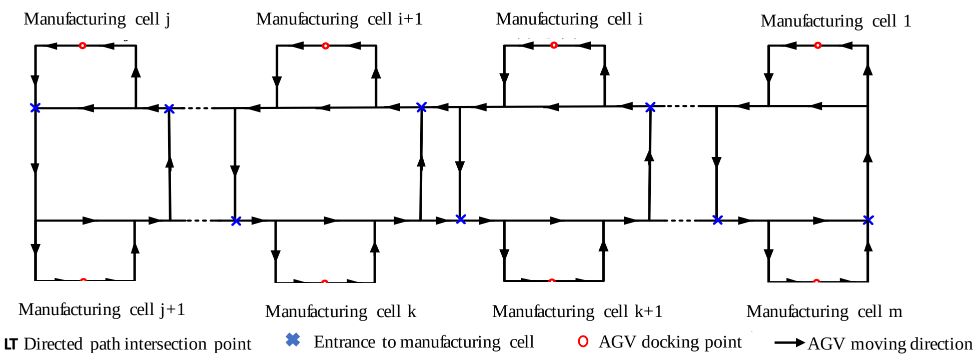

Fig. 2. AGV scheduling path planning based on mixed regional control model

b. Hormone regulation law

Farhy proposed a common hormone regulation law[7-8] which is monotonic and non-negative, and in which the rise and fall of the hormone level follows the Hill function rule, as given by formulas (1) and (2), below:

$$F_{up}(G) = \frac{G^n}{T^n + G^n} \tag{1}$$

$$F_{down}(G) = \frac{T^n}{T^n + G^n} \tag{2}$$

Here, G is a function of the independent variable; T is a threshold value, and $T > 0$; n is the Hill coefficient, and $n \geq 1$. If hormone A is regulated by hormone B, the following relationship exists between the secretion rate S_A of hormone A and concentration C_B of hormone B:

$$S_A(C_B) = aF_{up(down)}(C_B) + S_{A0} \tag{3}$$

Where a is a constant coefficient and S_{A0} is the initial secretion rate of hormone A.

c. Multi-AGV system scheduling model based on hormonal regulation

A multi-AGV scheduling system model based on the mixed regional control model can be built to conform to the hormonal regulation rule. In this multi-AGV scheduling system, the arrival of new production tasks stimulate each manufacturing cell, such that manufacturing cell hormones are secreted by the cells according to formula (4) according to the specific workpiece process, the processing time, and other information in the production task. The concentration of the hormone represents the ability of a manufacturing unit to perform a certain workpiece process[9-10].

$$H_M^i(t) = \frac{c}{\alpha_T \times (T^i / T_{av}) + \alpha_C \times (C^i / C_{av}) + \alpha_U \times (U^i / U_{av})} \tag{4}$$

Here, $H_M^i(t)$ represents the hormone concentration of the manufacturing cell which secretes at time t; T^i, C^i represent the processing time and processing costs of the workpiece process for the manufacturing cell i; U^i represents the machine tool utilization rate of the manufacturing cell; T_{av} and C_{av} represent the average processing time and processing cost for a workpiece process, respectively, performed in the same type of manufacturing cell; U_{av} represents the average machine tool utilization rate for a manufacturing cell of the same type; α_T, α_C, and a_U represent the weight of (T^i / T_{av}), (C^i / C_{av}) and (U^i / U_{av}), respectively, and $\alpha_C + \alpha_T + a_U = 1$; c is a constant and $c > 0$.

When $H_M^i(\mathrm{t}) \geq c$, it indicates that the manufacturing cell i is operating well and is capable of performing a certain processing task; when $H_M^i(\mathrm{t}) < c$, it indicates that the manufacturing cell i is poorly suited to certain processing tasks for some reason. Therefore, when a new processing task is to be undertaken, the task can be allocated to the most suitable machine according to the hormone concentrations of the manufacturing cell, rather than allocating tasks intensively.

The hormones secreted by a manufacturing cell spread and diffuse along the propagation path of the AGV. The AGV hormones will be secreted according to the hormone information and the AGV's own state hormone. When an AGV receives this hormone stimulation, the hormone concentration represents the capacity of the AGV to execute the task. Meanwhile, the AGV hormone secretion rate is regulated by the hormone concentration of the manufacturing cell. When $H_M^i(\mathrm{t}) \geq c$, the AGV hormone secretion rate is accelerated. The relationship between the manufacturing cell and itself is given by formula (5).

$$S_A^j(t) = aF_{up}\left[H_M^i(t)\right] + S_{A0}^j \tag{5}$$

Similarly, when $H_M^i(\mathrm{t}) < c$, the AGV hormone secretion rate slows down. The relationship between the manufacturing cell and itself is given by formula (6).

$$S_A^j(t) = aF_{down}\left[H_M^i(t)\right] + S_{A0}^j \tag{6}$$

Here, $S_A^j(\mathrm{t})$ represents the hormone secretion rate for AGV j at time t; S_{A0}^j represents the initial hormone secretion rate for AGV j at time t, and the AGV hormone concentration is given by formula (7).

$$H_A^j(t) = \frac{\int_0^t S_A^j(\tau)\,\mathrm{e}^{-\alpha(t-\tau)}\,d\tau}{\alpha_{T_D} \times (\mathrm{T}_D^j / T_{Dav}) + \alpha_{T_C} \times (\mathrm{T}_C^j / T_{Cav})} \tag{7}$$

Here, $H_A^j(\mathrm{t})$ represents the hormone secretion rate for AGV j at time t; T_D^j and T_C^j represent the theoretical minimum running time from the current location to the task target and the time required to complete the current task, respectively. If the AGV is currently idle, then T_C^j=0; T_{Cav} and T_{Dav} represent the average time required to execute this task and the average time required to complete the current task, respectively; α_{T_D} and α_{T_C} represent the weight of ($\alpha_{T_D}^j / T_{Dav}$) and ($\alpha_{T_C}^j / T_{Cav}$) respectively and $\alpha_{T_C} + \alpha_{T_D} = 1$.

The AGV with the largest hormone concentration will be chosen to execute the task after the manufacturing cell is stimulated by the hormone secretions of each AGV in the system, so that the workpiece transportation task is always executed by the best-suited AGV, thus shortening the overall run time and increasing the production efficiency of the system [11-13].

d. Task allocation and scheduling mechanism based on neuro-endocrine coordination mechanism

To improve the utilization of each machine in the system and reduce the latency time of each AGV, we propose a task allocation and scheduling mechanism based on both the neuro-endocrine coordination mechanism and the path layout of the mixed regional control model for a multi-AGV scheduling system. Task allocation for each manufacturing cell, combinatorial optimization, as well as the workpiece transport problems related to AGV task allocation are mainly solved by a task allocation and scheduling mechanism based on the neuro-endocrine mechanism, allowing the system to achieve a better production status, and maintain a relatively high production rate[14-15].

Assuming that a production task consists of a number of workpiece machining processes, W_p^q represents process q for workpiece p, production task set $\{\mathrm{W}=\mathrm{W}_p^q\}$, and the system has I manufacturing cells and AGV j, then the specific procedure for task allocation and scheduling based on the neuro-endocrine coordination mechanism can be expressed as follows:

(1) When there is a new production task, hormone $H_M^i(\mathrm{t})$ will be secreted by each manufacturing cell in response to the stimulation of this task and according to the processing type, processing time, processing costs, and other parameters of the workpiece process W_p^q;

(2) The maximum hormone concentration $H_M^k(\mathrm{t})=\max\{H_M^k(\mathrm{t})|1\le i\le I\}$ for a manufacturing cell will be achieved while it is coordinating with the other manufacturing cells, until this task is assigned to manufacturing cell *k* and removed from this cell;

(3) AGV hormone $H_A^j(\mathrm{t})$ will be secreted according to formula (7) when AGV *j* is stimulated by hormone $H_M^k(\mathrm{t})$ secreted by manufacturing cell *k*, after which the hormone will spread and diffuse throughout the system;

(4) The transportation task will be assigned to AGV *l* and then executed according to the maximum hormone concentration $H_A^l(\mathrm{t})=\max\{H_A^j(\mathrm{t})|1\le j\le J\}$ after manufacturing cell *k* receives the hormone being secreted by each AGV.

Steps (1) to (4) are repeatedly executed until all the workpiece processes have been assigned, at which point task allocation and scheduling are stopped for the new production task and the system continues to run. The most appropriate processing equipment and AGV will be assigned to each specific workpiece processing task by using this task allocation and scheduling mechanism, with coordination between the manufacturing cells and AGV when a new production task is requested, so as to improve the production efficiency of the system[16-17].

Ⅳ. MULTI-AGV SCHEDULING SIMULATION BASED ON NEURO-ENDOCRINE COORDINATION MECHANISM

The multi-AGV scheduling simulation experiment platform that we developed is shown in Fig. 3. This consists of the AGVs, manufacturing cells, monitoring terminals, and other modules. Manufacturing cells include the machines, the workpiece buffers, and the manipulators. The monitoring system, which was developed to satisfy specific monitoring terminal functional requirements, is responsible for system testing, automatic operation monitoring, system parameter setting, and remote connections. Fig. 4 shows the interface for the system parameter setting module, which is used to select an AGV and manufacturing cell, as well as set the warehouse configuration parameters.

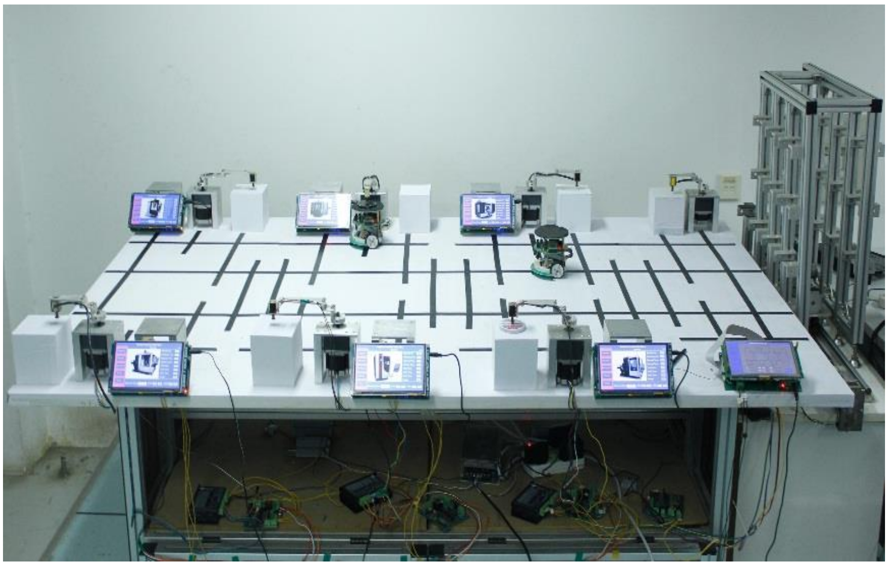

Fig. 3. Multi-AGV scheduling simulation experiment platform

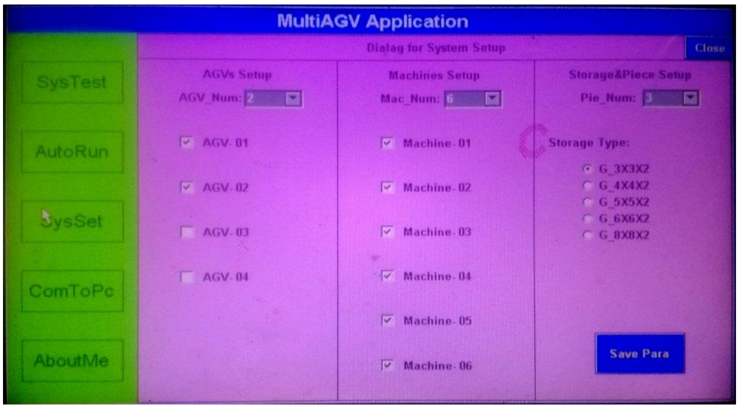

Fig. 4. Interface of system parameter setting module

a. Multi-AGV contrast experiment based on neuro-endocrine coordination mechanism

We performed an experiment whereby we assumed that there was a production task A with three workpieces, each of which required three processes. A certain amount of time will be required for the corresponding machine tool to complete each process. The actual production parameters are listed in Table 2. There are six machine tools. No. 1 and 4 are lathes, No. 2 and 5 are milling machines, No. 3 is a grinder, and No. 6 is a drill.

Table 2. Production parameters

Workpiece	Process	Process type	Processing time (s)	Processing cost
1	1	Milling	48	48
	2	Drilling	35	35
	3	Lathing	32	32
2	1	Lathing	40	40
	2	Milling	45	45
	3	Grinding	30	30
3	1	Lathing	45	45
	2	Grinding	31	31
	3	Milling	37	37

Specific experimental steps are as follows:

(1) Power on the system, initialize AGV, manufacturing cells and other modules, and reset various run time parameters of AGV.

(2) Configure the number of AGV, the number of manufacturing cells, automatic warehouse parameters and other parameters according to the actual parameters of the system.

(3) Input the production into monitoring terminal, allocating task according to the task allocation mechanism based on neuro-endocrine coordination mechanism. Here, the initialization parameters in formula (4) are shown in Table 3, and $\alpha_T + \alpha_c + \alpha_U = 1/3$, c=1.

Table 3. Initialization parameters of manufacturing cell A hormone secretion model

Processing type	Average processing time (T_{av} /s)	Average processing cost (C_{av})	Average utilization rate of machine tool (U_{av} /%)
Lathing	40	40	11
Milling	44	44	11
Grinding	30	30	11
Drilling	32	32	11

According formula (4), hormone values of manufacturing cell which manufacturing cell secretes are shown in Table 4.

Table 4. Hormone values of manufacturing cell *A*

Workpiece process	Manufacturing cell					
	1	2	3	4	5	6
W_1^1	—	1.38	—	—	1.38	—
W_2^1	1.50	—	—	1.50	—	—
W_3^1	1.27		—	1.33	—	—
W_1^2	—	—	—	—	—	1.37
W_2^2	—	1.39	—	—	1.47	—
W_3^2	—	—	1.45	—	—	—
W_1^3	1.75	—	—	1.75	—	—
W_2^3	—	—	1.42	—	—	—
W_3^3	—	1.67	—	—	1.67	—

The task can be allocated according to the hormone values of the manufacturing cell which have been shown in Table 4. After the completion of allocation, tasks processing sequence is shown in Table 5, and the corresponding Gantt chart of the production task is shown in Fig. 5.

Table 5. Processing sequence of production task *A*

Operation	W_2^1	W_1^1	W_3^1	W_2^2	W_3^2	W_1^2	W_3^3	W_1^3	W_2^3
Machine tool number	1	2	4	5	3	6	2	1	`3

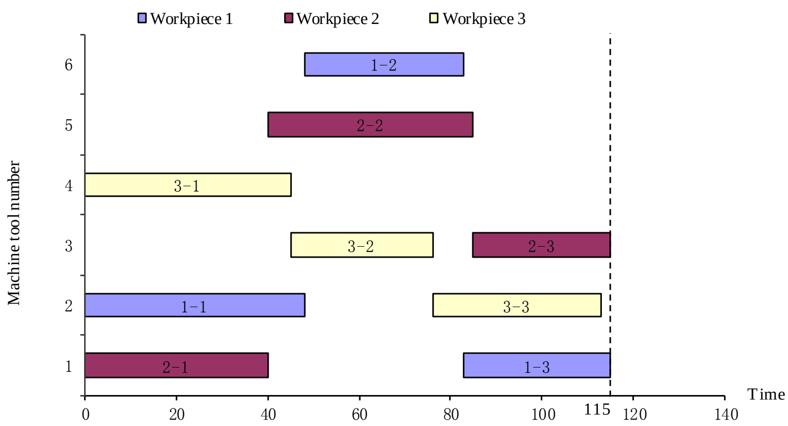

Fig. 5. Gantt chart of production task A

(4) After achieving Gantt chart of production task A, set the number of AGV 2, each manufacturing cell starts to schedule Multi-AGV according to processing sequence and task scheduling mechanism based on neuro-endocrine coordination mechanism. Here, initialization parameters of formula (5) ~ formula (7) are shown in Table 6. The hormone values which AGV secretes according to workpiece process are shown in Table 6.

Table 6. Initialization parameters of the AGV hormone model of production task *A*

α_{T_D}	α_{T_C}	T	n	a	T_{Dav}	T_{Cav}
1/2	1/2	1	1	1	20	20

(5) Appropriate AGV will be selected to schedule multi-AGV according to hormone values of the AGV, manufacturing cell control AGV according to anti-collision and deadlock mechanism of the multi-AGV based on DHMRCS. Meanwhile, it can monitor the status of machine tool and AGV in the region and feedback the information to the monitoring terminal.

(6) The running status of the module in system is monitored by the monitoring terminal according to the feedback information of the manufacturing cell, and statistical efficient transportation time and idle time of the AGV in operating process, so as to we will get the run time window and various time parameters of the AGV, specific time window is shown in Fig. 7, and various time parameters are shown in Fig. 7.

Table 7. Two AGV hormone values of production task *A*

	W_2^1	W_1^1	W_3^1	W_2^2	W_3^2	W_1^2	W_3^3	W_1^3	W_2^3
AGV1	0.13	0.13	0.07	1.00	0.40	1.00	0.40	1.00	0.40
AGV2	0.16	0.11	0.20	0.33	1.00	0.33	0.50	0.25	1.00

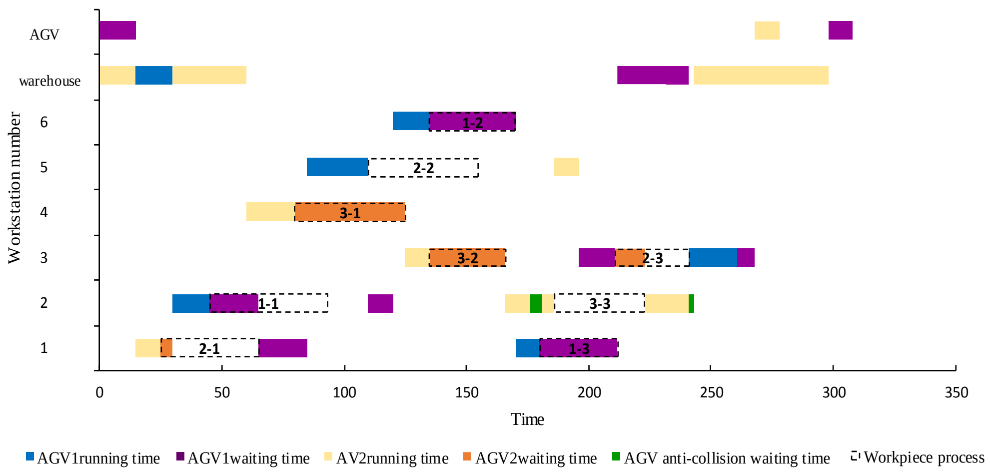

Fig. 6. Two AGV time window of production task *A*

Here No.1~6 workstation represents No.1~6 manufacturing cell; warehouse represents automated warehouse, storing workpiece blank and final product; AGV represents AGV warehouse district, AGV starts from warehouse district and returns warehouse district after running.

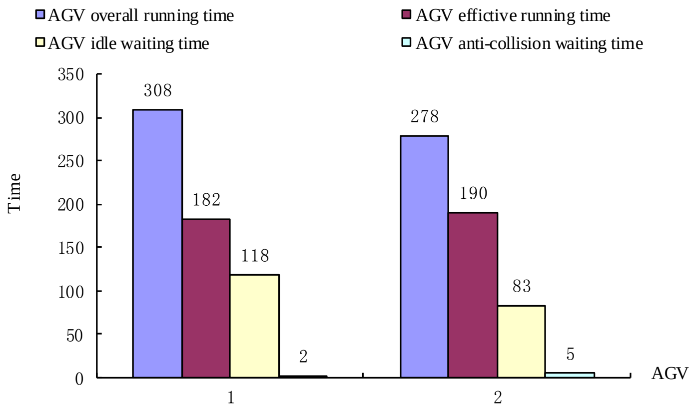

Fig. 7. Two AGV running time parameters of production task *A*

Two AGVs operating efficiency of production task A can be respectively obtained, as follows:

$$\eta_1 = \frac{182}{308} \times 100\% = 59.09\% , \quad \eta_2 = \frac{190}{278} \times 100\% = 68.35\%$$

(7) Set the number of AGV 3, repeat the above steps and the hormone values of three AGVs are shown in Table 7 and various running time parameters are as shown in Fig. 8.

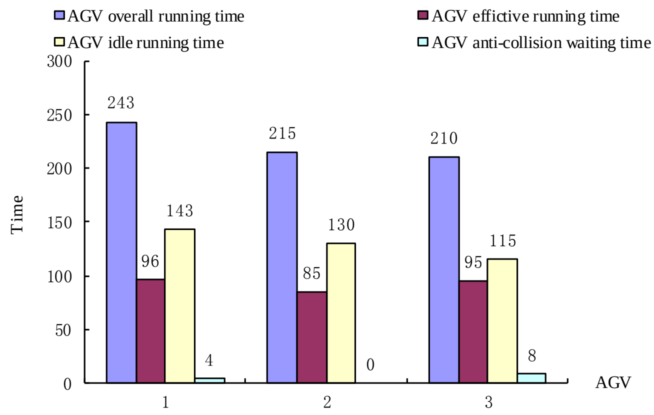

Fig. 8. Three AGV running time parameters of production *A*

Three AGVs operating efficiency of production task A can be respectively obtained, as follows:

$$\eta_1 = \frac{96}{243} \times 100\% = 39.51\% , \quad \eta_2 = \frac{85}{215} \times 100\% = 39.53\%$$

$$\eta_3 = \frac{95}{210} \times 100\% = 45.24\%$$

(8) Set the number of AGV 4, repeat above steps and the hormone values of three AGV are shown in Table 8 and various run time parameters are shown in Fig. 9.

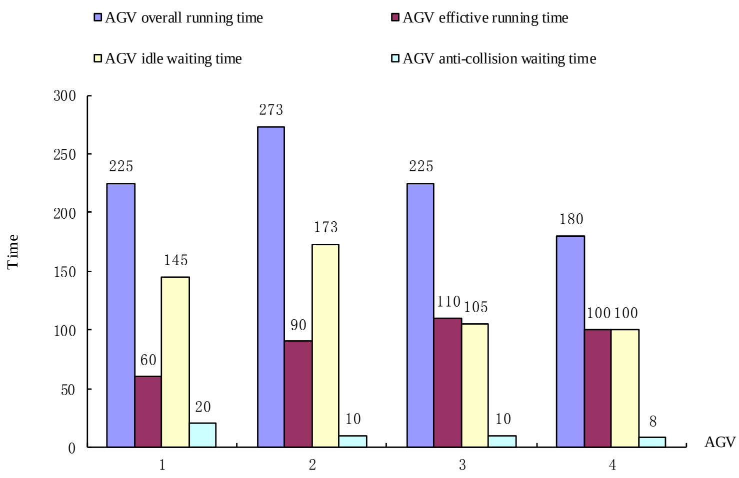

Fig. 9. Four AGV running time parameters of production *A*

Four AGVs operating efficiency of production task *A* can be respectively obtained, as follows:

$$\eta_1 = \frac{60}{225} \times 100\% = 26.67\%, \quad \eta_2 = \frac{90}{273} \times 100\% = 32.97\%$$
$$\eta_3 = \frac{110}{225} \times 100\% = 48.89\%, \quad \eta_4 = \frac{100}{180} \times 100\% = 55.56\%$$

It can be seen from the AGV operating parameter charts (Fig. 7, Fig. 8, Fig. 9), for a specific production task, the AGV overall running time is 308 s, 243 s, and 273 s, respectively, when using two, three, and four AGVs. This indicates that the shortest overall running time and the highest operating efficiency is attained with three AGVs. When a system has a small number of AGVs, whenever a new production task is received, the most appropriate AGV can always be selected to execute the task with a short idle time and anti-collision time for each AGV. As a result, each AGV will be fully utilized such that its operating efficiency is high, while the overall system production efficiency will be maintained at a high level. If it is appropriate to increase the number of AGVs in the system, the overall running time can be reduced to some extent and the production efficiency of the system can also be improved, but the AGV may have to wait for the workpiece machining to be completed after transporting it to the corresponding manufacturing cell, resulting in increased idle time of the AGVs. With the increased number of AGVs, the AGV anti-collision waiting time increases accordingly and the operation efficiency of the AGVs also falls. If there is a large number of AGVs in a system, the idle time and anti-collision waiting time of the AGVs will increase to a much greater degree, resulting in a greater overall running time and the low reliability of the system. For a specific production task, the appropriate number of AGVs should be selected to ensure that the production efficiency, AGV operating efficiency, and other operating parameters are maintained at an appropriate level, when taking full account of the operating parameters in the system.

b. Comparison of multi-AGV scheduling based on neuro-endocrine coordination mechanism and other scheduling strategies

For a production task of a given type, we compared the multi-AGV scheduling based on a neuro-endocrine coordination mechanism with that scheduling strategy in the literature that produces the shortest waiting time (SWT) [8]. Assume that the manufacturing system is required to perform production task *B*, and that each workpiece must spend some time in the corresponding machine tool when it incurs a certain processing cost. The production task parameter settings stated in the literature [8] are listed in Table 8. The above steps were repeated, producing the AGV running time with the neuro-endocrine coordination mechanism shown in Fig. 10.

Table 8. Parameters of production task *B*

workpiece	process	Processing time(s)	Processing cost
1	**1**	**41**	**41**
	2	**57**	**57**
	3	**56**	**56**
2	**1**	**35**	**35**
	2	**53**	**53**
	3	**41**	**41**
3	**1**	**48**	**48**
	2	**39**	**39**
	3	**38**	**38**

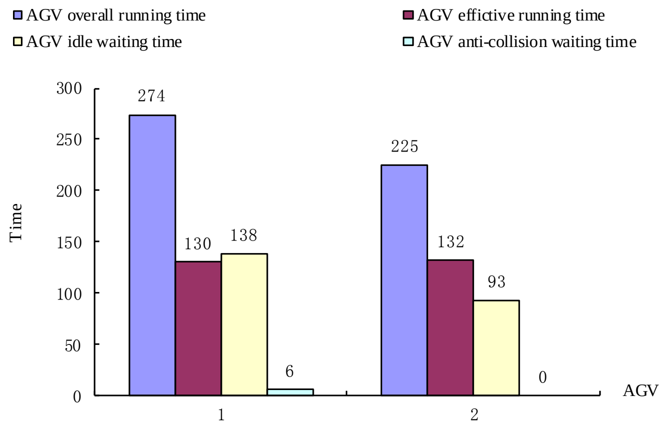

Fig. 10. AGV running time parameters of production task *B*

The AGV operation efficiency for production task *B* can thus be obtained, as follows:

$$\eta_1 = \frac{130}{274} \times 100\% = 47.45\%, \quad \eta_2 = \frac{132}{225} \times 100\% = 58.67\%$$

The results show that, for a specific production task, the overall running time of the task scheduling mechanism based on a neuro-endocrine coordination mechanism is 274 s, shorter than the 282 s with the task-scheduling strategy based on an SWT with a higher efficiency. For a given task, the results are more efficient and adaptive when the task scheduling mechanism based on a neuro-endocrine coordination mechanism is selected. Further research has shown that it is better to select the scheduling strategy based on the neuro-endocrine coordination mechanism.

Ⅴ. CONCLUSION

A multi-AGV task allocation and scheduling mechanism based on a neuro-endocrine coordination mechanism are proposed in this paper for a complex multi-AGV system scheduling. Based on the neuro-endocrine coordination mechanism that maintains homeostasis in an organism, task scheduling and coordination control problems for multi-AGV systems can be solved and the feasibility and efficacy of the method were verified through simulations. The results of our experiments showed that tasks can be allocated according to the current status of a machine tool when using the task allocation and scheduling that are based on the neuro-endocrine coordination mechanism, such that a better task processing sequence for the current state can be achieved. Meanwhile, tasks can be scheduled according to the current state of the AGVs to maximize the efficiency of the AGVs as well as the overall efficiency of the system. For a specific production task, it is better to select the scheduling strategy based on the neuro-endocrine coordination mechanism than that based on SWT with an appropriate number of AGVs, so that the operating efficiency of the system can be improved.

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