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Elevator Group Control Scheduling Approach Based on Multi-Agent Coordination*

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***Abstract* – Elevator group control scheduling problem is considered using the approach of multi-agent coordination. Unlike traditional elevator group control scheduling approaches that were implemented by a central agent, this scheduling proposed in this paper was implemented by many elevator agents, and every agent is able to calculate, reason and decide. Based on this, the structure of single elevator agent and the structure of system are designed, and coordination mechanism is then defined. Finally, in computer, the algorithm is simulated and compared with other scheduling algorithms. The results show the approach proposed in the paper can reduce effectively the average waiting time of passengers and rate of waiting long time of passengers, and it indicates an excellent applicability at most of traffic flow pattern.**

***Index Terms* – Multiagent, Agent coordination, Elevator group control, Elevator schedule**

I. INTRODUCTION

Multi-Agent system (MAS) is one of research branches of distributed artificial intelligence. Recently, multi-agent techniques are studied with keen interest to develop intelligence control systems for complicated problems. Especially, it can resolve efficiently many of scheduling problems such as workshop scheduling, traffic scheduling and power scheduling. For elevator group control scheduling (EGCS), MAS has also been applied to reduce system cost and improve serviceability. Japanese researcher Yasuhiro [1] designed a set of agents to manage system service. He established some fuzzy rules in terms of elevator states, and every agent can learn these rules by reinforcement learning algorithms. The conflicts of elevator running can be avoided by communicating among of elevator agents. Professor Hobort of Massachusetts University research EGCS based on multi agent reinforcement learning [2]. He designed every agent to control a car and defined reward function for every agent in terms of passenger waiting time. Elevator scheduling scheme was selected by maximization of public rewards of all agents, which was shown by author an excellent scheduling result. Additional, Jana Koehler and Daniel Ottiger of Switzerland presented a new elevator dispatch approach via multi-agent cooperation with auction [3]. In this paper, we present a new scheduling approach based on general partial global planning (GPGP). Unlike traditional EGCS that was implemented by a central agent, this scheduling was implemented by many elevator agents and every agent is able to calculate、reason and decide. We design the structure of single elevator agent and the system structure, plan coordination mechanism and program the algorithm. Finally, in computer, the program is simulated and compared with other elevator schedule algorithms.

II. SCHEDULING APPROACH

At present, most of elevator group systems (EGS) consist of a centre controller that produce scheduling commands to decide to up, down or stop for every elevator and some single elevator controller that execute the commands. However, elevator systems operate in high-dimensional continuous state spaces and in continuous time as discrete event dynamic systems. Their states are no fully observable and they are non-stationary due to changing passenger arrival rates. Obviously, centre controller has to deal with a larger number of dynamic information, and the functions of centre controller are required stronger, such as to predict traffic flow, to supervise running, to detect fault, and so on. Therefore, it is very difficult of building a centre controller containing all kinds of functions and complex to maintain it once with faults. In this case, this paper develops a new scheduling method that scheduling-command of every elevator running is produced by its relevant controller (we call the elevator and its controller an agent). The agent can decide the car of being controlled how to run. Coordination among many elevator agents is carried out continuously to ensure good performances. The characters of this method including: 1) the works of all agents are parallel, which enhance system's efficiency. 2) Every agent only plans itself, which make its task is simple. 3) The method proposed can avoid some unreasonable dispatches.

A. General Partial Global Planning

The partial global planning (PGP) approach to distributed coordination improved the coordination of agents in a network by scheduling the timely generation of partial results, avoiding redundant activities, shifting tasks to idle nodes, and indicating compatibility between goals [4]. General partial global planning (GPGP) being a development of PGP is a coordination algorithm described in a modular, domain independent way and can be tuned for particular intra-task environment behaviour. It includes five coordination mechanisms, and the mechanisms are independent in the sense that they can be used in any combination. The five coordination mechanisms are respectively: 1) Updating non-Local viewpoints:

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each agent has only a partial, subjective view of the current episode. Agents can, therefore, communicate the private portions of their subjective task structures to develop better, non-local, views of the current episode. 2) Communicating results: when an agent can't work for lacking relevant information, the result communication coordination is necessary for making the agent to work continuously. 3) Handling simple redundancy: potential redundancy in the efforts of multiple agents can occur in several places in a task structure. When such tasks are complex and involve many agents, the coordination of these agents to avoid redundant processing should be done. 4) Handling hard coordination relationships: hard coordination relationship is a compelling relationship. For instance, the behaviors of one agent have severe effects on others, which must be handle immediately. 5) Handling **soft coordination relationships: soft coordination relationships are handled analogously to hard coordination relationships except that they start out with high negotiability. It is a non**-compelling relationship, and good soft coordination can show agent's scheduling abilities.

B. Structure of Model

In this paper, we assume 4 elevators in elevator group system. The structure of every elevator agent is shown in fig.1.

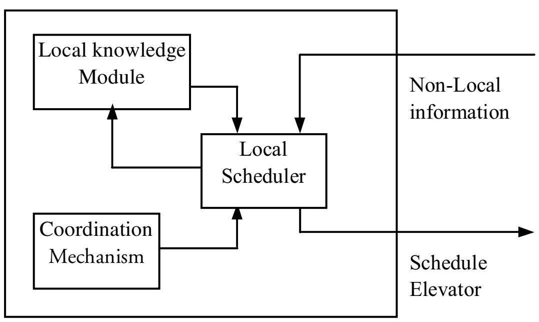

Fig. 1 the structure of single elevator agent

Each agent includes three modules: local knowledge, local planner and coordination mechanisms.

1) Local knowledge module (LKM). This module is a storage unit of saving three kinds of information: hall calls of the agent should respond to, car calls of itself, and the arriving time of predicting to every floor. And it also takes on a part of calculations. Namely, it will compute arriving time of elevator reaching every floor in terms of the information stored and local planning.

2) Local scheduler (LS). The objective of the module is to produce and modify local scheduling. See fig.1, there are three inputs into the module. The most important part is non-local information that is information of other elevator agent obtained by communicating with others. Note that if the non-local information affect agent's planning such as new calls or dispatch conflicts, the agent must modify or re-produce it's scheduling depending on coordination mechanisms. And new scheduling will be stored to local knowledge module, at same time, new scheduling will be used to implement elevator running. Therefore, the method proposed this paper would be allowed to schedule again.

3) Coordination mechanisms (CM). This module is the core of this structure. It includes that how to respond new call, how to identify traffic flow, how to deal with conflicts and how to assign idle elevator, which will be indicated later.

The structure of fig.1 is structure of single elevator Agent. We can use it to establish the whole structure of EGCS. It is shown in fig.2.

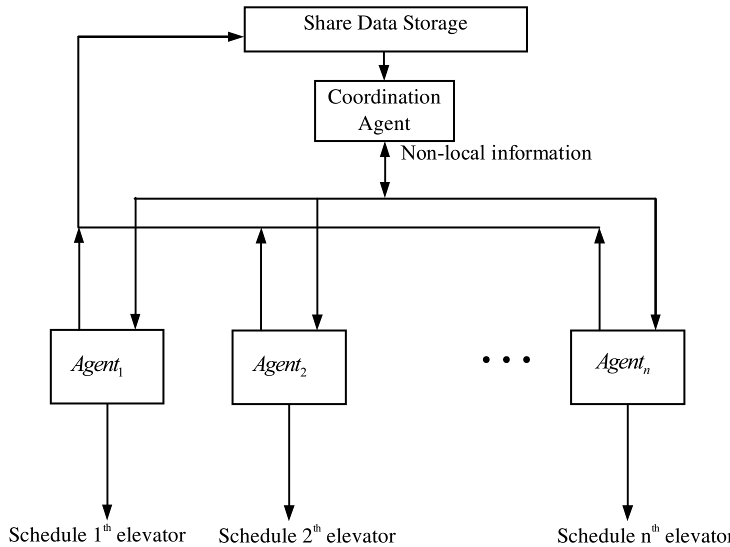

Fig.2 the structure of Multi-Agent system

$Agent_i$ (i=1,2,…,n) is represented as fig.1. Share Data Storage (SDS) will save the local scheduling scheme of every Agent. Coordination Agent (CA) is a manager that can distribute the information in SDS to the agent need the information, which make every agent know other agent's local scheduling scheme by CA.

C. Coordination Agent

See fig.2, CA will analysis the mutual relations between one agent and others, and arrange multi-Agent interaction d depend on the relations. When CA detect the following scenario:

1) Running direction of an elevator has changed. (From Up to Down, or Down to Up)

2) An elevator is idle state. (Stop and no passenger)

3) The reference of an elevator has changed. (The reference is defined by three principles: forward elevator running the same direction is one elevator's reference, and if no forward elevator the terminal is the reference, and can not be reference between two elevators)

CA will inform these agents to commute the local information and schedule again.

See fig.3, elevator A locate 3th floor and is running Up, B 11th and Up, C 8th and Down, D 14th and Down. In this case, depending on the principles of reference definition, the reference of A is B, and a dynamic district of A is defined from the location of A to B. the reference of B is top floor, C is lobby, and D is C. And B,C,D have respective reference district.

D. Planning of Single Agent

Every Agent has the ability of planning, and it can decide the scheduling itself in terms of non-local information, coordination mechanism and the local knowledge of itself.

1) The principles of planning

The planning of agent means to decide to which call should be responded. Therefore, every agent should be intelligent, and it can calculate and decide itself. Namely, it can arrange rationally the next actions. The principles include:

(1) When has a new call, the agent should judge whether the call belongs to its dynamics reference district or not, and if it is, the agent will plan the call to itself.

(2) If the call doesn't belong to any district of all agents, the CA will distribute the call by minimization of passenger waiting time.

(3) If not (1) or (2), it complies with the coordination mechanisms.

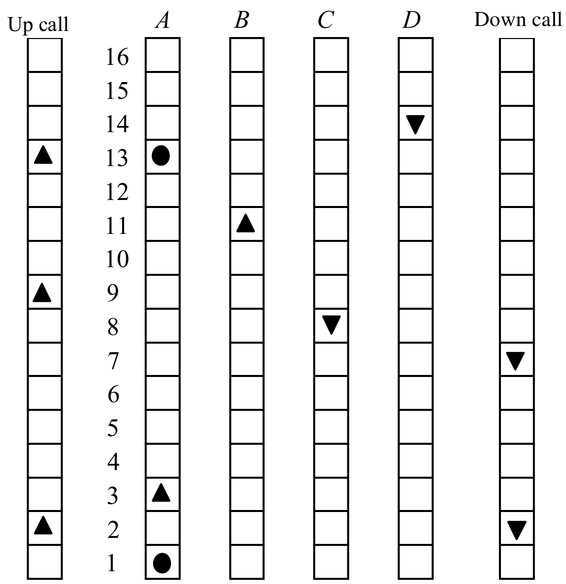

Fig.3. Elevator system schematic diagram

2) Coordination mechanism

Coordination mechanism is as follows:

(1) When the direction of one elevator changes (Up to Down or Down to Up), the all calls (include having be arranged to the other agent) that have not responded are arranged to the elevator agent.

(2) When LS find from non-local information conflicts that its planning does not in according with now reference district, it will cancel the former planning.

(3) When one elevator agent is idle, it will request CA, and the CA will judge whether the agent should to help the other agent or not.

(4) If not, the agent will change its running direction, and continuous work in terms of the first coordination mechanism.

III. Schedule Process

Base on above description, we summarize the process of the scheduling as follows:

1) Every agent comes into being a local planning.

2) The local planning information is saved in SDS.

3) CA detects all mutual relations among of agents.

4) Modify or replan the scheduling scheme depending on the request of CA, local planning information and the prediction to arriving time.

5) Do the above four steps, and up to task finished.

IV. Programme Realization

To illustrate the effectiveness of the proposed scheduling approach, we program the algorithm using VC6.0, and simulate in virtual elevator environment (VEE) of our lab. Firstly, we establish four threads that represent four elevator agents, a coordination agent and a share data storage. Getting

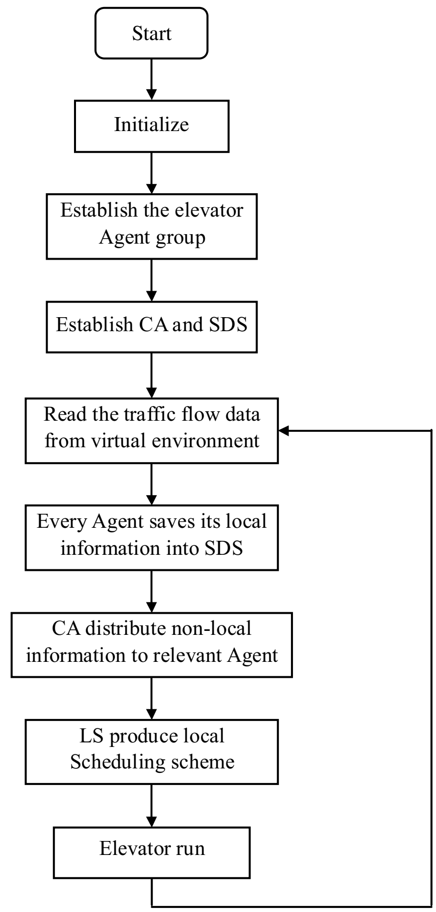

Fig.4. Algorithm of elevator group control scheduling based on multi-Agent coordination

the traffic flow from VEE, every agent begin local planning and produce its scheduling scheme, and then modify or replan its scheduling scheme in terms of non-local information and CA in order to ensure waiting time minimum. The whole flow chart of programme is shown in fig.4.

V. Simulation and Analysis

In VEE, we select the following parameters:

1) The parameter of environment

Building: 16 floors, the high of lobby is 4 meters, the other floors 3m.

Elevator: 4 elevators, velocity of running is 1.5m/s, acceleration $1m/s^2$, capacity 12 passengers, the time of open and close 1s, load time of a passenger 1s.

Traffic flow (TR): 4 compared traffic flows that are respectively:

TR1: Up-peak, 20 minutes, 440 passengers， inflow pattern 91%.

TR2: Inter-floor, 20 minutes, 225 passengers， interflow pattern 82%.

TR3: Down-peak 20 minutes, 370 passengers， outflow pattern 86%.

TR4：Uppeak-Interfloor-Idle-Downpeak, 60 minites, 726 passengers.

2) The scheduling algorithms

AL1: static zoning (be suit for peak patter).

AL2: genetic algorithm (all kind of patters).

AL3: multi-agent coordination algorithm (all kind of patters).

3) The performance

AWT: average waiting time of passengers.

ATT: average travel time of passengers.

RWLT: rate of waiting longer time of passengers.

ACD: average crowding degree of passengers.

NSS: numbers of start-up and stop.

The result of simulation is shown in table.I.

TABLE I
RESULT OF SIMULATION

Performance: Algorithm: Traffic flow:		AWT	ATT	RWLT	ACD	NSS
TR1	AL1	31.77	40.29	16.4%	8.97	356
	AL2	85.01	50.51	49%	11	355
	AL3	26.29	48.20	5%	10.44	395
TR2	AL1	37.45	27.31	21.3%	3.71	318
	AL2	25.05	30.40	8%	2.65	332
	AL3	19.36	24.10	4%	2.74	378
TR3	AL1	29.69	28.33	13.5%	5.28	311
	AL2	27.43	32.32	8.4%	6.68	311
	AL3	27.7	36.75	8.4%	7.36	339
TR4	AL1	34.88	31.36	17.9%	6.17	811
	AL2	56.87	34.52	23.3%	6.44	865
	AL3	28.96	36.08	8.9%	6.71	941

It is shown from the results of simulation that the comprehensive performances are excellent both static zoning (AL1) and multi-agent coordination algorithm (AL3) in the case of Up-peak traffic pattern (TR1). Compared with the two algorithms at TR1 in detail, we find that AL3 is superior to AL1 at the performance of AWT, however, the average travel time is much longer than AL1. It is the reasons that AL1 rule the floors every elevator should to respond, which distribute effectively the passengers to different elevators, decrease NSS, and therefore the time of travel is reduced. Fig.5 (a) and 5 (b) have a detailed comparison to AL1 and AL3, and they show that the algorithm of AL3 has a weakly superiority to AL1. At the pattern of TR2, AL3 has obvious superiority at all kinds of performance. This is because that AL3 can ensure the hall call be responded by the most suitable elevator via coordination among of agents, and it will make the service for passengers more balance. In fig.6 (a) and 6(b), the numbers of passengers every elevator carried are compared to at AL1 and AL3. As for the pattern of TR3, the three algorithms have respectively advantages. To the pattern of TR4, the algorithm of AL3 is better than others. Fig.7 (a), 7 (b) and 7 (c) have a comparison to the performance of AWT.

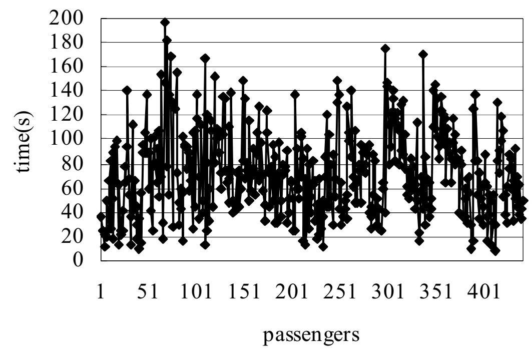

Fig.5 (a) the system time (the sum of waiting time and travel time) at AL1 in the case of the pattern of TR1

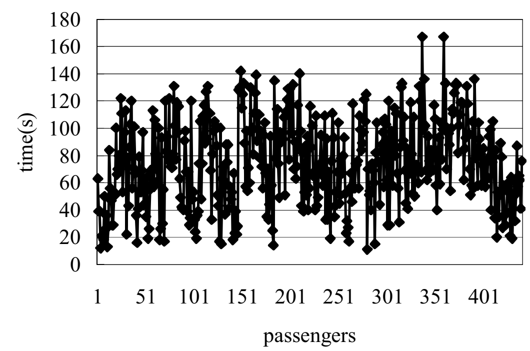

Fig.5 (b) the system time at AL3 in the case of the pattern of TR1

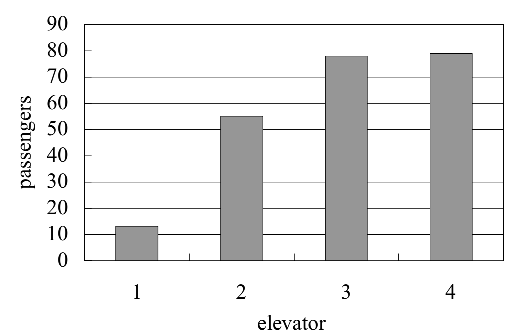

Fig.6 (a) the numbers of carrying passengers at AL1 and TR2

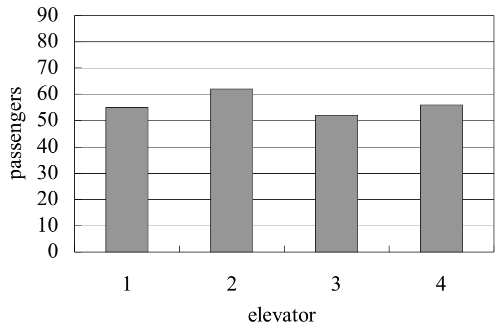

Fig.6 (b) the numbers of carrying passengers at AL3 and TR2

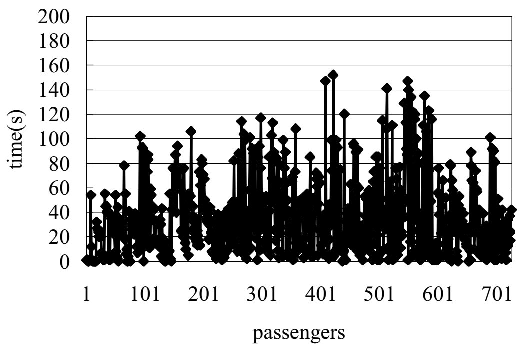

Fig.7 (a) the average waiting time at AL1 and TR4

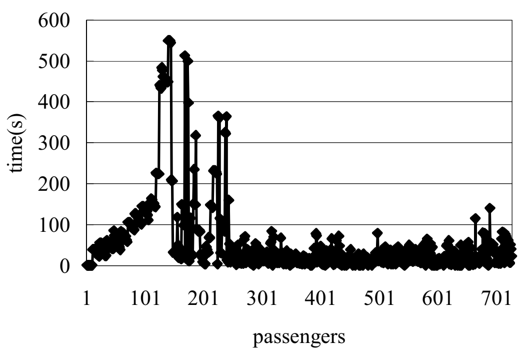

Fig.7 (b) the average waiting time at AL2 and TR4

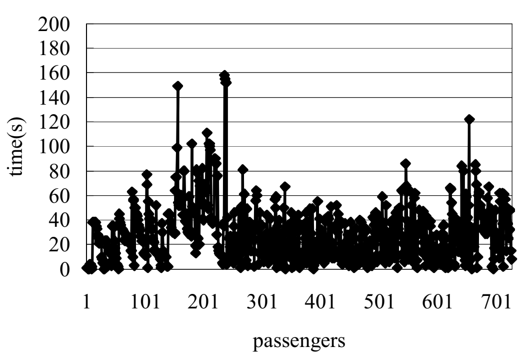

Fig.7 (c) the average waiting time at AL3 and TR4

Based on above simulated results, it is shown that the scheduling approach proposed in this paper has following good characters: 1) it has very strong adaptability. The simulated results indicate that the scheduling approach expresses a good performance of waiting time at most of traffic flow pattern, and comprehensive performance is better than others. 2) The performance of RWLT is the most excellent. This is the reason that we use minimum of waiting time as the aim, and allow modify and replan the scheduling scheme. 3) The efficiency of calculating has much improvement. Every agent can calculate and decide, and calculation of every agent is synchronized. However, the main problem of this approach is that the performance of NSS is large, which will result in much more consumptions power. The reasons that cause the disadvantage have two factors: 1) the approach does not consider the performance of power consumption. 2) The fact that modify and replan the scheduling scheme lead to the useless running of elevator. These problems need be improved further in the future research.

VI. Conclusions

In this paper, a new elevator group control scheduling approach is presented. Every elevator is regarded as an agent that is able to calculate、reason and decide. This scheduling was implemented by coordination of agents. Based on the above theory, we design the structure of every agent and the structure of the system, and compile the programme of the algorithm. Finally, in computer, the algorithm is simulated and compared with other scheduling algorithms. The results show a good performance of waiting time and rate of waiting long time, and it has good adaptability at most of traffic flow pattern.

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