The 31st International Technical Conference on Circuits/Systems,
Computers and Communications (ITC-CSCC 2016)

Applying Purchase Porter System to Actual Shopping Mall

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Abstract: We propose "Purchases Robot Delivery System" for shoppers in this paper. Each robot performs autonomous behavior and delivers purchases to the exit that shoppers use by the time shoppers go home. Delivery robots acting in only own work area cooperate each other and deliver all purchases autonomously by a bucket brigade method because delivery requests occur from many stores in various timing.

Keywords—**autonomous robot, own work area, bucket brigade method**

1. Introduction

We have proposed a purchase porter system in a shopping mall using software agents. Our system is effective in some simple shopping fields. However, its effectiveness is not confirmed for actual fields. We must apply our system to actual various fields to show its effectiveness.

This paper describes an expansion of our system to apply to actual large fields. In our system, each robot has an individual working area and delivers purchases by a bucket brigade conveyance method with adjacent others. In an actual field, many stores with various sizes are located at various positions, and passages of various widths go through. To apply our system to actual shopping malls, we maintain the bucket brigade method by changing the number of the working area to arrange depending on passage widths and store positions. Experimental results show that this application method is effective.

2. Porter System

The purpose of our porter system is to carry the purchases which have the delivery requests from each store to the destinations by designated times. A destination is the exit that a shopper uses at the time of return home. The robots deliver purchases based on a priority, because a delivery priority based at distance to the destination and the designated time is set in every purchase. However, they cannot build a delivery plan beforehand delivery requests correspondence to occur in various timings. Therefore, they decide delivery orders autonomously.

In addition, they have individual working area and work in only own working area to restrict the number of purchases to deliver at a time. When a porter robot receives delivery requests of purchases from a store of his working area, he receives the purchases from there. If a destination is an exit of his working area, he carries purchases by oneself. Otherwise he asks the porter robot of the adjacent working area which can carry the load efficiently for the transportation of them.

2. 1 Simple Field

To confirm the effectiveness of our system, we experimented using some simple fields as shown in Fig.1[1]. Four exits and many stores are located at the four and around a field. The previous experimental results have shown the effectiveness of our system for the fields of various scales. For a delivery request to occur in various timings, the introduction of the working area was effective.

2. 2 Actual Field

We apply our system to the shopping mall "Aeon Lake Town"[2] of Fig. 2 to confirm the effectiveness to actual fields. In real shopping mall, many stores are located along passages with various widths. To apply to such an environment, porter robots with working areas of the same space must work the bucket brigade in passages of various width. Therefore, we locate the robot of the number depending on the width of the passage as shown Fig.3.

2. 3 Porter Robot

Each porter robot has an original working area and can move only one's area. They go to get purchases in response to delivery requests from a store in their areas.

Then, they take the action of either next.

(1) A destination of a purchase is in one's area:
He delivers it to the destination directly.
(2) A destination of a purchase is **not** in one's area:
He hands a purchase to an adjacent robot the destination.

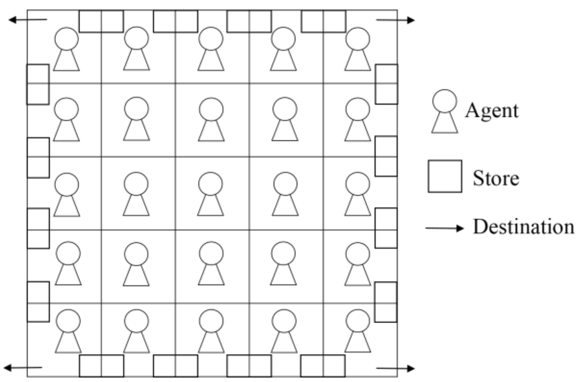

Figure 1: Previous field.

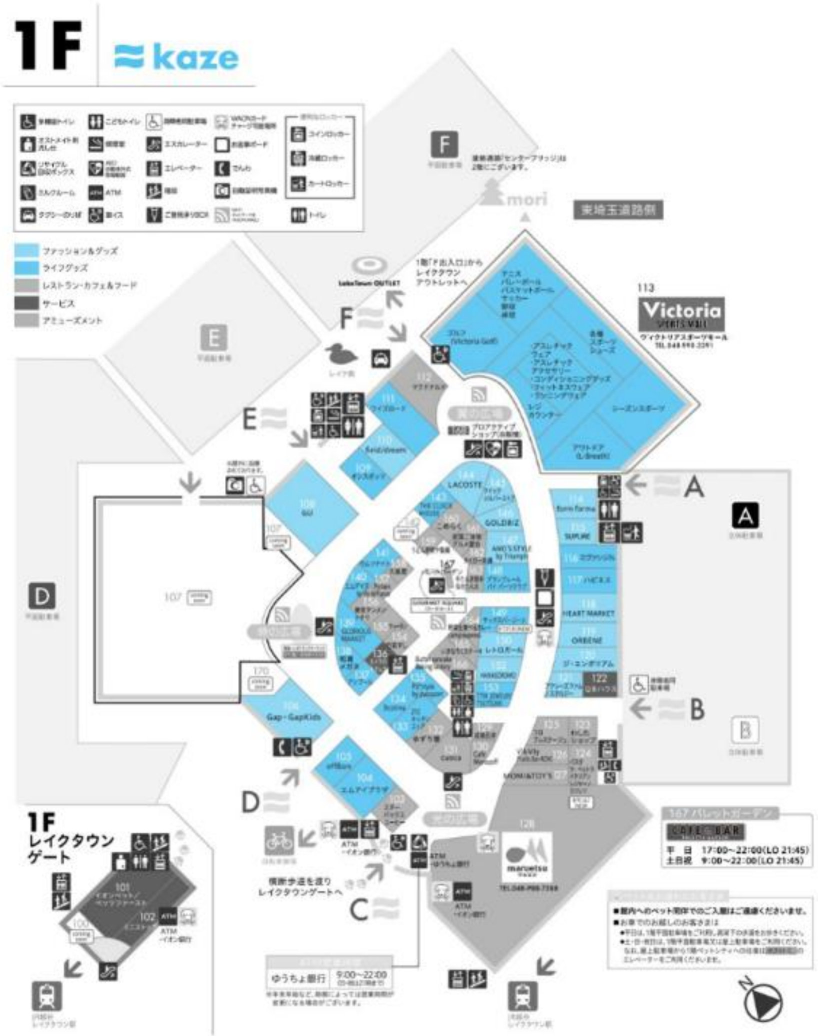

Figure2: Actual shopping mall.

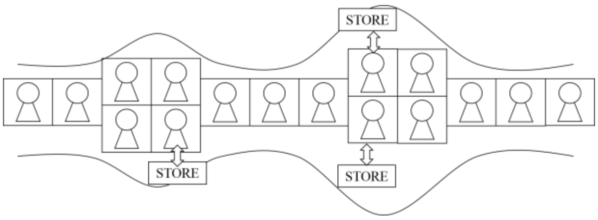

Figure 3: Applying to actual field.

Figure 4 shows the state that robot X receives requests R1 and R2 at the same time each from store S and robot Y. The contents of two requests are as follows.

R1: Delivery to destination 2 of purchase P1 of priority 10
R2: Delivery to destination 1 of purchase P2 of priority 20

In this situation, robot X may take two actions

Action1:
Receives purchase P2 with the highest priority from Y and deliver it to destination 1 afterwards

Action2:
(A2-1) Receives purchase P1 from store S
(A2-2) Exchanges P1 for P2 which Y holds
(A2-3) Carries P2 to destination 1

When X takes Action 2, Y carries P1 to destination 2.
If distance of Y is near X, X takes Action 1 unconditionally. When Y stands in the distance from X, X carries out Action 2 using the interval where Y nears X. In this way, each robot takes the action to evaluate to be most suitable depending on present situation.

The action of each delivery robot is two ways whether he has purchases. In what follows, the priority added to purchase should integrate both delivery target time and distance to the destination.

Without purchases
(a) Stands in the fixed position of the working area of oneself without delivery requests.
(b) If some delivery requests arrive, receives the purchase with the highest priority.

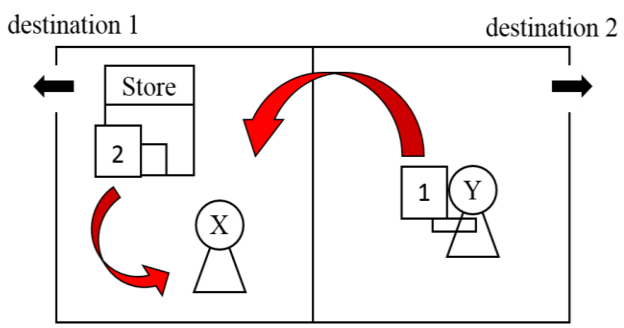

Figure4: Plural delivery request.

With purchases

(a) If his working area has a delivery destination of the purchase, carries it to the destination.
(b) If his working area has no delivery destination of the purchase, hands it to an adjacent robot near the destination.
(c) If some delivery requests arrive, receives the purchases.
(d) Acts for purchases with the highest priority in (a) from (c).

As for any situation, the robots act autonomously to carry purchases with the maximum priority efficiently

2. 4 Purchase

Every purchase has two information, which are destination and goal time in the delivery. Our system gives a delivery priority of a purchase to be dependent by the remaining time until the goal time and the distance to the destination.

Table 1 shows the empirical priority for goal times. In the case of shorter remaining time, the time priority is higher.

Table 2 shows the empirical priority for distances to destinations. If the remaining distance to a destination is shorter, the distance priority is higher.

Figure 5 shows the significance of the priority for the distance. The movement distance D for robot R to visit both A and B is;

Move 1: A to B : D = distance O+ distance Q
Move 2: B to A : D = distance P + distance Q

If X and Y are relations of expression (1), D is shorter Move 1 than Move 2.

$$\text{distance O} < \text{distance P} \qquad (1)$$

In other words, the total movement distance of a robot shortens first by going to the near destination. Therefore, the movement time for a robot also shortens.

The porter robots can deliver purchases by evaluating these priorities without being late for goal time.

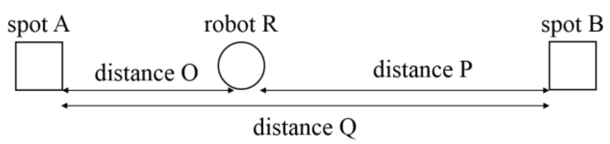

Figure5: Distance priority.

Table 1: Time priority.

remaining time t	t>50	50>t	40>t	30>t	20>t	10>t
m	1	2	3	4	5	6
time priority $f(m)$	3	11	26	50	85	133

Table 2: Distance priority.

distance l	l > 10	10 > l	8 > l	6 > l	4 > l	2 > l
n	1	2	3	4	5	6
distance priority $g(n)$	2	8	20	40	70	112

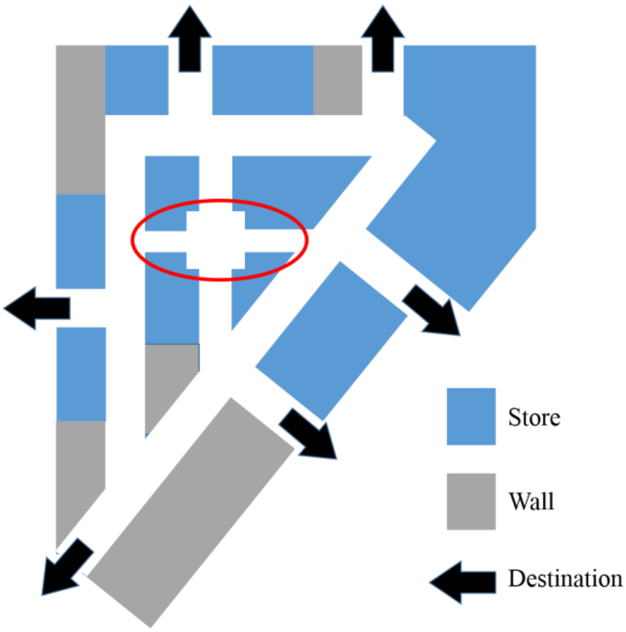

Figure6: Virtual shopping mall.

3. Experiments

We have experimented to confirm the effectiveness of our approach.

The experimental conditions are as follows;

1. The experiment fields are three types.
   1-1. Simple field based on Fig. 1
   1-2. Virtual shopping mall
   Figure 6 shows the experiment field which is a virtual shopping mall based on Fig.2 formed in a computer. Sixty-four stores and six destinations are located.
   1-3. A part of shopping mall
   This is a part of virtual shopping mall such as a red circle of Fig.6.
   Eight stores and two destinations are located.
2. An own work area is a square of one side of 5m.
3. The purchases occur from each store.
   One purchase produces every one minute from all stores.

Table 3: The results of experiments.

Fields	Delivery success rate (%)
Simple	97.8
Part	99.2
Virtual	91.9

Simple: Simple field
Part: A part of virtual shopping mall
Virtual: Virtual shopping mall

4. Each agent can verify the transportation situation of all purchases.
5. The finish condition: Delivery of all purchases is completed.

Table 3 shows the experimental results. In this table, the values are the mean of the one hundred times of experiments. “Delivery success rate” represents the ratio of purchases which the robots have been able to carry to the destinations before designated times for all ones. In “a part of virtual shopping mall”, porter robots were able to carry almost purchases to each destination before shoppers go to home because the field size is small compared with “virtual shopping mall”. On the other hand, the delivery success rate in “virtual shopping mall” is lower because the field size is huge and there is much number of purchases. However, our system can deliver almost all purchases in the actual field before designated times as well as the simple field.

From the results, our approach is effective to apply an actual large shopping mall.

4. Conclusions

This paper has proposed a purchase porter system using software agents. By experiments, we confirmed to apply purchase porter system for actual large shopping malls. Our future work is to experiment in a shopping mall of malti-layer floor.

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