How Do Customers Buy Them at a Supermarket? Behavior Analysis from Real Observation and Agent Simulation

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Abstract

This paper presents a customer behavioral model for grounding the number of purchase items in Agent-Based In-Store Simulator (ABISS). ABISS is a decision support system for a retail management. Using ABISS, we are able to virtually investigate the shopping paths of the customers and analyze the effect of sales promotion. To grounding the number of purchase items, first we conduct a field study using Radio Frequency Identification (RFID) and analyze the collected RFID data and Point-of-Sales (POS) data. Then we develop a decision model, which determined customers' "Shopping List", "Possession Money Limit", and "Staying time". The experimental result has revealed that we ground the number of purchasing items of obtained by the POS data, if we concentrate on the tuning of ABISS parameters on "Shopping List" and "Possession Money Limit".

Keywords: Agent-Based Simulation, Agent-Based Modeling, Customer Behaviors, Radio Frequency Identification

1 Introduction

Service management in supermarkets requires the analyses on the effects of sales promotion and the control of customer shopping paths in the store. So far, such analytic tasks cost so much in a real store, and it is difficult to measure the effects of sales promotion. To let them easily carry out such analyses, we have developed a decision support system with Agent-Based In-Store Simulator (ABISS), for retail management. Using ABISS, we are able to virtually investigate the shopping paths of the customers and analyze the effect of sales promotion (Figure 1)[1].

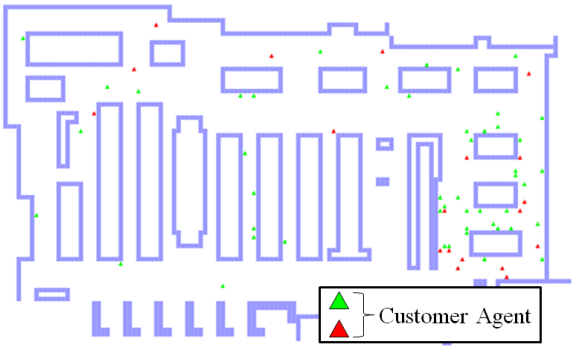


Figure 1. Snapshot of ABISS

To enhance the performance of ABISS, however, we must observe real customer behaviors and determine their behavioral parameters. Ordinarily, in a such analysis we must trace real shopping paths by human observers, which required very high costs and long time for the analysis. Instead, in this paper, we describe a new indirect measurement method: First, we utilize a general purpose RFID tag system equipped with both in market carts and shopping places; Second, purchased items are collected to the point of sales information gathered at the cashing register places; and Third, the gathered shopping paths with purchase information are compared with intensive simulation results by ABISS.

This paper presents the customers' behavioral model for grounding of the number of purchasing items in a supermarket and experimental result of the simulation. First, we conduct a field study using RFID and analyze the collected RFID data and Point-of-Sales (POS) data to build the model. Second, we build a decision model in which determined "Shopping List", "Possession Money Limit", and "Staying time". The result has re-

vealed that we ground the number of purchasing items of obtained by the POS data, if we consider only "Shopping List" and "Possession Money Limit" in ABISS.

The rest of the paper is organized as follows: Section 2 discusses the background of the research and related work; Section 3 explains the field study in the target store; Section 4 describes the setups of ABISS; Section 5 presents experimental results of ABISS; and Section 6 gives concluding remarks and future work.

2 Background and Related Work

A retail store performs many sales promotions in order to make sales increase. However, such sales promotion cost so much in a real store. Then, in order to perform sales promotion effectively, there have been so many researches about customer behavior in marketing science. Conventionally, many data mining is used [2], [3]. Moreover, flow line analysis of the customer using an RFID tag or accelerometer has been also used [4], [5] and [6]. In recent years, the method of predicting the effect of sales promotion by Agent-Based Simulation (ABS) has attracted attention. In the study of supermarket, we usually model the "Agent" buying behavior and walking behavior of a store. In order to predict the effect of sales promotion, it becomes important to have grounded with the number of purchases with the actual number of purchases of imagination. In order to ground the number of purchases, it is required to take the following into consideration: 1) the probability which purchases each goods, 2) the conditions which customer stops shopping. The probability which purchases each goods is calculated from POS data in many cases. On the other hand, the conditions which a customer stops shopping is seldom considered.

The conditions which a customer stops shopping in ABS is shown in Table 1. In [7], [8], [9], and [1], if Customer Agent purchases all the goods on the shopping list possessed beforehand, the model which stops shopping will be adopted. Moreover, in [9] and [10], the missing item from the side of the prices of goods, length of stay, and a store is also taken into consideration as conditions which stop shopping.

ABISS is one of the simulators for predicting the customer's of the supermarket in which we have been developing several years. ABISS carries out the virtual experiment of customers' purchasing and shopping paths in the supermarket. In ABISS, the model in consideration of the budget of a shopping list and a customer is adopted. In ABISS, the agent's parameter has been set based on the real POS data. Also, so far, we have experimented in change of the flow line length and the layout change. However, the customer's buying behavior model was not considered by the viewpoint of grounding of the number of purchasing items. In order to clarify the characteristics of the behavior model, this research investigates the conditions on which the customer agent of ABISS stop shopping in the sense of purchasing items. For the purpose, first, the real data on a customer's length of stay are acquired in the inside-of-a-shop experiment using an RFID tag system. Next, the limit of money possession with the staying time, the shopping list calculated from the POS data, and customer decision rules are set as ABISS parameters.

Table 1. The Conditions Which a Customer Stops Shopping in ABS

	Customer Reason				Store Reason
	Shopping List	Possession Money Limit	Staying Time	Purchased Weight	Stockout
Hayashi [7]	○	×	×	×	×
Miwa [8]	○	×	×	×	×
Macal [9]	○	×	○	×	○
Siebers [10]	×	○	○	×	○
Terano [1]	○	○	×	×	×

3 Field Study in the Target Store

3.1 Setup

The condition of target store and setups of field study is summarized in Table 2. The store layout and the placement of RFID antenna which ABISS targets are shown in Figure 2. An order of vegetable, fish, and meat category from the entrance is widely employed in Japan. In this store, we set 10 RFID antennas on display fixtures, and 6 RFID antennas on each registers. By the antenna arrangements, we are able to measure the whole cart moves inside of the store. The same RFID tags are also set in the 53 shopping carts. The antenna setup examples are shown in Figure 2. This field experiment was conducted from 9:00 to 21:00 on March 3-5, 2011.

Table 2. Condition of Target Store and Setups of Field Study

Location	Shimane Prefecture, Japan
Opening Time	9:00 – 21:00
Average of Customers Per Day	2000 customers
Experimental Period	March 3 – March 5, 2011
RFID Antennas	10 on display fixture 6 on each register
RFID Tags	53 on shopping cart (Half of shopping cart)

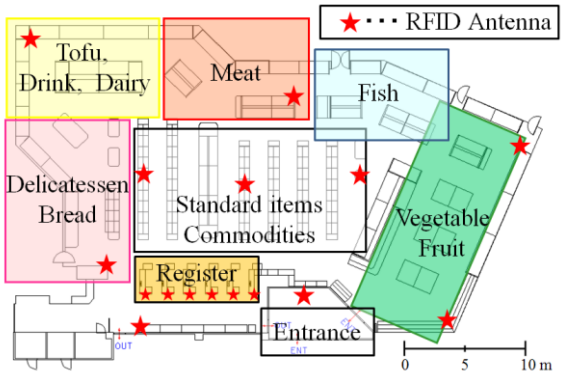


Figure 2. Store Layout and Position of RFID Antenna

3.2 Result

We analyze the RFID and POS data on March 4, 2011. Since sales promotion of the day was less than those in the other days, we are able to observe basics of the customer behaviors. The total number of RFID data on March 4 is 102,661 in the sense of the information communications. The POS data on March 4 is about 1,849 customers and 1,882 numbers of purchasing items. The analysis is conducted in the following procedures. First, we identify the RFID data for every customer. A customer's store entrance time is measured by the time of RFID of the Entrance and the antenna of a cart communicating at the first time. Also, a customer's store exit time is determined as the time of communicating at the antenna of the last of a register place. Second, we

(a) RFID Antenna on Display Fixture (attached the pink cover)

(b) RFID Antenna on a Shopping Cart (banded with white string)

Figure 3. Setup of RFID Antenna

give the relation of the POS data and the RFID data of each customer. That is, such data of the correspondence as register passage time and a customer's exit time are extracted. Accordingly, we get 100 data in which the customer's purchase items and shopping paths are related explicitly, although these data are independently collected. Since the other data have so many noises, we are not able to relate them correctly. The amount of key statistics of a customer's amount of money for purchases and their staying time are shown in Table 3. Moreover, scatter diagram of the histogram of a customer's amount of money for the purchase, the histogram of stay time, the amount of money for purchase, and stay time are shown in Figure 4.

The correlation values of a customer's amount of money for purchase and stay time are -0.007. It is a very small value, and the analysis which connected RFID Data and POS Data showed that they were independent.

4 Setups of ABISS

Based on the result in Section 3, we prepared three customers' buying behavioral models which are shown below and by which the customer changed the conditions which stop shopping. The flow figure of each model is shown in Figure 5.

1) Shopping List & Money Model

In this model, customer agents finish shopping when a shopping list become empty or the amount of purchase money exceeds a budget.

2) Shopping List & Time Model

In this model, customer agents finish shopping when a shopping list become empty or the staying time exceeds a schedule.

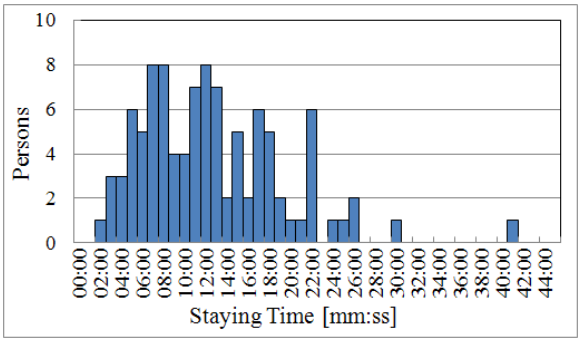
3) Shopping List, Money & Time model

In this model, customer agents finish shopping when a shopping list become empty, the amount of purchase money exceeds a budget or the staying time exceeds a schedule.

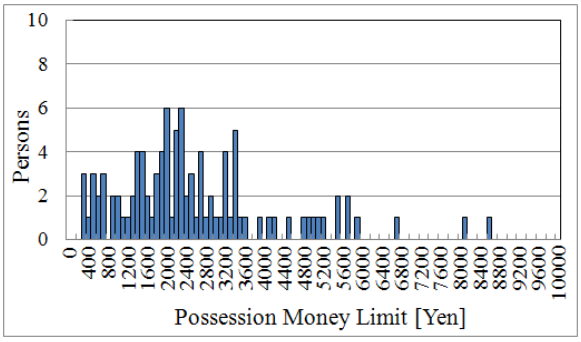
We calibrate the parameter from real data. The number of planned items and distribution of purchase money are calculated from the POS data on March 4, 2011. Also, the distribution of staying time is calculated from RFID data on March 4, 2011. The kind of parameters other than the above is the same as in [1].

Table 3. Basic Statistics of Money and Time

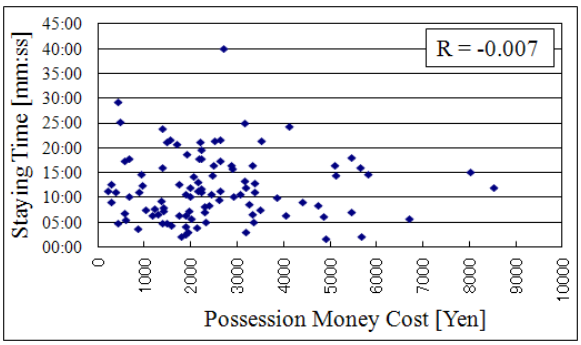
	Possession Money	Staying Time
Average	2524	0:12:01
Std Dev.	1643	0:06:45
Median	2208	0:11:07
Mode	1394	0:10:12
Min	204	0:01:51
Max	8529	0:40:13
N	100	100
R	-0.007	



(a) Histogram of Possession Money Limit

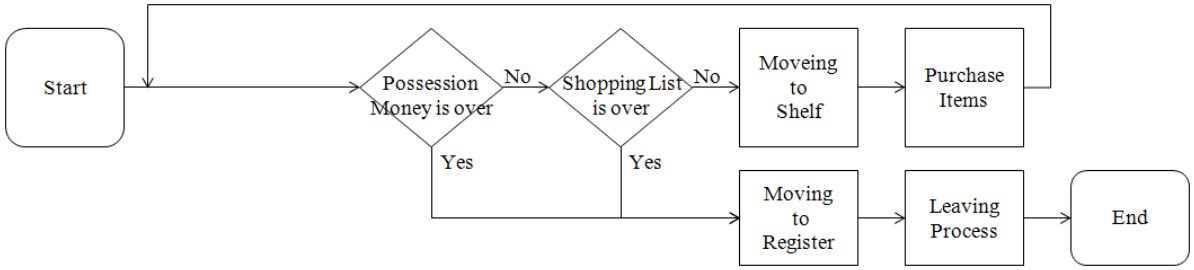


(b) Histogram of Staying Time

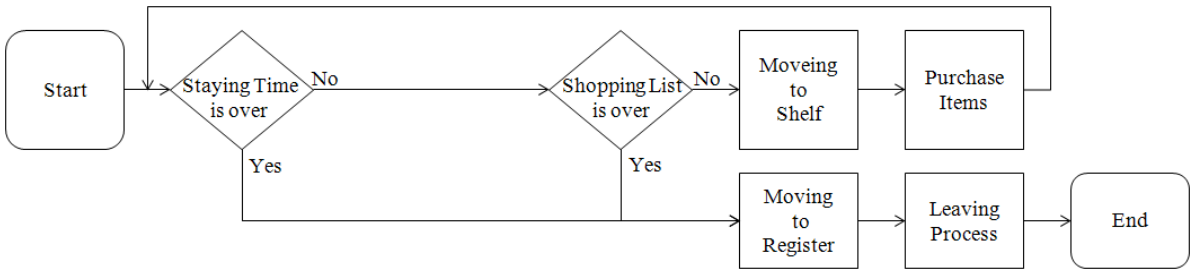


(c) Scatter Diagram of Staying Time and Possession Money Limit

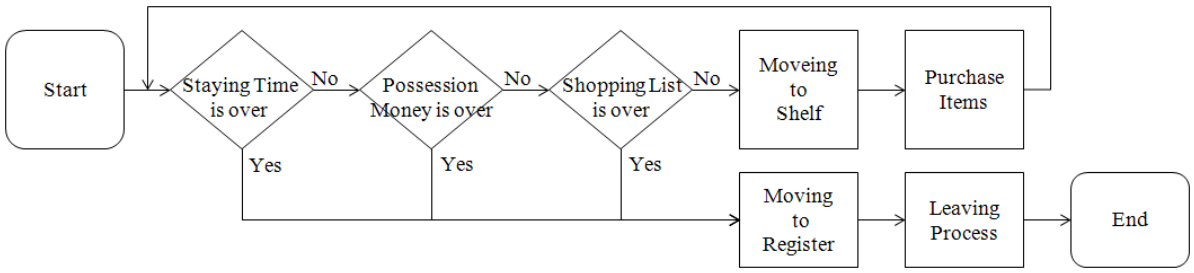
Figure 4. Results of Analyzing RFID data and POS data



(a) Shopping List & Money Model



(b) Shopping List & Time Model



(c) Shopping List, Money & Time Model

Figure 5. Flow Diagram of Customer Behavioral Model

Table 4. Experimental Settings on Customer Behavioral Model

Customer Behavioral Model	・Shopping List & Money Model ・Shopping List & Time Model ・Shopping List, Money & Time Model
Simulation Time	9:00 - 21:00 (43,200 simulation steps)
No. of Simulation Runs	3 times

5 Experimental Results of ABISS

Based on the model Section 4, we have conducted simulation experiments. We have conducted five 43200-step (representing the store's opening time) simulations. The experiment settings are summarized in Table 4. We have analyzed how the changes in model affected the customers' purchased number.

Table 5 shows number of real and simulated purchased item number of customers. We adjusted each experimental result so that the number of samples and real data may become the same. An error rate shows a difference with the number of purchasing items in the POS data on March 4, 2011. We have found that the Shopping List & Money Model gives the smallest error rate. It suggests that we can ground the number of purchasing items in ABISS of POS data even if we do not consider "Staying Time". It seems that the noise, for example conversation time with friends in a supermarket, is mixed with the data of "Staying Time".

Table 5. Experiment Number of Purchased Items Tuned to Real Transaction

	Samples	Purchased Number		Error Rate [%]
		Average	Std Dev	
POS	1849	18882		
Shopping List & Costs	1849	18513	243	-1.95
Shopping List & Time	1849	19503	4575	3.29
Shopping List, Costs & Time	1849	15845	257	-16.08

6 Conclusion

This paper has presented a customer behavioral model for grounding the number of purchase items in Agent-Based In-Store Simulator (ABISS). We have described the setups and the analyzing results of field study, and the models which changed a stopping condition of shopping and experimental results of ABISS. First, we have carried out field study with RFID tags and analyzed staying time. Second, we have made a model in ABISS which changed a limit of shopping. We have decided the limit from "Shopping List", "Staying Time", and "Possession Money Limit". The experimental results have suggested that we can ground the number of purchasing items in ABISS to POS data if we consider only "Shopping List" and "Possession Money Limit".

Our future work includes 1) analysis of customers' branching probability in a real store to ground walking flow, 2) development of decision support functions for store managers, and 3) analysis regarding customer information and product categories.

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