Effect of Consumer's Satisfaction Degree based on Multi-agent System Using Logit Model for Reference Price

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Abstract

We purchase various products and services in every day. A process, which selects the product and service by consumer, is called a purchasing decision process. Generally speaking, the purchasing decision process consists of five stages. There are problem cognition, information search, substitute validation, purchasing decision, and action after the purchase. We pay attention to the substitute validation as which a consumer estimates it among two or more alternative related with an item. In this paper, the product selection action of the consumer about the notebook PC in consideration of the synergistic effect of two or more attributes is studied. Further, we analyze the impact of the parameter about a consumer's degree of satisfaction on product selection using sugarscape model.

Keywords: Product selection action; Logit model; Consumer's degree of satisfaction; Sugarscape model

1. Introduction

In recent years, a marketing strategy plays a more important role for a corporate business by diversification of a consumer's need, or development of an information technology. Especially, a setup of product price is a very important problem which influences the profits of a corporate business. However, in a corporate business, taking the consumer reaction to the product price into consideration has not been a common sense. Instead, it depended on the intuition of the marketing manager, just like adopting the price of market readers, in many cases. In order to decide the suitable price of products, we have to extract the way of decision process of which from the information about the reaction to consumers' price. Therefore, many researches for understanding the relationship between the consumer behavior centering on the product selection and the price using the model of a marketing science are actually proposed.

We have to predict the number of products which will be sold, because we decide the price and the commodity composition to maximize the benefit of the corporate. However, it is necessary to evaluate the effect of the member which constitutes not only the product itself but its product, and its combination for product selection action to an item(Alvin et al. 1978). A logit model is one of the probability models which model a consumer's product selection. The logit model assumes that the probability of product selection depends on the utility which the consumer feels to the product, and it has contributed to analysis of consumer's behavior (Sakamaki & Saito 2006).

On the other hand, since the component of human society is complicated and diversified, it is difficult to understand mechanisms of phenomena generated as a result of decision making or interactions. Such phenomena occur in complex systems which take on unexpected aspects without dependence on the action rule of each human being. Therefore, we cannot use top-down approaches which analyze each component from phenomena. Then, the multi-agent system which is a bottom-up approach attracts attention as a tool of analyzing complex systems. It focuses attention on phenomena as a sum of the behavior of each individual which is a component of the system. We focus on sugarscape (Epstein and Axtell 1996) which is one of models of multi-agent systems. In this model, there is sugar which agent can eat on two-dimensional landscape. The agent with some genetic properties, for example, vision and metabolic rate, is generated in this space. After agent looks over as far as possible and sights the most sugary spot, it goes to the spot and eats the sugar. The agent consumes sugar which is the same as its metabolic rate at every step. If the agent does not have sufficient amount of sugar, the agent is eliminated from this space.
As a result of agent behavior based on the simple rules, it generates interesting phenomena as a whole. The author et al. has created a Sugarscape model which is composed of agents who act on reinforcement learning (Shibata et al., 2006).

This research considers the consumer behavior to the purchase of a personal computer using multi-agent system. We give the result of numerical simulation under the condition that maximize the consumer's degree of satisfaction

2. Consumer Behavior Selection Model

2.1 Logit Model

The product selection action of the consumer about a notebook PC is considered. The consumer feels Utility $V_k$ to each notebook PC. It is assumed that utility is the sum of the member of definitely decided with explaining variable $U_c$ such as an item attribute, and the random error term $e_k$ included the other various factors. Therefore, the utility $V_k$ is defined as follows (Sugita et al. 2005).

$$V_k = U_k + e_k$$ (1)

The selection probability of the product which a consumer selected is considered to be the probability that the utility of the product is higher than the utility of other products. It assumes that the attribute of the product can be classified from a size and maker of product.

This model is made in consideration of the special feature of evaluating the combination of between the maker and the size Notations used by this research are shown as follows.

$$i : \text{Maker } i \quad (i = 1, 2, \cdots, I)$$
$$j : \text{Size } j \quad (j = 1, 2, \cdots, J)$$

$$x^M_{ik} : \text{If PC } k \text{ is the maker } i, \text{ it is } 1, \quad (i = 1, 2, \cdots, I)$$
$$\text{otherwise } 0.$$

$$x^S_{jk} : \text{If PC } k \text{ is the size } j, \text{ it is } 1, \text{ otherwise } (j = 1, 2, \cdots, J)$$
$$0.$$

We apply the intentions of synergistic effect of two or more attributes; the deterministic utility over the product in consideration of the validation to the combination of attributes is expressed as follows.

$$U_k = \sum_{i=1}^{I} \alpha_i x^M_{ik} + \sum_{j=1}^{J} \beta_j x^S_{jk}$$
$$+ \sum_{i=1}^{I} \sum_{j=1}^{J} \gamma_{ij} x^M_{ik} x^S_{jk} + \theta_k p_k$$ (2)

The utilities of the maker and size are expressed by utility parameters $\varepsilon^M_i$ and $\varepsilon^S_j$ to the average price, respectively.

$$U_y = \sum_{i=1}^{I} \alpha_i x^M_{ik} + \sum_{j=1}^{J} \beta_j x^S_{jk}$$
$$+ \sum_{i=1}^{I} \sum_{j=1}^{J} \gamma_{ij} x^M_{ik} x^S_{jk} + \varepsilon^M_i p_k + \varepsilon^S_j p_j$$ (3)

A parameter $\alpha_i$ is a utility of maker $i$ to PC $k$, $\beta_i$ is a utility of size $j$, $\gamma_{ij}$ is a utility of maker $i$ and size $j$, $\theta_k$ is a utility of price $p_k$ for PC $k$. Since the personal computer always has attributes "size" and "maker", it satisfies the following condition.

$$\sum_{i=1}^{I} x^M_{ik} = \sum_{j=1}^{J} x^S_{jk} = 1$$ (4)

A consumer's purchase probability $p_k$ over product $k$ can be expressed as follows using the deterministic utility calculated from presumed values as a result of multiple regression analysis.

2.2 Reference Price

A reference price is a base price for a consumer to evaluate the price of items. The reference price is divided into an external reference price and an inner reference price. An external reference price is an actual retail price in a market. Similarly, an article of a journal and the price comparison between stores are also considered as the external reference price. In general, the external reference price is clear to anyone, and intelligible. On the other hand, the inner reference price exists in a consumer individual. Since the inner reference price is formed from the past purchase experience etc., it is unclear for others. The keys which presume an inner reference price are the following.

1. Reasonable price; the appropriate price estimated from the cost of the product.
2. Reservation price; the price considered that a consumer may pay so far.
3. Expected price; the price supposing the value which a product has.

In this paper, the inner reference price by the reasonable price is used. Concretely, the inner reference price for maker and size are $c_i$ and $c_j$, respectively.

2.3 Prospect Theory

Prospect Theory is considered to be one of the theories of the price from a consumer’s viewpoint. Prospect Theory assumes that a demand curve is a loose curved form instead of a linear form. A human being has the following tendency that an unhappier memory remains strongly in comparison with a happy memory. Prospect Theory reflected such a human being's special feature. The consumer has an appropriate price to a product and deter-
mines utility by whether the price of the product is higher than the appropriate price or low. Such a consumer's criterion of judgment is called the inner reference price as described before. The consumer is sensitive to a price, when the price of products exists near its inner reference price. Especially the fall of the utility in the case of losing profits is remarkable compared with the case where it gains. However, if an item price exists in the area which exceeded a certain fixed area from the inner reference price, then a consumer's utility does not change so much when the price may change a little. In this paper, the degree of satisfaction of the consumer is proposed from the viewpoint of Prospect Theory.

3. The Outline of Sugarscape Model

Sugarscape model is spatial distribution which disposed sugar, that is to say, landscape. There are ants called agents and sugar called environment on the landscape. The agents go to the spot of higher sugar levels and consume it. This space is torus-grid graph, and each coordinate \((x, y)\) has present level and maximum level of sugar.

Each agent has two genetic properties, metabolic rate of sugar and vision. The metabolic rate of sugar is the amount of sugar that the agent burns off at every time. The vision indicates range of environment which agent can see. For example, the agent with vision 2 can see 2 grids in vertical and horizontal direction (See Figure 1). Note that agent cannot see any grids in oblique direction, that is, the information of agent is not completely.

**Figure 1. Agent’s Vision**

After agent is born with some genetic properties in sugarscape, the agent complies with the simple rule; he looks as far as he can see, finds spot of largest amount of sugar, goes to there and eats the sugar. The concrete movement rule is described as follows.

**Agent Movement Rule**

- Agent goes to selected grid.
- Agent collect all sugar at new grid.

When agent collected much sugar, larger than its metabolic rate, agent keeps the extra sugar as asset and moves around sugarscape. Here, there is no limit on the amount of sugar which agent can accumulate. Note that agent consumes the sugar that is equal to metabolic rate at each period. When agent used up accumulated sugar, the agent is eliminated from sugarscape.

4. Proposal of the Degree of Consumer's Satisfaction

The degree of consumer's satisfaction for a personal computer is proposed using a consumer's item selection behavior model.

The following expression, which has the inner reference price as a variable, is the degree of satisfaction \(g_i\) of agent \(i\) for maker \(i\) and size \(j\).

\[
g_i^j(c_i^M, c_i^S) = f_j(y_i^d) \cdot S \cdot P
\]

where

\[
y_i^d = \frac{1}{2} \left( \sum_{j=1}^k x_i^M c_i^M + \sum_{j=1}^k x_i^S c_i^S \right) - p_i + c_i^M - p_j
\]

\(S\) is the number of customers who purchase the product. A function \(f_j(x)\) of agent \(t\) is assumed as follows.

\[
f_j(x) = \begin{cases} a_{ij}^x b_{ij}^x \sqrt{x} & (x \geq 0) \\ -c_{ij}^x d_{ij}^x \sqrt{-x} & (x < 0) \end{cases}
\]

Notations \(a_{ij}^x, b_{ij}^x, c_{ij}^x, d_{ij}^x\) are positive parameters for maker \(i\) and size \(j\) by which a behavior of agent \(t\) is characterized. These parameters express the degree of the preference which an agent feels, when the product exceeds a reference price. When the value is large, the more the difference of a reference price and an actual price is large, the utility value becomes higher. Then an agent likes the product more.

In this research, we set the agent's movement rule as follows. Here, a product agent exists instead of sugar on a grid.

**Product Selection Rule**

- Agent looks around within the limits of his vision on the left, right, top and bottom of the present position. And, agent finds the product agent that other agents have not purchase yet.
- Next, he calculates a purchase degree of satisfaction from the attribute and parameter of the product which the product agent within a view has.
- When two or more products exist in a view, he chooses a product with the highest degree of satisfaction.
He moves to the place and performs purchase processing.

When the product which he satisfies exists in a range of vision, an agent purchases a product and finishes action. On the other hand, when the product to satisfy does not exist, it moves in order to find a new product.

5. Simulation Results

In this experience, the notebook PC sales data in Osaka University co-op school store was used. Attributes are a date of sale, a maker, number of sales products, and a price. A tracking period is from November, 2004 to November, 2006. The number of product makers is 10, and the number of products is 2. The product price for the combination of attributes is used from Table 1.

Further, presumed parameters are shown in Table 2 as the result of multiple regression analysis.

Table 2. Presumed Result of a Parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate Value</th>
<th>EstimateValue</th>
<th>Estimate Value</th>
</tr>
</thead>
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<tr>
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<td>$\gamma_{11}$</td>
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<td>4.37</td>
<td>$\gamma_{41}$</td>
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<tr>
<td>$\alpha_6$</td>
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<tr>
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<td>$\gamma_{91}$</td>
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</table>

As a result of Table 2, the utility $\theta_i$ of PC price $p_i$ is zero in the used data. The reason is, the utility of consumer does not depend on the price of product. However, it depends on the maker and the size.

We show results of sugarscape which consists of agent with consumer’s satisfaction. We assume that there are 500 agents and 300 product agents on torus-grid graph $50 \times 50$. In this paper, we assumed all agents have metabolic rate 0, and vision is from 1 to 5. Figure 2 shows initial screen and final screen. A red point expresses an agent and the blue point expresses the product agent. Since the product agent has the attribute of size and maker, there are 20 kinds of product agent. Parameters, which characterize agent’s behavior, are set to

$$a_{ij}^p = 0.5, b_{ij}^p = 1.0, c_{ij} = 1.0, d_{ij} = 2.0.$$
From Figure 3, it shown that the agent has not chosen the product of B5 size of company B and C, the personal computer of A4 size of company D, and the personal computer of company E. And, the personal computer of B5 size is chosen in company A, H, and I. On the other hand, the personal computer of A4 size is chosen in company F and G.

Next, in case parameter $d_{ij} = 0.25, b_{ij} = 0.5, c_{ij} = 0.5, d_{ij} = 1.0$, Figure 4 shows the purchase number of the personal computer after the last step.

**Figure 4.** The Purchase Number of the Personal Computer with $a_{ij} = 0.25, b_{ij} = 0.5, c_{ij} = 0.5, d_{ij} = 1.0$

Since the parameter of Figure 4 is smaller than the parameter of Figure 3, the agent in Figure 3 reflects the preference in a product choice. Since preference of an agent shows the ambiguous situation, the number of purchase products shows the almost same result.

6. Conclusions

In this study, the consumer behavior using the sales data of a notebook PC is considered by the logit model. The degree of consumer's satisfaction is proposed by using Prospect Theory. By the result of simulation, we analyzed the impact of the parameter about a consumer's degree of satisfaction on product selection using sugarscape model.

References


