Video-based Conjoint Analysis and Agent based Simulation for Estimating Customer's Behavior

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Abstract. Conjoint analysis is a statistical technique to reveal customers' invisible preference using series of questions regarding tradeoffs in products. In this paper, we propose a new variant of this technique that uses products layout and customers' actions in a store instead of conjoint cards and answers. We demonstrate the effectiveness of this method by making agent-based in-store simulator that can reproduce the congestion in a store. The parameters of the agents in the simulator were determined by our technique – video-based conjoint analysis.

Keywords: Service, Science, Conjoint Analysis, Random Utility Maximization Model, Multinominal Logit Model, Behavior Analysis, Agent-based simulation

1 Introduction

Service science is an attempt to treat service as a problem of science and engineering. Progress of the processing speed of today's computers and the methodology of software designing make this approach possible [1]. Agent Based Simulation (ABS) is very powerful tools for service science. Concept of ABS is quite different from traditional numerical calculation of differential equations. ABS is effective especially in social science because bottom-up approach of ABS have high affinity with constructing complex systems [2].

In order to make a valid ABS, design of the agent is the most important thing. The term "agent" is used as the meaning of "customer" throughout this paper. To make a reliable agent, we must know customers' preference correctly, but at the same time, this is the most difficult thing in service industry.

There are two directions regarding customer survey: (1) asking to customers and (2) observing customers indirectly. Questionnaire [3] is the typical example of the former and behavior analysis [4] is the typical example of the latter. Both have pros and cons. Questionnaire is simple and convenient, but it usually needs incentive such as money to have people answer the questionnaire, and what is worse that people can not answer correctly to the questionnaire. Behavior analysis is based on the observation of the agents (animal or human). It can get more precise result because the action of agents represents what they think. But this method needs special instruments for recording or analyzing.

Conjoint analysis is a variation of questionnaire [5][6]. Through the series of indirect questions regarding tradeoffs of products, it can reveal the relative strength of the attributes of the products for customers. This method can prevent examinee to deceive examiner because the question is indirect and it is difficult to estimate what the examiner want to know.

Conjoint card is special tool of this method. The cards are examples of products that have tradeoff among many attributes such as price, size, or performance. Examinees are required to sort or choice these cards by their preference. The results of sorting or choice can be used to estimate relative importance of the attribute to the examinees.

By the way, the actions of customers in a store, such as turning the corner to some direction or stopping at the front of some shelf, can be thought as choice or sort. POS system is used for long time to analyze customers, but it stores only purchase data. Given the recent and rapid development of IT tools, it is relatively possible to store, retrieve and analyze almost every action of customers. In this paper, we propose an extension of conjoint analysis that can be carried out without conjoint card. In this method, each actual product in the store represents each conjoint card, and the stored records of customers' actions are translated into the choice or sort of the conjoint card.

The rest of this paper consists of the following sections. In Section 2, conjoint analysis – the theoretical background of this study – is reviewed. In Section 3, we propose a new method that extends conjoint analysis that doesn't need conjoint card. The effectiveness of the method is demonstrated in Section 4. We discuss the possibility of creating ABS using this result in Section 5. Section 6 is about conclusion and future work.

2 Conjoint Analysis

2.1 Basic Concept

Conjoint analysis is the statistical technique used in marketing research to determine the relative strength of the attributes of the product or service. It originated in mathematical psychology [5] [6].

The following is the typical procedure of conjoint analysis: A product or service is described in terms of a number of attributes. For example, PC may have attributes of size, mobility, memory, hard drive disk, CPU, and so on (Fig. 1). Each attribute can be broken into a number of levels. Examinees would be shown a set of products created from combination of levels and asked to choice, sort, or rate bye their preferences. Using the regression analysis, the implicit utilities for the levels can be calculated.

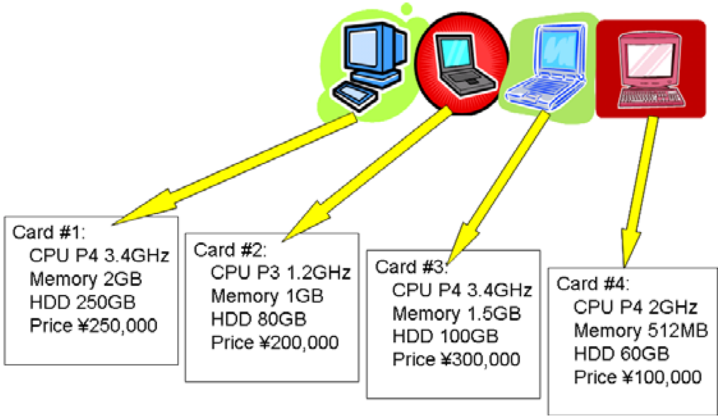


Fig. 1. An example of conjoint card: The combination of attributes of PC makes conjoint card. Examinees should asked to choice or sort these cards by their preferences..

2.2 Theoretical Background

To make the utility function, we use Random Utility Maximization (RUM) Model [5]. In RUM, the utility is formulated in the shape of linear functions (Eq. (1)).

$$U_{in} = \beta_1 x_{1in} + \beta_2 x_{2in} + \cdots + \beta_k x_{kin} + \varepsilon_{in} = V_{in} + \varepsilon_{in}, \quad \textbf{(1)}$$

where,

U_{in} : Utility of i - th choice of n - th people,

x_{kin} : k - th explaining variable of i - th choise of n - th people,

β_k : k - th parameter.

The choice probability can be calculated by Eq. (2).

$$P_n(i) = \Pr[U_{in} > U_{jn}, \quad \text{for } \forall j, \quad i \neq j] \quad \textbf{(2)}$$

If the number of the choice is two, we can rewrite Eq. (2) as Eq. (3)

$$\begin{aligned} P_n(i) &= \Pr[U_{in} \geq U_{jn}] \\ &= \Pr[V_{in} + \varepsilon_{in} \geq V_{jn} + \varepsilon_{jn}] \\ &= \Pr[\varepsilon_{jn} - \varepsilon_{in} \leq V_{in} - V_{jn}] \\ &= \Pr[\varepsilon_n \leq V_{in} - V_{jn}] \\ &= \mathrm{CDF}_\varepsilon(V_{in} - V_{jn}) \end{aligned} \quad (3)$$

If the CDF is logistic distribution, Eq. (3) will be Eq. (4).

$$P_n(i) = \frac{\exp(\mu V_{in})}{\sum_{j=1}^{J} \exp(\mu V_{jn})}, \quad i = 1, \ldots, J \tag{4}$$

Parameter estimation is done by Maximum Likelihood Estimation (MLE). Log likelihood is often used for actual calculation (Eq. (5)).

$$L = \prod_{n=1}^{N} \prod_{i=1}^{J} P_n(i)^{d_{in}} \text{ , or } \ln L = \prod_{n=1}^{N} \prod_{i=1}^{J} d_{in} P_n(i) \tag{5}$$

where,

$d_{in} = 1$ (if n - th person selects i - th choice),

$= 0$ (if not)

3 Video-based Conjoint Analysis: Conjoint Analysis without Conjoint Cards

In this section, we propose the extension of conjoint analysis. Usually, we need conjoint card to carry out conjoint analysis. As we mentioned in Section 2, conjoint analysis consists of the following two parts: (1) making conjoint cards, and (2) asking examinees to sort or choice the cards. We can substitute each part using IT tools. We discuss the possibility of extension of these two parts in order.

3. 1 Making Conjoint Card from Store Shelf

Table 1. Attributes and its levels of the food and drink sold in convenience store.

Attributes	Level
Category	Food, Snack, Drink
Temperature	Hot, Normal, Drink
Life time	Short, Long
Price	High,, Normal, Low

We have to remember the each conjoint card represents a possible product which has some combination of attributes. Fortunately, there are many kinds of possible products on a shelf in usual convenience store. Then we can approximately think the products on the shelf as the display of conjoint cards and the action taken at the front of the shelf can be translated into the action against conjoint cards.

In particular, if the products in a convenience store are intended, food and drink will be the object of conjoint analysis. Table 1 shows the example of possible attributes and level of food and drink. Fig. 2 and Fig. 3 show the shelf layout in some convenience store and the translation of products on the shelf to conjoint card.

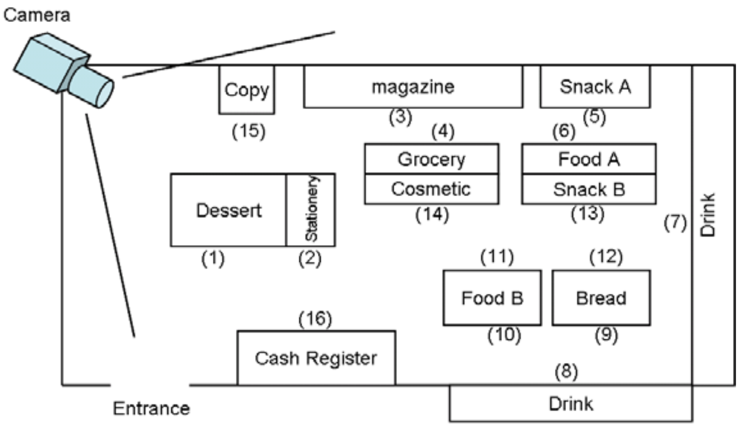


Fig. 2. The layout of a convenience store: Each shelf in the store is classified by the products.

Card #1 (Food, Hot, Long, Low) --> Position (6)
Card #2 (Food, Hot, Shot, High) --> Position (11)
Card #3 (Food, Normal, Short, Normal) --> Position (12)
Card #4 (Snack, Cold, Short, Normal) --> Position (1)
Card #5 (Snack, Normal, Long, Low) --> Position (5)
Card #6 (Snack, Normal, Long, High) --> Position (13)
Card #7 (Drink, Cold, Long, Normal) --> Position (7)
Card #8 (Drink, Cold, Short, Normal) --> Position (8)

Fig. 3. An example of making conjoint card: the product on the shelf can be translated into the conjoint cards. “Position” represents the shelf number in Fig. 2.

3.2 Reading Mind from Customers’ Action Instead of Asking Questions

The above idea is maybe considered at the time in the past, but there is no means to capture the customers’ action at the time. However, recent development of IT tools allows us to monitor and record customers every action. For example, RFID or very smart image processing methods can be used for this purpose.

We select spending time at the front of each shelf in the store as the substitution of customers’ choice for conjoint analysis. Longer spending time can represents they are interested in the products and vice versa. POS data is unsuitable for this purpose because it only tells us whether it sold or not. We need more detailed data such can represent how they want or how they wander to buy some products.

In this study, we use the video-based IT tools because it is easy to check the log (just watch the video). We adopt Vitracom's SiteView [7] for the analysis of video image. It can count, detect and track objects crossing the counting line in both direction at very high density. Fig. 4 shows the screenshot of counting people.

Fig. 4. Analyzing customers' action: Vitracom Siteview is used to analysis of customers' behavior. Siteview is video-based counting device. It can count objects crossing the counting line and can detect and track the objects using optimization algorithms.

4 Experiments

In order to examine the effectiveness of our method, experiments were done in two situations at the convenience store located in our campus. Table 2 shows the condition of the experiments. Fig. 5 shows scenes of these two situations.

Table 2. Condition of the experiments

Date	March 16th, 2007
Location	Convenience store in our campus (National Defense Academy of Japan)
Time	16:00-17:00 (Situation 1) 18:00-19:00 (Situation 2)
Objects	Food and drink

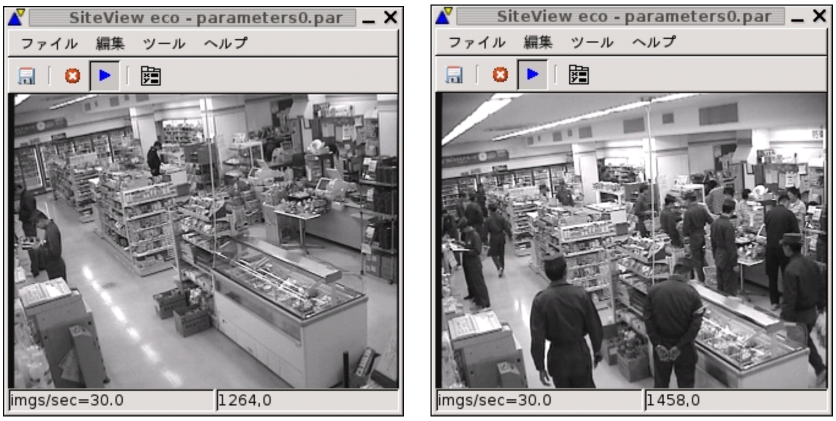


Fig. 5. Typical scene of Situations – (Left) Before meal: 16:00-17:00. In this situation, the store is sparsely populated (2 ~ 3 people in the store). (Right) After meal: 18:00-19:00. In this situation, the store is densely populated (10 ~ 15 people in the store).

4.1 The Results of Experiments

SPSS conjoint [8] is used to carry out these investigations. Fig. 6 shows the relative importance of attributes of the products in both experiments. Relative importance among attributes is almost same in situation 1 (before meal), but the category is the most important attributes in situation 2 (after meal).

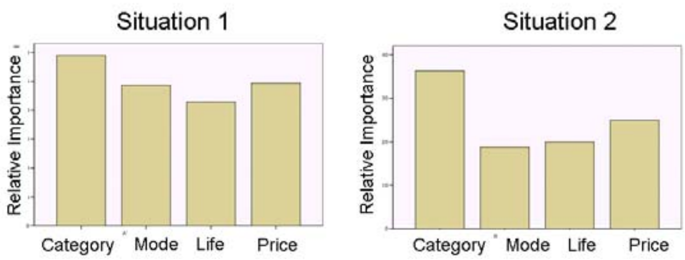
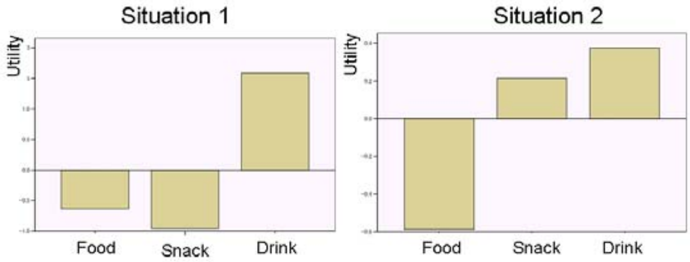
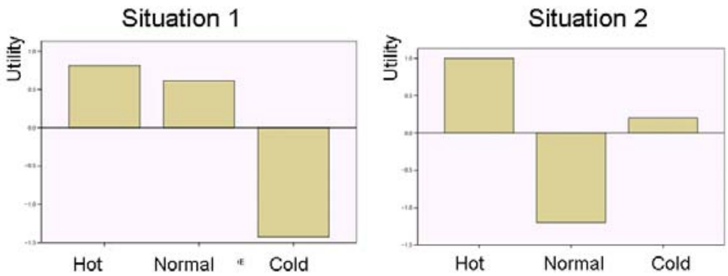


Fig. 6. The difference of relative importance to the utility function.

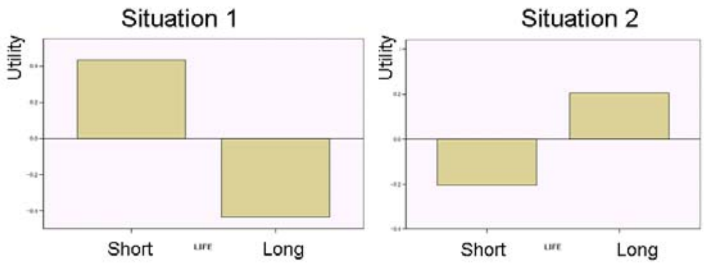
Fig. 7 (a)-(d) shows the effects of each attributes on the utility functions of the customers. These results clearly show the change of the parameters of the utility functions.



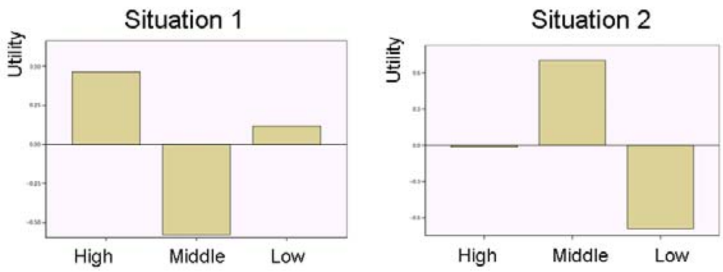
(a) Category of the Food



(b) Temperature of the food



(c) Lifetime of the food



(d) Price of the food

Fig. 7. The effects of each attribute on the utility function of customers

4.2 Simulating the efficiency of the possible products

When we get the estimation of the parameters of utility function for customers, we can simulate the rating of nonexistent products by calculating the utility function. The following two products show the opposite utilities between the situations.

- (Drink, Normal, Short, Low) gets high rating in situation 1 (= 5.61), but low rating in situation 2 (= 1.24).
- (Snack, Hot, Short, Middle) gets low rating in situation 1 (= 2.22), but high rating in situation 2 (= 4.00).

5 Agent based Store Simulator Incorporating the Results

We now are able to create agent based store simulator. We adopted AnyLogic [9] Pedestrian Library for this simulator. This library enables to make natural flow of people from point to point with route finding and collision avoidance mechanism.

This simulator has the same layout of the store is as shown in Fig. 2. Agents move around according to the sequence of waypoints in a store. The place in front of each shelf corresponds to each waypoint. Agents enter from the entrance and visit few waypoints and go outside from the exit. Waypoints are selected stochastically based on the preference of each agent. The average number of the selected waypoints for each agent is three. This number is set from the observation.

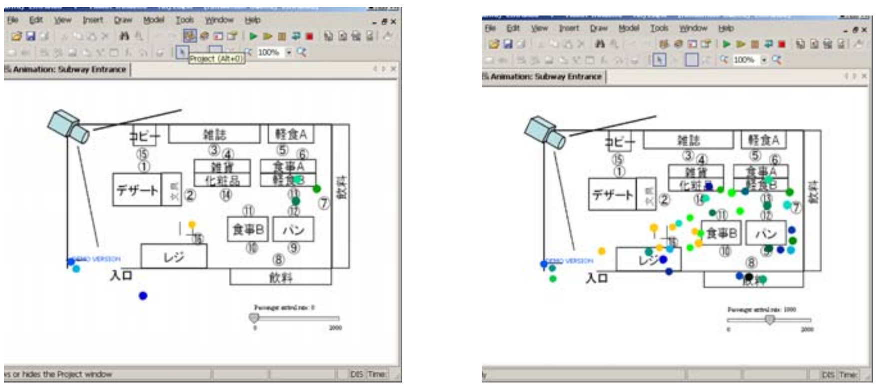


Fig. 8. Store simulator using AnyLogic Pedestrian Library: (Left) Off hours, (Right) Rush hours.

From the right part in Fig. 8, congestion can be seen at the front of cold drink shelf when the number of the people in the store increases. This result corresponds with real data that we observed. The next step is to find better layouts that can prevent congestion and this is an ongoing project.

6 Conclusion

Knowing customers' preference is the most important but difficult thing in marketing. We propose new investigating method that combines questionnaire and behavior analysis. In this method, customers are modeled as agents that maximize their utilities. The parameter of utility function of the agent is estimated with their actions in store such as flow line and sojourn time. More precisely, agents' action is used for creating the answer to the conjoint cards that consist of questions regarding tradeoff of products.

Experiments done in some convenience store show this method can differentiate the change of agent's preference. In the experiments, we can obtain good estimate value because of the several particularity of the situation. For example, (1) everyone is regular customer and familiar with the layout, (2) the target products (food and drink) have obvious tradeoff. We need to develop this method for broader range of situation.

This method can simulate not only existent product, but also nonexistent products. We tried to reflect this result in building customer-model for agent-based store simulator and reproduced the congestion that corresponds with observed data. As a future work, more precise design of the simulator and finding better layout that can prevent congestion is planned.

References

1. J. Spohrer, P. Maglio, J. Bailey, D. Gruhl, Steps Toward a Science of Service Systems, Computer, vol. 40, No. 1. (2007) 71-77
2. J. Epstein, Generative Social Science: Studies in Agent-Based Computational Modeling, Princeton University Press (2007)
3. P. Hague, Questionnaire Design, Kogan Page (1993)
4. R. W. Malott, M. E. Malott, E. A. Trojan, Elementary Principles of Behavior, Prentice Hall College Div. (1999)
5. P. Green, V. Srinivasan, Conjoint analysis in consumer research: Issues and outlook, Journal of Consumer Research, vol. 5, (1978), 103-123
6. A. Gustafsson, A. Herrmann, F. Huber (ed.), Conjoint Measurement: Methods and Applications, Springer-Verlag (2006)
7. Vitracom Siteview Web Page: http://www.vitracom.de
8. SPSS Web Page: http://www.spss.com
9. AnyLogic Web page: http://www.xjtek.com/