A study on modeling and optimization of item changes in vending machines

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1 Introduction

In the beverage vending machine business in Japan, operator companies contract for vending machine replenishment work. Workers called "route men" have responsibility to work actual replenishment and item (product) exchange.

In operator companies, their management task is to improve the efficiency and standardization of replenishment work performed by route men and to reduce opportunitiy lossess due to sold out by improving product lineup.

In this study, we will develop an optimization model to improve sales by improving the item changes of vending machine items for route men.

When the achievements of this study can be applied to actual operation tasks, the following merits and effects are expected for customers, operator companies, and route men.

- Customers: They can purchase items they like when they want it. Sold out of wanted items will be reduced.
- Operator companies: They can manage and improve service levels such as sales improvement and opportunity loss reduction. Also, it can be expected that optimization and standardization of route men's work.
- Route men: By following improvement suggestions, every route men can do a certain level of work that does not depend on individual experience or ability. They can also reduce failures.

2 Previous research

2.1 Research on consumer's item selection behavior

As representative research in recent years on consumer's item selection behavior for various products in the field of marketing, based on POS (Point of Sales) data in retail stores, there is a formalization of consumer's item selection behavior by Bayesian modeling.

However, since the quality and frequency of obtained information are different between retailers and vending machines, a model of item selection behavior for vending machines requires a different approach from those of retail stores.

2.2 Research on vending machines

Research on vending machines is conducted in several fields.

First, research on inventory delivery planning problem to realize efficient traveling work to multiple vending machines.

Secondly, it is a study on column optimization problem for vending machines. In existing research on this problem, optimization methods aimed at minimizing costs and profit maximization under a certain environment have been proposed. However, vending machines differ in the installation situation of each one. In addition, they are characterized by constantly changing preferred items by season, weather and consumer's taste. Therefore, in order to realize sales improvement and efficiency, proposal of a column optimization method that can respond to changing installation environment and consumer demand sequentially is required.

3 Model framework

With reference to previous research, we propose an optimization model that can respond to changes in installation environment and consumer demand and to propose appropriate item selection improvement plan at all times. We also examined the framework of virtual simulation for demonstration of proposed model.

3.1 Modeling vending machine state

As a model of changes in installation environment, we assume the following vending machine state and its change. Regarding the state of vending machines, we classified them according to whether their attributes are "fixed / changed" and "observable / unobservable" from route men.

- "fixed and observable" : Installation location . . . office, outdoor, school
- "changed and observable" : External factors . . . temperature
- "changed and unobservable" : Customer attributes . . . gender ratio

3.2 Customer's item selection model

In this research, we adopted a multinomial logit model for customer's item selection behavior for vending machines. The multinomial logit model is a model that expresses the probability that a customer selects one among plural selectable items with a logit of the utility value of these items.

3.3 Framework of item changes model: POMDP

As modeling of the optimal behavior that a route man should take, this study adopted reinforcement learning and Partially Observable Markov Decision Process (POMDP) as a framework of optimized model. POMDP is an extension of Markov decision process (MDP) by adding uncertainty to agent state observation.

To adjust the framework of POMDP to this problem, we adopted the premise that the route man can recognize information other than vending machine state. That is, although the route man can not recognize a part of the current vending machine state, he / she is aware of "parameter of the item selection model" and "transition probability of the vending machine state".

4 Simulation

Based on the framework and modeling so far, we carried out numerical simulation of item selection improvement model by virtual parameters for multiple models.

For the model proposed in this study, simulation was performed with multiple patterns, and accuracy and effectiveness were verified. We also prepared a model to be a comparative control of the evaluation, carried out the same simulation, and compared it with the proposed model.

By carrying out this simulation, the following conclusion was obtained.

- Even with a simple heuristic item selection improvement method that is not a proposed model, sales improvement can be expected rather than changing the item selection at all.
- It is considered that there is sufficient improvement ability even by heuristic item selection improvement method. By adopting the proposed model, we can expect further improvement of product line even though it is slight.
- The improvement effect that the proposed model greatly exceeded the outcome of the heuristic method could not be realized with these conditions and parameters.

5 Summary

As a result of simulation using virtual parameters, if the utility value of the items and the transition probability of the vending machine state are known, it is possible to realize comparatively satisfactory item changes and improvement.

However, under the conditions of this study, we could not achieve significant improvement compared to a simpler and heuristic approach. Especially, it was not possible to verify the effect of the method by estimating future expectation fee, and it was not possible to demonstrate the usefulness of the whole model.

As future tasks, it is necessary to develop into a model that can deal with situations with less information volume, and verify the effect under re-simulation.

In addition, this study is limited to simulation verification using virtual parameters. As a further research topic, it is indispensable to verify whether the proposed model can adapt to actual operation by using actual sales data or business data, in cooperation with a real vending machine operator company. Ultimately, we would like to aim to contribute to business improvement by providing the model proposed in this study to operator companies and adapting them to actual operation tasks.