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Demand Forecasting for Catering Bento by Machine Learning Using Automatic Estimation of Product Popularity

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Abstract

"Bento" is widely known as a part of Japanese food culture. There are many companies in Japan that produce thousands of bento every day. In recent years, the market for the catering bento industry has been expanding, and the demand for catering bento has been increasing. Catering bento companies seek to automate demand forecasting. The forecasters in the field forecast demand based on their intuition and experience. However, it is difficult for unskilled workers to make accurate demand forecasts. It is important to take into account the popularity of bento in order to forecast demand with a high degree of accuracy. In a previous study, MCMC sampling was used to estimate the popularity of bento. Specifically, based on past data on unit sales of bento, the number of sales of two products were compared to estimate which product was more popular. The problem with the popularity estimation in the previous study is that the popularity estimation is partially done manually by humans. The objective of this study is to automate the estimation of the popularity of bento. The novelty of this study is that products with similar popularity are grouped together based on an assumption. The assumption is that the popularity of bento is determined by the words in the product name and the characteristics of the dish. The new popularity estimation method is to calculate cosine similarity using four element groups and to group products with similar popularity by hierarchical clustering. The four element groups are dish name, dish category, cooking method, and the number of units sold. The popularity of the bento is estimated by MCMC sampling. To test the usefulness of the new popularity estimation method, we construct a demand forecasting model that takes into account the popularity of bento estimated by the new method. The forecasting accuracy of the proposed model and that of the conventional model are compared. The popularity of bento proposed in this study is used in the proposed model. The popularity of bento proposed in the previous study is used in the conventional model. The method used in the demand forecasting model is a gradient boosting decision tree. The features used in the demand forecasting model are the predicted total number of units sold on the forecast day, the temperature, the popularity of the bento, and the number of bento sold in the past. A numerical experiment was conducted using data provided by a bento manufacturing-sales company which manufactures and sells more than 10,000 catered bento per day. The company sells three types of bento, including daily bento, rice bowl bento and noodle bento. In the accuracy comparison using actual data, the proposed model and the conventional model had the same level of prediction accuracy. Thus, we conclude that the popularity of bento could be automatically estimated.

Keywords

Demand forecast, Popularity estimation, Machine learning, MCMC sampling and Time-series data.

Biographies

Koki Kitabayashi is with Department of Industrial Engineering and Management, Graduate School of Engineering, Kanagawa University. He is conducting research on demand forecasting for catered bento using machine learning. He entered Kanagawa University in 2018 and joined the Management Systems and Engineering Laboratory in 2020. After he received his undergraduate degree in Industrial Engineering and Management in 2022, he entered the graduate school of Kanagawa University. His presentation was given at the Mathematical Systems Academic Conference FY 2021 held online on February 10, 2022, and she received the "NTT Data Mathematical Systems Student Research Encouragement Award, Honorable Mention, 2021".

Hideki Katagiri is a Professor of Department of Industrial Engineering and Management at Kanagawa University, Japan. He earned his B.E., M.E. and Ph.D. in Engineering at Osaka University in 1995, 1997 and 2000, respectively. He was the Chair of IEEE SMC Hiroshima Section Chapter (2008-2010) and a Visiting Scholar at the University of Chicago Booth School of Business (2014-2015). He was a Visiting Professor of Hiroshima University (2016-2020). His research and teaching activities are in the areas of operations research and soft computing, especially, multi-objective optimization under uncertainty and data analysis using machine learning techniques. He is the author or co-author of more than 100 refereed journal papers and several co-authored or co-edited books in English.