

Demand Forecasting for Catering Bento By Machine Learning Considering Popularity Estimation Based On Culinary Similarity

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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 Japan, the market for the food delivery industry is expanding. This study focused on the catering bento industry, which manufactures and delivers bento.

Catering bento companies are seeking to automate demand forecasting. The forecasters in the field are forecasting demand based on intuition and experience. Many catering bento companies use prospective production. The accuracy of demand forecasting greatly affects the occurrence of food loss and opportunity loss.

It is important to take into account the popularity of bento in order to forecast demand with a high degree of accuracy. The number of bento sold increases or decreases depending on the popularity of bento. For example, many young Japanese men who order a catered bento want a hearty bento and like meat dishes to vegetable dishes.

The objective of this study is to develop a highly accurate demand forecasting model that can contribute to the reduction of food loss and prevention of opportunity loss for catering bento companies.

This study estimates the popularity of a group of products and proposes a demand forecasting model that takes popularity into account. First, for each bento, multiple vectors consisting of four groups of elements are created. The four element groups are dish category, cooking method, ingredients, and food group. The similarity between two vectors is calculated by the Cosine similarity for each group of elements. The similarity between two products is calculated by summing the Cosine similarity of each group of elements. Next, based on the similarity of the two products, multiple product groups are created by hierarchical clustering. The popularity of multiple product groups is estimated based on past data on unit sales of bento. Finally, we propose a demand forecasting model that takes into account the popularity of groups of products. 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 on the forecast day, the popularity of the bento, and the number of bento sold in the past. A numerical experiment was conducted at Company Y, which manufactures and sells more than 10,000 catered bento per day. Company Y sells three types of bento, including daily bento, rice bowl bento and noodle bento. Catering bento must be consumed on the day of sale. Therefore, forecasters in the field want to avoid producing more than the quantity demanded. In the accuracy comparison using actual data, the prediction accuracy of the proposed model was

better than those of the conventional model and the on-site prediction. The percentage of excess demand for boxed lunches in the proposed model was smaller than those in the conventional model and the on-site forecast.

Keywords

Demand forecast, Machine learning, MCMC sampling, Culinary similarity 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".

Kazuki Ota is with Department of Industrial Engineering and Management, Graduate School of Engineering, Kanagawa University. He entered Kanagawa University in 2015 and joined the Management Systems and Engineering Laboratory in 2017. After he received his undergraduate degree in Industrial Engineering and Management in 2019, he entered the graduate school of Kanagawa University. In March 2019, he received the Excellent Paper Presentation Award at the Electrical Society "Electronics, Information and Systems Division Study Group". This award is given to presenters under the age of 35 who presented outstanding papers at the Institute of Electrical Engineers of Japan "Electronics, Information and Systems Division Study Group" last year. Also, he received the "Best Student Paper Award" at the "International Conference on Machine Learning and Data Analysis 2019" held at the University of California, Berkeley in the United States. This award is given to outstanding papers from the viewpoint of uniqueness and importance from among student research presentations. He received his master's degree in Industrial Engineering and Management in 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.