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A Heuristic Solution Method for School Lunch Menu Optimization Problem Considering the Frequency of Ingredients and Dishes

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Abstract

Japanese school lunches are said to be more nutritionally balanced than those of other countries. This is due to the fact that school lunch menus are prepared in consideration of various items such as food categories and coloring of dishes. As a specific example, Japanese school lunches include not only meat-based dishes, but also rice and side dishes as part of the daily menu. In Japan, there is a style of cooking called Washoku. It is an expression of the Japanese people's respect for nature, and has been selected as an intangible cultural heritage because it is a traditional social practice that has been passed down from generation to generation. In the field of school lunch, there is a need for a system to support nutrition teachers in menu planning. There are many restrictions to be considered in menu preparation, such as nutritional intake standards, ingredient costs, and cooking time, and it takes a lot of time and effort to complete a menu. In Japan, the intake of 13 nutrients is determined according to the School Meal Intake Standards established by the Ministry of Education, Culture, Sports, Science and Technology (MEXT). Therefore, when preparing menus, it is necessary to keep within the upper and lower limits of the standard's intake. Previous research has proposed a menu planning model using a mathematical optimization solver that takes into account about 70 different constraints. However, the model has two problems: First, it does not adequately take into account the frequency with which food items and dishes are served. Second, the solution time is too long (about 6,000 seconds). The second reason for this is the number of decision variables and constraints in a month, which are enormous: approximately 200,000 and 10,000, respectively. On the other hand, another previous studies using genetic algorithms (hereafter referred to as GAs) have produced menus in a relatively short time. However, the number of constraints considered is quite small (six), and the frequency of serving ingredients and dishes is not taken into account. In general, in GA, as the number of constraints increases, the solution generated by crossing becomes infeasible in many cases, and it is time-consuming to change to a feasible solution. In this study, we formulate an automatic menu creation model that takes into account the frequency of serving ingredients and dishes as a mathematical optimization problem. Using the tabu search method, we propose a heuristic solution method that can find a good solution in practical time

when the number of constraints is large. The solution corresponds to a menu, which is a combination of dishes for a day. By exchanging dishes in the menu, a better solution is searched. In this study, a taboo list is provided to prevent the user from re-selecting a dish once it has been selected. Numerical experiments using real data of school lunch menus show that the proposed method reduces the solution time better than the conventional method.

Keywords
School lunch menu planning, Frequency of food and food offerings, Combinatorial optimization problem, and Heuristic solution method, Solving time

Biographies
Himawari Takeuchi is with Department of Industrial Engineering and Management, Graduate School of Engineering, Kanagawa University. Her research involves school lunch menus based on combinatorial optimization. She entered Kanagawa University in 2018 and joined the Management Systems and Engineering Laboratory in 2020. After she received her undergraduate degree in Industrial Engineering and Management in 2022, she entered the graduate school of Kanagawa University. Her presentation was given at the Mathematical Systems Academic Conference FY 2021 held online on February 10, 2021, and she received the "NTT Data Mathematical Systems Student Research Encouragement Award, Honorable Mention, 2021".

Takeshi Uno is an Associate Professor of Department of Mathematical Science, Graduate School of Technology, Industrial and Social Science, Tokushima University, Japan. He earned his B.E., M.E. and Ph.D. in Engineering at Osaka University in 1998, 2000 and 2003, respectively. He was a Research Associate (2003-2007) and an Assistant Professor (2007-2008) of Hiroshima University. His research and teaching activities are in the areas of operations research and soft computing, especially, optimal facility location and optimization under uncertainty. He is the author or co-author of more than 50 research papers including more than 20 refereed journal papers.

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.