CONSTRUCTION AND EVALUATION OF RECIPE RECOMMENDATION SYSTEM CONSIDERING USER TASTE PREFERENCES AND NUTRITIONAL BALANCE

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Abstract - Currently, there are many cooking and recipe sites. However, they often do not reflect a user's taste preferences nor include detailed nutritional information. In this study, we construct a novel system for recommending food recipes that reflect user's taste preferences and provide a nutritionally balanced set of ingredients, focusing on user's most and least favorite ingredients contained in the recipe and the nutrients of each ingredient. To recommend an appropriate food recipe, the method ranks food recipes by combining the personal preference score and the nutrition score for each recipe. For this, we first calculate the personal preference score for each recipe based on the user's most favorite and least favorite values for ingredients using his or her browsing history of cooking and recipe sites. We then calculate the nutrient score for each recipe based on the cosine similarity between the feature vectors of the nutritional value of each ingredient and the reference values for dietary intakes. In this way, the system ranks and recommends recipes based on the recipe scores by combining the personal preference score and the nutrient score for each recipe. Finally, we evaluated our proposed recipe recommend system through a user study.

Index Terms - Nutritional balance, Recipe recommendation, System construction and evaluation, User taste preference.

I. INTRODUCTION

In recent years, owing to the popularization of smartphones, opportunities to discover new recipes through cooking sites and applications have proliferated. In general, cooking recipe sites such as cookpad and allrecipes provide recipe search result rankings based on new arrivals or popularity. However, with such an enormous amount of food recipes on cooking sites, it is difficult to immediately find users' desired recipes even if users can narrow down their recipe search results by adding further search criteria such as cooking time and food expense. It could also be argued that choosing recipes based only on users' favorite tastes fosters biased eating habits leading to lifestyle diseases such as hypertension and metabolic syndrome. Better dietary habits can be promoted by allowing users to include the nutritional value of ingredients along with taste preferences as criteria when searching for recipes. Many users would likely consider it desirable to give priority to nutrition as well as taste preference when searching for a new recipe. Karikome and Fujii focused on only nutrient balance [1], [2]. They proposed a healthy menus recommendation system that helps users plan nutritionally balanced menus and visualized their dietary habits. The authors proposed a multi-objective-based recommender of menus that features an optimal balance between nutritional aspects, harmony, and coverage of available ingredients. They conducted experiments on real-world and synthetic dataset showed the approach they proposed to achieve the desired levels of nutrients, harmonization, and coverage of ingredients. Yajima et al. proposed a method to recommend "easy" cooking recipes by analyzing the content of recipes and considering seasonings and ingredients [3]. Ueda et al. proposed a scoring method for cooking recipes based on users' food preferences and the quantity of the ingredient in the recipe [4].

They extracted the users' recipe browsing and cooking history in order to reflect users' preferences. However, many websites that recommend recipes present them on the basis of entry date, access frequency, or the recipe's user ratings. They do not reflect the user's personal taste nor nutritional preferences. Therefore, in this paper, we focused on ingredients among factors for determining recipes such as cooking utensils, cooking methods, foodstuffs and so on. We construct a new food recipe recommendation system considering both users taste preferences and nutritional balance. Fig. 1 shows a conceptual diagram of our proposed recipe recommendation system.

The remainder of this paper is structured as follows. Section II provides a brief summary of related work. Section III explains our proposed food recipe recommendation system. Section IV discusses the experimental results of the proposed system. Finally, Section V concludes this paper and presents future works.

II. RELATED WORK

Recently, many studies pertaining to food recipe recommendation have focused on various components of a recipe, such as ingredients, nutrients, cooking utensils and cooking operation [5], [6].

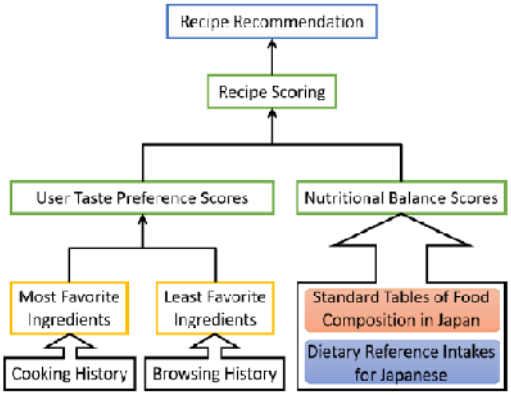

Fig. 1. Conceptual diagram of our proposed recipe recommendation system.

While most research models in terms of ingredients, Ueda et al. proposed a personalized recipe recommendation method based on user's food preferences [7]. Xie et al. proposed a hybrid semantic item model for recipe search by example. The hybrid semantic item model represents different features of the recipe data [8]. Forbes and Zhu present an approach for recipe recommendation to incorporate recipe content into a matrix factorization method. Experimental results showed the algorithm not only improves the recommendation accuracy but is also useful for swapping ingredients and creating recipe variations [9]. They only considered the users preferences of ingredients.

Another branch of research has focused on the recipe recommendation for healthy food in terms of nutrients. Mino et al. investigated the recommendation of cooking recipes for a diet in which the evaluation value of intake or consumption of calorie is considered in the events of a user's schedule during the period of a diet [10]. Cioara et al. proposed an expert system addresses the nutrition care process of the elders [11]. A food knowledge model is based on ontology and defined by the nutritionists. They only considered the nutrients of ingredients.

Here the elements of interest are the food ingredients, which can be combined in recipes [12], menus [13], and the nutritional concerns [14], [15], [16]. Our work is based on the same concept for recommending recipes considering both the user's personal taste preferences and nutritional balance of ingredients.

III. FOOD RECIPE RECOMMENDATION METHOD

A. Calculation of User Taste Preference Scores

In this paper, we calculate the user's taste preference score for each recipe based on the user's most favorite and least favorite values of 'likes' and 'dislikes' for ingredients [4]. We first calculate the total value for each recipe by adding the most favorite values and subtracting the least favorite values for ingredients. Furthermore, in order to eliminate bias towards the number of ingredients included in the target recipe, the personal preference score is calculated by dividing the number of ingredients into the total value. Let be a most favorite ingredient value, and be a least favorite ingredient value.

1) User's Most Favorite Ingredients: Ingredients that a user eats repeatedly are considered 'most favorite' ingredients. Recipes are broken down into their ingredients and a most favorite ingredient value is calculated by incorporating the frequency of use of ingredient in the recipes that the target user has eaten (: Ingredient Frequency) as well as the specificity of ingredient (: Inverted Recipe Frequency) based on the idea of TF-IDF into Eq. (1).

$$I_k^+ = IF_k^+ \times RF_k^+. \quad (1)$$

Here, we calculate the usage frequency of ingredient by utilizing the simple frequency ( ) for ingredient k during a definite period D as follows:

$$IF_k^+ = \frac{f_k^+}{D}. \quad (2)$$

Then, we calculate the specificity of ingredient k ( ) using the total number of recipes (C) and the number of recipes that contain ingredient k ( ) as follows:

$$IRF_k^+ = \log \frac{C}{C_k^+}. \quad (3)$$

2**) User's Least Favorite Ingredients:** We estimate the user's least favorite ingredients by considering the ingredients in the recipes that he/she has never cooked, even if he/she has browsed the recipe details. First of all, we extract recipes from the user's recipe browsing history if the recipes are not included in his/her cooking history. Next, we filter extracted recipes if cooking processes of the extracted recipes are more than the recipe that has the largest number of cooking processes in the user's cooking history. Furthermore, we exclude the ingredients from the filtered recipes if they are also included in the user's cooked recipes.

Table I: example of obtained nutrients.

protein	lipid	carbohydrate	dietary fiber
sodium	potassium	calcium	magnesium
phosphorus	iron	zinc	copper
vitamin A	vitamin C	vitamin D	vitamin E
vitamin K	vitamin B1	vitamin B2	niacin
vitamin B6	vitamin B12	folic acid	pantothenic acid

The recipes for estimating the user's least favorite ingredients as the blue color of the Venn diagram in Fig. 2. Then, we calculate the least favorite ingredient value as well as the most favorite ingredient value into Eq. (4).

$$I_k^- = IF_k^- \times RF_k^-. \quad (4)$$

Here, we calculate the usage frequency of ingredient by utilizing the simple frequency ( ) for the ingredient k that does not cook for a definite period D as follows:

$$IF_k^- = \frac{f_k^-}{D}. \quad (5)$$

Then, we calculate the specificity of ingredient k ( ) using the total number of recipes (C) from the user's recipe browsing history excluding the cooking history and the number of recipes that contain ingredient k ( ) as follows:

$$IRF_k^- = \log\frac{C}{C_k^-}. \quad (6)$$

B. Calculation of Nutritional Balance Scores

In this paper, we calculate the nutritional balance score for each recipe based on the daily nutrition value for each ingredient and the reference values of dietary intakes.

Firstly, we obtain the daily nutrition value for each ingredient included in a recipe from Standard Tables of Food Composition in Japan published by the Ministry of Education, Culture, Sports, Science, and Technology. The obtained nutrients are shown in Table. I.

Next, we generate the feature vector A which consists of the daily nutrient values for all ingredients of the recipe.

In addition, we generate the feature vector B which consists of the reference values of dietary intakes obtained from the Dietary Reference Intakes for Japanese announced by the Ministry of Health, Labor and Welfare. Furthermore, we normalize the feature vectors A and B as follows:

$$Y = \frac{X - X_{\min}}{X_{\max} - X_{\min}}. \quad (7)$$

Here, X denotes the given data and Y is a function that returns the normalized value. is the maximum value of the data and is the minimum value of the data. Then, we calculate the nutritional balance score of each recipe that is the cosine similarity between the feature vectors A and B based on their normalized values.

C. Recipe Scoring

In order to calculate the recipe scores, we first normalize both the personal preference score and the nutrient score for each recipe by Eq. (7). Since normalization may cause something with a score of 0, we do +1 on all scores normalized to eliminate it. Then, we calculate the score of each recipe by multiplying its personal preference score and nutrition score based on the above processing. Finally, we rank the recipes in search results based on their scores and recommend them to users.

IV. EVALUATION

A. System Example

An example of a recipe ranking about Meat and Potatoes through our proposed recipe recommendation system considering both user's taste preferences and nutritional balance is shown in Fig. 3. The left table shows a new arrival ranking of top-10 recipes that were searched for "meat and potatoes" through cookpad. The right table shows a recipe ranking that was re-ranked the new arrival ranking in the left table based on our proposed recipe scoring method. In particular, we found that the third recipe in the new arrival ranking was re-ranked as No. 2 of our proposed recipe ranking, the eighth recipe in the new arrival ranking was re-ranked as No. 3 of our proposed recipe ranking, and the ninth recipe in the new arrival ranking was re-ranked as No. 4 of our proposed recipe ranking. Also, the user's taste preference score and the nutritional balance score for each recipe are presented. As shown in the right table of Fig. 3, the top-ranked recipes with both high user's taste preference score and high nutritional balance score, we confirmed that our recommended recipes could reflect the user's most favorite ingredients and least favorite ingredients, and our recommended recipes could provide essential nutrition solely from the user's most favorite ingredients.

B. User Study

cookpad (New Arrival)

	Food Recipe
1	Basic meat and potatoes using pork belly
2	Sour match tomato de western-style meat and potatoes
3	Basic meat and potatoes
4	Easy in frying pan ! basic meat and potatoes
5	Gentle taste of meat and potatoes
6	Bamboo shoots and potatoes meat and potatoes with bacon
7	Meat and potatoes in our house
8	Ginger flavored meat and potatoes
9	Meat and potatoes with green pepper and leek
10	Citron ponzu with refreshing meat and potatoes

Re-rank

Proposed Method

	Food Recipe	Recipe Score	Personal Taste Preference	Nutritional Balance
1	Basic meat and potatoes using pork belly	3.154	1.577	2.000
3	Basic meat and potatoes	2.479	1.989	1.246
8	Ginger flavored meat and potatoes	2.300	1.716	1.340
9	Meat and potatoes with green pepper and leek	2.033	1.681	1.209
6	Bamboo shoots and potatoes meat and potatoes with bacon	2.006	1.681	1.193
5	Gentle taste of meat and potatoes	2.000	2.000	1.000
2	Sour match tomato de western-style meat and potatoes	1.938	1.684	1.151
7	Meat and potatoes in our house	1.887	1.407	1.341
4	Easy in frying pan ! basic meat and potatoes	1.785	1.577	1.132
10	Citron ponzu with refreshing meat and potatoes	1.149	1.000	1.149

Fig.3. Example of recipe ranking about Meat and Potatoes.

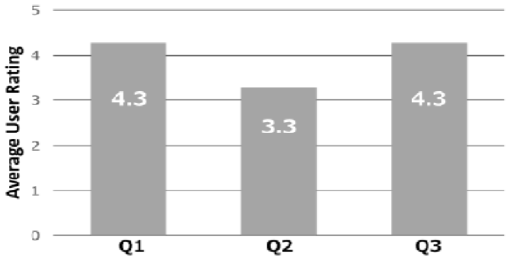

Fig. 4. Results of Q1 to Q3 in questionnaire.

The purpose of the user study is to evaluate the effectiveness of our proposed food recipe recommendation system. The study is completed by three subjects with a questionnaire. The results of the questionnaire showed that our proposed food recipe recommendation method can help users find recipes that suit users' requirements. In particular, we confirmed that subjects want to use their most favorite ingredients while paying attention to nutritional balance.

The subjects were one female and two males, we firstly recorded their cooking histories and recipe browsing histories. We then calculated the scores of recipes of Meat and Potatoes and presented top-10 recipes to each subject. After that, we conducted the questionnaire with the following six items.

Q1: Recipes reflected your most/least favorite ingredients.

Q2: Recipes that you want to cook are ranked on the top.

Q3: You want to use this system in the future.

Q4: Write strong and weak points that you considered.

Q5: Write improvement that you want to improve.

Q6: Write other functions that you want to add.

The average user rating of Q1--Q3 by using five-level scales is shown in Fig. 4, and high rating denotes good results. Our findings are discussed as follows:

- In Q1, the average user rating was high, we confirmed that most favorite ingredients and least favorite ingredients could be reflected in our recommended recipes.
- In Q2, the average user rating was low, because the recommended recipes including least favorite ingredients were ranked on the top.
- In Q3, the average user rating was high, we confirmed that our proposed recipe recommendation method is useful to satisfy users' requirements.
- In strong points of Q4, many opinions said that most favorite ingredients and least favorite ingredients were reflected in the recommended recipes. Other opinions said that recipe recommendation method was better to recommend recipes with users' most favorite ingredients without choosing a recipe. In weak points of Q4, such as an opinion said that most favorite ingredients were not ranked on the top but least favorite ingredients were ranked on the top.
- In Q5, some opinions such as differences between the recommended recipes, ranking mixed with other recipes, similar recipes, and so on.
- In Q6, some opinions of presentation information such as cooking times, calorie information, most favorite ingredients, and least favorite ingredients. Other opinions said that recipes should be divided by purposes.

C. Discussion

In summary, recipes including least favorite ingredients were ranked on the top, we need to present ingredients that would substitute for those least favorite ingredients. In addition, the user often eats while enjoying food appearance, photos were also used for choosing recipes. Based on the above, we obtained a good result for the recommended recipe ranking. Since the top-recommended recipes including least favorite ingredients, in the future, we need to improve the estimation accuracy of most favorite ingredients and least favorite ingredients. Furthermore, we considered that not only most favorite ingredients and least favorite ingredients or nutritional balance, but also other factors such as moods and cooking times are needed.

CONCLUSION

In this paper, we constructed a novel system for recommending food recipes considering both user's taste preferences and nutritional balance. In order to evaluate the effectiveness of the proposed system, we also conducted a user study on the recommended recipe ranking by our proposed system. The results showed that the proposed method can help users find recipes that suit users' requirements. In the future, we enhance the proposed method based on experimental results and verification experiments will be carried out with many more subjects. Furthermore, we will consider the validity periods of the user's cooking and browsing history.

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