Personalized Food Recommendation

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Abstract. In this paper a food recommender system giving general and personalized advice is described. The system is based on semi-formal knowledge of personal nutrition gained in a previous project (Food4Me). This project implements a manual expert knowledge based approach using a decision tree for recommending optimal adaptions to the individual nutrition behavior. The system was evaluated in a Proof-of-Principle study whose results lead to the current two research projects. The first project aims at an automated recommender system based on formalized expert knowledge building on the insights from Food4Me. This recommendation system is then extended by including it into an application which provides continuous feedback on the participant's nutritional behavior. Also individual preferences are integrated using approaches from critique based- and persuasive recommender systems. The second system uses an adapted collaborative filtering approach to recommend food based on healthiness and taste ratings of other users augmented by a rating based recommender system for sports. This recommender system is further extended by social support groups and game interaction in view of social motivation. In the future both projects might be used in combination to provide optimal health support.

Keywords: Food Recommendation, Personalized Recommendation, Social Recommender Systems, Collaborative Filtering.

1 Introduction and Motivation

Food recommendation challenges the way recommender systems are used, since it requires a strong adaption to the domain specific requirements in order to provide individually valid and practically usable health advice. On one hand, user ratings of food taste may be individually reliable in view of using them in a collaborative filtering approach. On the other hand, the variety of nutritional advice available and the difficulty of knowing all ingredients and nutrients in a given meal make it harder for consumers to judge the health value of their meal. Thus a personalized recommender based on expert knowledge may be necessary to provide good results.
On the other hand, the impact on nutritional behavior not only depends on the quality of the given recommendations but also on the context in which they

are given. This context may be the quantity and frequency of recommendations or the personal context of the receiving user. To increase the adaption rate, the system needs to provide strong motivational factors such as a user-centric design using state of the art usability features and social components such as user to user interaction.
As a first step towards personalizing food recommenders, the influence of considering individual biological markers on the overall adaptation success was studied in the Food4Me Project [1]. Although recommendations based on personalized dietary and biological information were previously implemented and evaluated, as described in [1], new biological markers and new insight into their correlation with nutritional aspects justified reevaluating the knowledge base by conducting the Food4Me project [1].
Furthermore, we aim at investigating approaches for automating the manual recommender, at comparing crowd sourced knowledge with expert knowledge and at improving the previous project's evaluation results in terms of effect on individual health.

2 Previous Research and Results

The previously conducted Food4Me project [1] included a Proof-Of-Principle study about the effect of personalization on healthy nutrition recommendations. The recommendation system applied was based on expert selected rules and considered the dietary intake, the phenotype and the genotype of participants. The study was split into four different recommendation groups [1]:

1. Control Group getting general health advice
2. Group L1 of personalized food recommendations based on dietary intake
3. Group L2 based on L1 and phenotypic data
4. Group L3 based on L2 and genotypic data

The dietary intake was recorded with a Food-Frequency-Questionnaire (FFQ) at different stages in the study. Based on that intake and the additional biological markers suggestions of adapting the participant's nutritional behavior were given together with explanations about the reasons for these suggestions [1]. The results [7] showed an overall positive impact of personalized recommendations on the users' nutritional behavior. While the control group reduced its energy consumption by 1050 kJ per day, the personalized groups reached an average of 1500 kJ per day. In between the different personalization features, the highest impact came from considering the dietary intake (-5050 kJ). The phenotypic addition L2 and the genotypic element L3 strongly increased either the healthy eating index or the energy reduction but always show negative influence on the opposite value.
Another part of the Food4Me project presented optimized meal plans instead of nutritional advice [6]. This study showed that meal recommendations are welcomed but should be provided in a flexible way.
In the research field of food recommender systems Freyne et al. [2] analyzed

that collaborative filtering can improve personalized recipe recommendations compared to content based approaches. They also found that the food item level provides better accuracies than the recipes, when available. In more recent work (Ge [3], 2015) food recommender systems are optimized algorithmically by using an extension of Matrix Factorization, but also optimized considering the human computer interaction responsible for the acceptance of recommendations. Building on this application they even consider the health and taste utility when recommending recipes [4], but are constricted to the calorie value.

3 Current Work on Personalized Food Recommenders

Building upon the results of the Food4Me project in the enable cluster both an automated recommender system based on expert knowledge and continuous dietary intake information and a recommender system using collaborative filtering on crowd based taste and health ratings will be implemented.
The knowledge based recommender will work closely with the results of the Food4Me study. The impact of dietary intake personalization will be amplified by offering a nutrition diary where the user can enter any food he consumed. To simplify this step, many food items and meals are backed up by recipes that can be searched and adapted to the real intake. The healthiness of these recipes is evaluated by the contributions of a food item to a set of food groups developed in a contributing foundational study [5] instead of focusing on specific nutrients. Based on the general dietary consumption guidelines from Food4Me a health scoring was developed that ranks food items or meals based on previous consumption in each food group from the user's diary and the food group contributions of the food item in question [5]. The representation of most items in form of recipes was not only chosen to simplify the user input process, but also to provide the user with a ranked list of options for his next meal instead of only health advice. To keep the transparency each meal recommendation is combined with the health advice causing its ranking, which enables the user to learn about the logical connection to his behavior and thus increases his motivation. An additional feature of this personalization is to filter out meals that contain elements excluded by the user profile because of either allergies and intolerances or individual and religious preferences.
The crowd based recommender considers the motivational and social components of adapting one's nutritional habits. It recommends the food that similar users rated with high taste and health values using a collaborative filtering approach. The users have the option to post meals which they previously entered into their nutrition diary. By doing so they receive social feedback on their previous nutritional behavior when observing the received ratings. Another social element that will be introduced in this system are support groups of 8-10 people. Those groups are created considering the similarity of health issues between users. Further options would be to involve family members or school peers as a separate group environment. Those groups offer the opportunity to exchange messages, share meals or exercises and to review each others nutrition diaries. In addition

to the social support those groups should provide a usage incentive by offering games and group recommendations (of food and sports activities) for the group to interact with. These games can either have an educational focus in terms of healthy food or motivate to do more exercise by requiring physical activity or by advertising the fun of group sport activities. Also games focused on fun aspects can be linked to the nutritional adaptation by providing the game avatars with special strengths or gadgets whenever a health goal is achieved.
Both systems will be evaluated in their impact on user adaption and thus allow conclusions about the value of expert knowledge against crowd intelligence. It also reviews the impact of self awareness and self-management introduced by the health advice in knowledge based recommendations against the impact of social awareness and peer group effects created in the crowd based solution. The inclusion of exercise is only considered as a social and motivational component at the moment, but could be extended when showing significant impact.

4 Long Term Vision

After successfully studying both project approaches, there will be further issues open for investigation. One vision is to build a hybrid recommender system that includes both the expert knowledge as well as the crowd ratings. A second vision currently is to create an analogous hybrid recommender system that ranks possible sport or fitness activities based on user ratings and their health effect. Further perspective extensions are meal and exercise recommendations for complete groups which will enable families or groups of friends to plan their meals ahead. Another extension with regard to the usability is automatic meal recognition from speech or images. The evaluation of both projects will show which of these visions show the best potential for further health improvement.

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