How to apply the User Profile Usability Technique in the User Modelling Activity for an Adaptive Food Recommendation System for People on Special Diets

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ABSTRACT

Interest among software professionals in the possibility of adapting software to user requirements has grown as a result of the evolution of software analysis, design and implementation thinking and the growth in the number of software systems users. Moving away from the traditional approach where the user has to settle for the options offered by software systems, different factors, like user needs, aspirations, preferences, knowledge level, goals and other distinguishing features, have to be taken into account for this purpose. Technically, this possibility is referred to as adaptiveness, and it requires user data. It is these data (user model) that determine the adaptiveness conditions. Our aim is to build a user model for adaptive systems applied to nutritional requirements, modelling user characteristics that affect their diets and help to improve their health. To build the user model, we apply the user profile usability technique. In order to validate our proposal, we analyse and design a preliminary prototype of an adaptive system capable of making food recommendations to satisfy specific user needs. This study revealed that diet is a propitious field for the development of adaptive systems and that user modelling is a good choice for design of this type of systems.

Keywords: User modelling, Diets, Usability techniques, User profiling, Human Computer-Interaction, Software engineering.

1. INTRODUCTION

Software engineering professionals are now taking an interest in the possibility of building applications that are accessible to a large number of users as a result of the popularization of the Internet as a means of disseminating information, the range and quality of new development tools, plus user heterogeneity and the demand for systems that adapt to user characteristics [1]. To do this, they take into account the particular characteristics of each user (for example, their individual needs, goals and characteristics). Adaptive systems emerged, as an alternative for addressing the problem of user heterogeneity and providing appropriate solutions according to user particularities, in order to cater for user idiosyncrasy [1] .

Today, obesity and overweightness constitute a serious health problem all over the world. The high obesity rate has unleashed a number of initiatives and financial resources in North American and European countries aimed at developing strategies and mechanisms to deal with and mitigate the effects of this alarming increase [2]. Due to the growth in the number of people who are overweight and/or suffer from a chronic disease, a healthy diet is a major question the world over. However, healthy eating is not about strict nutrition philosophies, staying unrealistically thin or depriving yourself of the foods you love. Rather, it is about feeling good, having more energy, and keeping yourself as healthy as possible without having to stick to strict diets [3]. Consequently, a healthy diet is important for keeping your weight right. However, there are not many recommendations for improving lifestyle [3]. Adaptive systems are an alternative for implementing a software application to promote healthy eating. An adaptive system is capable of changing its behaviour according to the goals, tasks, interests and other characteristics of users or user groups (for example, an adaptive virtual education system for maximizing student learning) [4]. In our research, we have considered adapting the user profile technique to model users of a software system that adapts existing meal plans to user circumstances. Our prototype system uses filtering (based on the user model) for adaptiveness, as well as the Apriori algorithm for the learning process [5]. Additionally, it makes recommendations according to user preferences. There are not many research papers on diet-related adaptive systems to support improved eating habits in the literature [2], [3], [6]. Neither are there many companies that provide a nutrition and diet counselling service [7]. Therefore, further research is required in this field.

Our research makes contributions to two areas: i) food and nutrition, and ii) user modelling, since we have not found many adaptive solutions related to the creation of customized meal plans to meet diets. The aim of this paper is to model the user employing usability techniques from the human-computer interaction (HCI) area in order to design a prototype adaptive system. Therefore, our original contribution to this research is to adapt HCI knowledge to software engineering (SE) applying usability techniques, and especially the user profile technique, in an adaptive system for generating 7-day diet meal plans (menus).

We have considered several criteria in the design of our prototype system, including, for example, user eating habits and level of physical activity. The system will be able to infer a series of food recommendations in order to create a 7-day diet meal plan for the user. The aim is to improve the user's eating habits, considering the healthy eating patterns specified by an expert nutritionist. The mission of the expert nutritionist is to provide nutrition recommendations according to the dietary requirements of each person (especially for users who are unfamiliar with this issue). However, as not everybody has access to an expert nutritionist on demand, we have built a prototype system that will enable people, especially people who require special diets, to easily and effectively plan a 7-day meal plan that improves their current eating habits.

Although there are some proposals on the integration of HCI usability techniques into SE processes [8], [9], [10], [11], [12] these techniques usually have two pitfalls that limit their use within SE [8], [9]. On one hand, there are no well-defined, comprehensive and detailed procedures to guide software engineers through the correct application of the technique. On the other, they do not prescribe the structure of the documents output by applying each of the steps of the technique. Therefore, this research paper focuses on adapting and applying a systematic and formalized user profile technique as part of the user modelling activity for the development of an adaptive system.

This paper is organized as follows. Section 2 describes the research method used. Section 3 reports the state of the art. Section 4 describes the development methodology. Section 5 explains the proposed solution. Section 6 discusses the results of this research. Finally, Section 7 outlines the conclusions and future work.

2. RESEARCH METHOD

We conducted a literature review covering the fields of SE, HCI [8], [9], [13] and adaptive systems [2], [3], [6]. Of the different research papers analysed, we selected the categorization of usability techniques proposed by Ferré. For each of the main SE activities, Ferré identified and compiled the related HCI usability techniques [14]. We selected the user profile technique for the user modelling activity on the following grounds. The aim of this technique is to gather information about the planned system users and provide details about who is to use the software [14]. Additionally, it serves as guidance for designing applications, always bearing in mind the user [8], that is, the user profile technique helps developers to get acquainted with who the users will be. In order to review the literature related to user modelling for adaptive dietary systems, we conducted a systematic mapping study (SMS) [15]. The electronic databases (DBs) used in the SMS were: IEEE Xplorer and ACM Digital Library. The search was divided into two phases. During the first phase, we examined the title and abstract of the papers (a total of 91) identified in both DBs. As a result, we selected 17 as potentially relevant papers for our research. During the second phase, we read the abstract, introduction and conclusions of each of the 17 papers to determine whether they described the user model for an adaptive system. Finally, as a result of the second phase, we retrieved eight relevant papers (primary studies) [16], [17], [18], [19], [20], [21], [22], [23]. The retrieved primary studies contain specific information on user modelling not for adaptive food systems but for other areas (education, news and commerce). Nonetheless, these primary studies do suggest that this is an emerging research field.

3. STATE OF THE ART

Usability is one of the key quality attributes in software development [9]. The HCI field offers usability techniques whose main aim is to output usable software. Some usability techniques have been adapted ad hoc for adoption in software applications development [24]. The research problem considered in this paper addresses how to adopt the user profile technique for user modelling in adaptive systems. To do this, we analyse and previously identify which obstacles have to be overcome to be able to apply this technique. Ferré [14] compiled a list of techniques recognized by HCI. He also determined the representative SE activities in which they are used. By adapting usability techniques, we can achieve the standards of systematicness required in SE for their adoption in the adaptive systems development process.

In order to discover the particular characteristics of users, it is necessary to identify the user profiles targeted by software system use. In this manner, it is possible to account for individual user needs [25]. On one hand, Hix and Hartson refer to this technique as a series of representative user classes in terms of the tasks that will be performed in order to determine the user skills and knowledge [26]. On the other hand, Mayhew presents user profiling as a method that describes the planned system users according to several attributes (for example, psychological, physical and knowledge characteristics) [13]. According to Nielsen, much of the information used to characterize user profiles can be gathered directly from questionnaires or interviews. However, the best results are achieved when users are observed or addressed in their own work environment [25].

There is no related work on user modelling for adaptive food systems in the literature. However, we have found a few papers on user modelling in other areas like education, commerce and news. First, Razmerita proposes an ontology-based user model for a semantic web [23]. Second, Salvador et al. propose a user model for adaptive hypermedia systems using a structure based on fuzzy theory [21]. Thirdly, Colak et al. [18] propose a user modelling approach to facilitate fast and powerful adaptation to user needs in a hypermedia educational system. Fourthly, Wongchokprasitti and Brusilovsky [22] report an open user model for an adaptive system that is capable of recommending or classifying news content so that users can easily find what they are looking for. Finally, Domik and Gutkauf [19] give tips for generating a user model as a basis for a user model for an adaptive visualization system. This model is generated by extracting user information through explicit and implicit modelling and by observing the user performing special tasks.

There are hardly any research papers describing proposals of adaptive systems for improving eating habits. First, Guixeres et al. [2] propose a ubiquitous monitoring platform enabling the clinician to gather information from patients in order to personalize and adapt their obesity treatment depending on their evolution. In the experiment conducted by Guixeres et al. [2], patients (children) were given a PDA to record what they ate and the physical activity that did in their natural environment. Secondly, Lee et al [3] reported the implementation of an adaptive personalized diet linguistic recommendation mechanism. This mechanism is based on type-2 fuzzy logic systems and the genetic fuzzy markup language. Third, Pinter et al. [6] propose an expert system for nutritional counselling focused on the medical supervision of the patient's diet at home. This originality of this research is that it includes harmony rules in the 7-day meal plans. The harmony rules assure that the diet provides the right quantities of the different food nutrients with respect to their respective share of the total energy value [6].

4. DEVELOPMENT METHODOLOGY

In this section, we describe the development methodology used to design a prototype adaptive food recommendation system. On one hand, traditional methodologies aspire to systematize the software development process and render it predictable and efficient. The main problem with this approach is that a lot of activities have to be performed to follow the methodology, and this holds back the development stage [27]. On the other hand, agile methodologies have two key differences from traditional methodologies. The first is that agile methods are adaptive —not predictive—. The second is that agile methodologies are people and not process oriented [27] where changes are expected events that generate value for the customer [28]. On these grounds, we opted for the agile methodology known as adaptive software development (ASD) [29]. In the following, we briefly describe the activities comprising each of the three phases of this methodology: speculate, collaborate and learn.

First, we planned and designed several activities with a view to carrying out proofs of concept on a preliminary prototype during speculation. These activities were: identify system requirements, design the user model, plan the adaptive components (growth, conservation, release and reorganization) and finally design the prototype [30]. The basic requirements that we identified were that the system should be capable of preparing 7-day menu plans based on the needs of each user and take on board new user requirements with time. The second step during speculation was user model design. Bearing in mind the important role played by users, we conducted a thorough investigation of this issue. It became the major focus of our research, as mentioned above. This paper describes the two main activities (identify system requirements and design the user model) carried out during speculation and reports a rough design of the user model of the adaptive food recommendation system for people with special diets. A description of the activities carried out for user modelling follows. First, we conducted a preliminary investigation using several reference sources, such as articles ([2], [3], [6]), books [31] and web sites [7] related to the food and nutrition context. Later, we prepared a database of questions taking into account the basic items required for user modelling (for example, personal information, information related to user experience and skills and information on user habits and interests). We used the user profile usability technique since users play a leading role in system development and in the design of the user model. As this technique had not yet been formalized, we opted to adapt it for the purposes for this research. In the user profile technique, we use a questionnaire to gather information about users which is the basis for user modelling. Figure 1 shows an excerpt of the questionnaire that we used and which was built into the prototype.

Second, with a clear idea about what they aimed to achieve and two-way communication, the work team members embarked, during collaboration, upon the scheduled tasks. Finally, having analysed prototype planning and development, the team members started, during learning, to develop the adaptive cycle components (growth, conservation, release and reorganization), looking in particular at how the system learns [30]. In this regard, we used the focus groups technique to ask the user whether or not he or she would like to add any characteristic or requirement (for example, recent illness, different preferences or any current nutritional need) that may affect the preparation of the visualized menu [29]. For learning purposes, we initially used the Apriori learning algorithm [5].

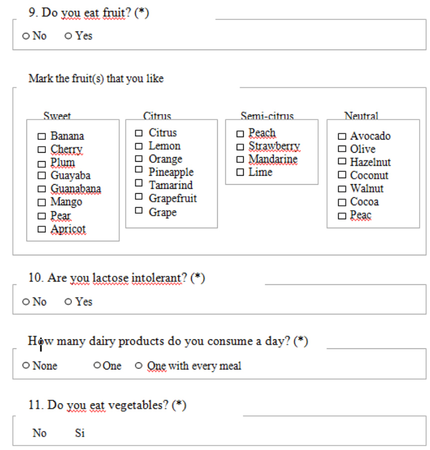

Figure 1: Part of the prototype screen with some user modelling data.

5. PROPOSED SOLUTION

User Modelling

We used the user profile technique, employed in HCI for user analysis, for the user modelling activity. User profiling is a way of gathering information about the planned system users [14]. Different procedures for applying this technique have been reported in the analysed literature [13], [14]. The approach proposed by Mayhew [13] is a good option, because it offers a comprehensive description of the technique as regards what to do and how to do it. According to Mayhew [13], the user profile technique is divided into 12 steps. In the following, we describe the first three steps of this user modelling technique. In Step 1 (Determine user categories), as we did not have access to expert nutritionists, we conducted preliminary research resorting to different reference sources (for example, papers, books, web pages) in order to determine possible user categories. Likewise, for Step 2 (Determine key user characteristics), we held a meeting in order to solicit the opinions of team members in order to design a questionnaire template. In this step, we relied mainly on the Donostia Hospital diet codes manual to create a preliminary version of the questionnaire that would later determine the food menus [31]. In Step 3 (Prepare draft questionnaire) we inspected and expanded the questionnaire template developed in the previous step. We conducted a similar analysis for each of the 12 steps of the user profile technique in order to identify the tasks required to apply the technique. Table 1 illustrates Mayhew's user profile technique [13] as formalized in this paper, giving a brief description of the tasks to be carried out.

We used the user profile technique to determine the key information to be gathered (for example, personal and medical data, habits and context) for user modelling with regard to special diets. In this manner, some of the by user modelling output data were also used as prototype input data. Later, we identified the user profiles (for example, hospital patients and overweight patients) in the food systems area.

Table 1: User profile steps and tasks

Technique steps		Tasks
1	Determine user categories	Consult experts or other reference sources with regard to possible user categories related to eating habits
2	Determine key user characteristics	Create a questionnaire template and record user characteristics
3	Prepare draft questionnaire	Expand the questionnaire template
4	Gather management feedback on the draft questionnaire	Formalize questionnaire data approval and entry
5	Review the questionnaire	Review feedback on the questionnaire for adoption
6	Pilot the questionnaire	Invite two users participating in the design of the pilot questionnaire for an interview
7	Review the questionnaire	Review the interview feedback and adopt suggestions in questionnaire
8	Select user sample	Recruit the user sample
9	Administer questionnaire	Distribute questionnaires to participating users
10	Design data input format	Use a spreadsheet to design the input format of the data to be summarized
11	Enter, summarize and interpret data	Analyse and summarize the data in a similar format to the template suggested by Mayhew
12	Report data	Complete a summary form stating the conclusions and design implications

We designed a questionnaire (adapted from Mayhew [13]) in order to create user profiles based on the guidelines given in the user profile technique. The questionnaire is divided into four sections: demographic data; tastes, preferences and habits; medical record, and food consumption and budget. The first version of this questionnaire was drafted in Step 2 of the user profile technique. An excerpt from the questionnaire used is shown in Figure 1. The user completes this questionnaire only once as part of initial user-system interaction, that is, the questionnaire is not displayed the second time that the user logs into the system. We gathered food recommendations from this initial questionnaire-based user-system interaction. The user profile technique can be applied to form a rough idea of the type of users of such applications: a segment composed of personal data, including characteristics, such as habits, medical data and context.

By way of a proof of concept on the preliminary prototype, we decided to use just data on user current weight, stature and level of physical activity, plus the standardized body mass index (BMI) for men and women.

Prototype analysis and design

We first conducted preliminary research into aspects like nutrition, diet preparation, most common diseases among the population requiring special diets, preparation of daily meal plans based on the hospital diet code manual [32]. After analysing these issues, we determined the problem to be solved. The first step was to model the user for the prototype (which we called the GOOD EATING system 1.0). To do this, we took into account expert-based knowledge [32] and decided that the system should be machine learning capable. A number of different rules represent the user model based on expert knowledge. They drive the inference process during adaptation [32]. Our prototype is based on user types for which certain characteristics and rules were defined beforehand. Table 2 presents a fragment of the rules considered for the creation of the prototype system. Additionally, the user model also includes a machine learning system based on data gathered from successive interactions with users. In this paper, we used the following user characterization for modelling: group of people aged between 13 and 50 years. The user information applied in order to model the GOOD EATING system 1.0 is based on the following criteria: (i) the personal and demographic data of the users (country, gender, age, stature, weight, number of meals per day and type of food), (ii) tastes (eating habits and known allergies), (iii) religion (Christian, Muslim, Jewish and not applicable), (iv) medical record (including data on dietary recommendations for people with common and rare chronic diseases), (v) usual level of physical activity (sedentary, moderately active and active), (vi) recommended calorie intake for a particular physical constitution, body mass index and level of daily physical activity (weight, stature and BMI are considered for this purpose).

Table 2: Example of rules

Rules	Pseudocode

R10: Is female
R11: Exercises
R20: Is sedentary
R21: Is moderately active
R22: Is active
R40: Is male
R50: 1800 kcal diets
R51: 2200 kcal diets
R52: 3000 kcal diets
R60: Has an illness
R70: Suffers from diabetes
R71: Diabetes diets
R80: Suffers from high cholesterol
R81: Low-cholesterol diets
	BMI_Women=20.9 ; BMI_Men=22.4
	Read (RealWeightWoman, StatureWoman)
	Function Weight (RealWeightW, IdealWeightW)
	{// begin Function Weight
	If (RealWeightW> IdealWeightW) {
	If (R60 ==True) {
	If (R70 ==True){
	R71=True
	print (R60, R70, R71)
	} Else {If (R80 ==True) //high cholesterol
	{R81=True}
	print(R80, R81) }
	} Else { R51=True
	print (R51)}
	} //END IF RealWeigntWoman
	print (" Ideal Weight Woman is: ", IdealWeightW)
	} // End Function Weight
	//***************
	Function Weight_Two(RealWeightWTwo, IdealWeightWTwo)
	{
	If R22==True {Kilocal=IdealWeightWTwo*40
	Function Weight (RealWeightWTwo, IdealWeightWTwo)
	print(R22)
	} Else { Kilocal= IdealWeightWTwo *30
	Function Weight (RealWeightWTwo, IdealWeightWTwo) } }
	} //End Function Weight_Two
	//*********
	If (R10 ==True) {
	IdealWeightWoman=(StatureWoman)^2*20.9
	If (R11==True){
	If (R21==True) {
	Kilocal=IdealWeightWoman*35
	Function Weight (RealWeightWoman, IdealWeightWoman)
	print (R11, R21)
	} Else {
	Function WeightTwo(RealWeightWoman, IdealWeightWoman)
	} Else // If R11
	{ Function Weight (RealWeightWoman, IdealWeightWoman)}
	}Else //If R10
	{IdealWeightWoman= (StatureWoman)^2*22.4 ….}

According to our analysis, the key criteria are the recommended calorie intake for a particular physical constitution and BMI, and the level of daily physical exercise. These two criteria, together with user preferences, have been used to implement the preliminary prototype. This prototype asks users a series of questions in order to gather their personal and medical data and their tastes and preferences that are later used to generate the food recommendations. The questionnaire items (see Figure 1) were prepared based on research into adaptive systems, user modelling, diet manuals and a review of commercial nutrition systems.

Prototype implementation

After assessing different options (for example, taking into account which products are easier to find in order to prepare economical menus by considering the climate of a particular country) for developing rules based on data gathered from the user and all the above-mentioned criteria, we decided to implement the prototype considering the criteria of user food preferences and recommended calorie intake by user constitution, BMI and daily physical activity. Using these criteria, we output three 7-day diet meal plans by number of calories (1,800, 2,200 and 3,000 kilocalories). These are the diets considered in the Donostia Hospital menu code manual (Basque Country, Spain) [31]. Figure 2 illustrates an excerpt from the 1,800 calorie 7-day recommended diet plan.

		MONDAY	TUESDAY	WEDNESDAY
BREAKFAST	A	Coffee, skimmed milk, saccharine	Coffee, skimmed milk, saccharine	Coffee, skimmed milk, saccharine
		25 g bread	25 g bread	25 g bread
		Margarine and fruit	Margarine and fruit	Margarine and fruit
LUNCH	A	Lentils	Leek and Potato Soup	Cream of vegetable soup
		Roast Chicken	Salmon	Roast beef
		Fruit	Sugar-free fruit flan	Fruit

Figure 2: 1,800 calorie 7-day diet meal plan

The dishes included in these three diets are the benchmark dishes for the menus recommended by our prototype GOOD EATING system 1.0. We also have to calculate the ideal weight of the user using the following formula:

$$\text{Ideal weight} = (\text{StatureWoman})^2 \times \text{BMI} \qquad (1)$$

Where BMI is the body mass index, which is 22.4 for men and 20.9 for women [27]. These BMI values were considered for the purposes of rough calculation. The GOOD EATING system 1.0 takes the result of Equation (1) and the level of physical activity entered by the user to calculate the recommended calorie intake [31]. It then allocates the dishes to the 7-day diet meal plan as appropriate: (i) if the level of physical activity is sedentary, the recommended calorie intake is: ideal weight x 30, (ii) if the level of physical activity is moderate, the recommended calorie intake is: ideal weight x 35, (iii) if the level of physical activity is active, the recommended calorie intake is: ideal weight x 40.

6. DISCUSSION

Note that the questionnaire built into the prototype GOOD EATING system 1.0 is a pilot version. This questionnaire includes data output by user modelling and is designed to populate the database based on information supplied by the user with respect to the following categories: food preferences (eating habits), religion, medical record and recommended calorie intake according user physical constitution and BMI. Additionally, it is planned to add the categories of climate, place of residence (location), budget, meal preparation time and meal rating into prototype development.

The system learns automatically as the users use the system and rate the recommended menus. Accordingly, the system is capable of continuously improving its recommendations, that is, it uses the user ratings to learn which menus receive better ratings and recommends these meal plans in preference to others with worse scores.

Our research has two shortcomings. On the one hand, we have not tested the prototype with real users in order to evaluate its effectiveness. Through user testing we would be able to find out whether the recommended diets are healthy and improve eating habits. On the other hand, we were unable to contact food and nutrition experts to request feedback, comments and suggestions and relied exclusively on the literature in this regard. However, the researchers do have practical experience in the field of usability.

7. CONCLUSIONS AND FUTURE RESEARCH

In this paper we proposed a method for modelling users of an adaptive food recommendation system applying the user profile usability technique. To do this, we had to adapt the technique for application (for example, we used other reference sources, such as specialized books, because we did not have access to an expert nutritionist to determine possible user categories). Our proposal is the result of preliminary research to partially validate, by means of a proof of concept (through prototyping), the user profile technique as far as step 3. With regard to the prototype, several iterations of user testing of the proposed system are required to adapt the system to their needs. We are aware that there still is a long way to go both in this particular case and also in the area as a whole. The fact that the few studies that we have found were published recently attests to this point. Our system considers several criteria, for example recommended calorie intake according to physical constitution, BMI and level of daily physical activity.

This research was motivated primarily by the fact that there are hardly any studies on usability techniques applied in the user modelling activity for the development of adaptive food recommendation systems in order to create menus for customized diets recommended by a nutritionist. The results of our research show that user modelling by means of usability techniques is perfectly feasible in the field of adaptive systems design for any user and especially useful for users requiring special diets. As future work, we will validate the other user profile technique activities and extend our study to develop new proposals for other contexts (for example, in the field of healthcare and sports). Additionally, we plan to run two experiments with two user groups in order to test our prototype system. Group 1 will be composed of subjects following their usual diet, whereas Group 2 will be composed of subjects following diets recommended by the GOOD EATING system 1.0. By comparing the results of these experiments, we will be able to fine tune and improve the prototype.

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