Socially Aware TV Program Recommender for Multiple Viewers

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Abstract —*With the increasing amount of research on smart TVs, users are interacting with them in an evermore convenient way. However, current program recommendations mainly focus on using individual profiles and require users' active participation when multiple viewers coexist. In this paper, we propose a socially aware program recommender for multiple viewers of a digital TV that rates and selects TV programs based on individual and group preferences. For this task, the proposed recommender generates recommendations for users by merging user profiles and combining their common interests. In this way, programs that all users prefer are automatically selected and ambiguous or conflicting programs are mediated based on user feedback. Through subsequent experiments with a smart TV equipped with the program recommender, we found that the performance of group recommendations improved when individual profiles and the group's common interests were used, and that users preferred different strategies when they were with other people.*[*]

Index Terms — **Digital TV, group recommendation, group decision making, ubiquitous computing.**

I. INTRODUCTION

Digital TVs are one of the most popular consumer products in every home around the world, and have evolved such that they can now provide personalized and adaptive services to users. Due to their popularity, various technologies have been developed that contribute to making the system even more intelligent. For example, electronic program guides (EPGs) provide users with program schedules and detailed information that enables them to search for desired programs from among a number of available programs, and the TV-Anytime Forum specifies the metadata of digital TV [1]. Consequently, additional technologies and applications have become available for consumers, and systems have become more intelligent by exploiting user information such as profiles, history, feedback, preferred program schedule, and the real-time program information offered by EPG and TV-Anytime specifications [2]-[4].

However, although these technologies have improved how well digital TVs respond to users, they must also take into account groups of users that may want simultaneous access to the device, in addition to the above technological achievements.

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Unlike the selections for a single user [5]-[7], selections associated with a group of users are more complex, thus making it far more difficult to deliver the best solution in terms of diverse user preferences and levels of satisfaction. Only limited research, aimed at realizing a future smart TV, has contributed to resolving these limitations; Yu and Zhou proposed a group recommendation algorithm that merges individual user profiles into a group profile based on the distance minimization algorithm [8]. However, this merging only included individual preferences as group characteristics were omitted in the final recommendations. In other studies, Masthoff discussed various selection strategies based on social theory and found that users were not dedicated to a specific selection method, but may use different strategies in selecting programs [9]. The universal controller, proposed by Yoon and Woo, allowed users to intuitively control a smart TV as a group, but it required users to be actively involved in the control [10]. As such, even though various strategies have been developed in attempts to assist the selection of TV programs for a group of users, individual preferences are mainly used in generating lists of preferred programs and in final program selection.

To overcome the above-mentioned limitations, we propose a socially aware program recommender that rates and selects TV programs that meet both group and individual preferences. For this task, the proposed recommender generates a group profile by linearly combing user profiles with common interests. The program recommender then determines the best program based on the group profile in one of following three ways. In the case in which all users are interested in the same program, the assistant automatically selects it as the best program and recommends it, though alternative programs would also be indicated. In the case where users have similar preferences, age, and/or interests, the assistant determines the program to view by sifting through the feedback obtained regarding the list of preferences for a set of possible programs. Otherwise, the recommender selects a program by asking for both category and programs of interest.

We implement a prototype of the proposed program recommender using a digital TV and then evaluate its performance based on the feedback provided by a number of participants in a smart home test-bed. Through this experiment, we found that the proposed social-aware program recommender improved the performance of group recommendations by reflecting both user and group preferences. The recommender was also able to determine an appropriate decision strategy to allow users to harmoniously decide which of the programs of interest to watch.

The remainder of this paper is organized as follows. We first describe the framework for the socially aware TV program recommender for generating and mediating the selection. Then, we present the implementation of the framework integrated in a smart TV, before showing our experimental setting and results, and discussing implications of the results. Finally, we conclude by presenting future directions of the socially aware program recommender.

II. SOCIALLY AWARE TV PROGRAM RECOMMENDER

The aim of future digital TVs is to improve the provision of relevant programs to users. Similarly, the proposed program-program recommender aims to assist a TV in selecting the best program for a group of users watching it at the same time. For this task, the proposed recommender is integrated with a smart TV to manage the potential selections. The recommender is thus comprised of group profile generation, decision strategy determination, and a final selection. Fig. 1 shows the overall architecture of the social-aware TV program recommender.
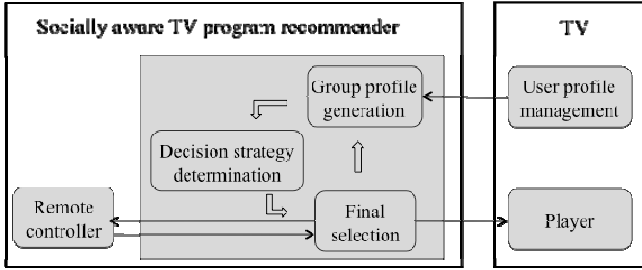

Fig. 1. Socially aware TV program recommender.

As seen in Fig.1, in the group profile generation, users' profiles are merged and combined into a common profile. The group profile, which describes a set of weights and terms reflecting all users' preferences, is then used to rate the programs available on the TV. Next, an appropriate decision strategy is determined based on the group and user profiles. The selection decision attempts to select an appropriate TV program based on the program list rated by the group profile; it automatically determines the highest ranked program between the users. Otherwise, if there are one or more users whose preferences are different, the group is asked to select their preferred program from the list of recommendations. In this case, mediation information consists of categories or programs prior to recommendations being made.

A. Group Profile Generation

In group profile generation, a group profile representing all users is generated by linearly combining individuals' profiles with group characteristics. There are two steps required to obtain the group profile. First, a merged profile is obtained from individual users' profiles. The user profile describes preferences related to the metadata of TV programs, including various terms such as genres, subcategories, keywords, and actors with corresponding preference values. In this step, the average of the weights associated with each term is calculated

as the group preference. Next, the merged profile is combined to generate a list of common interests, which can be extracted from the users' histories or be explicitly set by the users. The group profile thus describes the users based on the terms they used in their individual profiles.

Now, we will describe how the individual profiles are merged into a group profile in further detail.

Let a set of terms used in describing TV programs be $Term = \{term_1, term_1, \ldots, term_N\}$, where the preferences are associated with the terms and specify each user's level of interest in the terms. Each user has a set of weights corresponding to the terms, represented as $UP_i = \{up_{i,1}, up_{i,2}, \ldots, up_{i,N}\}$; each preference $up_{i,j}$ is an integer value, ranging from -5 to 5, where 5 is the highest preference and -5 is the lowest preference. Similarly, let the preferences of the group be $GP = \{gp_1, gp_2, \ldots, gp_N\}$. The goal of merging the profiles is to obtain GP from the individual user profile UPs.

In this process, users' profiles are first merged into an intermediate group profile based on their preferences. Here, users' preferences are normalized with their minimum and maximum preferences since they have different scales.

$$mp_j = \frac{\sum_{i=1}^{M} nup_{i,j}}{M}, \tag{1}$$

where M is the number of users and $nup_{i,j}$ are the normalized preferences obtained from the equation

$$nup_{i,j} = up_{min} + \frac{(up_{max} - up_{min}) \cdot up_{i,j}}{up_{i,max} - up_{i,min}}. \tag{2}$$

In (2), up_{max} is the upper bound and up_{min} is the lower bound of the preference range and $up_{i,min}$ and $up_{i,max}$ indicate the preference range of the profile for each user; the normalization process reweighs all preferences in the range. The updated preference mp_j thus describes the preferences of an intermediate group profile that equally reflects individual preferences.

Next, the merged profile is combined with a common profile to boost common interests of the group since it equally includes the individual user profiles. These two types of profiles are then linearly combined with a certain weight, such that

$$gp_j = \lambda \cdot mp_j + (1 - \lambda) \cdot cp_j, \tag{3}$$

where cp_j are the preferences of $term_j$ in the common profile. The constant λ is the weight for linearly combining the two profiles and is obtained from

$$\lambda = 1 - \frac{\sum_{i=1}^{M} \sum_{k=1}^{M} \mathrm{sim}(UP_i, UP_k)}{M(M-1)}, \text{ where } i \neq k. \tag{4}$$

Here, the function $\mathrm{sim}(UP_i, UP_k)$ indicates the level of similarity between the users in a group, and the constant λ is the weight obtained from the average similarity of users and

thus represents the group similarity. This similarity is calculated by the cosine function [11]

$$\text{sim}(UP_i, UP_k) = \cos(UP_i, UP_k) = \frac{UP_i \cdot UP_k}{\|UP_i\| \cdot \|UP_k\|}. \qquad (5)$$

Therefore, gp_j is the reweighted preference integrated from both individual preferences and common group preferences. The combination takes into consideration the impact of the similarity between individual user profiles and group common interests. Based on the obtained group profile, TV programs available at a given time can be rated via a content-based recommendation.

B. Decision Strategy Determination

After obtaining a group profile, an appropriate decision strategy is determined according to the type of group and the users' preferred programs. Unlike the mixed initiative approach, which uses program recommendations and automatic decisions [12], we use three types of decision strategies: automatic selection with recommendation, program recommendation, and category recommendation. The automatic selection strategy is the most deterministic situation, in which all users in a group have one program in agreement. It thus selects the program with the highest group preference, though it also recommends other programs. The program recommendation strategy is assigned when a group consists of similar users; i.e., the group has common interests and programs can be individually recommended. In the category recommendation strategy, the recommended programs are categorized when the group is composed of users of different ages and genders as each user is likely to have divergent preferences and interests. Fig. 2 shows the overall procedure of decision strategy determination.
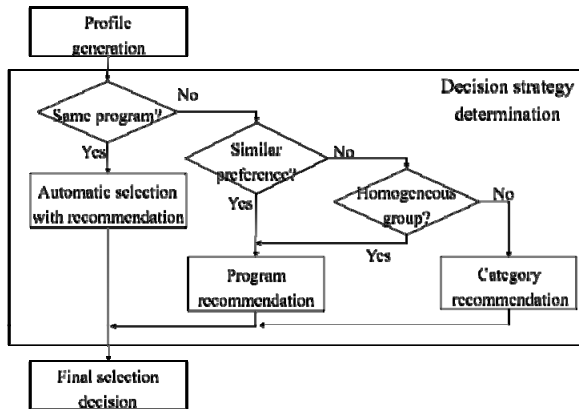

Fig. 2. Decision strategy determination.

From the figure, an appropriate decision strategy is assigned when a group profile is given from a user group. Based on the similarities and the type of group, one decision strategy is assigned to the group recommendation. In the case that users have the same interests, their programs of interest are generated, with the most highly rated program among them being selected for viewing. In the case of groups with different

preferences, a list of programs ordered by these preferences is generated. Otherwise, the programs contained in highly rated categories are proffered as the user recommendations.

C. Final Selection

Finally, the best program for the users is selected based on the list of recommended programs and the strategy employed in the determination stage. In the case of the automatic selection with recommendation strategy, the final selection is already determined and thus the recommendation is given to users as additional information to notify them of other available programs and selection results. In this strategy, the program recommender does not make the final decision and asks users to decide on the program to watch based on these recommendations. Mediation thus begins with a list of recommendations when automatic selection cannot decide on a clear program for the users to watch. In the case of the program recommendation strategy, the programs given by the group profile are contained in the recommendation, and programs from the highly rated categories are selected for as recommendations.

To support interoperability between the proposed program recommender and a digital TV, a Unified Context is used to describe mediation information such as the programs available and the final selection [13]. The mediation information described in the Unified Context is illustrated in Fig. 3.

Fig. 3. Mediation information described in the Unified Context.

In the figure, the mediation information includes details of how to arbitrate the user selection. It includes a list of users and the recommendations and selection strategy decided upon by the selection assistant. It also contains detailed information about the programs available and the selected program. Here, the selected program is included only when the program recommender has already made its decision. Based on this mediation information, a remote control can be used to mediate the final decision for a group of users. The assistant finalizes its decision soon after the users select one of the recommended programs.

III. IMPLEMENTATION

We implemented the proposed social-aware program recommender in a combined system comprised of a component integrated into a smart TV and a UI component deployed in a remote control device. For this purpose, we modified the smart TV to deliver related user profiles [14] after identifying potential users. The proposed recommender then gathered the user profiles from the smart TV and determined the most appropriate programs and decision strategy for the users after merging them into a group profile. The remote controller, equipped with the user interface, then visualized the recommendations and gathered feedback from the users to make a final decision about the program to view; examples of the implemented social-aware TV program recommender are illustrated in Fig. 4.
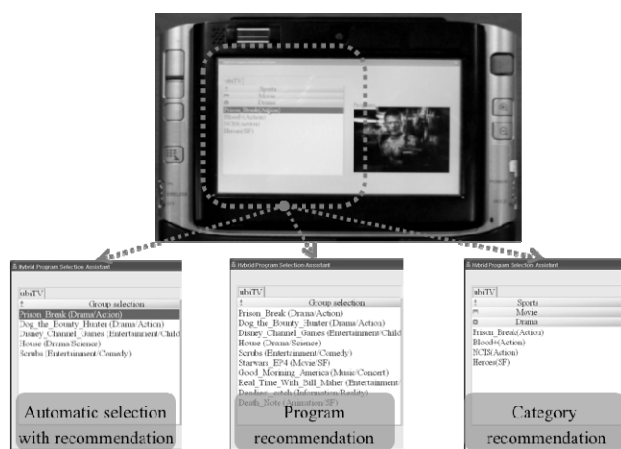

Fig. 4. Implementation of the socially aware TV program recommender.

Fig. 4 presents the TV programs recommended on the remote controller based on the strategy used. In the automatic selection strategy, higher-rated programs are recommended and one of them selected. On the other hand, a set of programs ordered based on group preferences or categorized by genres can also be recommended through the remote controller. Based on the information provided, users can jointly select the most appropriate program for the group. We then applied the proposed program recommender to a smart home test-bed that mimics a smart living room with different sensors and applications.

Fig. 5 shows three users watching TV together. The digital TV recognizes the existence of these potential users and then analyzes their profiles. The proposed recommender gathers their profiles and a common profile stored in the TV database, before merging the profiles and combining them into a common profile. The users are then placed into one of three situations according to their preferences pertaining to the available programs. In the case that the users have the same preferences, they just watch the selected TV program. On the other hand, they may need to discuss the program they wish to watch since they have different preferences. As an alternative, they can select a category or program from the category recommendation.

Fig. 5. The socially aware TV program recommender with a digital TV.

IV. EVALUATION

To verify the effectiveness of the proposed recommendation method, we evaluated it based on the feedback provided by a number of participants in the smart home test-bed. The following section describes how we evaluated the proposed program recommender in terms of evaluation method and results.

A. Method

1) Subjects

We recruited 12 participants from the general university population. The age of participants ranged from 25 to 29 and included both graduate students and administrative staff. In addition to the participants, four actors (friends and family members) were constantly involved to make the experiment more realistic in terms of controlling the experiment. Two of the actors were of similar age to the participants, with the other two of different ages, thus forming a friend and family group, respectively.

2) Preferences gathering

We then compiled the individual and group preferences. For this task, we used a graphical user interface (GUI) to allow the participant to set his/her preferences regarding the metadata of TV programs; i.e., preferred genres, subgenres, actors, and keywords. In addition to the individual preferences, we also gathered group profiles from the participants and actors.

3) Experiment

In the main experiment, we measured the performance of the program recommender in recommending which of 144 TV programs should be viewed; the 144 programs included a wide range of TV programs. We observed the proposed program recommender in three ways, personal choice, friends group, and family group. In each group, there were 48 possible programs to select from, and to make a selection two actors (e.g., friends or parents) were involved. The proposed program recommender then recommended programs ordered by the rating algorithms, as participants were asked to specify their preferred programs from the list of programs. We then compared the performance of the three recommendation methods by controlling the weight value; *F-measure* is a harmonic value used to combine *precision* and *recall*, and was

used here to compare the performance of the recommendation methods [15]:

$$F - measure = \frac{2 \cdot Precision \cdot Recall}{Precision + Recall}. \qquad (6)$$

In addition to the performance measurement, we also investigated which of the decision strategies the users preferred in selecting a TV program when they were together with their family members or friends. We thus asked each participant questions about the decision strategies in terms of satisfaction associated with convenience and correction of the selection after the recommendations were offered. These questions were rated based on a 5-item *Likert* scale, a system usability scale (SUS) [16].

B. Results

We first examined the differences between the personal profiles and group profiles of the participants. To determine each participant preferences, we applied a contents-based recommendation to programs in the participant's profile and counted the number of programs with preference ratings exceeding 75%. Fig. 6 represents the number of preferred programs in terms of personal, family, and friend groups.
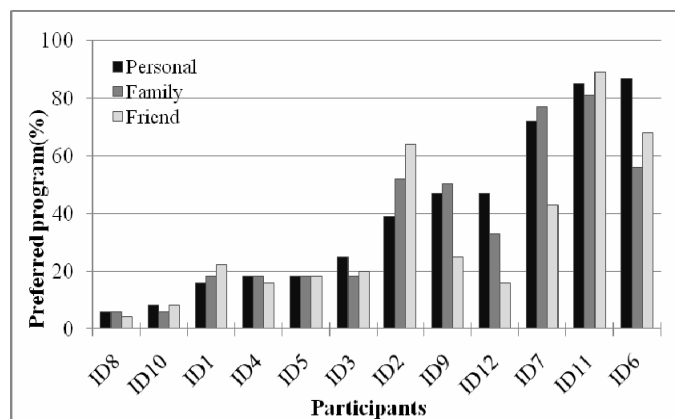

Fig. 6. Participants' preferred programs according to type of groups.

As can be seen in Fig. 6, a large number of programs were rated high in terms of personal preference, with other programs highly rated the programs related to the family and friend preferences as well. In spite of this fact, the participants had different preferences when they were alone or together with other people.

The results show that the proposed program recommender improved the performance of recommendations when participants watched TV with their friends or family. Then, to compare the performance of the recommendation strategies, we divided the participants into two groups based on their preference: lower and higher rating group. Recommendations based on the proposed group profile, merged individual profile, and common profile were subsequently applied to each of the groups; we then calculated the *F-measure* by analyzing the *precision* and *recall* of the recommendations. Fig. 7 compares the group recommendation approaches.

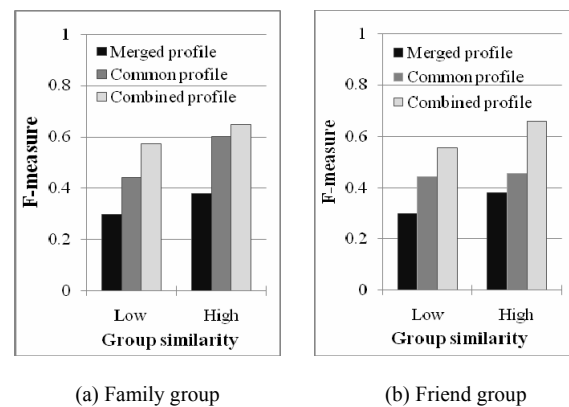(a) Family group   (b) Friend group

Fig. 7. A comparison of the recommendation approaches.

The figure shows that the performance of the recommendations made using the proposed method is higher than either the common or the merged individual profiles for both the family and friend groups. In fact, the recommendations based on the merged individual profiles produced the lowest performance in both the lower and higher rating groups. Furthermore, the figure shows that though the common profile-based recommendation improved the performance of the recommendation, the combined profile had larger improvements. These improvements can be further derived from Fig. 8, which shows the number of preferred programs in each category.
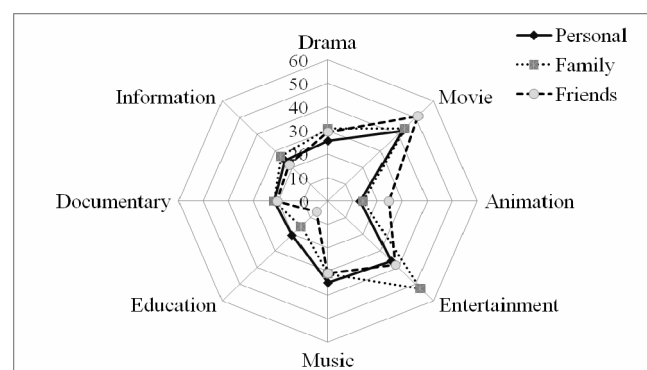

Fig. 8. The preferred programs for each group and category.

Overall, it was found that participants had different preferences when they watched TV with other people. Although their preferred programs spread in every category when they were alone, their choices changed to other categories when in a group. In the case of the family group, participants preferred programs in the entertainment category that might be acceptable for all members of the family; consequently, their interests in educational programs decreased. Participants also showed different changes in the friend group; their preferences for movies, entertainment programs increased, and animation programs. However, they did not like educational programs when they were with their family and friends. Therefore, these category changes were reflected by the combination of individual and common profiles.
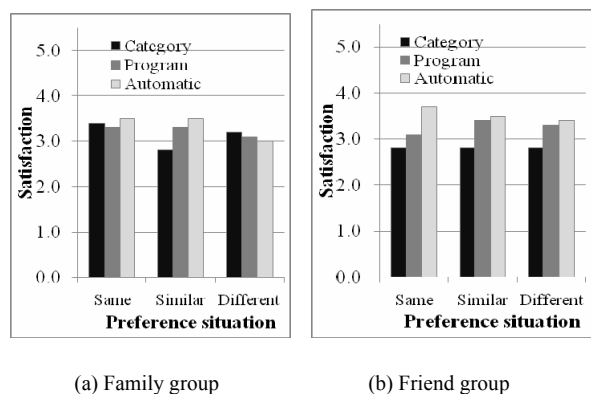
(a) Family group   (b) Friend group

Fig. 9. The preferred decision strategies of the participants.

As seen in Fig. 9, the participants preferred the automatic decision with program recommendation, as noted by the preferences of the both family and friends groups. The automatic decision was highly regarded since the selection and alternatives presented their preferred programs. Similarly, the automatic decision and program recommendation was preferred in both the family and friends groups. On the contrary, the participants were not as interested in the categorical recommendation in the friend group. In other words, the categorical recommendation was only preferred when the group consisted of heterogeneous users with different ages. Therefore, the decision strategy of the proposed social-aware program recommender can be deemed sufficient for supporting the selection of programs for multiple viewers of a digital TV.

In summary, the results showed that users had different preferences when they watched TV with other people. The proposed recommendation method improved the group recommendation performance by encouraging users to enjoy both their individually preferred programs as well as the group-preferred programs. With the recommendation, the program recommender assisted users in conveniently and harmoniously selecting programs of common interest based on the different decision strategies.

V. CONCLUSION

In this paper, we proposed a socially aware program recommender for multiple viewers of a digital TV. The selection method computed a group profile by linearly combing individual and common profiles. It then decided upon an appropriate program by either making a decision automatically or by asking users to discuss a list of recommendations of possible programs. Through an experiment with a smart TV, we found that the proposed program recommender improved the performance in program selection compared with other group recommendation methods, and its multiple strategies was useful in helping users select their programs with other people.

As a future work, we will improve the recommendation and decision strategies to making the selections more flexible to the users' situation. We will also observe the program recommender with real groups of users for longer periods.

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