Diversified Utility Maximization for Recommendations

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ABSTRACT
Consider the problem of recommending a list of movie titles for a group of users subject to the diversity of their tastes. The goal is to recommend a list of items, such that the interests of each user are covered. We cast this problem as maximizing a diversified utility function of the group, optimal solution of which can be found greedily. We conduct a user study in order to evaluate the performance of the proposed method. Evaluation results show that our method represents an effective strategy compared to various settings in which a convex combination of utility and diversity is maximized.

1. INTRODUCTION
It is often the case that multiple users share a single account with an online recommender, e.g., family members may share the same account with a movie recommendation service on their TV. The use of a single account by multiple users poses a challenge in providing recommendations satisfying the spectrum of their tastes. One solution to this problem is to recommend a list of diverse movies, in order to cover a range of tastes and increase user satisfaction. However, there exists a tradeoff between increasing the list diversity and maintaining the utility of the results [4].

Let $E$ be the ground set of $L$ recommendable items and $w(e)$ be the utility of item $e \in E$. The goal is to recommend a subset of items $S \subseteq E$ with the highest utility and diversity for users. A common approach to diversified ranking is based on the notion of maximal marginal relevance (MMR) [1]. In this approach, utility and diversity are represented by two independent metrics, and marginal relevance is a convex combination of these metrics:

$$S_{\text{MMR}} = \arg \max_{S \subseteq E : |S| = K} (1 - \lambda)w(S) + \lambda f(S),$$

where $K$ is the cardinality of $S$, $\lambda \in [0, 1]$ is a parameter that balances the importance of utility and diversity, and $w(S)$ is the sum of utilities of all items in $S$. The utility $w$ is a modular function of $S$, whereas the diversity $f$ is typically a submodular function of $S$. Under these assumptions, the objective in Equation 1 is submodular in $S$. Therefore, a $(1 - 1/e)$-approximation to the optimal solution can be computed greedily [3].

In this paper, we consider a different objective function, the optimal solution of which can be found greedily. Our objective is to maximize the utility of recommending a list of items to a group of users subject to the diversity of their tastes. Items with high utility are expected to be included in the list as long as they have a contribution to the diversity of the list. The utility remains the primary concern, but it is subjected to maintaining the diversity.

2. DIVERSIFIED UTILITY MAXIMIZATION
The main idea of our approach is to maximize utility weighted by diversity and cover each increase in diversity by the item with the highest possible utility. The increase in diversity can be viewed as the probability that a user chooses the item, in the sense that items that are similar to the previously recommended items are less likely to be chosen. When the item is chosen, we would like to maximize the satisfaction of the user, i.e., the utility of the choice. Formally, our optimization problem is given by:

$$A^* = \arg \max_{A} \sum_{k=1}^{L} g_A(a_k)w(a_k),$$

where $A = (a_1, \ldots, a_L)$ is an ordered set of $L$ items that we also call a list, and $g_A \in \mathbb{R}^+$ is a vector of gains in diversity, where:

$$g_A(a_k) = f(A_k) - f(A_{k-1})$$

is the gain associated with choosing item $a_k$ after choosing items in $A_{k-1}$. The sets $A_k$ and $A_{k-1}$ are the first $k$ and $k - 1$ items in list $A$, respectively. We refer to our approach as diversified utility maximization (DUM), since our objective is to maximize the utility weighted by the increases in diversity.

For a general function $f$, the problem in Equation 2 is NP-hard. However, when $f$ is submodular, the problem can be solved optimally by a greedy algorithm [2]. The items are ordered in decreasing order of utility, $A^* = (a^*_1, \ldots, a^*_L)$, where $w(a^*_1) \geq \ldots \geq w(a^*_L)$, and they are added to the recommended list in this order. When $g_A(a_k) > 0$, item $a_k$ is added to the list. Otherwise, the item is not added because it does not contribute to the diversity of the list.

The above solution is meaningful when the length of the recommended list, i.e., the number of non-zero entries in $g_{A^*}$, can be controlled. This is possible for a range of submodular functions. One such function is:

$$f(S) = \sum_{t \in T} \min \left\{ \sum_{e \in S} [\text{item } e \text{ covers topic } t], N_t \right\}.$$

Here, $T$ is a set of topics and $N_t$ is an integer threshold for a topic $t$. For this $f$, the recommendation list is guaranteed to contain at most $\sum_{t \in T} N_t$ items, such that each topic $t$ is covered by at least $N_t$ most relevant items in this topic.

3. USER STUDY
We conduct a user study in the movie recommendation domain. The ground set $E$ are 1,000 most popular movies on IMDb\(^1\). The utility $w(e)$ of a movie $e$ is approximated by its overall popularity, i.e., the number of people who rated $e$.

\(^1\)http://www.imdb.com – The Internet Movie Database.
Bob and Alice plan a vacation and can take several movies with them. Bob loves family movies and Alice loves fantasy movies. Which movies should they take with them? Below are four lists of recommended movies. Please tell us what you think about these lists. Choose the most appropriate judgment.

**Instructions**

**List 1**
- Toy Story
- Shrek
- Up
- Ratatouille

**The list is good for**
- Bob
- Alice
- Bob and Alice

**List 2**
- LOTR 1
- LOTR 2
- LOTR 3
- The Shining

**The list is good for**
- Bob and Alice
- Neither

Figure 1: An example questionnaire from the user study. We show only two lists out of four.

Our study consists of a set of tasks. In each task, we ask a Mechanical Turk worker to consider a situation, where Bob and Alice go for a vacation and can take several movies with them. Bob and Alice prefer two different movie genres. The workers are asked to rate four lists of movies, based on how these movies are appropriate for Bob and Alice. We generate one task for each pair of 18 most identical, and they are shown in random order to avoid position bias. Each task has different movie genres that movies in the recommendation list cover various aspects of users' tastes. This method guarantees that movies in the recommendation list cover various aspects of user tastes with high utility items. We conduct a user study showing the effectiveness of our method compared to models that maximize a convex combination of utility and diversity. In the future, we plan to apply DUM to other domains, such as document summarization and Web search result diversification. We also plan to extend our study to groups of more than two users and evaluate the performance of DUM for various combinations of genres.

### 4. CONCLUSION

We propose a method to maximize the utility of recommended items subject to the diversity of users’ tastes. This method guarantees that movies in the recommendation list cover various aspects of user tastes with high utility items. We conduct a user study showing the effectiveness of our method compared to models that maximize a convex combination of utility and diversity. In the future, we plan to apply DUM to other domains, such as document summarization and Web search result diversification. We also plan to extend our study to groups of more than two users and evaluate the performance of DUM for various combinations of genres.

### 5. REFERENCES


