Evidence-based Medical Recommender Systems: A Review

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Abstract

Recommender Systems are effective methods that have been developed successfully in e-commerce to provide personal recommendations based on user’s previous preferences. A recommender system assists users in a decision-making process to suggest interesting items from overwhelming flood of data available in the system. Suitably adapting the technology, recommender systems for medical purposes have been presented in some researches, which are applied in medical care or diagnosis called Medical Recommender Systems. They are intelligent methods that originally contain the medical knowledge from both historical data and example cases, as well as utilized for Telemedicine. Moreover, to maximize the effectiveness and quality of medical services, not only medical knowledge but also available external evidences named “Evidence-based Medicine” should be considered together. Therefore, this paper proposes Medical Recommender Systems combined with Evidence-based Medicine, which is called “Evidence-based Medical Recommender Systems”.

Keywords: Recommender Systems, Evidence-based Medicine, Telemedicine

1. Introduction

Recommender systems are approaches of information systems providing recommendations based on a person’s previous preferences which have been successfully established themselves for many applications in electronic commerce, entertainment, and marketing [1, 2, 3, 4, 5]. The most common objective of a recommender system is to make a recommendation of yet unrated items to an interested user based on his/her preferences [4]. A recommender system can suggest to a user the items with the highest rating estimated by many different methods ranging from machine learning via approximation theory to a multitude of heuristics [1, 6, 7]. Recommender systems are commonly classified by the filtering methods they employ, viz. content-based filtering, collaborative filtering, knowledge-based filtering and hybrid approaches [3, 4, 7].

Content-based filtering recommends new items to an interested user by matching the new items’ profiles (the classical example of an item is a movie, whose profile may contain parameters such as genre, title, director and actors) with the profiles of items the interested user has previously been interested in (called user preferences) [3, 4]. User preferences can be elicited from sources that are explicit (e.g. questionnaires) and implicit (e.g. transactions when visiting websites) [1]. Content-based filtering was derived from information retrieval and items to be recommended are described by textual information.

Collaborative filtering is the technique most widely used in recommender systems [3, 5]. There are two major versions of collaborative filtering, memory-based and model-based [3]. The former collaborative filtering recommends, in its user-based version for instance, an item to a new user based on a rating obtained as average over the item’s ratings given by similar users (evaluating the entire user-item rating matrix). In its item-based version, memory-based collaborative filtering works analogously. The latter one, first creates a model of similar users, based on a rating matrix, and derives the rating of a particular item that might be recommended from the model. Statistical and learning techniques are utilized to create the model [3].

Furthermore, two approaches can be distinguished: the item-based approach (based on groups of items) and the user-based approach (based on groups of users who share similar interests) [2]. Even
though, collaborative filtering the most successful technique applied in recommender systems, however, it does have shortcomings [3] as outlined below.

- **Sparsity problem:** when the number of user ratings is very small compared to the number of user ratings that need to be predicted [1, 3], prediction accuracy fails and predictions are insignificant. There are two related problems as follow:
  - **Cold start problem:** degrades the feasibility of the calculation upon initialisation and occurs when there are only few users rating a small set of items, i.e. there is insufficient information to draw any inferences [3, 6].
  - **New user problem:** when a new user joins a user group and has not yet rated an item, making it impossible to recommend an item to the new user [3].

- **Scalability problem:** when a search is conducted following the inclusion of new users and new items in all the user-item rating matrices, the corresponding computational overhead results in poor scalability, particularly for real-world applications [3]. One approach to addressing this problem is to first reduce dimensionality, e.g. by Principle Component Analysis (PCA) or Singular Value Decomposition (SVD) [8].

**Knowledge-based filtering** employs domain knowledge to infer similarities between items to make recommendations. The restaurant guide Entrée [9], for instance, may recommend the top-rated vegetarian restaurants in the vicinity to a new user wishing to eat vegetarian. This technique avoids the new user problem by using domain knowledge without requiring any ratings from new users.

**Hybrid filtering** combines different filtering techniques in recommender systems, such as content-based and collaborative filtering techniques, or knowledge-based and collaborative filtering techniques [10], to eliminate the drawbacks of a single technique and to improve system performance [4]. For instance, “collaboration via content” [11] is based on traditional collaborative techniques but also maintains the content-based profiles of each user. To make a recommendation, this technique finds a correlation between the content-based profile of a particular user and the profiles of other users. It avoids the sparsity problem of the traditional collaborative approach, because it is not based on user-item rating matrices.

So far, a wide range of recommendation techniques has been successfully developed, particularly for e-commerce. Therefore, it suggests itself to employ recommender systems also in other application areas.

2. **Medical Recommender Systems**

The development of information systems to predict the risk associated with individual diseases has been a topic of intensive research for already some decades [12, 13]. The main goal of the development is to assist physicians in making decisions without directly consulting specialists such as computer-aided method. Prediction should not only be accurate, however, a recommender system should also be able to help physicians to define appropriate treatments, to predict the risk to patients of undesirable outcomes, to assess individual patient risk [14], and to present that risk to patients in a personalized way with respect to their illness and possible undesirable outcomes of treatments.

The best way to cope with diseases is to detect their symptoms as early as possible. This, however, is difficult in remote areas, such as the rural areas of Thailand, where medical specialists and facilities are scarce and insufficient. Therefore, to support general practitioners in diagnostics and to reduce the risk of hazardous complications, it would be beneficial if physicians could detect diseases before their outbreak so that patients could be transferred from inadequate hospitals to well-equipped ones.

Recently, studies employing collaborative techniques of recommender systems in medical care have been conducted [12]. Their motivation is to advise a consulting patient based on the medical records of patients with similar indications. Reasons to employ collaborative filtering techniques in searching medical databases are above all to maximize the effectiveness and quality of medical care [15]. Collaborative filtering requires access to user profiles to identify user preferences and make recommendations. To transfer the recommender systems' methodology to medical applications, patients are identified with users, patterns containing data of medical histories and physical examinations are identified with user profiles, for both users and patients a notion of similarity is employed, and patient diagnoses are identified with user ratings. Therefore, it is a logical development to employ recommender systems to solve the medical problems.
Davis et al. [12] presented a collaborative filtering method by combining the memory-based and model-based approaches for the personalized diagnosis of diseases. The method aims to predict the diseases patients may contract in the future based on their medical records. To this end, it calculates values of similarity between patients’ data and patterns taken from a medical database employing International Classification of Diseases codes (ICD-9-CM) from [16], and predicts the patients' diseases according to the closest matches found in the database. Folino [13] proposed a recommendation engine for disease prediction that combines clustering with an association analysis technique of machine learning. This combined technique, called CORE, has two main phases. The model generation phase is to build a model by grouping similar patients based on ICD-9-CM cases using their medical histories, and the disease prediction phase is to predict the diseases patients may acquire by comparing the patients’ patterns with the model. Duan presented a system recommending nursing care plans [15]. The system makes sequential recommendations base on users’ interactions, modifying a ranked list of suggested care plan items at each step in care plan construction. To rank items, the traditional association rule measures, which are support confidence and lift, are applied.

Concerning to physicians’ knowledge in a collaborative filtering technique, Komkhao et al. [17] presented K-InCF, which is a knowledge-based incrementally working collaborative filtering algorithm. It was proposed and applied to a medical recommender system to predict the risks of Caesarian section due to cephalopelvic disproportion for pregnant women before their delivery and, thus, to replace the current practice of detecting and assessing criteria during labor and delivery. This approach is expected to be helpful in improving the quality of medical services in remote areas with insufficient infrastructure, such as rural regions of developing countries. The structure of the K-InCF algorithm in a medical recommendation system is illustrated in Fig.1, which consists of initialization phase, learning phase, and prediction phase. The physicians’ knowledge is applied in the learning phase. The risk factors of Cesarean delivery are identified by the specialist physicians called “Expert Rules”.

![Figure 1. Structure of the K-InCF Algorithm [17] in a Medical Recommendation System](image)

### 3. Applying a Medical Recommender System for Telemedicine in Thailand

In remote areas of Thailand, some community hospitals have not only insufficient physicians who have usually not enough abilities and experiences to diagnose all types of diseases but also insufficient infrastructure [24]. Therefore, the quality of medical services still needs to be improved [18].

In 1994, the Ministry of Public Health released a project of Telemedicine, which is the utilization of Information and Communication Technology (ICT) to deliver health services to remote hospitals in Thailand for improving the quality of medical services. In 1998, the utilization of Telemedicine Network has established and illustrated the usefulness of telemedicine also for many applications in
clinical medical education and services [18]. Nevertheless, the Telemedicine Network of the Ministry of Public Health (MOPH) was discarded in 2003 due to some problems, viz. the human resources lack of IT skills, economic crisis, fast changing of technologies, and the government is not stable [19].

Even though, there are several obstacles for telemedicine establishment, however, there are many projects still have been developing as follow: Eye Examination Robot and Mekong Basin Disease Surveillance System (MBDS).

National Electronics and Computer Technology Center (NECTEC) cooperating with Mettaphracharak Wattraikhing Hospital has developed a project of Eye Examination Robot for delivering eyes diagnosis over long-distance area [23]. Aim to provide eyes diagnostic support that helps physicians by providing remote diagnosis for patients in remote area hospitals.

MBDS: A Trust-Based Network [20] that aims to detect infection of diseases and outbreaks control in cross-border of six countries located in Mekong sub region, and then sharing, exchanging information among the collaborative countries. MBDS is one of the Program for Monitoring Emerging Diseases (ProMED) in which mainly detect emerging disease and serve as an early warning system in order to avoid the outbreak [21].

In order to enhance medical care services, the strategies of telemedicine foundations have been announced by Ministry of Information and Communication Technology, which is partially defined in ICT 2020 framework [22]. It aims to utilize the information technologies to improve Thai living standards. Therefore, to support this policy, we intend to contribute a new concept of recommender system, which can be applied in telemedicine in the case of maximizing the effectiveness and quality of medical services.

### 4. Evidence-based Medical Recommender Systems

At present, several researchers intend to improve the performance of medical recommender systems referring to the telemedicine. They try to propose efficient methods or approaches: implying artificial knowledge of physicians, applied in the medical recommendation.

#### 4.1 Recommendation based on Evidence

In Thailand, physicians also utilize “Evidence-based Medicine: EBM” [25], which is considering the population-based information of patients, in order to make a diagnosis or cure decision. This evidence, however, can determine the strength of the medical recommendation. Herein, the medical evidence can be derived from experimental study or observational study, case report and expert opinion. They are grouped in to two major ones: formal and informal. The formal evidence is the medical researches (reports), in contrast, the experience or expert opinions are one of informal evidence.

<table>
<thead>
<tr>
<th>Level of Strength</th>
<th>Description</th>
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<tr>
<td>Grade A</td>
<td>Recommendation based on RCT</td>
</tr>
<tr>
<td>Grade B</td>
<td>Recommendation based on Meta-Analysis of Observational Study</td>
</tr>
<tr>
<td>Grade C</td>
<td>Recommendation based on Observational Study</td>
</tr>
<tr>
<td>Grade D</td>
<td>Recommendation based on Case Report and Expert Opinion</td>
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For instance, the highest strength (Grade A) of recommendation should be derived from the “Meta-Analysis of Randomized Controlled Trail: RCT”, which is an experimental study; on the other hand, the strength is very low (Grade D) when the case report or expert opinions are applied in the recommendation. In fact, the diagnosis cannot focus on the highest strength of recommendation only, but also need other evidences considered to trust. Table 1 illustrates the strength of recommendation.

Intend to enhance the effectiveness or efficiency of medical recommender systems, especially applied in Thailand, not only efficient recommendation approaches focused but also the medical evidences from both formal and informal ones; they should be combined to the medical history of patients, which will be called “Evidence-based Medical Recommender Systems”. The proposed idea is presented in Fig. 2.
The Evidence-based Medical Recommender System consists of intelligent algorithms, such as neural network, fuzzy theories, support vector machine, data mining techniques, which utilize the hybrid filtering techniques: collaborative filtering, content-based filtering, and knowledge-based filtering. The collaborative filtering method is applied for medical history of patients; the content-based filtering is used for experimental studies, as well as the knowledge-based filtering is applied for the case reports and expert opinions. The physicians can access the system anywhere that the Internet available. The recommendations will be delivered to the physicians based on their patients’ physical examination, and then the physicians consult the patients as their diagnosis.

4.2 Case Study: Caesarian Section due to Cephalopelvic Disproportion for Pregnant Women

According to several studies, the common indications for Caesarean sections are dystocia, fetal distress, breech presentation and repeated earlier Caesarean sections [26, 27]. It has been proposed to restrict Caesarean deliveries to cases of true cephalopelvic disproportion, with symptoms such as advanced cervical dilation and adequate uterine contractions combined with molding and arrest of the fetal head [28]. In medical care, it is very difficult to diagnose this case in remote areas, such as the rural areas of Thailand, where medical specialists are insufficient. Therefore, to support general physicians in diagnostics and to reduce the risk of hazardous complications, the telemedicine technology: Evidence-based Medical Recommender System can be utilized.

The system will be constructed with these following gathered data: the medical history of pregnant patients in normal delivery and Caesarian section cases. Combining with the correct evidences, they are the results of experiments, case report of diagnosed patient, and medical specialists’ knowledge. The K-InCF [17] will be applied to be the intelligent algorithm working with the hybrid filtering techniques: collaborative filtering, content-based filtering, and knowledge-based filtering.

5. Conclusion

The concept of evidence-based medical recommender system is proposed. The strength of medical recommendations is based on the collected data and evidences cooperated with intelligent algorithms. The intelligent algorithms are used to extract and filter the medical recommendations from the data, which are according to the physical examination of diagnosed patient. To implement the effective telemedicine in Thailand, not only medical data and intelligent algorithms, but also networking infrastructure is focused. The networking must be available covering remote areas, and then the telemedicine technology can enhance the medical diagnosis.
6. References


