Intelligent Consumer-Centric Electronic Medical Record

Gang LUO, Selena B. THOMAS, Chunqiang TANG
IBM T.J. Watson Research Center, 19 Skyline Drive, Hawthorne, NY 10532, USA
{luog, selenat, ctang}@us.ibm.com

Abstract: Web-based, consumer-centric electronic medical records (CEMRs) are currently undergoing widespread deployment. Existing CEMRs, however, have limited intelligence and cannot satisfy users' many needs. This paper proposes the concept of intelligent CEMR. We introduce and extend expert system and Web search technology into the CEMR domain. The resulting intelligent CEMRs can automatically provide users with personalized healthcare information to facilitate their daily activities. We use automatic home medical product recommendation as a concrete application to demonstrate the benefits offered by intelligent CEMRs.

Keywords: Intelligent consumer-centric electronic medical records, automatic home medical product recommendation, expert system, medical knowledge, consumer health informatics

1 Introduction

The rapid deployment of electronic medical records (EMRs) is an important trend in the healthcare business. In 2004, President Bush announced plans for most Americans to have EMRs by 2014 [1]. Shortly after that, a few major Internet companies, including Google [2], Microsoft [3], and Revolution Health [4], launched their Web-based EMR services for ordinary consumers. These consumer EMRs are often connected with hospital EMRs [2]. They allow a user to enter his medical information into his own EMR through a Web interface.

The healthcare industry is moving toward a more consumer-centric focus because of the skyrocketing healthcare cost, the aging population, the increasing lack of doctors, and the improved accessibility of medical information. Web-based, consumer-centric EMR (CEMR) can help ordinary people directly manage their health by themselves. Consequently, it is regarded as one of the most effective methods of addressing the upcoming healthcare crisis. Users typically have a wide range of healthcare needs, the fulfillment of many of which requires intelligent reasoning. Existing CEMRs, however, have limited intelligence (e.g., perform a table lookup to check drug-drug interactions) and the benefits of CEMR are far from being fully realized.

In this paper, we propose the concept of *intelligent CEMR* (iCEMR), by introducing and extending expert system and Web search technology into the CEMR domain. Figure 1 shows the architecture of iCEMR. The expert system uses medical knowledge to convert information in the EMRs into a set of "search guide information" reflecting the user's medical situation and healthcare needs. Then the Web search engine uses this search guide information to retrieve personalized healthcare information. This approach

combines the bests of closed-domain expert systems with those of open-domain search systems. The expert system's built-in knowledge helps generate high-quality queries, while the search system can discover Web pages previously unknown to the expert system.

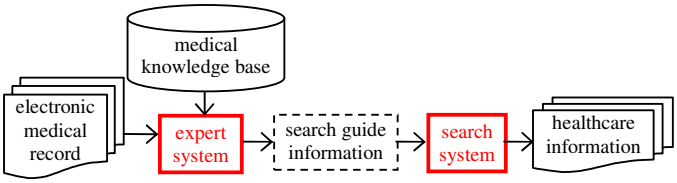

Figure 1. Architecture of iCEMR, an intelligent consumer-centric electronic medical record system.

iCEMR intelligently anticipates users' needs in advance and automatically provides a comprehensive set of healthcare information. Users often do not know beforehand exactly what they want due to lack of medical knowledge, while they usually can tell whether the healthcare information is helpful when they are presented with such information. Below, we use several examples to illustrate the usage scenarios of iCEMR. All these examples come from real life experience of ordinary consumers.

As a first example, partly due to the aging population and the trend to move chronic care patients from hospitals to home, many people need home medical products (HMPs) to facilitate their daily activities. In fact, about 50% Americans have one or more chronic conditions, and a large percentage of these people use HMPs [5]. Healthy people also use HMPs for various purposes. For instance, (1) a person with arthritis can use bendable utensils to aid self-feeding (see www.allegromedical.com/housewares-c5256/sure-hand-bendable-utensils-p500669.html), (2) a person taking eye drop medication would appreciate the Autodrop Eyedropper Aid (see www.allegromedical.com/daily-living-aids-c519/autodrop-eyedropper-aid-p176278.html), and (3) a policeman or singer can perform respiratory training using the PowerLung Sport Lung Exerciser (see www.allegromedical.com/respiratory-therapy-c534/powerlung-sport-p211207.html). We encourage readers to browse the above Web pages to obtain some hands-on experience.

Consumers often are unaware of the HMPs that can help them and have difficulty in finding those HMPs due to several reasons. First, the number of HMPs on the market is enormous. The HMP shopping Web site AllegroMedical [6] alone has more than 42,000 HMPs. Moreover, each year many new HMPs enter the market as medical knowledge and technology improve. Second, consumers cannot always obtain needed advices from their physicians, because many physicians receive little training on HMPs and are unfamiliar with the HMP market. Third, existing HMP shopping Web sites support keyword search and catalog browsing. However, for consumers with little medical knowledge, it is challenging to either come up with the right search keywords or navigate to the relevant part of the HMP catalog. Therefore, it is generally desirable to have iCEMR automatically recommend relevant HMPs to users based on their past medical records.

As a second example, consider a senior person who has the chronic disease gout. This person is looking for a city that he can move to and spend his retirement life. To reduce the pain caused by gout, it would be helpful if that city has nice weather. It would be even better if that city has a hospital good at treating gout. Similarly, consider a family with a deaf child. The householder plans to change his job. It would be nice

for this family to move to a city that offers free after school program for deaf children with free transportation covered by city tax. It would be even better if some local community in that city has support group for deaf children. In general, it is desirable for iCEMR to automatically recommend best living cities based on users' past medical records.

As a third example, many people with various health issues can benefit from participating in a local weight loss program, exercise program, or preventive healthcare program. Based on the user's living place, income level, and past medical records, iCEMR can automatically make such recommendations.

The above examples show that iCEMR can provide personalized healthcare information tailored to a user's medical situations and healthcare needs. This paper specifically studies automatic HMP recommendation, a popular usage scenario of iCEMR. Our description remains at a high level due to space constraints. The details of our techniques, experimental results, and related work are available in [7].

2 System Overview

2.1 User Interface

iCEMR provides its intelligent functions to users through a Web interface. Figure 2 shows the main Web page of iCEMR, where each button on the right side corresponds to an intelligent function. If the user clicks a button, she is directed to a page specifically designed for the corresponding function. Various functions can have different user interfaces in the follow-up pages. In this paper, we focus on the HMP recommendation function.

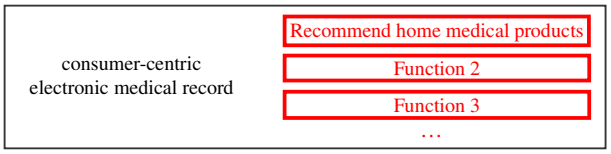

Figure 2. The main Web page of iCEMR.

The user interface of the HMP recommendation function is specially designed to fully utilize medical knowledge, while also making the system accessible to ordinary users with little medical knowledge. For this purpose, iCEMR provides users with explanations of difficult medical concepts in layman terms. The user interface also strives to minimize a user's efforts while collecting as complete information from the user as possible. iCEMR uses past medical records and built-in medical knowledge to automate the information gathering process. Moreover, iCEMR provides reminders to encourage the user to fill in missing information. Complete information is essential to recommend a comprehensive list of HMPs to the user.

To recommend HMPs, iCEMR needs to know the user's diseases, symptoms, and other medical conditions and healthcare needs, all of which are termed topics in this paper. A user's medical records typically contain an overwhelming amount of information. To minimize the user's efforts in using iCEMR to find HMPs, iCEMR automatically extracts a preliminary set of topics from the user's medical records and then uses medical knowledge to expand these topics into a more comprehensive set of

topics. iCEMR uses a topic-selection interface to let user input mainly through making selections among those topics [8], as opposed to the traditional keyword interface that is difficult to use for ordinary people with little medical knowledge.

2.2 Recommendation Techniques

For each topic *T* selected by the user, *T*'s name can be used as a query to retrieve HMPs directly. This straightforward approach, however, is often ineffective because a semantic gap can exist between the name of a topic *T* and the underlying medical meaning of *T*. Especially, if *T* is a symptom, the underlying medical meaning of *T* is to treat *T*, which can be in contrary to the literal meaning of *T*. In this case, the keyword query of *T* cannot properly retrieve those HMPs that are used to treat *T*.

For example, consider a user who has the symptom "weight loss." She would like to gain weight rather than losing weight. For a HMP used for this purpose, its description can include either "address unintentional weight loss" or "for general weight gain." As a second example, consider a user who has the symptom "chills." She would like to keep herself warm rather than becoming chilled. For a HMP used for this purpose, its description is likely to include "help keep warm."

To bridge the semantic gap, we use expert system technology and medical knowledge to provide semantic translation from topics to their underlying medical meanings. The results are the "*search guide information*" pre-compiled by medical professionals for the search system. For each topic *T* selected by the user, its search guide information is a set of phrases. The HMP search for *T* is performed using *T*'s search guide information to increase the chance that the retrieved HMPs can reflect *T*'s underlying medical meaning. The search results for all the search guide information are combined together and returned to the user as HMPs recommended by iCEMR.

One key challenge in automatic HMP recommendation is to combine and rank HMPs retrieved by ***different*** queries. Traditional ranking methods only consider documents retrieved by a single query and the computed document-query relevance scores are incomparable among multiple queries, e.g., the scores are on different orders of magnitude depending on the numbers of terms in the queries. To address this challenge, we first develop a set of heuristic constraints that any reasonable ranking formula should satisfy. Then we extend the language modeling method to meet these constraints, by utilizing the semantic properties of our application scenario and by folding all the relevant factors into a single ranking formula. This extended language modeling method computes a global ranking of the HMPs retrieved by multiple queries. Our method is further enhanced to provide diversified search results so that the top ranked Web pages do not describe redundant HMPs retrieved for different topics.

3 Results

We implemented a prototype iCEMR system supporting the function of automatically recommending HMPs. We crawled Web pages from AllegroMedical [6], the first and one of the largest HMP shopping Web sites. A complete evaluation of iCEMR is presented in [7], showing that iCEMR significantly outperforms AllegroMedical's keyword-based HMP search engine.

To give the reader a feeling of the contents returned by iCEMR, we present detailed results of the returned Web pages for a typical medical scenario corresponding to the

topics "weight loss" and "hand weakness." We encourage readers to browse the Web pages below to obtain some hands-on experience. The recommended relevant HMPs include Vitol Incredible Quick Weight Gain (rank 1, www.allegromedical.com/dietary-supplements-c522/incredible-quick-weight-gain-5000-calories-4-lbs-1812-g-p196658.html), Genesis Nutrition Weight Gain Vanilla (rank 2, www.allegromedical.com/dietary-supplements-c522/weight-gain-vanilla-50-oz-3-lbs-2-oz-1418-g-p195559.html), Boxtopper with Built-Up Handle (rank 3, for weak hand, www.allegromedical.com/daily-living-aids-c519/boxtopper-with-built-up-handle-just-insert-and-lift-p192930.html), and T-Bar Cockup (rank 5, for weak hand, www.allegromedical.com/exercise-fitness-c523/t-bar-cockup-with-attachment-holes-left-p187430.html). In general, for a medical scenario, iCEMR can simultaneously retrieve desired HMPs for multiple, diverse topics that the user cares about.

4 Related Work

GuidedMed [9] and iMed [8] are two consumer-centric medical search engines using expert system technology. Both systems focus on *disease diagnosis* and use disease diagnosis knowledge to help users find disease information related to their medical situations. The application in this work is recommending HMPs, which differs radically from disease diagnosis. Since different application domains naturally have differing challenges, they are addressed with distinct techniques.

Cimino has built an Infobutton Manager for EMRs [10]. For each medical concept appearing in the EMR, the Infobutton Manager provides a fixed set of questions that physicians ask most commonly. The answer to each such question is retrieved from a database or online resource in real time using a manually pre-constructed query. The Infobutton Manager anticipates physicians' needs in advance, while iCEMR anticipates consumers' needs in advance.

Zeng et al. [11] proposed automatically adding into EMRs explanations for medical phrases in layman terms. These explanations can help consumers understand the contents that physicians write in the EMRs. That work is orthogonal to this iCEMR work, whose focus is on facilitating consumers' daily activities.

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