Health Recommender Systems: A Systematic Review

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ABSTRACT

Nowadays, a large volume of clinical data spread over several websites on the Internet makes it difficult for individuals to locate useful information for improving their health. Furthermore, the overabundance of medical information (for example, on medications, medical tests, and treatment recommendations) has made it difficult for medical professionals to make patient-centered judgments. These concerns highlight the need for recommender systems to be used in the healthcare industry to assist both end-users and medical professionals in making more efficient and accurate health-related decisions. We present a thorough overview of existing research on health recommender systems in this paper. Unlike other relevant overview articles, this work delves into recommendation scenarios and methodologies. Food recommendation, drug recommendation, health status prediction, healthcare service recommendation, and healthcare professional recommendation are all examples of this type of recommendation. The major HRS techniques were presented, and the results were discussed.

Keywords

Health Recommender Systems, Recommender System, Machine Learning, Collaborative Filtering.

1. INTRODUCTION

Information technology have sparked a slew of new ideas and breakthroughs in a variety of industries today. Recommender systems (RS) have been a cutting-edge breakthrough in the service business in this area [1]. When it comes to web-based services, RS wants to make items more accessible and provide potential clients more options. Many iterations of Recommender System have been employed in online marketplaces (such as eBay, Amazon and Flipkart), and it is being adopted by many companies on the internet. Recommender System, on the other hand, is not confined to online product marketing. Recommender System, on the other hand, serves as a decision-making aid by giving decision-makers with alternatives (substitutes) [2, 3]. Information systems, such as ERP systems, have aided in the optimization of decision-making processes and the effectiveness of communication routes and infrastructures in health care. In the healthcare industry, RS plays an important role in supporting decision-making concerning people’s health. Recommender System have already been used in health services as Health Recommender Systems (HRS) for educational, nutritional, and activity aid objectives, according to the studies [4-7]. However, according to Park et al. [3]’s review study and literature searches of scholar databases, relevant papers are scarce in the field. Several studies on the use of RS in health information services have been published in the literature. Literature searches, on the other hand, revealed that there is no evidence or commencement of a review of studies and practices in Health Recommender Systems. In the field of Health Recommender Systems, where resources are limited, this is an acceptable result. However, it is critical to offer a set of skills to researchers engaged in Health Recommender Systems research. As a result, this paper provides a preliminary survey of the literature in the Health Recommender Systems domain. The literature was rigorously evaluated, and the findings were presented in perspective of the Health Recommender Systems purpose and methodologies. Recommender System and Health Recommender Systems will be introduced in the sub-sections that follow. The review methodology, findings discussion, and conclusion sections were then outlined.

1.1 Recommender Systems

As the amount of “big data” on the internet grows, recommender systems have become more important in terms of data filtering and mining. It was recognized in the early 1990s that information filtering techniques were required in order to retrieve information properly. “Recommender systems are a type of information filtering (IF) technology that aims to offer information items (e.g. movies, music, books, news, photos, web pages, etc.) that are likely to be of interest to the user,” according to the definition. In Recommender Systems, there are three basic forms of filtering described in the literature [2]:

- Collaborative Filtering: It is based on information gathered and compiled from users. Example: Amazon
- Content-based Filtering: It is based on knowledge acquired from users and past data unit descriptions. For example: Netflix
- Hybrid Filtering: It combines a variety of methodologies and techniques, primarily collaborative and content-based filtering.

1.2 Health Recommender Systems

Health Recommender Systems are a type of RS that is used in the medical field. It has been used by professionals as a diagnostic tool and by users as a personal health advice tool [2]. As a communication medium, the Internet has become the primary source of health information and advice for users. According to Fernandez et al., the health information sought on the internet is characterized as follows [1]:

- Videos, web blogs, images, tutorials, forums etc.
- Medical organizations publication, governments, patients etc.
- Recipes on herbal cures for cancer, etc. 

As a result, HRS play an important role in filtering information for users’ self-diagnostic searches on the web, as well as the categories that they are searching for. Furthermore, physicians have employed HRS for diagnostic and instructional purposes. In this way, web-based diagnostic recommender systems can be used to suggest online health resources (HealthyHarlem), cancer-related web sites, and educational resources with patient records (MyHealthEducator) [1].
1.1 Recommender System Issues
Aside from standard filtering issues (such as sparsity, cold start, and scalability), there is a major socio-technical challenge with RS. In this context, privacy is a crucial and rising problem. Using data from several sources may create concerns about the usage of personal information.

“The combination of weak ties (an unexpected connection that offers unexpected suggestions) and other data sources can be leveraged to determine the identity of individuals in an anonymized dataset,” according to [9]. As a result, it could expose a significant weakness, particularly in health data, which is a sensitive matter in terms of privacy.

<table>
<thead>
<tr>
<th>Type</th>
<th>Definition</th>
<th>Pros</th>
<th>Cons</th>
<th>Example systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collaborative filtering</td>
<td>Gathering and analysing data on user activities and behaviours, as well as forecasting what users are likely to do based on their similarities to other users.</td>
<td>It has the ability to make sophisticated recommendations.</td>
<td>Issues with sparsity, cold start, and scalability</td>
<td>LinkedIn, Amazon, Facebook</td>
</tr>
<tr>
<td>Content-based filtering</td>
<td>Examining past data and current user preferences, and predicting based on item features</td>
<td>It is not necessary for the kick-off information to be extensive.</td>
<td>The scope of the source of recommendations is limited.</td>
<td>Internet movie database</td>
</tr>
<tr>
<td>Hybrid recommender systems</td>
<td>Combining content-based capabilities with a collaborative approach, or combining the two approaches into a single model</td>
<td>Result in recommendations that are more accurate and effective than other alternatives. The answer to the chilly start and sparsity problems</td>
<td>More knowledge engineering is required.</td>
<td>Netflix</td>
</tr>
<tr>
<td>Knowledge-based recommender systems</td>
<td>Gathering information about users and developing a strategy for making a recommendation based on what products can suit their needs</td>
<td>There is no need to ramp up because suggestions are not based on user ratings.</td>
<td>The ability to make suggestions is fixed.</td>
<td>Restaurant Recommender</td>
</tr>
<tr>
<td>Mobile Recommender Systems</td>
<td>Mobile RS, in addition to classic techniques, incorporates spatial data and allows for context-sensitive recommendations.</td>
<td>Effective recommendations based on regional data</td>
<td>transplantation, validation, and generality issues in a heterogeneous and noisy environment</td>
<td>Taxi Routing app (Uber, OLA)</td>
</tr>
</tbody>
</table>

2. LITERATURE REVIEW
Advances in technology have required innovation in every business, and in the medical profession, having a reliable system that can quickly select a doctor based on a patient's needs is vital, as life is at risk [13] (Haughom 2016). Organizations and consumers may now save and access health-related data online, thanks to the Internet's accessibility, and the usage of a recommender system has allowed them to use the data more efficiently.

2.1 Recommender Systems
A recommender system is a tool that makes recommendations to end users about products and items that will be of interest to them. It makes the user's life easier by providing them with the thing of their choosing. It also makes it simple to discover the interests of the end user [16] (Alluhaijdan 2013). The immediate aim of a recommender system is to give recommendations to users who have specific preferences, which serve as the input. These systems make recommendations based on a user's past preferences for or purchases of a product. Item-based filtering [17] (Badrul et al. 2001) is a strategy that uses a user's previously selected items to find comparable items. These are then passed on to other users as recommendations. Another strategy in recommender systems is user-based collaborative filtering [18] (Melville and Sindrewhani 2013). The ratings of other active users are used to recommend their most highly rated items to other users. Demographic filtering [19] (Saforced and Salah 2013) is another type of recommendation strategy that uses the demographic characteristics of users to suggest new products. Different recommendation strategies, such as content filtering, collaborative filtering, and so on, are integrated to generate recommendations in the hybrid recommendation methodology. Recommender systems are widely applied in a variety of fields due to their utility. They are demonstrating their worth in the medical field. The demand for recommender systems is increasing on a daily basis, thanks to the ever-increasing volumes of healthcare information available on the Internet. Despite the fact that very minimal work has been done in the healthcare field, major gaps have been identified, allowing for the development of an effective system that can recommend doctors based on patient preferences.

2.2 Recommender Systems in Healthcare
People prefer to use the Internet to gather information about disease and its treatment in today's information age. Many health portals are now giving related information, but recommender
systems are proving to be the greatest sources due to their ability to filter out important information in a timely manner. [20] Cheung et al. (2019) identified key difficulties that must be addressed in the near future to improve the recommender system's efficiency. The recent huge data availability on the Internet has necessitated the development of an optimal solution that allows for quick access to connected information. Tabari and [21]Memariani (2019) proposed a mathematical model that lays the way for the development of an efficient resource sharing decision management system. Furthermore, the study presented by [22] Schafer, Hor-Fraile, and Pawan (2017) discussed current literature on the utility of recommender systems published in the recent decade in the healthcare arena. To filter out publications from top-ranked journals, the author utilised a keyword search. Only English-language journals were considered. The major goal was to find holes in the healthcare profession. With the increasing amount of information available on the Internet today, the digital world is made up of big data, and there is a lot of interest in anticipating client interest and behavior. [23] Guha et al. (Blue and OPTUM Inc 2018) went on to examine the influence of data analytics on the healthcare domain and future possibilities, highlighting the use of technologies such as cloud computing and the Internet of Things (IOT), as well as their accompanying obstacles. [22] Schafer, Hor-Fraile, and Pawan (2017) analyse the progress achieved by recommender systems in locating appropriate healthcare and intervention for medical aid in [22] Schafer, Hor-Fraile, and Pawan (2017). The study looked at the future of a recommender system in the medical arena, as well as the problems that it would face.

2.3 Patient-Based Recommender Systems
Finding similar people with a certain problem is an important feature of the healthcare system. In the medical field, patient-based decision-making has the potential to greatly boost the utility of recommender systems. In this sense, patients can be thought of as a key component of healthcare recommendation systems. [23] Blue and OPTUM Inc (2018) proposed approaches for locating similar patients to patient X in their article. Following the calculation of patient similarity measures, the ranking of subsequent patients was completed. In addition, recommendations for top-ranked related patients were generated. Recommender systems are also utilized to make medication recommendations based on a patient's symptoms. [24] Ceyhan, Orhan, and Domnmori (2017) created an algorithm that proposes medical tests based on an examination of the patient's symptoms and anamneses. It recommends tests to patients based on their symptoms and conditions using sequential minimal optimization, J48, and Random Forest. [26] Qian et al. also examine the impact of patients' emotions on recommender systems (2019). The author used the user's rating and social data with the user's reviews to create emotional information. Finally, health promotion, theoretical considerations, and behavior modification theories were recognized as three groups related to healthcare systems. [25] Chen et al. (2017) highlighted an enhancement in healthcare system design to capture a patient's emotion, in which a video conference-based system was developed to overcome the challenge of time and space in the healthcare sector. A 5G cognitive system was employed, which consisted of two parts: a resource cognitive engine and a data cognitive engine. To study the system's quality further, a speed emotion recognition prototype was used to assess the effectiveness of the planned task. When working with patient data in healthcare, one of the most obvious concerns is privacy and confidentiality, which must be addressed with extreme caution. The Paillier homomorphic encryption scheme was employed by Kaur, Kumar, and Batra (2018) [27] to improve healthcare accuracy, security, and performance. The focus of the presented essay was on ensuring patient anonymity, which is crucial when dealing with healthcare data. Furthermore, Hoens, Blanton, and Chawla (2013) [28] recommend system contains a privacy-friendly framework. Patients can rate doctors in a secure setting utilising two architectures that use a secure privacy framework and an anonymous contribution system. The main focus, however, is on encrypting data to improve the system's stability.

2.4 Experts Recommender Systems in the Healthcare Domain
Many expert systems in the recommender system domain have been deployed in recent years to address diverse concerns. The Shanghai Medical League Appointment Platform's performance has been improved thanks to the development of an algorithm [29] (Huang et al. 2012). This is a time-sharing technique for reserving doctors for patients that focuses entirely on assisting in the proper management of appointment and scheduling time between patients and doctors while ignoring other key characteristics. The [30] Hussein et al. (2013) recommender system includes making disease predictions for a given patient using multiple tree disease classification models, but the main focus was on disease and no effort was made to propose any criteria or features by which a doctor for a given patient could be evaluated. Wiesner and Pfeifer (2010) [31] presented research on health recommender systems that attempted to exploit various concepts, challenges, and technical issues. They proposed an online recommender system in which patients can enter their disease symptoms. Expert doctors who have registered with the system are able to recognize diseases. There is, however, no method for determining a doctor's fitness for a certain patient. Diet plays an important impact in a person's health and immunity to disease. Mika (2011) [32] established a framework for recommending a healthy diet to patients, which aids in the prevention and treatment of heart disease. It is based on a person's family history, as well as basic disease information and the patient's food preferences. Mobi Day (Lamber et al. 2009) [33], a mobile application-based recommender system, offered a tailored context-aware mobile service that is embedded in medical information systems. It aids patients in their day-to-day job at the hospital by utilizing relevant data, such as the patient's current location and previous message-reading habits. It is made up of a server that provides a message and then watches the user's behavior in order to forecast trends. Duan, Street, and Lu (2008) [34] offer a nursing-recommender system that uses correlations between nursing diagnoses, outcomes, and interventions to provide a rank list of suggested care plans based on pre-selected elements. The research is entirely focused on association measures like support and confidence.

2.5 Existing Doctor- Recommender Systems in healthcare
All of the prior studies that have been discussed thus far have mostly focused on predicting disease based on treatment. When it comes to picking a doctor, little effort has been taken to specifically grasp the patient's preferences. Although various doctor-recommender systems have been established, their reach and effectiveness are severely limited. Narducci et al. (2015) [35] suggested a recommender system that used the semantic
association between a patient’s symptoms and treatment to discover comparable patients and then recommend doctors who were highly rated by them. The system’s biggest flaw was the lack of any specified technique for evaluating how a patient rates a certain doctor. Salunke, Kasar, and Smita (2015)[36] created a doctor profiler using natural language processing and user evaluations in their recommender system. The focus was on creating recommendations based on user ratings, although it was unclear which types of characteristics patients rated a certain doctor on. Guo et al. (2017)[37] presented a doctor-recommender system that identified significant opinion leaders who will affect people’s perceptions of doctors. The authors identified doctors who are experts in a certain condition based on co-authorship and citation relationships, and then used their expertise to recommend a doctor for that disease. The suggested work’s fundamental flaw was that it only functioned with internet data. If no online data is available, the proposed algorithm fails to produce a viable answer. In the field of doctor-recommender systems, there has been very little research. Currently available systems use a variety of machine-learning algorithms to obtain suggestions for doctors. Furthermore, the scope of such systems’ quality evaluations is quite limited. Because most of the relevant work on doctor recommendations has focused only on recommendation algorithms, a number of key research problems about doctor recommendations have arisen, including the following: Which criteria do patients use to choose a doctor? How can we learn about a patient’s preferences when searching for a doctor? How may these criteria/preferences be utilized to assess a doctor’s suitability for a certain patient? What criteria can we use to assess a doctor’s performance? Also, how can we evaluate the quality of a medical recommender system? The proposed research investigates the issues raised above and proposes a novel adoptive algorithm to address them.

3. FINDINGS AND DISCUSSION

Various papers were identified as having the potential to contribute to the HRS review. Table 2 contains a list of papers, as well as their goals and methodologies. HRS were studied in terms of user groups and system design [5, 7, 8, 11], and a set of research attempted to explore physical activities and nutrition-based recommender systems [4, 6, 12], according to the review results. In addition, two of the research [1, 12] sought to identify obstacles and possibilities. In terms of health marketing, personal suggestions, and self-examination, electronic health records were also part of HRS [5, 7, 11]. Telemedicine has been identified as a hot topic in HRS [8]. In terms of managing health affairs for housebound and mobile patients, the present investigations revealed that telemedicine and diagnosis applications were the primary focus of HRS studies. In HRS, it is vital to note that semantics is a difficult topic that is an important input in predicting online user behavior [13]. As a result, articles in the HRS development phase place a strong emphasis on semantics. Furthermore, Software-oriented Architecture (SOA) was frequently used as the foundation for development approaches [1, 8]. SOA was chosen for HRS development because of its versatility and compatibility with web services. However, the algorithms are not the most important aspect of HRS. In terms of user behavior, it is critical to design an algorithm with high prediction rates [11]. From a methodological standpoint, it was discovered that content-based and collaborative-based filtering were the most regularly employed, although hybrid RS and developing approaches in filtering (profile-based) were also being used more frequently.

Filtering methods, SOA methodologies, and linguistic research were discovered to be merged on an HRS platform to produce algorithms. As a result, the importance of algorithms is critical in terms of health. HRS algorithms were constrained by tight limits in this scenario due to privacy issues in RS as well as the sensitivity of human health records.

HRS’s problems and prospects, on the other hand, have been highlighted in various publications [1, 2, 12]. The key problem was identified as privacy, and the opportunity was identified as its role in the diagnostic process.

The Aim and methods are highlighted in the studies were listed in Table 2.

<table>
<thead>
<tr>
<th>Paper</th>
<th>Aim of Paper</th>
<th>Methods</th>
<th>Ref#</th>
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<tbody>
<tr>
<td>How recommender systems could support and enhance computer-tailored digital health programs: A scoping review (2019)</td>
<td>the potential of recommender systems to support and enhance computer-tailored digital health interventions. The aim is threefold, to explore: (1) how recommender systems provide health recommendations, (2) to what extent recommender systems incorporate theoretical models and (3) how the use of recommender systems may enhance the usage of computer-tailored interventions.</td>
<td>collaborative method with demographic filtering and knowledge-based filtering</td>
<td>20</td>
</tr>
<tr>
<td>An efficient multi-party scheme for privacy preserving collaborative filtering for healthcare recommender system (2018)</td>
<td>A privacy preserving healthcare recommender system is proposed and the scheme is evaluated with respect to various attributes in a distributed environment.</td>
<td>Arbitrary distributed dataset based collaborative filtering</td>
<td>27</td>
</tr>
<tr>
<td>A Hybrid Recommender System for Patient-Doctor Matchmaking in Primary Care (2019)</td>
<td>Model patient trust in family doctors using a huge dataset of consultation histories, taking into consideration the temporal dynamics of their relationships.</td>
<td>Hybrid Recommender system (heuristic baseline and a collaborative filtering)</td>
<td>38</td>
</tr>
<tr>
<td>A hybrid IT framework for identifying high-quality physicians using big data Analytics (2019)</td>
<td>Based on signaling theory, present a four-dimensional IT framework. Expertise knowledge, online evaluations, profile descriptions, and service quality are all used as signals in the model to identify high-quality clinicians.</td>
<td>Machine Learning</td>
<td>39</td>
</tr>
<tr>
<td>An adaptive doctor-recommender system</td>
<td>The proposed approach tackles the issue of personalization by analyzing a patient's desire to choose a doctor. It constructs a doctor's ranking function using a revolutionary adopting algorithm.</td>
<td>Hybrid doctor-recommender system (content base, collaborative and demographic filtering)</td>
<td>40</td>
</tr>
<tr>
<td>DeepReco: Deep Learning Based Health Recommender System Using Collaborative Filtering</td>
<td>suggested intelligent HRS, which offers a chance for the health care sector to migrate from a typical scenario to a more personalised paradigm in a tele-health environment by demonstrating how big data analytics can be leveraged to construct an effective health recommender engine.</td>
<td>Convolutional Neural Network (CNN) deep learning method, collaborative filtering</td>
<td>41</td>
</tr>
<tr>
<td>Recommender systems in the healthcare domain: state-of-the-art and research issues</td>
<td>The article delves into many types of suggestion scenarios and methodologies of healthcare recommendation. And create working examples to provide a thorough grasp of recommendation systems.</td>
<td>Machine Learning</td>
<td>42</td>
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</table>

4. CONCLUSION

A literature review on Health Recommender Systems was undertaken in this study, and the results were given. HRS are a potential development for healthcare services, according to the major conclusion. HRS has been spread out in numerous domains of the health business, according to the studies, and HRS applications have become progressively incorporated in health service systems. There were a lot of research linked to HRS use, design, and methodology in the literature. Emerging HRS investigations were also discovered to be on the rise in the literature in this regard. However, the HRS domain is new, it will take some time to provide mature research and enhance filtering algorithms. Furthermore, privacy concerns are a key problem that must be addressed. The goal of this work was to contribute to the literature by

(1) Expressing an opinion on HRS literature
(2) Highlighting HRS studies
(3) Providing a set of review methodologies for future research in the subject.

As a preliminary study, more research covering a broader set of criteria, as well as academic journals, might be carried out as the next step in the HRS literature review.

5. REFERENCES


[38] Qiwei Han , Mengxin Ji , Inigo Martínez de Rituerto de Troya , Manas Gaur , Leid Zejnulovic 2019 “A Hybrid Recommender System for Patient-Doctor Matching in Primary Care” March 2019.

