Defining architectures for recommended systems for medical treatment. A Systematic Literature Review

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***Abstract*—This paper presents a Systematic Literature Review (SLR) related to recommender system for medical treatment, as well as analyze main elements that may provide flexible, accurate, and comprehensive recommendations. To do so, a SLR research methodology obey. As a result, 12 intelligent recommender systems related to prescribing medication were classed depending to specific criteria. We assessed and analyze these medicine recommender systems and enumerate the challenges. After studying selected papers, our study concentrated on two research questions concerning the availability of medicine recommender systems for physicians and the features these systems should have. Further research is encouraged in order to build an intelligent recommender system based on the features analyzed in this work.**

Keywords: Recommender System, Machine Learning, Assisted Medicine.

I. Introduction

Health is a primordial necessity of people [1], and, as technology advances, more medical information is required to be available for patients and doctors, improving diagnosis [2]. However, medical errors really kill many people a year [3]. This situation can be caused by some issues as: expert diagnosis depends by physician experience, and many health centers don't have medical experts for critical diseases, and it can be hard to avoid mistakes [3]. CDC reports from 2.6 million deaths every year in the U.S., 715,000 occur in hospitals, therefore, if estimates are correct, 35% of all hospital deaths are due to medical errors. Also, reports from the US state that more people die in a given year as a result of medical errors than from motor vehicle accidents, breast cancer, and AIDS [4]. See Figure 1.

On the other hand, advances in computing have allowed us to support medical systems from basic systems to carry medical records, medical lab examining, manage appointments, deal with insurance companies, and so on. During recent years AI techniques have achieved significant progress in healthcare, we believe that the physicians will not be replaced by machines in the closely future, but AI can certainly support doctors to get better decisions. The massive quantities of health care data and rapid development of big amounts of data analytic methods has made possible the recent successful applications of AI in healthcare. Machine learning is the base of many information retrieval applications, those effect our day to day lives directly or indirectly. One of the commonly used application of machine learning algorithms is Recommender Systems, to making decisions fully autonomously [5]. Machine Learning deals with the development, analysis and study of algorithms that can automatically detect patterns from data and use it to aid and perform decision making [6].

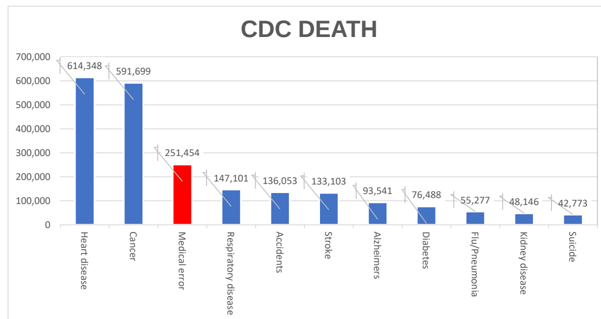

Figure 1. Medical errors are the number three of the death in US - Centers for Disease Control and Prevention CDC

Recommender systems are transformed into support systems necessary to ensure that the decisions are supported by the previous analyses, based on the experience that is stored in the system. Normally, recommendation techniques can be of various types: collaborative filtering (CF), content based (CB), knowledge-based (KB) ,and hybrid recommendation technologies [7]. Each recommendation technology has its advantages and limitations.

Our goal with this paper is to review the existing medicine recommender systems and to describe their approaches and features. The aims and offerings of this article are followings: to offer a review of the actual challenges related to medicine recommender systems; supply a systematic and analytic review of the actual methods for medicine recommender system and the way in which these have been applied; to investigate future challenges for medicine recommender system and the roll that it can play.

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II. Recommender systems

A. Approaches

Collaborative filtering. - One approach that has a wide application is collaborative filtering. This method uses a large amount information on user's behaviors, activities or preferences and estimating what will users like based on their similarity to other users. The recommendations are generated based on relationships between users and elements. These recommendations use neighborhood (e.g. An algorithm generalized by Amazon.com's recommender system is item-to-item collaborative filtering ¡people who buy x also buy y¿ it is one of the most famous example of collaborative filtering).

Content-Based filtering. - Another approach of recommender systems is content-based filtering. Content-Based filtering is centered on a description of the item and a profile of the user's preferences. This method tries to recommend items that are similar to those that a user liked in the past. In specific, several chosen items are compared with previously classified ones by the user and the best matching items are recommended. This approach has its origin in information retrieval and information filtering research (e.g. Pandora Radio is a good example of a content-based recommender system that plays music with characteristics like the song provided by the user as an initial data). Demographic approach is considered like a variant of content-based method, this algorithm uses demographic information instead of element's properties.

Knowledge based recommender. - This method generates recommendations of products based on predictions about needs and preferences of the users (e.g. recommend natural medicine for treatment of liver diseases). Utility based method is known like a variant of knowledge based system, in this approach the users are responsible for defining the desired features.

Hybrid recommender. - Recent research has shown that a hybrid recommender method is more effective in some cases, this method combines two or more approaches described in this section. [8] determines some hybridization approaches, for example, mixed, weighted, or cascade these methods allow the hybrid recommender system with more flexibility in the recommendation process

B. Strengths and weaknesses of recommender systems techniques

All recommendation techniques have their specific strengths and weaknesses, as addressed in [3], [7], and [9], and summarized in Table I.

III. Methodology

Based on the methodology of systematic reviews by Barbara Kitchenham [10], a scheme was developed for the review, selection and extraction of information, as follows:

a. Research question.

b. Keywords.

c. Review method.

- Sources and search strategies.
- Search strings.
- Studies selection criteria.
- Information Extraction.

d.Studies included and excluded.

Technique	Strengths	Weaknesses
Collaborative	Offering recommendations that someone never searched before. Sharing of knowledge with users that have similar preferences.	Cold start, scalability, sparsity
Content-based	This method generates recommendations with classic retrieval process and machine learning approach.	This method generates overspecialized recommendations
Knowledge-based	Recommending products in complex domain. Sensitive to short-term variance.	Suggestion ability is static
Hybrid	This approach generates higher performance recommendations. Avoid limitations through combining two or more different approaches.	Complexity implementation and Need external information that usually not available

Table I
Strengths and weaknesses of recommender systems techniques

A. Research question

The scope of this work was addressed on articles related to intelligent tools for recommender systems. The research questions are:

- RQ1: Which of the recommender systems, that can be adapted for treatments, is available to doctors?
- RQ2: What features should a medicine recommender system for physicians have?

B. Keywords

A review of the previous literature was carried out, consisting on analyzing a number of documents related to the subject that facilitate identifying the keywords obtained from the titles, summaries and introduction. Table II shows the list of words obtained through the Keywords.

Code	Title	keywords
R01	An Intelligent Medicine Recommender System Framework	Recommendation system framework, Intelligent Medicine, decision tree
R02	A recommendation system based on domain ontology and SWRL for anti-diabetic drugs selection	Ontology, OWL Web Ontology Language, Recommendation system
R03	A Recommendation System Using Machine Learning	Recommendation system, machine learning
R04	A Migraine Drug Recommendation System Based on Neo4J	drug recommendation system; migraine; medication recommendation; graph database

Table II
Preliminary review and terms

C. Review method

a) Sources and search strategies: The following research databases were used for search: ACM Digital Library, IEEEXplore and Web of science.

b) Search strings: Based on the research question, keywords were defined for the searches: Recommendation systems , medicine recommender systems, efficient suggestion tool, decision support , medication errors. To generate the search string, the logical operators “OR” and “AND” were used, leaving: (medicine OR drug) AND (recommendation OR recommender) AND (systems)

Study Inclusion Criteria: The search was executed with the following criteria:

- The publications date was considered from 2015 onwards.
- Research results are only in the area of Sciences and Computing.
- The scientific productions are primary studies (conference articles, journal articles).
- The search for default will be in the English language due its scientific relevance.
- The studies must have information relevant to the research question.

Study Exclusion Criteria: The articles with these characteristics were deleted: 1. Not available. 2. The duplicates. 3. The incomplete. 4. Who do not answer the research question.

c) Studies selection criteria: Once the results were obtained, the selection of primary studies are based on considering the following:

- There is current information of medicine recommender systems or medicine support decision tool for development frameworks in the summary.
- There is relevant information for the review in the conclusion or introduction.

d) Information Extraction: Selection criteria for studies establish the pattern of extraction of relevant information for this work. For each selected article, at least one of the following elements will be synthesized:

- Proposals or models for efficient medicine recommender systems or support decision tool.
- Results.
- Relevant conclusions.

D. Studies included and excluded

In the first extraction process, 178 cases were obtained. Then, another selection procedure was carried out in which 12 relevant articles were obtained. Table III shows their distribution:

Flowchart describing the selection included and excluded papers, see Figure 2

Source	Results	(+-)Relevant	No Relevenat	Repeated	Incomplete	Relevant
IEEE	82	15	53	0	9	5
ACM	19	5	10	0	0	4
WebOfScience	77	20	50	4	0	3
Total	178	40	113	4	9	12

Table III
INCLUDED AND EXCLUDED PAPERS

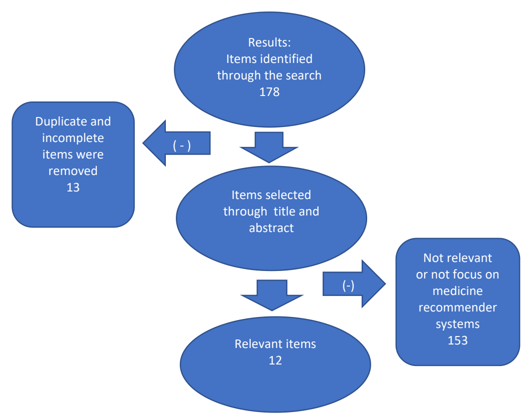

Figure 2. Flow chart the process used to select included and excluded papers

IV. RELATED WORK

This research is situated in recommendation of treatments and the supply of medicine, to support the physician and improve the medical prescription process. Based on this, the following related articles were found:

[3] is based on a hybrid approach. A design of a medicine recommender system framework is proposed. A mistaken-check mechanism is proposed for ensure the safety and quality of their recommendations.

[11] This medication recommender system uses semantic web. There is a great satisfaction level of user.

[4] Is a design of an intelligent mobile agent architecture for medicine prescription. Analytic Hierarchy Process AHP and Case base reasoning CBR strategies are used in this system. Follow an evaluation and validation method for this system by the simulation of medical scenarios.

[12] This system provides personalized dosage adjustment, optimizes Therapeutic Drug Monitoring TDM, and process large numbers of requests, provides an interface with other clinical applications.

[13] Presents a medicine recommender system using a graph database. Its approach is based on a collaborative filtering. Patients are evaluated according to their similarity of features. The evaluation showed that the algorithm gives recommendations with a good accuracy.

Code	Ref	Kernel recommender system
SR1	[3]	Hybrid method, SVM support vector machine, ID3 decision tree, BP neural network algorithms
SR2	[11]	Ontology for medication classification and KB
SR3	[14]	Collaborative filtering
SR4	[15]	Sentiment analysis, topic modeling - hybrid matrix factorization
SR5	[4]	CBR Cased-based reasoning, AHP Analytic Hierarchy Process
SR6	[16]	Collaborative filtering, clustering
SR7	[17]	Similarity matrices, collaborative filtering
SR8	[12]	Decision making in medical domain.
SR9	[18]	Artificial neural network and case-based reasoning
SR10	[19]	Ontology model
SR11	[13]	Collaborative filtering algorithm
SR12	[20]	Fuzzy recommender algorithm

Table IV
KERNEL RECOMMENDER SYSTEM
Note: The codes used for recommender systems, will use throughout the document

V. RESULTS

Among the selected studies, we found relevant evidence to satisfactorily answer the research question.

RQ1: Which of the recommender systems, that can be adaptable for treatments is available to doctors?

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Table IV presents existing models for a medicine recommender system. Information sources for the medicine recommender systems are shown in TableV.

Code	Information extraction
SR1	Medicine database and expert knowledge database, Open data set
SR2	Medication's technical data is limited sole source obtained from the Government Pharmaceutical Organization (GPO), MySql database
SR3	On line drug store
SR4	Experimental data is obtained from platform Yelp, it is a crowd sourced review website
SR5	Medicine database, patient database
SR6	Genomic Data, Drug bank, chembl
SR7	PubChem database, 536 approved drugs on 578 diseases are collected from the National Drug File-Reference Terminology
SR8	Database clinical HL7.
SR9	Electronic Medical Record database (EMR)
SR10	Knowledge base provided by a hospital specialist in Taichung's Department of Health, Database of the American Association of Clinical Endocrinologists Medical Guidelines for Clinical Practice for the Management of Diabetes Mellitus (AACEMG)
SR11	Graph database NEO4J, simulated medical data for 100,000 patients
SR12	Righ Heart Caterization (RHC) large dataset, 5735 critical illness

Table V
INFORMATION EXTRACTION FOR THE MEDICINE RECOMMENDER SYSTEMS

Medicine area includes uncommon recommender technologies, and this review focuses on the design of the medicine recommender system. Commonly used recommendation techniques include collaborative filtering (CF), content- based (CB), knowledge-based (KB) techniques and hybrid recommendation technologies. Each recommendation technology has advantages and limitations, see Table I and Figure 3.

In the reviewed studies, it has been shown that the recommendation systems are more effective when performing hybrid combinations [3] [21]. Hybrid recommender systems can be quite successful. The question of interest is to understand what types of hybrids are likely to be successful in general or failing such a general result, see Figure 4 and 5. For this reason, the recommender systems need to be compared through their implementation of frameworks, efficiency and precision results, so the best strategy is selected.

Other effective technique to have good accuracy in recommender system is to use the model domain based on the ontology of the product [21] [23], see Figure 6. Ontological modeling is an inherent process for building an ontology application regardless of the application domain. After completing a domain analysis, key concepts and their relationships are identified in order to best portray the domain. The product ontology treats products, classification scheme, attributes, and units of measure as key concepts.

6 shows the relation between the recommender system type and the domain model. The most popular combination of medicine recommender systems is hybrid with an ontological domain. This mix facilitates the recommendation of multiple items, since it is based on the more complete type and the more flexible domain model.

RQ2: What features should a medicine recommender system for physicians have?

In this review some different approaches of medicine recommender systems were found. However, it is necessary to integrate the different criteria and determine the main features that are necessary in this type of recommendation systems. It was identified the features of this kind of medicine recommendation system and was classified as follows: **Approach.-** The most used is collaborative filtering see Figure 3. The hybrid approach is also used for its accuracy in the recommendations but its implementation can be complex. Three features are

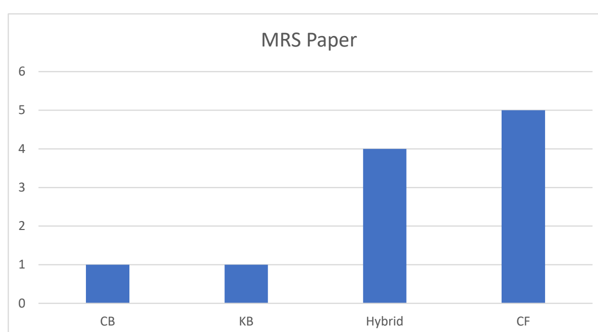

Figure 3. Distribution of medicine recommendation methods

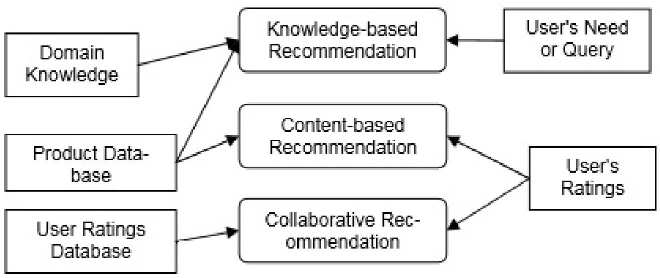

Figure 4. Recommendation techniques and their knowledge sources [22]

Code	Approach	Accuracy	Complexity	Algorithm	Model domain
SR1	Hybrid	High	Medium high	SVM,Neural Network, ID3	Database
SR2	Knowledge	Medium	Low	-	Database
SR3	Collaborative	Medium	Medium	K-means	Database
SR4	Hybrid	Medium	Medium	-	Real Dataset
SR5	-	Medium	Medium	-	Database
SR6	Collaborative	Medium	Medium	Clustering	Database
SR7	Collaborative	High	Medium	Proposed	Database
SR8	-	-	-	SVM	Database
SR9	Hybrid	High	Medium high	Neural Network	Database
SR10	Knowledge	High	-	-	Database
SR11	Collaborative	Medium	-	ID3	Database
SR12	Collaborative	Medium High	-	SVM	Dataset

Table VI
FEATURES OF MEDICINE RECOMMENDER SYSTEMS

determined in the classification by approach: 1. How collaborative is it? and 2. How accurate is it? 3. Another feature that is deduced is the level of complexity. **Algorithm.-** The most used type machine learning algorithm for medicine recommender systems is SVM Support Vector Machine [3] [12] due its high accuracy, efficiency and scalability. Another algorithm used are k-means, decision tree, matrix factorization, fuzzy logic, clustering, neural networks, Bayesian [24]. **Model Domain.-** The most used model domain for medicine recommender systems are database see Figure 6, it is used with collaborative filtering and hybrid approach, it is used to obtain a good coverage.

In the table VI, it shows features of medicine recommender systems found in the selected studies. A reaserch about metrics for the features needs to be done in future Works. In this section it will only be reported if the feature is presented in the paper.

VI. DISCUSSION

After studying the selected papers, an analysis was carried out to check the advantages and limitations of the medicine recommender systems (see Section IV). This analysis focused on the two research questions, i.e., the availability and features of medicine recommender systems for physicians.

From the analysis, an effective alternative can use several approaches generating a hybrid system. This approach offers high accuracy in the recommendations. In general, using recommendation techniques that include collaborative filtering (CF), content-based (CB), knowledge-based (KB) and hybrid recommendation technologies. [3] [15] [18][22]

The main problem of hybrid recommender systems is related to the complexity implementation. This approach combines two or more methods and the information processing is slower the rest of them. But, it frequently suffers if the amount of data to process is high. The hybrid approaches for e-health should use collaborative filtering to obtain a better and more satisfactory personalization in the recomendation. [24][19]

The information reviewed in the articles determining that a recommendation system must contain: database system module, data preparation module, recommendation model module, evaluation module, and data display module. The module related to the recommendation is considered important from these modules. From the information reviewed, it is determined that there are some algorithms for medical recommendations such as SVM, ID3 decision tree and BP neural network, and it is intuited that there are other algorithms that can be used [3]. It will be necessary in a research process additionally to investigate each of these algorithms to determine which is the most appropriate according to the proposal. When it comes to a new application area, a new recommendation framework is necessary to solve these problem On the other hand it is also necessary to put emphasis on the evaluation model to avoid misdiagnosis and eliminate

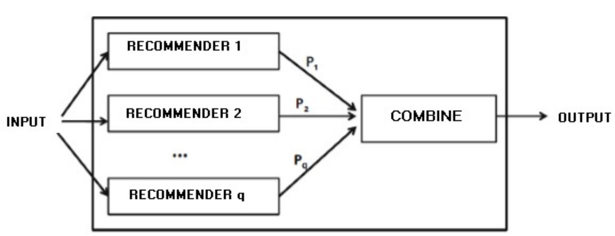

Figure 5. Hybrid recommender system design

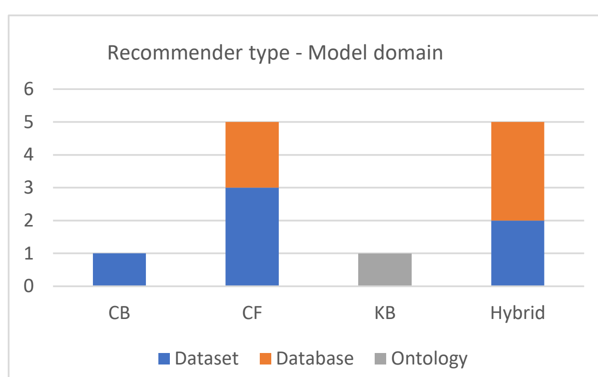

Figure 6. Approach related on kind of recommender and model domain

errors.

It was also found that an important factor could be the preferences of both patient and doctor and, in this sense, it would be important to ask whether the recommendations system should consider the preferences that users have about the use of certain medications. It should be considered the scope; it could be important information to store the previous decisions made by the doctor in similar diseases or include the doctor criteria in the selection of a drug especially in relation to the preferences of a pharmaceutical house [15] [4]. This personalization can support a best relationship between the doctor and the system and therefore in the use of it.

An important decision to make is how the system reaches the doctor. Due technology advancement, many articles talk about use of mobile systems, but this support carried out by the system should be evaluated [4] [25]. First, it would be thought that a system that can be visualized in any device. For our proposal, the display mode is not fundamental.

VII. Conclusion and Future works

In the present review were found 178 papers and through a systematic analysis process, 12 articles were obtained and their comparison was made.

From the comparison made it was possible to identify strengths and weaknesses, this process was carried out to determine if there are a medicine recommender valid for physician that provide a supply of medicine and then research their features.

The recommender systems analyzed confirm that a system for physician should use a high level of accuracy, in this case hybrids approach are recommended, although the complexity is high. This hybrid approach should allow collaborating filtering for obtain user satisfaction and better personalization.

The use of machine learning algorithms like SVM support vector machine will allow high accuracy, efficiency and scalability.

Considering the domain model, it is interesting to review that a database approach is adopted, see Figure 6, due the large amount of information that is required and the accuracy that must be defined.

For the future work it is important to make new studies related to metrics to measure and categorize these recommender systems, to define a metric oriented to accuracy, complexity, coverage, robustness. Without forgetting criteria to evaluate a recommender system to define in [24].

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