A Systematic Review of Nutrition Recommendation Systems: With Focus on Technical Aspects

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ABSTRACT

Background: Nutrition informatics has become a novel approach for registered dietitians to practice in this field and make a profit for health care. Recommendation systems considered as an effective technology into aid users to adjust their eating behavior and achieve the goal of healthier food and diet. The purpose of this study is to review nutrition recommendation systems (NRS) and their characteristics for the first time.

Material and Methods: The systematic review was conducted using a comprehensive selection of scientific databases as reference sources, allowing access to diverse publications in the field. The process of articles selection was based on the PRISMA strategy. We identified keywords from our initial research, MeSH database and expert's opinion. Databases of PubMed, Web of Sciences, Scopus, Embase, and IEEE were searched. After evaluating, they obtained records from databases by two independent reviewers and inclusion and exclusion criteria were applied to each retrieved work to select those of interest. Finally, 25 studies were included.

Results: Hybrid recommender systems and knowledge-based recommender systems with 40% and 32%, respectively, were the mostly recommender types used in NRS. In NRS, rule-based and ontology techniques were used frequently. The frequented platform that applied in NRS was a mobile application with 28%.

Conclusion: If NRS was properly designed, implemented and finally evaluated, it could be used as an effective tool to improve nutrition and promote a healthy lifestyle. This study can help to inform specialists in the nutrition informatics domain, which was necessary to design and develop NRS.

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Keywords

Nutrition; Diet; Information Science; Informatics; Computing Methodologies

Introduction

Nutrition is the essential basis for health and development of human life from the earliest stage of fetal development into old age. Healthy food and proper nutrition are indubitable requirements for survival, physical development, mental growth, performance and productivity, health, and well-being [1-5].

The combination of information technology (IT), information sci-

ences and nutrition has generated the concept of nutrition informatics. This branch of health informatics has become a novel approach for registered dietitians and dietetic technicians to practice in this field and make a profit for health care. The first scientific use of term 'nutrition informatics' referred to 1996; however, the dietitians have been applying the nutrition information and assuming technology for decades. The first paper exhibiting the potential usage of the computer to analyze dietary intake was published in 1962. Health care has included IT to establish patient care by the use of electronic health records, gather population data through the collection of personal health records and support clinical research via the reuse of data. Moreover, dietitians have involved particular electronic tools developed for managing patient tray service, indexing, and evaluation of nutrients [6-17].

Though most people have been informed about the significance of healthy eating habits, they incline to neglect suitable behaviors because of urban lifestyle and/or unwillingness to spend cognitive attempt on food provision. Those barriers prevent people from healthy food intake [18-20]. Nutrition recommendation systems (NRS) are one of the main technologies applyed in nutrition informatics scope. They are explored as an effective tool in order to support users for changing their eating behavior and reaching the goal of healthier food choices. NRS not only recommends users' preferences for food, but also recommends healthy diet choices; in addition, it can advise appropriate diet and keep pursue of eating behavior, realize health problems, and lead into alteration user behavior [21-24] .

Generally, recommendation systems have developed an efficient and effective technology to extract valuable information and then use it in an effectual way. A recommender system can predict the preferences of users for unrated items and recommend new items to users. The capability of these systems depends on technical requirements and proper design based on system types and functionality. Several various techniques have been proposed for developing personalized recommendations; these varieties in applied techniques and design may create various types of recommendation systems, including collaborative filtering recommender systems (CF), content-based recommender systems (CB), knowledge-based recommender systems (KBS) and hybrid recommender systems (HRS) [21, 24-28].

There has been no detailed investigation to review NRS and their characteristics. The purpose of this study is to review recommendation systems in the nutrition field with focus on characteristics, types and evaluation methods. Moreover, this study uses a systematic review approach based on PRISMA guideline.

This systematic review responds to the following research questions:

RQ1: Which types of recommendation systems are mostly used in the field of nutrition?

RQ2: Which Artificial Intelligence (AI) techniques or intelligent methods are applied in NRS?

RQ3: What are the main modules of these NRS?

RQ4: Which platforms design NRS?

Material and Methods

This systematic review was conducted based on the preferred reporting items for systematic reviews and meta-analysis (PRISMA). Figure 1 displays the process of PRISMA for data collection and analysis.

Search strategy

The papers from PubMed, Scopus, Embase, Web of Science, IEEE (Institute of Electrical and Electronics Engineers) and Google Scholar databases were searched without time limitation (up 10 January 2019).

The PICO (population, intervention, comparison, and outcome) criteria were used to define the search string: population (P), intervention (I), comparison (C), and outcome (O). The population was defined based on whom

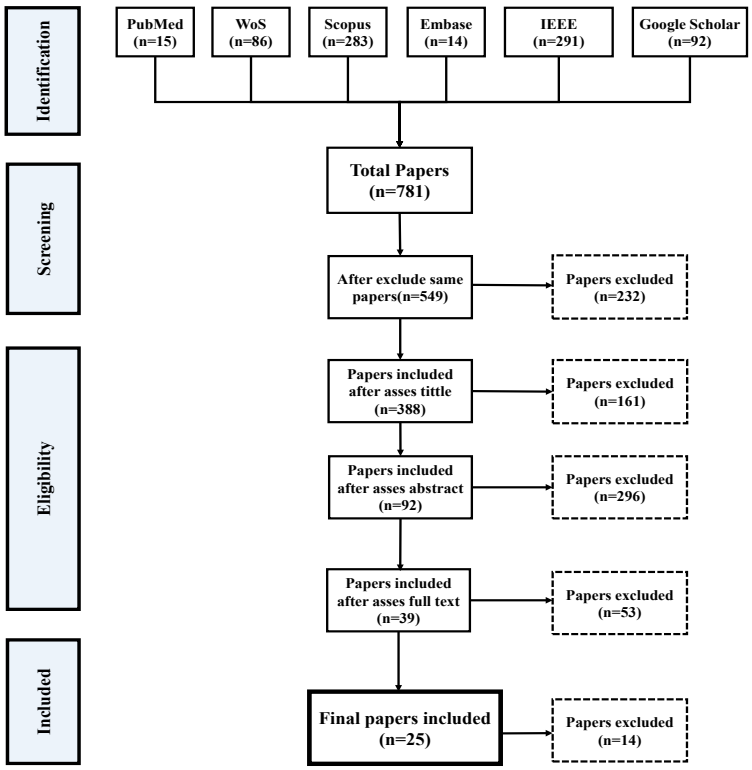

Figure 1: Process of PRISMA for data collection and analysis

systems were designed for. The intervention was the usage of recommendation systems in the nutrition field. The comparison was excluded and the outcomes were the characteristics and types of developed NRS as well as their methods of evaluation.

We identified keywords from our initial research and matched them with those existing on the database of Medical Subject Headings (MeSH), which is managed by the US National Library of Medicine. In addition, we used an expert working in the medical branch libraries to improve the quality of searches. The search strings based on MeSH and title, abstract and keywords were as follows: (nutrition* OR diet OR food* OR meal) and (recommend* system*).

Inclusion and exclusion criteria

The inclusion criteria were original articles and proceedings. Moreover, just articles which focus on NRS and have health-promotion goals, and papers up 10 January 2019 were included. Exclusion criteria were Non-English papers, any types of publication other than journal articles and proceedings (review papers, letters, etc.), and non-human study papers. Furthermore, papers focusing on systems other than recommendation systems such as expert, clinical decision support systems and those only working with business and marketing purposes were excluded.

Selection process

In the primary screening, two individual reviewers screened titles and abstracts of the articles based on the research and PICO questions and the papers were classified into three sets completely. The first set (number 1) contained the papers with certainly inclusion criteria. The next set (number 2) contained the papers that their inclusion criteria were not

clear for reviewers. Lastly, set (number 0) referred to the papers with no inclusion criteria, which were ineligible and excluded from the screening. The reviewers assessed the papers with different assigned numbers and discussed them. All the papers with similar numbers (one or two) were involved for the next stage. Following, the full text of the involved papers was achieved for the second-stage of screening and then evaluated by two reviewers. Finally, we were certain about 25 papers, then summarized and reported them in tables and charts according to the aims of the study.

Data extraction

In this phase, 6 variables were extracted in order to response to the research questions. These variables contained the name of the system, type of recommendation system, artificial intelligence (AI) or intelligent techniques applied in recommendation system, system modules and type of system's platform.

Results

Table 1 shows data extracted from the 25 articles reviewed [23, 29-52]. The sixth variables of the selected papers are presented in Table 1.

Type of recommendation system

As presented in the fourth column of Table 1, the types of recommendation system were studied. The frequency (%) of recommendation system types is presented in Figure 2.

AI or intelligent techniques apply in recommendation systems

As shown in the fifth column of Table 1, various AI or intelligent techniques have been applied in recommendation systems. The types of these techniques with their frequency in the researches are stated in Figure 3.

The seventh column of Table 1 illustrates the type of system's platform. Figure 4 demonstrates the frequency of the type of system's platform. Based on the chart, the frequented platform applied in NRS was a mobile application with 28%.

Discussion

Despite the various application of recommendation systems in many domains, there is not much evidence for using recommendation systems in health informatics or medicine [53]. According to the Valdez framework [53], if we want to design or assess the health recommender system, it will be necessary to consider 3 main aspects. First of all, we should understand the health domain. In this aspect, answering these two questions is very important: 1) which one of following items is recommended (nutrition, medicine, sport)? In addition, 2) who is it recommended to (the patient, the doctor, the nurse, policy maker)?

Another aspect that should be considered is the understanding of technical specifications and data analysis methods used in health recommendation system. The third aspect that needs to be addressed in the analysis of health recommendation system is the understanding of the methods and techniques of evaluating recommender systems. Besides, this paper for the first time reviewed the technical specifications of NRS.

The items in the results have been discussed in the following:

Type of recommendation systems

Hybrid recommender systems (HRS) are the mostly used recommender type in nutrition recommendation systems (Figure 2). As these systems use a combination of other systems type, they could compensate disadvantages of one type of recommendation system by another type. Moreover, hybrid types are applied in order to increase the recommender's performance [21, 25].

AI or intelligent techniques applied in recommendation systems

In NRS, rule-based techniques are frequently used (Figure 3). The reason behind that might

Table 1: A brief Summary of Evaluated Technical Result for each Unit

Number	Title , authors name, year and country	Name of the system	Type of recommendation system	Type of AI techniques applied in recommendation system	System modules	System Platform
1	A Mobile Application for Managing Diabetic Patients' Nutrition: A Food Recommender System Norouzi et al. [23] 2018 Iran	Iranian Snack Recommender System	Knowledge-based recommender systems (KBS)	Rule base	Patient's profile, recording physical activity, recording users favorites, periodic reports, setting for reminder, recording lab results, requesting for snack	Mobile Application
2	PERSON—Personalized Expert Recommendation System for Optimized Nutrition Chen et al. [29] 2018 UK	PERSON	Hybrid recommender systems (HRS)	Deep learning neural network, Genetic Algorithm (GA)	Word Embedding & Padding model , a DNN model for product categorization, decision recommendation model, an operational state machine	-
3	A Chronic Disease Diet Recommendation System Based on Domain Ontology and Decision Tree Chen et al. [30] 2017 Taiwan	-	Knowledge-based recommender systems (KBS)	Rule base, Decision tree, Domain Ontology	-	Web base application
4	Diet-Right: A Smart Food Recommendation System Rehman et al. [31] 2017 Pakistan	Diet-Right	Knowledge-based recommender systems (KBS)	Rule baseAnt Colony Optimization (ACO)	-	-
5	Yum-Me: A personalized nutrient-based meal recommender system Yang et al. [32] 2017 USA	Yum-Me	Hybrid recommender systems (HRS)	Food Preference Elicitation Algorithm. User State Update Algorithm k-means++ Algorithm for Exploration Images Selection Algorithm	-	Web browser, Mobile application, smart watch
6	PREFer: A prescription-based food recommender system Bianchini et al. [33] 2017 Italy	PREFer	Hybrid recommender systems (HRS)	Ontology	Recipes, menus and prescriptions, users' profiles	Web application
7	DFRS: Diet Food Recommendation System for Diabetic Patients based on Ontology Kumar and Latha [34] 2015 India	DFRS	Hybrid recommender systems (HRS)	Ontology, K-Means clustering algorithms, rule-base, SelfOrganizing Map (SOM)	Data Processing Module, Diet Planning Module, Food Ontology Construction Module, Food Recommendation Module	-
8	Nutrition for Elder Care: a nutritional semantic recommender system for the elderly Espin et al. [35] 2015 Spain	NutElCare	Hybrid recommender systems (HRS)	Rule base, Domain Ontology	Knowledge base and items representation, User profiling and learning techniques of user interests, Obtaining and providing recommendations about items in the knowledge base through semantic similarity measures	-

Number	Title , authors name, year and country	Name of the system	Type of recommendation system	Type of AI techniques applied in recommendation system	System modules	System Platform
9	u-BabSang: a context-aware food recommendation system Oh et al. [36] 2010 South Korea	U-BabSang	Content-based recommender systems (CBR)	Multi agent system	-	Windows base software
10	A Disease-driven Nutrition Recommender System based on a Multi-agent Architecture Ivaşcu et al. [37] 2018 Romania	-	Hybrid recommender systems (HRS)	Multi-agent system Rule base Ontology	Hospital Agent, User InfoKDA, GUIAgent, HealthKDA, FoodKDA, UserProfileAgent, RecommenderAgent	mobile application
11	Nutrilize a Personalized Nutrition Recommender System: an enable study Leipold et al. [22,38] 2018 Germany	Nutrilizesystem	Knowledge-based recommender systems (KBS)	-	An accurate nutritional food database, a user nutrition profile, a recipe database, and a knowledge-based utility function for each nutrient.	mobile application
12	A hybrid framework for a comprehensive physical activity and diet recommendation system Ali et al. [39] 2018 South Korea	-	Hybrid recommender systems (HRS)	Rule base	Modules are divided into two categories i.e. main module and supporting modules. Main module represents the main working engine of the framework while the supporting modules provide services to the main module. These modules are: Data Acquisition and Processing, Context Generation,Expert Knowledge Repository,Presentation	-
13	A personalized diet and exercise recommender system in minimizing clinical risk for type 1 diabetes: An in silico study Xie and Wang [40] 2017 USA	-	Knowledge-based recommender systems (KBS)	A Nonlinear Autoregressive Moving Average with Exogenous Inputs (NARMAX) Model	-	-
14	The Research and Design of Recommendation System for Nutritional Combo Li and Yang [41] 2016 China	-	Hybrid recommender systems (HRS)	-	This system has 2 main modules. Web Module(Log in module, Registering module, Saving module, Singular screening module, Recommendation module) and Back-end recommendation module	-
15	Online Recommender System for Personalized Nutrition Advice Franco [42] 2017 UK	Nutri	Knowledge-based recommender systems (KBS)	Rule base	-	mobile application
16	A healthy food recommendation system by combining clustering technology with the Weighted slope one Predictor Bundasak [43] 2017 Thailand	-	Hybrid recommender systems (HRS)	Self-Organizing Map (SOM), K-mean clustering analysis	-	-
17	DIETOS: a recommender system for health profiling and diet management in chronic diseases Agapito et al. [44] 2017 Italy	DIETOS	Content-based recommender systems (CB)	-	DIETOS User Profiler, DIETOS Reminder, DIETOS History, CKD Calculator, DIETOS Foods Filter and DIETOS Security	Web application

Number	Title , authors name, year and country	Name of the system	Type of recommendation system	Type of AI techniques applied in recommendation system	System modules	System Platform
18	Health-aware Food Recommender System Mouzhi Ge et al. [45] 2015 Italy	-	Collaborative filtering recommender systems (CFR)	-	-	mobile application
19	Mobile Nutrition Recommendation System for 0-2 Year Infant Anggraini et al. [46] 2014 Indonesia	Nutrisi	Knowledge-based recommender systems (KBS)	Rule base forward and backward chaining method	-	mobile application
20	Profiling basic health information of touriststowards a recommendation system for the adaptive delivery of medical certified nutrition contents Giuseppe et al. [47] 2014 Italy	-	Content-based recommender systems (CB)	-	Users Data Manager module, Users Profile Creation module, Recommendation System module, Adaptive Food Selection module, Security Layer module	Web application
21	The runner - Recommender system of workout and nutrition for runners Donciu et al. [48] 2011 Romania	The Runner	Hybrid recommender systems (HRS)	semantic web and ontologies		web application
22	A recipe recommendation system based on automatic nutrition information extraction UETA et al. [49] 2011 Japan	-	Collaborative filtering recommender systems (CF)	NLP	-	mobile application
23	Application of Data Mining Techniques in a Personalized Diet Recommendation System for Cancer Patients Husain et al. [50] 2011 Malaysia	-	Knowledge-based recommender systems (KBS)	Data mining techniques of Case-based Reasoning, Rule-based Reasoning and Genetic Algorithm	User management module, diet planning module, menu construction module and menu adaptation module.	-
24	Food recommendation system using clustering analysis for diabetic patients Phanich et al. [51] 2010 Thailand	Collaborative filtering recommender systems (CF)	Self-Organizing Map (SOM) K-mean clustering		-	-
25	Design of Diet Recommendation System for Healthcare Service Based on User Information Kim et al. [52] 2009 South Korea	Content-based recommender systems (CB)	Multi agent system		Nutrient Extraction Module, Preference Configuration Module	-

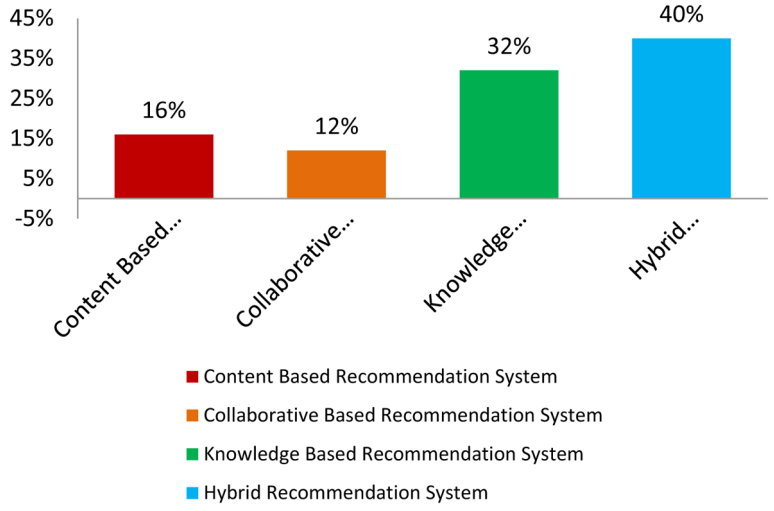

Figure 2: The frequency (%) of recommendation system types

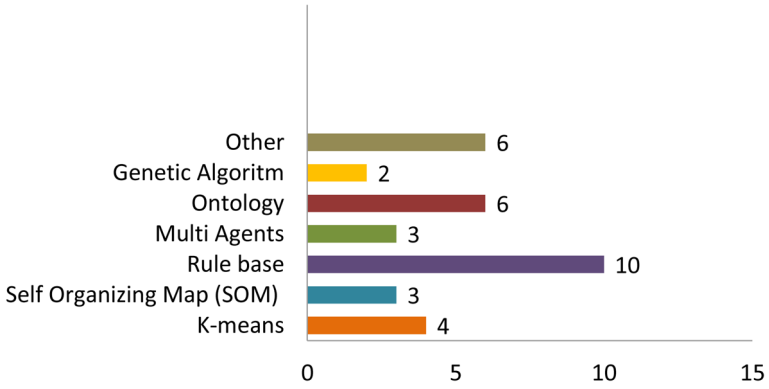

Figure 3: Frequncy of AI or intelligent techniques applied in recommendation systems

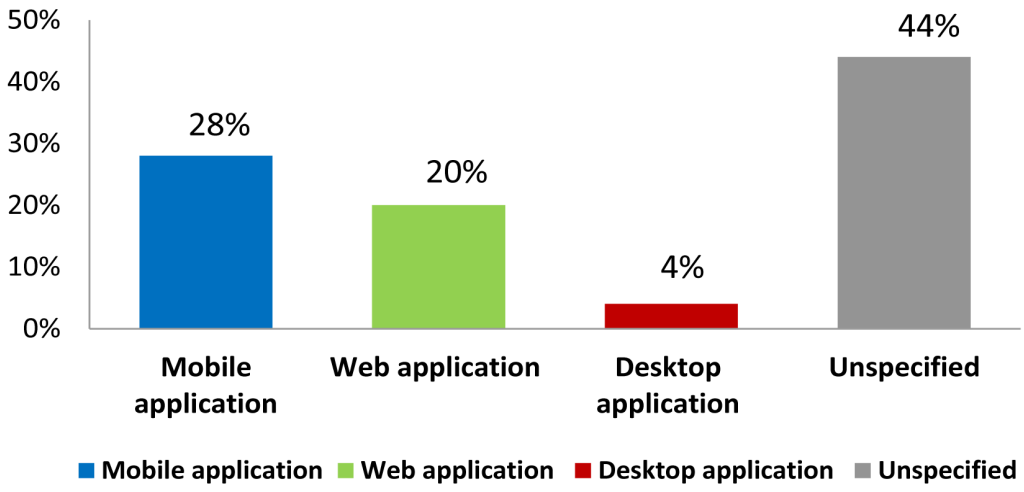

Figure 4: Frequncy of type of system's platform

be the simplicity, transparency, and consistency of rule-based techniques with nutrition knowledge. Ontology techniques also have been used for the same reasons to show the knowledge and concepts of relations in a clear manner.

Cold start, which is one of the classic problems in recommendation systems, happens when a new user uses the system with no preferences [54]. Although this situation seems to not occur frequently in NRS, recommendation of collaborative filtering, which is content-based, is made by [41] to overcome this issue.

Type of system's platform and their structure

Owing to the penetration of smartphones, their processing, connectivity capabilities and their accessibility [55, 56], mobile applications had a growth in the medical field [56]. As it has been shown that mobile apps have potential effects on health behavior change [57] and chronic disease management [58], they have been used in the most of reviewed systems for NRS as shown in Figure 4.

In addition, web technology, due to its cross-platform specificity leading into the use of multiple clients with different hardware and operating system, is popular for these recommendation systems.

This is the first systematically review of the recommendation systems in the nutrition field with focus on characteristics and types. The study offers some important insights into the condition of recommendation systems in the nutrition field with focus on technical aspects. This study can help to inform specialists in the nutrition informatics domain, which was necessary to design and develop NRS.

However, there are many mobile applications in the nutrition field useing "recommendation system" technology which have not been mentioned in the design methodology [57]. This study concentrates only on research, which explicitly discusses the use of the recommendation system.

Conclusion

In this paper, we systematically reviewed the recommender systems in nutrition scope with a focus on characteristics and types. The results of this investigation show that hybrid recommender systems (HRS) are mostly used recommender type in NRS. Many AI or intelligent techniques applied in recommendation systems, which are one of the most frequented techniques, are systems based on rules. Furthermore, the frequented platform applied in NRS was a mobile application. If NRS is properly designed, implemented, and finally evaluated, it can be used as an effective tool to improve nutrition and promote a healthy lifestyle.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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