A Review of Healthcare Recommendation Systems Using Several Categories of Filtering and Machine Learning-Based Methods

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2022 International Conference on Computing, Communication, and Intelligent Systems (ICCCIS) | 978-1-6654-6200-6/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICCCIS56430.2022.10037604

Abstract: **Health-care Recommendation Systems (RSs) is a famous application of AI (artificial intelligence) that involves the investigators worldwide. Several ML methods are utilized to develop health-care RSs. Selecting the best ML method to give customers a service/product is an interesting task in health-care RSs. Currently, it is observed in the buying pattern of individuals from in-shop to online the outcome in accessibility of OI (online information) which is exponentially improved day by day. In shopping scenarios, these RSs must be capable of advising reliable solutions to the customers. The medical health-care RSs have to manage a large quantity of data by cleaning the reliable data depending on the data analysis, generated on the user behaviour made by the customers during their online terms. RSs can suggest suitable items to customers based on their interests and existing favourites, leading to improved sales. This paper described the overview of health-care RS, phases of RSs such as IC (information collection), learning, and recommender or predictor. This paper presents an overview of three main methods used to construct health-care RSs that are content-based, collaborative filtering (CF)-based and hybrid (HB)-based filtering methods and discuss several ML-based methods used in health-care RSs with their performance comparison. The ML-based methods include; MFM (matrix factorization model), CNN, MLP, SVD, etc.**

Keywords: **Machine learning methods (ML), singular value decomposition (SVD), convolution neural network (CNN), Content-based (CB), healthcare recommendation system (RS).**

1. Introduction

With OI volatile development, it has progressively not been easy for people to attain a high rate and reliable data. An EIF (efficient information filtering) instrument [1] to support people manage data load, RS has been extensively utilized in movies, music, news, and e-commerce; instances are defined in figure 1.

Recommendation Systems	Categories	Recommendation Systems	Categories
amazon.com	E-commerce	Alibaba.com	E-commerce
ebay.com	E-commerce	last.fm	Music
pandora	Music	NetEase	Music
YouTube	Video	TikTok	Video
NETFLIX	Movie	movielens	Movie
facebook	Social network	twitter	Social network
BBC NEWS	News	Google News	News

A recommendation system can give PR (personalized recommendations) efficiency by using the recommended method to study URs (user requirements) from massive UBD (user behaviour data).

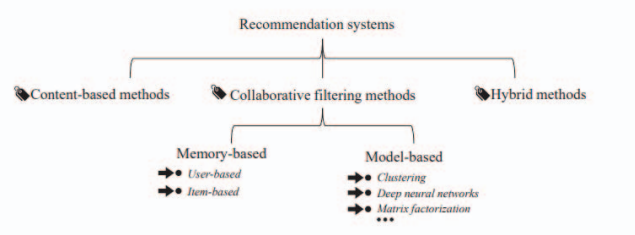

Figure 2. Categories of recommendation methods [3],[23]

Health has increased attention from people worldwide. The fast growth of current society and the affected enhancement of living morals. People are enthusiastic about living a good life and maintaining a good body state. The current vision of well-being expresses that well-being is no longer simply the lack of infection. WHO (world health organization) shows *"health"* as a state-run comprehensive social, PHY, and mental wellbeing.

Several non-communicable diseases contain cancer, heart attack, diabetes, CRD (chronic respiratory disease), etc., accounting for greater than 63 per cent of the total deaths. The major reasons for diseases are environmental, dietary, lifestyle, and occupational. Normally speaking, most of the causes may be prohibited. Behaviour alters may also efficiently enhance the current health-state.

RSs are utilized in several fields, such as e-learning, e-commerce, tourism, health, etc. RSs are worldwide utilized in the e-learning area to recommend objects to customers of their attention. The objects are suggested depending on the purchase background of users. Depending on the analysis, user preference can also make predictions. This method can consist as part of personalization because it helps each user purchase the product of their interest. RS can create an honest relationship with users and raise the sale rate; if the approval is suitable. RS in the e-learning area has increased the care of the BC (business community). An E-commerce site utilises the RS to advise the books normally bought by users. Mostly, RS available today depends on the gathered data of customer's background, explicit rating, and ownership data.

RSs have also become important in medical health-care, recommending HI (health-care information) to patients and health professionals based on their needs. RS gives various opportunities in the medical area through various ML methods. The difficult issues using unstructured information can be effectively solved using various ML methods. RSs and their uses surveyed in this article are shown in Table 1 [3].

Table 1. RS methods and applications domain fields surveyed

Methods [3]	CB	CF	Hybrid	CI	SN	CA	GA
e-govt	One	Three	Four	Four			
e-business		One	Three	Four	One		
e-commerce/ shopping	Three	One	One	One	Two		
e-library	Two	Two	Three	One			
e-learning	Two			Two			
e-tourism	Five	Nine	Nine	Three	Two	Eleven	
e-resource	Nine	Sixteen	Fifteen	Eight	One	One	
e-group Activity	Nine	Five	Five	One			Two
Total	**31**	**37**	**40**	**27**	**6**	**12**	**2**

Abbreviations: CB (content-based), CF (Collaboration filtering), CI (Computational intelligence), SN (Social networks), CA (Context aware), and GA (group aggregation).

The use of RS in health-care is growing with time. The accessibility of the INTERNET connection gives the organization and customers to preserve and access health-related information online.

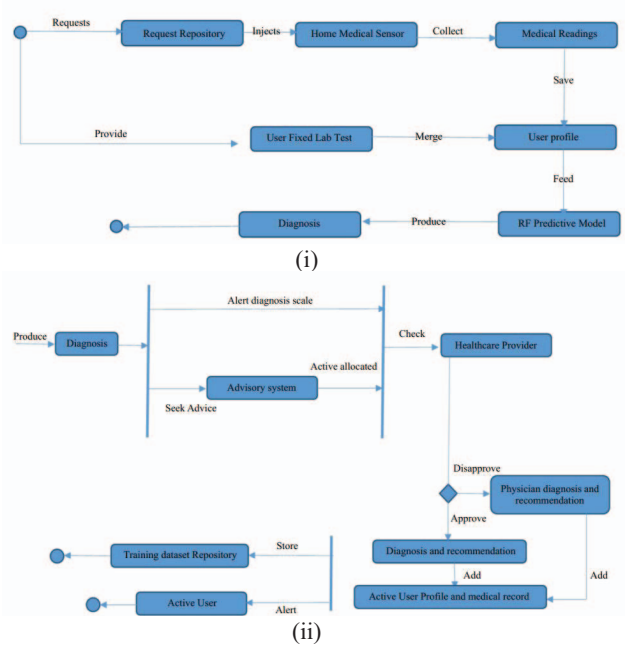

Figure 3(i) Diagnosis detection scenarios and (ii) Medical Recommendations Flow [22]

Figures 3(i) and (ii) show the flow of disease detection and medical advice recommendation. The patients are receiving maturity in retrieving health-related information online. RS usage has given customers to access data more precisely. Defined in Table 2 is the comparison analysis with different existing medical RSs. The health-care RSs methods used by each previous work are defined in table 2 [22].

Table 2: Comparison of Developed health-care RS (recommendation system) [22]

Platform	CB	CF	KB (knowledge-based)	CA (context aware)	FL (fuzzy linguistic) and TC (text classification)
Appointment area: Doctor	True				
CDD (chronic disease diagnosis)		True			
DRS (dietary recommendation service)	True		True		
CA and RE (Collaborative assessment and recommendation engine)	True				
Clinical RS for NP (nursing plan)			True		
MobiDay			True	True	
RS for DS (doctor selection)					True

RS are world widely used in the health-care industry. Nowadays, giving patients better HS (health services) enables doctors and hospital staff to make decisions. RS methods in medical health-care demand consider different needs than other platforms such as e-learning, e-commerce, etc. This article described several ML-based methods RS for medical health-care. The outcomes of the existing proposed RS are also shown in this paper. The existing proposed review paper defines the analysis of the RSs normally in medical health-care.

The review article is prepared as a trail. Section II describes classification and recommendation models. Section III describes the overview and the phases of RSs. Section IV discusses the RS filtering and ML-based methods and existing experiment outcomes. Section V presents the RS for health-care conclusions and future scope.

II. Classification and Recommendation Models

This section presents several classifications and recommendation models used in health-care systems. It analyzed the various health-care problems and developed an RS that gives users a high recommender quality. Various stages are followed for evaluating and emerging heath RS using DL and ML methods.

A. Classification Model

Anuj Kumar et al. (2021) [4] discussed ML (machine learning) method for verifying disease prediction using an ML-based classification model that classified the patients' disease according to the sign and symptoms were given by the customers as input to the system. In this article the classification of multiple diseases using the ML method is discussed. Here, they will utilize the concept of supervised ML in the design and execution will be completed by relating DT (decision Tree), RF (random forest), NB (naive bayes), and KNN (k nearest neighbour) methods that will support in early-stage detection of infections precisely and better patient's care. The outcomes confirmed that the RS would be user-oriented and functional for patients to identify diseases quickly. Baha lhnaini et al. (2021) [5] presented several ML methods and models studied in the past to detect diabetes disease. These systems may not properly manage the huge number of multi-featured databases on diabetes disease. SHRS (Smart health-care recommendation system) was introduced for diabetes infection depending on DL (deep learning), ML, and IF (information fusion) views. Utilizing If, they can remove the unrelated weight of system evaluation abilities and raise the researched model performance to precisely detect and recommend this dangerous infection. Lastly, the ensemble ML-based method was proficient for diabetes classification. The intelligent RS was calculated depending on a well-defined diabetes database, and its evaluation was compared with current growths from the survey. The research system attained a 99.6 per cent Acc rate, higher than other DL and ML approaches. The research work was better for multi-disciplinary diabetes disease classification and recommendation systems. The research enhanced disease analysis evaluation supports its employees in the AC (automated classification) and RSs for diabetes patients. Rudra et al. (2019) [6] proposed a disease prediction using ML models. The patients have to go personally to the hospital for a more time-consuming checkup for any tiny issue. Also, managing the telephonic calls for appointments was not an easy task. Like, an issue can be resolved by utilizing a disease prediction application by giving complete guidance regarding health has been improved due to several infections and minimum DPR (doctor patient ratio). So, in this research model, they concentrated on giving accurate and instant disease classification to the customers about the signs they enter along with the rigorousness of the disease classified. Various ML methods were utilized to ensure accurate and quick predictions for the classification of diseases. Kashif Naseer Qureshi et al. (2019) [7] represented and surveyed an outline of M-health systems, proposed an architecture, applications, skills and described ML methods. They proposed a secured android-based architecture to gather patient information, an effective CBM (cloud-based model) for information storage. The classification method that can predict cardiovascular diseases confers their importance are also described. Also, the implemented classification framework is compared with current performance metrics methods such as Acc, SN, and SP. The simulation outcomes define inspiring outcomes in the form of the predictive research method for RSs.

Several implementations of the proposed methods, problems, performance metrics, simulation tools, and further research work describe the heath RS used in classification and recommendation models are defined in Tables 3 and 4.

Table 3: Analysis of the several multiple disease classification Models

Author Name/ Year	Methods	Problems/Issues	Parameters	Simulation Tool	Further Improvements
Anuj Kumar 2021 [4]	DT, NB, RF, KNN	It is utilized for prediction and regression but normally deals with prediction issues. It prevents the issue of overfitting due to intensive interference in the database and is not based on overfitting.	Accuracy : 0.951	Python	It will use filter-based FS (feature selection) approaches to get better results.
Baha et al. 2021 [5]	Ensemble ML method	Predicted classification problem and one dimensional optimization problem	Accuracy = 99.6	Python	The difficulty of the deep ensemble method will be measured shortly for the precise and quick outcome of this method.
Rudra et al. 2019 [6]	KNN, DT, SVM, NB	-	Accuracy	Python: Django	-
Kashif et al. 2019 [7]	SVM, DT, KNN, and NB	This proposed model was adopted for several difficult and real-world problems.	Accuracy	Python	It will consider the study with other diseases such as TBI, etc.

B. Recommendation Model

Komal Kumar Napa et al. (2020) [8] discussed the ML method for multi-disease with medical recommendations introduced to give precise MRs (medical recommendations) for the patient's sorrow from several infections. This method made suitable recommendations for the patient's sorrow from a heart attack, cold, obesity, fever, ortho, etc. S-ML (supervised-machine

learning) methods like SVM, RF, DT, etc. The simulation and calculation of the analysis were carried-out on an example database made only for analysis and were not attained from any source. The proposed simulation analysis defined that the RF classifier method yields a decent recommendation Acc of 96.8 per cent to the other existing methods. So, the research method was careful to implement dependable recommendations to the health-care industry patients. Deepika Sharma et al. (2020) [9] discussed the research work utilizes all infection or disease classification structure-based on CNNs to separate various diseases based on the important metrics of patients. After the detection process, a FIS (fuzzy-inference-system) method was utilized to evaluate the risk-levels of the patients. In the final phase, depending on the data given by the threat analysis, the patients were delivered with the possible reference about the rigour performance of the associated diseases for reliable treatment. The research system was calculated utilizing various databases regarding the disease, and the results seem promising. P. Nagaraj et al. (2020) [10] defined the RSs as emerging very famous because they could predict users' preferences. Creates the research depends on the customer profile, previous calculations/ and other extra-learning, an illustration, logical customer data, and orders. It may be implemented in the medical health-care field by enchanting the benefits of environmental data to endure health enhancement and prediction. RS structure has been effective in both the academic and industry worlds. The implemented work provided the recommender outline in e-health service data to patients. HI (health information) systems turned into a critical phase for health-care services. This article showed recent enhancements in the market, limitations, and probabilities in e-health about health RS and evolving practices. Richa Sharma et al. 2021[11] analyzed the evaluation of various ML methods on public medical health-care databases to choose the reliable one for the research work. This work considered that the RF method is best based on the outcomes. They introduced a suitable self-based hybrid method for a smart health-care environment to measure customers from various perspectives and recommend suitable events.

Table 4: Analysis of the several multiple disease recommendation Models

Author Name/Year	Methods	Problems /Issues	Parameters	Simulation Tool	Further Improvements
Deepika et al. 2020 [9]	CNN Type-2 fuzzy systems	Overfitting	Accuracy = 0.89 Specificity= 0.833 Sensitivity = 65.5 RMSE = 1.266	MATLAB	The proposed system will improve more by deploying IoT sensors, and real-time data is gathered for calculation.
P. Nagarah et al. 2020 [10]	Multi-tasking Recommendation system	Expensive treatment	MAE (Mean Absolute error), accuracy Rank Accuracy	-	The proposed system may classify novel medical cases.
Richa Sharma et al. 2021 [11]	C3D model and CovnLSTM model	Various problems in fields such as security, healthcare, banking, retail, and IA (industrial automation)	MAE = 0.1039 RMSE = 0.1339 Precision=1 Recall =1 F1-score = 1	Weka	It will help to improve the costs and uncontrollable risks.

III. Basic Concepts and Phases of RS

It is an information FS (filtering system) category that seeks to classify a customer's preference for an object. It has been extensively used to mention books, videos, and news, on the internet [12]. In the medical health-care field, the uses of RSs comprise supporting the administrative procedure in the facility of personalized-care [13], verifying key review leaders among doctors [14], supportive patients to explore pre-emptive health-care help in the preparation of personalized therapy [15], and currently mentioning patients with doctors-based on their existing session background [16].

A. Phases of RS (recommender system)

There are approximately three phases of RSs: IC (information-collection), LP (learning phase), and prediction or recommender phases.

Phase 1: Information Collection

It gathers important data related to patients and makes a patient profile depending on the qualities, resources, or nature retrieved by the patients. A RE (recommender engine) cannot work completely without building a well-known profile. RS is based on inputs gathered in distinct paths like an implicit, explicit, and hybrid review. The explicit review takes inputs defined by patients according to their interest in items, while implicit review takings patient fidelity not directly through considering patient nature [17].

Phase 2: Learning

It consists of a valuation composed in the current phase as i/p and procedures this review by utilizing a LA method to activate the patient features as an outcome [18].

Phase 3: Prediction or Recommender

Better objects are recommended for patients in this prediction or recommender step. By studying the review collected in the DC (data composed) step, a calculation may be created the system's, memory-based entities of patients [16]. The phases of RS are defined in figure 4.

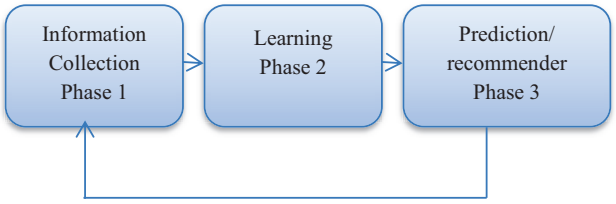

Figure 4. Different Phases of RSs [18]

B. Distinct Categories of Filtering based RS

In this section, three different categories for filtering methods are discussed and defined in table 5.

1) CBF (content-based filtering) RS

This method mainly focuses on calculating feature sets of objects to create calculations. It is generally utilized in the case of DRs (document recommenders). This method recommends using patient profiles that manage various items' attributes and patients' existing buying backgrounds. Patients give their fidelity in terms of +ive, -ive, and neural. POSITIVE ratio objects are mentioned to the patient [18].

2) CBBF (collaborative based filtering) RS

It predicts undefined results by making a patient item matrix of selections for items by patients. Customer profile's correspondence is considered by matching the patient item matrix with patients' preferences and interests. The area is created between collections of patients. The patient who has not valued particular items before becoming recommenders to those items by measuring +ive rating defined by patients in his area. The collaborative filtering in the RS may be utilized either for the recommender [19]. Figure 5 shows the complete procedure of the collaborative filtering method.

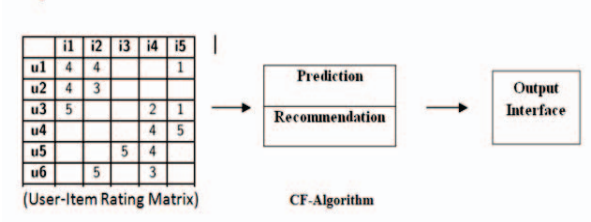

Figure 5. CBBF (collaborative–based filtering) Method [19]

3) HF (hybrid filtering) RS

It consists of the techniques above to increase RS's accuracy rate and performance. It is achieved in any subsequent methods; constructing a URS (unified recommender system) associations both of the above two methods, developing some CBBF in a CB method, and using some CBF in the collaborative method. The method utilizes various HTs (hybrid techniques) like CH (cascade hybrid), WH (weighted hybrid), MH (mixed hybrid), and SH (switching hybrid) given to their operators [3].

Table 5. Comparison of RS methods [3,20]

Methods	Defined Methods	Merits	Demerits
MB (memory-based) CF (collaborative filtering)	User and Item-based CF	• Easy to run • Simple to add data • Data (content) should not be considered. • Effectiveness scalability	• Based on the categorical suggestions • The problem is the cold start • Problem in sparsity • Limited scalability for large database
Model-based CF	Slope 1 CF	• Prediction efficiency improves • Enhance problems with scalability and sparsity	• Expensive model • Data lack in an FM (factorization matrix)
HCF (hybrid-collaborative-filtering)	The mixture of model and memory-based CF	• Reduce the sparsity challenges • Improves the effectiveness of calculation	• Increase difficulty • Limitation for operation
CBF	CBF method using HMM (hidden markov model)	• No problem with shortage and cold start • It gives privacy	• Requires brief detailing of items • Needs ordered user-profile
HF (hybrid filtering)	Grouping of content and collaboration filtering method	• content and collaboration filtering methods are complementary strengths and limitations	• It is not easy to implement
CI (computational intelligence) method	The mixture of FL (fuzzy logic), NN, and AI	• Advances the handling of data and resolves new issues.	• Disappointment to identify the precise outcomes for varying conditions. • It was deprived of giving optimal detaching of load.

4. Several ML-based Methods are used in Healthcare RS (recommender system)

RS methods and DM (Data mining) are becoming famous and significant in exploring domain information safety and confidentiality methods. PRs (personalized recommendations)

can be productive in interesting novel patients that increase several privacy materials. The authors analyse the different privacy preserving-based RSs such as MFM (matrix factorization model), SVD, CNN, etc.

A. MFM (matrix factorization model)

MFM is a popular method that resolves the existing problem, such as high-sparsity. In the main format, the features of both patients and items by an array-of-factors result from PRPs (patient rating patterns). This method has become favourable due to its improved prediction accuracy and scalability. It is an effective method to uncover the HS (hidden structure) behind the information. They are normally used to process huge datasets and give scalability keys. These are utilized in IR (information retrieval) domain and map both items and patients to a joint LF (latent-factor) space of dimensionality [19]. A vector Qi may present each item. Correspondingly, an individual patient may be defined by a vector. Pu. These fundamentals evaluate the amount to which the patient will select the product. The (.) product Qi ^{t}Pu defines the communication between patient and item and is denoted by eq (i) : Ui = Qi ^{t}Pu ……. (i)

It can measure RQ (recommender quality) like the MAE parameter. A calculation for individual DL-based RS is analyzed with distinct no. of epochs. The unique technique is calculated with MAE as defined in table 6 and figure 6.

Table 6. Comparison analysis between no. of epochs and MAE of MFM method [21]

Epochs	MFM (Matrix Factorization Model)	SVD
2	0.089	0.079
4	0.075	0.066
6	0.068	0.05
8	0.065	0.056
10	0.064	0.054

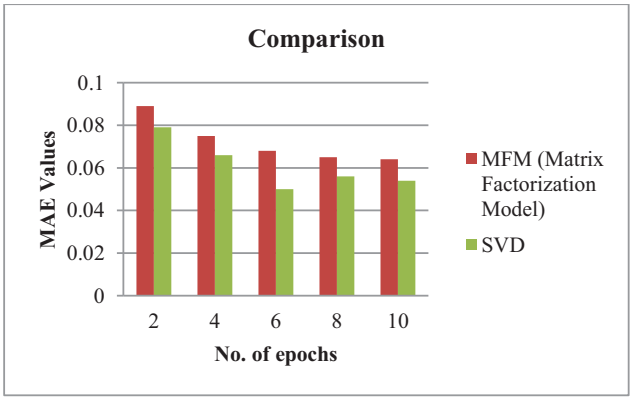

Figure 6. Performance metric with MAE [21]

Table 7. Comparison between K and RMSE of distinct techniques

K	MF	SVD
5	2.761	2.743
10	2.695	2.677
15	2.70	2.68
20	2.74	2.722

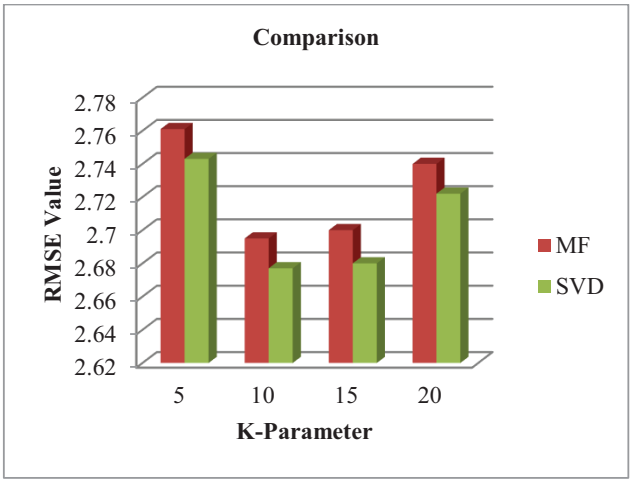

Figure 7. Comparison between k-parameter and RMSE of distinct techniques [21]

Figure 7 shows that the RMSE of the methods based on CF approaches differs from the K variable and attains a value when K = 10. The minimum value is, the maximum accuracy. It means better recommender quality.

B. MLP (multilayer perceptron) with auto-encoder

It is a type of FFNN (feed-forward-neural-network) that has several HLs (hidden layers) in which perceptron utilizes the arbitrary AF (activation function) [20]. The auto-encoder is a method that depends on USL (unsupervised learning) that attempts to recreate its i/p information in the o/p. An auto-encoder NN utilizes the BP (backpropagation) method that evaluates the incline of the exception method w.r.t the NNs weights, as defined in figure 8.

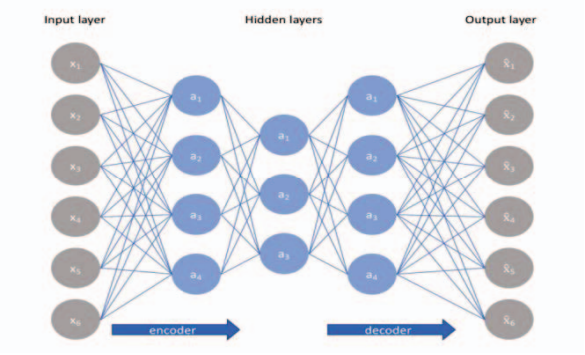

Figure 8. Auto-encoder NN [21]

AE may have consisted at the core of the RL (representation learning). They encode i/p, normally by interchanging huge into small vectors that record the vectors that are the most important feature sets used for DC (data compression), rebuilding for USL, and DR (dimensionality reduction).

C. CNN (Convolutional Neural Networks)

The main categories of FFNN comprising CLs (convolution layers) consider the global and local feature sets to improve precision and effectiveness. This NN is utilized for modeling sequential information.

D. AN (Adversarial Networks)

A generative NN (neural network) comprises two sections, a discriminator and a generator. In a min-max game structure, the 2 NNs are trained instantaneously by challenging.

E. SVD (Singular Value Decomposition)

It is a normal method for DR, and SVD arranges the basis for RSs. SVD technique is suitable for developing LF (latent factors) in the possibility of RSs to solve the existing issues handled by CBBF. The important holds of this method are predictive accuracy and scalability [3].

V. Conclusion

Medical Healthcare RS has been a popular subject for over two eras. Improved by the fast growth of IT skills, medical health-care RS has been broadly utilized in real-time. This article has surveyed the recommendation system and its phases, such as information collection, learning-phase, and prediction or recommendation. There are three different categories of filtering-based RS for health-care available that are defined in table 5 along with their detailed description, merits and demerits. CI methods have improved the processing of data and resolves new issues. Different privacy preserving-based RSs are also analyzed for medical health-care, such as MFM (matrix factorization model), SVD, CNN, etc. MFM (matrix factorisation model) is a most successful model that assists in resolving the existing problem, such as high sparsity. SVD is used for the dimensionality reduction approach and improves the prediction accuracy and scalability rate compared with the other methods. However, despite all of these advances, the current generation of recommender systems surveyed in this paper still requires further improvements to make recommendation methods more effective in a broader range of medical applications. With further improvement a novel DL method can be developed to classify the disease and create a recommender model to optimize the error rate values.

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