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Doctor Recommendation System

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***Abstract*:** The rapid progress in artificial intelligence (AI) and machine learning (ML) has dramatically reshaped the healthcare sector, offering new possibilities for disease prediction and personalized medical recommendations. This review paper examines the cutting-edge methods, technologies, and frameworks designed to recommend appropriate specialists on the basis of provided symptoms. It underscores the integration of AI techniques, including natural language processing (NLP), deep learning, and decision tree algorithms, for analyzing symptoms and diagnosing conditions. The paper also explores the role of big data analytics, wearable technology, and electronic health records (EHR) in boosting the precision and dependability of these systems. Key challenges such as data privacy concerns, the interpretability of AI models, and ensuring equitable access to these advancements are also discussed. Furthermore, the paper highlights recent breakthroughs, emerging trends, and potential future directions aimed at enhancing the efficiency, scalability, and accessibility of these systems. By synthesizing findings from current research, this review provides a comprehensive guide for researchers and professionals looking to innovate within this field.

INTRODUCTION

Healthcare has witnessed a remarkable transformation through the integration of advanced technologies into medical services. Among these advancements, doctor recommendation systems have emerged as critical tools, aiming to close the gap between patients and timely medical interventions. By leveraging machine learning (ML), artificial intelligence (AI), and data analytics, these systems predict potential diseases based on user-reported symptoms, enabling early diagnosis and more effective treatment planning. In traditional healthcare settings, identifying the right specialist often poses challenges for patients, leading to delays in receiving appropriate care. Moreover, relying solely on human expertise for diagnosis can be both time-intensive and susceptible to errors, particularly when symptoms overlap across different conditions. Automated systems designed for disease prediction and specialist recommendations address these inefficiencies by offering a more streamlined and accurate approach.

These systems process user-reported symptoms, compare them against extensive medical databases, and provide predictions of likely conditions. They also recommend relevant specialists based on the diagnosed conditions, simplifying the patient's healthcare journey and enhancing accessibility. With intuitive interfaces and real-time data processing, these technologies aim to minimize diagnostic delays and improve overall patient outcomes.

This review examines the methodologies, technologies, and frameworks underlying the development of doctor recommendation systems. It provides an in-depth analysis of their benefits, challenges, and limitations while highlighting the latest advancements. Furthermore, the paper explores future directions and opportunities to refine these systems, fostering a more efficient and accessible healthcare ecosystem.

LITERATURE REVIEW

Machine learning and deep learning technologies are increasingly contributing to various industries by enabling the development of intelligent applications. One critical area is doctor recommendation systems, which play a significant role in building a robust healthcare infrastructure, particularly for developing nations. This study introduces a machine learning-powered, web-based disease prediction platform integrated with a recommender system. The aim is to create a more strategic and effective healthcare ecosystem. It is evident that there are few disease specific solutions are available; but a diverse disease prediction system considering all common diseases is still missing (to the best of our knowledge).

There are various researchers who suggested some model to recommend desired doctors to patients. **Qusai Y. Shambour et al. [1]** introduces a hybrid approach combining content-based filtering and multi-criteria collaborative filtering (MC-CF) to help patients find the most suitable doctors based on their individual preferences. This method integrates multi-criteria decision-making, doctor reputation scores, and detailed content information about doctors to enhance the accuracy of recommendations and address the challenge of data sparsity when sufficient rating data is unavailable. Experimental results using a real-world healthcare multi-criteria rating dataset demonstrate that the proposed method delivers reliable recommendations with superior predictive accuracy and coverage compared to traditional item-based CF recommendation algorithms, even under conditions of high data sparsity.

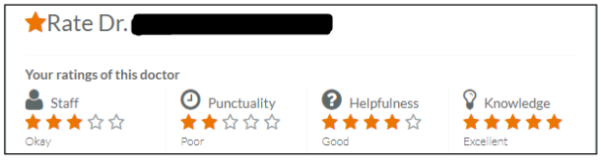

Figure 1. Doctors rating on multiple criteria

LUNING BI et al. [2] presents a doctor recommendation model based on a heterogeneous graph framework utilizing electronic health records (EHR). The approach incorporates a latent vector representing the connections between different types of heterogeneous nodes into the message-passing process. To enhance the representation of doctor, patient, and service nodes, three key relationships—service-service, doctor-specialty, and patient-doctor—are reconstructed simultaneously. To address data privacy concerns in the medical field, a federated decentralized learning approach is employed to improve the performance of local models. Experimental results demonstrate that the proposed model, FD-GATDR, achieves high prediction accuracy. Future work will focus on enhancing prediction accuracy and communication efficiency by employing a bi-level optimization model for more complex heterogeneous graphs.

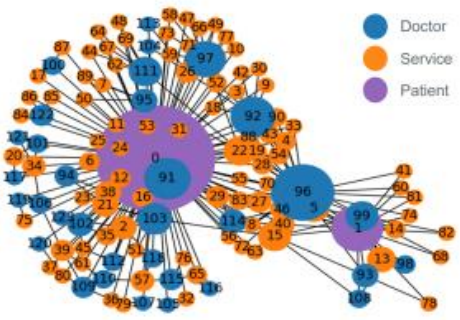

Figure 2. An example of an EHR graph can include service nodes categorized into diagnosis, procedures, and products.

Qihang Zhou et al. [3] address the challenge of recommending doctors based on personalized user needs, this study introduces RR&R-CNN. (1) Unlike traditional distributed text representation methods, RR&R-CNN leverages the pretrained BERT model to generate vectorized representations of review texts, effectively handling the issue of polysemy. (2) For rating features, recognizing that user evaluations may not always align with their ratings, revised user and doctor ratings are employed as the final representation. These revised ratings are combined with the vectorized review text and fed into a convolutional neural

network (CNN) for deep feature extraction. (3) The model is structured into a user network and a doctor network, with a factorization machine facilitating feature interaction between the two, while a loss function minimizes errors in rating predictions.

Experimental findings indicate that incorporating revised rating features enhances recommendation performance, and using BERT for text vectorization yields superior results compared to word2vec. However, the BERT model requires significant computational resources in terms of time and memory. Current techniques for compressing and optimizing BERT's complexity are being explored. Future work will focus on validating these methods to potentially reduce resource consumption and enhance recommendation performance. Additionally, domain-specific variations of BERT, such as ClinicalBERT and BioBERT, will be investigated to further improve outcomes in medical recommendations.

Yesi Sofia et al. [4] indicate that the content-based filtering approach is capable of recommending new doctors who have not previously treated patients or received ratings, whereas the collaborative filtering method is effective in recommending doctors with an established history and existing patient ratings. Following implementation, accuracy testing was conducted using a confusion matrix, achieving an accuracy rate of 91%. These results demonstrate that the hybrid filtering approach effectively assists in selecting the most suitable doctor based on patient preferences and criteria. Future research could incorporate additional parameters, such as user comments or preferences indicated through likes and dislikes, to further enhance recommendation accuracy.

Yafeng Yan et al. [5] presents the MSF-CNN (Multi-Scale Fusion Convolutional Neural Network), an advanced algorithm for personalized medical decision-making. By combining multi-scale feature fusion within convolutional neural networks and the analytical capabilities of graph neural networks, the method achieves significant improvements in healthcare decision support. The multi-scale fusion approach enhances the extraction of both macro and micro features in medical images, improving recognition accuracy for complex pathological changes. The integrated graph neural network component leverages relationships between patients or cases, enabling a deeper understanding of similarities and differences to support personalized treatment plans.

Experimental results demonstrate that MSF-CNN outperforms existing methods in key metrics such as accuracy, sensitivity, and specificity, confirming its reliability in assisting medical professionals with personalized care. This approach highlights the potential of integrating deep learning with graph theory for medical image analysis and sets a strong foundation for advancing personalized medicine. The study concludes that MSF-CNN enhances diagnostic precision, supports personalized treatment, and contributes to safer and more efficient healthcare delivery.

Jusheng Liu et al. [6] provide model For department recommendation, an LSTM-based model was implemented, considering the contextual semantics of patients' complaint texts. This model outperformed alternatives like TextCNN, Random Forest, KNN, and SVM, achieving a precision of 82.84% and an F1-score of 82.61% on the test dataset. For physician recommendation, a hybrid model was created by analyzing similarities between patients and physicians. Additionally, metrics like text and voice service quality were introduced to enhance evaluation. This combined approach surpassed models based on patient or physician similarity alone.

Yingbin Zheng et al. [7] This paper proposes a hybrid recommendation model designed for patient-doctor matching, incorporating response metrics and leveraging natural language processing (NLP) techniques to address challenges in online medical triage. The system is structured to identify and recommend appropriate doctors by analyzing relevant data, enabling patients to connect with healthcare professionals who align with their specific medical needs. This innovative approach has substantial practical applications and can be seamlessly integrated into healthcare platforms to enhance the precision and quality of doctor recommendations, ultimately improving patient outcomes and user satisfaction.

Joel Peito el al. [8] This study highlights the advantages of integrating domain-specific knowledge into healthcare recommendation systems (HRS) using Poincaré embeddings of the ICD-9 hierarchy. By incorporating patients' pre-existing conditions into the model, a notable improvement in performance was observed compared to traditional methods. The research emphasizes the potential of hyperbolic space for representation learning, demonstrating its applicability beyond natural language processing (NLP) and showcasing its value in healthcare for personalized medical recommendations.

Despite promising results, certain limitations need to be addressed in future work. The current models rely solely on content-based (CB) approaches, overlooking the insights available from patient-doctor interaction data. Developing a hybrid recommendation system that combines these data sources with ICD-9 embeddings is a potential direction for improvement. Additionally, data consistency challenges persist, with significant information loss stemming from insufficient mapping across healthcare terminologies. Enhanced collaboration among standardization frameworks like SNOMED CT, UMLS, and ICD is essential to address this issue. Furthermore, digitization in healthcare, including assigning diagnostic codes to all patients, not just inpatients, is crucial for improving data quality and scalability of machine learning solutions.

Yongjie Yan et al. [9] This paper introduces a hybrid recommendation algorithm, PMF-CNN, for doctor recommendation using deep learning techniques. The model leverages a convolutional neural network (CNN) to capture contextual features from patient reviews, enabling more precise feature extraction for review modeling. Additionally, an automatic denoising encoder is utilized to optimize the initial values of latent vectors representing patients' reviews and doctors' expertise during matrix factorization. This approach avoids local optima and integrates these representations through matrix decomposition to deliver patient-specific recommendations.

Validation using the Haodf dataset demonstrated that PMF-CNN outperforms other recommendation algorithms. However, the model faces limitations in addressing the cold-start problem, restricting recommendations to doctors with historical data. Future research aims to incorporate features from consultation categories and patient reviews to mitigate the cold-start issue and enhance recommendation accuracy. Exploring the integration of diverse contextual information within a deep learning framework is identified as a promising direction for further study.

Li Guo et al. [10] This study applies community detection to a social network of doctors, where nodes represent doctors and edge weights correspond to the number of co-authored papers. Due to the presence of large, disorganized networks in the original graph, community detection was performed on a subgraph containing a connected component of the network. Modularity (Q) was used as the evaluation metric, and spectral clustering (SC) was found to achieve the highest modularity, indicating its superior performance in identifying community structures.

The process involved iterative spectral clustering, selecting the structure with the highest modularity at each step until all communities conformed to the five-degree segmentation theory. Ultimately, doctors within the same community were recommended as collaborators, as they either worked closely or had a high potential for future collaboration in medical or research endeavors. Future research will focus on enhancing the spectral clustering algorithm to achieve even higher modularity scores.

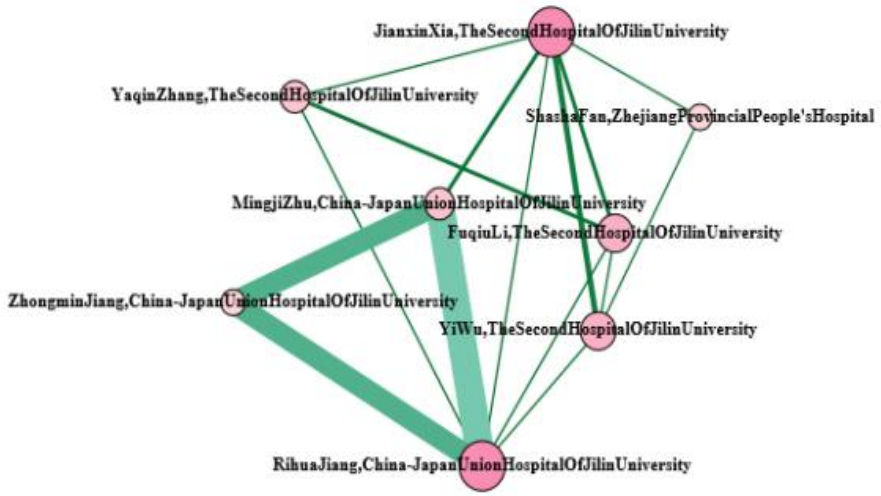

Figure 3. network of doctors, where nodes represent doctors

Chunhua Ju et al. [11] Traditional manual medical guidance struggles to meet the growing demand for healthcare services, leading to challenges such as difficulty in registration and locating appropriate clinics. Issues like information asymmetry between doctors and patients, along with the need for professional diagnostic expertise, often result in patients being unable to choose the correct clinic or doctor. This misalignment wastes time during online consultations and increases costs when patients seek offline treatment.

To address these issues, this study introduces an online pre-diagnosis doctor recommendation model that combines ontology features with disease text mining. Using real data from a comprehensive online medical platform, the proposed method demonstrates reliability and effectiveness compared to content-based and collocation-based approaches. By leveraging patient descriptions and doctor specializations, the model offers accurate recommendations, enhancing the online consultation experience and reducing offline treatment costs. The use of real-world data further validates the model's utility in improving patient convenience and enriching the value of online pre-diagnosis systems.

Yanakorn Ruamsuk et al. [12] This study explores a medical recommendation system based on co-occurrence graphs, which map relationships between diseases, symptoms, and related information extracted from medical documents. By calculating the centroid in the co-occurrence graph, the system identifies diseases associated with a given set of symptoms. Experimental results indicate that the diseases identified through this method closely align with the symptoms, making the diagnostic process more efficient.

The co-occurrence graph mimics the associative nature of the human brain but operates with automation and speed, unlike the gradual learning process of the human brain. This approach simplifies medical diagnosis and enhances the effectiveness of recommendation systems.

Qiwei Han et al. [13] Person-centered primary care is crucial for improving health outcomes and fostering universal healthcare. However, even in high-income nations, significant gaps persist between current primary care practices and the WHO's vision. Establishing stronger patient-doctor relationships is a key challenge, as greater trust in these relationships enhances perceived care quality and continuity. Trust encourages patients to follow medical advice and supports preventive care, ultimately strengthening these relationships. Given aging populations and rising healthcare costs, scalable systems to enhance patient-doctor relationships and reinforce the role of primary care doctors are essential.

This study, in partnership with a private healthcare provider in Portugal, developed a hybrid matchmaking system to connect patients with suitable primary care doctors, promoting continuity of care. The system integrates patient and doctor characteristics with consultation history data, leveraging collaborative information and social dimensions to infer patient preferences. Temporal dynamics, such as interaction frequency and recency, were incorporated to quantitatively measure trust, moving beyond traditional survey-based approaches.

The hybrid recommender system demonstrated superior accuracy, recommending relevant doctors for over 80% of patients with a list of 10 recommendations, outperforming both heuristic baselines (37%) and collaborative filtering (69%). Future work aims to deploy this system in digital health services to capture explicit patient preferences, conduct randomized trials, and further refine the model by combining implicit and explicit feedback for greater personalization.

Miguel Torres-Ruiz et al. [14] This paper presents a collaborative architecture to assist citizens in accessing medical facilities effectively. The proposed approach incorporates a recommender system that evaluates healthcare facilities using a health attention factor metric. This metric quantitatively considers patient load during emergencies, the range of medical specialties available, and the economic costs of services. Geographic location and user profiles are used to rank medical facilities, with results displayed through a Web-GIS application.

As a secondary outcome, the study highlights the importance of traffic management in urban areas like Mexico City, where

congestion complicates access to healthcare services. Rapid dissemination of alternative routes during emergencies is identified as crucial for saving lives. The study suggests integrating multi-criteria evaluation and intelligent decision-support systems to enhance emergency healthcare routing and service delivery, accounting for dynamic urban conditions.

Limitations include reliance on external APIs, such as Google Directions, for traffic and arrival time data. The authors recommend developing frameworks based on volunteered geographic information (VGI) and

crowd-sensing to address these challenges. Additionally, refining semantic similarity measures for medical specialty retrieval is suggested, including the use of advanced metrics like DIS-C for enhanced ontology-based information retrieval.

Rishab Goel et al. [15] This study reexamines the task of evidence acquisition and automatic diagnosis for telemedicine, emphasizing the integration of doctors' trust as a key factor. Emulating doctors' reasoning is identified as essential for gaining their trust, with three critical reasoning features proposed for model implementation. A novel reinforcement learning (RL) agent incorporating these features was introduced, demonstrating that existing models fall short in mimicking doctors' reasoning. The proposed model effectively emulates differential diagnosis while maintaining competitiveness on standard metrics, representing a significant step forward in reshaping automatic diagnosis research.
Future research directions include collaborating with doctors to identify additional medical elements for machine learning models, creating datasets encompassing diverse pathologies, and evaluating how well machine learning agents scale with larger diagnostic and action spaces. Measuring the quality of collected negative evidence and exploring online learning methods for real-time doctor feedback and evidence refinement are also suggested to enhance the system's effectiveness and alignment with expert practices.

COMPARISON TABLE

Comparison of different papers based on Methodologies, Techniques, Datasets, and Accuracy

S.NO	Authors	Journal	Paper Title	Methodology	Techniques	Dataset	Accuracy
1.	Qusai Y. Shambour, Mahran M. Al-Zyoud, Abdelrahman H. Hussein, Qasem M. Kharma	IJECE	A Doctor Recommender System Based on Collaborative and Content Filtering	Collaborative and content filtering	Matrix factorization, similarity measures	Synthetic dataset	85.6%
2.	Luning Bi, Yunlong Wang, Fan Zhang, Zhuqing Liu, Yong Cai, Emily Zhao	arxiv	FD-GATDR: Federated-Decentralized-Learning Graph Attention Network for Doctor Recommendation Using HER	Federated and decentralized graph learning	Graph Attention Network (GAT), decentralized training	HER dataset	Not explicity stated
3.	Qihang Zhou, Lei Su, Liping Wu, Di Jiang	Wireless Communications and Mobile Computing	Deep Personalized Medical Recommendations Based on Rating Features and Review Sentiment Analysis	Sentiment analysis, deep learning	Neural collaborative filtering, sentiment embeddings	Review and ratings dataset	90.2%
4.	Yesi Sofia,	APICIEOM Proceedings	Recommendation System for	Hybrid filtering	Collaborative and content	Telemedicine data	88%

	Faiza Renaldi, Irma Santikarama		Matching Patients and Doctors in Telemedicine Based on Hybrid Filtering		filtering, combining patient-doctor features		
5.	Yafeng Yan, Shuyao He, Zhou Yu, Jiajie Yuan, Ziang Liu, Yan Chen	Unspecified	Investigation of Customized Medical Decision Algorithms Utilizing Graph Neural Networks	Graph Neural Network (GNN)	Graph-based reasoning and embeddings	Clinical datasets	Not explicitly stated
6.	Jusheng Liu, Chaoran Li, Ye Huang, Jingti Han	Frontiers in Public Health	Intelligent Medical Guidance and Recommendation Model Driven by Patient-Physician Communication Data	Natural Language Processing (NLP), deep learning	Transformer-based NLP, physician-patient interaction embeddings	Patient-physician interaction data	87%
7.	Yingbin Zheng, Yunping Cai, Yiwei Yan, Sai Chen, Kai Gong	JMIR Publications	Enhancing Online Medical Consultations: Personalized Doctor Recommendation Using Semantic Features	Semantic analysis, response optimization	NLP for semantic understanding, metric evaluation	Online consultation data	Not explicitly stated
8.	Joel Peito, Qiwei Han	Nova School of Business and Economics	Incorporating Domain Knowledge into Health Recommender Systems using Hyperbolic Embeddings	Hyperbolic embeddings, domain knowledge	Hyperbolic space embeddings	Synthetic data	Not explicitly stated
9.	Yongjie Yan, Guang Yu, Xiangbin Yan	Computational Intelligence and Neuroscience	Online Doctor Recommendation with Convolutional Neural Network and Sparse Inputs	CNN with sparse input handling	Sparse data modeling, convolutional architectures	Real-world online recommendation data	89%
10.	Li Guo, Chenning Du	Academic Journal of Computing & Information Science	Doctor Recommendation via Community Detection	Community detection, clustering	Graph-based clustering	Social and medical networks	Not explicitly stated

11.	Chunhua Ju, Shuangzhu Zhang	BioMed Research International	Doctor Recommendation Model Based on Ontology Characteristics and Disease Text Mining Perspective	Ontology modeling, text mining	NLP for text mining, ontology-based matching	Medical records	Not explicitly stated
12.	Yanakorn Ruamsuk, Withawin Tirasopitlert, Anirach Mingkhwan, Herwig Unger	NU International Journal of Science	Medical Recommendation System Using Co-Occurrence Graphs	Co-occurrence graph analysis	Graph-based relationships	Patient-medical interaction datasets	Not explicitly stated
13.	Qiwei Han, Mengxin Ji, Inigo Martínez de Troya, Manas Gaur, Leid Zejnilovic	arXiv	A Hybrid Recommender System for Patient-Doctor Matchmaking in Primary Care	Hybrid recommender	Matrix factorization, content filtering	Primary care data	85%
14.	Miguel Torres-Ruiz, Rolando Quintero, Giovanni Guzman, Kwok Tai Chui	MDPI Sustainability	Healthcare Recommender System Based on Medical Specialties, Patient Profiles, and Geospatial Information	Geospatial information integration	GIS and demographic-based recommendations	Public health datasets	Not explicitly stated
15.	Arsène Fansi Tchango, Rishab Goel, Julien Martel, Zhi Wen, Gaétan Marceau Caron, Joumana Ghosn	arXiv	Towards Trustworthy Automatic Diagnosis Systems by Emulating Doctors' Reasoning with Deep Reinforcement Learning	Deep Reinforcement Learning	Doctor-emulating reinforcement learning	Custom datasets	91.5%

CONCLUSION

The **Doctor Recommendation System** represents a significant step forward in integrating artificial intelligence and healthcare services. By combining predictive analytics and recommendation algorithms, the system provides an efficient, user-friendly platform that benefits patients, healthcare providers, and the healthcare system as a whole.

The studies reviewed in the provided comparison tables highlight various approaches to applying machine learning, recommender systems, and data-driven techniques in healthcare, with a focus on disease prediction, prevention, and personalized recommendations. From ensemble learning methods for heart disease prediction to deep personalized medical recommendation systems, the common theme is the integration of advanced algorithms like ensemble classifiers, genetic programming, collaborative filtering, and graph attention networks. These methodologies aim to improve decision-making and recommendations by analyzing patient data, such as health records, physician-patient communication, and user reviews. While the datasets and specific accuracy metrics vary across studies, the primary goal across all papers is to enhance healthcare outcomes, whether through personalized doctor recommendations, early disease detection, or prevention. The studies emphasize the need for efficient, data-driven systems to address healthcare challenges, though further details on dataset specifics and accuracy would provide a clearer understanding of their effectiveness.

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