

Intelligent healthcare recommender system for advanced healthcare services

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Abstract

The introduction of cutting-edge technologies has brought about a lot of changes in the healthcare industry. The application of intelligent recommender systems to improve healthcare services is one of the noteworthy developments. In order to provide cutting-edge healthcare services, the research investigates the architecture, application, and possible effects of an Intelligent Healthcare Recommender System (IHRS). The purpose of IHRS development, its architecture, features, difficulties, and potential are all covered in the paper.

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It is clear from a thorough review that IHRS has enormous potential to transform healthcare delivery by offering effective and individualized suggestions to healthcare practitioners as well as patients. Recommender systems have drawn a lot of interest recently from a variety of industries, including healthcare. Healthcare providers may find it easier to make wise decisions, improve patient outcomes, and provide higher-quality treatment overall with the help of recommender systems. This paper discusses the applications, difficulties, and potential future directions of recommender systems in the healthcare industry. Research examines various recommender system types utilized in the healthcare industry, including hybrid, content-based, and collaborative filtering methods. The research also goes into the significance of ethical, security, and data privacy concerns in the creation and application of healthcare recommender systems. Lastly, it outlines possible future possibilities for this field's developments and study.

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1. Introduction

Machine learning (ML) and artificial intelligence (AI) technologies are causing a paradigm change in the healthcare industry toward enhanced, individualized services. The development of Intelligent Healthcare Recommender Systems (IHRS) has shown promise in addressing the difficulties and complexities involved in the provision of healthcare [1]. These systems offer individualized recommendations for therapies, interventions, and healthcare providers by utilizing patient data, medical expertise, and AI algorithms. Nevertheless, the sophistication and flexibility needed to provide advanced healthcare services are sometimes lacking from the healthcare recommender systems that are now in place. The research proposes to create an Intelligent Healthcare Recommender System (IHRS) that can provide tailored recommendations for different types of healthcare need in order to close this gap.

Recommender systems have become further dominant in the healthcare industry as a outcome of improvements in machine learning algorithms and the expansion of healthcare data availability [2] [3]. Recommender systems, sometimes referred to as recommendation engines or recommendation systems, are information filtering systems that forecast and suggest products or courses of action depending on the tastes and actions of the user. In order to enhance engagement and personalize user experiences, these technologies have been widely implemented in social networking, e-commerce, and entertainment platforms. By offering

individualized treatment suggestions, drug adherence support, disease preventive methods, and clinical decision support, recommender systems have the prospective to completely renovate the healthcare industry and advance patient care. The paper's main goal is to give a thorough review of recommender systems used in the healthcare industry. Paper also discusses about the various kinds of recommender systems that are employed in the medical field, such as knowledge-based, collaborative filtering, content-based, and hybrid systems. Also paper examines the several uses of recommender systems in the healthcare industry, including clinical decision support systems, drug adherence assistance, illness prevention and management, and tailored therapy recommendations.

2. Literature Survey

The use of intelligent recommender systems is spreading across a number of industries, such as e-commerce, entertainment, and healthcare. These systems are essential to the healthcare industry because they improve patient outcomes, facilitate clinical decision-making, and maximize the use of available resources. Numerous scholarly investigations have emphasized the possible uses of recommender systems in the healthcare industry, including tailored treatment suggestions, linking patients with healthcare providers, and health behavior modifications. Nevertheless, there are a number of obstacles to overcome in the deployment of healthcare recommender systems, such as algorithmic biases, trust issues, and data privacy concerns. Notwithstanding these obstacles, new developments in AI and ML methodologies present fresh chances to create stronger and more efficient healthcare recommender systems.

Tran et al. [4] suggested and offered a thorough summary of the literature on healthcare recommender systems that is currently available. Their work included insights on recommendation methodologies and scenarios, which set it apart from other relevant overview articles that have already been published. They have provided insights into the recommendation scenarios that these systems offer, including prescription and food recommendations, health status predictions, suggestions for physical activity, and recommendations for healthcare professionals. They also created functioning examples to provide a thorough grasp of recommendation systems. Lastly, they talk about the difficulties of developing recommender systems for healthcare in the future.

Karthick et al. [5] talked about the overview of recommender systems in their paper, covering their main features, functioning, and goal. Their study proves the value of recommender systems in the healthcare industry, where individualized recommendations are necessary to improve service quality due to the volume of data and complexity of medical judgments. They also talked about big data and how it connects to healthcare recommender systems, highlighting the abundance of data that is accessible from many sources including social media, wearable technology, and electronic health records. The difficulties in applying recommender systems in the healthcare industry were also covered in their study.

Ismail et al. [6] created and put into use smart contracts to effectively detect healthcare insurance fraud in order to secure the healthcare system. They offer a taxonomy of fraud scenarios and used a blockchain technology that was appropriate for detecting fraud pertaining to health insurance. In order to choose the optimal platform automatically and effectively, they suggested and put into practice a recommender system based on decision maps. They suggested a taxonomy of 102 blockchain platforms in order to create the recommender system. They discovered twelve fraud scenarios in the literature, which they then used to build and implement smart contracts. They made use of the top two blockchain platforms that were determined by their suggested map-based recommender system for decision-making, specifically designed for fraud involving healthcare insurance.

Wasid et al. [7] a personalized healthcare recommender system (HRS) was suggested and debated. That was created with the reasonable assumption that individuals with similar illnesses and ailments would be subject to similar risk factors. In order to discover patients who are similar, the developed HRS compares a patient's disease symptoms and past medical information with those of other patients. Based on the medication or treatment previously administered to similar patients, the HRS suggests a course of action to currently enrolled patients after identifying similar individuals. They have carried out numerous trials to demonstrate and verify the efficacy of the created recommender system.

Shakil et al. [8] examines and suggests a two-tier paradigm for talking about patient medical data security and privacy. They contend that the bulk of current work is delegated to outside organizations who oversee healthcare systems. They explained their position as follows: patient data is first randomly generated using a homomorphic encryption process, after which the patient's identity is anonymized. Their framework serves two fundamental purposes. It is autonomous from outside intervention

on the one hand, and enhances privacy by combining a two-layer design for patient data security on the other. Their study incorporates a privacy mechanism within the research recommendations and suggests that the suggested method could serve as a benchmark for safeguarding patients' confidentiality and integrity.

Daniela et al. [9] highlighted how recommender systems have emerged, particularly in collaborative healthcare, to communicate with medical auxiliary personnel and assist doctors in their decision-making and practice. It is possible to interact with patients' preferences and concerns as well as doctors'. This is due to the development of cutting-edge medical tools like virtual reality and surgery robotics. Thus, from a practical standpoint, their study explores the use of recommender systems in three common areas of collaborative healthcare: medical, surgery robots, and augmented/virtual reality. Their findings cover practical guidelines for recommender system design in collaborative healthcare in addition to offering insights on the integration of recommender systems with healthcare auxiliaries.

Sharma et al. [10] presents a clever Health Recommender System (HRS) that makes use of the Convolutional Neural Network (CNN)-Discrete Wavelet Pooling (LDW-Pooling) method. They say that the primary goal of the intelligent health recommender system is to assure the timely accessibility of critical data while maintaining its reliability, authenticity, and quality. The convolutional layers and the activation functions they work are the primary components of a conventional CNN architecture. Feature extraction efficiency and accuracy are increased by the Learning Discrete Wavelet Pooling (LDW-Pooling) technology, which offers a universal replacement for traditional pooling methods. They assessed their intelligent recommendation engine's performance with a widely used multi-disease dataset. Based on a variety of parameter values, their investigation shows that the suggested deep learning method works better than alternative methods by generating less errors. They surpassed earlier deep machine-learning systems with their suggested solution, which earned an astounding accuracy rate of 98.1%.

Torres-Ruiz et al. [11] suggests a new, methodical, cooperative strategy built on patient-centered technology. The architecture of the recommender system was developed to support the health service level using medical specializations as a foundation. Their system generated suggestions by analyzing the user's profile as a citizen and a prioritized list of healthcare facilities. In order to semantically compute the similarity of medical specialties and provide medical facilities with response capacity, health

service kind, and nearby user geo-graphic location, they thus built a health attention factor. Taking into consideration the challenges outlined in the state-of-the-art, their method therefore integrates semantic and spatial processing to tackle concerns connected to recommenders in mobile devices and the variety of objects in the healthcare domain. After their recommender system was verified in numerous Mexico locations, a Web-GIS application displayed the geographical representation of the medical facilities filtered by the recommendations.

Sarkar et al. [12] examined and offered a literature review of the Health Recommender Systems (HRS) field as a whole, covering the literature, developments, goals, and techniques of HRS as well as the novel idea of using HRS to prescribe medication. They claim that modern information technology has sparked a huge number of advancements and breakthroughs in practically every industry. Recommender systems (RS) in this context have been leading the service industry to new heights. Upon examining web-based services, it can be determined that RS has played a significant role in improving product reachability and offering a plethora of options to prospective clients. The decision-makers can also utilize this RS as a tool to aid in their decision-making. Healthcare systems keep up with the evolution of RS in the service sector. Health RS (HRS) is growing in importance as a platform for healthcare services, alleviating the burdensome schedule of going to the doctor and standing in line for hours to get checked.

Etemadi et al. [13] explains and presents a system designed to systematically locate, categorize, and contrast existing healthcare recommender system (HRS) research. The 41 papers that were published between 2010 and 2021 were the subject of their study, which offered a systematic literature review (SLR) technique for HRSs. The articles that were chosen for the SLR fall into five categories: collaborative, content-based, knowledge-based, context-based, and hybrid. Outcomes in order to study the chosen HRSs, seventeen crucial characteristics were determined, and every paper was examined to determine the benefits, drawbacks, kinds of evaluation, and instruments. They also talked about the difficulties, potential paths, and unresolved problems. They came to the conclusion that while HRSs are still developing, they are still in the early phases of development. It highlights the requirement for a framework that is scalable, private, and trustworthy in order to upkeep the enhancement of patients' and healthcare professionals' confidence in HRSs. Their study shows that different healthcare systems do not use the same medical

codes. Furthermore, their analysis notes that in order to solve cold start issues, new patterns are required.

Deepika et al. [14] A thorough overview of healthcare recommendation systems and related concepts was given by their research. Their survey begins with the prehistoric history of healthcare and progresses gradually until Healthcare 4.0. A review of the Healthcare 1.0 to Healthcare 4.0 roadmap was conducted in order to identify the many technological verticals that are contributing to the digital transformation. Additionally, their study offers a comprehensive analysis of recommender systems, healthcare system kinds, and healthcare systems themselves. Additionally, a thorough examination of healthcare recommender systems and their various varieties was given. In the end, the conversation focused on the issues and challenges that remain to be addressed in relation to the implementation and adoption of the human-centric healthcare 4.0 ecosystem. In order to quickly generate the required answers, this is incorporated in the research to identify prospective research questions and gaps.

Kwiatkowska et al. [15] stated in their paper about the primary concerns that should be taken into account when implementing Recommender Systems (RS)-based tools and techniques in the healthcare industry. These concerns include ensuring recommendations are transparent, protecting patient privacy regarding medical data, adhering to medical regulations regarding medical software, and analyzing both short- and long-term ethical issues like belief formation and behavior modification. Furthermore, consideration needs to be given to the doctor-patient connection, human factors, and patient empowerment.

3. Types of Recommender Systems

Recommender systems are a type of information filtering system that assists consumers in selecting the appropriate item from a vast catalog by precisely taking their preferences and areas of interest into account. It assists users in a variety of fields to make wise decisions, including e-commerce, health, agriculture, finance, social networks, education, and sports [16]. The type of recommender systems is shown in Figure 1.

Content-based Recommender Systems: These recommender systems make recommendations to users based on how closely the features of the recommended goods match their preferences.

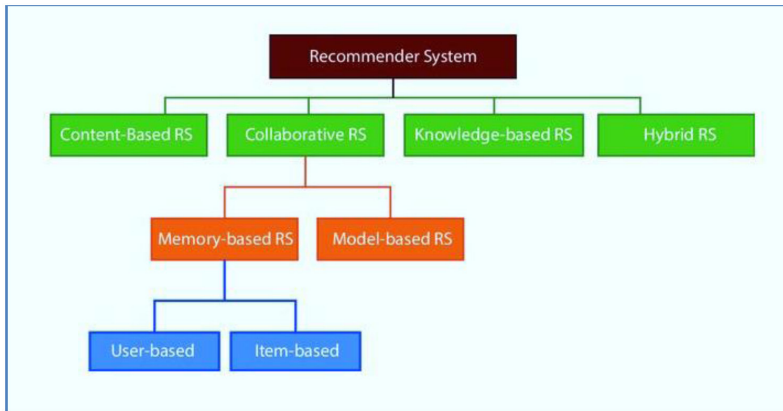


Figure 1

Types of Recommender System

Collaborative Filtering Recommender Systems: These systems suggest products to consumers by analyzing their preferences and comparable user behaviors.

Knowledge-based Recommender Systems: These systems make recommendations to users based on their explicit knowledge of the items and their preferences.

Hybrid Recommender Systems: To produce recommendations that are more varied and accurate, hybrid recommender systems integrate the best features of content-based and collaborative filtering techniques.

4. Applications of Recommender Systems in Healthcare

Numerous applications have demonstrated the value of recommender systems, and new methods of utilizing the approaches are suggested annually, some of them are [17]:

Personalized Treatment suggestions: Giving patients individualized treatment suggestions is one of the main uses of recommender systems in the medical field.

Medication Adherence: Encouraging patients to take their medications as prescribed is another significant use of recommender systems in the medical field.

Disease Prevention and Management: Personalized approaches for illness prevention and management are also suggested by recommender systems.

Interventions for Health Behavior: Recommender systems can help medical practitioners make tailored recommendations for actions that encourage people to adopt healthier lifestyles.

Clinical Decision Support Systems: By giving medical practitioners tailored diagnosis recommendations, recommender systems are essential to clinical decision support.

5. Design and Architecture of IHRS

The guiding concepts of the architecture and design of IHRS are adaptability, scalability, and user-centricity. Recommendation algorithms, a user interface for communicating with patients and healthcare professionals, and modules for data gathering and preprocessing are some of the system's essential parts [18]. As figure 2 shows architecture of intelligent health recommender system. In order to provide tailored suggestions, IHRS analyzes patient data, medical records, and contextual information using a combination of supervised and unsupervised learning algorithms. To guarantee interoperability and data interchange, the system is made to smoothly interface with other healthcare systems now in use, such as electronic health records (EHRs) and telemedicine platforms.

A variety of features are available in IHRS with the goal of enhancing patient outcomes and healthcare delivery. Health monitoring and alerts for early detection of health issues and timely interventions; telemedicine integration for remote consultations and follow-ups; personalized

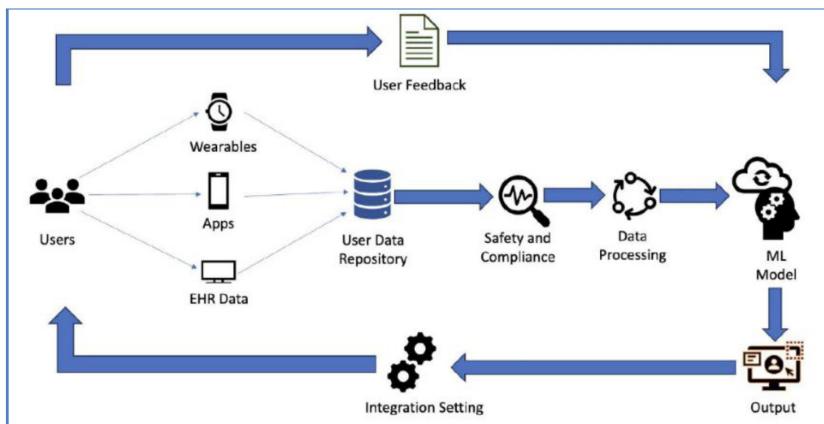


Figure 2

Intelligent Healthcare Recommendation System Architecture

treatment recommendations based on patient preferences, medical history, and clinical guidelines; healthcare provider matching to assist patients in finding the most suitable providers based on their needs and preferences; and a feedback mechanism for continuously improving the system's performance and recommendations.

There are multiple processes involved in implementing IHRS:

- Gathering and preparing data, creating machine learning models, integrating with healthcare systems, testing, and assessment.
- Patient surveys, wearable technology, electronic health records, and other sources are some of the ways that patient data, including demographics, medical histories, and treatment outcomes, are gathered.
- Next, the data undergo preprocessing to deal with missing values, eliminate noise, and harmonize formats in preparation for analysis.
- With the preprocessed data, machine learning models such as collaborative filtering, content-based filtering, and hybrid approaches are trained to produce customized suggestions.
- Standard protocols and APIs are used to interface the system with other healthcare systems already in place, guaranteeing smooth data interchange and compatibility.
- In order to determine the system's performance, accuracy, and user satisfaction, real-world data is used for testing and evaluation.

6. Challenges and Solutions

There are a number of obstacles to overcome in the implementation of IHRS, such as worries about data security and privacy, problems with acceptance and trust, performance and scalability constraints, and interoperability with current systems [19]. Many approaches are put forth to address these issues, including standardization initiatives to guarantee interoperability and data exchange, transparency and explain-ability mechanisms to foster system trust, encryption and anonymization techniques to safeguard patient data, and optimization strategies to increase scalability and performance.

The Data Quality and Availability: The quality and availability of data is a major obstacle to the successful implementation of recommender systems in the healthcare industry.

Privacy and Security Issues: The privacy and security issues around healthcare data provide a serious obstacle.

Ethical Issues: When using recommender systems in the healthcare industry, there are a number of ethical issues to take into account.

Interpretability and Transparency: Patients and healthcare providers may find it challenging to comprehend recommender systems in the healthcare industry since they frequently lack these qualities.

Integration with Current Healthcare Systems: Because of the intricacy of the healthcare IT architecture, recommender system integration with current healthcare systems is difficult.

7. Conclusion & Future Work

In conclusion, the design, implementation, and possible effects of an Intelligent Healthcare Recommender System (IHRS) for providing cutting-edge healthcare services are discussed in this research article. IHRS provides individualized recommendations for interventions, therapies, and healthcare providers by utilizing AI and ML technology. This improves patient outcomes, advances clinical decision-making, and maximizes resource use. IHRS has the enormous potential to transform healthcare delivery and influence the direction of customized medicine, despite its obstacles and constraints. The recommender systems, which offer individualized suggestions for clinical decision support, medication adherence, therapy, and illness prevention, have enormous potential to improve healthcare outcomes. However, there are a number of issues that must be resolved, including as interpretability, privacy and security issues, ethical issues, data availability and quality, and interface with current healthcare systems. Subsequent investigations ought to concentrate on crafting increasingly sophisticated machine learning algorithms, merging real-time data streams, facilitating wearable technology and the Internet of Things integration, tackling privacy and security issues, and augmenting interpretability and transparency. We can realize the full promise of customized medicine and enhance patient care globally by tackling these obstacles and developing the field of healthcare recommender systems. In order to improve transparency and trust, the paper concludes with a discussion of the future directions of IHRS. These include expanding into other healthcare domains like mental health and preventive care, collaborating with industry and academia to further advance the field of intelligent healthcare recommender systems, and integrating with wearables and the Internet of Things for real-time health monitoring.

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