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Review

Integrating Artificial Intelligence and Big Data into Smart Healthcare Systems: A Comprehensive Review of Current Practices and Future Directions

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Abstract: The COVID-19 pandemic has unveiled both the vulnerabilities and resilience of global healthcare systems, sparking a surge in innovation, including the accelerated adoption of Artificial Intelligence (AI) and big data analytics. This paper provides a comprehensive examination of the incorporation of these technologies within the advancement of contemporary, intelligent healthcare systems, with a keen focus on their potential to transform health management globally. This study explores the roles of AI and big data in bolstering the adaptability, efficiency, and productivity of healthcare services while also empowering individuals with actionable insights for enhanced health outcomes. Besides identifying key opportunities for AI and big data synergies within smart medical systems - encompassing disease detection and prevention, personalized medicine, resource allocation, and healthcare accessibility - this study delve into the critical ethical considerations accompanying their use. These include the essential principles of explainability, trustworthiness, privacy, security, and healthcare equity. Emphasis is placed on the importance of transparent, accountable, and ethically robust implementation strategies to ensure the responsible deployment of these technologies. Furthermore, the inherent privacy and security challenges associated with big data and AI in healthcare are addressed, detailing potential risks such as data breaches, data misuse, and patient confidentiality threats. Also, this study highlights the significance of incorporating privacy-preserving techniques, such as differential privacy and federated learning, in AI and big data analytics. This paper proposes a forward-looking paradigm for embedding AI and big data analytics within the core infrastructure of smart healthcare systems, outlining best practices and providing recommendations to leverage their transformative potential effectively and ethically. The insights and findings offered aim to guide future research, policy, and implementation efforts focused on harnessing the power of AI and big data to enhance global health resilience, stimulate innovation, and drive constructive change within the realm of intelligent medical facilities.

***Keywords*:** artificial intelligence, analytics, big data, intelligent systems, healthcare

1. Introduction

Due to the substantial increase in the global population, conventional healthcare systems cannot meet the growing demand. This situation necessitates the immediate implementation of intelligent solutions to provide global assistance.

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The primary objective of smart healthcare systems is to enable patients to independently monitor and track their health status while optimizing the utilization of existing resources. Furthermore, this development signifies a significant advancement towards fully interconnected urban areas, commonly called smart cities, wherein all aspects of daily life are seamlessly integrated with the Internet [1-2].

As patients' technological literacy increases, there is a global demand for smart and interconnected healthcare services. Consequently, companies operating in the industry must adjust their strategies to adapt to the evolving demands of contemporary patients. This entails prioritizing the consumer and embracing preventive innovative parenting startups incorporating Artificial Intelligence (AI)-enabled solutions, care models, and cost-effective healthcare approaches.

Therefore, many nations emphasize integrating Artificial Intelligence (AI) within the healthcare sector, particularly in response to the ongoing epidemic. The Chinese government has publicly declared its objective of positioning China as a global frontrunner in Artificial Intelligence (AI) by 2030, particularly emphasizing the healthcare sector. In 2019, China experienced a substantial rise in investment, amounting to $ 7.4 billion, representing a year-on-year growth of 54% [3-4].

Therefore, the advancement and augmentation of smart healthcare are imperative to effectively address the substantial demand for healthcare systems. The utilization of big data and Artificial Intelligence (AI) technologies has the potential to enhance operational efficiency and facilitate prompt responses. The enhancement of patients' outcomes can be readily achieved across various healthcare facilities. Researchers, governments, doctors, medical staff, and patients must collaborate to implement these technologies effectively.

Recently, there has been extensive research on intelligent healthcare systems leveraging Artificial Intelligence (AI) and advanced analytics of large-scale data sets as suggestions or reviews. This paper highlighted architecture, characteristics, applications, and smart healthcare challenges. The following five questions (W for "what") are at the heart of this study: (i) What exactly is a "smart healthcare system", and how do its features and potential uses in healthcare work together? (ii) What applications and advantages might big data analytics have for smart healthcare systems? (iii) What potential uses and benefits could AI offer for advanced medical systems? (iv) What is the architecture of a smart healthcare model that uses both AI and big data analytics? Finally, (v) What challenges does the healthcare industry present in implementing AI and big data analytics?

Inclusion and Exclusion Criteria: The selection criteria for this systematic review were designed to present a comprehensive analysis of the current landscape of Artificial Intelligence (AI) and big data in the healthcare sector, with a special focus on their ethical implications, privacy, and security concerns.

Inclusion Criteria: Include peer-reviewed academic articles, case studies, and reports published in English within the last twenty years. These sources needed to focus primarily on the intersection of artificial intelligence and big data within the healthcare context. A particular emphasis was placed on works that discussed the ethical implications of these technologies, the privacy and security challenges inherent in their use, and their potential to improve healthcare outcomes and services.

Exclusion Criteria: We excluded non-English language articles, articles published more than twenty years ago, and sources focused solely on big data or AI without discussing their application in the healthcare sector. Studies that did not offer concrete insights into ethical, privacy, or security considerations were also excluded from the review.

By adhering to these criteria, we ensured a focused and relevant literature synthesis, providing a balanced and comprehensive view of prospects and obstacles associated with using AI and big data in healthcare.

The primary aim of this study is to thoroughly investigate the integration of Artificial Intelligence (AI) and big data analytics in the development and enhancement of modern smart healthcare systems, focusing on improving efficiency, adaptability, and productivity. Furthermore, by identifying key opportunities and challenges, this study aims to furnish valuable insights and guidance for implementing AI and big data technologies in healthcare, ultimately contributing to global health resilience and innovation. The methodology deployed in this study can be outlined as follows:

• Investigation of Current Smart Healthcare Systems: We thoroughly examined the technologies underpinning recent smart healthcare systems. This included an analysis of their core requirements, distinct characteristics, and a broad range of applications within the healthcare sector.

• Exploration of Big Data's Role in Healthcare Systems: We delved into an in-depth discourse on big data's role in healthcare systems. This exploration incorporated a study of its key components, architecture, and its indispensable value, particularly in resource-constrained settings. Furthermore, we examined the difficulties of applying big data in these contexts.

• Assessment of AI's Potential in Healthcare Systems: An extensive analysis was performed to uncover the potential of artificial intelligence in healthcare systems. Our study covered a variety of AI applications and techniques and highlighted the existing challenges that must be addressed for successful AI integration.

• Review of Recent Advancements in AI and Big Data for Smart Healthcare Systems: We comprehensively reviewed the latest work and advancements in AI and big data solutions to enhance smart healthcare systems.

• Identification of Open Issues and Future Research Directions: identify unresolved matters and suggest potential avenues for future research in smart healthcare. The focus was significantly centered on the effective integration of AI and big data technologies, emphasizing their potential to revolutionize healthcare delivery.

This systematic approach allowed us to provide a comprehensive and current overview of the role and potential of AI and big data in modern smart healthcare systems and to highlight critical areas for future research.

The remainder of this paper is laid out as follows: The work background is provided in Section 2 by examining smart healthcare systems, their key technologies, requirements, characteristics, and applications. Further, Section 3 discusses big data over healthcare systems components, architecture, the importance of resource-poor healthcare, and challenges. Section 4 discusses AI's role in healthcare systems, including its applications, AI techniques, and existing challenges. Sections 5 and 6 explore related work and recent solutions for smart healthcare systems, followed by open issues and future research directions in Section 7. Finally, in Section 8, the paper is concluded.

2. Smart healthcare systems

Recently, there has been a rise in the demand for innovative medical systems and solutions. "Smart healthcare" encompasses using various technologies, including sensors, Global Positioning Systems (GPS), wireless networks, and the Internet, to provide medical services. The objective is to acquire information dynamically, establish connections between individuals and organizations pertinent to the healthcare field, and subsequently make informed decisions to meet the demands set forth by healthcare system users [5-7]. Figure 1 presents the overall framework of smart healthcare, which Yin et al. [8] have introduced.

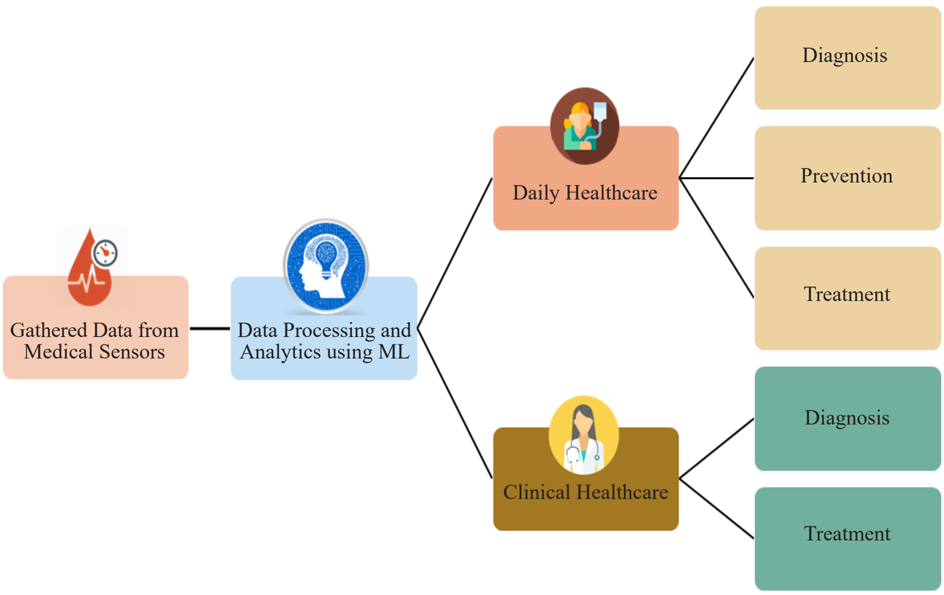

Figure 1. The smart healthcare framework

Frameworks for computing platforms often embody a convergence of broader principles, encompassing optimization techniques, database administration, human-machine interaction, and machine-learning algorithms [9]. Furthermore, a system for analyzing health data collected via the Internet of Things (IoT) has been presented [10] - Figure 2 shows various attributes considered while modeling healthcare systems and platforms.

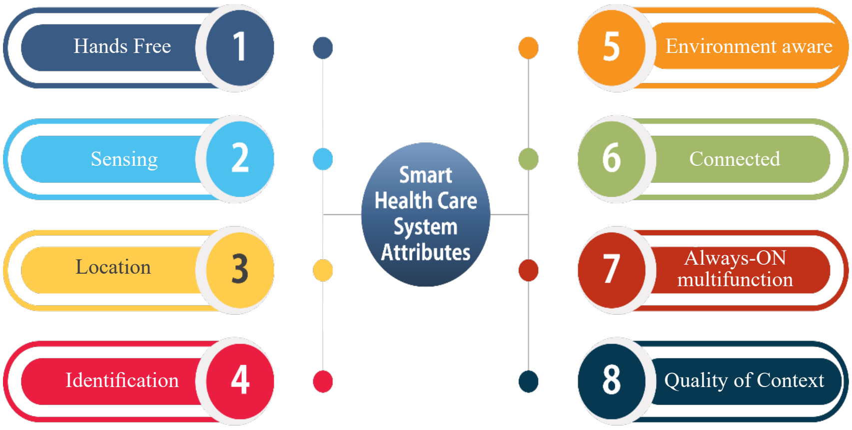

Figure 2. Smart healthcare system attributes

Moreover, there's a new version of smart health care that uses AI and big data. The main difference between traditional smart healthcare and AI healthcare is the amount of user data and the analytics on this data performed using AI algorithms which achieve more efficiency. Figure 3 identifies the smart healthcare system work scenario, while Figure 4 presents the work scenario of the smart healthcare system with AI and big data.

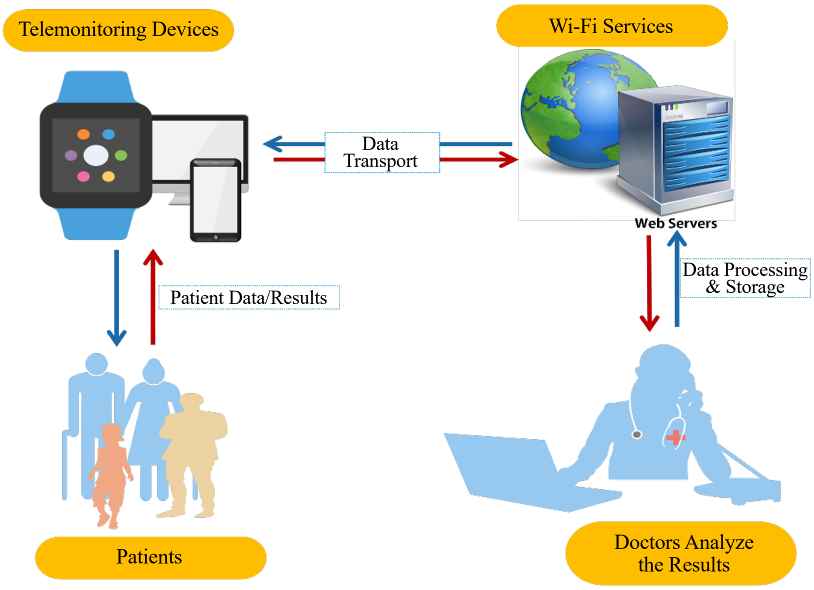

Figure 3. Smart healthcare system work scenario

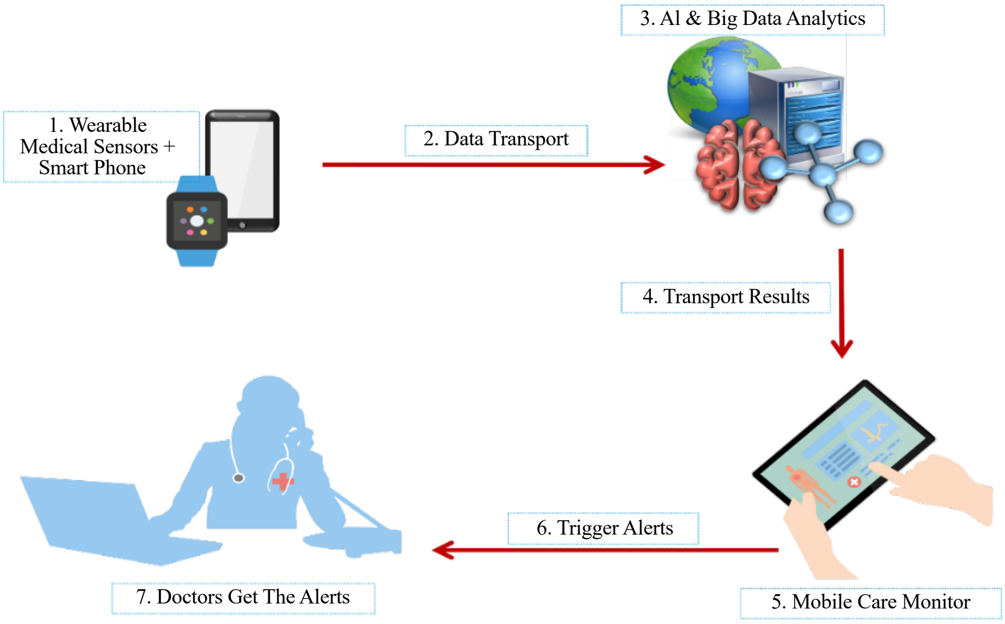

Figure 4. Smart healthcare system with AI and big scenario

2.1 *Key technologies and requirements*

Deploying a smart healthcare system requires merging and employing many technologies to achieve system functionality successfully. Bluetooth, GPS, sensors, Microelectromechanical Systems (MEMS), and many other technologies are key for smart healthcare systems [11-14]. Figure 5 presents the key technologies for smart healthcare systems.

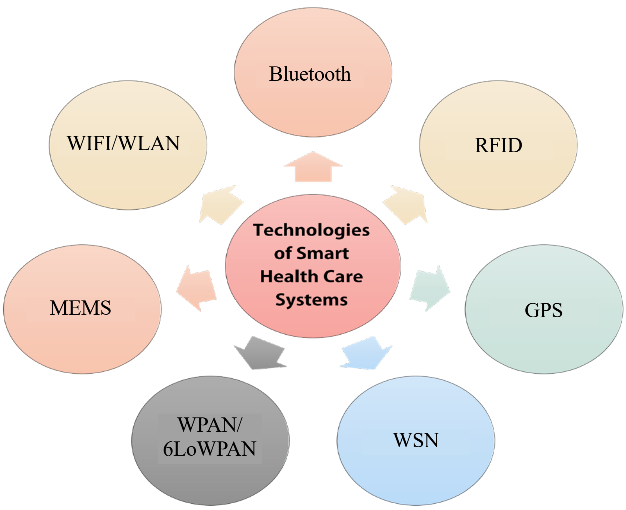

Figure 5. Important technologies for smart healthcare systems

Furthermore, many factors must be considered for smart healthcare systems to be built successfully. These needs can be broken down into two categories: functional and nonfunctional. Functional requirements refer to the precise specifications associated with each component utilized within healthcare systems. However, nonfunctional requirements are concerned with the quality attributes of the healthcare system [13-14].

2.2 *Characteristics*

There are too many characteristics for a successful smart healthcare system. However, the main characteristics that should be in every smart healthcare system are (i) context awareness; (ii) sensitivity; (iii) personalized; (iv) responsively; (v) adaptively; (vi) intelligence; (vii) ubiquity; (viii) transparency and (ix) anticipatory. Moreover, there are many other characteristics, such as computing heterogeneity, network dynamicity, and efficient resource-constrained computing [15-17].

2.3 *Applications*

With the rapid increase in personal health and nutrition awareness, smart awareness healthcare systems have been widely used and have many applications, from home care and self-management to acute care [18-20]. Figure 6 presents the domains of smart healthcare systems applications and uses.

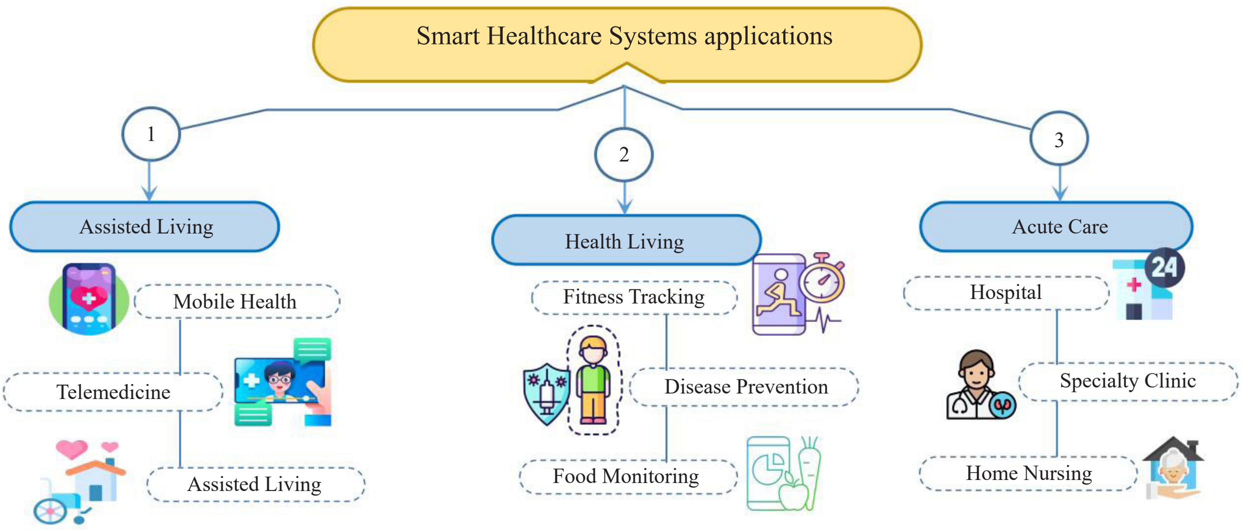

Figure 6. Smart healthcare systems applications and uses

3. Big data over healthcare systems

Since the term "big data" was raised in the technical world, it has many different definitions representing big unmanageable quantities of data records by conventional software programs or internet-primarily based platforms. Douglas Laney determined that the expansion of big data occurs in three dimensions: velocity, variety, and volume [21].

In current years, the term "big data" has attained unprecedented notoriety worldwide. Given that large amounts of information are unmanageable using a conventional software program, we want technically superior packages and programs that could use rapid and cost-efficient computational electricity for such tasks. Furthermore, implementing novel fusion algorithms and synthetic AI algorithms might be essential to take advantage and make feel from these big quantities of information. Indeed, it'd be amazing to gain computerized decision-making through neural networks and other Artificial Intelligence (AI) techniques. But on the other hand, big data may be blurry without suitable programs, tools, and hardware. Thus, the world must create higher and higher strategies to handle these infinite amounts of data for green evaluation to advantage of potential insights. This can improve healthcare, security, transportation systems, and other parts of the social infrastructure by making them greener, smarter, and more interactive.

3.1 *Components and architecture*

The big data health care system consists mainly of five connected layers as follows: (i) data layer; (ii) data aggregation layer; (iii) analytics layer; (iv) information exploration layer, and (v) data governance layer. Every layer has many components that work together to achieve layer functionality [22]. Figure 7 discusses in detail big data smart healthcare components and architecture.

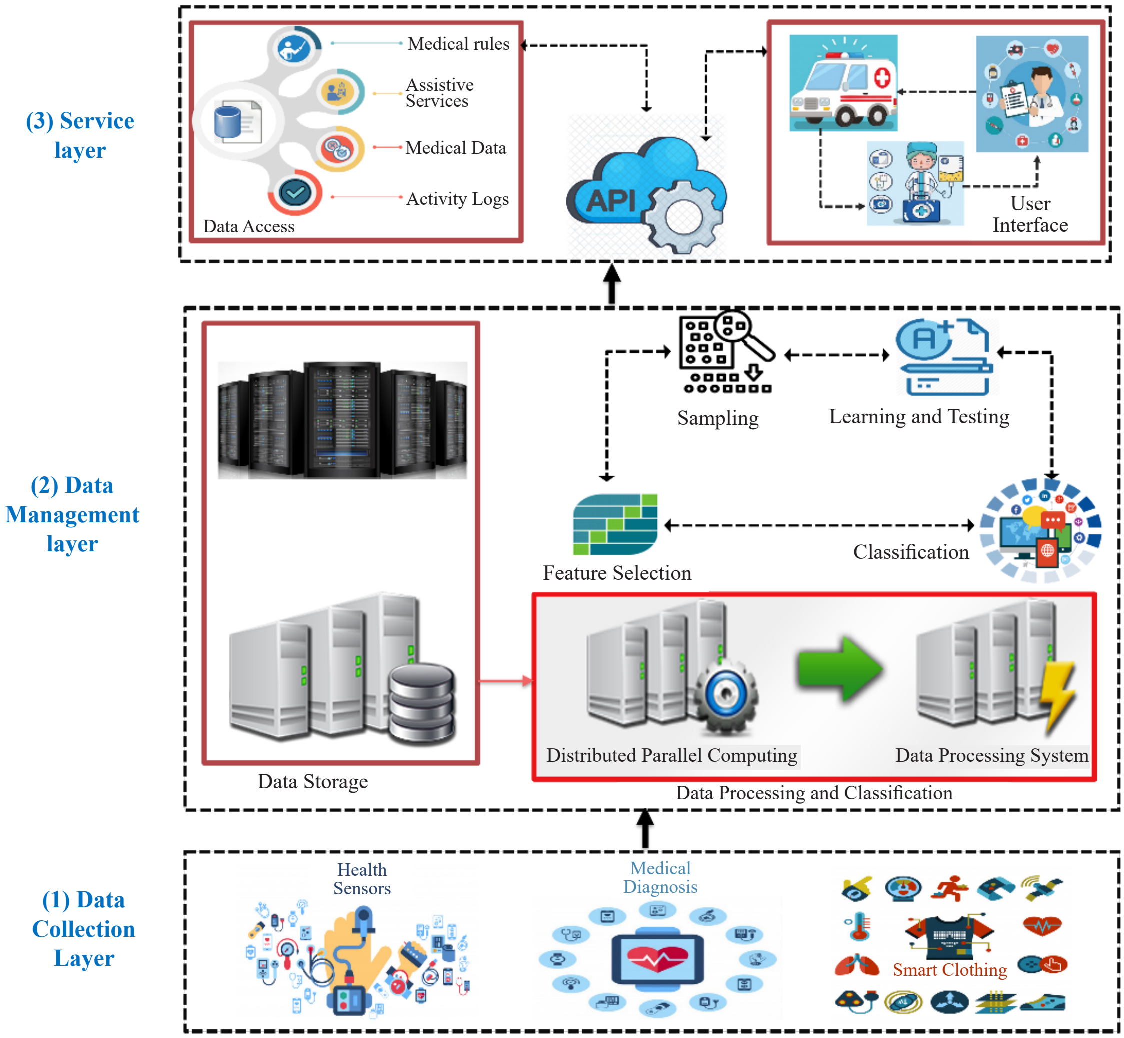

Figure 7. Big data healthcare architecture

3.2 *Speeding up time for big data*

With rising pandemics worldwide, it's very important to find new solutions to help predict and diagnose diseases. Of course, the use of large amounts of data is crucial. To speed up the development process of such a solution using big data. Three major aspects must be considered while discussing the time needed for big data analytics in healthcare systems [23]. The first concerns clinics or research: different databases must be integrated to find better organizational domains. The second is about in-patient and out-patient treatment of both in and out-patients with their data. Finally, temporal and monitors: it's the time for helping with prediction processes by big data tools.

3.3 *Importance of big data in resource-poor health care*

The significance of big data has recently increased due to its extensive range of applications in our daily lives. It has been expanded to include many aspects of hospitality and medical services. These applications vary from medical strategic planning to telemedicine. The many ways in which big data can be used in intelligent healthcare systems are outlined in Figure 8.

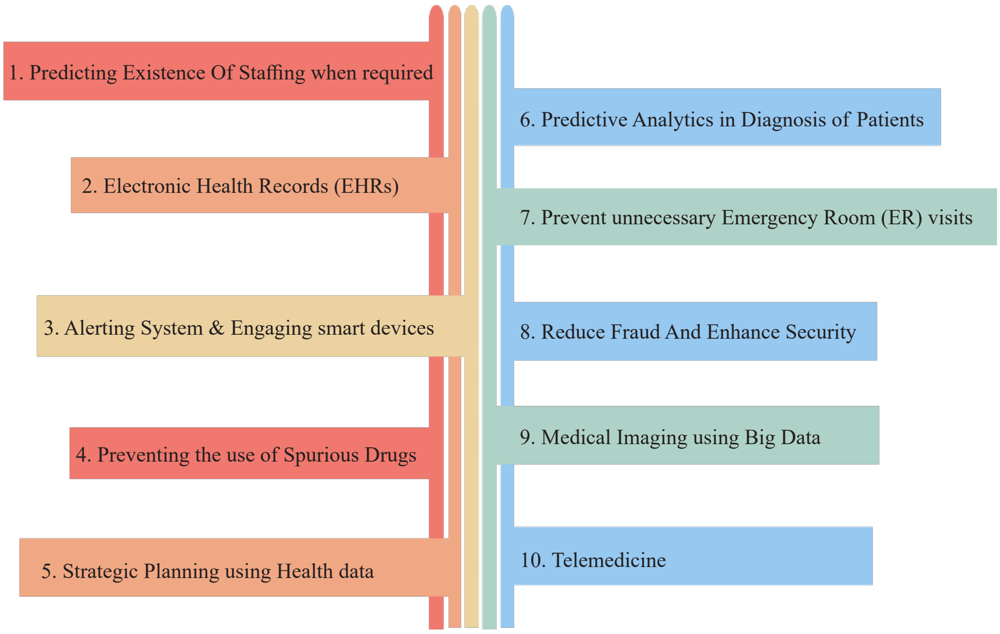

Figure 8. Summary of big data applications in smart healthcare

3.4 *Challenges*

Employing big data and getting the best of its analytics in smart healthcare systems face many challenges [24]. These challenges could be summarized as follows: (i) storage of large amounts of data; (ii) data cleansing or scrubbing; (iii) unified data format; (iv) quality and accuracy; (v) images pre-processing; (vi) data security; (vii) visualization; (viii) querying and data sharing and (ix) meta-data regarding.

4. AI over healthcare systems

Artificial intelligence can be principally divided into two significant categories. The first category is Artificial General Intelligence, which primarily focuses on the initial investigations and portrayals of Artificial Intelligence. The second category, Narrow Artificial Intelligence, is characterized by a machine's ability to execute a singular task. Applications within the healthcare sector serve as examples of Narrow Artificial Intelligence. The next subsections detail the main concepts of emerging AI in intelligent medical facilities. Smart AI medical facilities can be defined as healthcare systems that possess the capacity to execute intelligent tasks, conduct analytics, and provide diagnoses like those performed by human medical experts. AI has been widely used in mobile health applications, as well as health informatics. Figure 9 concisely overviews AI's uses in smart healthcare.

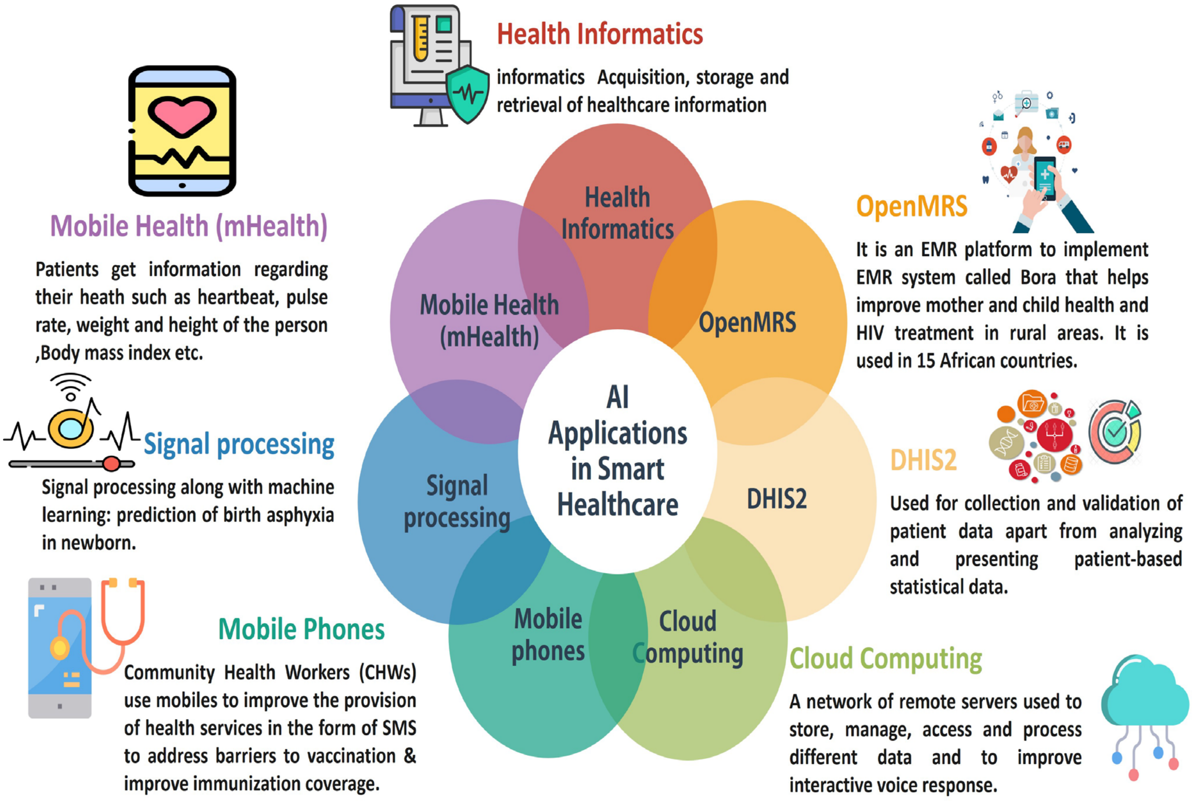

Figure 9. Summary of AI applications in smart healthcare

Many advanced techniques lie under the umbrella of AI technology. There are four main techniques commonly used in the domain of artificial intelligence healthcare systems as follows: (i) expert systems, (ii) machine learning, (iii) fuzzy logic, and (iv) Natural Language Processing (NLP). AI has seen a significant rise in healthcare applications, offering promising diagnosis, treatment, and patient care advancements. However, the full emergence of AI and employing it in smart healthcare systems face many obstacles and challenges as follows: (i) unstructured patients' data; (ii) Internet connectivity issues; (iii) shortage of professional medical trainers; and (iv) speedy diagnosis. Also, the integration of AI in healthcare brings other challenges to AI-Enabled Healthcare Systems (AI-HS) related to explainability, trustworthiness, ethics, quality assessment and bias risk, and privacy preservation, which are discussed in the following subsections.

4.1 *Explainability and trustworthiness in AI-HS*

The adoption of AI in healthcare is contingent upon its ability to provide accurate predictions and explain its decision-making processes clearly and clearly. The need for explainability in AI stems from the necessity for physicians, patients, and other healthcare stakeholders to understand and validate the underlying reasoning of AI-assisted decisions, which is critical to engender trust and confidence in these systems.

Therefore, explainable AI (XAI) solutions are emerging as vital to modern healthcare systems. These solutions can provide interpretable and comprehensible explanations for complex AI models, making the decision-making process transparent. By allowing healthcare practitioners to understand the basis for AI recommendations, XAI can contribute to better clinical decision-making, improved patient outcomes, and increased trust in AI-driven healthcare applications [25].

As Rasheed et al. [26] emphasize, developing XAI techniques that provide interpretable and transparent results is crucial. The black-box nature of many machine learning models poses a significant obstacle to obtaining informed consent from patients, making the improvement of explainability and interpretability an ethical requirement [27].

Trustworthiness in AI systems, which encompasses reliability, safety, and robustness, is equally critical. Given the sensitive nature of healthcare data and the potential life-or-death consequences of medical decisions, AI solutions in healthcare must be trustworthy. They should function as intended, consistently and accurately, in various scenarios and under different conditions. They should also be robust enough to handle unexpected situations, anomalies in the data, or potential manipulations, without compromising their performance or the safety of the patients [26].

Developing trustworthy AI systems involves addressing reliability, accuracy, and safety challenges. Blockchain architecture, for instance, can enhance trust by tracing data origin and monitoring the training procedure for model degeneration and dishonest conduct [28-29]. As we navigate towards more integrated AI and big data applications in healthcare, ensuring explainability and trustworthiness and maintaining stringent privacy and security protocols are paramount. Future research, policy, and implementation efforts should prioritize these aspects to promote the responsible and effective use of AI and big data in healthcare, ultimately contributing to more resilient and smart healthcare systems.

4.2 *Ethical considerations, quality assessment and bias risk in AI-HS*

Ethical concerns in healthcare AI are vast, with algorithms making crucial decisions that directly affect human lives. Ensuring fairness, transparency, and unbiasedness in these algorithms is paramount. Moreover, respecting the confidentiality of patient data is essential, even when it may negatively impact model performance [26]. Ethical frameworks like the European General Data Protection Regulation (GDPR) provide rules for data-driven decisions and methods, offering a regulatory structure to address these ethical challenges [27].

Integrating AI and big data into healthcare systems raises several ethical considerations. These are intrinsically linked to explainability, trustworthiness, privacy, security, and healthcare equity principles. As AI continues to reshape healthcare, these ethical implications require scrutiny to ensure the alignment of these technologies with established medical ethics principles [28].

Quality assessment is vital for ensuring the effectiveness and trustworthiness of AI systems in healthcare. It is particularly important to assess and mitigate the risk of bias, which can be introduced if the training data does not represent the population. The gap between human-centered and machine-centered disease diagnosis highlights the potential for bias in AI models and systems [28-30].

4.3 *Privacy and security in AI-HS*

As AI and big data technologies continue penetrating healthcare systems, health data privacy, and security concerns are escalating. Health data is highly personal and sensitive, and its misuse can lead to serious repercussions, such as identity theft, discrimination, and violation of patient rights. AI-driven healthcare solutions often require extensive data obtained from many sources, such as Electronic Records of Health (EHR) and health imaging data, genomics data, and wearable device data. While this data is invaluable for training AI models and enabling personalized healthcare, the issue presents notable concerns regarding confidentiality and safety [27].

One of the key challenges is ensuring that this data can be used for AI training and clinical decision-making without violating patient privacy. Techniques such as anonymization, differential privacy, and federated learning are emerging as potential solutions, allowing for data utilization for AI model development while preserving privacy. Moreover, strict data governance policies and robust security measures are needed.

Rasheed et al. [26] provide a detailed overview of privacy challenges and potential solutions, including a taxonomy of privacy preservation techniques. Techniques such as differential privacy and homomorphic encryption can protect sensitive patient data while allowing for the development of effective machine learning models [27] to prevent unauthorized access, data breaches, and other security threats.

In conclusion, as AI continues to evolve and integrate into healthcare, it is crucial to address these considerations to ensure the development of AI systems that are explainable, trustworthy, ethical, and privacy-preserving. Further research and development in these areas will be essential in realizing the full potential of AI in healthcare.

5. Related work

Recently, there has been extensive research on creating smart healthcare systems that integrate new technologies such as IoT, AI, and big data to guide global society toward the development of intelligent urban centers and lifestyles characterized by advanced technological integration and efficiency; it is imperative to take proactive measures. Nevertheless, ongoing endeavors are being made to further enhance these systems' sophistication. The subsequent subsections provide an overview of the latest scientific research conducted in this field.

Mansour et al. [31] developed a model for diagnosing cardiovascular illness and diabetes using AI and IoT convergence techniques. The described model consists of data collection, preprocessing, classification, and parameter adjustment. Wearables and other sensors on the IoT make data collecting easy, and AI techniques exploit that data to provide accurate medical diagnoses. Cascaded Long Short Term CSO, an implementation of the Crow Search Optimization (CSO) algorithm, aims to optimize the parameters of the CLSTM model, specifically the 'weights' and 'bias' parameters, for better medical data classification and disease diagnosis. Also, this research used the isolation Forest (iForest) method for filtering out anomalous data. Thus, diagnostic outcomes are enhanced with the use of this paradigm. Health records were used to validate the model's accuracy. Therefore, the model reported in the experiments demonstrated superior performance in diagnosing both heart disease and diabetes, achieving accuracies of 96.16% and 97.26%, respectively. Using feature selection techniques that mitigate the challenges posed by high-dimensional data and streamline computational processes has the potential to enhance future performance. Furthermore, it has been observed that hybrid metaheuristic algorithms can overcome the limitations associated with the CSO approach, such as low search accuracy and a tendency to converge towards local optima.

Rathi et al. [32] proposed a scalable, responsive, and reliable healthcare solution based on IoT and edge computing that uses low-latency AI to treat patients. Data is gathered, processed, and analyzed at edge nodes, then stored and made available permanently at edge data centers. Appointments are made for patients, and the controller and edge nodes supply them with instantaneous means of care. Simulations are used to test and measure the system's performance. Promising results were found for total runtime, computation, optimization, and transmission delay.

Furthermore, transmission latency was modeled using a neural network to evaluate system performance in an operational environment. Besides, edge nodes collect data, perform processing and analysis, and then pass that data along to edge data centers for long-term storage and accessibility. Patients are scheduled for appointments and then given immediate access to care from the controller and edge nodes. The evaluation of the system's efficiency and effectiveness is conducted through simulations. Overall execution, computation, optimization, and transmission delays showed promising outcomes. Furthermore, a neural network model was employed to evaluate the real-world performance of the system in terms of transmission latency. However, this project's findings are limited to three specific machine-learning models. Subsequent research endeavors aim to explore novel laboratory datasets, employ advanced machine learning models, and employ diverse feature selection strategies in forthcoming investigations.

Authors in [33] have presented an additional healthcare application utilizing an Electrocardiogram (ECG) dataset based on Critical Healthcare Task Management (CHTM) paradigm. A model was developed to allocate resources to fog nodes at the fog layer. The network administration, from the edge to the cloud, is given via a multi-agent system. The proposed method efficiently manages critical activities despite the obstacles of delivering interoperability, sharing resources, scheduling, and dynamic task allocation. Data from simulations showed that compared to the cloud, The implementation of this strategy results in a substantial reduction in network utilization, with a decrease of 79%.

Additionally, it leads to a significant improvement in reaction time, with a reduction of 90%. Moreover, the strategy effectively reduces network delay by 65%, energy consumption by 81%, and instance cost by 80%. This work's future advancement should consider users' mobility and incorporate modifications to handle all essential indicators effectively.

Hossain and Muhammad propose a smart healthcare architecture with a deep-learning pathological diagnostic system [34]. A patient's own Electroencephalography (EEG) readings can be utilized to diagnose illness. The acquisition of EEG signals is facilitated by using an intelligent headgear, which subsequently transmits the collected data to a server for mobile edge computing within the established framework. Before uploading to the cloud, the server performs initial signal processing. The cloud server plays a significant role in performing complex computational tasks, employing deep learning techniques to identify and analyze potential abnormalities in the examined individual. The authentication manager within the cloud infrastructure facilitates communication between users and developers of the framework. The findings derived from conducting experiments on a publicly accessible database provide empirical evidence supporting the feasibility of the proposed framework. In subsequent investigations, researchers aim to explore alternative fusion techniques, including the extreme learning machine, the Boltzmann machine, and the multilayer perceptron. Furthermore, edge computing can be integrated to alleviate the strain caused by extensive data transmission to the cloud.

A remote disease detection system based on Electroencephalogram (EEG) data is introduced in [35]. The proposed system utilized a deep convolutional network that executes 1D and 2D convolutions. The fusion network is employed to combine features extracted from multiple convolutional layers. One of the networks is a Multilayer Perceptron (MLP) with adjustable hidden layers and an autoencoder. The experiments were conducted utilizing a publicly accessible EEG signal database that has been categorized into two distinct classifications: “normal” and “pathological”. The empirical findings indicate that the proposed system, which utilizes a convolutional neural network followed by a multilayer perceptron with two hidden layers, attains an accuracy exceeding 89%. The method under consideration is also assessed within a web-based environment. The outcomes are what would be expected from using only a nearby server. The subsequent propositions delineate potential advancements that may transpire in the foreseeable future. One potential approach is employing a tree-based Convolutional Neural Network (CNN) model to allocate the computational tasks across multiple concurrent processors. This has the potential to enhance the efficiency of the decision-making process. Furthermore, an examination of a residual CNN can also be conducted. Furthermore, it is suggested that the proposed technology could undergo field testing within a real medical facility.

The ambient assisted living healthcare system encounters numerous obstacles in managing the substantial healthcare data generated by the IoT-based device, such as the storage and analysis of big data, latency, timing jitter, scalability, reliability, and mobility. Hassan et al. [36] proposed a novel cloud-based framework consisting of five stages, which combines the naive Bayes algorithm with the firefly algorithm. The patient’s health data is stored and analyzed in the cloud to make real-time predictions about the status category based on sensor data using an online mode. Additionally, a local monitoring unit is implemented during an Internet disconnection. The objective of the proposed system is to incorporate personalized and standardized medical protocols to operate as a personal medical assistant that can effectively understand the unique characteristics and peculiarities of individual patients. A novel algorithm that integrates the Naive Bayes (NB) and Firefly Algorithm (FA) has been developed to efficiently identify the crucial features required for the optimal performance of the Hybrid Algorithm for Active Learning. The system under consideration has successfully achieved the utmost level of precision by employing a minimal number of features, thus augmenting the efficacy of the classification procedure. Additional enhancements can be achieved by leveraging edge computing and machine learning methodologies.

Medical imaging modalities play a crucial role in the automated diagnosis of various diseases. AI, machine learning, and deep learning have demonstrated significant potential in the analysis and interpretation of medical images, surpassing the capabilities of human experts. Nadia et al. [37] proposed a framework for the automated classification of COVID-19 using CT lung images, employing CNN and Transfer Learning (TL). An optimization algorithm was employed to optimize various hyperparameters of Convolutional Neural Networks (CNNs) and Transfer Learning (TL) to identify the optimal configurations for each pre-trained model utilized, thereby improving the classification performance. Two distinct datasets were utilized in conjunction with four distinct scaling techniques. The obtained outcomes of the standard performance metrics exhibit significant promise.

Authors in [38] proposed an innovative automated, and dependable breast cancer classification framework. The system utilized CNN and incorporated TL technology along with Metaheuristic optimization techniques. The utilization of the Manta Ray Foraging Optimization (MRFO) technique was implemented to enhance the adaptability of the framework through the optimization of hyperparameters. The framework under consideration achieved an accuracy of 97.73% on histopathological data and 99.01% on ultrasound data, as reported. However, the proposed systems in [37-38] are limited to a single modality and can be extended to other modalities and cough sounds.

Authors in [39] developed an intelligent healthcare recommendation system for addressing diabetes issues, employing deep learning and data fusion methodologies. Data fusion can potentially alleviate the computational burden required for disease prediction and treatment by the system. The present study investigates the efficacy of an intelligent recommendation system by employing a widely used diabetes dataset. Furthermore, the performance of this system is evaluated and compared to the most recent advancements reported in the academic literature. The system under consideration attained a level of accuracy of 99.6%, surpassing that of all existing deep machine-learning techniques.

Consequently, the suggested methodology exhibits superiority in generating interdisciplinary recommendations for managing diabetes. The proposed approach can potentially enhance the performance of automated diagnostic and recommendation systems for diabetic patients, offering significant benefits in diagnosing illness. Nevertheless, it is crucial to prioritize the development of a comprehensive and efficient disease prediction and recommendation system that encompasses all known human diseases. Examining the deep ensemble algorithm's complexity will imminently be undertaken to enhance efficiency and precision.

Table 1 provides a comprehensive overview of the relevant literature. Developing smart healthcare systems based on IoT, AI, and big data technologies has been widely studied, and it involves several issues and challenges. For instance, while AI and big data offer remarkable potential for improving healthcare systems' efficiency and productivity, integrating various systems poses several challenges, including limited availability of resources, concerns regarding security and privacy, the need for interoperability, and effective energy management.

Table 1. Related work summarization

Research	Application	Tools	Algorithms/Model	Findings	Future directions
Mansour et al. [31]	Diagnosing cardiovascular illness and diabetes	AI and IoT	Cascaded Long Short Term CSO Optimization algorithm	Diabetes and heart disease diagnosis with 96.16% and 97.26% accuracy.	Using Feature selection methods and hybrid metaheuristic algorithms.
Rathi et al. [32]	Healthcare solutions to treat patients	AI, IoT, and edge computing	Three machine-learning models	Scalable, responsive, and dependable solution.	Use new laboratory datasets, machine learning algorithms, and feature selection strategies.
Alatoun et al. [33]	CHTM	IoT, edge, and cloud	Multi-agent system	Network usage (79%), latency (65%), and energy consumption (81%).	Manage vital indicators with user mobility and model changes.
Hossain and Muhammad [34]	Pathological diagnostic system	EEG signals, edge computing, and AI	Deep learning	The results confirm the viability of the suggested framework.	Using other fusion methods, such as the Boltzmann machine.
Muhammad et al. [35]	A remote disease detection system based on EEG data	EEG signals and AI	Deep convolutional network	Achieves an accuracy of over 89%.	Use a tree-based CNN model to distribute the workload.
Hassan et al. [36]	AAL cloud-based framework	Cloud + IoT	NB + FA	Achieves high precision with a minimal number of features.	Leveraging edge computing and employing machine learning methodologies.
Nadia et al. [37]	Automated classification of COVID-19 using CT lung images	AI	CNN + TL + Optimization	The standard performance metrics exhibit significant promise.	Use other modalities such as CXR and cough sounds.
Nadia et al. [38]	Breast cancer classification.	AI	CNN + TL	Accuracy of 97.73% on histopathological data and 99.01% on ultrasound data.	Use other modalities.
Ihnaini et al. [39]	smart healthcare recommendation system	AI	Deep machine learning and data fusion	The proposed system achieved 99.6% accuracy.	The complexity of the deep ensemble algorithm.

Additionally, some studies have suggested that the potential for enhancing the precision of the developed models remains by exploring new feature selection methods and hybrid metaheuristic algorithms. Furthermore, there is a need to investigate the real-world performance of the proposed systems, considering factors such as user mobility and modifications to manage vital indicators. Overall, future research should focus on developing more comprehensive, effective, and efficient healthcare solutions that leverage the full potential of emerging technologies while addressing the challenges associated with their integration into healthcare systems.

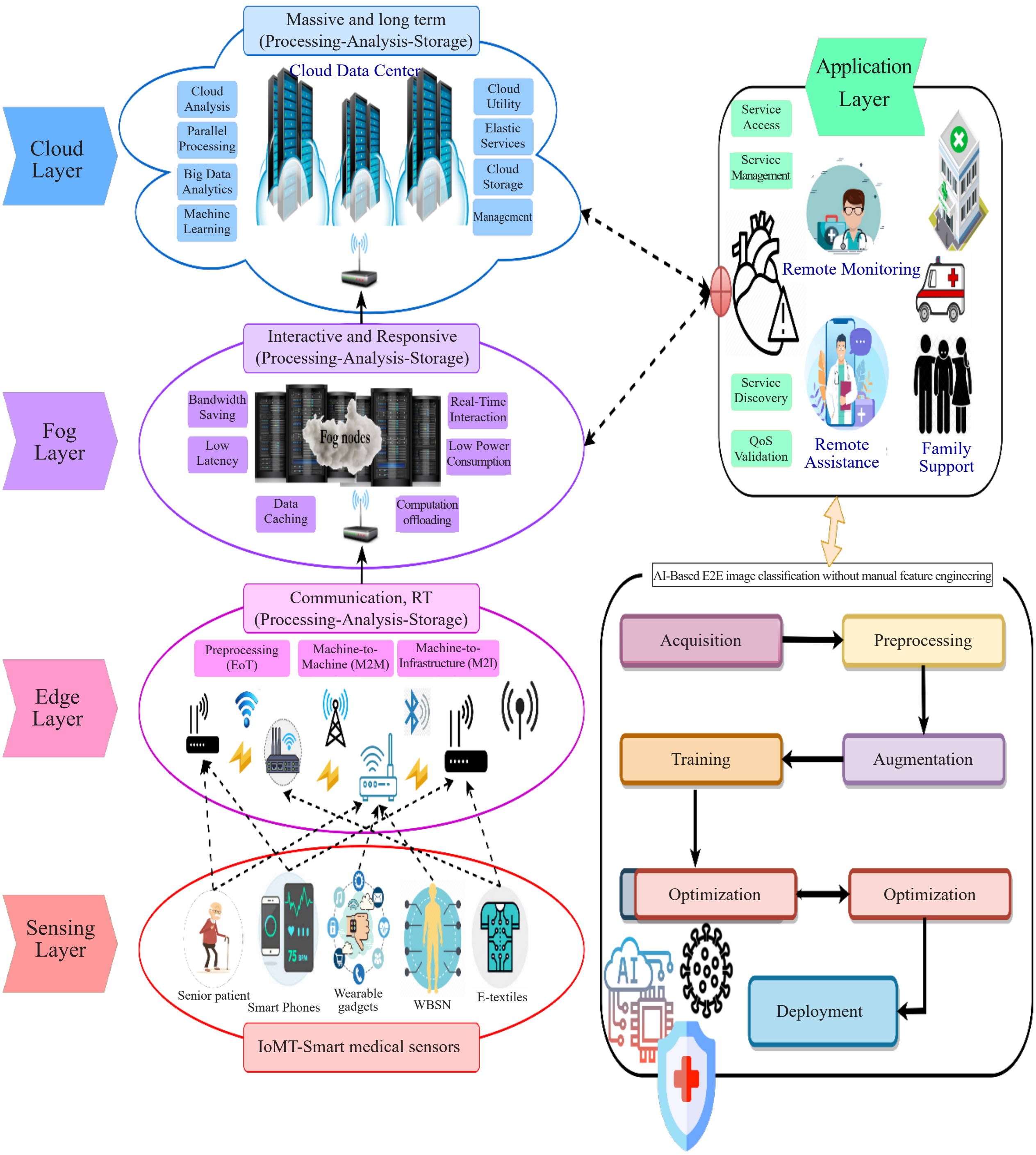

Figure 10. The amalgamation between AI, cloud computing, and big data

6. Big data and AI solutions for smart healthcare systems

The escalating quantity of data produced by healthcare systems has resulted in a burgeoning acknowledgment of the significance of astute and interactive analysis of this data to manage health systems effectively. This analysis is particularly valuable for optimizing resources, enhancing the quality of care, extracting diseases, and improving health outcomes. The amalgamation between AI, cloud computing, and big data is crucial. Figure 10 depicts the necessary steps for such an amalgamation model. The analytics procedure involves [40] (i) collecting data from various data sources, (ii) big data preprocessing cycle that includes transformation, integration, cleansing, and normalization; (iii) Big data analytics via machine learning techniques, (iv) Analytic models, and (v) analytics options such as decision-making, predictive analytics, descriptive analytics, and optimization techniques.

With the great advance in AI, it has emerged in many applications, as discussed above. One of these applications is healthcare systems development. Many investors worldwide make great investments in this field [41-44]. This section presents and discusses promising AI and big data solutions and startups.

Due to a recent report presented by Plug and play tech center this year, there are top nine leading companies in this field as follows: (i) Remedy Health; (ii) Subtle Medical; (iii) Quid; (iv) BioSymetrics; (v) Sensely; (vi) InformAI; (vii) Owkin and (viii); Binah.AI [45]. Table 2 summarizes the contributions of each leading company and shows the advantage of emerging AI in healthcare systems. In addition, the AI innovations in healthcare and hospitality systems based on a previous study [46] are summarized in Figure 11.

Table 2. Leading AI companies and their contributions

Company	Contributions
Remedy Health [47]	Low cost. Proactively screen. Virtual patients' interviews. Immediate Decision Making.
Subtle Medical [48]	Combining AI and radiology. Emerging technologies in their systems, such as NVIDIA, INTEL, GOOGLE CLOUDS, etc., bring the best AI solutions to hospitality.
Quid [49]	Fast data read and response. Creating dynamic visualizations.
BioSymetrics [50]	Building models and interrogation. Familiar toolsets. Combining pre-processing, machine learning, and architecture.
Sensely [51]	Supporting 32 different languages. Empathy-driven platform.
InformAI [52]	Accessing 10X bigger medical datasets. Providing AI data augmentations, models optimization, and 3D neural networks' toolsets.
SaliencyAI [53]	Improving the pharmaceutical industry and its data analytics using powerful AI algorithms, computer vision, and software architectures.
Owkin [54]	Improving hospitality services through a large AI-powered network connecting a wide range of hospitals around the world.
Binah. AI [55]	Offering signal processing-integrated data science. Real-world problem-solving with a production focus. Robust mathematical underpinnings: intelligence that can be put to use.

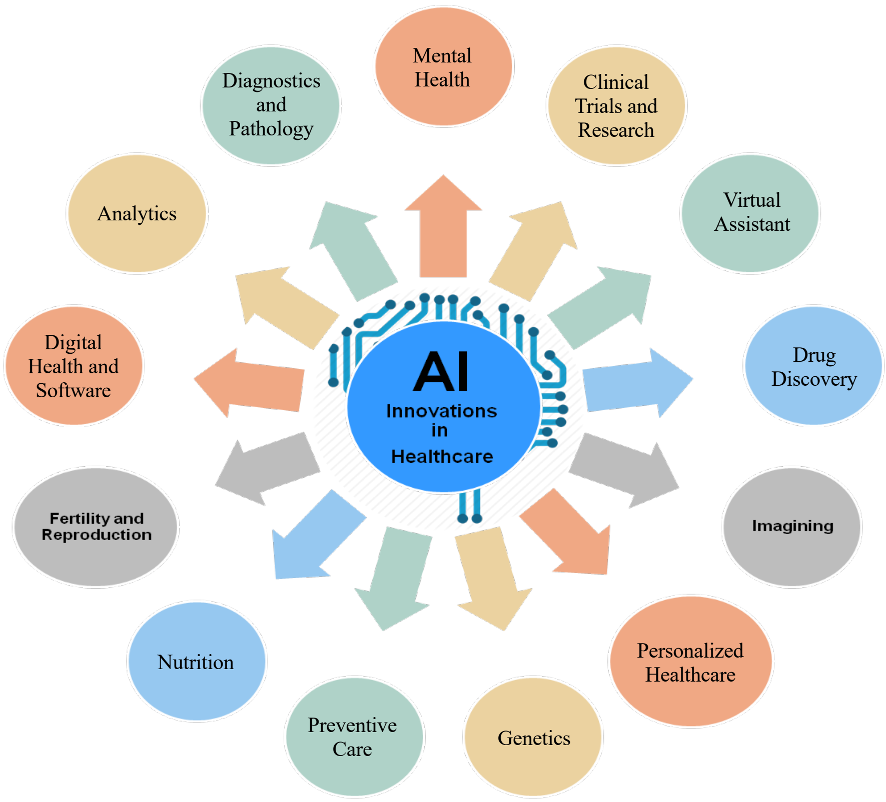

Figure11. AI innovations in healthcare systems

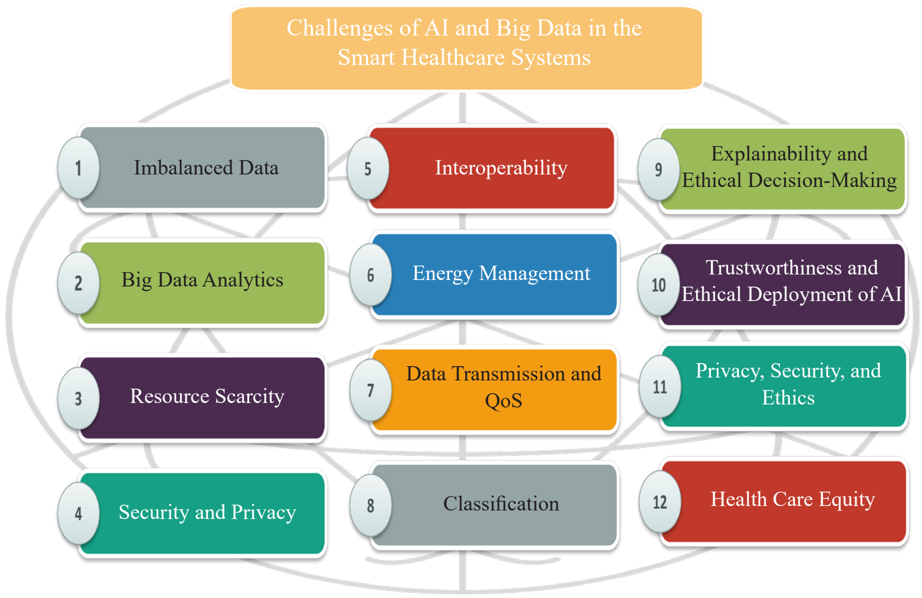

Figure12. Challenges of AI and big data in the smart healthcare systems domain

7. Open issues and future research directions

Artificial Intelligence (AI) and big data analytics have become indispensable tools for healthcare practitioners and specialists aiming to improve the quality of their services and foster sustainability in healthcare systems by developing intelligent healthcare systems. This section discusses the difficulties of integrating Artificial Intelligence (AI) and big data. The challenges in this context include resource scarcity, security and privacy concerns, interoperability issues, energy management considerations, and the utilization of big data analytics, as visually represented in Figure 12 [56-61].

Researchers must develop innovative solutions to overcome the following challenges promptly and ensure the effective integration of AI and big data in smart healthcare systems:

1. Imbalanced data: The problem of imbalanced data structures in big data and machine learning is a significant concern that warrants further investigation, particularly with distributed processing and the overall accuracy achieved by the chosen features.

2. Big data analytics: The objective is to establish standardized protocols for the utilization of big data in healthcare, to promote its widespread adoption, facilitate seamless data exchange, and optimize its potential. Additionally, efforts will be directed toward identifying and leveraging both existing and untapped sources of big data within healthcare systems while ensuring the integrity and security of such data [62-63].

3. Resource scarcity: The challenge of resource scarcity involves the development of intelligent resource allocation systems to ensure the availability of high-quality resources and promote equitable distribution [64]. The allocation of these resources is predominantly centered within major hospitals in urban areas of considerable size, thereby posing challenges in accessing patients residing in rural and remote regions. Deploying cloud models such as fog and edge to minimize time consumption is crucial.

4. Security and privacy: Health information within the system threatens its confidentiality and security. In the given situation, there exists a possibility that confidential personal data may be disclosed to external entities. It is imperative to rely completely on technology while addressing the multifaceted privacy and security issues [65].

5. Interoperability: Integrating big data technology with pre-existing project solutions is paramount. It is imperative to provide support for the existing tools to facilitate the processes of data ingestion, modeling, and visualization.

6. Energy management: An intelligent power management system provides various benefits to reduce energy costs. The system will facilitate the detection of billing issues and identification of cost reduction opportunities, such as implementing lower rates, improving power factors, or adopting peak demand management strategies. Expenditures can be distributed or apportioned to various departments or tenants to incentivize adopting energy-efficient practices and recoup associated expenses. Moreover, through estimating energy demands, establishing performance benchmarks and efficiency goals, and evaluating advancements, analyzing energy consumption can uncover instances of inefficiency in equipment and aid in formulating a comprehensive plan of action to optimize energy usage. Integrating intelligent load management into certain strategies may be a viable approach [66-67].

7. Data transmission and Quality of Service (QoS): Four stages are involved in data transfer: Data collection from sensors to storage is the initial stage. Data integration from numerous data centers is the second stage. Data organization is the third stage before the integrated data is sent to processing platforms like cloud platforms. Data analysis is the final step before data is sent from storage to the analysis host. Large data transmissions encounter observable difficulties at each of these stages. Intelligent preprocessing techniques and data compression algorithms are needed to reduce data size before transmission to maintain QoS effectively.

8. Classification: A data mining technique that divides unstructured data into structured classes and groupings, assisting users in knowledge discovery and future planning. Making informed decisions is made possible by classification. In classification, there are two stages: the learning process and the creation of rules and patterns. Large training data sets are provided during the learning process, and analysis occurs. After then, the execution of the second step, which involves testing or evaluating data sets and archiving the correctness of classification patterns, begins.

9. Explainability and Ethical Decision-Making: From an ethical perspective, explainability in AI systems is crucial. Decisions made by AI models, particularly in critical healthcare settings, must be transparent and understandable. This transparency promotes ethical decision-making and patient autonomy and aligns with the patient's best interests. Clear and interpretable explanations for AI-driven decisions ensure healthcare providers can correctly assess the recommendations and verify that they align with the patient's best care practices [29].

10. Trustworthiness and Ethical Deployment of AI: Trustworthiness in AI systems encompasses aspects such as reliability, safety, and robustness, which directly contribute to the ethical deployment of AI in healthcare. Trustworthy AI systems function reliably and safely under various conditions, upholding the "do no harm" principle and ensuring fairness and justice in AI-enabled healthcare by robustly handling anomalies and potential manipulations.

11. Privacy, Security, and Ethics: Respect for privacy and security is an ethical mandate in healthcare and a regulatory requirement. Significant patient privacy concerns arise with ai applications, often necessitating extensive and diverse health data. Upholding patient data confidentiality and its secure handling maintains trust in AI-enabled healthcare systems. Several issues should be addressed, such as potential risks like data breaches, misuse of data, and threats to patient confidentiality, and several strategies should be proposed to mitigate these risks. These strategies include implementing robust data governance policies, employing advanced data encryption methods, regular security audits, and fostering a culture of data privacy within healthcare organizations. Furthermore, the importance of incorporating privacy-preserving techniques like differential privacy and federated learning in AI and big data analytics should be considered.

12. Healthcare Equity: Ensuring Justice in AI Adoption: Lastly, adopting AI in healthcare must adhere to justice, ensuring equitable access to AI-enhanced care for all patients. The potential for AI technologies to inadvertently exacerbate health disparities if their benefits are not equally accessible due to socioeconomic, geographical, or other barriers necessitates strategies promoting healthcare equity [30].

8. Conclusions

Integrating big data analytics and Artificial Intelligence (AI) heralds a transformative era for healthcare systems, particularly in resource-limited environments. Big data's continuous information analysis capabilities can potentially improve healthcare quality and foster cost-effective medical practices. Furthermore, its prowess in pattern recognition significantly contributes to advancements in evidence-based medicine. Coupling this with AI-driven solutions presents a golden opportunity to bolster global public health initiatives. However, as we have emphasized throughout this paper, the ethical considerations of AI adoption cannot be understated. As we continue to develop and integrate AI applications, we must prioritize the principles of explainability, trustworthiness, privacy, security, and healthcare equity. The privacy and security of user data within healthcare systems are paramount and must be upheld to ensure the trust and acceptance of these technologies. To this end, we have addressed potential risks and proposed mitigation strategies such as implementing robust data governance policies, employing advanced data encryption methods, performing regular security audits, and fostering a culture of data privacy. Incorporating privacy-preserving techniques in AI and big data analytics is another significant component of ethical technology adoption. Moreover, explainability and trustworthiness are pivotal in promoting patient autonomy and ethical decision-making, ensuring AI models' reliable, safe, and robust function, and maintaining a fair and just healthcare system. When applied judiciously, these principles can guide us toward the seamless, effective, and ethically sound integration of AI and big data analytics into healthcare systems.

Conflict of interest

The author has no conflicts of interest to disclose.

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