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Healthcare 4.0: recent advancements and futuristic research directions

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Abstract
In recent years, Healthcare 4.0, the fourth healthcare revolution, has piqued the interest of numerous researchers around the world. Healthcare 4.0 is a relatively new term that has evolved from Industry 4.0 to meet diverse requirements in the healthcare domain. Healthcare 4.0 serves as a technological catalyst for accelerated growth by integrating cutting-edge industrial technologies. Despite the evolving nature of Healthcare 4.0 research, a complete and systematic survey of recent research on it has been scarce. Conspicuously, this study intends to present a systematic survey by investigating the recent trends, key constraints, and application areas of Healthcare 4.0. Further, a comprehensive survey of the research is used to identify the essential technologies required for the effective adoption of Healthcare 4.0. The research was conducted using the PRISMA methodology and an exhaustive search of all easily accessible libraries and academic repositories was made to obtain the relevant literature. At last, a diversity of outstanding issues are also presented to assist scholars and professionals who are interested in undertaking futuristic research in the current field.

Keywords Healthcare 4.0 · Predictive analytics · Optimization · Machine learning · Smart Healthcare · Artificial intelligence

1 Introduction

Healthcare 4.0, the fourth healthcare revolution is the realization of the concept of accelerating medical innovation while improving the efficiency of patient care. Healthcare 4.0 refers to the recent breakthroughs in the medical domain through the introduction of automation, management, and information processing systems. Healthcare 4.0 is interpreted as the enhanced interconnection between cyber and physical aspects, and interconnection solutions provided by innovative information and communication technologies such as Big Data, the Internet of Things (IoT), and cloud computing [1, 2]. The integration of these technologies forms the Healthcare 4.0 systems, which is believed to provide real-time personalized healthcare to patients, physicians, and caregivers [3]. In the wake of tremendous

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advances in medical devices, clinical advances, and data analytics, there has been a growing interest in utilizing engineering approaches to deliver healthcare services throughout the world. These technological innovations have opened up immense possibilities for innovation, as well as significant concerns for healthcare delivery.

The implementation of Healthcare 4.0, in particular, supports the transition from a hospital-centred system to a patient-centred organization, in which multiple departments, roles, and responsibilities are merged to provide optimal patient healthcare outcomes. Healthcare 4.0 enhances the capabilities of the traditional medical system which helps to strategize support in terms of providing quality care remotely [4]. The goal of Healthcare 4.0 is to improve patient experience, health promotion, cost control, and clinical satisfaction. It encompasses the deployment of processing capabilities for data management and offers the flexibility to access information regardless of location. Such revolutionary changes can bring about a significant impact on every aspect of our society that has started to embrace these technological innovations. Therefore, despite its benefits, there are many concerns about the successful implementation of Healthcare 4.0 as given in [5].

Despite significant progress in smart and connected healthcare, further research, innovation, dissemination, and impact will be required to achieve Healthcare 4.0. Accordingly, this paper conducts a systematic review of Healthcare 4.0 and provides a glance at the topic, relevance, and various outcomes by focusing on the corpus of previous research, utilizing the online available scientific databases and digital libraries. The purpose of this study is to explore the transition to Healthcare 4.0, outline the different key pillars, highlight various application areas, and identify challenges and prospects for Healthcare 4.0 research.

The rest of the paper is structured as follows. Section 2 describes the approach used to conduct the review. Section 3 discusses revolutions in healthcare. Section 4 includes a description of key technologies. A review of recent works in Healthcare 4.0 is provided in Sect. 5. Section 6 describes important healthcare application areas. In Sect. 7, we explore some of the most pressing open challenges and issues. The discussion over research questions is presented in Sect. 8. Finally, Sect. 9 provides a summary of the paper.

2 Research methodology

The systematic research work is carried out and presented using the PRISMA approach outlined by Moher et al. [6]. Subsequent sections provide an in-depth insight into each action taken to achieve this research goal.

2.1 Research questions

In the presented work, we thoroughly evaluate the research procedures employed by numerous researchers by proposing some salient research questions. The research questions formulated to complete this study are enlisted in Table 1.

2.2 Search criteria and sources of information

To carry out this review, we explored various research studies published in the area of healthcare using modern technologies. Table 2 shows the various online databases and digital libraries that have been used to perform the study. Nonetheless, with the advent

Table 1 Research questions

S. no.	Research questions
RQ1	How the healthcare field has been revolutionized?
RQ2	What are the main pillars of Healthcare 4.0?
RQ3	What are the different application areas of Healthcare 4.0?
RQ4	What are the recent real-time implementations of Healthcare 4.0?
RQ5	What are the main barriers/challenges in Healthcare 4.0 adoption?

Table 2 Online scientific databases and digital libraries for paper selection

S. no.	Scientifc databases and search engine	URL
1	IEEE Xplore	https://ieeexplore.ieee.org
2	ACM Digital library	https://dl.acm.org
3	Science Direct	https://sciencedirect.com
4	Springer	https://link.springer.com
5	Scopus	https://scopus.com
6	PubMed	https://pubmed.ncbi.nlm.nih.gov
7	Wiley	http://onlinelibrary.wiley.com
8	Taylor and Francis	http://www.tandfonline.com

of smart medical devices and computing technologies, we are witnessing remarkable advances in smart and connected healthcare. However, in this study, we mainly emphasized relevant papers published in the interval from 2017 to 2022. In order to retrieve the most relevant papers related to the current study, the following search terms are considered, following the PRISMA approach.

- Healthcare
- Diagnosis OR Prediction
- Industry 4.0 technologies
- classification
- Personalized OR Ambient healthcare
- Tele-medicine OR E-care

2.3 Inclusion and exclusion criteria for article selection

In the first stage, 441 quality papers are selected from different scientific databases and libraries as mentioned in Table 2. These selected papers are examined based on the inclusion-exclusion criteria enlisted in Table 3. In the next screening step, only 64 papers are selected out of the initial 441 papers. In the next phase, each paper is examined and the papers with irrelevant abstracts and review studies are excluded which results in selection of 46 papers for the systematic analysis. Figure 1 illustrates the flow-chart of paper selection procedure.

Table 3 Inclusion/exclusion criteria

Included/excluded	Criterion
✓	Articles published in the interval 2017–2022
✓	Articles published in English language
✓	Articles published in reputed peer-reviewed journals
✓	Articles covering healthcare aspects
×	Duplicate papers from multiple sources
×	Articles written in foreign languages
×	Short papers, editorials, thesis reports

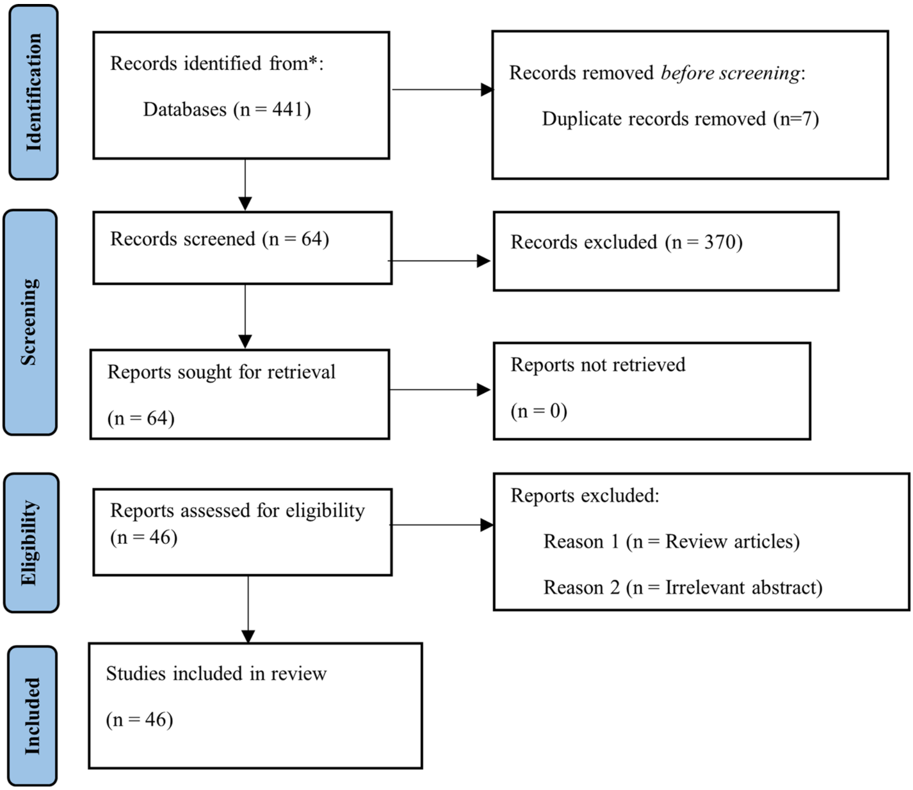

Fig. 1 PRISMA statement to show the selection process

3 Evolution of Healthcare

Healthcare is continuously focused on providing quality care services to its patients and other stakeholders. Several revolutions in the healthcare industry have been witnessed in the past few decades that transformed the healthcare domain to new heights with several major innovations [7]. The major and advanced innovations that occurred in each of these revolutions are briefly explained below and presented in Fig. 2.

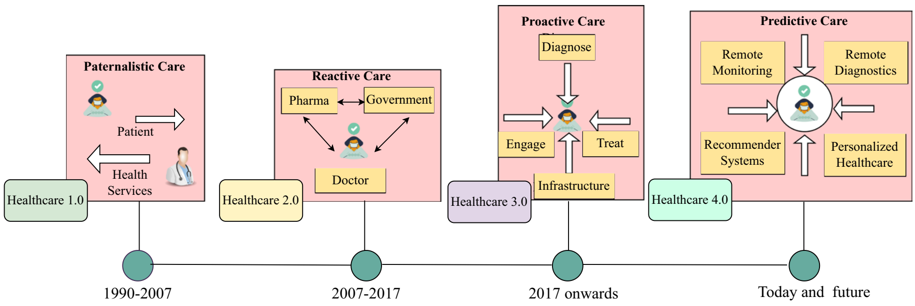

Fig. 2 Evolutions in Healthcare

Healthcare 1.0: The healthcare sector had its first revolution, known as Healthcare 1.0, in the latter 1990s, with an emphasis on increasing service efficiency and minimizing bureaucracy [8]. The innovation turned a generous system of home medications and unskilled clinicians providing paternalistic care into a much more advanced, smart, and data-centric system known as the medical-industrial complex. Automation was first introduced in this revolution with the incorporation of administrative systems.

Healthcare 2.0: The goal of the second healthcare revolution was to boost efficiency and data exchange. Sharing of information was centred not only inside one institution but also within a group of related healthcare organizations. The new revolution focused on responding according to the symptom, illness, and individual requirements [9].

Healthcare 3.0: Healthcare 3.0 emphasized proactive care and could guarantee preventative treatment prior to the beginning of an illness or disease symptoms [10]. Along with other important technologies like big data analytics and wearables powered by the Internet of Things, electronic medical records (EMR) were also widely used in this revolution.

Healthcare 4.0: A paradigm shift from proactive care in Healthcare 3.0 results in predictive care and a more patient-centric approach rather than a hospital-centric approach, i.e., Healthcare 4.0, which delivers patient empowerment in addition to a cost-effective and mobile healthcare ecosystem. This revolution is dedicated to current and future technologies, with a focus on the use of cutting-edge technologies such as the Internet of Things (IoT), blockchain, artificial intelligence (AI), and big data analytics to provide high-quality care [11].

4 Key technologies of Healthcare 4.0

Healthcare 4.0 promotes the digitization of healthcare through the use of advanced technologies. These technologies provide patients with greater reliability, convenience, satisfaction, and transparency. This section outlines some of the important technologies used in Healthcare 4.0 to improve healthcare outcomes. Figure 3 depicts various key technologies for Healthcare 4.0.

4.1 Cyber-physical systems

Cyber-physical systems (CPS) are an essential part of Healthcare 4.0 that interconnects the physical and virtual worlds [12]. These systems are increasingly deployed in hospitals to

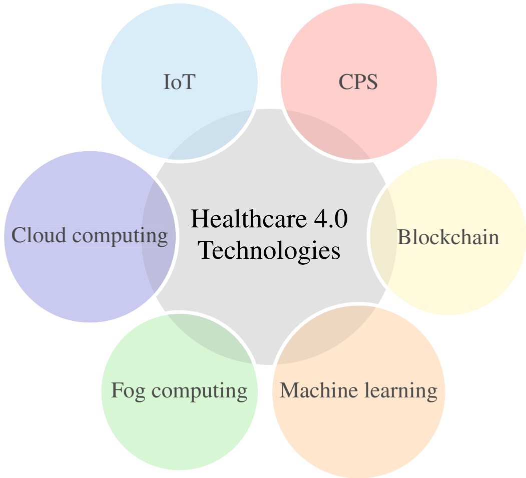

Fig. 3 Important Healthcare 4.0 technologies

provide consistently high-quality services. CPS has a major impact on healthcare and medical applications, and it quickly provides a platform for positive communication between patients, clinicians, and health personnel.

4.2 Internet of things

The Internet of Things (IoT) is enabling a revolutionary field of opportunity in healthcare. To give patients more control over their lives and treatments, it connects to the internet and medical devices and collects vital information. It is beneficial for testing, evaluating, and treating patients to improve overall satisfaction [13]. A health service based on the Internet of Things combines all available resources as a system to carry out activities, including diagnosis, tracking, and virtual operations electronically.

4.3 Cloud computing

Cloud computing is a newly formed computing paradigm that aims to provide a variety of computing services over networked media such as the Internet [14]. This strategy provides various benefits to potential customers, including pay-as-you-go, scalability, online delivery of software and virtual hardware services, and the elimination of the need for businesses to own, operate, and upgrade their software and hardware infrastructures. In healthcare, the services of cloud computing infrastructure are used for the computation of data using third-party data centres. Moreover, it also provides services for efficient storage of patients', and hospital data [15].

4.4 Fog computing

To meet current medical concerns, cloud computing alone is not the ideal option. Additionally, the Healthcare 4.0 environment's needs are not met by the services and applications directly offered via cloud computing. It has certain drawbacks, including low real-time response and delay. A minor delay in healthcare might cost a patient his or her life; so, to improve services and applications, healthcare also utilizes the potential of fog computing to offer quality services in a delay-sensitive environment [16].

4.5 Machine learning

The health sector uses artificial intelligence to examine a variety of medical data. It is an important piece of technology that is created and run by machines with the aid of a computer. It gathers data and gives doctors and patients properly demarcated output [17]. AI provides techniques for treatment and prevention to enhance patients' life expectancy. It aids in personalized medicine, diagnosis, severity determination, drug development, and patient monitoring.

4.6 Blockchain

A blockchain is a distributed public ledger that is secured by a peer-to-peer network and registers transactions and maintains assets without the need for centralized authority. The records on the blockchain are grouped in a logical block structure. These blocks are linked sequentially one after the other, and the entire chain is referred to as a blockchain. Blocks placed anywhere on the blockchain cannot be changed without changing other blocks [18].

5 Review of recent works in Healthcare 4.0

This section summarises various research works carried out by numerous researchers worldwide. These works are presented by considering multiple parameters, such as major contributions, Healthcare (HC), Cyber-physical Systems (CPS), Internet of Things (IoT), Cloud Computing (CC), Machine Learning (ML), Prediction Systems (PS), Alert Generation (AG), and Fog Computing (FC).

6 Application areas of Healthcare 4.0

The use of Healthcare 4.0 technologies is a matter of the future. These technologies are affecting almost all spheres of our lives. The novel revolution of Healthcare 4.0 can offer several applications in the following scenarios.

- *Monitoring physiological and pathological signals:* The adoption of advanced medical and environmental sensors such as accelerometers, temperature and humidity sensors, as well as ECG, glucose, blood pressure, and gas sensors-enables continuous monitoring of patient's physiological and pathological health attributes [19]. These attributes can be used to monitor and provide quality care services to patients.
- *Self management, wellness monitoring and prevention:* Self-management solutions are widely encouraged in Healthcare 4.0. These solutions can use algorithms to help prevent disease by identifying modifiable risk indicators and developing strategies to change health behaviours [20].
- *Personalized healthcare and recommender systems:* Recommender Systems are one of the most important innovations in Healthcare 4.0 that are responsible for identifying

user's needs by speculating the data from the user-item interactions automatically [61]. These are used to provide personalized care to patients and to facilitate healthcare tips based on users' needs. These have also been used to recommend doctors to patients based on medical history.

- *Telemedicine and disease monitoring:* Telemedicine is characterised by the provision of medical services where location is a key issue for medical practitioners to share diagnostic information over long distances using information and communication technologies [62]. In the current scenario of the Covid-19 pandemic, it is very risky to move to the hospitals for routine checkups. Health 4.0 provides telemedicine services in these critical scenarios. Several diseases such as diabetes and chronic respiratory failure have been monitored and treated in past through the application of telemedicine.
- *Assisted living:* Assisted living (AL) lies somewhere between community care and the nursing home [63]. Health 4.0 provides various services for AL that are generally used for elderly patients wherein critical parameters are continuously sensed and transmitted to a central hub. Based on the deviation in any of the parameters, emergency assistance is provided to these patients.

7 Open issues and challenges

Although the use of Healthcare 4.0 technologies has resulted in a wide range of healthcare frameworks, many research issues and challenges need to be addressed for real-time implementation. Figure 4 presents various challenges for the implementation of Healthcare 4.0.

7.1 Data diversity and management

The healthcare frameworks confront data from a multitude of sources, such as electronic medical records, user apps, IoT devices, etc. Such data is commonly interpreted as big data

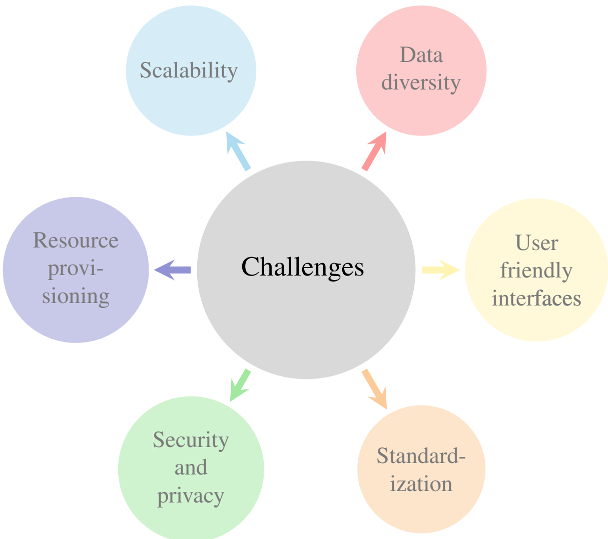

Fig. 4 Important Healthcare 4.0 technologies

and is subject to the 5 V's of big data: volume, value, veracity, variety, and velocity. Due to the diversity of data sources, building machine learning models based on such heterogeneous data is time-consuming and tedious. Consequently, standard protocols and formats are essential to managing extremely disparate data from multiple data sources, such as text, picture files, and so on.

7.2 Scalability

Healthcare 4.0 should be extended up to the entire country or region to meet the escalating expectations of patients and encourage improved health operations. It would save patients' time waiting for consultations and reports and hence provide immediate access to a certain level of medical services.

7.3 Resource provisioning

The emergence of a multitude of applications has led to the generation of a massive amount of data. It is imperative to store, analyze and interpret massive amounts of data in real time. In a highly unpredictable and dynamically changing environment, communication and computationally intensive resources are inevitably limited. To mitigate this, autonomous resource management strategies must be implemented so that these resources are readily available when needed.

7.4 Security and privacy

Healthcare 4.0 has enormous potential to enhance patient health outcomes and experience by delivering real-time services. However, addressing the privacy and security of any healthcare framework is a persistent and significant challenge as hackers are increasingly interested in health data. This puts patients' data at tremendous risk. Hence, significant steps are required to ensure the security and privacy of data at different stages when designing healthcare systems.

7.5 Standardization

Another critical issue is the lack of healthcare regulations. This aspect has enormous implications for security, privacy, data transfer, and synchronization between layers. To solve this problem, standardization activities are necessary, such as a dedicated organization to standardize healthcare technology. It facilitates real-time response and resolution of data discrepancies. In addition, a well-established regulatory system must be put in place ahead of patients for proper tracking and management.

7.6 User friendly interfaces

End-users of healthcare services should be included in the development team to share their insights, preferences, and concerns. As a result, Healthcare 4.0 will have a user-friendly interface and patient-centred care.

8 Discussions and implications

The proliferation of information and communication technologies profoundly affects every aspect of life, including the health industry. Our systematic survey has helped us to find answers to various research questions as laid down earlier in Sect. 2. The first research question, RQ1, aimed to find answers to various revolutions in the healthcare domain. To answer this question, a thorough study has been conducted to determine the significant and advanced innovations that occurred in each of these revolutions. Table 4 has been presented, which shows each revolution's main objective and focus. Besides, different technologies and methods are also presented along with the limitations of each revolution. It is clear from the study that the current revolution focuses on predictive care and is more patient-centric rather than traditional hospital-centric. Future researchers will focus on developing real-time applications to meet the current needs of healthcare. Healthcare 4.0 is characterized by continuous integration, digital systems, and the implementation of electronics and information technology (IT) to provide a range of services. RQ2 attempted to analyze the various key technologies particularly used in the healthcare domain. Figure 3 shows the range of particularly popular technologies among researchers. Many research works use IoT-based medical devices for data acquisition. The collected data is analyzed using machine-learning techniques over the fog-cloud integrated platform. Moreover, to ensure the security of the data, numerous researchers implemented blockchain technology. RQ3 finds an answer to the different application scenarios of Healthcare 4.0. The current study has identified the critical areas of healthcare contexts to deliver services. Various application areas, recommender systems, and remote monitoring are prevalent among researchers, and a lot of work is in progress. The answers to RQ4 are achieved by exploring in-depth literature of current works in the healthcare domain. A comparative analysis based on many key technologies is also presented in the related domains of study. RQ5 aimed to identify future challenges and open issues to advance research in healthcare. One of the prime challenges found in the literature is the security and privacy of healthcare data. Future research will focus on exploring these challenges that emerged from the current study (Table 5).

9 Conclusion

This article provides readers with insights into different aspects of successfully implementing Healthcare 4.0. The survey was conducted using the PRISMA method, in which articles from different databases were explored for article selection. The survey is divided into five distinct sections. The first part discussed the various revolutions, starting from Healthcare 1.0 to Healthcare 4.0. The second part outlines various vital technologies necessary for successful implementation. The third part broadly discussed various implementation frameworks of Healthcare 4.0, utilizing the widely available key technologies. The fourth part highlighted distinct application areas of Healthcare 4.0 and their applicability. Finally, the last part highlighted the open issues and research challenges in Healthcare 4.0. Identifying trends, issues, and theoretical gaps through this scoping assessment has been the first step in developing such a road map, enabling the first mapping and integration of the body of knowledge on Healthcare 4.0. Consequently, future research will focus on leveraging the theoretical integration of the

Table 4 Summary of transition from traditional care to patient-centric healthcare

Parameters	Healthcare 1.0	Healthcare 2.0	Healthcare 3.0	Healthcare 4.0
Key objective	Enhanced performance and paperwork reduction	Boost productivity and data exchange	Delivers patient-centred services	Offer real-time analytics and reporting services
Target	Effortless automation	Collaboration with other organisations	Physical interaction with patients	AI-based interaction with real-time monitoring and diagnostics
Information transmission	Intra-organization	Within a community of hospitals and doctors	Within a country	Healthcare distribution network around the globe
	Major technologies utilized	Laboratory information management systems	Cloud computing and electronic data interchange	EMR, AI, IoT, CPS
Demerits	Standalone devices with limited computational resources	Only sharing critical information without interacting with patients	Different protocols with little accessibility	Industry 4.0 untested technologies

Table 5 Review of existing work in healthcare

References	Year	Major contributions	HC	CPS	IoT	CC	ML	SA	PS	AG	FC	Limitations of approach
[21]	2021	Presented a system that limits COVID-19 outbreaks	✓	×	✓	✓	×	✓	×	×	×	For efficiency and latency reduction in transfer of data to cloud servers, fog servers may be introduced as a middleware
[22]	2021	Importance of Fog Computing in Healthcare 4.0	✓	×	✓	✓	×	×	×	×	✓	Paper provides an in-depth overview of Fog-Cloud Computing in IoT environment. However, important design issues like security were not addressed by the authors
[23]	2021	The authors proposed an accurate and reliable smart healthcare system for IoT platform to detect dysphonia using edge computing	✓	×	✓	×	✓	×	×	×	×	Proposed model need cloud storage and alert generation for timely information dissemination
[24]	2021	The authors reviewed several surveys and suggested the need for Fog Computing for Health 4.0	✓	×	✓	✓	×	×	×	×	✓	Several important topics like Fog and integration with IoT-Cloud. Data analytics modules for prediction have not been addressed
[25]	2021	The authors present a taxonomy of fog-computing for Healthcare 4.0	✓	×	✓	×	×	×	×	×	✓	Only few recent technologies are considered. Several state-of-the-art technologies are skipped
[26]	2021	The authors developed an efficient AI and IoT convergence-based disease diagnosis model for smart healthcare systems.	✓	×	✓	✓	✓	×	✓	×	×	Despite, various recent algorithms are available. Only classical machine-learning algorithms are considered for the implementation
[27]	2020	The authors aimed at exploiting deep learning technique and its applications in health care	✓	×	×	×	✓	×	✓	✓	×	Presented a theoretical model with no implementation
[28]	2020	The authors propose a blockchain-based Smart Healthcare System (SHS) to provide intrinsic security and integrity of the system.	✓	×	✓	×	×	✓	×	×	×	The security model is implemented at cloud layer
[29]	2020	The authors develop a Compression then Encryption based dual watermarking to protect the electronic patient records(EPR) data for healthcare system	✓	×	×	×	×	✓	×	×	×	To achieve efficient results, the dataset of smaller size is not enough
[30]	2020	Introduced mobile health monitors vital indicators including pulse rate, skin temperature, and hospital conditions like humidity, CO, and CO2 levels.	✓	×	✓	✓	×	×	×	✓	×	Provided hardware implementation of the framework using IoT-based sensor kit. For doctor-patient consultations, the video may be included

Table 5 (continued)

References	Year	Major contributions	HC	CPS	IoT	CC	ML	SA	PS	AG	FC	Limitations of approach
[31]	2020	The authors presented the concept of blockchain technology and then highlighted the prime applications of blockchain technology in healthcare.	✓	×	×	×	×	✓	×	×	✓	Presented a review considering only limited areas of healthcare.
[32]	2020	A smart healthcare system is proposed for heart disease prediction using ensemble deep learning and feature fusion approaches.	✓	×	✓	×	✓	✓	✓	×	×	Comparison of Ensemble techniques with other state-of-the-art ANN based Deep learning approaches is missing. Moreover, the model is trained with only small training data
[33]	2020	The authors analyze the smart healthcare architecture, its threats, vulnerabilities and the security measures to provide a secure smart healthcare system.	✓	×	✓	✓	×	✓	×	×	×	The authors merely considered IoT for discussing security aspects. Several other integrative technologies are not considered
[34]	2020	The authors propose a holistic AI-driven IoT e-Health architecture based on the Grey Filter Bayesian Convolution Neural Network.	✓	✓	✓	✓	✓	×	✓	×	×	Advanced machine learning may also be considered
[35]	2020	The authors assess healthcare IoT security and privacy.	✓	×	✓	×	×	✓	×	×	×	The authors discussed only theoretical aspects of security and privacy
[36]	2020	The authors reviewed the performance of the IoT-based healthcare system along with its advantages and limitations.	✓	×	✓	✓	✓	✓	✓	✓	×	Only general review is provided without any practical implementation
[37]	2020	The authors present a review of existing literature and applications available for the healthcare system using blockchain technology.	✓	×	✓	✓	×	✓	×	×	×	Provide a simple use case of healthcare. While the scalability is complex
[38]	2020	The authors present a healthcare system based on IoT and Blockchain for human activity recognition by remotely monitoring vital/non-vital signs collected from wearable sensors.	✓	×	✓	×	×	✓	×	×	×	Tiny dataset, consisting of 10 users is used for performing the experimentation
[39]	2020	The authors proposed a framework for fall detection in patients using image processing.	✓	×	×	×	✓	×	✓	×	×	Several sensors for fall detection are available, which are not utilized

Table 5 (continued)

References	Year	Major contributions	HC	CPS	IoT	CC	ML	SA	PS	AG	FC	Limitations of approach
[40]	2020	The authors reviewed the IoT-cloud frameworks and realized the need of Fog Computing in their review paper.	✓	×	✓	✓	×	×	×	×	✓	Review of fog for health applications is presented without its implementation in any health scenario
[41]	2020	The authors proposed IoMT-based architecture for health monitoring in Covid-19 patients.	✓	×	✓	✓	×	×	×	×	×	Initial level approach is presented
[42]	2020	The authors propose to use existing Explainable Artificial Intelligence (XAI) models in conjunction with clinical knowledge to obtain more benefits in AI-based systems.	✓	×	×	×	✓	×	✓	×	×	This paper presents the theoretical aspects of the introduction of AI for healthcare applications
[43]	2020	The authors provided the overview and applications of smart healthcare systems.	✓	×	✓	×	×	×	×	×	×	This paper present very initial work in healthcare
[44]	2020	The authors presented a proximity-based resource approach to minimize output delay in a mobile service public cloud.	✓	×	×	✓	✓	×	✓	×	×	Only responsiveness and resource usage are evaluated
[45]	2020	The authors proposed an effective Urine-based Diabetes (UbD) monitoring system based on the Internet of Things.	✓	×	✓	✓	✓	×	✓	✓	×	Though, this paper present certain factors to be considered. However, different categories and severity of the disease are not predicted
[46]	2020	The authors proposed a drug-recommender system in the healthcare environment.	✓	×	×	×	✓	×	✓	×	×	For serious health issues, the drug recommendation system suggested by authors is not suitable
[47]	2019	Presented a machine learning-based security policy for healthcare Systems.	✓	×	×	×	✓	✓	✓	×	×	Only few decision-making algorithms are considered
[48]	2019	The authors presented a state-of-art survey about various features of BAN, specifically communications, sensors, applications, requirements, standards, protocol, and security aspects.	✓	×	✓	×	×	✓	×	×	×	The paper presents only a basic introduction to Wireless Body Area Networks
[49]	2019	The authors developed a prototype model for healthcare monitoring systems that uses the Internet of Things (IoT) and Cloud Computing.	✓	×	✓	✓	✓	×	✓	×	×	This paper presents a hardware implementation of Healthcare management considering only heart rate and body temperature

Table 5 (continued)

References	Year	Major contributions	HC	CPS	IoT	CC	ML	SA	PS	AG	FC	Limitations of approach
[50]	2019	The authors present recent developments and state-of-the-art research related to three critical elements that enable an Energy autonomous wearable sensors (EAWS)	✓	×	✓	×	×	×	×	×	×	Presents a review of wireless sensors considering energy management
[51]	2019	The authors presented a comprehensive survey of existing techniques, including state-of-the-art methods and the most recent trends for health applications.	✓	×	×	×	✓	×	✓	×	×	Several application scenarios are left untouched
[52]	2019	The authors identified the open research challenges in security and privacy of SHS and provide directions for future research	✓	✓	×	×	×	✓	×	×	×	This paper merely describes the theoretical aspect of security and privacy
[53]	2019	The authors identified different technologies, capabilities and research status of Industry 4.0 in the medical field	✓	×	×	×	×	×	×	×	×	The authors provided a taxonomy of role of Industry 4.0 for the medical industry. However, various latest technologies, such as blockchain, Artificial Intelligence etc., that are the backbone of Industry 4.0 are left untouched
[54]	2019	The authors presented a security scheme for healthcare applications.	✓	×	×	×	×	✓	×	×	×	Enforcing on-demand security with the inclusion of risk-based authentication may put a check on impersonation problems and data theft
[55]	2019	The authors introduced a new paradigm in vision sensor IoT technologies by analyzing the behaviour of babies through an intelligent multi-modal system	✓	×	×	×	✓	×	✓	×	✓	Use of CNN based model for motion detection instead of motion detection mechanism may effectively present actions/motion patterns
[56]	2018	The authors proposed a framework for image forgery detection using a medical and natural image.	✓	×	×	✓	✓	×	✓	×	×	Novel deep learning-based R-CNN, Faster R-CNN that are suitable for image processing tasks are not utilized for achieving the purpose
[57]	2018	The authors proposed a healthcare model using Internet of Things based medical sensors	✓	×	✓	×	×	×	×	×	×	This paper primarily focuses on IoT sensors without any emphasis on other enabling technologies for its implementation

Table 5 (continued)

References	Year	Major contributions	HC	CPS	IoT	CC	ML	SA	PS	AG	FC	Limitations of approach
[58]	2018	The authors presented an IoT-cloud-based cognitively smart patient monitoring platform.	✓	×	✓	✓	✓	×	✓	×	×	EEG cloud big data lacks a cognitive framework
[59]	2018	The authors presented an Ambient Assisted living-enabled framework for healthcare applications to monitor physical activities.	✓	×	✓	✓	×	×	×	×	×	Processing, analytics and storage of data at the cloud results in the overloading of cloud servers. Therefore, some of the analytics may be performed by using an additional fog layer
[60]	2018	The authors proposed a fruit fly optimization-based task offloading algorithm (FOTO) which improves offloading and resource allocation to acquire the nominal energy consumption under the existing restraints in healthcare.	✓	×	✓	✓	×	×	×	×	×	Very few parameters are considered for the evaluation of the proposed methodology
[11]	2018	The authors presented a taxonomy of fog in a Health scenario considering several important issues.	✓	×	✓	✓	×	×	×	×	✓	The authors discussed about the three layered architecture. However, its implementation with real datasets is missing

literature obtained in this work as a conceptual basis for constructing a road map for implementing Healthcare 4.0.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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