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Survey of Big Data Analytics in IoT-Driven Healthcare Applications: A Comparative Approach

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***Abstract*—Integrating the Internet of Things(IoT) with advanced big data analytics (BDA) is crucial for reducing healthcare expenses and identifying potential risks. IOT BDA has an effect on information gathering, storing, extracting, and utilizing in the healthcare sector. It offers several benefits across many medical organizations' disciplines and improves the healthcare services. This review critically summarizes the advantages and disadvantages of IoT and BDA when individually used. The necessity of integrating the IoT and BDA is explained in detail. The scope for future work is proposed based on the various research gaps identified in the literature. Applications of IoT, Big data analytics techniques, challenges of IoT enabled healthcare are also discussed.**

***Index Terms*—Big Data, Internet of Things, Big Data Analytics, Healthcare**

I. Introduction

Imagine a world where hospitals are not just buildings, but living, breathing organisms, each patient a cell connected by a digital circulatory system. This captivating transformation is made possible by combining two technological wonders: the Internet of Things (IoT) and Big Data Analytics for the health sector.

A. IoT: The Pulse of Smart Healthcare

In this realm, medical devices are not mere tools; they are intelligent companions. IoT bestows life upon them. Sensors embedded in medical equipment, wearables, and even within patients' bodies, diligently collect data – heartbeats, oxygen levels, body temperature – relaying it in real-time to a central hub.

These digital whispers merge into a symphony of information, creating a real-time health profile for every patient. A surgeon in London can monitor a patient's vital signs in Tokyo, an ICU bed "talks" to the ventilator, orchestrating oxygen flow seamlessly. This interconnected ecosystem does not just treat diseases; it foresees them, allowing preventive care by spotting anomalies long before they manifest.

B. Big Data Analytics

But wait, this data deluge holds secrets far too intricate for the human mind to decipher. This is where Big Data Analytics steps into transmuting raw data into golden insights. It gazes at the patterns of millions, comparing genomes, identifying genetic predispositions, and predicting disease trajectories.

In hospital corridors accessorized with screens displaying real-time data visualisations, doctors morph into diagnosticians of the future. Treatment plans are tailored with pinpoint precision, minimizing adverse reactions, and optimizing outcomes. Disease outbreaks are spotted at their inception.

Moreover, this duo extends beyond hospital walls. Wearables prompt users to take a walk if their activity drops, smart pill dispensers remind the elderly to take their medication, and AI-driven chatbots offer medical advice, comforting the worried at any hour.

In this health sector, there is a proverb that says “Prevention is better than cure" which transforms into a adopting healthier lifestyle throughout, instead of becoming a victim of diseases. Hospital beds are not just for the sick but a safe place for proactive well-being.

So, in this new era of healthcare, remember that it is not just about the "Internet of Things" or "Big Data Analytics." It is about a synchronization established; an orchestra conducted by innovation.

The rest of this paper is structured as follows. In Section II we introduce the related work which will give insights into various referred papers and their summary toward Big data Analytics and IOT in health care. In Section III different big data analytics techniques are discussed along with the steps that are necessary before analysis such as data preprocessing, collection, and visualization. In Section IV, the different applications of IOT in health care are summarized. Section V throws light on different challenges encountered in the IOT healthcare sector. Sections VI and VII talk about comparative study and analysis of various big data techniques and future work. Finally, we conclude this paper and discuss what can be improved in future research.

II. Related Work

To anticipate diseases in the healthcare industry, combined approach includes IoT and Big Data analytics is proposed[1]. They created a system that uses the Internet of Things to track the wellness of the heart and send alarms when something is off. For those who are elderly or less mobile, this is beneficial. But IoT alone is insufficient to accurately anticipate diseases. To address this issue, an advanced data analysis and machine learning approach is proposed to enhance the system's ability to detect early disease warning signs.

IoT makes it possible for machines, people, and services to communicate with one another to enhance daily life. Real-time access to diagnosis and treatment has benefits for the healthcare industry as well. The usage of IoT in health care facilities and its future developments, with an emphasis on the management of healthcare using IoT is discussed[2]. It demonstrated how wearable sensors and the IoT make it possible for medical care to be provided anywhere. But there are still difficulties with Big data management, privacy, and significant expenses. Future IoT healthcare developments include seizure and stroke prediction, as well as the use of sensors for on-demand medical assistance.

Wearable biosensors enable personalized health solutions as a result of the fusion of technology and healthcare, which is fueled by the expansion of IoT and Big Data. But there are still issues with device dependability and safety, which calls for cooperation between tech creators and medical specialists. A special edition is covered that analyses the role of IoT in smart health sensors with an emphasis on wearables and Big Data analytics for informed devices, with the goal of enhancing individualised tele-health interventions and healthier lifestyles[3].

Emerging technologies like 6G, extended reality (XR), and IoT big data analytics can address current issues in healthcare like staffing and telehealth. These innovations could lead to novel services like telepresence and improved patient experiences. XR improves healthcare practices, while IoT generates data for better services and treatments. A research gap is filled by reviewing how these technologies converge to shape the future of healthcare, discussing applications, challenges, and directions[4].

The use of Deep Learning in Healthcare analytics such as electronic medical records, Genomics, and the development of drugs is examined[5]. Deep learning techniques are used to process the information in the medical data. These techniques can also be used by biomedical data to improve the level of guidance to doctors and improve medical health. Furthermore, the challenges and difficulties encountered in using Deep Learning for Healthcare analytics are discussed.

Healthcare is being transformed into Healthcare 4.0 by Industry 4.0 technologies including IoT, Cloud Computing, and Big Data. The impact they have on conventional healthcare services is examined[6], along with applications, advantages, and multidisciplinary difficulties.

The demand for advanced healthcare solutions has increased due to the rise of chronic disorders like COVID-19. IoT-driven wearables collect a lot of health data, which poses a significant data challenge. Machine learning approach is used to handle large datasets generated by IoT for healthcare[7]. It provided an insight into the most recent machine learning developments for efficient healthcare strategies for healthcare professionals and authorities.

III. Big Data Analytics Techniques

By choosing the suitable big data technology, an organisation will be able to handle the elevation in volume, velocity, and variety of data in a better way[8]. Big data analytics involves the usage of various techniques and tools to manage and extract insights from large datasets. This process confines several key components: data collection, storage, processing and visualization.

Data collection: In this stage, data is gathered from a variety of sources, including unstructured (such as text, photos, and videos) and structured (such as databases). Sensors, social media, online transactions, polls, and other sources can all be used to collect data. Import.io is an effective tool for extraction of WebPages data.

Data Storage: After data collection, The data must be stored in a fashion that makes retrieval fast and easy. Big data is frequently stored and managed using tools like distributed file systems (like Hadoop HDFS) and NoSQL databases (like MongoDB and Cassandra). These tools are configured to provide high availability, fault tolerance, and data redundancy.

Data Processing: Analysing and extracting insights from big data often involves complex computational tasks. Technologies like Apache Spark provide distributed computing capabilities to process data in parallel across a cluster of machines. MapReduce, a software framework, is commonly used for distributed, parallel processing of massive data collections.

Data Visualization: Converting unprocessed data into useful visual representations like graphs, charts, and dashboards is an essential step. Data analysts and decision-makers can better understand patterns, trends, and anomalies in the data with the use of visualisation. Users can generate dynamic and educational visualisations that support data-driven insights and well-informed decision-making using tools like Tableau, Silk, CartoDB,Power BI, and D3.js.

IV. Applications of IOT in Healthcare

Certainly, there are several innovative and unique ways in which IoT (Internet of Things) can be applied in healthcare beyond the conventional(traditional) use cases. Here are some innovative applications:

Smart Pill Dispensers and Medication Monitoring: IoT-enabled pill dispensers can remind patients to take their medications at the right time and track their adherence. These devices can also connect to healthcare providers, alerting them if a patient misses a dose or requires a medication adjustment.

Personalized Nutrition Monitoring: IoT devices can track a patient's diet and nutritional intake in real-time, analyzing data to provide personalized dietary recommendations and helping individuals make healthier food choices.

Emotion and Stress Monitoring: Wearable IoT devices equipped with sensors can measure physiological responses such as heart rate variability, skin conductivity, and even brainwave patterns. This data can be used to monitor emotional well-being and stress levels, allowing for early intervention or stress management techniques.

Patient Comfort and Satisfaction: IoT sensors in hospital rooms can monitor environmental factors such as temperature, lighting, and noise levels. This data can be used to create more comfortable and personalized patient experiences, potentially leading to faster recovery times.

Fall Detection and Prevention: IoT-enabled wearable devices can detect sudden changes in motion and orientation, alerting caregivers or medical personnel in real-time if a patient falls. This can be especially useful for elderly or at-risk individuals.

Wound Management: Smart bandages equipped with IoT sensors can monitor wound healing progress by tracking factors like moisture, infection, and inflammation. Healthcare providers can receive real-time updates and adjust treatment plans accordingly.

Assisted Living for Elderly: IoT devices in assisted living facilities can monitor daily activities and routines of elderly residents. Anomalies or deviations from normal behavior patterns can trigger alerts to caregivers, ensuring timely intervention in case of emergencies.

Telemedicine Enhancements: IoT devices can facilitate remote patient monitoring, allowing doctors to assess vital signs, conduct physical exams, and provide medical advice virtually. This is especially valuable for patients in remote areas or those with limited mobility.

Hospital Workflow Optimization: IoT sensors can track the movement of medical equipment, staff, and patients within a hospital, optimizing workflows, minimizing wait times, and improving resource allocation.

Pharmacy Inventory Management: IoT sensors in pharmacy storage areas can monitor medication inventory levels in real-time. This ensures medications are always available and prevents stockouts, helping to streamline patient care.

Predictive Healthcare Analytics: By analyzing data from IoT devices, machine learning algorithms can predict disease outbreaks, track trends in chronic conditions, and help healthcare organizations allocate resources more effectively.

Sleep Quality Monitoring: IoT-enabled sleep trackers can monitor sleep patterns, providing insights into sleep quality, duration, and potential disruptions. This information can assist in diagnosing sleep disorders and improving overall sleep hygiene.

Remote Rehabilitation and Physical Therapy: IoT devices can guide patients through personalized physical therapy exercises at home, tracking progress and adjusting routines based on real-time feedback.

Medication Authenticity Verification: IoT technology can be used to verify the authenticity of medications through embedded sensors and blockchain technology, reducing the risk of counterfeit drugs entering the supply chain.

These unique applications of IoT in healthcare demonstrate the potential to revolutionize patient care, improve outcomes, and enhance the overall healthcare experience. However, it's important to consider data privacy and security measures when implementing IoT solutions in the healthcare sector.

V. Challenges in IoT-enabled Healthcare

The acceptance of Internet of Things (IoT) technology in the healthcare industry has the capacity to transform how patients are cared for, diagnosed, and treated. IoT-enabled healthcare offers several benefits such as enhanced monitoring, improved patient outcomes, and streamline procedures by connecting medical equipment, sensors, and systems. Various challenges in IoT-enabled healthcare are discussed below:

1) **Security Challenges:** As more companies are adopting IoT, new security concerns will inevitably arise. These challenges might be related to the device's restrictions.The following are a few of these security challenges [2].

a) Rise of botnets: A botnet can impact a hospital without the management being aware of it[9]. This occurs due to the organization's insufficient security measures, preventing effective tracking of the botnet across all its devices.

b) Increased number of IoT devices: More IoT devices will result in greater security vulnerabilities being affected by businesses, which will increase the challenges for security experts.

c) Need for encryption: Encryption techniques are an efficient method of denying hackers access to information and are one of the important challenges for IoT security [10].

d) IoT financial-related breaches: Because organisations such as banks use IoT for electronic transactions, hackers will attack the devices and make illegitimate transactions. Currently, few organisations have adopted blockchain or machine learning to control financial fraud prior to its occurrence [11, 12]. Despite that, not every organisation agrees to this kind of security measure.

2) **Interoperability:** IoT devices used in the healthcare industry can have different vendors and communication protocols. For precise data sharing and efficient patient care, it is essential to provide seamless interoperability among these systems and devices.

3) **Reliability and Quality of Service:** IoT devices are essential for monitoring and treating patients. It is critical to ensure the reliability and optimal functioning of IoT-enabled healthcare systems.

4) **Energy Efficiency and Battery Life:** IoT devices used in healthcare systems operate on battery power. For systems that must run for longer periods of time, it might be difficult to increase battery life while maintaining precise and continuous monitoring.

5) **Ethical and Social Concerns:** The use of IoT devices in healthcare raises moral concerns about patient consent, data ownership, and the possibility of biases in the algorithms that are used to make diagnoses and prescribe treatments.

VI. Comparative Analysis of Big Data Analytics Approaches

A continuously rising demand for useful analytical tools has been apparent in recent years. In the analysis of massive amounts of data (Big Data, BD), this trend is also observable. Business performance, competitive advantage, and decision-making are all areas where organisations are aiming to leverage the power of big data [13, 14]. The management of healthcare has recently evolved from a disease-centered paradigm to a patient-centered paradigm, especially in value-based healthcare delivery models [15]. It is vital to handle and analyse healthcare Big Data in order to provide excellent patient-centered care and adhere to the specifications of the model. Big data analytics techniques including data mining, statistical analysis, web and text mining, and social media analytics are used in the healthcare domain. It assists with ac-

tivities like improving diagnosis, preventing disease and providing real-time patient alerts.

Big Data Analytics in healthcare encompasses several types [16, 17, 18]: Descriptive Analytics examines historical and present data to provide insights into healthcare decisions, outcomes, and quality. It helps in creating reports, visualizations, and historical data queries[16]. Predictive Analytics forecasts future trends by analyzing historical health data for patterns and relationships. It assists in predicting treatment responses, foreseeing dangers, and locating hidden patterns. Prescriptive Analytics, uses knowledge of medical data and offers suggestions for complex healthcare choices. It serves as a guide for drug prescriptions, treatment options, and personalized medicine. Discovery Analytics utilizes existing knowledge to uncover new innovations, such as discovering new drugs, identification of undiagnosed diseases, and suggesting alternative treatments. It advances both medical research and healthcare procedures.

Collaboration between Data Scientists and Healthcare providers is necessary in order to maximize the benefits for both patients and medical organizations. One can deploy advanced federated learning algorithms in healthcare data analytics to safeguard data privacy and uphold the decentralized structure of the IoHT (Internet of Healthcare Data Things). Deep Q-Network(DQN) plays an important role in both conducting missing value analysis and labeling unlabeled data[19].

Data science greatly benefits from the convergence of big data analytics, machine learning, and artificial intelligence (AI). Deep Learning (DL), a category of machine learning that is inspired by neural networks, excels at interpreting complex data patterns. Its potential application in fields like IoT and healthcare is very promising[20]. Because neural networks in deep learning are organized in a similar way to how the brain is organized, they can extract complex details from data. This makes it easier to understand hierarchical data in the IoT space, and it benefits the healthcare industry by enabling quick decisions based on wearable and sensor data. Collaboration between disciplines results in significant shifts in the way decisions are made and how data is analyzed, creating breakthroughs across a range of industries.

Healthcare offers various prediction and prevention techniques. The main concern lies in fully capitalizing on all these opportunities because they are insufficient. A decentralized approach is being adopted by various parties involved, such as data scientists, experts in deep learning fields, and data set owners. The use of a Decentralized Transfer learning Model combines various deep learning techniques onto a unified platform, resulting in enhanced predictions[21] and optimized outcomes.

Advanced analytics are used in the healthcare industry to process vast amounts of patient and medical information for improved clinical outcomes and insights[22]. The integration of numerous scientific disciplines, including bio informatics, medical imaging, sensor informatics, medical informatics, and health informatics [23], enables the analysis of enormous patient data sets and the discovery of trends, correlations, and predictive models. A single article cannot adequately address the variety of Big Data Analytics methodologies employed in the healthcare industry.

In conclusion, when evaluating different approaches in Big Data Analytics, it is very essential to consider the type of data, the available analytical tools, and the expected outcomes. Utilizing several methods in combination often proves to be beneficial, and provides an efficient approach to manage data and obtain valuable insights.

VII. Comparative Study

A comparative survey of research papers which focus on integrating Big Data Analytics and Internet of Things technologies is presented in Table I.

Table I. A comparative survey on integrating Big Data Analytics and Internet of Things technologies

SI.No	Research Findings	Future Work	Ref
1	–Recommended the electrocardiogra (ECG) system with Internet of Things assistance for secure data transmission for ongoing cardiovascular health surveillance. –Helped to comprehend the many healthcare technologies, such as ECG and the monitoring of EMG	–Explores existing local health systems technology and uses the latest technology that will be developed for the next research.	[24]
2	-Various healthcare data platforms and machine learning algorithms are discussed. -Big data lifecycle challenges like processing, storage, and security are addressed. -Big data analytics framework is presented for real-time disease prediction, including cancer, diabetes, Alzheimer's and heart.	-New mining techniques should be created to enable the extraction of sensitive data from the enormous amount of health data.	[25]
3	-The potential of Big Data Analytics is analyzed in healthcare, and focused on the use of unstructured and structured data in medical facilities. –Only a few dimensions are investigated to characterize the use of data by healthcare institutions.	–Future studies may look at the advantages that healthcare organizations obtain from analyzing both unstructured and structured data in the clinical domains, in addition to any challenges they face in these domains.	[26]
4	–An architecture of real-time data analytics for an IoT-based smart healthcare system is presented. –Radio-frequency identification technology and wireless sensor network is comprised. The proposed work discussed various data analytics tools to attain high-performance, like Spark, Kafka, NodeJS and MongoDB. –A diagnosis of Wolff–	NA	[27]

SI.No	Research Findings	Future Work	Ref
	Parkinson–White syndrome by logistic regression is outlined to evaluate the performance of the developed system. –The results suggest that the proposed system can process medical data in real-time with a high accuracy rate successfully and handle huge amounts of data.		
5	–A data analytics and privacy preservation model using deep learning approach is introduced for IoT-enabled healthcare systems to address the security issue. –To analyze the health-related information in the cloud a convolutional neural network(CNN) is used. –A secure access control module is presented to work on the attributes of the user for the IoT based healthcare system. –The recall, F1 score and precision of the proposed CNN classifier are achieved at a higher accuracy rate. Higher performance is achieved by increasing the size of the training set.	–The future scope shall focus on larger datasets to standardize the performance of the system and to overcome the time constraints and cost of the work. –By introducing a security module which is based on blockchain, the user identity protection policies can be enhanced. –The performance gets better by collecting real time data and updating the system.	[28]
6	– In order to accurately and comprehensively predict the disease that the patients are experiencing, a novel system is developed that employs the most effective machine learning algorithm and collects data from the patients, including audio recordings, symptoms, medical reports.	NA	[29]
7	–Implemented a new system which is capable of being used in several disease prediction studies using Big Data Analytics and Internet of Things. –Developed an electronic monitoring system for realtime miscarriages, prediction systems to help women who are pregnant and save the lives of baby's. –In order to react in the event of a miscarriage and prevent unfavorable effects, clinicians really obtain the clustering findings and track their patients via mobile app. Women who are pregnant, however, only get recommendations based on their actions.	– The future work shall focus on improving the proposed scheme by incorporating more health care sensors to collect data related to healthcare about a human being, and collect risk factors from texts, images and social networks.	[30]
8	–A multisensory IoT-based real-time vitals monitor is designed to sense BP, SPo2, BT, and PR and continuously these signals are transferred to the big data analytics system which helps in improving diagnostics in an advanced stage. –Developed a mobile application to transfer measured data with an overall health condition to the doctors and patients.	Future work focus on i) generating an automatic notification which will specify location of the patient to ambulance, friends or family, ii) a medicine dispensing system module which notifies patients about out-of-schedule and scheduled medications, iii) A module which tracks Covid-19 patients using wearable sensors, and sends prescriptions to pharmacies for delivery of medicines to patients.	[31]

VIII. Conclusion

In this paper, the integration of Big Data Analytics and IoT in healthcare is examined. IoT applications, Big Data Analytics techniques, challenges in IoT-enabled healthcare are discussed in detail. Comparative analysis showed the effectiveness of various analytics approaches. This paper demonstrates how the usage of big data and IoT can improve the performance and personalized service in healthcare. The combination of Big Data Analytics and IoT is transforming healthcare, enhancing patient care, but issues need to be resolved. There is a lot of potential for improved healthcare outcomes and experiences as these sectors continue to advance.

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