The Symbiotic Relation of IoT and AI for Applications in Various Domains: Trends and Future Directions

Aman Jolly, Vikas Pandey, Praveen Kumar Malik, and Turki Alsuwian

1 Introduction

The network of devices that are linked to the Internet is referred to as the Internet of Things (IoT). IoT is an umbrella phrase that refers to any device that is able to transmit and receive data via a network. In most cases, these gadgets take the form of sensors that monitor various physical parameters, such as the amount of light, humidity, or temperature. IoT is continuing to proliferate across a variety of corporate sectors, which has resulted in the development of brand-new possibilities for cooperation and innovation. Devices are able to gather data, take actions depending on that data, and then report the results of those activities back to a centralized server. This technology has been around for quite some time, but only lately has there been an explosion of new inventions in this sector of the industry. Artificial intelligence (AI) and the Internet of Things (IoT) are the two primary motivating factors behind the recent uptick in interest about linked gadgets. When coupled, AI and IoT provide even more opportunities for analyzing data and discovering new insights into how we may enhance the quality of our lives. In this article, we will discuss AI and IoT, focusing on how these two technologies might

A. Jolly (✉)
Department of CSE, Delhi Technological University, Delhi, India
e-mail: amanjolly_2k20phdco07@dtu.ac.in

V. Pandey
School of Engineering, Babu Banarasi Das University, Lucknow, Uttar Pradesh, India

P. K. Malik
School of Electronics and Electrical Engineering, Lovely Professional University, Phagwara, Punjab, India

T. Alsuwian
Electrical engineering department, Najran University, Najran, Saudi Arabia
e-mail: tmalsuwian@nu.edu.sa

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collaborate to provide innovative answers to common challenges. Some of the core areas where IoT has been used at its peak are as follows:

1. 5G: The next generation of wireless communication, 5G, will increase Internet access and network connection. The innovative design of 5G allows it to simultaneously connect more devices at greater speeds with less delay. This cellular IoT application was developed for the advantage of users at minimal cost and with increased speed. Using this innovative program, we can fully automate several sectors with the aid of smart grids. In the future, 5G will expand to support larger devices across wider regions, bridging the gap between smart cities and wireless vehicle communication. The public and commercial sectors may both profit greatly from this potential use of IoT. With 5G, it will be possible to remotely manage even more types of devices via software. The infrastructure for smartphones, tablets, and other mobile devices, as well as for sensors, medical equipment, and automobiles, is being established by IoT and 5G.
2. The Internet of Things and Augmented Reality: The connection between IoT and augmented reality is becoming stronger all the time. While IoT bridges the gap between physical assets and digital infrastructure, augmented reality (AR) brings digital components into the physical world. The future of AR and IoT seems bright in the medical field. Surgeons may, for instance, use software designed to reconstruct a body part in three dimensions, together with equipment monitoring the required statistics in real time. This software can be found on mobile devices. All these things could make difficult operations simpler for surgeons and more rewarding for patients who are patient.
3. Smart Cities on the Rise: The popularity of smart city technologies is at an all-time high right now, and analysts predict that interest in and investment in smart city technology will continue to soar in the not-too-distant future. City councils and other local authorities believe that smart city solutions are effective ways of involving the general public in the day-to-day operations of municipal administration and maintenance. Providing more comfort and convenience for the populace is just a minor portion of the whole bargain. Interactivity is being given a significant amount of consideration in the development of smart city initiatives all around the globe. There is a growing consensus that engaging individuals in a manner that requires greater hands-on participation is beneficial in all matters pertaining to the day-to-day maintenance of an urban space, which pays huge dividends for everyone concerned. Safe, habitable, and environmentally sustainable cities will not be possible without IoT-based smart city technologies. As city populations are expected to grow dramatically in the future, these strategies will become even more important.
4. Blockchain Technologies and Information Security: One of the most important developments in IoT technology is blockchain. Put together, IoT and blockchain technology are living up to their hype. As of today, the reliable exchange of money and data between IoT devices become possible once the blockchain technology provides them with a simple infrastructure for doing so. When these two phenomena are put together, they live up to their hype. The decentralized

nature of blockchain is analogous to the dispersed nature of the Internet of Things. The latter provides anonymity and security to numerous networks and the owners of those networks, while the digital signatures and private keys that accompany each transaction assure that the environment of the Internet of Things will be secure. IoT devices are intended to simplify a person's or an operational unit's day-to-day activities in some way. This necessitates the ongoing creation of personal data and introduces significantly increased opportunities for cybercriminal activity. In addition, it is anticipated that the quantity of data will exponentially increase in the same way as the number of machine-to-machine interactions increase. As a consequence of this, the decentralized structure of blockchain will cause massive numbers of data to be accessible whenever they are required and with a minimal number of associated security issues.

All the aforementioned applications require the use of IoT in various domains because IoT acts as a bridge between hardware sensors and the digital infrastructure. This work will focus on all the applications that employ IoT device to obtain real-time data, which will be further fed into the AI-based prediction models. In this review analysis, seven domains have been identified where AI and IoT are being employed: healthcare, sustainability, information security, education, pollution monitoring, robotics, and autonomous vehicles.

Healthcare Applications The IoT of the future will make it much simpler for doctors and nurses to keep track of their patients' activities and vital signs. This will be made possible by advancements in 5G wireless technology, AI, and sensor technology. A smart glucose-monitoring system and smart insulin pens will also be of assistance since they will automatically transmit the patient's important information to a monitoring system. This will serve to direct assistance, particularly in the situation involving insulin. The pen will be able to evaluate the quantity of insulin that has to be administered on the basis of the data that is derived from the patient. Security and patient safety are of the utmost importance in the clinical setting, and IoT may assist in enhancing the monitoring and transfer of patient data. The whole world has been forced to reconsider the significance of remote healthcare. It won't be long until patients and physicians won't even have to physically interact with one another, which might be quite helpful in times of lockdown. IoT developments will soon have stronger effects on healthcare, which will result in the proliferation of increasingly intelligent medical equipment.

Better Way to Store Data and Perform Data Analytics We've just recently become used to storing information on the cloud before it became necessary to make a switch. Edge computing, in its simplest form, enables interconnected gadgets to carry out computations, store results, and locally view results. Edge computing is a hybrid method of data processing that is altering the trajectory of the Internet of Things. The actual value that IoT may bring about via data analysis is in managing and analyzing these data. Therefore, machine learning and artificial intelligence will play increasingly crucial roles. These developments will aid in making our lives simpler and more comfortable and will provide efficient methods for completing jobs.

2 Recent Works on IoT and AI in Various Domains

2.1 Healthcare

The healthcare industry has always relied on a small number of centralized agents freely disseminating raw data to the public. This system still faces substantial threats and weaknesses. With AI, however, the system would consist of several agents working together and effectively interacting with their preferred host. The most cutting-edge and fascinating innovations in the area of intelligent healthcare include federated learning (FL), AI, and explainable AI (XAI). FL operates in a decentralized way and keeps the communication based on a model in the favored system without transmitting raw data. Multiple healthcare constraints may be alleviated with the integration of FL, AI, and XAI methods. In [1], Rahman provides a comprehensive evaluation of FL as it relates to the use of AI in forward-thinking medical settings. They used FL-AI in several healthcare technologies and categorized the results.

Using multisensing, edge-based, and on-device AI components, T. Montanaro et al. [2] constructed a real-time IoT-aware healthcare system that comprises three layers: an edge computing layer, a data visualization layer, and an intelligent data-acquisition layer. (i) Three sublayers make up the intelligent data-acquisition layer. (1) Advanced sensors include motion, temperature, location, and electric charge buildup in skin sensors. These devices gather data for deductions. (2) Computation and data preprocessing devices control the selection and collection of sensor data. (3) AI modules contain microcontrollers linked with AI algorithms. These algorithms identify data irregularities, accurately differentiate between behaviors and between people, classify measured data, etc. (ii) The edge computing layer receives data from the preceding layer, provides a gateway to the top layer, handles multiple protocol communications, and performs additional analyses. This layer may accept data from the bottom layer, transmit changes to it, transfer data to the top layer, and receive notifications and updates from the upper layer. This layer allows communicates with employers, families, and intimate partners. (iii) The data visualization layer connects storage and user interactions. Web dashboards provide authorized users with local device warnings and historical occurrences. Healthcare providers may utilize this dashboard to give people ideas. Advanced data analysis is also possible. Finally, REST APIs connect with lower levels and contain a database to store data.

M. M. Kamruzzaman et al. [3] identified new difficulties, possibilities, case studies, and edge-AI applications for linking healthcare in smart cities. Relevant publications and journals were studied, analyzed, and appraised, and this review also included secondary data sources such as Google Scholar, Science Direct, etc. Only papers including AI, edge AI, IoT, and deep learning (DL) were reviewed. The study selection and data abstraction yielded 22 relevant articles/research papers, which were grouped into two subtopics: edge AI and healthcare in smart cities. They addressed how the machine-learning (ML), DL, and IoT models could be used in healthcare. The accuracy of the models implemented in various research papers was assessed. A. Alghamdi [4] developed a VGG-Net model for analyzing electrocardiogram (ECG) images. VGG-MI-1 showed sensitivity, specificity, and accuracy values of 98.76%, 99.17%, and 99.02%, respectively, and the VGG-MI2 model showed sensitivity, specificity, and accuracy values of 99.15%, 99.49%, and 99.22%, respectively, which were the best so far.

Zhao-xia Lu et al. [5] examined the technical aspects of IoT, cloud computing, big data analysis, and machine learning in clinical medicine. They highlighted the application of AI and IoT in various medical scenarios and discussed challenges and future prospects in this rapidly evolving field. COVID-19 exacerbated the global scarcity of nurses and physicians. Automated tools employing IoT, cloud computing, ML, etc. may be helpful. IoT devices monitor real-time data and send them to the cloud. 5G has increased medical staff's accuracy and speed. Cloud computing services include processing power, machine learning, and storage. They provide data exchange, remote consulting, etc. Large data sets are analyzed by using big data. They can cluster, classify, and visualize data and can mine text. Clustering sorts data by proximity. Classification mining maps data to labels by using decision trees, neural networks, etc. Text mining methods shape unstructured medical data through preprocessing, segmentation, and semantic analysis. Visualizing data uses charts and graphs. This may prevent, diagnose, and cure illnesses. Machine learning creates data-driven models. High-dimensional, high-variance data are analyzed. Medical analysis uses supervised and unsupervised learning. Preprocessing techniques express data by using piecewise linear representation and Fourier transform. By using the sliding window, top-down, bottom-up, and other methods, time series data are segmented, but sliding window is the best method. Diminution involves feature selection and change, k-clustering, SVMs, etc. Decision trees, k-nearest neighbors, SVMs, naïve Bayes, etc. identify and classify data. Behavior detection monitors patient behavior by using CNNs or RNNs. Unsupervised learning detects abnormal values. Clustering is simpler. Patient data privacy is also vital. K anonymizes identifiable information but not attributes. L-diversity and T-closeness models reduce granularity. Many clinical uses of IoT and 5G are have been explored. IoT and 5G allow remote diagnostics. Thanks to using IoT patient data and ML graphs, medical practitioners can cooperate. Neonatology, cardiology, and skin cancer screening have been used with near-professional precision. ML may be used for supplementary diagnostics, triage, and alerts for patient vitals. Patients' histories and conditions may be used to produce exercise and food regimens. Cloud-based medical photos may be examined by ML systems to diagnose patients. IoT data, cloud sharing, and ML and AI analysis may assist in diagnosis, spot warning signals, notify emergency services, and provide remote services. This study examines IoT-assisted wearable sensor systems, AI, blockchain difficulties, and other concerns that must be addressed to improve their use in Health management system (HMS).

The study by Junaid et al. [6] aimed to explain the need for and uses of new technologies (sensor-IoT-AI-blockchain) in the healthcare sector by analyzing these technologies as well as past approaches and methodology. In the healthcare administration system, Junaid et al. [6] utilizes papers and survey research on topics such as sensors, IoT, AI, and blockchain. The majority of the data used in their study came from a network of intelligent wearable IoT devices. These devices monitor a patient's vital signs and other pertinent data and display them in real time. For instance, the LIFE Shirt is a multisensor extended HMS that collects and analyses a patient's health data. This information is obtained from the patient by means of the device. In addition to that, an AI-based data synthesis was carried out in order to provide data for testing and validation purposes. There are no well-known data sets that are available for purchase in a prepackaged manner. A smart health ecosystem that limits access to a patient's electronic health record (EHR) might be built with the use of smart contracts. As a result of this research, Junaid et al. [6] concluded that a single ledger that is maintained by healthcare stakeholders may record a patient's entitlements, and smart contracts automate information gathering and distribution and calculate benefits in real time. The acquisition and analysis of real-time patient data from hospital and home devices is facilitated by using sensing technology. It's possible that a real-time analysis may increase the accuracy of patient safety monitoring and incident prediction. When using ML, decisions are made on the basis of studying the data rather than on the basis of making intuitive assumptions. The proposed HMS is able to function by collecting data from its users via the use of smart wristbands and then feeding that information into an artificial neural network (ANN) for risk assessment. The findings of the studies demonstrate that the suggested HMS is capable of accurately assessing the health states of patients.

Ramasamy et al. [7] offered an AI-enabled combination of the Internet of Things with a cyber-physical system (IoT-CPS) for doctors to identify illnesses in patients. Human intelligence improves AI. Computers are better at arithmetic and numbers, whereas humans excel at logic and reasoning. AI might make things "thinkable." Two algorithms make up the AI-powered IoT-CPS algorithm. The first component of the algorithm generates classification rules by categorizing the training data set of patients' illnesses. The second part of the algorithm classifies patients according to their symptoms in order to make disease predictions for the disease-testing data set. The experimental findings show that the suggested AI-enabled IoT-CPS method outperforms state-of-the-art algorithms on accuracy, precision, recall, F-measure, and execution time when diagnosing patients' illnesses. Figures 1 and 2 display the IoT-CPS process.

The importance of the Internet of Things and artificial intelligence in COVID-19 was the primary focus of the research carried out by Praveen Kumar et al. in 2022 [8]. The Internet of Things was studied on a new level: how it manages the COVID-19 epidemic. In this research, long short-term memory (LSTM) with a recurrent neural network (RNN) was employed for diagnostic purposes because

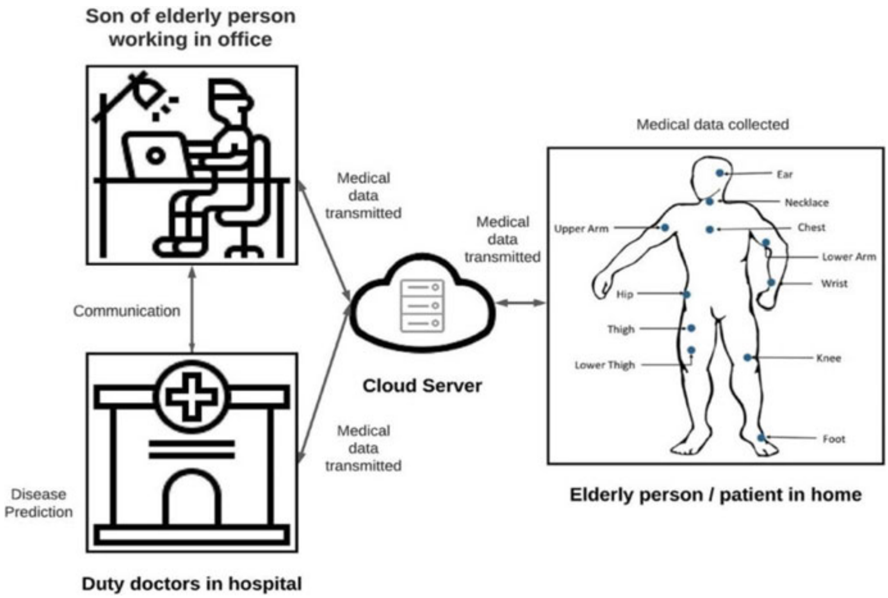

Fig. 1 IoT-CPS [7]

this architecture is particularly helpful in assessing the acoustic aspects of coughing and breathing. Real-time data on a patient's temperature and respiration levels are gathered via the use of a large number of IoT sensors.

The purpose of this chapter is to examine the use of various sensing devices to gather various types of information. The research focuses mostly on using AI systems on data sources. The major objective of this work is to gather data on the temperature and respiration rate of COVID-19 patients in real time by using a number of sensors.

Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV), Middle East Respiratory Syndrome Coronavirus (MERS-CoV), and Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) constitute serious public health hazards. These viruses risk countless lives and inflict economic damage. Recent IT and networking advances have led to IoT and AI applications in numerous sectors. The healthcare and diagnostic sectors are impacted by IoT and AI. By interfacing with smart gadgets and biometric sensors, they have expanded into telemedicine, healthcare, and disease prevention. Even though IoT and AI may improve disease diagnoses, surveillance, and quarantines, their influence is limited insofar as they aren't integrated or deployed quickly for a sudden outbreak. Conventional procedures fail to prevent large-scale illnesses and halt worldwide outbreaks via prediction, resulting in many deaths. Sungho Sim et al. [9] proposed a combined Internet of medical Things and AI (IoMT-AI) framework model to handle COVID-19 outbreaks. IoMT uses (1) remote monitoring, (2) prescriptions tracking, and (3) biometric sensors to provide health data to doctors. Image signal processing and

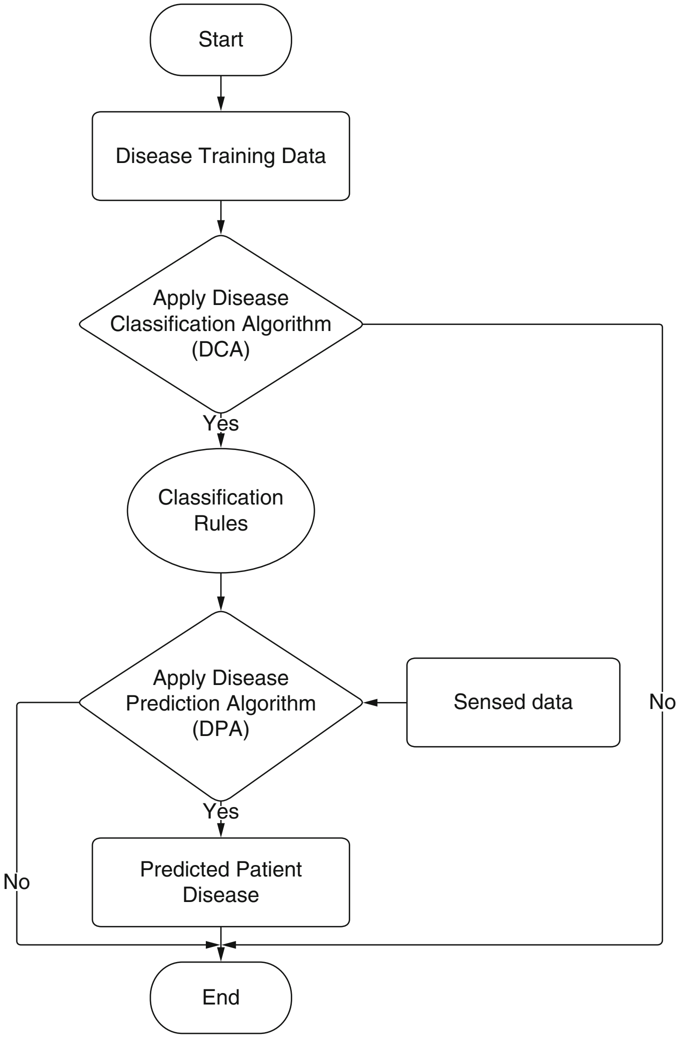

Fig. 2 Flowchart of an AI-enabled IoT-CPS [7]

virus infection detection using AI can carry out disease surveillance, risk prediction, medical diagnosis and screening, curative research, virus modeling and analysis, and the management of lockdown measures, as shown in Fig. 3 (Table 1).

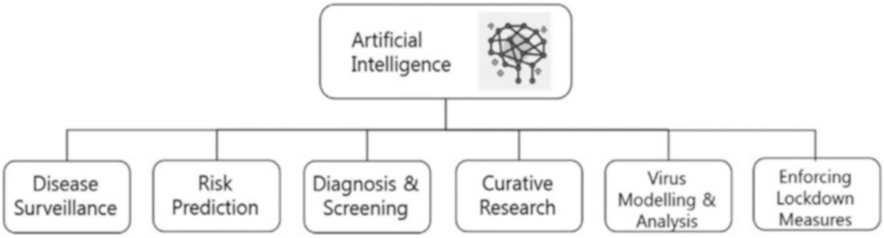

Fig. 3 Applications of AI in medical IoT [10]

2.2 Sustainability

Internet of things (IoT) makes it possible to digitalize a wide variety of tasks and procedures, including the distribution of water, preventive maintenance, and smart manufacturing. Although IoT technologies and ideas such as edge computing hold a great deal of potential for the digital transition to sustainability, they are not yet making contributions to the sustainable development of the IoT industry. This sector has a significant carbon footprint because it makes use of a limited supply of raw materials and a significant amount of energy in its production, operation, and recycling processes. However, its sustainable vision collides with edge artificial intelligence (edge AI), which demands more energy, which is why the green Internet of Things (GIoT) paradigm has emerged as a study topic to reduce carbon footprints. In article [11, 12], the authors investigate the process of designing and developing edge-AI GIoT systems. The concepts discussed in the paper are highlighted by using a real-world example of an Industry 5.0 application case. To enhance operator safety and operation tracking, a smart Industry 5.0 workshop should be held. This application takes advantage of an IoT mist architecture that is equipped with AI. After the application situation has been explained, the energy consumption and carbon footprint of the application are analyzed. This article offers guidelines for aspiring developers who want to design edge-AI GIoT systems using the aforementioned technologies (Table 2).

2.3 Information Security

The Internet of Things (IoT) has altered how humans live and has permeated all facets of human life, but it has also given rise to worries over data security, which in turn have led to a variety of technical ethical and security difficulties. For the information security of a company, these problems often center on the demand to obtain user data and maintain privacy when the IoT is deployed. This requirement becomes more sensitive when discussing the security of corporate information. The

Table 1 Recent works on IoT and AI in healthcare

Paper	Authors and year	Methodology	Data set	Advantages	Limitations/future scope
[1]	Rahman et al., 2022	This integrates the FL-AI into healthcare technologies and classifies them.	Arrhythmia database [13, 14] of ECG signals from the PTB-XL data set [15, 16]	Federated learning has more benefits than traditional machine-learning approaches do. Data security keeps locally training data on devices, so a data pool is not required. It contains heterogeneous data because it uses data from different users. Real-time continual learning is enabled by models that are continuously improved with client data. Hardware efficiency is improved by using less-complex hardware; federated learning does not need one complex central server for analysis.	The whole procedure runs over the Internet, so privacy and security are always major concerns in this field, especially in competent healthcare systems.

[3]	M. M. Kamruzzaman et al., 2022	This employs a systematic review of 425 articles between 2016 and 2021, using AMSTAR tools.	Multiple data sets [3]	Pros of healthcare AI and IoMT with smart cites include the following: (1) It will minimize processing delays and data traffic for essential analysis and patient monitoring. (2) Implementing a hierarchical edge-based computing system enables scalability, low latency, and the fortification of training model data, allowing researchers to evaluate COVID-19 with a reliable local edge server. (3) The SEG 3.0 strategy, which integrates, associates, and enables semantic interoperability, may be used everywhere in smart cities to enhance heterogeneous data.	Edge AI presents security and computational complexity problems.

(continued)

Table 1 (continued)

Paper	Authors and year	Methodology	Data set	Advantages	Limitations/future scope
[2]	T. Montanaro et al., 2022	This improves the precision and reliability of IoT in healthcare by using ultrathin, skin-compatible, flexible, high-precision piezoelectric sensors, low-cost communication technologies, on-device intelligence, edge intelligence, and edge computing.	ECG5000 [17, 18]	Some health conditions, such as a heart failure, are time critical, yet cloud-based solutions are slower. Onboard devices are quick and have minimal latency. The approach fosters hybrid solutions that combine advanced sensor technology with low-cost, low-power IoT technologies, and AI. Onboard intelligence further reduces latency.	The reliability of IoT devices and sensors can be further improved, and by using blockchain technologies, we can provide additional security and privacy to users.

[5]	Zhao-xia Lu et al., 2021	This summarizes AI and IoT in clinical care, analyses obstacles, and discusses current and potential advancements.	GHWA/WHO; Nursing Report 2020 [19, 20]; World Population Prospects 2019 [21, 22]; Tang X. data set [23, 24]	(1) Integrating AI with IoT gives IoT greater intelligence and is being utilized to improve health care. Remote diagnostic and treatment cooperation may advance service parity. Combined with medical IoT, real-time vital sign data may be acquired and utilized to detect when NICU and CCU patients are in early danger. (2) AI and IoT can deliver speedy and accurate diagnoses and treatments for emergency care, buying rescue time and opening the green life channel. (3) The early identification of high-risk VTE patients and appropriate management may minimize VTE incidence and enhance patient quality of life.	(1) The security of IoT devices is a concern. Because there are so many interconnected devices, one compromised device can compromise many others. (2) IoT devices lack standards. They are still new, and there are numerous vendors, each of which has a different standards and structures for data. (3) AI models focus on particular diseases, such as cancer or skin disease. Medical diagnoses sometimes need to have the entire picture because one part can affect another. (4) Medical ethics are concerning to some people. Patients have difficulty accepting diagnoses made by computers.

(continued)

Table 1 (continued)

Paper	Authors and year	Methodology	Data set	Advantages	Limitations/future scope
[6]	Junaid et al., 2022	This proposes an HMS that uses user-provided data gathered from connected smart wristbands to anticipate health status hazards by using an ANN. The experimental findings demonstrate the utility of the suggested HMS for assessing health conditions in humans.	Health data from wearable IoT devices [6]	Smart contract promotes restricted access to the patient's confidential medical data. Real-time analysis may improve patient safety monitoring and incident prediction accuracy. With ML, decision-making is based on data analysis rather than intuition.	The scarcity of cost-effective and accurate smart medical sensors, unstandardized IoT system architectures, the heterogeneity of linked wearable devices, multidimensional data, and interoperability are difficulties. Privacy and ethical difficulties and the lack of a legal framework to enable smart contracts are open research challenges in this sector. Healthcare data are diverse, incomplete, and ambiguous. Training an ML model with that much data is difficult.

[7]	Ramasamy et al., 2022	This proposes cyber-physical systems (CPSs). The smart device is programmed to help elderly people in emergencies. The sensors collect data from various parts/joints of the subject and process that data to draw conclusions.	Kaggle data set	(1) The experimental findings show that the suggested AI-enabled IoT-CPS method outperformed the state-of-the-art algorithms on accuracy, precision, recall, F-measure, and execution time when diagnosing patients' illnesses. (2) The accuracy when using IoT + CPS is the highest when compared to all the other techniques, i.e., naïve Bayes, SVMs, KNN, and ANN. Comparisons between accuracy and F-measure are as follows: naïve Bayes—83.5% (F-measure—83.8%), SVM—83.9% (F-measure—83.7%), KNN—75.0% (F-measure—75.7%), ANN—78.9% (F-measure—78.2%), and AI-enabled IoT-CPS—85.1% (F-measure - 86.4%).	(1) Disease propagation and contagiousness can be determined by mobile phone location, as a future scope. (2) Data encryption was not considered while writing this paper, but because health and condition data are personal, leaking it may embarrass individuals or swamp them with spam calls about treatments and drugs. (3) The large amount of information on IoT and CPS devices makes them targets for fraudsters, other criminals, and unethical users.

(continued)

Table 1 (continued)

Paper	Authors and year	Methodology	Data set	Advantages	Limitations/future scope
[8]	Praveen Kumar et al., 2022	This uses long short-term memory (LSTM) with a recurrent neural network (RNN) for the diagnosis of COVID-19 and collects data from IoT sensors.	Coughing and respiratory samples and thermal and breathing levels, obtained from various IoT devices [8]	The proposed approach shows the following: (1) IoT manages risky patients so that conditions such as hyperglycemia, pulse rate, and heart infections may be diagnosed. (2) IoT is inventive and powerful at fighting COVID-19 and can be used for strengthening patient data.	Taking evolutionary approaches may solve the problems of interference and complexity in migrating data. Prediction isn't perfect. Electronic enforcement, which incorporates secrecy and trust, is another difficulty.
[9]	Sungho Sim et al., 2021	This proposes a framework where IoMT handles monitoring the patient from a remote location and tracking medication prescriptions by using biometric sensors. And AI/ML handles image signal processing and virus infection detection by using AI.	WHO [25, 26]	While research on AI and IoT for health services has advanced, cost-effective and inexpensive smart healthcare services have received little attention. AI-driven IoT (AIIoT) for smart healthcare could change many facets of healthcare, but several technological hurdles must first be overcome.	Future research on a model for an international integrated viral defense system might build on existing analyses and make use of already-acquired data. To this end, it is important to collect detailed information on viral outbreaks on a global scale and in a timely fashion in order to create a system for the prevention of viral illness transmission and prevalence and for early warning signs.

Table 2 Recent works on IoT and AI for sustainability

	Authors and year	Methodology	Data set	Evaluation parameter	Advantages	Limitations/future scope
[11]	Paula Fraga-Lamas et al., 2021	This proposes an edge-AI GIoT system that improves operator safety and operation tracking.	Visual Wake Words Dataset, CIFAR-10, Google Speech Commands, and ToyADMOS (ToyCar)	Accuracy Visual Wake Words Dataset—80%, CIFAR-10—85%, Google Speech Commands—90%, and ToyADMOS(ToyCar)—85%	(1) Data may be captured and processed on the same device, reducing network connection difficulties. (2) When processing is carried out locally, all communication-related delays are eliminated, resulting in a latency that converges to the inference latency. (3) Reduced communication between IoT edge devices and the cloud reduces the risk of data loss, theft, or leakage. (4) Reducing IoT edge device connectivity with the cloud decreases bandwidth demands and costs, thus improving bandwidth efficiency.	Network, physical, software, and encryption threats require more protection. On-device learning must be protected against intrusions. The IoT industry is fragmented, so a fully standardized framework is needed to address edge-AI GIoT needs. Future developers must address how edge-AI GIoT devices affect CO_2 emissions. Such expansion varies from nation to nation depending on their available energy.

development of AI-based security solutions for IoT sensor networks has been a recent trend.

In [27, 28], the authors built a platform for the administration of information security that was comprised of four parts: the management of IoT data mining, management of equipment, management of keys, and management of databases. Testing for concurrency, stress, high data volume, and security were improved, together with the original architecture for physical security, which was also reorganized.

The purposes of this chapter are to provide some fresh suggestions for applying information security technology to IoT-based corporate management and to advocate for the use of IoT in industrial and commercial management in the near future. The following features are included in the functionality of the platform: authorization and revocation, staff scheduling, data storage and backup, rank role administration, and data encryption and mining (Table 3).

2.4 Education

In most cases, the services and administrations that rely on traditional libraries cannot function without them. A reader must follow a multistep procedure to borrow books, which includes entering a library to preserve books of interest, bringing books to a certain spot (i.e., the circulation desk), showing the librarian their identity for verification, and lastly confirming the books to borrow. The many occurrences of the targeted books being borrowed by others throughout the preceding method make it difficult to ignore them. If a reader doesn't know in advance which branch has the books they're looking for, they'll have to make many trips to different libraries. However, in the era of the "smart library," obtaining books requires only a few steps via a smart terminal device: confirm and make an appointment for the intended books and fetch the books under the smart guide and devices furnished by the library. This is the optimal schedule for the borrowing process. Thanks to the immense potential of AI and IoT, library circulation efficiency has greatly improved over more-conventional approaches.

One study [29] conducted an extensive literature review on the use of AI and IoT technologies in proposed future smart libraries in order to formally offer a systematic, organized, and comprehensive strategy for such a possible topic. When compared to librarianship that relies on only human effort, the smart library model, which incorporates AI and IoT, provides far superior service, as seen in the aforementioned smart circulation service. Smart service, smart sustainability, and smart security are the three primary foci of the author efforts. There is a wide variety of use cases for AI and IoT in a smart library. According to the findings of [29, 30], its authors have formally described the development of the smart library (Fig. 4).

Machine-learning and deep-learning techniques, including natural language preprocessing, deep-learning models, recurrent neural networks, and deep-learning-based recommendation systems, have been used throughout this study.

Table 3 Recent works on IoT and AI for information security

	Authors and year	Methodology	Data set	Evaluation parameter	Advantages	Limitations/future scope
[27, 28]	Hongbin Sun et al., 2022	With the current state of global informatization as a backdrop, this work is being carried out to maintain the information security of enterprises and provide modern upgrading means for enterprise management; to popularize cutting-edge IoT management technology for enterprises; and to address issues of information security in enterprise management.	The authors gathered 1000 groups of user data to create a data set, of which 800 groups were used for training and 200 for testing.	The response time of the system is measured according to four aspects: (1) concurrency testing: 0.136 s (information input); (2) stress testing: 0.137 s (event entry); (3) large data volume testing: 0.126 s (gap analysis); and (4) security testing: 0.124 s (gap analysis).	The proposed management system for IoT information security has outperformed other systems. The average response time to an event is less than 0.25 seconds; CPU consumption does not exceed 20%; and the memory requirements are not excessive. Thus, this product improves business information security management.	Limitations: (1) Different sectors' information security demands aren't considered. (2) The existing management platform is memory-intensive. Future scope: (1) It should address the information security demands of diverse sectors. (2) It should gather more corporate information security data and enhance the memory algorithm.

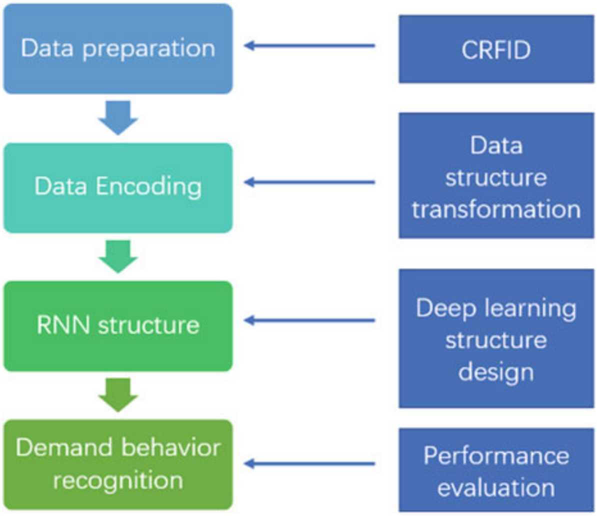

Fig. 4 The workflow of the personalized activity-learning system [31]

Using IoT with the help of artificial intelligence may significantly lessen the likelihood that sensitive data or valuables will be compromised. A new authentication system is being suggested to ensure the anonymity of readers. IoT and AI can work together to create a sustainable timetable that takes into account real-world requirements. The article proposes many AI-assisted IoT methods for controlling the library's lighting in order to maximize the efficiency of its use of natural light (Table 4).

2.5 Pollution Monitoring (Table 5)

2.6 Robotics (Table 6)

2.7 Other Related Works

Apart from the above-mentioned domain, Several papers have been identified that are relevant to the theme. Gültekin et al. [32] presented a deep learning approach based on multisensory data fusion for fault diagnosis in an industrial autonomous transfer vehicle. They focused on real-time fault detection and condition monitoring using edge artificial intelligence for industrial autonomous transfer vehicles [33]. Malik et al. [34] discussed the latest trends in the design and application of smart antennas. Rogers and Malik [25] explored the opportunities and challenges of planar and printed antennas for IoT-enabled environments. Abdul Rahim and Praveen Kumar Malik [36] analyzed and designed a fractal antenna for efficient communica-

Table 4 Recent works on IoT and AI for education

	Authors and year	Methodology	Advantages	Limitations/future scope
[29]	Siguo Bi et al., 2022	This tries to solve the problems with traditional libraries by (1) providing a consistent definition of smart libraries; (2) surveying IoT technology in use; (3) using AI to enhance IoT devices and user experiences; (4) comparing CRFID with mobile IoT technology; (5) comparing AI technologies, including deep learning, OCR, recommender systems, and KNN and SVMs; and (6) separating smart libraries according to their services, sustainability, and security. Thus, better and more-specific solutions may be built for each phase of the library book-borrowing process. to improve customer experiences.	AI-assisted IoT reduces the danger of exposing private information and objects. Novel authentications can preserve readers' privacy. IoT and AI can arrange sustainability on the basis of practical demands. AI-assisted IoT solutions are offered to regulate light shading in libraries to enhance natural light consumption.	Smart libraries have advanced AI-assisted IoT, but there remains room for growth. The performance values of smart services for cutting-edge recommendation-based situations, such as accuracy and recall, are low. When combined with IoT, strong natural language processing (NLP) technologies such as bidirectional encoder representations from transformers (BERT) and graph-based neural networks with side information improvement might power upstream or downstream data processing. Existing smart security systems deal with homogenous data from sensors such as radio-frequency identification (RFID) sensors. With the diversity of smart library situations, processing heterogeneous data from multipurpose sensors such as RFID, near-field communication (NFC), Bluetooth, and infrared sensors, among others, might be challenging.

Table 5 Recent works on IoT and AI for pollution control

	Authors and year	Methodology	Data set	Evaluation parameter	Advantages	Limitations/future scope
[37]	Chao-Tung Yang et al., 2021	This proposes a conceptual PM AIIoT framework that includes an approach for low-cost sensing technologies. IoT sensors and IoT industrial environmental quality sensors should follow a protocol.	PM 2.5 data set [37]	R2 compares each sensor's performance in FRM/FEM. R2 demonstrates near-perfect consistency around 1; near 0 shows no relationship. The Kaiterra/LE200 model used in plan tower sensor and reference instrument correlated well (R2 = 0.98). ITRI calibrates plan tower sensors by providing the most accurate and reliable data, according to the best-performing tester.	The paper examines the integration of AI and IoT (AIIoT) into PM monitoring, indoor air-quality management, and future advances. It summarizes existing PM monitoring approaches, including the use of sensors for data collecting. Light scattering theory is followed to characterize most low-cost PM AIIoT sensors.	AI for PM monitoring should combine current air control infrastructure with satellite data to produce an accurate estimate of air quality. AI in PM monitoring can identify air pollution from garbage burning, transportation, manufacturing, resource distribution, and population density. This needs an AI that can geospatially interpret air-quality data.

Table 6 Recent works on IoT and AI for robotics

	Authors and year	Methodology	Data set	Advantages	Limitations/future scope
[38]	Katy Borner et al., 2020	Many research articles have analyzed how AI, robotics, and IoT are utilized in research and how frequently they come together (be it two at a time or all three of them). Emergent ideas should display originality, persistence, and accelerated expansion, should establish a research community, according to the four-attribute model of technological emergence: burst detection and visualization, top organizations and funding, scientific mapping and classification systems, and coauthor networks.	WOS publications and NSF awards	Because AI, IoT, and robots have been converging, we should expect the border between hardware and software to blur much more rapidly than we had previously anticipated. The combined potential for innovation across all fields bodes well for the progress of humanity and the quality of its future.	Some of the current research in these areas is undertaken by military agencies, making it difficult to collect its results in public databases. Only 1998–2017 WOS publications and NSF grants were analyzed. As a part of future scope, authors may want to study more data sets, such as studying the federal business opportunities (FBO) database to further understand financing for sales and trading.

tion networks in vehicular models. Shaik and Malik [39] conducted a comprehensive survey on 5G wireless communication systems, addressing open issues, research challenges, channel estimation, multi-carrier modulation, and applications. Malik, Wadhwa, and Khinda [40] conducted a survey on device-to-device and cooperative communication for future cellular networks. Tiwari and Malik [41] focused on wideband microstrip antenna design for higher "X" band frequencies. Kaur and Malik [42] presented a study on multiband elliptical patch fractal and defected ground structures microstrip patch antennas for wireless applications. Shaik and Malik [43] retrospectively analyzed channel estimation techniques for 5G wireless communications. Finally, Malik and Singh [44] proposed a multiple bandwidth design of a microstrip antenna for future wireless communication. These papers collectively contribute to the understanding and application of IoT and AI in various domains.

3 Conclusion and Future Directions

IoT and AI have offered wonderful opportunities for organizations to enhance efficiency, visibility, and profitability. AI and IoT are altering our world. More companies than ever are making use of IoT. ML, AI, rapid feedback, and remote monitoring are here and not slowing down. Businesses that embrace the IoT revolution early avail themselves of several possibilities. The intention of this work is to present various new future directions in the field of AI and IoT by exploring their applications in various domains, such as healthcare, education, sustainability, robotics, pollution control, and much more. Every application of AI and IoT has unique advantages and disadvantages. But security and privacy concerns are the most common shortcomings emerging as open challenges. These will be stepping stones for future research. More real-time case studies are needed in order to measure the real-time effects of AI-assisted IoT on the environment.

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