Internet of Things

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Artificial Intelligence-based Internet of Things Systems

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Internet of Things

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Preface

This book aims to bring together leading academic scientists, researchers, and research scholars to exchange and share their experiences and research results on all aspects of Internet of Things (IoT)-enabled artificial intelligence-based technologies. It also provides a premier interdisciplinary platform for researchers, practitioners, and educators to present and discuss the most recent innovations, trends, and concerns as well as practical challenges encountered and solutions adopted in the fields of AI-based IoT. This book aims to attract researchers and practitioners who are working in information technology and computer science. This book is about basics and high-level concepts regarding artificial intelligence paradigm in the context of Internet of Things. This book covers a wide range of AI-enabled IoT technologies. This book aims to explore the insight paradigm of the AI-based IoT technologies which will bring a smooth platform for the scope of industry-academia. The wide-range contents will differentiate this edited book from others. The contents include functional framework and protocols for IoT-based system, intelligent object identification, intelligent sensors, learning and analytics in intelligent IoT-enabled systems, CRISP-DM frame work, RFID technology, wearable sensors, IoT semantics, knowledge extraction, applications of linear regression, classification, vector machines and artificial neural networks for IoT devices, Bayesian learning, decision trees, deep learning frameworks, computational learning theory, multi-agent systems for IoT-based ecosystem, machine learning algorithms, nature-inspired algorithms, computational intelligence for cloud-based Internet of Things, and trustworthy machine learning for IoT-enabled system in IoT related topics. The above topics are likely to be embedded with the AI-enabled IoT technologies for future generation automation.

Chapter 1 explores IoT architecture; analyzes IoT network's technical details; and describes communication enabled technologies. Moreover, this chapter deals with various AI-based technologies integrated into IoT, edge computing, and trust models for IoT appliances. Recent AI-based projects and research challenges concludes this chapter.

Chapter 2 has formulated an overview of the IoT environment which illustrates IoT architecture, gateways, nodes, middleware, OSs, framework, protection, storage and computation, communication or networking technologies of IoT, and interfaces for the efficient utilization of data in an ecosystem. This chapter moreover illustrates the hierarchy of the intelligence of the IoT ecosystem, which describes the process of generation of data, derivation of desired information from those raw data, processing, and manipulation.

Chapter 3 illustrates a detailed view of ML and DL applicability in WSN and IoT. This chapter also describes a complete view of various neural networks (NN) and support vector machine (SVM) types that incorporate frequent, deep neural networks, quarter and ellipsoidal SVMs, and subspace-SVM forms, which are relevant to wireless and IoT appliances. This chapter provides an in-depth summary of various communication issues in IoT that are addressed by neural networks and SVM, and application and motivation for using those techniques. Followed by intrusion detection in IoT with NN and SVM, a case study on outlier detection WSNs data and future research implementations is discussed.

Chapter 4 evaluates the different methods of machine learning that deal with the challenges posed in the handling of IoT data. Big data is generated through the communication of Internet of Things/smart devices, and this data stored at cloud. The taxonomy of machine learning algorithms is described in this chapter, explaining how different techniques are applied to data generated using IoT devices. It will also address the future problems of machine learning for IoT data analytics.

Chapter 5 aims to explore DL frameworks for IoT. The chapter begins with a discussion on the development and architecture of the DL framework. This chapter then discusses about various DL models associated with deep reinforcement learning approaches for IoT. The potential applications, including smart grid management, road traffic management, industrial sector, estimation of crop production, and detection of various plant diseases are discussed. Various design issues and challenges in implementing DL are also discussed. The findings reported in this chapter provide some insights into DL frameworks for IoT that can help network researchers and engineers to contribute further towards the development of next-generation IoT.

Chapter 6 addresses the technique that combines the capability to learn and evolve solutions for large-scale dynamic systems. The chapter deals with the extended classifier system (XCS) which is an amalgamation of reinforcement learning (RL) and genetic algorithms (GA). While RL learns the model-free problem environment, the nature-inspired GA evolves better decision-making rules and improves the existing ones. The motive is to provide intelligent computation for fog-cloud-based IoT systems through XCS. The chapter reveals how the XCS algorithm estimates the optimal number of IoT workload that is to be processed in fog, the remaining of which is transferred to the cloud. The optimal number of workloads estimated by the XCS algorithm balances the energy cost and delay in the fog-cloud based resource allocation (RA) system.

Chapter 7 integrates machine learning and IoT in a portable scale to perform high-accuracy verification system. This model uses a pre-trained convolutional neural network (CNN) on a Raspberry Pi. The CNN will analyze pixels from a signature image taken by the Pi camera to recognize abnormalities and differences and to identify false signature. Other than requiring a secure digital authentication to operate, it also informs the user immediately on the app execution and image being scanned via a cloud-based system. The system is expected to provide on-the-spot signature verification and minimize any logistic issue that stems from faulty signature to an organization**.**

Chapter 8 illustrates the facilitators of Internet of Things like machine to machine (M2M), radio frequency identification (RFID), and software-defined networking (SDN). Machine to machine (M2M) is a communication system in IoT that endorses the group of devices to communicate with each other. The mobile communication system is optimized by M2M and standardized by 3GPP. The motivation of this chapter is that the communication system facilitated with IoT has performed their actions autonomously without the assistance of a human.

Chapter 9 discusses different types of framework, pros and cons of every framework, architecture, and different criteria to choose the better framework which will be useful for Internet of Things–based applications. Moreover, this chapter discusses architecture, generative models, and deep reinforcement learning for IoT applications.

Chapter 10 presents the active ongoing research in optimizing deep learning models for inference at the edge using connection-pruning, model quantization, and knowledge distillation. This chapter describes the techniques to train/retrain the deep learning models at the resource-constrained edge device using new learning paradigms such as federated learning, weight imprinting, and training smaller models on fewer data.

Chapter 11 presents a survey of techniques that have been introduced to exploit the pros and mitigate the cons of NVMs when used for designing IoT systems. This chapter classifies these techniques along several dimensions to highlight their similarities and differences. Keeping consideration that NVMs are rapidly growing in IoT systems, this chapter will encourage and motivate further researcher and scientists in the field of software technology for NVMs-based IoT.

Chapter 12 describes the digital abstraction of the physical aspects of a city using digital twin to simulate scenarios to understand behaviors of a particular event. This study analyzes the use of artificial intelligence techniques and IoT used in digital twin approaches to analyze cyber security risks in the smart city environment.

Chapter 13 discusses Cognitive Internet of Things (CIoT) which inherited numerous challenges from artificial intelligence, IoT, and cognitive systems. Therefore, the challenges of these fields should be studied to extract the challenges in designing CIoT. In the literature, there is no study on extracting the challenges considering associated technologies to CIoT. In this chapter, the challenges of the associated technologies are summarized. Then, some important challenges in designing CIoT are obtained.

Chapter 14 uses reinforcement learning techniques to find patterns of user dynamics and to determine the incentive prices. Specifically, the authors adapt the state-of-the-art reinforcement learning framework for dock-less BSS rebalancing. Different from existing research, the authors make full use of the benefits of destination incentives. In addition, they further extend the reinforcement learning framework to docked BSSs by adding station capacities to the state space of the reinforcement learning agent. They have examined the performance of our schemes based on real-world datasets. An experiment result reveals that the hybrid incentive scheme outperforms the source-incentive-only scheme.

Chapter 15 discusses vital applications of IoT and Bayesian learning to the monitoring, messaging, and accident analysis on highways. The chapter adopts the case approach in presenting advances in IoT and cloud technologies and builds a concept around a scenario to demonstrate real-life applications and contextual relevance of Bayesian learning models.

Chapter 16 discusses the processes, challenges, and solutions concerning designing an airport smart parking system. IoT parking sensors, Open Automatic License Plate Recognition (OpenALPR) library, and the IBM cloud-based IoT platform are integrated to tackle technical challenges, including the automatic identification of plate numbers, models, and colors of vehicles in parking spaces, in both indoor and outdoor parking environments. The chapter also addresses several issues related to the system, that is, the system architecture design, the selection of sensing technologies, and hardware and software platforms, while taking into account specific characteristics of IoT and AI technologies.

Chapter 17 presents an overview of research on using end-to-end deep learning technologies for computer vision-based autonomous driving systems. It briefly discusses the ethics of autonomous driving; it also describes autonomous driving paradigms and the associated deep learning methodologies. Furthermore, it proposes an IoAT-compatible low-cost, low-latency, high-accuracy, and high-reliability CNN-LSTM based autonomous driving model that incorporates temporal information, transfer learning, and navigational command. It also provides a detailed analysis against existing models. Finally, the chapter draws its conclusions and discusses future research directions to further improve system performance.

In Chap. 18, the Bayesian learning and decision trees are presented in respect of their ability to entrench optimum intelligent prediction in IoT-enabled domain. Succinct elucidation of the potential application of an intelligent IoT-driven system is presented as a possible panacea to address some of the problems in food production cycle especially in post-harvest storage and wastage.

We are sincerely thankful to the Almighty for supporting and standing by us at all times, through thick and thin, and guiding us. Starting from the call for chapters till the finalization of chapters, all the editors have given their contributions amicably, which is a positive sign of significant teamwork. The editors are sincerely thankful to the series editors Prof. Giancarlo Fortino and Prof. Antonio Liotta for providing constructive inputs and allowing an opportunity to edit this important book. We are thankful to reviewers around the world who shared their support and stood firm toward quality chapter submission.

Kolkata, West Bengal, India — Souvik Pal
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Key Features

1. Addresses the complete functional framework workflow in AI-enabled IoT ecosystem.
2. Explores basic and high-level concepts, thus serving as a manual for those in the industry while also helping the beginners to understand both basic and advanced aspects in AI-enabled IoT ecosystem related technology.
3. Based on the latest technologies, and covering the major challenges, issues, and advances in AI-based IoT environment.
4. Explores intelligent object identification and object discovery through IoT ecosystem and its implications to the real world.
5. Explains concepts of IoT communication protocols, intelligent sensors, statistics and exploratory data analytics, nature-inspired algorithms, computational intelligence, and machine learning algorithms in IoT environment for betterment of the smarter humanity.
6. Explores intelligent data processing, deep learning frameworks, game theory, and multi-agent systems in IoT-enabled ecosystem.
7. Explores vector machines and artificial neural networks for IoT devices, and big data analytics in IoT-based environment.
8. Explores security and privacy issues and trustworthy machine learning related to data-intensive technologies in AI-based IoT ecosystem.

About the Book

The edited book *Artificial Intelligence-based Internet of Things Systems* is intended to discuss the evolution of future generation technologies through Internet of Things in the scope of artificial intelligence. The main focus of this volume is to bring all the related technologies in a single platform, so that undergraduate and postgraduate students, researchers, academicians, and industry people can easily understand the AI algorithms, machine learning algorithms, and learning analytics in IoT-enabled technologies.

This book uses data and network engineering and intelligent decision support system-by-design principles to design a reliable AI-enabled IoT ecosystem and to implement cyber-physical pervasive infrastructure solutions. This book will take the readers on a journey that begins with understanding the insight paradigm of AI-enabled IoT technologies and how it can be applied in various aspects. This proposed book will help researchers and practitioners to understand the design architecture and AI algorithms through IoT and the state-of-the-art in IoT countermeasures.

It provides a comprehensive discussion on functional framework and knowledge hierarchy for IoT, object identification, intelligent sensors, learning and analytics in intelligent IoT-enabled systems, CRISP-DM frame work, RFID technology, wearable sensors, IoT semantics, knowledge extraction, applications of linear regression, classification, vector machines and artificial neural networks for IoT devices, Bayesian learning, decision trees, deep learning frameworks, computational learning theory, multi-agent systems for IoT-based ecosystem, machine learning algorithms, nature-inspired algorithms, computational intelligence for cloud-based Internet of Things, and trustworthy machine learning for IoT-enabled systems. This book brings together some of the top IoT-enabled AI experts throughout the world who contribute their knowledge regarding different IoT-based technology aspects. This edited book aims to provide the concepts of related technologies and novel findings of the researchers through its chapter organization. The book explores AI-enabled IoT paradigms which will be utilized as a part of betterment of mankind in the future era. Specifically, the far-reaching references of various works and executions will be observed to be significant accumulations for engineers and organizations. The primary audience for the book incorporates specialists, researchers, graduate understudies, designers, experts, and engineers who are occupied with research on Internet of Things, artificial intelligence, machine learning, and applications.

Contents

About the Editors

Souvik Pal is an associate professor in the Department of Computer Science and Engineering at Sister Nivedita University (Techno India Group), Kolkata, India. Prior to that, he was associated with Global Institute of Management and Technology; Brainware University, Kolkata; JIS College of Engineering, Nadia; Elitte College of Engineering, Kolkata; and Nalanda Institute of Technology, Bhubaneswar, India. Dr. Pal received his MTech and PhD degrees in the field of computer science and engineering from KIIT University, Bhubaneswar, India. He has more than a decade of academic experience. He is author or co-editor of more than 15 books from reputed publishers, including Elsevier, Springer, CRC Press, and Wiley, and he holds 3 patents. He is serving as a series editor for Advances in Learning Analytics for Intelligent Cloud-IoT Systems, published by Scrivener-Wiley Publishing (Scopus-indexed); Internet of Things: Data-Centric Intelligent Computing, Informatics, and Communication, published by CRC Press, Taylor & Francis Group, USA; Conference Proceedings Series on Intelligent Systems, Data Engineering, and Optimization, published by CRC Press, Taylor & Francis Group, USA. Dr. Pal has published a number of research papers in Scopus/SCI/SCIE Journals and conferences. He is the organizing chair of RICE 2019, Vietnam; RICE 2020 Vietnam; ICICIT 2019, Tunisia. He has been invited as a keynote speaker at ICICCT 2019, Turkey; ICTIDS 2019, 2021 Malaysia; and ICWSNUCA 2021, India. His professional activities include roles as associate editor and editorial board member for more than 100+ international journals and conferences of high repute and impact. His research area includes cloud computing, big data, internet of things, wireless sensor network, and data analytics. He is a member of many professional organizations, including MIEEE; MCSI; MCSTA/ACM, USA; MIAENG, Hong Kong; MIRED, USA; MACEEE, New Delhi; MIACSIT, Singapore; and MAASCIT, USA.

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Rajkumar Buyya is a Redmond Barry Distinguished Professor and director of the Cloud Computing and Distributed Systems (CLOUDS) Laboratory at the University of Melbourne, Australia. He is also serving as the founding CEO of Manjrasoft, a spin-off company of the University, commercializing its innovations in cloud computing. He served as a Future Fellow of the Australian Research Council during 2012–2016. He has authored over 625 publications and 7 textbooks including *Mastering Cloud Computing* published by McGraw Hill, China Machine Press, and Morgan Kaufmann for Indian, Chinese, and international markets, respectively. He also edited several books including *Cloud Computing: Principles and Paradigms* (Wiley Press, USA, Feb 2011). He is one of the highly cited authors in computer science and software engineering worldwide (h-index = 132, g-index = 294, 92,500+ citations). "A Scientometric Analysis of Cloud Computing Literature" by German scientists ranked Dr. Buyya as the World's Top-Cited (#1) Author and the World's Most-Productive (#1) Author in Cloud Computing. Dr. Buyya is recognized as a "Web of Science Highly Cited Researcher" for 4 consecutive years since 2016, a fellow of IEEE, and Scopus Researcher of the Year 2017 with Excellence in Innovative Research Award by Elsevier, and he has recently (2019) received "Lifetime Achievement Awards" from two Indian universities for his outstanding contributions to cloud computing and distributed systems.Software technologies for grid and cloud computing developed under Dr. Buyya's leadership have gained rapid acceptance and are in use at several academic institutions and commercial enterprises in 40 countries around the world. Dr. Buyya has led the establishment and development of key community activities, including serving as foundation chair of the IEEE Technical Committee on Scalable Computing and five IEEE/ACM conferences. These contributions and international research leadership of Dr. Buyya are recognized through the award of "2009 IEEE Medal for Excellence in Scalable Computing" by the IEEE Computer Society TCSC. Manjrasoft's Aneka Cloud technology developed under his leadership has received "2010 Frost & Sullivan New Product Innovation Award." Recently, Dr. Buyya received "Mahatma Gandhi

Award" along with gold medals for his outstanding and extraordinary achievements in the field of information technology and services rendered to promote greater friendship and cooperation between India and the world. He served as the founding editor-in-chief of the *IEEE Transactions on Cloud Computing*. He is currently serving as co-editor-in-chief of the journal *Software: Practice and Experience*, which was established 50 years ago. For further information on Dr. Buyya, please visit his cyberhome: www.buyya.com

Part I
Architecture, Systems, and Services

Artificial Intelligence-based Internet of Things for Industry 5.0

Bhanu Chander, Souvik Pal, Debashis De, and Rajkumar Buyya

1 Introduction

Nowadays, wireless communications, IoT devices, intelligent sensors, industrial IoT, mobile edge computing, and communication protocol are the buzz words in industry-academia. In general, IoT works through implanting short-range moveable transceivers into an eclectic arrangement of devices and everyday objects, enabling novel communication procedures among people and things and things themselves. Therefore, IoT would add a new dimension to information and communication. IoT devices are interconnected devices through a piece of inventive communication machinery such as RFID, Wi-Fi, GSM, Bluetooth, and many more, which can help improve people's living standards [1–4]. The latest survey reports that the number of IoT devices like embedded devices, sensors, game consoles, laptops, and smart devices anticipated to reach more than 60 billion in 2025. In general, IoT expertise's evolution is very similar to the current society, where people and devices practically

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integrated into information systems over wireless sensors technology. IoT integration's main intention is information sharing, enabling smart surroundings to identify objects then retrieve information. Embedded devices play an essential part in IoT, which mainly connect with intelligent sensors for information gathering. In detail, embedded devices interact with the physical environment with these sensor nodes [3–5]. Nowadays, the IoT platform provides advanced control and monitoring services for novel appliances to expand their working efficiency.

The *Internet of Things* (IoT) is defined and used by a well-known researcher Kevin Ashton in the early days of 2000. From Kevin Ashton's explanations, the IoT is a system/structure of material things in the real world to link to the Internet through intelligent sensors. Ashton also conceived the *RFID* technology, which heavily applied to transportation tracking services without any human interventions. Now there are different definitions available based on their specific idea in the real-world scenario. For instance, from IEEE, "IoT is a framework of connected devices thru the internet, for new appliances and services enable the interaction in the physical and virtual world in the form of M2M communication" [3]. From Internet Architecture Boards (IAB) definition, "IoT is the networking of smart objects, meaning many devices reasonably communicate in the presence of internet protocol that not directly operated by human beings but exist as components in buildings, vehicles or the environment" [6].

As discussed above, most IoT systems are becoming increasingly dynamic, mixed, and multifaceted; thus, the organization of such an IoT system/model is challenging. IoT System-oriented services need to enhance efficiency and variability to attract more abusers. In recent times, artificial intelligence (AI) reaches tremendous success in numerous domains by employing modifications in computing technologies [5]. Machine learning (ML) is another unique technology and a subpart in AI applied on IoT for better services. Both AI and ML are recognized as the critical parts for IoT to make intelligent network management and operations. Many kinds of research work produced better results by applying AI and ML in pattern recognition, natural language processing, object detection, and network sharing. Hence, the IoT domain can also benefit from leveraging support from AI and ML. There are huge chances by employing AI- and ML-based models to IoT to make profound analytical and in-depth progress of well-organized smart real-world appliances [6, 7].

Before knowing the technical research trends of IoT, everyone needs to take a look and understand how an IoT works and impacts our everyday life. Every researcher and data scientist tries to import and understand IoT preliminaries according to their visualizations and then requirements. After all, there is no universal definition of IoT and its visualization requirements. Internet of Everything (IoE), Internet of Cloud Things (IoT), and Web of Things (WoT) come from the IoT visualizations and have their respective definitions of working protocols. However, IoT is designed based on integrating various standards and enabling technologies with dissimilar sensing, computational capabilities, connectives, and storage capacities. Here in IoT systems, the integration standards in employed devices present high-rated challenges while authentic connections of everything. The challenges on integration in IoT devices are considered significant IoT issues since those are fundamental to the further development of IoT projects [7–9]. Nowadays, numerous standardization administrations, associations, researchers, and manufacturing industries make an effort on IoT expansions, modernization, and setting things in the right way. However, there is still a lack of a broad context with combined ethics beneath one IoT.

2 Industry 5.0 Paradigm

When it comes to the twenty-first century, most of the domains turn into digitalization. However, we admit that companies struggle to digitalize their business by incorporating AI, IoT, and Industry 4.0 technologies. Apart from the mentioned technologies, the subsequent step of the Industrial Revolution seems in the upcoming days and is named Industry 5.0 [2–6, 10–14]. The term Industry 5.0 was familiarized in early 2015; however, it was called the Fifth Industrial Revolution, which built tremendous influence in different domains, especially day-to-day business, because of the velocity of added industrial, technical enhancement and shifting human process integration [15–18].

The First Industrial revolution or Industry 1.0 started at the end of the eighteenth century; it symbolized industrialized mechanical arrangements consuming coal, human, water, and stream power. The Second Industrial Revolution or Industry 2.0 commenced in the last quarter of the nineteenth century, and it represented mass manufacture through the use of electrical energy [19–22]. The discovery of the telephone, mass production, telegraph, introduction of assembly lines, and mechanization are few features of Industry 2.0. The Third Industrial Revolution or Industry 3.0 started in the early twentieth century. It established computerization and then microelectronic skills into the industrialized field. A higher level of automation is accomplished using robots, information technology, and microprocessors – most of these twentieth-century initiatives are closely related to information and communication technology (ICT). Computer-integrated manufacturing, computer-aided processing planning, computer-aided design, and flexible manufacturing systems are some of the fields taking advantage of the third revolution. In recent times at the start of the twenty-first century, Fourth Industrial Revolution or Industry 4.0 started with the inclusion of cyber-physical systems (CPS), which makes revolutionary changes in manufacturing. Industry 4.0 was predominantly characterized by CPS, cloud computing, big data analytics, augmented reality, IoT, simulation, and intelligent devices. This means it entirely focuses on end-to-end digitalization and incorporating digital industrial ecosystems by seeking completely integrated solutions [20–24]. Besides, it highly focused on IoT objects that connect with the industrial plant.

Industry 5.0 emphasizes collaboration among humans and machinery types, which means the Fifth Industrial Revolution is more captivated by forward-thinking human-machine interfaces through human-machine interaction. Industry 5.0 main intention is to progress Industry 4.0 to an advanced level. For this, it brings the concept of collaborative robots which are also known as cobots. With the successful integration, cobots will fulfil today's need for enterprises that produce personalized products [20–24]. Hence, with improved manufacturing, software tools, the Internet of Everything, and robotics using technical progressions, Industry 5.0 is familiarized in manufacturing and medicine than other allied areas.

It provides chances for a customer to experience mass customization in different groups' collaboration across the world. Technology innovations do not consider the foundation of revolution for the organization, and there is a need for customer goals. To fulfil the customer goals, Industry 5.0 follows some set of principles:

Mass customization – suggest actual price and comfortability of various product or service customization to customers.

Customer-centric – concentrate on customer goals and try to resolve hurdles in business expansion through reengineering

Green computing – also an emphasis on environmental conditions.

Cyber-physical systems – prepare an intelligent system from the human serving the customers by gaining maximum benefits from the human with machine intelligence [16–18, 20–24] (Table 1).

Reasons for Adopting Industry 5.0 in Manufacturing

Industry 5.0 will advise or solve the issues associated with removing human workers from dissimilar manufacturer procedures from the discussions mentioned above. However, there is a need for advanced technologies to boost the Industry 5.0 manufacturer [16–18, 20–24]:

Multiscale modeling and simulation – advances of digital twin with intelligent autonomous schemes arise difficulties in valuation monitoring of manufacturing sites. In this context, visualization tools play a crucial role in constructing the

Table 1 From Industry 1.0 to Industry 5.0

Phase	Period	Description	Identification by	Key point
Industry 1.0	1780	Industrial manufacture based on stream and water machines	Mechanization Water and stream	First mechanical loom
Industry 2.0	1870	Mass production with electrical energy	Electrification Division of labor Mass production	First assembly line
Industry 3.0	1970	Automation with electronic and IT system	Automation Electronics IT systems	The first programmable logic controller
Industry 4.0	2011	The connected device, data analytics, computerized machinery programs to automate the industry production	Globalization Digitalization IoT, robotics, big data, cloud computing	Cyber-physical systems
Industry 5.0	Future	Cooperation among human intelligence with a machine to improve products and services	Personalization Robotics and AI Sustainability	Human-robot co-working Bio-economy

policies for managing and personalizing genuine products and then product outlines.

Miniature sensor data interoperability – usage of sensor nodes highly increased from smart homes to autonomous manufacture cobots and distributed intelligent systems. These intelligent sensor nodes sense and collect real-world raw data, which is an unavoidable asset to the next Industrial Revolution. However, with the progress of energy optimization, fast and effective customization process, selection of a local agent for pre-processing data, and creating high modeled distributed intelligence in IoT, Industry 4.0 is still an open research issue.

Virtual reality with digital twin – with the result of continuous growth in big data and AI-based cobots, it is even more feasible to create more realistic digital twins. It properly allows industry experts to allow reduced wastage in the process flow and system design. Hence, the digital twin with advanced visualization techniques will tremendously increase the throughput of all the sectors.

Real-time trackers – will boost real-time production tracking, facilitating the customers' sales orders with manufacture orders and supplementary material. Virtual training will assist in some cases: when trainee or trainer on different locations but learns a specific job in a virtual/simulated atmosphere. This type of training pointedly decreases the costs than time for both parties.

Intelligent autonomous systems – artificial intelligence models have great deals in autonomously controlling production lines in the manufacturing industry. Up-to-date AI-related ML and DL models effectively make changes in intelligent systems and solutions that assist in decision-making scenarios.

Transfer learning – transfer learning policies guide the schemes mentioned earlier, securely and progressively in Industry 5.0.

Computer vision with DL and RL and GPU-based computation has shown great potential in reproducing primitive vision besides sensory abilities. However, for advanced performances of Industry 5.0, cobots proficiencies must be improved suggestively.

Problems and Limitations in Industry 5.0

Industry 5.0 resolves most of the manufacturing issues associated with removing human workers from different procedures. However, it must incorporate additional forward-thinking skills since humans may add innovative manufacturing skills in the coming days. There are numerous skills in the developing stage, some of them pointed in this section.

1. Before incorporating advanced skills into industrial management, there is a need for how an autonomous system can incorporate ethical principles.
2. There is a need for proper verification and validation of ethical behavior inside the autonomous system model.
3. Implementation operation transparencies and fast and competent manufacturing might have significance in an overproduction phenomenon.

4. The outcome results must be understandable ethical behavior solutions in an autonomous scheme. In particular, industrial experts are facing adapting and implementation issues.
5. Tuning and validation will avert somewhat serious problems among technology, experts, stockholders, society, and businesses.

3 Elements of IoT

As we mentioned in the introduction, understanding IoT building blocks will give some visualization and a better perception of the IoT's actual meaning than functionality [23]. We listed six fundamental elements of IoT, which are noted in Fig. 1.

Identification
In any communication or data transmission network, the term identification plays a considerable role. The precise identification is key to the IoT structure to name and match services with their claim. However, it is tricky to addressing object ID and its corresponding IP address in the IoT system. An ID indicates a particular object or device's name, and an address indicates its present address inside the network territory. Differentiation among object identification then addresses authoritative since identification models are not inimitable; moreover, objects might practice with public IP addresses inside the network. Hence the designed models must overcome the hurdles mentioned above and identify every object inside the network correctly.

Sensing
IoT setup intends to gather information from a particular region/area, organized through sensing devices. Sensing devices/objects collect real-world data from the surrounding atmosphere and send it back to the database or cloud for additional

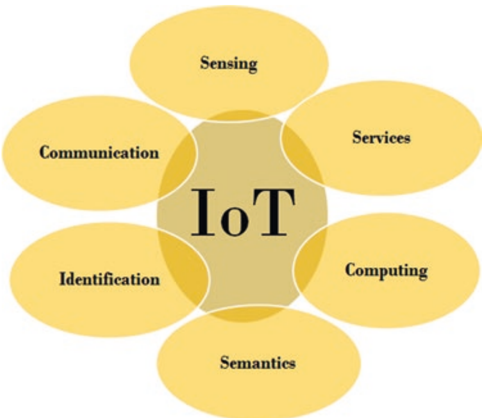

Fig. 1 Internet of Things elements

processing: sensors, wearable devices/sensors, and actuators utilized mainly for sensing purposes. For example, single-board computers (SBCs) like Arduino Yun and Raspberry PI combined with sensors and integral TCP/IP and safety functionalities are naturally used to grasp IoT products. Such devices characteristically attach to a central managing portal to deliver the essential data by clients.

Communication
In general, most IoT objects contain adequate resources; with these limited resources, objects connect with heterogeneous devices/objects in the company of lossy, noisy connotations. Wi-Fi, Bluetooth, NFC, RFID, and IEEE standards some IoT communications; in the next section, a brief description provided a better understanding.

Computing
The computing power of hardware devices is also an essential concern in IoT. The computation components like microprocessors, microcontrollers, and software-oriented appliances represent the brain to a particular appliance. Arduino, Raspberry PI, UDOO, MULLE, and Gadgeteer are hardware platforms designed for IoT appliances. Some other platforms are real-time-software operating systems (RTSOS), for real-time IoT functions; TinyOS, for lightweight operations; and cloud platforms, for too big data processing in real time. Still, some of the computing components have drawbacks, and research community is working on them to perform well.

Services
IoT offers a wide variety of services. Most of them are divided into identity-based services, in which most of the real-time appliances come in this category; information-aggregative services, which accumulate real-world raw sensor data connected with appropriate IoT applications; collaborative-aware services, which use the collected data to data analytics for decision-making; and ubiquitous-based services, aimed to represent collaborative systems to work anytime, anywhere when they are required by clients. Still, the above mentioned services are not reached or achievable to a comfortable stage; many complications besides challenges have to be answered.

Semantics
Semantic operation in IoT performs to useful abstract information smartly from different objects. It is similar to knowledge extraction, like finding resources that improve the model performances. Resource Description Framework (RDF), World Wide Web Consortium (W3C), Efficient XML Interchange (EXI), and Web Ontology Language (OWL) are some of the well-known semantic technologies adopted in IoT systems.

4 IoT Architecture

IoT and its variant inclusion into various domains and organizations will enhance the product or working performances. However, these proposals are severe and complicated to implement when it comes to real life since the number of devices, protocols, and working conditions is entirely dissimilar from one device to another. In other words, the problem of creating a consistent architecture of IoT unavoidably arrives in this phase. Before designing IoT architecture, it is better to understand the factors that affect IoT behavior, making it easier to find reliable IoT solutions. Moreover, it will reduce the various resources spent on IoT design. Before revealing the enigmas and providing an explicit construction of this creativity, it is vital to recognize what this idea means [23–28]. In essence, IoT architecture is the combination of great fundamentals network tools. It is measured as a global network setup collected of several allied devices that rely on communication, networking, sensory, and then information processing types of machinery. See Fig. 2.

4.1 Perception Layer

IoT is a kind of worldwide physical interrelated system in which things can couple and then be measured remotely. The perception layer is considered an initial stage for IoT schemes, and it is like a bridge between real and digital worlds. In some cases it is acknowledged as a sensing layer. Most of the perception layer deals with intelligent wireless devices like intelligent sensors, tags, and actuators. These wireless schemes with tags or sensors are now talented to inevitably sense and then exchange info among different devices. Devices may diverge in procedure and size

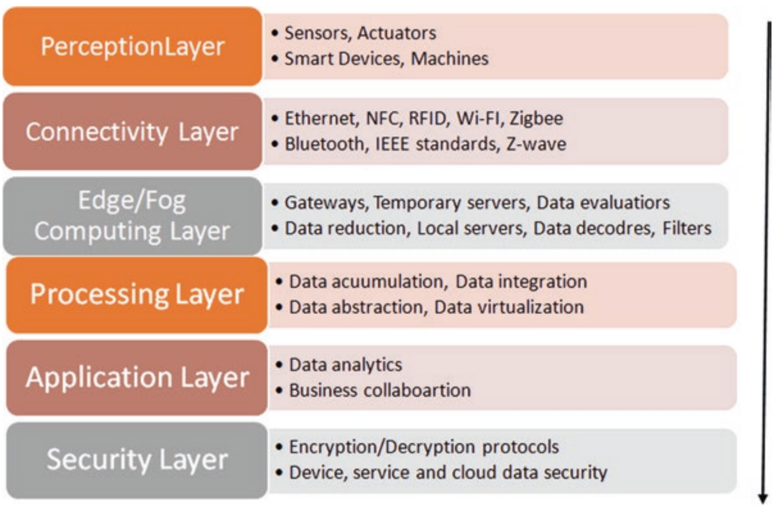

Fig. 2 Internet of Things architecture

from miniature to ad hoc vehicles. Sensors accumulate environmental conditions, transform them into electrical signals, and then forward them to IoT schemes. Actuators transform electrical signals collected from IoT scheme toward physical activities. It must note that IoT architecture does not make any limitations on elements and their deployed locations. It means objects/devices can lace in a small place to corners of the world.

4.2 Connectivity Layer

The connectivity layer is considered the second phase of the IoT scheme since it takes care of complete communications across devices, systems, and then cloud centers that made the perfect IoT scheme. The communication connectivity among physical layers to cloud centers can be achieved thru TCP/UDP or software/hardware modules. Ethernet connects fixed IoT devices; Wi-Fi are widespread wireless connectivity applied on home IoT setups; NFC is data transmission among two devices; Bluetooth is used to transfer small-size data, not applicable for large data files. In some unique scenarios, IoT uses message-oriented protocols depending on the application requirement for data connectivity. Advanced Message Queuing Protocol (AMQP), Constrained Application Protocol (CoAP), Data Distribution Service (DDS), and Message Queue Telemetry Transport (MQTT) are some of them.

4.3 Edge or Fog Computing Layer

Edge/fog computing is vital for IoT systems to satisfy the increasing volume of connected devices and real-world services. The intention of designing edge/fog computing is to store and pre-process the sensed data as fast as it sensed and adjacent to its sources as possible. So it can save time and resources for IoT devices; also, it will decrease the scheme latency time, which can improve performance accuracy. Usually, edge/fog computing takes place on gateways and local servers distributed over the network.

4.4 Processing Layer

The processing layer collects all the data across the IoT schemes. It applies preprocessing models to use abstract information for decision-making or make data available for any further operations. Real-time data is observed with API and used for non-real purposes, and it stands like a hub among event-based and query-based data ingesting. After collecting multidimensional data from various devices and applying data abstraction methods, at that moment, only other connected devices can understand the data.

4.5 Application Layer

Data analysis is done through software applications to bound with appropriate answers for main business questions/requirements in the application layer. In IoT, hundreds of IoT requests diverge in intricacy and function, using different expertise stacks than functioning schemes. In present days, various applications are constructed right on top of IoT stages that can suggest software-related advance setups through ready-to-use utensils for data mining, pattern, and forward-thinking analytical skills.

Business Layer

The information collected and pre-processed in IoT schemes can only help problem-solving/decision-making systems achieve excellent results. The business layer is well-defined as a distinct stage, advanced, and challenging to describe in a single application layer for this motive.

4.6 Security Layer

In any network-related application, the word security has its place. In IoT, the security layer plays a crucial part, covering all the services mentioned above/layers. It is tough to discuss the security topics of IoT in one single paragraph or a section. There are different security levels in IoT schemes: in *device security*, IoT-related devices need low-resourced authentication services, physical metal shields, and chips that can boost procedures to avoid unauthorized code. *Connection security* is mostly data transfer in IoT done through wireless channels, which is easy for attackers to steal or alter the data. Hence, when the data sent over a device or network, it must be in an encrypted format. In *cloud security*, sensed information kept in the cloud must be encoded to mitigate hazards of revealing delicate info to trespassers. Hence, always pay attention to security protocols to certify that security is high at all stages, from the smallest devices to multifaceted analytical schemes.

5 Enabling Technologies

5.1 Radiofrequency Identification (RFID)

RFID communication technology is specially designed for transportation tracking made of tags and readers. RFID is considered an automatic identification mechanism that involuntarily identifies the target tag signal with suitable data. Hence, it was employed extensively in various hazardous and impassive atmospheres. As we mentioned above, the RFID structure completes with tags and readers. The tag consists of address bars attached to objects as a small microchip handled by the antenna. The electromagnetic pitch is applied to send and collect data records from an entity over a tag. The data records stored on a tag can only be read or abstracted by readers only when both tags and readers are placed at a specific angle or range. The reader forwards a signal to read the tag's information, and the antenna on the patch receives it, acknowledging the signal by sending appropriate data. In record, three tags are available in RFID communication: passive tag, which obtains signals from tags working on batteries; active tag, in which tags abstract energy from readers' signals, which means those do not have batteries; and, finally, active reader active tag, which works on both low and high frequencies. RFID tags are professionally applied on real-world appliances since they automatically monitor payments, goods or baggage tracking, inventory management, tracking of products, and product lifecycle supervision and then update the information without any third-party or human interference. RFID technologies can fit into different domains to design and enhance model/systems accessibility and then efficiency. However, there are some drawbacks for implementation of RFID because most IoT WSNs appliances are built in harsh environments, where the signals are disturbed and intercepted and there is a chance for the entire device to collapse.

5.2 Power-Line Communication (PLC)

In PLC, data records are forwarded through the attached cables. It means a sender modulates the data records into the transfer medium; when it reaches, receivers demodulate the data records and then read them. By doing this, data transfer with power cables, where one can both power it up and then at a similar time control/retrieve data from it in a half-duplex style. Hence, PLC attracts a communications model in intelligent meters (AMI), HEMS, BEMS, and solar panel-intensive care schemes that understand smart society. There are low-speed and then high-speed kinds of PLC, each of which uses a different communication procedure.

5.3 Electronic Product Code (EPC)

EPC was utilized to recognize RFID tags; it is in string type 96-bit long and placed on tag/patch. Out of these 96-bits, 8 bits represent header which aimed to identify the version of the protocol, 28 bits refer to the unique address of the system that manages the data on tags, 24 bits hold the type of product to be recognized, 36 bits mention the serial number of the tag. Finally, the last 2 bits are being hold the by the organization that created the tag.

5.4 Wireless Sensor Network

Wireless sensor networks collect small tiny sensor nodes employed to gather sensed data from surrounding atmospheres. Computer networks, micro-electro-devices, and wireless technology combinations made the formation of WSNs. In the past, wired sensor networks/nodes used for communication, which places very local amenities, overcome WSN technology developed and produce possible results with various appliances. It is a known fact that WSNs drive IoT systems and enhance performance precision. Due to the node's resource constraints, deployment topology, connection, detection of neighbors, and transmission paths are the essential tasks in WSN formation. WSN is a vital element of IoT as it combines mixed sensor data, systems, and appliances. Researchers designed various inclusion techniques for IoT, the Internet, and WSNs, but still face many challenges that need optimal solutions and research under study.

5.5 Near-Field Communication

NFC technology is applied for data transmission and small communication setup when two objects are near to each other. It is similar to radio communication but works by touching or two objects closer to the exact location. The communication range of the NFC depends on the scale of the object's antenna. Hence, NFC technology is mostly not recommended to isolated locations, and it also not safer due to its limitations easily vulnerable to attackers.

5.6 Actuator

Actuators apply to specialized appliances, and they work significantly when the objects are in motion. It creates various motions like rotary, spherical, linear, and oscillator; then, it creates power from using them into kinetic energy. Actuators consider three types: electrical-based, employed on motors; hydraulic-based, hydraulic fluids; and pneumatically based, which use compressed air.

5.7 Machine to Machine (M2M)

M2M communication is similar to LAN and WAN networks; devices gather data from various sources and sent it back to other devices within the network. In M2M, stored data records are monitored and automatically take some assigned tasks depending on the applications. Moreover, the performance of M2M depends on software-controlled communications among machines and devices.

5.8 ZigBee

The main intention of ZigBee's innovation is to expand the application regions of WSN and IoT. It is a special kind of flexible wireless networking technology, better performance for short communicated appliances like intelligent home automation, healthcare, and industrial appliances. ZigBee is designed with MAC and IEEE protocols; besides, it has four-layer architecture, namely, physical, MAC, network, and application layer.

5.9 Wireless Fidelity (Wi-Fi)

Wi-Fi is a famous wireless network ability and an excellent fit for data-intensive IoT-based solutions. It has high wireless access for a small area with an intelligent transportation system. It has collective versions, and some of them are as follows: IEEE 802.11a delivers a data rate of 54 Mbps, and IEEE 802.11a data rates up to 2.4 GHz.

5.10 IEEE 802.15.4

IEEE 802.15.4 (low-rate wireless personal area networks – LRWPANs) act as a sublayer for the MAC layer. It provides effectual communication for low-power consumption data rate, high security, and low cost and supports a vast number of sensor nodes at a time. Based on these specifications, IEEE 802.15.4 is considered a basis for various communication technologies like ZigBee, Z-Wave, Bluetooth, etc. However, it does not provide QoS; also, this is a fascinating topic to research.

5.11 Z-Wave

Z-Wave communication technology initially designed smart home automation appliances like door switches to a central controller. The working procedure of Z-Wave is quite similar to ZigBee, both employed with mesh topology and low wireless standards to improve the low-resource devices. Z-Wave functions in the 868 MHz frequency band, while ZigBee functions in 2.4 GHz. Besides, Z-Wave left the software-side encoding, but ZigBee practices the 128bit AES on the hardware side.

5.12 Bluetooth LE

Bluetooth or IEEE 802.15.1 stands for the information exchange among fixed and mobile devices over a short distance using industrial, scientific, and medical (ISM) bands. It heavily applied to smart home, smart city, healthcare, security, military appliances, fitness, and industries. Bluetooth SIG, Bluetooth BLE, Bluetooth 4.0, and Bluetooth 5.0 are the latest versions of collecting and aggregating sensed data from IoT-based sensor nodes. Bluetooth technology was very much suitable for short-range monitoring appliances.

6 Artificial Intelligence (AI) in the Internet of Things (IoT)

The operative functions of the Internet are insistently from the “Internet of Computers (IoC)” to the “Internet of Things (IoT).” There is a need to deliberate the importance of AI techniques to allow intelligent Internet communications. In present days, wireless sensor networks are becoming hot research topics because of their reality applications, incredible remote monitoring of events in fields like healthcare, weather report, seawater levels, event predictions, etc. Besides, intelligent sensors were employed heavily in electronic-based home appliances, smart cities, and gadgets to mobiles [22–25, 29–36].

The idea of IoT is “the pervasive presence around us of a variety of things or objects – such as Radio-Frequency Identification (RFID) tags, sensors, actuators, mobile phones, Etc. Through unique addressing schemes, they can interact with each other and cooperate with their neighbors” [36]. Hence, the changes in IoT protocols and services will surely have a good impact throghout the world. AI approaches also help IoT build robots whose situatedness evolves roles that avoid persistent human command [37–40].

Figure 3 deals with the IoT data flow diagram. Data initially comes from the IoT-enabled devices and IoT appliances, and then through IoT gateway, it goes to a cloud-based server. Here data has been analyzed via different analytic tools and learning and training methods. Then recommendation systems come into the picture for optimal actions; actuators are there for transferring the flow toward IoT appliances for further processing. However, we can say that innovative IoT standards are vital for shuffling from today’s sensor networks into systems of intelligent sensors permitted with actuation types of machinery. These kinds of upcoming schemes will involve the “Internet of Intelligent Things (IoIT).” These are the successive evolutions of networking to create the experienced ubiquitous, living, intelligent Internet connections. It seems necessary to give familiar objects the capability to understand their backgrounds and make conclusions freely [36–45]. At present, decisions or conclusions no need to forward to central decision-making nodes. Through great intellect of sensors and giving them the skill to turn by affording to the incentive professed by sensors, empowering the IoIT to reply improved time-critical conditions, since the conclusions complete in a noncentralized manner.

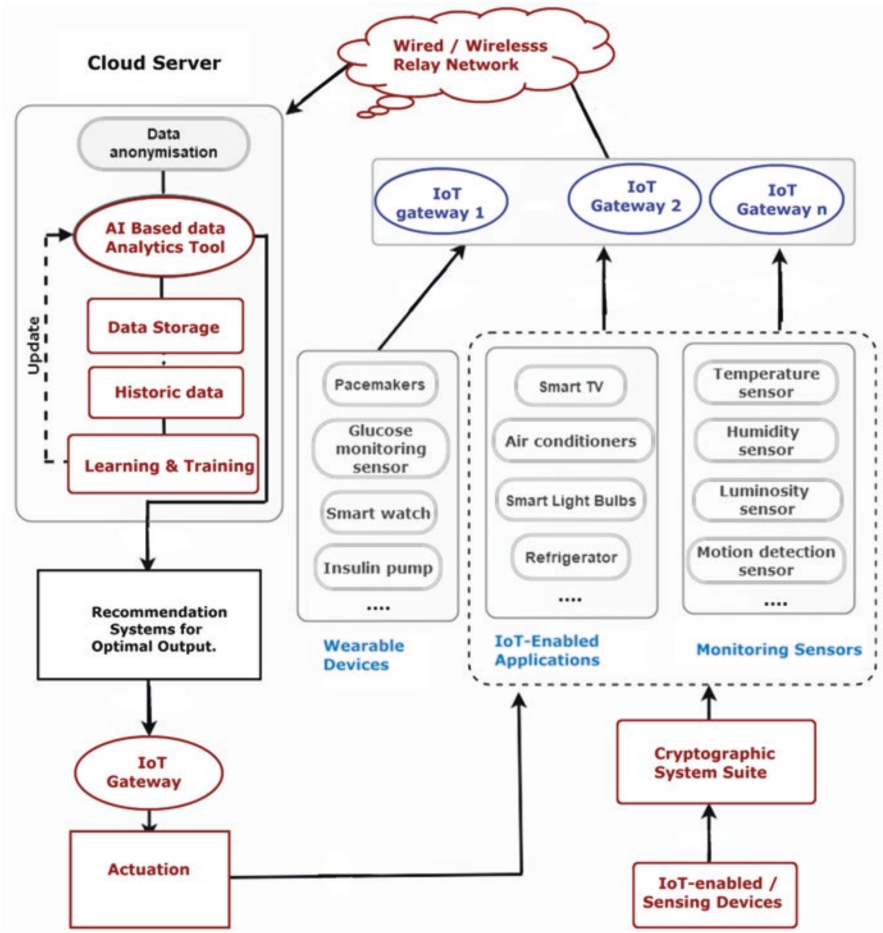

Fig. 3 IoT Data workflow diagram

The Internet of Things helps us collect data, which is one of the most valuable resources today due to its role as a catalyst. When paired with another catalyst, artificial intelligence, as shown in Fig. 4, vast volumes of unstructured data can be easily shifted through, resulting in industry insights and well-informed decisions.

6.1 Artificial Intelligence for Intelligent Sensing

AI for intelligent sensing talks about the ML models to recognize valuable patterns or forecasts from the information collected by the intelligent sensors. For example, active sensor learning dynamically increases class volumes identified by the model. As the data is composed in a real-time environment, a predefined approach for data acquisition must follow episodic retraining or careful querying [32–36].

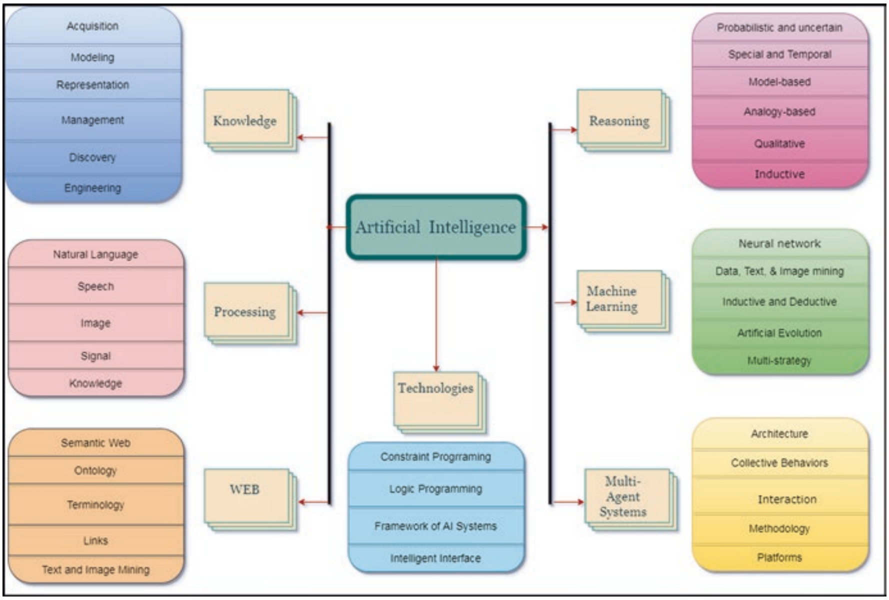

Fig. 4 Artificial intelligence classification

Unsupervised models are best suited for active learning schemes, aiming to categorize events with no prior knowledge with numerous dissimilar ambient sounds.

6.2 Decision Tree in IoT

DT solves classification problems by applying sorting techniques based on respective features. In DT, numerous procedures are used to find the most attractive feature that best splits the training examples; some are information gain and Gini index. The complete process of a DT is as follows: first, pre- and post-pruning applied to reduce the tree size; second, searched space among the objects adjusted; third, optimized search model employed to eliminate the redundant features; and fourth, a structure of resultant tree transformed into an appropriate data structure like set of rules. DT effectively applied IoT-based real-time applications such as pattern recognition, decision-making, environment monitoring, detection of security parameters, healthcare management, etc.

6.3 Random Forest in IoT

Random forest (RF) comes under the category of supervised learning models. RF consists of numerous trees built randomly and then skilled to make a vote for a good class. At last, the most voted class is elected as the final classification result. In general, RF utilizes decision trees to build subset rules for voting, so the result classification is the average of the DT results. Besides, RF computational accuracy overcomes the feature selection where it requires the fewest input parameters, but it cannot be applicable in real-world applications. RF models were highly applicable to IoT devices in various domains. For instance, RF models skilled with features obtained from the network traffic correctly recognize IoT device categories because RF precisely holds real-world implications for correctly categorizing unauthorized IoT devices.

6.4 Clustering

K-means – the main goal of k-means is to cluster the unlabeled data features into K number of clusters or sets; here, data points fitting to the identical cluster must have some likenesses. Typically, k-means is a fast and highly scalable ML technique. In some cases, employed MapReduce to analyze the several minor datasets then offers a cluster approach for a high dimensional of small data based on the K-means procedure [39–41]. Researchers designed the K-means cluster and then categorize travel pattern consistencies.

Density-based spatial clustering of applications with noise (DBSCAN) clusters the unlabeled datasets based on the data point density (data point with the highest count of close neighbors) values. It is a widely used clustering system with several real-world requests like anomaly exposure in temperature data, traffic control, emotions recognition, and X-ray crystallography.

6.5 One-Class Support Vector Machine (OC-SVM)

OC-SVM comes under a semi-supervised technique, and it is an extension for SVMs. It generates a boundary line among the trained data when the new data after some operations lie outside the boundary line commented as an outlier or anomaly. Because of its nature of work, OC-SVMs are useful in anomaly detection in WSN, network intrusion detection, and IoT-based machine performance evaluations.

6.6 Ensemble Learning Models in IoT

Ensemble learning (EL) combines various basic classification practices and produces a collective, effectual output. Research work on EL experiments shows that learning models vary by precise application. So, the research community starts combining various dissimilar classifiers to expand precision. Moreover, EL models use numerous learning techniques which lessen the variance, robust in contradiction of overfitting. EL has been effectively used for online intrusion and anomaly detection in IoT-based environmental datasets and evaluating real-time datasets for accurate IoT devices' decision-making.

6.7 Neural Networks

Neural networks (NNs) with the condensed representations are the quickest models to process the new data instances. From the innovations, NN has diverse NNs with a distinct structure and appliances. The feed-forward neural network (FFNN), also called multilayer perceptron, is considered the most common type of neural network in functional appliances. In FFNN, every layer's activity is determined through the nonlinear function or active function. An FFNN with a minimum of two hidden layers can estimate a random mapping from a finite input space to a finite output space with sufficient hidden units. Nevertheless, the issue is detecting the optimal weights for an FFNN comes under the NP-complete problem. The model has various learning approaches, like adaptive moment estimation, stochastic gradient descent, adaptive slope, Nesterov's accelerated gradient, adaptive delta, and RMSProp. FFNN in IoT applies as a solution for energy efficiency, decision-making, feature selection, energy management, reducing computation complexities, etc.

6.8 Support Vector Machine (SVM) in UIoT

SVMs perform classification by forming the splitting hyperplane among two distinct classes by calculating the distance's data attributes. SVMs are chosen for large datasets with many feature attributes but contain tiny sample points. The main advantage of SVMs can perform in real-time intrusion exposure and then inform the training patterns energetically. SVM variants like QS-SVM, CE-SVM, and SVDD are widely used in numerous security applications like an outlier and intrusion detection; moreover, they are effective in memory storage with less time complexity.

6.9 Internet of Intelligent Things (IoIT) for Social Networks

Social media plays a crucial role in a current digital world, where millions of people regularly participate, connect, and express their ideas, views, and suggestions. With this connection and sharing of ideas, many people can answer complex issues more efficiently than single individuals. Nowadays, intelligent sensors are automatically categorizing the actions of crowded people in real time. IoT turns out to be an enabled model for other networking forms than computation like IoIT and robotics as a service in another side of the networking world. These novel models efficiently add cleverness to the things linked to the Internet or consider things as robots, cobots, services, and users. Employing principles studied in social networking to the IoT might bring tremendous changes as well as advantages.

Usually, humans and robots, or a mixture of them, form web communities – however, such groups are shaped by intelligent avatars in the virtual world of the IoT. Continuous research links other biological creatures, automated to be proficient in intelligent processing, into social networks. Co-location object relationship, social object relationship, and ownership object relationship are examples of SIoT.

6.10 Principal Component Analysis

Principal component analysis (PCA) orthogonally plans data facts onto an L-dimensional linear subspace, termed the principal subspace. PCA deals with high-dimensional datasets based on reiterative expectation expansion practice and data compression; data visualization comes under PCA applications. Hence, PCA is considered the most crucial pre-processing procedure in ML.

Canonical correlation analysis (CCA) variant of PCA deals with two or more variables. Here the main goal is to recognize a consistent pair of extremely cross-correlated linear subspaces. Hence, inside one of the subspaces, there is a relationship among each factor along with a solitary component from the other subspace.

6.11 Bagging

The bagging objective is to enhance the precision and stability of ML-based techniques and then diminish the overfitting. In this method, training datasets are engendered by arbitrarily selecting data points from the unique training set with substitutes. So, on each originally produced training set, an ML practice is trained. In ML, there are numerous approaches like DT, RF, and neural networks, for which the bagging method advances the outcomes.

6.12 Artificial Intelligence in Analytical Skills (IoT)

Various business organizations have hired analytical skills for quite a few decades; nowadays, numerous organizations attract to planning their AI abilities. From the past few decades, organizations/companies synthesize their skills for efficient utilization of data and their statistical analytics and quantitative procedures to progress decision-making. However, currently, those companies are mainly engrossed in discovering and operating AI to strengthen each other. AI is not statistical, like ML and

DL, which quickly increases supremacy besides demand [29–34]. Analytics-oriented clusters inside the administrations may want to concentrate their care mainly on these machineries or obtain novel skills in nonstatistical portions. The innovation analytics has transformed into various versions, some of them mentioned below.

Analytics 1.0 – it is an age of artisanal expressive talent and the initiation of scrutiny and writing utensils. In this stage, it conquered the commercial analytics for years, and the price stayed mainly determined by the objective of interior decision provision rather than progressive analytical abilities. Analytics 2.0 – this stage big data analytics stands like Hadoop, and then information-based innovations such as Google and Facebook led to data experts' advent. The main intention is to shift from "internally designed decision support" to "data products" designed for the data and then analytics for use by clients. Analytics 3.0 – large-scale corporations make data, then analytics-based productions, and then analytical events with numerous ML models. Analytics 4.0 – AI and cognitive-based models are heavily applied in analytical sophistication by various organizations. It adopts various model accuracy levels and applies with AI models and superior use of self-rule in the performance of approaches as automated ML. Some reasons for adopting AI into analytics are a mixture of skills and internal partnerships needs AI [34–42]. For instance, computer knowledge requires understanding the embedded learning data models. Another reason is that accurate data analytics with immense data processing and cutting-edge statistical models are required. ML is the central part of many approaches to AI and analytical techniques. The usage of ML in analytical procedures is started several years back and may be more aware of predictive analytics. ML uses supervised learning where both the creation and results from values are known.

AI is steadfast on the rise and will play a considerable role in analytics 4.0 because of its potential in transforming business models; hence, the influence of analytics 4.0 will possibly be greater and also higher unsettling than preceding automation evolutions. Moreover, organizations that shift to analytics 4.0 more fast-track than those that do not apply any AI model. The procedure toward understanding AI achievement starts with the primitive consideration of AI, how AI will influence creativity, the new abilities, and what a workable act policy should be applied. Businesses that control their present analytical abilities can have a much quicker and more active start with AI.

6.13 Deep Learning for Analytics (IoT)

Due to the development of various networks and miniature technologies, IoT-based devices collect massive sensed data from surrounding environments where they deploy. Moreover, depending on the applications, these IoT devices/objects will result in fast and real-time data streams. Here, deploying analytical models on such substantial data streams for finding original information, forecasting forthcoming structures, and then taking control of results is vital. It makes IoT applications a well-intentioned standard for business and a quality-of-life enlightening skill.

From the past few years, most of the IoT appliances are designed with dissimilar research fields such as military, smart city, healthcare, and agriculture. The success of these applications is because of intelligent learning mechanisms for prediction or data analytical outlines. DL has been aggressively employed in many IoT appliances in present times with consideration of various ML tactics. The combination of DL-IoT is considered a top strategic technology in future applications. The main reason for implementing DL in traditional ML is that it quickly addresses the emergent analytical services needed in real-time IoT appliances [40–44]. Besides its variant's derivatives big data, the expansion of IoT needs stakeholders to identify their meaning, building blocks, abilities, and challenges. There is a strong collaborative relationship between IoT and big data: IoT is a significant information producer for big data. Similarly, it is a significant mark for extensive data analytical skills to expand the methods and then services of IoT applications.

To better understand IoT-based data analytics requirements, it needed to determine the features of IoT data and how they dissimilar from those of big standard data [40–44]. Some of them are mentioned below:

1. Large-Scale Streaming Data: IoT deployed with vast numbers of devices placed in distributed manner collects enormous data from IoT applications, leading to a high volume of continual streaming data.
2. Heterogeneity: IoT is a heterogeneous connected network, so numerous IoT data acquisition device assembles dissimilar result in data heterogeneousness.
3. Time and Space Relationship: At present, a maximum of IoT appliances real-world based, here sensor devices involved to a definite position, then have a position and timestamp for every single data substance.
4. High-Noise Data: Due to dynamic environment changes, miniature error bits, and noisy data produced in IoT requests, before applying them to any decision-making systems, it needs to eliminate them; otherwise, it will affect the outcome results.

While obtaining confidential information from big data is a talented technique to improve our lives' excellence, it is not a simple, straightforward job. There is a need to go outside the outdated inference learning models' abilities, innovative skills, practices, and infrastructures to deal with such composite and thought-provoking tasks. Fortunately, due to the contemporary developments in ML and DL variants, it is easy for big data analytics and information abstraction appropriate for IoT appliances. IoT appliances like fire detection and vehicular identification need fast and continuous streaming data for quick movements to accomplish their targets.

Numerous researchers have projected methods and outlines for fast real-time streaming data analytics that influence cloud setups' abilities than its services. As mentioned earlier, appliances need fast analytics in slighter-scale platforms such as fog/edge computing for the IoT. For example, healthcare-related applications must make quick decisions on a particular time instance; otherwise, it may cause a patient's loss. These kinds of decisions should be maintained thru quick analytics with multivariate datasets. Hence, accurate identification must be performed in IoT quickly and in real time to prevent fatal mistakes.

6.14 Edge Computing in IoT

In general, the connected objects in IoT generate vast amounts of data, collecting and processing that much of data at one of the appropriate/suitable objects to turn data into useful information. Hence, nowadays, the entire IoT setups apply significant data operations; big data support IoT applications since the tribunals of gigantic sensing then stimulate information maintained in IoT. Also, IoT collects unstructured, multivariate data that needs additional analysis to be abstract the valuable information [38–44] because of the heterogeneous connections. With the rapid development of various technologies, IoT becomes the next technology revolution; however, it will confuse ample data storage, processing, and systematic analytical skills. IoT employs real-time applications to work with continuous streaming, disturbing the data storage dimensions in numerous establishments. Hence there is a need for additional data centers for handling collected data from IoT appliances. One probable answer is to transfer the information to the cloud via leveraging the application platform as a service. Nowadays, cloud computing is one of the well-established technologies, and it offers computing facilities or data storing on the Internet.

IT companies like Google Cloud, Amazon Web Services, and IBM Cloud analytics present cloud services. Cloud computing offers various advantages like proficiency, capability, and flexibility to store and then use sensed data information. However, data from vast quantities of objects spanning a vast geographical region must be stored, managed, and analyzed proficiently in IoT-related appliances. However, when cloud computing is employed in IoT, new encounters will come into action. Fog or edge computing is talented enough to outspread cloud computing faster than it assists in overcoming mentioned issues. In brief, as a replacement for performing entire computational processes at the center of the cloud, fog/edge computing offers computing and then storage facilities to devices at the edge of the system. The node/object with fog computing capability of any network can efficiently perform the data storage, computation, and heterogeneous network connectivity. These devices/objects are employed at any place of the network and assemble the IoT things with connected applications [38–45]. Usually, different kinds of data are collected from IoT objects and transferred to suitable object/place for additional analysis based on the application necessities. Here, the priority-based information that is required to be forwarded instantly can be managed on fog/edge computing nodes, which are nearer to the IoT campaigns that create significant evidence. The low-priority data records can then be forwarded to some collective nodes/objects for additional processing and then scrutiny. Besides the advantages of fog/edge computing, it has limitations and tribunals while integrating IoT with fog/edge computing. Establishing fog/edge computation and assigning adequate resources to IoT things is the most significant task. In IoT, every time, a minor number of services are demanded by IoT devices; hence each fog/edge service node contains inadequate communication, computation, and storage capabilities. In this context, every fog/edge computing node should be optimally accomplished and composed for IoT devices to deliver demanded service resourcefully. How to adjust the allocated resources of a fog/edge node is also a tricky task. It means focusing on the resource managing between the fog and edge nodes is the hot research topic in IoT fog/edge computing. Hence, when applying fog/edge computing nodes to a particular service, there is a need to verify the different requirements like energy consumption, node cost, and service availability. Also, safety and confidentiality problems in fog/edge computing structure are also vital problems.

6.15 Federated Learning

Federated learning (FL) [46–48] is a machine learning methodology in which an algorithm trains across numerous decentralized edge devices or servers that keep local data samples without exchanging them.

As shown in Fig. 5, users use local data to train local models to update the global model at the base station. The global model aggregates and sends to the local models for training. These processes carry out again and again until the global model converges.

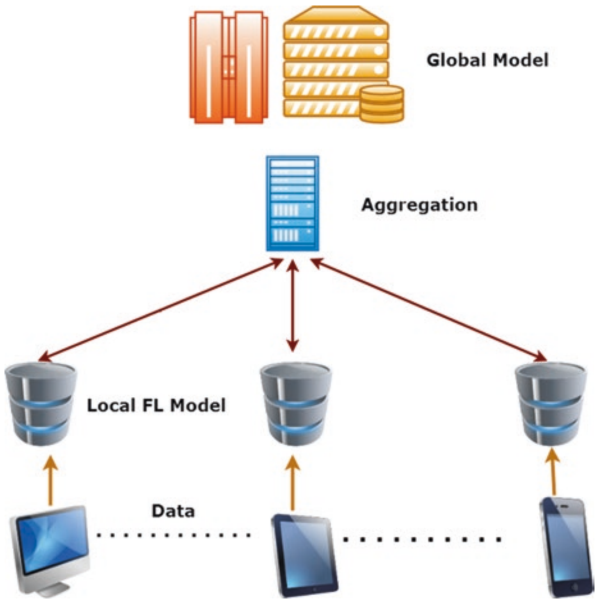

Fig. 5 Fundamental FL architecture

Federated learning allows devices to learn from a shared model collectively. With proxy data, the shared model first trains on a server. The model is then downloaded and improved by each device utilizing data – federated data. The device uses locally available data to train the model. The model's modifications compile into an update, which delivers to the cloud. The device retains the training data and individual updates [48, 49]. The model compresses via random rotations and quantization to ensure faster downloads of these updates. When the devices communicate their models to the server, the models integrate to form a single model. It is repeated for multiple cycles until the model is of good quality.

The following is the technique for federated learning as shown in Fig. 6:

1. A training model will send to the devices.
2. The devices are programmed to learn from local data.
3. The devices give the server encrypted updates on the parameters.
4. The devices are grouped by the server. The server aggregates the updates it receives from each set of devices to conduct a single update to the current model for each group.
5. The new updated model is delivered to the devices for on-device testing (again, the notion of decentralization is at play here), and a fresh round of training follows.

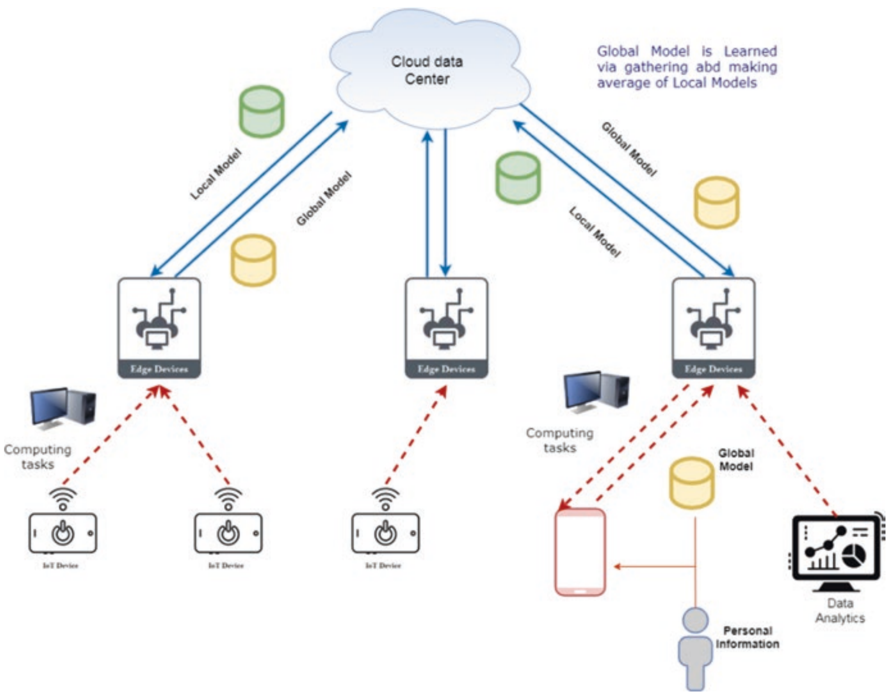

Fig. 6 Process of FL

Advantages of Federated Learning

Here we are discussing some of the FL benefits [47]. Firstly, FL allows smartphones to learn a shared prediction model cooperatively while keeping the training data on the device rather than uploading and storing it on a central server. Secondly, it brings model training to the edge, to devices like smartphones, tablets, IoT, and even "organizations" like hospitals that must adhere to tight privacy regulations. It is a significant security benefit to keep personal data local. Thirdly, it allows for real-time prediction because prediction takes place on the device itself. FL eliminates the time lag caused by sending raw data to a central server and then shipping the findings back to the device. Fourthly, because the model stores on the device, the prediction process can continue even if there is no Internet connection.

7 AI-Based Trustworthiness in IoT Systems

From the inclusion of IoT, many of us thought IoT turns human living more comfortable and stress-free. However, some researchers stated that IoT means "Internet of Garbage" because it consists of malware, copyrights, spam, etc. However, it builds with improved communications, better address, strict moderation, and effective community administrations. After collecting the information from the garbage-liked network, finding appropriate value is the most significant task. It is a known fact that IoT is rapidly growing and makes novel demands. From the above discussion, big data analytics, real-time monitoring with streamed data, and another critical discussion are efficient communication capabilities and ensuring security requirements in such a large-scale network. The deployed software applications with appropriate network connections should also be secure.

Clients and operative workers of smart IoT objects will be highly susceptible since their data is accessible on a network. IoT devices and services have three key issues – data confidentiality, privacy, and trust. The IoT object/device must authorize with an entity or person before starting data sharing and access to service. The model of securing IoT systems and their related components is called cybersecurity. Cybersecurity protocols have the most important in dealing with miniature devices, where IoT-based cybersecurity systems mostly avoid attackers stealing sensitive data. There are countless cybersecurity approaches like cryptographic protocols, firewalls, antivirus, intrusion detection systems, and scanners, which secure socket layers. ML, DL, blockchain, and quantum-resistant crypto-techniques profoundly apply to IoT schemes for better security. Also, some issues have happened recently, like small IoT wearable devices collect user's data, which are transformed to device providers since it connects with their respective databases [43–45]. Then these device providers sell the collected user data to other business companies without the user's permission. Business companies make continuous notifications based on the information and advertisements via social networks to that particular user. How to avert these kinds of data ethics in IoT-based schemes is also the most significant challenge apart from security requirements.

8 AI Tools for IoT

Sl. no.	AI tools	Features
1	SensiML Analysis Toolkit [50]	1. Build small algorithms that run on IoT endpoints rather than in the cloud 2. Acquire datasets that are reliable, traceable, and version-managed systems 3. To quickly generate autonomous working computer code, this tool can be used for advanced AutoML code generation 4. Option to select our desired interface and AI knowledge level, keep complete control over our algorithm, and design edge tuning models
2	Vertica Analytics Platform [51]	1. Analysis of communication and network 2. Analysis of embedded systems and customer behavior 3. Analysis of IoT systems and scalable, SQL-compliant time series analysis
3	DewSim [52]	1. SCE resource management – computing capabilities of intelligent devices fluctuate due to owner contact computing capabilities 2. Computing and networking practices use many resources on intelligent devices 3. Data is uploaded/downloaded from/to nodes via WLAN
4	iFogSim [53]	1. Network communication can be done 2. Mobility and edge processing can be simulated 3. Some parameters like energy efficiency, network protocols, and heterogeneity cannot be exhibited
5	IoTSim [53]	1. In IoTSim, IoT devices are modeled, and performance analysis realized 2. But, edge devices, energy efficiency, mobility, communication protocols cannot be modeled
6	IoTSim-Edge [54]	1. It allows researchers to model mobile IoT devices 2. It allows researchers to model a variety of IoT protocols 3. It is in favor of a high-energy-consumption profile 4. It allows for the abstraction of graph modeling

9 Applications of the Internet of Things

From the introduction, Internet of Things (IoT) applications convey incredible value into our daily life. With the new-fangled innovations in wireless networks, intelligent sensors, and revolutionary computing capabilities every day, a new IoT-enabled product proclaims. IoT applications project to train billions of everyday things/objects with connectivity as well as intelligence. This section attempts to overview and discuss numerous domains like intelligent homes, structural health monitoring, environment, logistics, agriculture, health, lifestyle, and industry domains with IoT applications.

9.1 Agriculture

As the world's population increases, the demand for a food source tremendously raised. Developed governments and research institutions are helping agriculturalists to use cutting-edge methods to raise food production. Smart farming is one of the fastest-growing fields in IoT. Here farmers are using expressive visions from the data to yield a healthier return on investment. Smart irrigation determines the quantity of moisture in the soil, releases the water with irrigation pipes for controlling water-usage, and regulate traditional peats with the help of IoT sensors. In greenhouse control, the weather-related information of a greenhouse could monitor and control to harvest the most delicate situations for growing plants. The stored sensible facts from various sensors in a centralized server where they analyze then improve different control strategies.

9.2 Augmented Reality

Augmented reality (AR) enhances how persons require, realize, and display information without disturbing the real world. Mobile augmented reality (MAR) with superimposing virtual elements over fundamental substances on the screen gives added value and enhances the interface with reality. It can increase efficiency and manufacture services by allowing staff to see the most relevant sensor data in the control panel like the view option. US-based DAQRI designed a helmet that can protect workers from falling objects and assist them in avoiding mistakes. Besides, the DAQRI device is also proficient in diagnostics besides sensing risks with thermal vision. Caterpillar, the heavy machinery company, uses AR technology to look at the machine and also instantly see a visual overlay that states when several mechanisms need to replace filter operations and how much fuel is needed. User booklets and technical papers are infamously tedious, so Bosch company incorporated AR to create overlay text, videos, and augmented 3D simulations over a piece of equipment.

9.3 Virtual Reality

With the continuous growth of virtualization, the number of connected devices with the Internet is increasing significantly. Since virtual reality (VR) shows great potential to revolutionize the market, compared with traditional video systems, VR has ultrahigh definition with apparent, dynamic changes that possess significant challenges for realizing such potential. Smart cities are highly involved with virtual reality technologies, and China has previously established VR-based smart cities with virtual and real-world guidelines for emergency department fire monitoring.

Simultaneously, Japan implemented the Tokyo virtual lab, which simulates traffic situations by integrating street and traffic information; moreover, it also assists the vehicle driver in critical situations.

9.4 Mixed Reality

Mixed reality (MR) combines VR and AR services to build physical, virtual objects that exist and intermingle in real time. Recent surveys concluded that companies' investment in MR would reach more than 4.4 billion dollars by the end of 2020. MR-based Microsoft HoloLens and wearable holographic computers are used in the education and training phases. With 3D modeling with MR, professionals can effortlessly shape their projects up in a shared virtual atmosphere. In healthcare, MR has numerous training and education applications like surgeries taught remotely by professionals as they do them in real time.

9.5 Smart Locks

IoT in smart home security has empowered operators to do away with traditional locks and make interest in smart locks. Since smart locks do not require any physical key to open, an alternative operator can open the doors with biometric info like iris scans, fingerprints, and face mappings.

9.6 Smart Factories

Smart factories involve enterprise asset management – IoT-based power-driven asset management increases operational efficiency, optimizes resources, and better controls the sales lifecycle, compliance procedures, and receptive bright atmospheres. WebNMS is an example of an IoT smart factory platform that affords energy managing to improve businesses' energy ingesting.

9.7 Intelligent Road Toll and Traffic Monitoring

With the accumulated data from the implanted sensors, cameras, traffic regulators, and IoT devices, we can effortlessly automate the timings of road traffic lights on busy roads and highways. IoT devices enable collecting road toll when a car enters into its zone and automatically lift the barrier after successful toll collection like fasting.

9.8 Smart Intelligent Grid

In electric power generation, IoT is used resourcefully to monitor the power generation of various power plants. Moreover, IoT-based schemes are effectively applied to observe substations, towers, electricity consumption, and dispatch lines. IoT devices also assist clients with intelligent meters by measuring different parameters and networks. High processing-capable IoT devices can enhance the intelligent grid performance in processing, disaster recovery, reliability, and warnings.

9.9 Intelligent Robotics

The Internet of Robotic Things (IoRT) has numerous applications and can analyze and optimize machine performances in real time from the data facts collected from intelligent sensors. Service and humanoid robots use logistics delivery, rescue, agriculture, security, health and defense, and entertainment. However, the recent pandemic crisis has shown that much more advances are needed in IoRT technologies.

9.10 Waste Management

Most metropolitan cities face waste management issues, one of the most inefficient actions in a city. The techniques used in waste management are not identical; IoT strategies can support municipal waste hoarders in monitoring their trucks' schedules, the volume of waste dumps, and the course's overall proficiency.

9.11 Near-Field Communication (NFC) Payment

Nowadays, every retail payment is made over NFC, since in NFC-based payments, the client/customer can use his/her NFC-enabled intelligent devices to make contactless payments. It reduces the time required to make the payment and increases the security and indemnity of payment.

9.12 AI-Enabled Internet of Underwater Things

IoUT (Internet of Underwater Things) with intelligent sensors and autonomous underwater vehicles are relevant to detect underwater treasure and enemy submarines. IoUT also assists in the detection of minerals, corals, reefs, and metals. In general, finding underwater resources requires sensors with video capturing devices that are fulfilled by IoT schemes.

9.13 Intelligent UAV

Because of the UAVs' high-range agilities and autonomy, they can offer a wide range of amenities to IoTs. UAV-based IoT schemes efficiently apply for crowded surveillances with face recognition and mobile edge computing with inadequate energy power and dimensions. Moreover, in auto spacing, UAVs with theory-based game platforms are highly applied for locating terrestrial stations. UAVs with AR/VR/MR technologies allow isolated operators to navigate in explicit scenes of interest. UAVs are also helpful in optimal clustering of IoT devices and reduces transmission power.

9.14 IoT-Based Forensic Applications

There are countless models implanted for IoT security and privacy with available resources; however, it is still an open research issue. Nowadays, a little focus shifted toward digital forensics in IoT. Since IoT security is still developing, there are high probabilities of breaches in IoT. Active digital forensics procedures must be established in equivalent with security explanations to track attacks and find reliable digital evidence to expose perpetrators. Inspecting the VitalPatch will disclose associated forensics objects of individuals like ECG trends, heart rate, activity monitoring, port scans, timeline logs, etc.

9.15 Intelligent Healthcare Systems Using IoT Systems

Wearable IoT devices allow constant monitoring of physiological constraints, which assist in ongoing health than fitness monitoring. Moodable is a mood-enhancing device to monitor and improve our mood in a day. In detail, moodable is a head-mounted wearable that sends low-intensity current to the brain, elevating our mood. Ingestible sensors – miniature-sized sensors – monitor the medicine inside our body and advise us if it notices any anomalies, which helps diagnostic patients with early warnings. Moreover, it is applicable in reducing emergency room wait time, enhancing drug management, tracking patients, and ensuring critical hardware staff availability.

9.16 Intelligent Disaster Management

Intelligent disaster management helps in minimizing potential damage from upcoming disasters. Besides, it confirms instant and suitable recommendations to the victims for fast regaining. Nowadays, the IoT skill has reached its advanced level and has probability to be very beneficial in disaster conditions. IoT system with satellite communication and geographic information arrangements helps in risk minimization. It suggests prevention, makes early warning, and utilizes social media to avoid awareness creation, relief and response measures, and missing person search.

9.17 Music

Up to date, most of the IoT applications are designed for environmental monitoring, industrial manufacturing, energy optimization, intelligent home automation, intelligent healthcare, and transportation. But in present day, it is gradually valuable for the music technology industry also. Google's Universal Orchestra and MIT's patchwork are some notable examples of IoT-based music innovations. SoundWire and JackTrip are some of the remote performances designed by well-known multinational companies, enabling instrumentalists in different locations to accomplish as if they were in a similar room. In rhythmic vibration, actuators collect data and then start to tremble with a rhythm and then intensity relative to that of the music playing, and this aids wearer to sense the rhythm of the music. With auto-tune instruments, instrumentalists can play tools over the allied device. The device is implanted with sensors that sense the traces on the screen of the devices. It then auto-initiates the similar movement on essential musical tools, letting instrumentalists play tools remotely over the device.

Different applications have been described in Fig. 7.

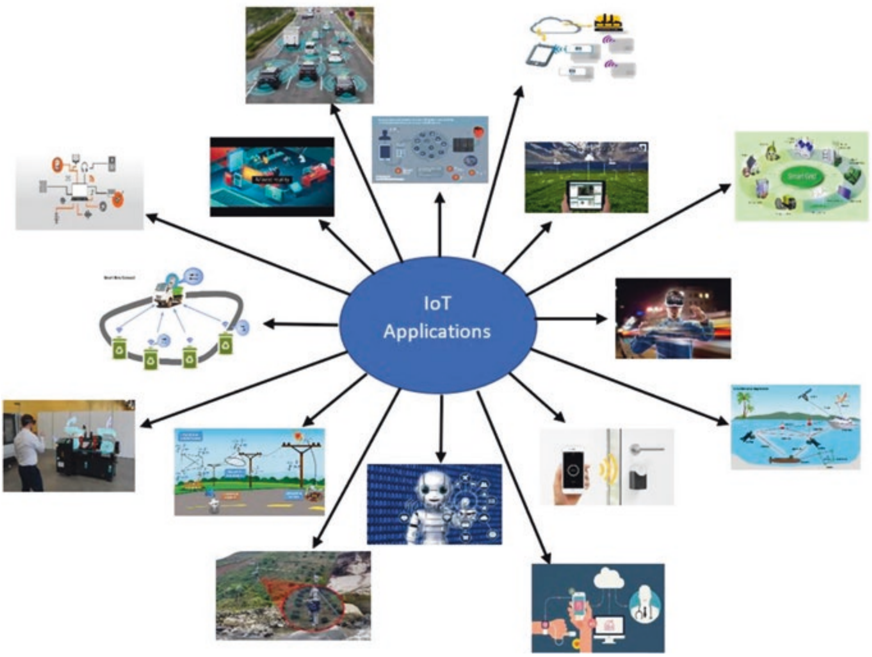

Fig. 7 Internet of Things application domain

10 Consumer Electronic Products for IoT

Product name	Product picture	Features	Applications	Limitations
Bit Defender Box	 *Source*: http://iotlineup.com/	Provides high-security solutions for scan and efficiently blocks incoming threats. It protects all our IoT devices, even when we go out! Acts as an intelligent wireless router	Smart home safety, smart automation network safety	Battery optimization Bugs, overreliance on technology
SmartMat intelligent yoga mat	 Source: http://iotlineup.com/category/iot_health_and_fitness	SmartMat notices when we are out of position and then gives us immediate advice on precisely our position	Health and fitness, exercise equipment, smart healthcare	Compatibility and complexity, cost, security
Lockitron Bolt – smart lock	 *Source*: http://iotlineup.com/category/iot_consumer_security_cameras	Provides home security with intelligent lock options when far away from our home environment	Home security and safety, home smart healthcare, consumer smart locks	Cost, integration, lack of connectivity standards
Philips Hue Hue Go	 *Source*: http://iotlineup.com/	It comes under an intelligent lighting scheme. It continuously changes the way we experience light with intelligent controls	Home energy management, home computerization, indoor lighting	Data breach, overreliance on technology, security
Airfy iBeacon for home automation	 *Source*: http://iotlineup.com/	It permits us to make our home smart using one or more Wi-Fi routers with optimal WLAN connections	Home automation, home appliances, robotics	Battery optimization Bugs, cost
Smart door locks	 *Source*: http://iotlineup.com/category/iot_smart_locks	It allows a console to open the door, wireless-based custom access codes for explicit members	Home automation, security, smart city	Compatibility and longevity

Product name	Product picture	Features	Applications	Limitations
Smart Bluetooth Trackers	 *Source*: http://iotlineup.com/category/iot_smart_locks	Smart Bluetooth-based devices, with the help of short-range indications, digitally tie necessary items to our smartphones. We will get an immediate alert (chirp, beep, bleat, or make noise) if you start to leave somewhat behind, and a moveable app will direct you back to the unstable object	Health and fitness, smart city, consumer smart locks	Lack of standards for authentication, data breach, connectivity issues
Smart bike tracker	 *Source:* http://iotlineup.com/category/iot_smart_locks	These devices track a bike's place and then send alarms if the bike leaves a nominated zone. In addition, smart locks also allow multiple riders to share a single bike	Home security and safety, home computerization, consumer smart locks	Need efficient results on ride analytics and crash alerts
Amazon Dash Button	 *Source*: http://iotlineup.com/IoT_home_applinaces	It is one of the finest inventions of IoT, which makes life simple and relaxed. It helps us make our orders quickly and correctly without missing and reorder from a high brand	Home security and safety, health and fitness	Overreliance on technology, security, cost
Ring Alarm Smoke and CO Listener	 *Source*: http://iotlineup.com/	It is a device that allows manufacturing companies to accomplish their carbon monoxide indicators with more comfort. It offers a warning when our smoke indicator alarms	Home security and safety, consumer appliances, home automation, consumer smart locks	Overreliance on technology, connectivity
WeMo Insight Smart Plug	 *Source*: http://iotlineup.com/IoT_home_applinaces	It is an IoT-based invention that aids us in regulating our lights and applications by revolving them on or off. It also creates guidelines, timetables, and energy consumed by our devices and helps us protect our home through providing the required information	Home security and safety, home automation	Data breach, compatibility, and complexity, cost, security