# A Review on Artificial Intelligence in Internet of Things and Cyber Physical Systems

**Anandakumar Haldorai**
Department of Computer Science and Engineering, Sri Eshwar College of Engineering, Coimbatore, India.
[1]anandakumar.psgtech@gmail.com

Correspondence should be addressed to Anandakumar Haldorai**:** anandakumar.psgtech@gmail.com

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**Abstract** – With the use of Internet of Things (IoT), businesses can easily collect real-time information on all physical components in their operations. The use of Artificial Intelligence (AI) is growing in IoT applications and businesses, signaling a shift in how these businesses operate. Across the globe, businesses are rapidly adopting IoT technology to develop cutting-edge products and services, therefore creating a novel market niches and strategic directions. IoT and CPS (Cyber-Physical Systems) integrated with data science could potentially stimulate the next generation of "smart revolution." The problem that emerges then is how to effectively manage big data engendered with less current processing capacity. This paper reviews the elements of AI, IoT and CPS, including the components of IoT-CPS as well as defining the relationship between AI and IoT-CPS. In the review, it is noted that AI is vital in many application scenarios, but there are problems associated with this technology in the modern world. To deal with problem in an AI-enabled IoT environment, a more reliable AI system should be researched and integrated in real-life applications.

**Keywords –** Artificial Intelligence (AI), Internet of Things (IoT), Cyber-Physical System (CPS).

## I. INTRODUCTION

Every new device will have some kind of interconnected intelligence, such as an intruder alarm that communicates with a phone. The term "Internet of Things" (IoT) [1] is used to describe all of these interconnected devices. There is no limit to the things that may be connected together, from machines and cars to home electronics and even furniture, clocks and humans. Artificial intelligence (AI) is a field of study dedicated to developing computer systems capable of thinking like a human making it possible for industry digitalization to grow at a faster pace. Everything in the planet, from people to animals to plants to machines to appliances to dirt to rocks to lakes to buildings, may become self-sufficient if they are all connected together and "smart judgments" are made about how to use that data.

Machine Learning (ML) [2] module, which enhances Data Analysis (DA) and human learning module are needed to create an autonomous environment, including its physical objects. DA would analyze/evaluate all forms of data created over a specific timeframe to potentially determine the previous data patterns and be more effective and efficient in the future, while ML would design effective approaches to aid the process of learning in different devices and components of the network to render them autonomous and self-reliant. There has been a recent upsurge in efforts to integrate DA and ML into the sensors of embedded system and smart systems. In that regard, it is fundamental to re-evaluate assumptions concerning the value and meaning of work and life in relation to the possibilities presented by underlying technological advancements of AI. With the rapid rate at which DA and ML are developing AI, it is important to consider and explore emerging opportunities and risks.

The Internet of Things (IoT) is a major driving force behind this development; it foresees a future where every available surface is covered in Internet-enabled, intelligent devices [also known as "Smart Objects" (SOs)][3] that are linked together via wireless protocols like Bluetooth, infrared, and Wi-Fi. Relationships between humans, between humans and physical objects, and between physical objects will all be possible via these links. Another related concept, "Internet of Everything" (IoE), holds that all physical and digital objects are interconnected in some way. A cyber-physical system (CPS) is the result of applying these ideas to the real world. Information would be abundant in such a world, making it possible to learn anything. It will be necessary for specialists in fields as diverse as Big Data Analytics (BDA) [4], Machine Learning (ML), Data Mining (DM), Pattern Recognition (PR) and Database Management Systems (DBMS) [5] to develop new methods to process data. The concepts of IoE, CPS and IoT are the primary focus of this article's discussion of AI's intuitive workings, difficulties, and potential applications.

Networked Cyber-Physical Systems (CPSs) [6] may be widely implemented in the future decades to meet global demands in sectors including energy, water, healthcare, and transportation. Intelligent CPSs combine control, communication, and computing into a single system, which is able to accomplish the deep integration and real-time interaction of computation, communication, and control thanks to the shared effect of cyber computing and physical process, which is founded on intelligent perception and cyber communication. In addition to enabling autonomous operation and coordinated effort across all parts of the system, it is capable of detecting and controlling the underlying physical mechanisms in a foolproof, dependable, efficient, and time-critical manner. Key technologies and products in the automotive, aerospace, national defense, industrial automation, healthcare, medical, industrial control, and transportation sectors are all benefiting from the exponential growth of CPS technology. However, CPSs feature a complex integration between their physical and cyber infrastructures. In addition, cyber acquisition, communication, computation, and control are profoundly intertwined, which poses significant obstacles to associated industries such as cyber assaults, high dimensional data catastrophes, communication network congestion, etc.

This paper reviews the concepts of AI, IoT and CPS, and discusses the components of IoT-CPS as well as defining the relationship between AI and IoT-CPS. To achieve this rationale, the remaining sections of the article have been organized as follows: Section II focuses on reviewing the concept of AI defining the aspects of (i) analytical concepts and learning, and (ii) intelligence or smartness. Section III focuses on IoT with concepts such as (i) Internet of everything, (ii) things and everything, and (iii) AI enabled IoT, discussed. Section IV focuses on CPS identifying it as an integration of a variety of disciplines. Section V introduces the components of IoT-CPS where a discussion of (i) smart objects, (ii) data processing and data storage, and (iii) communication networks, has been presented. In Section VI, the relationship between AI and IoT-CPS has been defined in discussion of (i) AI enabled IoT-CPS, (ii) Use cases of AI enabled IoT-CPS, and (iii) Cognitive AI and IoT-CPS. Lastly, Section VII presents a conclusion to the article as well as future research directions.

## II. ARTIFICIAL INTELLIGENCE

### *Analytical Concepts and Learning*

Artificial Intelligence (AI) is the study of making robots to behave like intelligent beings, allowing them to do jobs that were formerly thought to be exclusively human. The use cases, adaptability, processing speeds, and capacities of AI-based systems are expanding quickly. However, AI is only about "choosing" the correct option at the right moment, whereas human intelligence is genuinely about "taking" the ideal decision at the proper time. In simple terms, AI lacks the freedom of creative uncertainty that humans possess. While it may be claimed that human creativity would always play a key part in effective work, AI-based systems have ingeniously eliminated repetitive human labor and can provide outcomes in very little time. "Narrow AI" [7] describes the majority of current research in the field of artificial intelligence. This implies that technology is only useful for improving specific kinds of work.

The multidisciplinary aspect of AI has been bolstered by the contributions of experts from many fields, including philosophy, psychology, sociology, physics, biology, and statistics, mathematics, and computer science among others. The data from these fields has to be analyzed so that the underlying principles may be uncovered. The human brain can do this feat with relative ease, but it requires considerable time. This is due to the fact that real-world data has characteristics that are less than ideal, such as its massive size, lack of structure, variety of origins, need for near-real-time processing, and constant flux. AI may be seen as a set of methods for making effective use of data in a way that is comprehensible to the people who give it, adjustable (in the event of mistakes), relevant to the current context, and meaningful. Data science is the study of creating and perfecting tools and techniques for analyzing massive data sets for insights. Ideas for new tools often emerge from the field of computer science, where researchers focus on optimizing algorithms and creating scalable data storage systems.

Analytical concepts emerge from a much wider range of disciplines and fields of study: hard sciences (e.g., graph theory, physics, and statistics) as well as social sciences (e.g., sociology, political science, and economics). BDA, DBMS, DM, ML and PR are allwidely used in the field of data science. ML is one of the primary methods for achieving AI. Some learning issues are within the capabilities of the human brain. For instance, the abundance of optical neurons within the human vision framework allows for effortless detection of objects. Animals, plants, and other organisms besides humans are all capable of learning. Learning is something that all living things do, whether it is a bird teaching itself to fly, a youngster mastering language, a plant adjusting to its new surroundings, and so on. The capacity to absorb new information and adapt to new circumstances is crucial to our very existence.

Machine learning (ML) refers to the process of teaching a computer to learn and improve its own performance in ways that mimic human learning. Supervised, reinforcement, and unsupervised learning are the three most common approaches to learning (including ML). There are a variety of other approaches that may be used to acquire knowledge, such as transfer learning, deductive learning, inductive learning, active learning, and supervised learning. Some even try to emulate the natural selection and gradual improvement of living things by drawing inspiration from biology. The purpose of ML is not just to give machines the ability to think for themselves, but also to create algorithms that facilitate this process.

The term "learning" refers to the process of gaining or refining knowledge, which includes the acquisition of new behaviors, abilities, and values. Information synthesis may also be a part of this process. Learning can also be defined as a process through which systems adjust its settings to enhance its functionality in the future. In order for robots to simulate human learning, scientists developed a technique known as Machine Learning (ML). ML is a relatively new area of study in the field of computer science; it endows inanimate systems with the capacity to learn without the need for explicit programming. In IoT environment, where data's variety, volume, velocity, and complexity are all so great that a human programmer can't possibly supply explicit, fine-detailed requirements for carrying out the work, the notion of ML is developed to focus on implicit learning abilities that would allow a computer or system to ultimately learn to adapt to its surroundings and make autonomous judgments.

To make up for the lack of a true "smart" component in CPS or IoT, ML has emerged as a viable method for achieving AI, predicated on the ideology that machines have to be given accessibility to data for autonomous learning. Many academics have expressed confidence in the path humanity will take to develop AI that can effectively mimic human behavior. Without a doubt, we are making rapid progress toward that goal. We owe a great deal of the progress we've made in recent years to the radical shifts in our understanding of how AI operates, which have been driven mostly by ML. There is no reason not to give ML the credit for making machines intelligent.

### *Intelligence or Smartness*

The intelligence or smartness of the Internet of Things may be found at both the molecular and the systemic levels. Although these phrases may conjure images of talking refrigerators and driverless cabs from the distant future, they really represent much more. For the time being, data, devices, and connection are the primary concerns of SOs. Data analysis using BDA is a useful tool for uncovering previously unseen patterns and correlations in the data. At the end of the day, it is the analysis of ML of big data, which gives the system its intelligence. The scope of ML's influence on the concept of "smartness in robotics" is shown quite clearly in **Table 1**. It provides a small number of instances of animals whose intelligence has been mimicked by various artificial intelligence technologies.

These robots already do, or may soon be able to do, the same tasks as their animal counterparts, and share some of their traits. Research is helping these AI robots behave more like their live equivalent, but it has yet to replicate all of the traits of the living creature. It is clear that more work has to be done before robots can be considered "intelligent" in the same way that humans are. The driving principle behind ML is to allow algorithms to continually learn from available data and automate the analytical models. The timely processing of this information necessitates its storage or monitoring in some fashion. Although a large amount of data is being produced at any one time, not all of it will necessarily be of any value. The objective is to efficiently gather and analyze important data.

## III. INTERNET OF THINGS

Video chatting with friends on another continent was unthinkable even a few decades ago. However, it is quite standard practice these days. All of this is a result of technological advancements, both in terms of decreasing prices and the introduction of more capable equipment. Whether it is sending an email, paying a bill, transferring money, or booking a taxi, people can get things done using their smartphones. Internet of Things (IoT) has been in existence since 1991, and it has been growing ever since. As personal computers, tables, laptops and mobile phones become more accessible and affordable to the general public; the Internet of Devices emerged and expanded. According to research firm Gartner, Inc., the number of Internet-connected devices in use in the globe was expected to grow from 6.42 billion in 2016 (up 30% from 2015) to 20.82 billion in 2020 [8].

The potential for IoT is enormous, since >5.5 million new devices were linked every day in 2016. Due to the dynamic nature of the connections that comprise an IoT, several fields have begun to adopt it as their own [9]. As a result, the Internet of Things may also be seen as a fusion of several fields. The overlapping nature of IoT ideas and technologies is reflected in the variety of fields shown in **Fig 1**. The Internet of Things (IoT) is basically a network that links computers, smartphones, and other electronic devices to the real world. There is certain SOs on both devices that let people to communicate, receive, and analyze data, creating a two-way connection between the devices. In the network, these SOs stand in for the entity to whom they are connected (whether that entity is a person or an inanimate object).

### *Internet of Everything*

Most individuals cannot differentiate between the Internet of Things and the Internet of Everything. "The Internet of Everything" is the "intelligent linking of people, process, data, and things," as defined by Cisco. The IoE bridges the gap between the digital and the real worlds. It is not enough to enable machines to communicate with one another; we also need to pave the way for everything (whether biological, inanimate, or purely virtual) to discuss one another. As of now, IoT lacks this virtual object. While the Internet of Things (IoT) may comprise SOs (connected to real-world objects and people) and the internet backbone, it does not integrate intelligent non-Physical Entity (PE) (a virtual representation of a real-world object). Humans, physical objects, cyber objects, and physical objects may all link with one another, as well as humans and cyber objects. IoT and IoE are related but often interchangeable terms.

IoE has become a buzzword for describing the practice of adding intelligence and connection to previously unconnected physical or digital objects in order to endow them with novel capabilities. A website with embedded intelligence that can determine whether a user is being frustrated by an irrelevant ad or delighted by a flash sale is one such example. Imagine a website that adapts to each individual visitor, such that the same content is presented in a variety of formats depending on who is seeing it. With this transformation, in the not-too-distant future, it will also be possible to create internet-based facilities to allow those with physical impairments to reap the advantages of the Internet as well. Then then will the Internet's entire potential be realized. The internet is available to everyone and everything. Therefore, it is necessary to grasp the foundational ideas upon which the IoE and IoT rest.

*Things and Everything*

There has to be a crystal-clear understanding of what is meant by "things" and "everything" when discussing the Internet of Things and the Internet of Everything, respectively. It is easy to think of the idea that under IoT, the 'thing' is any item that can be linked to the internet. But our definition is the opposite way around. An item might have more characteristics than only its physical form. The 'thing' (whether biological or inorganic) needs (i) a means of producing or collecting data, (ii) a mechanism for processing that data, (iii) a channel via which to transmit or receive data, and (iv) a means of uniquely identifying itself. To understand what the Internet of Things really is about, it is important to keep in mind that "Things" are actual, material items. We cannot reduce the Internet we know today to a collection of physical devices. A webpage, for instance, cannot be considered a PE since it does not physically exist somewhere. This is especially true for frequently used services like social networking, online shopping, etc. These "intelligent services" and "objects" together constitute "everything." Thus, the IoE is comprised of the interconnection and intraconnection of physical world "things" and cyberspace "intelligent services" [10].

*AI enabled IoT*

The Internet of Things (IoT) is a significant idea that includes an overwhelming number of networked actuators, sensors, data processing, and data storage capabilities. Therefore, any device with IoT capabilities may collect data about its environment, transmit, store, and interpret that data, and then take appropriate action. The processing stage is crucial to the subsequent step of taking appropriate action. How much processing or action an Internet of Things service is capable of doing is a good indicator of how intelligent it is. An IoT system that isn't smart will have insufficient resources and won't be able to adapt to new circumstances. A better IoT system, nonetheless, will integrate AI and might accomplish the projected intent of automation and adaption. A small number of real-world applications of AI to the Internet of Things are addressed.

*Robots*

Advancements make in the past few years have been dedicated to robotics (such as those identified in **Table 1**) that look and behave more like people and can communicate with us using a range of human emotions. Robots are essentially self-contained IoTs due to the fact that they include a variety of sensors, actuators, and artificial intelligence that allows them to learn and adapt over time.

**Table 1.** Examples of robots constructed due to recent developments in robotics

| Robot | Brief Description |
|---|---|
| **Pepper from SoftBank Robotics: SoftBank** | Robotics' Pepper is a humanoid robot designed to interact with people. It can read human expressions, gestures, vocal inflection, word choice, and other cues to determine how a person is feeling. It recognizes happiness, sorrow, rage, and surprise and responds with appropriate gestures, touches, words, and on-screen expressions. It can navigate its environment and engage in conversation with nearby people and machines. Retailers all across the world use Pepper to communicate with their consumers. |
| **Sophia from Hanson Robotics** | This robot is a social humanoid robotic system with over fifty different face expressions. It can have a conversation with a person while looking them in the eye. For the first time ever, a robot named Sophia has been granted full citizenship in a nation. She has also participated in many interviews and performed at a concert. |
| **Robotic Kitchen from Moley Robotics** | Moley Robotics' state-of-the-art Robotic Kitchen is a fully functioning robot designed to work in a kitchen. It can make meals of professional quality from its integrated recipe database and has robotic arms, cooking system and touchscreen device that aid engagement with humans |

In order to function properly, these robots make extensive use of technologies like natural language processing, machine learning, object identification, tracking and detection, shape recognition, block-chain technology for evaluating inputs and outputs, voice identification, facial identification, obstacle identification, haptics, speech-to-text identification, etc.

*Voice assistants*

Voice-based cloud services provide customers with virtual desktop assistants. They use nearby smart devices and third-party apps to carry out a wide range of activities. They can do a wide variety of jobs in response to voice requests, including answering questions, contacting taxis, making dinner reservations, playing music, and controlling smart lighting. Only a small subset of popular voice assistants are (i) Amazon Echo, Amazon Tap, and other Amazon devices all have Alexa, the company's speech assistant. The Alexa Skills Kit (ASK)[11] is a group of pre-defined skills, which can be upgraded and customized with new features. (ii) Apple Inc.'s Siri is employed in the Apple Homepod [12], which performs a similar function. (iii) Google Home's version of the Assistant can distinguish between up to six people and get relevant information for each one during conversations. Various branches of AI have been used to create these voice assistants, making them versatile. Voice assistants are able to function in real time because of the continuous application of AI techniques such as autonomous far-field voice detection, speech-to-text conversation, wake word detection, natural language understanding and processing, dialogue management, contextual reasoning, conversational AI and question answering.

*Smart Devices*

Aside from voice assistants and robots, the IoT also includes SOs/devices (e.g., in **Table 2**)that aid people in their work. Applications such as computer vision, transfer learning, deep neural networks, expression and speech recognition, voice recognition, face recognition, and object detection are used by AI-enabled SOs.

**Table 2.** Examples of smart devices

| Smart Device | Brief Description |
|---|---|
| **Smart Oven by June** | By June, a smart oven should have been developed that can reliably prepare meals to perfection. It can monitor the food being cooked in an oven with the assistance of food thermometer and HD camera and alter cooking settings as needed. Alexa controls this oven, which learns the user's preferences to tailor an automated cooking routine to them. |
| **SkyBell by Honeywell** | Honeywell's SkyBell alludes to HD Wi-Fi doorbell, which lets you respond to visitors using your phone or a voice assistant. When someone rings the doorbell, the camera records their face and transmits a live stream to the homeowner's phone. SkyBelleven allows its user to have a conversation with someone when physically apart from them. To a certain extent, this has deterred would-be intruders and robbers. |
| **Smart Lights by Deako** | Deako's smart lights may be managed from afar using a smartphone and voice assistants like Alexa and Google Home. They are linked through the web, allowing for periodic software updates. |
| **Automotive AI by Affectiva** | Affectiva's Automotive AI is a sensing AI built for use in cars and can be installed in autonomous vehicles such as robo-taxis. By monitoring the passengers' facial expressions and vocal tones, the system can infer how they're feeling emotionally and mentally. |

*Industrial IoT*

In addition to its application in networked homes, IoT also offers vast potential in a variety of industrial settings. The products identified in **Table 3** analyze a firm statistically and financially and then make forecasts using AI and ML.

**Table 3.** Examples of industrial IoT products

| Industrial IoT Products | Brief Description |
|---|---|
| **Prime from Alluvium** | Alluvium offers industrial solutions, one of which is called Primer. On the basis of the acquired data, the sensors within a network, and assets, Primer produces a stability score assessment in real time. The system's goal is to foresee possible problems in advance, allowing operators to quickly spot abnormalities and implement the required fixes across a wide range of scales, from individual sensors to the whole facility. |
| **Plutoshift** | Plutoshift is an alternative IoT-based product for the business world. It helps industrial firms monitor their assets' performance in real time, determining the financial impact, and make informative decisions. |

Resultantly, when IoT and AI are used together, they may maximize each other's potential and benefit. Due to the increasing volume of data produced by the Internet of Things, ML and BDA hold the promise of discovering very valuable insights hidden within the data. The information generated by the IoT is meaningless without the assistance of AI. Data generated by IoT is too vast for human analysis, therefore the technology must rely on AI to sift through it and extract useful insights. Further, the machine will be able to learn independently in case a new format of data is identified, something that might be challenging for non-AI IoT systems.

## IV. CYBER-PHYSICAL SYSTEMS

As stated by Lee[13], HelenGill of the NSF (National Science Foundation) in the US first used the term "CPSs" about 2006. CPS are "engineered systems that are constructed from, and rely upon, the seamless integration of computer algorithms and physical components," as defined by the National Science Foundation. Current thinking is that it is a system that runs on and is monitored by computational processes (both within individual parts and throughout the whole), is well-connected via the Internet, and can be accessed by its users with relative ease. Wiener developed an automated aiming and firing system for anti-aircraft weapons during World War II. Even though he did not use any high-tech computers, his control logic was in essence a calculation, albeit one performed using analog circuits and mechanical components. This idea has developed out of an awareness of urgent need. Autonomous vehicles were the stuff of science fiction only a few decades ago, but now engineers are really building prototypes of fully autonomous vehicles with cutting-edge features that should significantly lower accident rates. Futuristic road networks might be able to connect with automobiles over the web and share data to aid in traffic controls, accidents, etc., further enhancing this idea. There is a possibility that they are linked to other public facilities like hospitals and police stations.

Today, CPSs emerge from the combination of elements traditionally separated by a communication framework, such as infrastructure, SOs, embedded computing devices, people, and physical surroundings. These systems include infrastructures where everything is connected to everything else, such as in a smart city, grid, factory, building, house, or automobile. They need to provide a scenario that is robust, versatile, effective, and economical. For instance someone gets injured in a car accident and is brought to the hospital, only to be told that they need to first file a police report or wait for police officers to come. If systems were linked together in any way, authorities would be alerted to the crash right away. There would be no delay in therapy since all the required steps would be completed immediately. However, this does not mean that the physical world should not also reflect such linkages. A traffic monitoring system, for instance, should link up with law enforcement and hospitals, but never with someone's private security setup at home. The potential for security breaches and additional strain on the database and the network infrastructure is increased by their integration. Therefore, it is essential that the connections between devices and systems be meticulously designed, taking into account all of the potential benefits and drawbacks. An autonomous platform that supports both individual items and the system as a whole is required to make all of these interdependencies and mechanisms function precisely and effectively.

### *CPS: An Integration of Disciplines*

In many scenarios, the CPS technology [14] originates in the business world, and it is this sector's contribution to the consumer goods market that drives the next wave of advancements. As a result, CPS relies on a foundation built from a plethora of different disciplines (e.g., in **Table 4**).

**Table 4.** A variety of CPS discipline

| CPS Discipline | Brief Description |
|---|---|
| **Machine Learning (ML)** | In order to make educated decisions in the future, without the need for constant human monitoring, the platform provides a means to study the system's tendencies based on data gathered in the past. |
| **Big Data Analytics (BDA), Data Science** | Over time, the large, linked system's accumulated data will be processed and analyzed to enhance its efficacy. To deal with the 'Big Data' problem, ML algorithms are often reworked. |
| **Cognitive Science** | The fields of psychology, philosophy, neurology, anthropology, computer science, and linguistics all play significant roles in cognitive science. Intelligence research focuses on the human brain and its capabilities. The objective is to comprehend how different kinds of organisms learn and use information. |
| **Design** | A reliable, fault-tolerant, and efficient architecture that links all the parts together as needed is essential for the system as a whole. |
| **High Performance/Cloud Computing:** | In most cases, the problems under consideration are either too complicated to be addressed on one commodity computer in a considerable duration of time, or else the resulting code is too difficult to understand due to a lack of resources (a lot of training data is required). These challenges may be overcome with the help of high-performance/cloud computing, which makes use of high-end or specialized hardware or accumulates the processing power from different units. Data must be sent to several units and related processes must be performed concurrently, making parallelism a necessary notion. |
| **Process Science** | Automation of manufacturing processes is becoming increasingly necessary across industries. |
| **Wireless Sensor Networks (WSN), Communications** | It would be impossible for the system to function without information being sent from one thing or system to another, and wireless communications between those objects or systems would be essential to this process. |

| | |
|---|---|
| **Software** | In order to function, every machine and system requires some sort of program or application. Application softwares like these would be designed with a particular platform or function in mind. |
| **Embedded Systems** | Embedded systems like cameras, thermometers, and other sensors would be present in the various gadgets and devices that make up a CPS. Depending on the use case, various embedded systems and sensors could be included in various gadgets. |
| **Mechatronics and robotics:** | These areas look for human-like behavior in order to accomplish a variety of goals. These won't need to be physically managed or given any predetermined instructions; instead, they'll be smart enough to know what to do when the time comes. |
| **Cybernetics** | There are ramifications for technological, organic, mental, and social structures. This field is in great demand since it allows any associated device to store, analyze, send/receive data. |

These potential disciplines for CPS are not all-inclusive. Given the multidisciplinary character of the study, many of the terms are interchangeable. In addition, more disciplines may work together in the future to develop CPS in some way.

## V. COMPONENTS OF IOT–CPS

Given our current understanding of the interconnected nature of IoT and CPS, it is the ecosystem that will have the most impact moving forward. Since CPS is itself a collection of smaller systems, we may focus first on the framework and constituents that make up the Internet of Things. It is clear from **Fig 1** that an IoT system consists of many different components. The Internet of Things necessitates data processing and storage on both a microscopic (i.e. local) scale and a macroscopic (i.e. system-wide) scale, in addition to network infrastructure and security (i.e. in every SO locally). SOs have to be equipped with data intelligence, decision-making, and data process capabilities. To make this possible, they should have inbuilt data processing models to evaluate the sensor information and data and possibly make an informed judgment. The main prospects for such sophisticated DA are machine learning and data analytics. Similarly, on a macro scale, more than a billion objects will create data autonomously, and this data will be transported across the network to distant data storage locations for critical DA, all occurring in real time.

A steady stream of information will be created, stored, and processed. It follows that the intelligence of the IoT will emerge as a result of the collaborative efforts of BDA and ML. It is possible for any SO to have restricted data storage and data processing capabilities. A smart watch may notify the wearer to get up and move about if they have been sitting or lying still for too long. On the other hand, it does not wake the person up when they are napping. When the user is asleep or sitting, it knows the difference. It can do this without sending the data to a distant server for processing. It takes in data and does some basic analysis in order to trigger the alert. An integrated smart gadget with the ability to make quick decisions is at your disposal. Remote data storage and processing may be required for use in long-term decision making or insight discovery. When an "everything to everything" link is made possible, the physical realm will be communicating with sensors and actuators, and the online realm will be inundated in information. It is safe to assume that the network will be quite intricate, and that data will be constantly being created throughout the CPS. Parts of the IoT-CPS will be managed by specialized analysis systems.

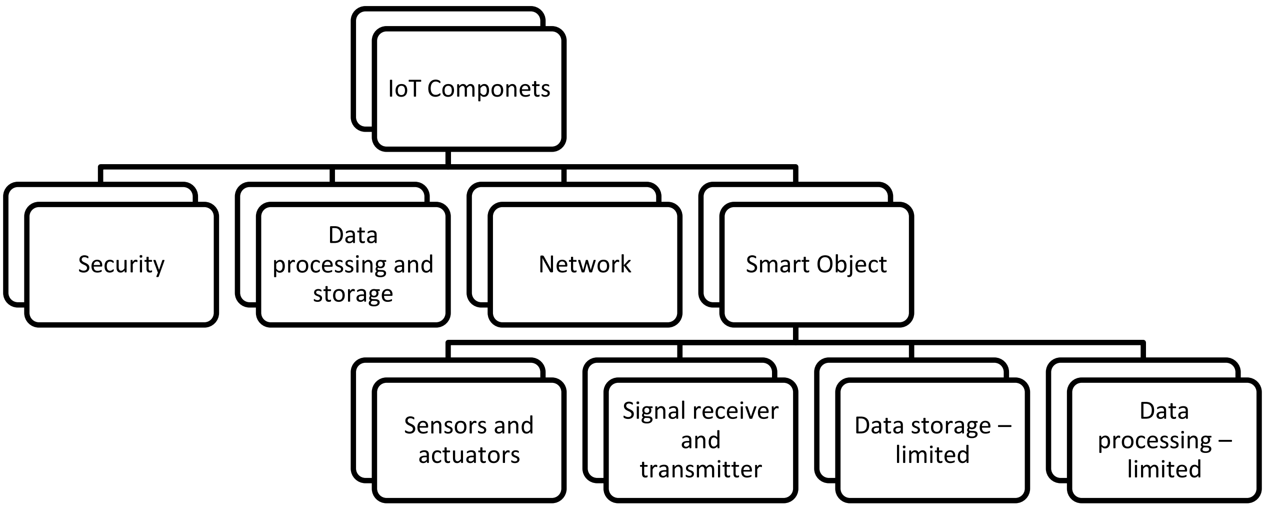


**Fig 1.** Structure of the IoT architecture

One central hub or single point of processing is not required for all data. Therefore, just the necessary data is taken and processed at the time it is required. Decisions may be improved with reasonable real-time analysis of the data. Each of the

IoT's constituent pieces plays a crucial role in creating and processing data, but the system as a whole is responsible for its overall operation. The next sections will go through some specifics of the IoT.

*Smart Objects*

It will take millions (or more) of data-generating SOs to catch up with such a massive idea. These components will serve as the system's foundation. There are two parts of the physical universe to think about: the PE and the SO. Any entity that is not capable of interacting with the IoT directly but is nevertheless essential to the system is considered a PE. Objects of this kind will have a SO associated with them. When it comes to artificial intelligence, these SOs are the network communicators. They may be anything that is linked to the PE in some way, such as an implanted chip, wearable device, or smartphone. Thus, a SO is defined as the hardware that facilitates a PE's connection to the "Internet of Things." Although the PE and SO are real-world items, the Internet itself is just a virtual concept. Therefore, it follows that a digital representation is necessary for them. The SO's digitized copy of the PE is the digital entity (DE). In this scenario, our smartphone (the PE) acts as the SO, and the social networking application (DE). In some cases, PE will be built into the SO itself, such an autonomous vehicle.

Physically embodied SOs can perceive, store, process (locally), and interact (through networking), much like their digital counterparts, Des [15]. Within the unified CPS, SOs have the potential to function as autonomous, self-governing agents, collaborate with other entities, and share data with human users and other computers. Deliberate Execution Element (DE) is a virtual programming element with independent goals. They might be any kind of service or they could just be cohesive data entry. A digital entity (DE) may act as a digital proxy for a physical entity (PE) in the virtual world (DP). Users in the virtual world may be thought of as DPs, and likewise, our online personas (DP) are thought of as being "us" (wherewe are the PE). All PEs are represented in the digital realm by their respective DPs. Digital representations (or DE) of PE may take many forms, including avatars, 3D frameworks (or instances of class within object-oriented programming languages), or social networking profiles.

However, DPs in the IoT environment have two primary characteristics: (i) There should be only one unique identifier for each DP. There has to be an automated system for linking the DP to the PE. (ii) Any variation in the former allows for a reload of the pertinent digital parameters relevant to the PE's properties. Alterations to the DP'might' also have an effect on the PE, which would be shown in the real world by means of actuators. Wireless technologies are required to transfer the data produced by these SOs, and the objects themselves must be easily identified. Using a distributed database, all data transmissions may be gathered, analyzed, and processed. The expansion of digital storage space will also be aided by the Internet of Things. Data analytics and Machine Learning (ML) are discussed once again because of the need to gather, transmit, and evaluate such enormous data in order to mine useful data in real time (see **Fig 2**).

*Data Processing and Data Storage*

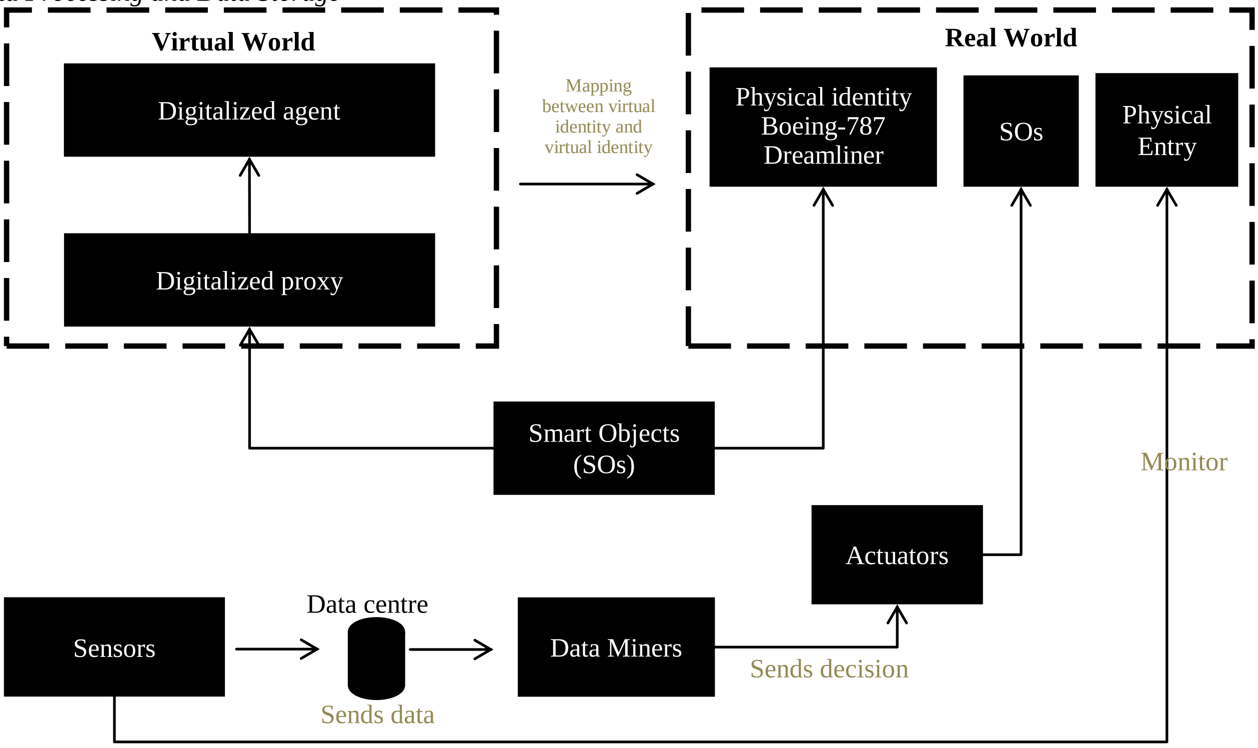


**Fig 2.** The mapping of the virtual world to the real world

The ultimate goal of CPS and IoT is to establish an autonomous model, which can adapt to a wide variety of conditions throughout the world and help people improve their quality of life. As nodes in a network, SOs makes up the building blocks of the IoT-CPS architecture, along with the edges connecting them. Assuming all the connections and nodes are in place, data is constantly being generated and transferred from a single node to the other. It is a mystery to the SOs, and they cannot figure out what to do with it. They have no way to store it, and they have no idea how to utilize it in any way, thus the system is rendered worthless. Lacking sufficient data storage and processing units would make it impossible to achieve the goals of autonomy, decision-making, and action-taking. This is a crucial component that should be provided both at the SO level and on a global scale for the whole system to function.

Whenever new information enters the system, it will be processed by the SOs and kept briefly there before being sent to the central repository. Rather of constant updates, the system's data storage may only receive huge, aggregated batches of data at regular intervals. BDA plays a significant part in the efficient real-time management and use of both forms of data. The data must be saved, however it is unclear what steps must be taken during data processing. We anticipate that an IoT-CPS will function independently, observing its environment (through various parameters), learning from its mistakes, assessing the current situation's requirements, and taking appropriate action. In order for an object/system to mimic human behavior, it must be able to learn from data without human interaction. Artificial intelligence (AI) makes it possible to accomplish all of these things efficiently.

### *Communication Networks*

Big data analysis is performed in real time across various systems, thus having a solid and dependable network infrastructure is essential [16]. Network service providers face substantial new hurdles when practically every tangible resource is virtualized. There ought to be cutting-edge wireless technologies that can accommodate this sudden influx of gadgets. Intelligent networks are required for intelligent devices. It is not a novel concept to have machines and gadgets linked to communication networks. Incorporating intelligence into both the devices and the network is what sets IoT apart as a technological breakthrough. This will enable networks that can autonomously determine whether or not a link between two items is necessary, and adjust the strength of that connection accordingly. Smart networks may also be secure in a clever way. They can quickly spot instances of theft or infiltration and take appropriate action. Many such talents have yet to be developed into useful tools.

The 5$^{th}$ Generation (5G) networks can possibly accommodate the requirements of IoT, including those that need to communicate over greater distances. These networks will be smarter and quicker, but it might be difficult to foresee the practical applications for such a large data transfer rate. For instance, a 5G-connected smart water heater may appear needless. Many of the devices that will join the IoT network at its peak have not yet been conceived of. It is possible, for instance, that our digital assistants are not really housed in our mobile devices and might be holographic projections that follow us around and are also online. The latest iteration of Bluetooth, Bluetooth Low Energy (BLE), is very efficient in its use of electricity. The BLE connection between the device and the smartphone allows for the transmission and reception of very tiny data packets. Therefore, Bluetooth connection seems to be a decent option for small devices, which are not being carried around in most cases, including those that may not have to be connected throughout the day.

On the other hand, BLE may not be the best option for long-distance reliable connections or the transmission of very large data. People who need wireless Internet access in such a setting often have just one logical option: Wi-Fi. Transfer rates of between 150 and 200 Mbps are typical, with a maximum of 600 Mbps. While this may be useful for file transfers, in the context of the Internet of Things (IoT), it is much too power-hungry. There are a number of alternative communication protocols that might serve as the backbone of the Internet of Things. There are a variety of wireless networking protocols in use, includingLoRaWAN, Sigfox, near-field communications, 6LowPAN, Z-Wave, and Zigbee.

## VI. AI & IOT–CPS

The 1$^{st}$industrial revolution, which occurred between 1760 and 1840, sped up the development of mechanical devices. The 2$^{nd}$ industrial revolution, which occurred between 1870 and 1914, helped propel society toward more wealth and increased urbanization. A "smart" or "cyber" revolution is happening right now. Smarter softwares, novel materials, agile robotics, revolutionary innovations (such as 3D printers), and a plethora of customized online services are all products of the convergence of several technologies and sciences [17]. This smart revolution is developing at a rate that is exponentially faster than the first two stages of the industrial revolution. The product sellers are under pressure to include AI into almost all of their strategies due to the increasing popularity of AI research and development. Nearly every company today has a massive trove of data at its disposal and relies on AI to help it put that information to good use.

### *AI Enabled IoT–CPS*

In the IoT-CPS context, there is an abundance of information, which is always there in the Internet of Things. The SOs should be endowed with some innate intelligence and the capability to do local processing on a limited scale. More data is needed, nevertheless, to make a conclusion based on evidence. Keeping this information in-house for analytical purposes is not always possible. This is where the macroscopic version comes into play, with data being exchanged and analyzed in a decentralized manner across several places. Once the results of the analyses have been combined, the final decision can be communicated back to the SO, from where actuators can carry out different functionalities. In case there is a significant amount of time between data transmission and putting decisions into actions, then the data is meaningless. The full significance of this vast data cannot be captured in real time by conventional analytic methods. Although the amount, velocity, and diversity of data are too great for complete analysis, the range of possible connections and correlations between diversified sources of data is significantly extensive for analysts to grasp manually. A modest ML framework requires (i) learning algorithm (advanced or basic), (ii) data transformation capabilities, (iii) adaptable and automation processes, (iv) ensemble modeling, (v) scalability, and (vi) decision-making in real-time, in order to cope with such large amounts of data.

The components of the IoT-CPS applications communicate with one another in a dynamic physical setting. Therefore, such a networked setting presents a formidable new invention with the potential to alter established businesses. Smarter, more linked versions of sectors including manufacturing, energy, emergency response models, agriculture, defense, vital infrastructure, buildings, transportation, healthcare, and so on will be upgraded. Assets in such organizations should be system-aware so they can predict when problems may arise. Devices becoming “system-aware” mean that they could detect both their immediate surroundings and the larger system in which they were embedded. To fully grasp the concept of a "bright planet," improvements in AI must be applied to a networked IoT-CPS situation.

*Cognitive AI and IoT–CPS*

There is more to the IoT than just the intersection of WSNs (Wireless Sensor Networks), embedded systems, security systems, and data storage systems [18]. Imagine a world where all of its inhabitants are linked together by some kind of artificial intelligence. This may seem fantastical, but it is just this kind of innovative interconnection that has made the Internet of Things so popular recently. Filtering the data via a series of predetermined criteria is the standard approach to dealing with programmable computing. To accomplish all that the Internet of Things promises to do, however, will not be a very efficient use of resources. The reason for this is because of their lack of adaptability, which hinders their ability to meet the needs of a more diverse and complex global community, where the information processing capacity continues to depreciate at an exponential rate while going mostly underutilized. Psychological frameworks, as opposed to integrating a variety of protocols, communicate and learn from the latent inter-linkage within the relationships with the environment, things and humans.

Accordingly, they are probabilistic rather than deterministic. This gives them the capacity to keep up with the unprecedented amount, diversity, unpredictability, and oddness of data being generated by the Internet of Things. We refer to these mental structures as cognitive computationmodels. These architectures are crucial components of the IoT-CPS AI. They can make sense of what scholars term the "unstructured" 80% of the world's data. Audio recordings, video clips, online diaries, photographs, emails, and tweets are all examples of unstructured data. This indicates that most organizations are prepared to bring into the light previously hidden components of the Internet of Things. This cognitive understanding, when combined with the Internet of Things, produces Cognitive IoT, which is defined as a model that integrates and learns from the physical world.

"Cognition" refers to the mental, sensory, and experiential steps involved in gaining information and insight. Therefore, it makes sense to think of cognitive IoT as an expansion of IoT that can comprehend, reason, and learn [19]. When comparing human intelligence with cognitive IoT, the meanings of these three components of cognition are different. 'Understand' in the context of the Internet of Things refers to the capacity to ingest vast quantities of data from the network and deduce their significance. It would have the ability to form ideas, recognize different things, and establish connections among them. An IoT that can "reason" is one that can identify applicable solutions to issues and answers to questions without being to be expressly coded. Lastly, a cognitive IoT has to "learn," or draw its own conclusions about the world based on the information it has already accumulated [20].

**Table 5.** Use cases of AI enabled IoT-CPS

| AI enabled IoT-CPS cases | Brief description |
|---|---|
| **Energy Utilization** | Small-scale algorithms have been created for the purpose of decreasing the coffee machine's energy usage (ARIIMA). It may be adapted and used in different contexts to lessen energy use; for instance, in residential temperature control systems to improve efficiency and cut down on waste. The system will learn how to effectively change the temperature in each home to the preferences of its inhabitants. |
| **Traffic/Routing** | One area of application for ML is traffic management and routing. You'll be given suggested routes based on a variety of factors such as traffic, road conditions, weather, and more. |
| **Cost Savings** | The ability to predict outcomes is very valuable in a manufacturing scenario. Machine learning computations may learn typical operating conditions by accumulating data from various sensors in or on machines. As a result, it can pinpoint the device if anything goes wrong and sound an alert. Doing so would prevent mishaps and save money. One company, Augury, does this very thing by installing ultrasonic sensors and vibrations in their machinery, which allows them to save money by anticipating potential breakdowns. |

*AI-Enabled IoT–CPS Application Scenarios*

Robots are not built to overtake the human intelligence, but rather to facilitate their work by lightening their load. The necessity for human beings to keep their advantage over robots is self-evident. When combined with human intellect, AI is at its most powerful. It emphasizes the concept that computers and humans each have their own unique areas of competence, with the former excelling in arithmetic and counting and the latter excelling at logic and reasoning. Complementing one another rather than being incompatible, these varying intelligences are fascinating and useful in their own ways. This means that AI is the technology, which should be considers as "thinking things" a reality. **Table 5** presents some specific use cases of AI implementation and usage in an Internet of Things and Cloud-Provided Services (IoT-CPS) context.

In the application scenarios above, the world projects an "Internet of Things" in which "the Internet" and "the Things" each possess the capacity for independent thought. In this process of mental inculcation is where the 'intelligent' aspect of the Internet of Things rests. Despite the fact that this seems considerably exaggerated, this is the focus of upcoming AI studies.

## VII. CONCLUSION AND FUTURE RESEARCH

Intelligent homes, intelligent textiles, intelligent pharmaceuticals that determine how their contents will affect the body, and so on are all projects for the near future research. The researchers from every field will work together to create a smart cyber network of interconnected things. However, the question of whether or not we are on the verge of a creative disaster remains a prevailing concern. Inevitably, as an increased number of AI systems are released into the society,we will have to reconsider how the widespread use of computers is changing the quality of human existence. While these systems have many positive outcomes, they also increase the knowledge imbalance between data producers and data holders, increase the possibility of privacy breaches, and increase the codification and entrenchment of prejudices. This is because there are increase cases of variety and complexity in the IoT-CPS. In the future, it will be difficult to keep track of every case of unethical behavior or violation of security. These negative outcomes are expected if either the software or hardware fails or has defects. To deal with these outcomes in an AI-enabled IoT, another reliable AI system should be integrated. In that case, future research should focus on determining the development of a novel AI-enabled IoT system, which is reliable and able to reduce the issues of software and hardware failures in the future.

### Data Availability

No data were used to support this study.

### Conflicts of Interests

The author(s) declare(s) that they have no conflicts of interest.

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### Ethics Approval and Consent to Participate

The research has consent for Ethical Approval and Consent to participate.

### Competing Interests

There are no competing interests.

### References

[1]. G. Bigini, V. Freschi, and E. Lattanzi, “A review on Blockchain for the Internet of Medical Things: Definitions, challenges, applications, and vision,” Future internet, vol. 12, no. 12, p. 208, 2020.

[2]. M. Pota, G. Pecoraro, G. Rianna, A. Reder, M. Calvello, and M. Esposito, “Machine learning for the definition of landslide alert models: a case study in Campania region, Italy,” DiscovArtifIntell, vol. 2, no. 1, 2022.

[3]. P. Visconti, G. Giannotta, R. Brama, P. Primiceri, A. Malvasi, and A. Centuori, “Features, Operation Principle And Limits Of Spi And I2c Communication Protocols For Smart Objects: A Novel Spi-Based Hybrid Protocol Especially Suitable For Iot Applications,” Int. j. smart sens.intell. syst., vol. 10, no. 2, pp. 1–34, 2017.

[4]. I. K. Nti, J. A. Quarcoo, J. Aning, and G. K. Fosu, “A mini-review of machine learning in big data analytics: Applications, challenges, and prospects,” Big Data Min. Anal., vol. 5, no. 2, pp. 81–97, 2022.

[5]. K. Mershad and A. Hamieh, “SDMS: smart database management system for accessing heterogeneous databases,” Int. j. intell. inf. database syst., vol. 14, no. 2, p. 115, 2021.

[6]. U. Baroudi, M. Aldarwbi, and M. Younis, “Energy-aware connectivity restoration mechanism for cyber-physical systems of networked sensors and robots,” IEEE Syst. J., vol. 14, no. 3, pp. 3093–3104, 2020.

[7]. J. Y. Chang, “Artificial intelligence-based colorectal polyp histology prediction using narrow-band image-magnifying colonoscopy: a stepping stone for clinical practice,” Clin. Endosc., vol. 55, no. 5, pp. 699–700, 2022.

[8]. W. Kenton, “What is the Internet of Things (IoT)? How it works and benefits,” Investopedia, 17-Sep-2014. [Online]. Available: https://www.investopedia.com/terms/i/internet-things.asp. [Accessed: 23-Nov-2022].

[9]. L. Rainie and J. Anderson, “The Internet of Things connectivity binge: What are the implications?,” Pew Research Center: Internet, Science & Tech, 06-Jun-2017. [Online]. Available: https://www.pewresearch.org/internet/2017/06/06/the-internet-of-things-connectivity-binge-what-are-the-implications/. [Accessed: 23-Nov-2022].

[10]. “Instrumentation of the environment: A design for connecting cyberspace with physical infrastructure for intelligent network flows,” in Service Science, World Scientific, 2009, pp. 213–241.

[11]. S. Rozga, "Applying our learnings: Alexa skills kit," in Practical Bot Development, Berkeley, CA: Apress, 2018, pp. 591–640.
[12]. P. Dempsey, "The teardown: Apple HomePod," Eng. & Technol., vol. 13, no. 4, pp. 84–85, 2018.
[13]. E. A. Lee, "The past, present and future of cyber-physical systems: a focus on models," Sensors (Basel), vol. 15, no. 3, pp. 4837–4869, 2015.
[14]. B. Dafflon, N. Moalla, and Y. Ouzrout, "The challenges, approaches, and used techniques of CPS for manufacturing in Industry 4.0: a literature review," Int. J. Adv. Manuf. Technol., vol. 113, no. 7–8, pp. 2395–2412, 2021.
[15]. P. E. Rybski and W. D. Smart, "Introduction to the special issue on the science behind embodied AI : The robots of the AAAI competition and exhibition," Auton. Robots, vol. 22, no. 4, pp. 321–323, 2007.
[16]. T. Reis, T. Funke, S. Bruchhaus, F. Freund, M. X. Bornschlegl, and M. L. Hemmje, "Supporting meteorologists in data analysis through knowledge-based recommendations," Big Data Cogn. Comput., vol. 6, no. 4, p. 103, 2022.
[17]. A. Sharma*, Research Scholar, Department of Mechanical Engineering, MMDU Mullana, Haryana, India., B. J. Singh, and Professor, Department of Mechanical Engineering, MMDU Mullana, Haryana, India., "Evolution of industrial revolutions: A review," International Journal of Innovative Technology and Exploring Engineering, vol. 9, no. 11, pp. 66–73, 2020.
[18]. A. A. Baradaran and F. Rabieefar, "NEMOCED: New energy model and optimal cluster estimation based on density to increase lifetime in wireless sensor networks," Int. J. Wirel. Inf. Netw., 2022.
[19]. M. Rossi, G. D'Avenio, S. Morelli, and M. Grigioni, "Augmented Reality App to improve quality of life of people with cognitive and sensory disabilities," in 2020 IEEE International Workshop on Metrology for Industry 4.0 &IoT, 2020.
[20]. M. Hossain and J. Xie, "Third eye: Context-aware detection for hidden terminal emulation attacks in cognitive radio-enabled IoT networks," IEEE Trans. Cogn. Commun. Netw., vol. 6, no. 1, pp. 214–228, 2020.