# Industry 4.0 Significance and its Applications

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## Abstract

**Abstract.** The Industrial Internet of things is getting more attention nowadays both from academia and industry. IoT would help in connecting objects to the internet. Here the object may mean differently in different domains. In the context of the manufacturing domain, the Industrial Internet of things (IIoT) would help in connecting all elements including different types of machines and material handling devises used in product manufacturing. IIoT may be defined as a set of interconnected intelligent machines with reduced operational cost and capable of monitoring on their own. IIoT is also known by other names such as Industry 4.0, Industrial IoT, and Smart manufacturing. IIoT not only would help in connecting machines through the wireless network but also enable machine-machine communication with minimum human intervention. IIoT would make use of sensors for collecting data about product manufacturing. IIoT is capable of handling modern-day complex business processes. Industrial Internet (IIoT) provides better visibility in terms of understanding operations of the company by making use of sensors, hardware, software, and the cloud. Improved decisions are possible using IIoT, hence many industries have started implementing IIoT. The main objective of this article is to review existing technologies, identify gaps and provide direction for further research.

**Keywords**
Industry 4.0, Smart Healthcare, Smart Manufacturing, Smart city, Smart surveillance, Smart agriculture

## 1 Introduction

Many Industries predict that there is a bright future for IIoT. The industries have already started working at a high pace for harnessing the full potential of IIoT. However, IIoT is still in its infancy. Though many industries have started implementing IIoT, they are facing huge challenges. To become successful, they have to overcome these challenges. Also, for becoming successful, a complete understanding of IIoT is required. One of the challenges in IIoT is to get data from different types of sensors and also their organized storage. Also, the large amount of data generated during manufacturing can be used by IIoT devices for reducing the cost of production thereby improving the productivity of the organization. Thus, IIoT is a subset of IoT but the focus is on manufacturing a product safely, efficiently, and meeting customer expectations. IIoT implementation typically involves applications such as machine learning, edge computing, cloud computing, etc.). Thus, IIoT has the objective of making intelligent decisions for serving people working in the industry as well as help in meeting customer expectations.

According to one survey, 70 billion devices will be connected through the internet by 2025 and their market share will be around 14 trillion US Dollars.

Before implementing IoT technologies, certain points will have to be understood- IoT technologies have made efficient usage of raw materials in product manufacturing, there is a possibility of large amounts of electronic waste generation due to IIoT implementation, IoT implementation may result in the reduction of labor which is the biggest social challenge, The effects of IoT devices in the long term needs further exploration. Also, these devices consume lots of energy both during manufacturing and operation.

For improving quality of service (QoS), IIoT may use a trust-based communication protocol. This would ensure higher transparency and achieve pre-defined service levels. Many researchers have been working on creating a smart grid. A grid will have many elements such as users, cloud (collection of data centers), wireless sensor network (WSN). A WSN may have a humidity sensor, temperature sensor, motion sensor, video sensor, etc. Researchers are working on creating a smart grid with supervisory control and data gathering networks with an optimum number of trust nodes.

Many of the IIoT implementations have three-layered architecture (Figure 1): Application layer: The type of service provided by the application layer varies with the application; Network layer: It carries data from a layer to another layer. The layer uses Blockchain technology, an Intelligence Intruder detection system, Key management, an encryption system for enforcing security; Edge layer: Using this layer, IoT devices can interact with their clients such as sensors, smart meters, etc. Since, this layer being exposed physically in the IoT architecture, the layer is subjected to several attacks. This layer is protected by using security components such as a multi-factor authentication mechanism, endpoint anti-malware solution, secure channeling, etc. In this context, the proposed work assumes special significance.

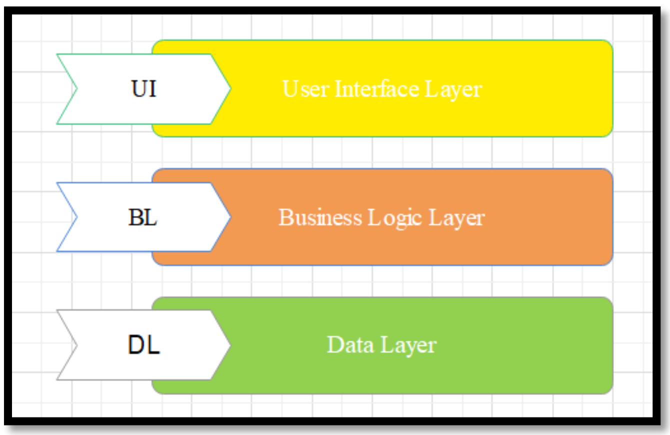


Figure 1. The architecture of IIoT implementation

## 2 Literature review

An attempt has been made in the following paragraphs to elaborate on the IoT benefits and challenges in different domains. IoT technology has made it possible to work together with computer systems, networks, and physical objects and has given rise to Cyber-physical systems (CPS).

### 2.1 Camera networks

Camera networks (Figure 2) are required for robots for 3D object recognition purposes. Normally, a robot equipped with a single camera may find it difficult to properly recognizing a 3D object. This is mainly due to improper lighting, improper camera orientation, occlusion, etc. Thus, the quality of a 3d-object recognition system can be enhanced by having an IoT-based multi-camera helping or supporting each other. Wireless sensor network (WSN) is the major element of IoT. Nowadays, the data handled by these WSN is increasing and hence collection and analysis by a single wireless node are becoming more difficult. Moreover, the power and bandwidth of these wireless nodes are limited.

Many researchers have started working on this problem. During the 3D object recognition system proposed by (Shuang Liu et al.,2020), local nodes are made responsible for making local decisions. So that, all original data need not be transported to a single decision node. However, all local decisions made by nodes will be taken to a fusion decision node where a final (best) decision will be made. This results in less power and bandwidth requirements by the fusion

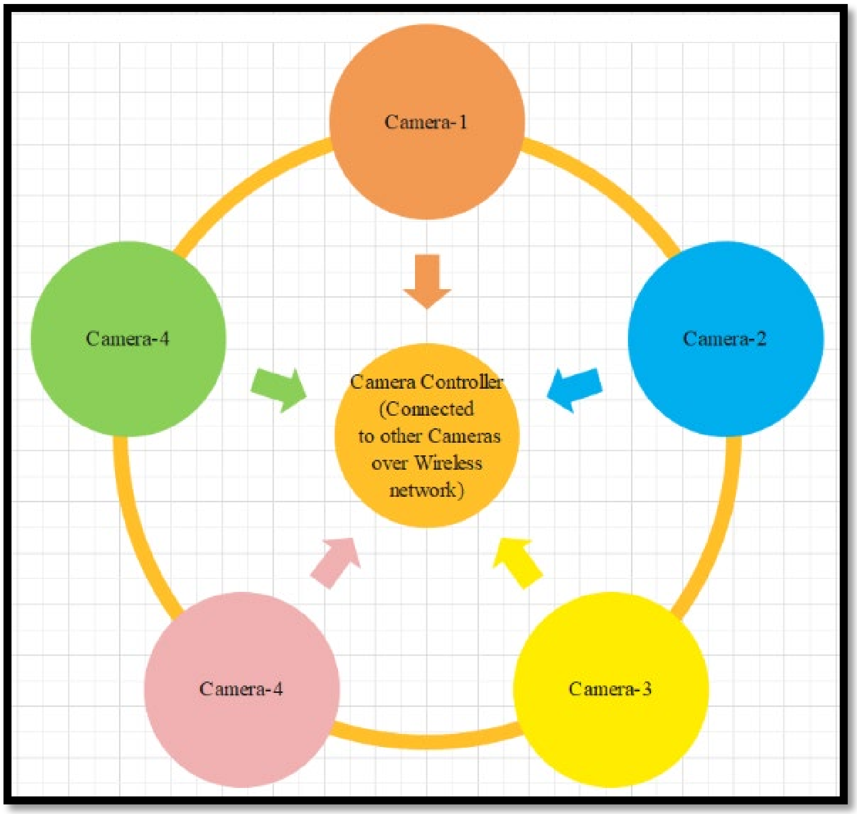


Figure 2 Camera network architecture

node. All local nodes make decisions based on the collected data. These decisions are known as local decisions. The best decision will be made by the fusion node after considering all local decisions. This is the best example of data fusion. They have observed that data fusion has helped in enhancing object detection accuracy.

### 2.2 Healthcare

As per the United Nations, the population of elderly people will be about 2 billion by 2050 and significant changes are required in healthcare for meeting the challenges (WHO 2015). Many of them will be suffering from chronic diseases (e.g., Diabetes, Respiratory diseases, cardiovascular diseases, etc.). Health monitoring systems (HMS) and Health Smart Home (HSH) are applications that provide monitoring based on situation, for meeting the needs of elderly people. Implementation of these technologies faces many challenges (Figure 3). The challenges are - environment monitoring by remote fashion, availability of intelligence system, availability of situation-dependent services, etc. Presently, in the sensor network, several devices and data rates are identified depending on the application in hand. Selection of multi-media devices is constrained by cost and privacy (Mshali Haider et al. 2018, Bisio et al.2019). Health monitoring systems (HMS) and Health Smart Home (HSH) use either centrally controlled or controlled locally. In systems using a centrally controlled fashion, the centrally located node is functional for the capturing of data from the different nodes available in the network, providing the necessary treatment, etc. Many health care systems make use of centralized architecture (Mshali Haider et al.2018). But, when the volume of data involved becomes huge, responding in real-time is a challenge (Carnevale Lorenzo et al. 2019). Raiche Michel et al. (2012) have proposed an HSH application, which makes use of distributed architecture using service-oriented architecture. This will determine the optimum context-aware sensing based on the activities of people (Mshali Haider et al.2018).

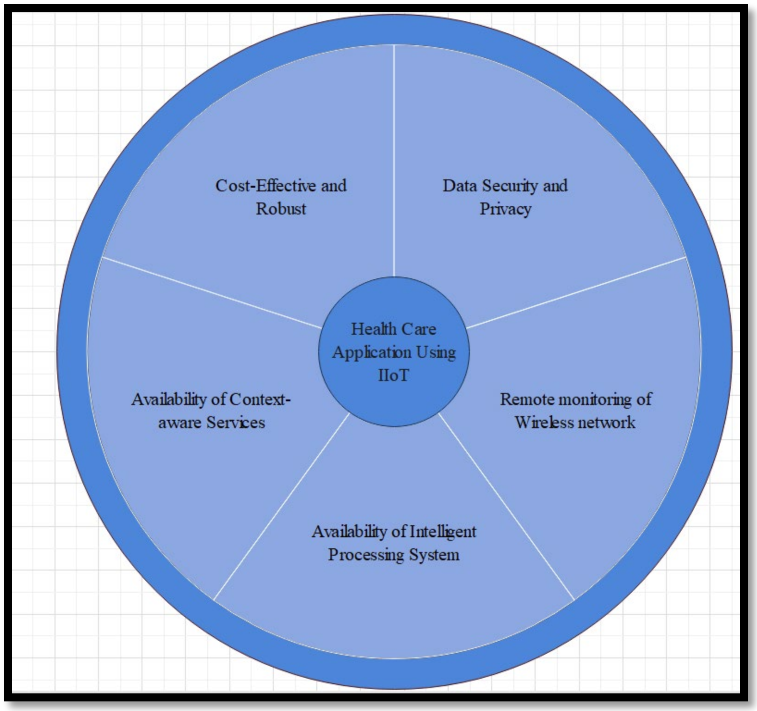


Figure 3 Challenges in IIoT based health care applications

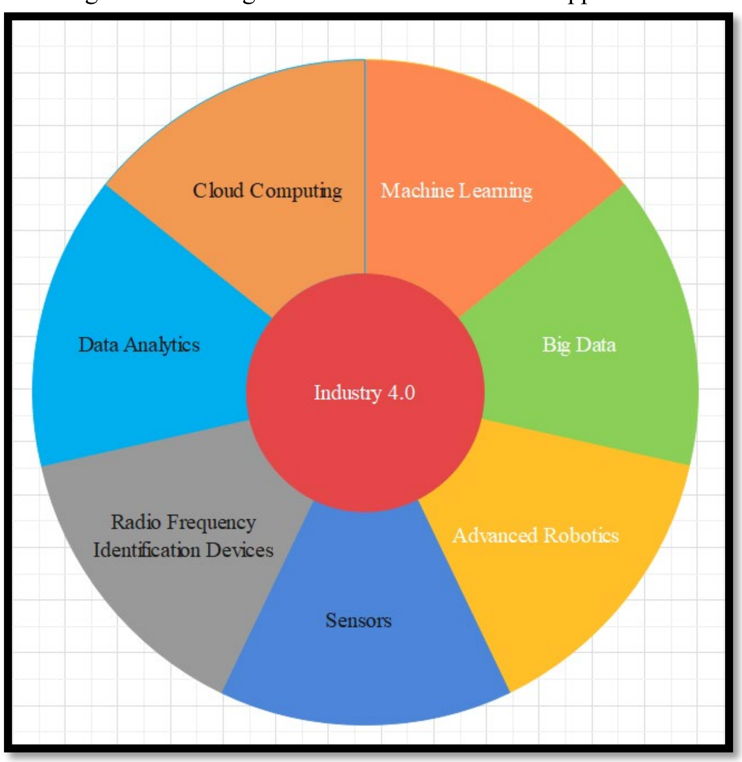


Figure 4. Industry 4.0 Technology- Components deployed in smart factories

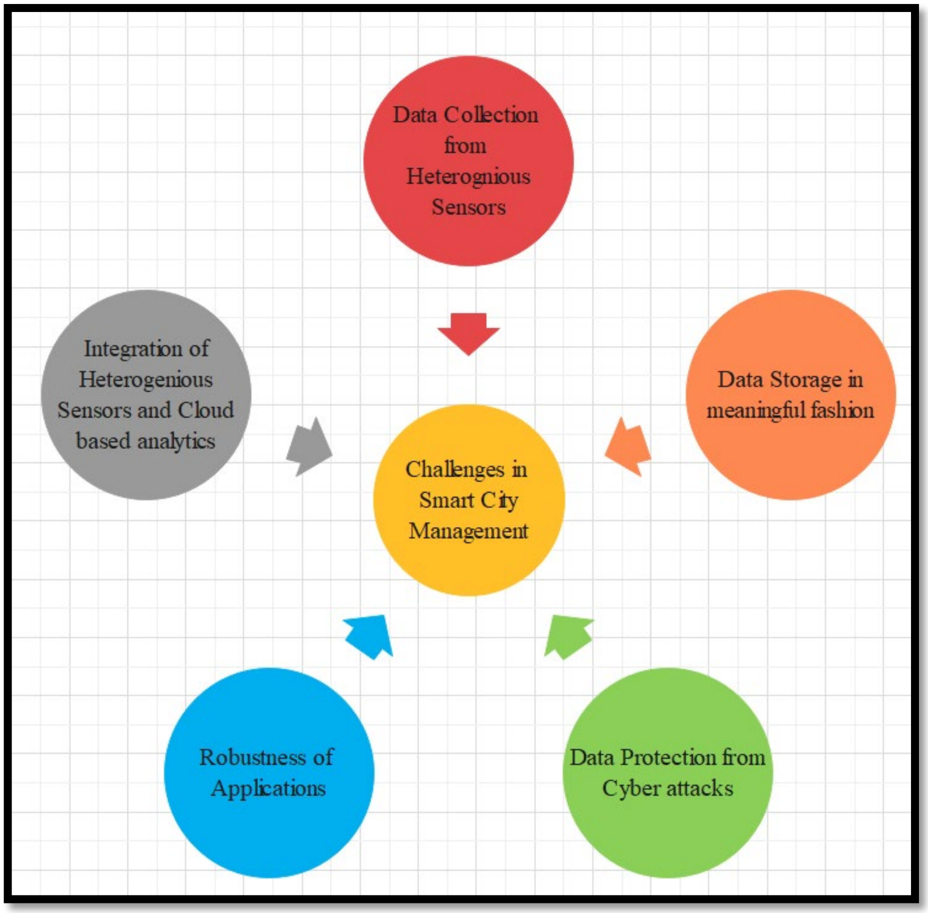


Figure 5. Challenges in Smart City Management

### 2.3 Smart factories

Smart factories are made by using Industry 4.0 (Figure 4) technologies. Integration of real-world objects such as machines with networks and virtual world objects has resulted in cyber-physical systems. In a smart factory, all smart objects (e.g., operators, equipment, material, etc.,) interact promptly for achieving the organizational objectives (Zhong et al.2015). Cloud services realize product manufacturing as a service available over the Internet (Da Xu et al. 2014). RFID as a component of IoT are used for object or asset tracking both in manufacturing as well as logistics operations (Zheng et al. 2018, Wang et al.2016, Tsai et al. 2018). RFID technology is making it possible for tracking objects in real-time (Hofmann et al. 2017, Bagdadee et al. 2020, Biresselioglu et al. 2020, Bielski et al. 2020). Thus, it helps all the elements of the supply chain to receive updates and be in synchronization.

### 2.4 Smart cities

By the year 2050 greater than 68% of the global population live in cities (United Nations, 2018). This will cause multiple challenges including providing an excellent living experience for citizens. This highlights the importance of smart city management. With the introduction of Big Data and IoT technologies researchers are trying to make use of these technologies in solving different problems associated with smart city management (Asri et al.2019, Al-Ali et al. 2017,Alletto et al. 2015, Bhagya et al. 2018). The smart city management system will do data collection and processing by making use of IoT technologies (Abdmeziem et al.,2016, Al-Masri et al. 2018, Bose 2017). The main advantage of IoT technologies is that they transform physical objects into intelligent devices capable of exchanging information and taking decisions on their own without the intervention of human beings. In a smart city project, sensors will be installed in a different area of the city and hence this causes enormous data collection from these sensors (Duarte et al. 2013). One of the biggest challenges (Figure 5) here is that the captured from these heterogeneous sensors will have to be collected and stored in an organized way before processing and analysis (D'Oca et al.2015). The advent of a vast amount of data has caused the emergence of machine learning, as well as real-time data analytics, which is becoming more popular (Zhao et al.2015).

### 2.5 Smart surveillance

Many smart city projects use IoT technology mainly in (i)fire detection (Ruihang et al.2020) have collected fire images and videos from standard data sets for analysis (ii) accident prevention: (Varun et al.2020, Ajanovic et al. 2019) have studied the accidents records from Beijing, containing time and coordinates of accidents, for predicting accidents. They have used spatial-temporal models for predicting accidents and warnings (Figure 6) and advising people in crowded areas.


Figure 6. Challenges in Smart Surveillance systems.

### 2.6 Smart agriculture

Several IoT-based applications are developed for meeting many agricultural requirements (Angelita et al.2020). Many researchers have worked on predicting diseases in plants by using IoT-based applications. This would certainly help the spreading of the disease (Thorat et.al.2018). Thorat et al. (2018) have studied by collecting leaves of many plants. They captured images of these leaves and did disease prediction by using a convolution neural network (CNN). They have reported good accuracy in prediction. IoT based application also helps in counting which is useful in agriculture. Fruit counting is one area where IoT is being used and high accuracy is (Hassina et al.,2020, Aazam, et al. 2018, Abdou et al. 2019).

### 2.7 Smart environment

A smart city aims to provide a clean environment to the citizens. A clean environment includes considering the following factors.

*Air quality monitoring*

Nairui Liu et al. (2020) have used RNN models for the accurate prediction of air quality classification. They compared their classification results with that of the support vector method and random forest method. They claimed the approach gave better accuracies than possible with existing machine learning techniques.

*Garbage detection*

Smart cities require efficient garbage detection methods because manual methods are time-consuming and inefficient. Many researchers have worked on smart garbage detection methods for both identifying, classifying, and subsequent removal of waste (Minhaz et al.2020). CNN DL-based applications (Figure 7) are efficient in detecting garbage in city areas and getting rid of waste.

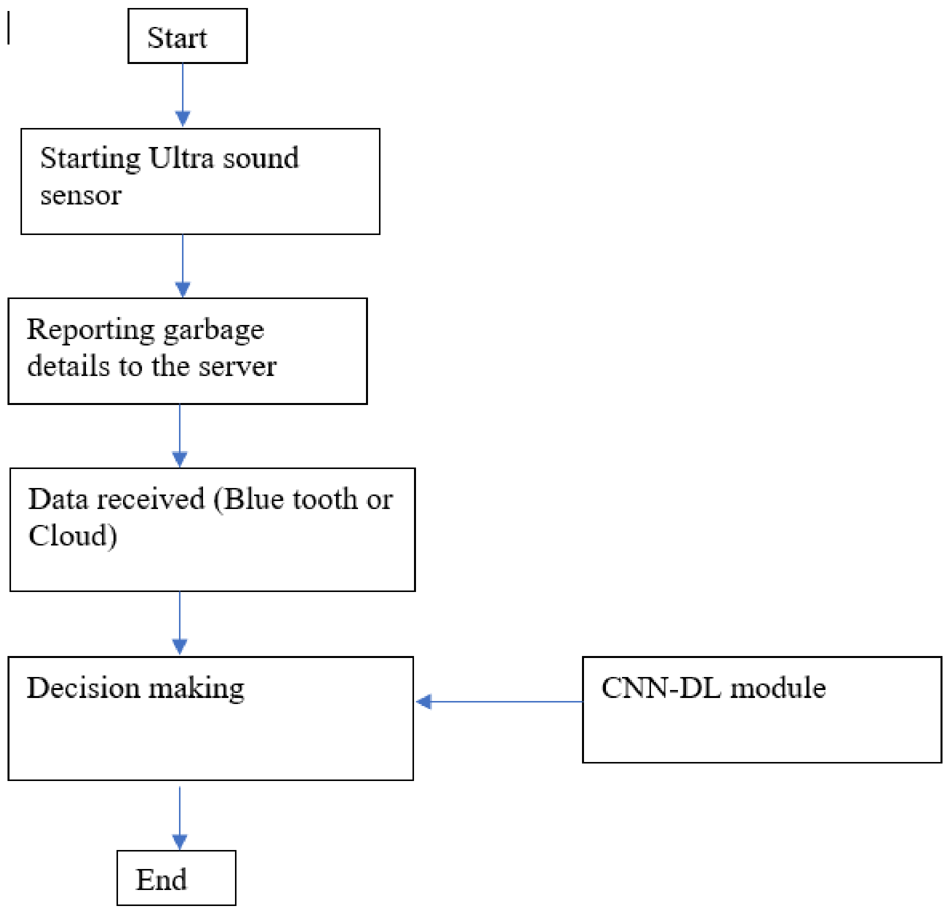


Figure 7. Working principle of a Garbage detecting system

### 2.8 Smart parking

Smart parking would help city dwellers in parking their vehicles quickly and easily (Muhammad et al. 2021, Brincat et al. 2019). They proposed a smart parking solution that makes use of a set of camera and CNN-based algorithms. Figure 8 shows the modules of a smart parking facility application.

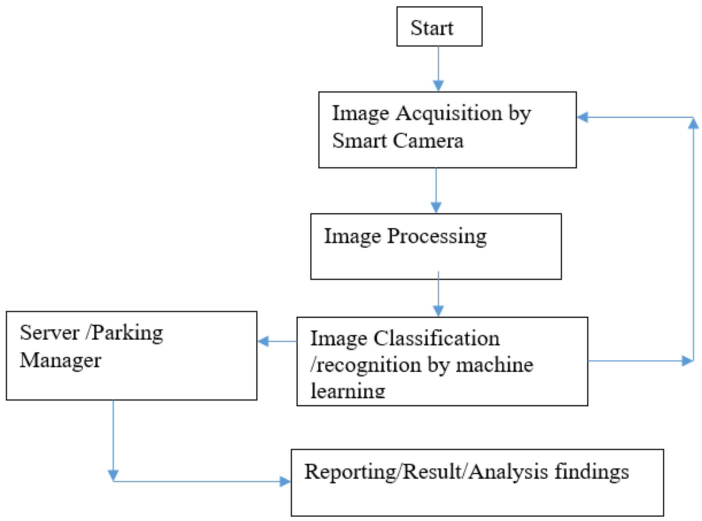


Figure 8. Modules of a typical smart parking facility application

### 2.9 Smart Transportation

Smart cities require efficient transportation systems for enhancing the quality of commuting for citizens. The objective of smart transportation is to reduce the wastage of fuels as well as reducing the damage to the city infrastructure. Smart transportation systems will also enhance the safety and comfort of citizens. Zahra Karami et al. (2020) designed a method for managing the crowd and reducing network congestion. Yunchao Qu et al. (2019) designed a smart method of determining the crowd density in stations by using the call data records (CDR) from end-users mobile and reporting the station administration regarding overcrowding, if any, for taking necessary action. Salma Bradai et al. (2018) designed a mobile crowdsensing framework, using edge computing technology. They could able to validate sensory data using the DL models and could process data locally by using edge computing.

## 3 Conclusion

An effort has been made in this article, to review the existing literature about Industry 4.0 applications. The article narrates how IIoT is being used in different domains-camera networks, smart city, smart agriculture, smart parking, smart transportation, etc. Though, much work has been done by many researchers still the application of Industry 4.0 is still in infancy. The collection of massive data from heterogeneous sensors is a difficult problem. This clearly shows the significance of designing solutions for items such as design and development of new network architectures, new schemes for managing both structured and unstructured data, sensor size and cost reduction, multi-sensor fusion, operating with multiple varieties of sensors from different manufacturers, data incompatibility issues, meaningful organization of data, sensor life prediction modeling, sensor-energy consumption management.

Protection of cyber-physical systems from cyberattacks can be another significant problem that may require designing applications such as creating Strong passwords and authentication, Secure audit, increased non-cryptographic applications, protection of CPS data from attacks, capability for identifying cyber-attacks, and design and development of the emergency alert system. This is very much required in sectors such as Manufacturing, Smart city management, Nuclear-power plants, Power generation units, Oil and natural gas, Agriculture, Aerospace.

Increasing the effectiveness of intruder detection is another problem that requires the immediate attention of researchers. This requires the development of applications such as the capability for retrieving traces of any occurring attacks and enhancing the robustness of Anomaly detection algorithms. This is useful in sectors such as Manufacturing, Smart city management, Nuclear-power plants, Power generation units, Oil and natural gas, Agriculture, Aerospace.

Reduction in hardware costs is, very much required, for ensuring a cost-effective security system for protecting CPS. This again another problem that would require the immediate attention of researchers. Reduction in hardware costs would make Industry 4.0 applicable to other un-touched areas. This is very much required in sectors such as Manufacturing, Smart city management, Nuclear-power plants, Power generation units, Oil and natural gas, Agriculture, Aerospace.

To increase the efficiency and robustness of classification using machine learning and AI is another area, that requires immediate consideration of researchers. This can make Industry 4.0 based applications achieve operational excellence. This is very much required in sectors such as Manufacturing, Smart city management, Nuclear-power plants, Power generation units, Oil and natural gas, Agriculture, Aerospace.

To protect citizens from deadly diseases and to secure their life is another problem that requires the immediate attention of researchers. This is possible when the applications develop the ability to inform citizens in advance about the impending pandemic. This is very much required in sectors such as Smart city management, Nuclear-power plants, and Power generation units.

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