# Chapter 14
# Applications of Internet of Things With Deep Learning

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## ABSTRACT

*In recent times, it is observed that many technologies converge to result into efficient systems. Among others, internet of things has wide applications. IoT is a collective network of devices that collect data, compute, communicate, and act accordingly. The data surge has resulted in various kinds of data analytics for which machine learning and deep learning are extensively used. IoT collects data in real time and processes this data. Deep learning mechanism has a potential to make IoT systems efficient. The deep learning in IoT is the disruptive innovation that leads to various smart things. This chapter highlights the prominent applications in which deep learning has blended with IoT and discusses the applications like smart cities, smart homes, smart farms, smart supply chain management, and smart healthcare. The chapter concludes with a discussion on the challenges and limitations of the IoT infrastructure.*

## INTRODUCTION

Internet of Things (IoT) is a very popular and an efficient technology that connects the world together. It connects the physical world to the digital world. The recent evolution or innovations have seen different disruptive technologies like Artificial Intelligence (AI) playing a prominent role in the well-being of humans as well as in the future of mankind.

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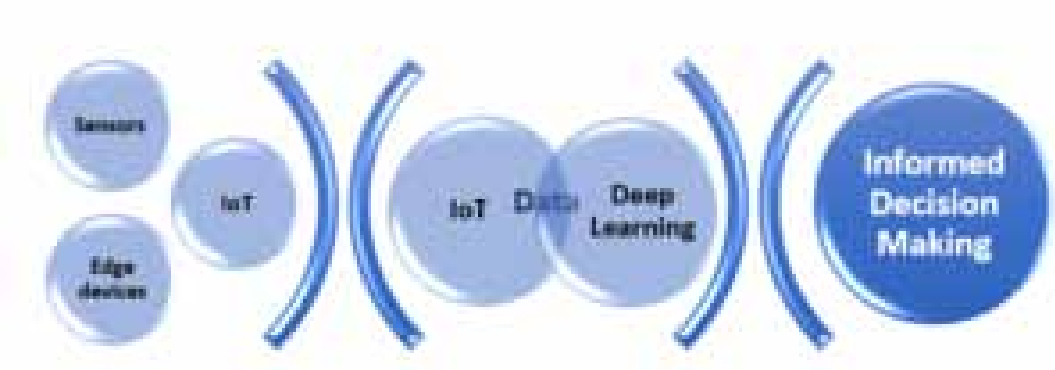
Industry 4.0 has given the necessary push to the process advancements that are needed in industries to work better or more efficiently. There is an interconnection between additive manufacturing, cloud computing, cyber security, big data analytics, autonomous robots, IoT, Artificial Intelligence and Augmented Reality. When all these are well connected, it results in today's much expected digital transformation. The massive growth in big data has fueled the rise in the number of IoT applications.

Machine learning is a field that helps the machine/models to learn from previous data. To learn, the models require huge data. Machine learning helps to extract the features and classify the output based on the understanding of the user. There are certain minute features that might be overseen to include in the machine learning model. So, a deep learning model extracts all the possible features and classifies based on those multiple features, thus improving the accuracy of classification. Whether machine learning or deep learning, both require huge data sets as inputs.

Smart systems are standalone systems that combine data sensing and actuation to analyze a situation and help to take informed decisions. Figure 1 shows the relation between the IoT and deep learning. The IoT devices like types of sensors and edge devices generate huge amount of data continuously in real time. This data forms the input to deep learning models. The more the data is made available by IoT devices, the accurate the recognition, prediction and image retrieval is offered by deep learning models. This provides valuable insights for decision making in business. As stated, IoT and DL are vital technological trends in the recent time (Saleem and Chishti 2021).

*Figure 1. Relation between IoT and Deep Learning*




Different deep learning architectures like Convolutional Neural Network (CNN), Recurrent Neural Network (RNN), Auto-Encoder (AE), Generative Adversarial Network (GAN), Restricted Boltzmann Machine (RBM) and Deep Belief Network (DBN) are used in IoT applications. CNNs can classify, detect and predict images and text data and are used in image recognition tasks. CNN detects important features from data without manual intervention. RNN is used in applications that are based on time-series problems, prediction problems, image description generation, etc. RNNs are the only networks that have internal memory because of which it can store records and identify pattern in it. AEs are unsupervised learning techniques that are trained to eliminate noise from signals and these are used in image compression and denoising. GANs are used in video prediction, generating image datasets, human faces. Cartoon characters, 3D object generation etc. RBMs help in reduction of dimensionality, classification and regression.