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CHAPTER 5

ADVANCED TOPICS IN ARTIFICIAL INTELLIGENCE

5.1 Deep Learning Fundamentals

Deep learning is a specific subfield of machine learning: a new take on learning representations from data that puts an emphasis on learning successive layers of increasingly meaningful representations. The deep in deep learning isn't a reference to any kind of deeper understanding achieved by the approach; rather, it stands for this idea of successive layers of representations. How many layers contribute to a model of the data is called the depth of the model. Other appropriate names for the field could have been layered representations learning and hierarchical representations learning. Modern deep learning often involves tens or even hundreds of successive layers of representations— and they're all learned automatically from exposure to training data. Meanwhile, other approaches to machine learning tend to focus on learning only one or two layers of representations of the data; hence, they're sometimes called shallow learning. In deep learning, these layered representations are (almost always) learned via models called neural networks, structured in literal layers stacked on top of each other. The term neural network is a reference to neurobiology, but although some of the central concepts in deep learning were developed in part by drawing inspiration from our understanding of the brain, deep-learning models are not models of the brain. There's no evidence that the brain implements anything like the learning mechanisms used in modern deep-learning models. You may come across pop-science articles proclaiming that deep learning works like the brain or was modeled after the brain, but that isn't the case. It would be confusing and counterproductive for newcomers to the field to think of deep learning as being in any way related to neurobiology; you don't need that shroud of "just like our minds" mystique and mystery, and you may as well forget anything you may have read about hypothetical links between deep learning and biology. For our purposes, deep learning is a mathematical framework for learning representations from data.

What do the representations learned by a deep-learning algorithm look like? Let's examine how a network several layers deep (see figure 1.5) transforms an image of a digit in order to recognize what digit it is.

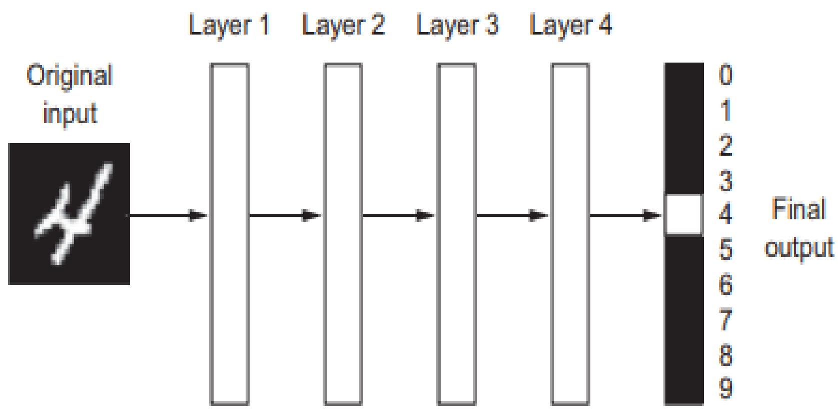

Figure 1.5 A deep neural network for digit classification (Chaudhary *et al.*, 2020)

As you can see in figure 1.6, the network transforms the digit image into representations that are increasingly different from the original image and increasingly informative about the final result. You can think of a deep network as a multistage information-distillation operation, where information goes through successive filters and comes out increasingly purified (that is, useful with regard to some task).

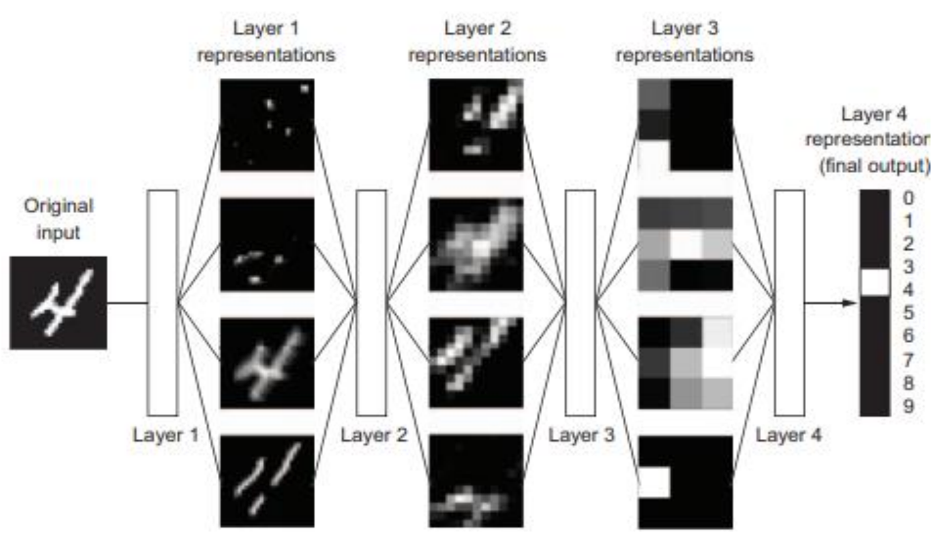

Figure 1.6 Deep representations learned by a digit-classification model (Chaudhary *et al.*, 2020)

So that's what deep learning is, technically: a multistage way to learn data representations. It's a simple idea—but, as it turns out, very simple mechanisms, sufficiently scaled, can end up looking like magic.

5.1.1 Understanding how deep learning works

At this point, you know that machine learning is about mapping inputs (such as images) to targets (such as the label "cat"), which is done by observing many examples of input and targets. You also know that deep neural networks do this input-to-target mapping via a deep sequence of simple data transformations (layers) and that these data transformations are learned by exposure to examples. Now let's look at how this learning happens, concretely. The specification of what a layer does to its input data is stored in the layer's weights, which in essence are a bunch of numbers. In technical terms, we'd say that the transformation implemented by a layer is parameterized by its weights (see figure 1.7). (Weights are also sometimes called the parameters of a layer.) In this context, learning means finding a set of values for the weights of all layers in a network, such that the network will correctly map example inputs to their associated targets. But here's the thing: a deep neural network can contain tens of millions of parameters. Finding the correct value for all of them may seem like a daunting task, especially given that modifying the value of one parameter will affect the behavior of all the others!

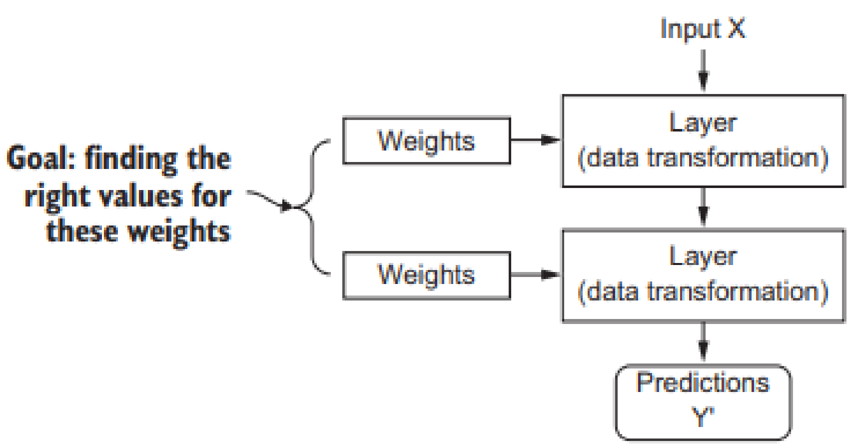

Figure 1.7 A neural network is parameterized by its weights (Chaudhary *et al.*, 2020)

To control something, first you need to be able to observe it. To control the output of a neural network, you need to be able to measure how far this output is from what you expected. This is the job of the loss function of the network, also called the objective function. The loss function takes the predictions of the network and the true target (what you wanted the network to output) and computes a distance score, capturing how well the network has done on this specific example (see figure 1.8).

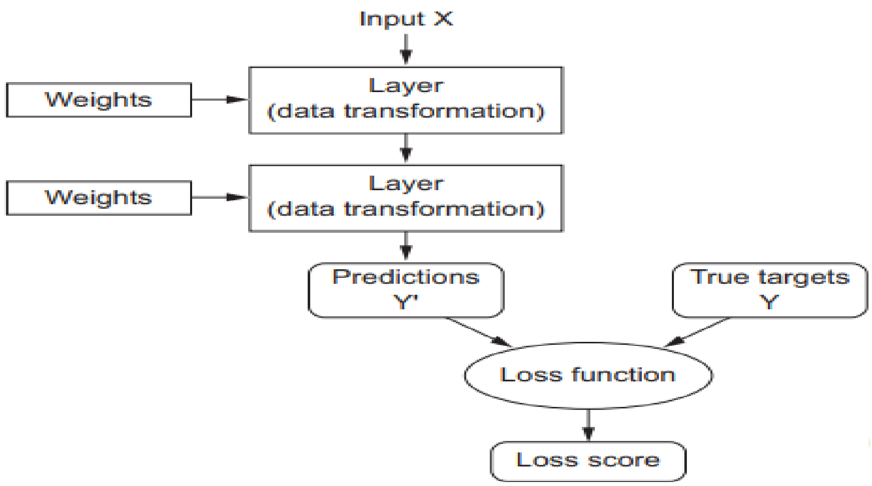

Figure 1.8 A loss function measures the quality of the network's output (Chaudhary *et al.*, 2020)

The fundamental trick in deep learning is to use this score as a feedback signal to adjust the value of the weights a little, in a direction that will lower the loss score for the current example (see figure 1.9). This adjustment is the job of the optimizer, which implements what's called the Backpropagation algorithm: the central algorithm in deep learning. The next chapter explains in more detail how backpropagation works.

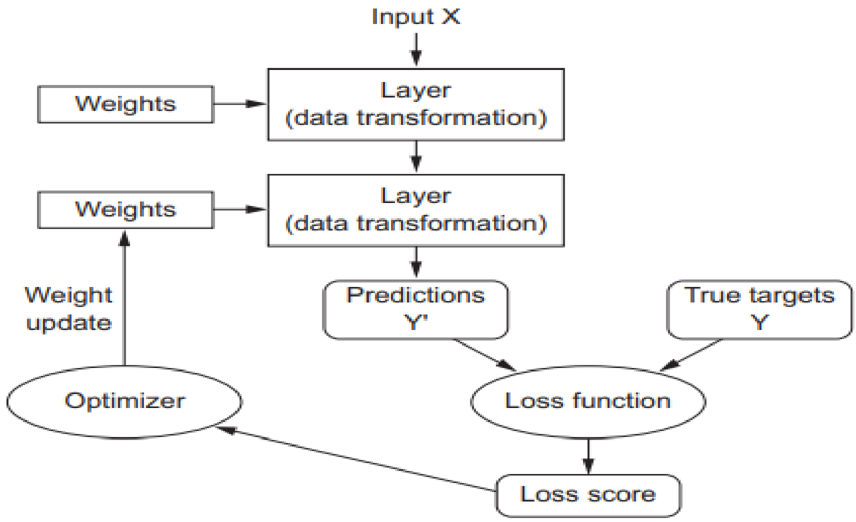

Figure 1.9 The loss score is used as a feedback signal to adjust the weights (Chaudhary *et al.*, 2020)

Initially, the weights of the network are assigned random values, so the network merely implements a series of random transformations. Naturally, its output is far from what it should ideally be, and the loss score is accordingly very high. But with every example the network processes, the weights are adjusted a little in the correct direction, and the loss score decreases. This is the training loop, which, repeated a sufficient number of times (typically tens of iterations over thousands of examples), yields weight values that minimize the loss function. A network with a minimal loss is one for which the outputs are as close as they can be to the targets: a trained network. Once again, it's a simple mechanism that, once scaled, ends up looking like magic.

5.2 Convolutional Neural Networks (CNNs)

Convolutional neural networks (CNNs), or convnets for short, are a special case of feedforward neural networks. They are very similar to the neural networks presented above in the sense that they are made up of neurons with learnable weights and biases. The essential difference is that the CNN architecture makes the implicit assumption that the input are image-like, which allows us to encode certain properties in the architecture. In particular, convolutions capture translation invariance (i.e., filters are independent of the location). This in turns makes the forward function more efficient, vastly reduces the number of parameters, and therefore makes the network easier to optimize and less dependent on the size of the data. In contrast to regular neural networks, the layers of CNNs have neurons arranged in a few dimensions: channels, width, height, and number of filters in the simplest 2D case. A convolution neural network consists, just as an MLP, of a sequence of layers, where every layer transforms the activations or outputs of the previous layer through another differentiable function. There are several such layers employed in CNNs, and these will be explained in subsequent sections, however, the most common building blocks which you will encounter in most CNN architectures are: the convolution layer, pooling layer, and fully connected layers. In essence, these layers are like feature extractors, dimensionality reduction and classification layers, respectively. These layers of a CNN are stacked to form a full convolutional layer.

Before we proceed with an overview of the different layers, we pause a bit at the convolution layer. Essentially, a convolution layer uses a convolutional kernel as a filter for the input. Usually, there are many of such filters. During a forward pass, a filter slides across the input volume and computes the activation map of the filter at that point by computing the pointwise product of each value and adding these to obtain the activation at the point. Such a sliding filter is naturally implemented by a convolution and, as this is a linear operator, it can be written as a dot-product for efficient implementation.

1. Convolutions layer

This layer is the core building block of a CNN. The layer's parameters consist of learnable kernels or filters which extend through the full depth of the input. Each unit of this layer receives inputs from a set of units located in small neighbourhood in the previous layer. Such a neighbourhood is called as the neuron's receptive field in the previous layer. During the forward pass each filter is convolved with input which produces a map. When multiple such feature maps that are generated from a multiple filters are stacked they form the output of the convolution layer. The weight vector that generates the feature map is shared which reduces the model complexity.

2. Pooling layers

The pooling2 layers are used to sub-sample the feature maps (produced after convolution operations), i.e. it takes the larger size feature maps and shrinks them to lower sized feature maps. While shrinking the feature maps it always preserve the most dominant features (or information) in each pool steps. The pooling operation is performed by specifying the pooled region size and the stride of the operation, similar to convolution operation. There are different types of pooling techniques are used in different pooling layers such as max pooling, min pooling, average pooling, gated pooling, tree pooling, etc. Max Pooling is the most popular and mostly used pooling technique. The main drawback of pooling layer is that it sometimes decreases the overall performance of CNN. The reason behind this is that pooling layer helps CNN to find whether a specific feature is present in the given input image or not without caring about the correct position of that feature.

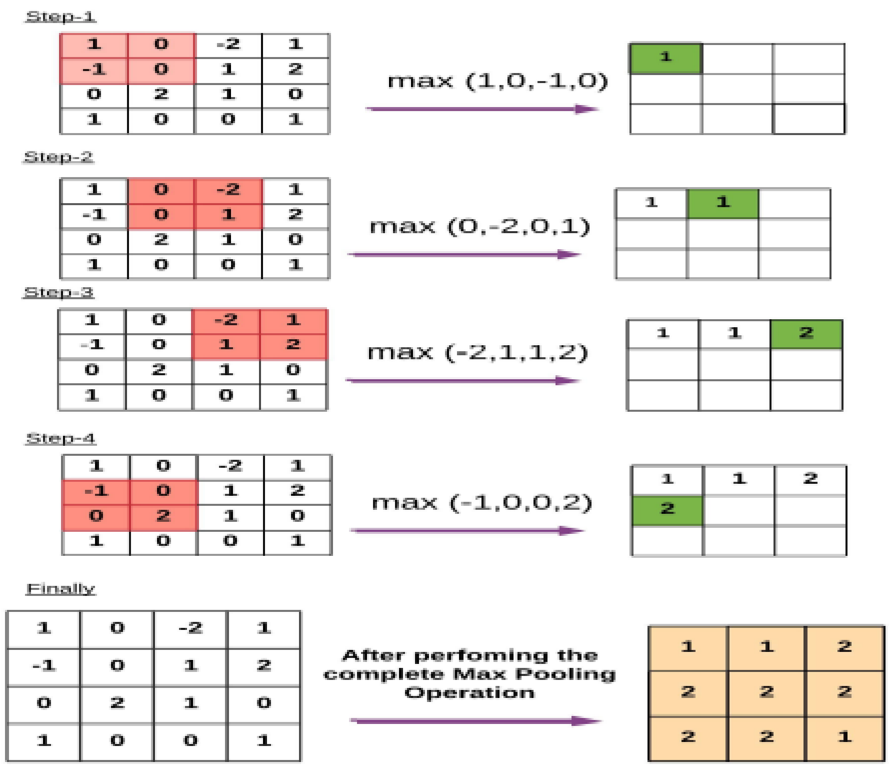

Figure 10: an example of max-pooling operation (Ghosh *et al.*, 2019)

3. Non-linearity Layer

This is a layer of neurons which apply various activation functions. These functions introduce nonlinearities which are desirable for multi-layer networks. The activation functions are typically sigmoid, tanh and ReLU. Compared to other functions Rectified Linear Units (ReLU) are preferable because neural networks train several times faster.

4. Fully connected layers

Usually the last part (or layers) of every CNN architecture (used for classification) is consist of fully-connected layers, where each neuron inside a layer is connected with each neuron from it's previous layer. The last layer of Fully-Connected layers is used as the output layer (classifier) of the CNN architecture. The Fully-Connected Layers are type of feed-forward artificial neural network (ANN) and it follows the principle of traditional multi-layer perceptron neural network (MLP). The FC layers take input from the final convolutional or pooling layer, which is in the form of a set of metrics (feature maps) and those metrics are flattened to create a vector and this vector is then fed into the FC layer to generate the final output of CNN as shown in Fig.16.

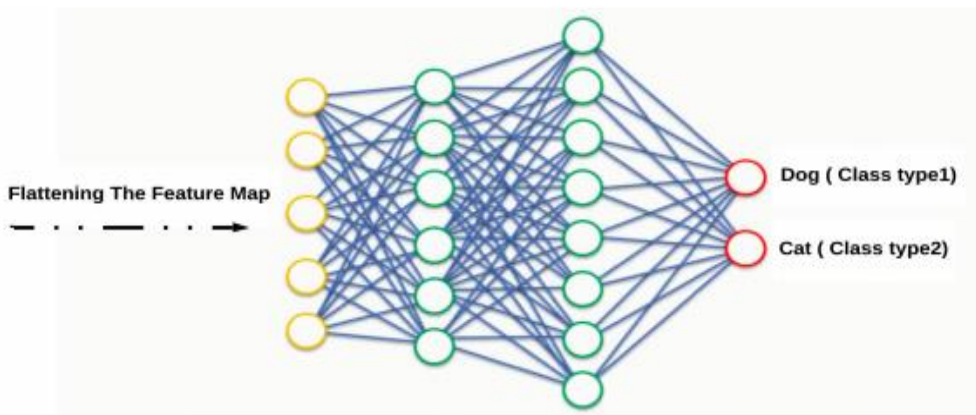

Figure 16: The architecture of Fully Connected Layers (Ghosh *et al.*, 2019)

5. Rectified Linear Unit Layer

The next layer encountered is the Rectified Linear Unit Layer (ReLU). This is where the activation functions take place. The activation function is initially set at a zero threshold. The activation gradient only functions at 0 and 1 and does not include intermediary gradients like its predecessors. Due to its linear, non-saturating form, it is said that ReLUs greatly aid in the declining gradient of error. However, due to the fragile nature of a ReLU, it is possible to have even 40% of your network dead in a training dataset.

5.2.1 Different Types of CNN Models

1) LeNet

- LeNet is a pioneering convolutional neural network (CNN) architecture developed by Yann LeCun and his colleagues in the late 1990s. It was specifically designed for handwritten digit recognition, and was one of the first successful CNNs for image recognition.

- LeNet consists of several layers of convolutional and pooling layers, followed by fully connected layers. The architecture includes two sets of convolutional and pooling layers, each followed by a subsampling layer, and then three fully connected layers.
- The first convolutional layer uses a kernel of size 5×5 and applies 6 filters to the input image. The output of this layer is then passed through a pooling layer that reduces the spatial dimensions of the feature maps. The second convolutional layer uses a kernel of size 5×5 and applies 16 filters to the output of the first pooling layer. This is followed by another pooling layer and a subsampling layer.
- The output of the subsampling layer is then passed through three fully connected layers, with 120, 84, and 10 neurons respectively. The last fully connected layer is used for classification, and produces a probability distribution over the 10 digits (0-9).
- LeNet was trained on the MNIST dataset, which consists of 70,000 images of handwritten digits, and was able to achieve high recognition accuracy. The LeNet architecture, although relatively simple compared to current architectures, served as a foundation for many later CNNs, and it's considered as a classic and simple architecture for image recognition tasks.

2) AlexNet

- AlexNet is a convolutional neural network (CNN) architecture that was developed by Alex Krizhevsky, Ilya Sutskever, and Geoffrey Hinton in 2012. It was the first CNN to win the ImageNet Large Scale Visual Recognition Challenge (ILSVRC), a major image recognition competition, and it helped to establish CNNs as a powerful tool for image recognition.
- AlexNet consists of several layers of convolutional and pooling layers, followed by fully connected layers. The architecture includes five convolutional layers, three pooling layers, and three fully connected layers.
- The first two convolutional layers use a kernel of size 11×11 and apply 96 filters to the input image. The third and fourth convolutional layers use a kernel of size 5×5 and apply 256 filters. The fifth convolutional layer uses a kernel of size 3×3 and applies 384 filters.

The output of these convolutional layers is then passed through max-pooling layers that reduce the spatial dimensions of the feature maps.

- The output of the pooling layers is then passed through three fully connected layers, with 4096, 4096, and 1000 neurons respectively. The last fully connected layer is used for classification, and produces a probability distribution over the 1000 ImageNet classes.
- AlexNet was trained on the ImageNet dataset, which consists of 1.2 million images with 1000 classes, and was able to achieve high recognition accuracy. The AlexNet architecture was the first to show that CNNs could significantly outperform traditional machine learning methods in image recognition tasks, and was an important step in the development of deeper architectures like VGGNet, GoogleNet, and ResNet.

3) Resnet

- ResNets (Residual Networks) are a type of deep learning algorithm that are particularly well-suited for image recognition and processing tasks. ResNets are known for their ability to train very deep networks without overfitting
- ResNets are often used for keypoint detection tasks. Keypoint detection is the task of locating specific points on an object in an image. For example, keypoint detection can be used to locate the eyes, nose, and mouth on a human face.
- ResNets are well-suited for keypoint detection tasks because they can learn to extract features from images at different scales.
- ResNets have achieved state-of-the-art results on many keypoint detection benchmarks, such as the COCO Keypoint Detection Challenge and the MPII Human Pose Estimation Dataset.

4) GoogleNet

- GoogleNet, also known as InceptionNet, is a type of deep learning algorithm that is particularly well-suited for image recognition and processing tasks. GoogleNet is known for its ability to achieve high accuracy on image classification tasks while using fewer parameters and computational resources than other state-of-the-art CNNs.
- Inception modules are the key component of GoogleNet. They allow the network to learn features at different scales simultaneously, which improves the performance of the network on image classification tasks.

- GoogleNet uses global average pooling to reduce the size of the feature maps before they are passed to the fully connected layers. This also helps to improve the performance of the network on image classification tasks.
- GoogleNet uses factorized convolutions to reduce the number of parameters and computational resources required to train the network.
- GoogleNet is a powerful tool for image classification, and it is being used in a wide variety of applications, such as GoogleNet can be used to classify images into different categories, such as cats and dogs, cars and trucks, and flowers and animals.

5) **MobileNet**

- MobileNets are a type of CNN that are particularly well-suited for image recognition and processing tasks on mobile and embedded devices.
- MobileNets are known for their ability to achieve high accuracy on image classification tasks while using fewer parameters and computational resources than other state-of-the-art CNNs.
- MobileNets are also being used for keypoint detection tasks.
- MobileNets have achieved state-of-the-art results on many keypoint detection benchmarks.

6) **VGG**

- VGG is a type of convolutional neural network (CNN) that is known for its simplicity and effectiveness. VGGs are typically made up of a series of convolutional and pooling layers, followed by a few fully connected layers.
- VGGs can be used by self-driving cars to detect and classify objects on the road, such as other vehicles, pedestrians, and traffic signs. This information can be used to help the car navigate safely.
- VGGs are a powerful and versatile tool for image recognition tasks.

5.2.2 Applications of CNN

Image classification: CNNs are the state-of-the-art models for image classification. They can be used to classify images into different categories, such as cats and dogs, cars and trucks, and flowers and animals.

Object detection: CNNs can be used to detect objects in images, such as people, cars, and buildings. They can also be used to localize objects in images, which means that they can identify the location of an object in an image.

Image segmentation: Mean-shift segmentation was utilized to split the image into the items with uniform spectral and spatial information as a nonparametric clustering strategy. As several input dataset sources for the image segmentation, major multispectral bands (green, blue, red, and near-infrared) were combined with DSM (digital surface model). A minor oversegmentation rather than undersegmentation was used to highlight the significance of spectral similarity, and all image classifications were turned into GIS (Geographic Information Systems) polygons with distinct geometric shapefiles.

Video analysis: CNNs can be used to analyze videos, such as tracking objects in a video or detecting events in a video. This is useful for applications such as video surveillance and traffic monitoring.

5.2.3 Advantages of CNN

- CNNs can achieve state-of-the-art accuracy on a variety of image recognition tasks, such as image classification, object detection, and image segmentation.
- CNNs can be very efficient, especially when implemented on specialized hardware such as GPUs.
- CNNs are relatively robust to noise and variations in the input data.
- CNNs can be adapted to a variety of different tasks by simply changing the architecture of the network.

5.3 Recurrent Neural Networks (RNNs)

Recurrent Neural Networks (RNNs) are a type of feed-forward neural networks. Compared to other feed-forward networks, RNNs have recurrent layers that can pass information over time-steps. This allows parallel and sequential computation. It emulates the human brain by considering time as part of the network. Although, training RNNs was hard when they were first introduced in the 1980s but advances in processing power and optimization have made it possible. RNNs take a sequence of input and model them one element at a time. In this way the network retains a state while modelling each input element across the sequence of inputs. This makes RNNs unique.

RNNs are applied in modelling functions for which input and output are composed of sequences and are time dependant. Additionally, many classification algorithms (support vector machines) exist that do not consider time. Other models that consider time have short-range considering only a few timesteps (previous, current, next) also known as sliding window. Recurrent Neural Networks use loops in the network to model temporal behaviour with better accuracy in the field of time-series, audio, and natural language processing (NLP).

RNNs are used for data that are ordered, context sensitive, and dependant. The design of RNN allows feedback in such a way that it is possible to capture temporal effects. RNN has a feedback connection that it uses to learn from input sequences. To keep track of the time-steps connections a parameter matrix is used. RNNs take a sequence of inputs e.g. in video analysis and generate a series of output e.g. in natural language translation. The output at each time-step depends on the current input and the input of the previous time-steps. The gradient is computed using a backpropagation through time (BPTT) algorithm. The application of RNN requires the input or output or both to be in sequence. For example, speech synthesis, music generation, time-series prediction and natural language translation. The input/output format for RNNs makes it unique from other deep networks. In most of the machine learning models, the input and output sizes are fixed. Whereas in RNNs the size can vary for the input and output at each time-step. RNNs input/output relation can be of three types. The first is one-to-many: single input and a sequence of outputs, e.g. creating an image caption form an image. The second is, many-to-one: sequence input and single output, for example in sentiment analysis replace a sentence with a word. The third type is, many-to-many: for example take a video and label each frame. Similarly, the input of an RNN has three dimensions including batch size or number of records, number of columns in vector per time-step, and number of time-steps. Figure 3-12 and figure 3-13 show a normal input vector vs recurrent neural networks input, and the time-step in RNN input processes respectively.

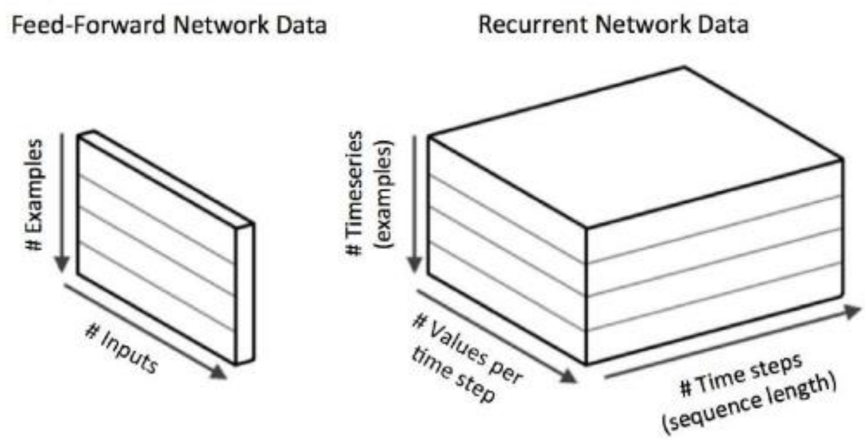

Figure 3-12. Normal input vector vs recurrent neural networks input(Chaudhary *et al.*, 2020)

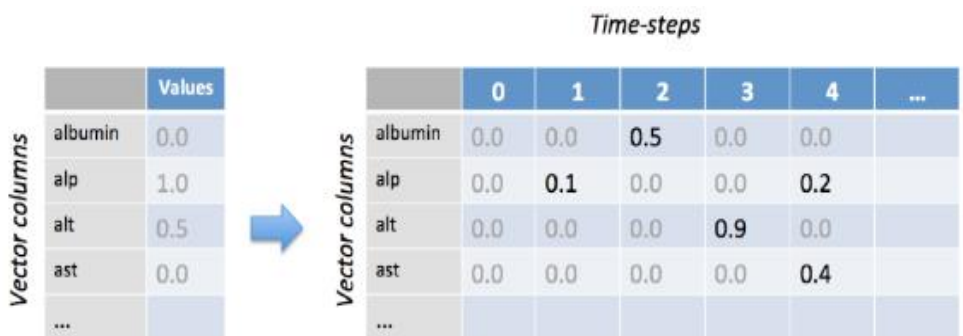

Figure 3-13. The time-step in RNN input (Chaudhary *et al.*, 2020)

As shown in figure 3-14, at each time step, the values of a vector column do not have to be the same. Markov modelsis also an option when time is considered as a dimension as they are used in modelling sequences. However, with Markov model, computation becomes impractical for wider dependencies as their context window grows rapidly. RNN hidden layers can model the states thus as the number of time-steps increases so do the hidden layers.

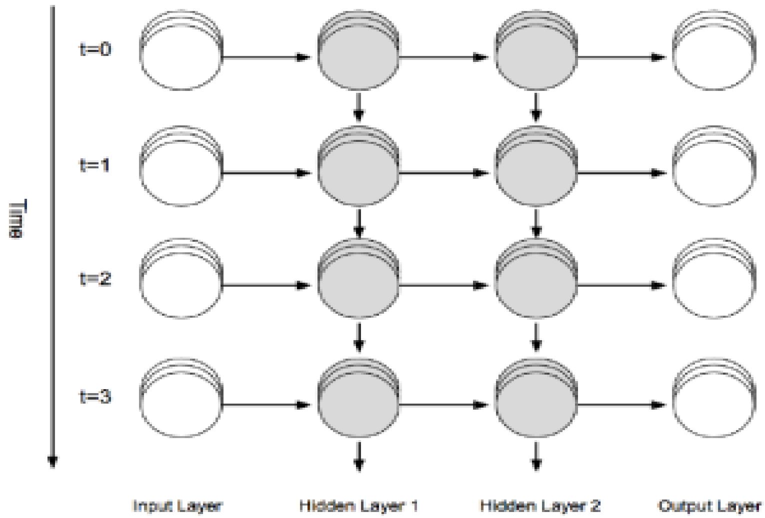

Figure 3-14. Recurrent Neural Network unrolled on the time axis (Chaudhary *et al.*, 2020)

5.3.1 Types Of RNN

Feedforward networks have single input and output, while recurrent neural networks are flexible as the length of inputs and outputs can be changed. This flexibility allows RNNs to generate music, sentiment classification, and machine translation. There are four types of RNN based on different lengths of inputs and outputs.

1) One to One

This type of RNN behaves the same as any simple Neural network it is also known as Vanilla Neural Network. In this Neural network, there is only one input and one output.

2) One To Many

In this type of RNN, there is one input and many outputs associated with it. One of the most used examples of this network is Image captioning where given an image we predict a sentence having Multiple words.

3) Many to One

In this type of network, Many inputs are fed to the network at several states of the network generating only one output. This type of network is used in the problems like sentimental analysis. Where we give multiple words as input and predict only the sentiment of the sentence as output.

4) Many to Many

In this type of neural network, there are multiple inputs and multiple outputs corresponding to a problem. One Example of this Problem will be language translation. In language translation, we provide multiple words from one language as input and predict multiple words from the second language as output.

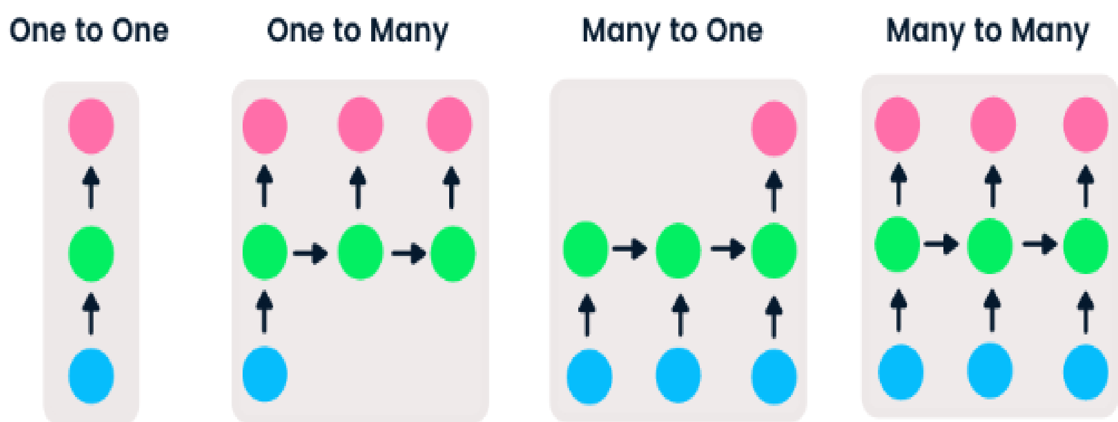

Figure 5.1: types of RNN

https://www.datacamp.com/tutorial/tutorial-for-recurrent-neural-network

5.4 Generative Adversarial Networks (GANs)

GANs are a type of generative models which can generate novel data based on the input dataset. They are mainly used in images. This idea can be applied to sounds and videos. GANs use two models that are trained in parallel in an unsupervised way. The goal is to generate new data or image in case of input image with similar characteristics as the training data. An important aspect of GAN is its fewer number of parameters as compared to other deep networks. The first network also called generative network creates images from the input images while the second network called the discriminator network classifies these generated images as synthetic or real. The idea is to train the GAN so that the generated images are as close as possible to the real image such that the discriminator would mistake. During training GANs, the parameters get updated as more realistic images of the training set are generated. In this way, it becomes hard for the discriminator network to distinguish between real and synthetic images. By structure, a discriminator network is usually a standard CNN. The discriminator network takes input images and classifies them. GAN trains both networks in parallel in unsupervised way. Figure 3-6 shows GAN architecture processes.

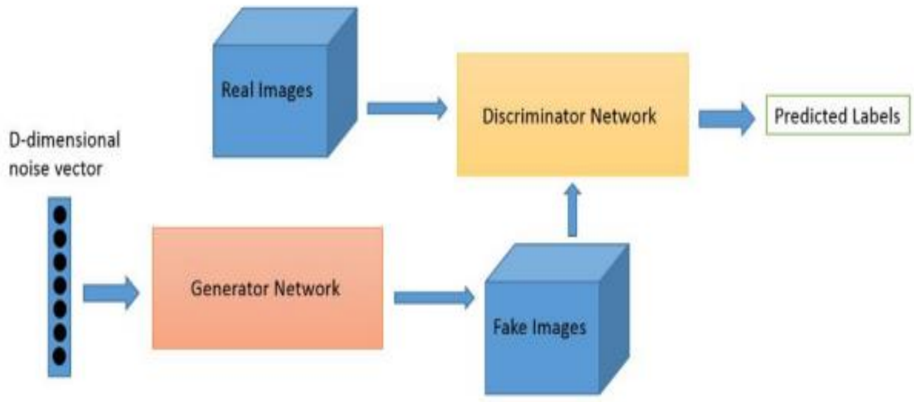

Figure 3-6. GAN architecture (Aziz, 2020)

The generative network in GANs on the other hand generates images from the training dataset with a layer known as deconvolutional layer. The deconvolutional layer ("deconvnet") is used to show relation between feature activations and input images. Deconvolution allows generating images as output from output by mapping features to pixels (see figure 3-7).

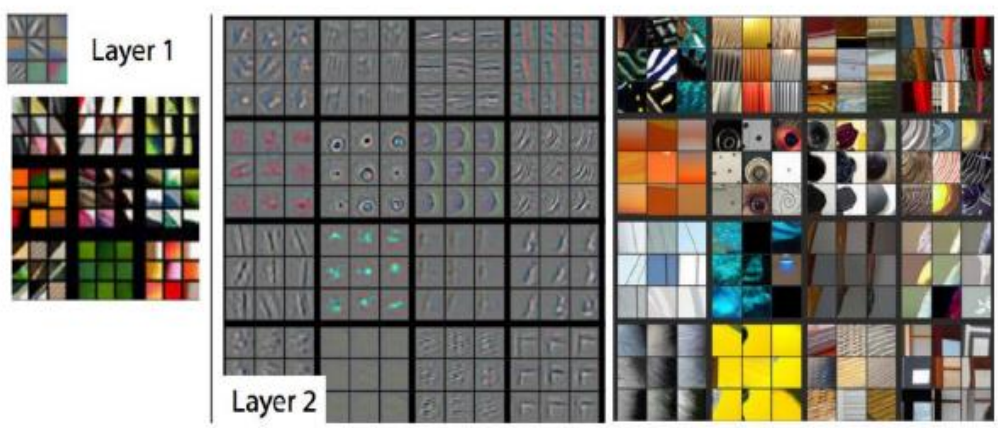

Figure 3-7. Visualizing deconvolutional layers (Aziz, 2020)

Backpropagation is used to update the parameters of the generative network. The training continues until generated images are realistic enough for discriminator network to make a mistake. There are several variants of GANs and one of them is Deep Convolutional Generative Adversarial

Network (DCGAN). The convolutional network in DCGAN does not use max pooling instead it has convolutional stride for spatial downsampling. Similarly, fully connected layers are removed. Another change in convolutional network architecture is using batch normalization in both generators and discriminators to stabilize learning. The model also uses ReLU function in each layer except the output layer of the generator which is hyperbolic tangent tan. While in the discriminator LeakyReLU activation is used. Figure 3-8 shows DCGAN generator architecture.

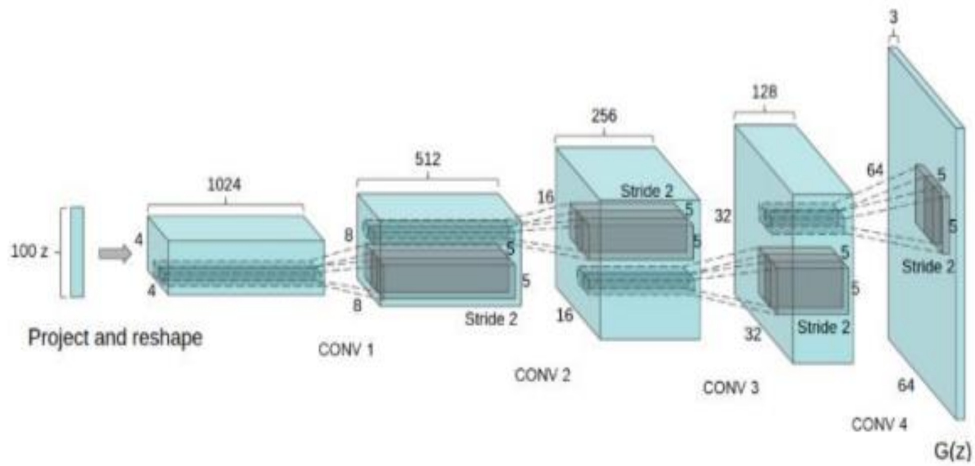

Figure 3-8. DCGAN generator architecture (Aziz, 2020)

Below (figure 3-9) figure of bedrooms is generated from DCGAN after training of five epochs.

Figure 3-9. Bedroom images generated from DCGAN (Aziz, 2020)

5.4.1 Application Of Generative Adversarial Networks (GANs)

GANs, or Generative Adversarial Networks, have many uses in many different fields. Here are some of the widely recognized uses of GANs:

Image Synthesis and Generation: GANs are often used for picture synthesis and generation tasks, They may create fresh, lifelike pictures that mimic training data by learning the distribution that explains the dataset. The development of lifelike avatars, high-resolution photographs, and fresh artwork have all been facilitated by these types of generative networks.

Image-to-Image Translation: GANs may be used for problems involving image-to-image translation, where the objective is to convert an input picture from one domain to another while maintaining its key features. GANs may be used, for instance, to change pictures from day to night, transform drawings into realistic images, or change the creative style of an image.

Text-to-Image Synthesis: GANs have been used to create visuals from descriptions in text. GANs may produce pictures that translate to a description given a text input, such as a phrase or a caption. This application might have an impact on how realistic visual material is produced using text-based instructions.

Data Augmentation: GANs can augment present data and increase the robustness and generalizability of machine-learning models by creating synthetic data samples.

Data Generation for Training: GANs can enhance the resolution and quality of low-resolution images. By training on pairs of low-resolution and high-resolution images, GANs can generate high-resolution images from low-resolution inputs, enabling improved image quality in various applications such as medical imaging, satellite imaging, and video enhancement.

5.4.2 Advantages of GAN

The advantages of the GANs are as follows:

- **Synthetic data generation:** GANs can generate new, synthetic data that resembles some known data distribution, which can be useful for data augmentation, anomaly detection, or creative applications.

- **High-quality results:** GANs can produce high-quality, photorealistic results in image synthesis, video synthesis, music synthesis, and other tasks.
- **Unsupervised learning:** GANs can be trained without labeled data, making them suitable for unsupervised learning tasks, where labeled data is scarce or difficult to obtain.
- **Versatility:** GANs can be applied to a wide range of tasks, including image synthesis, text-to-image synthesis, image-to-image translation, anomaly detection, data augmentation, and others.

5.5 Transfer Learning and Fine-Tuning

The traditional supervised learning paradigm breaks down when we do not have sufficient labeled data for the desired task or domain to train a reliable model. Transfer learning allows us to deal with this scenario by leveraging the data of some related task or domain, known as the source task and source domain. We transfer the knowledge gained by solving the source task in the source domain to the target task and target domain as illustrated by Figure 2-1. Specifically for neural network based models that are used throughout this thesis, this knowledge relates to the learned representation.

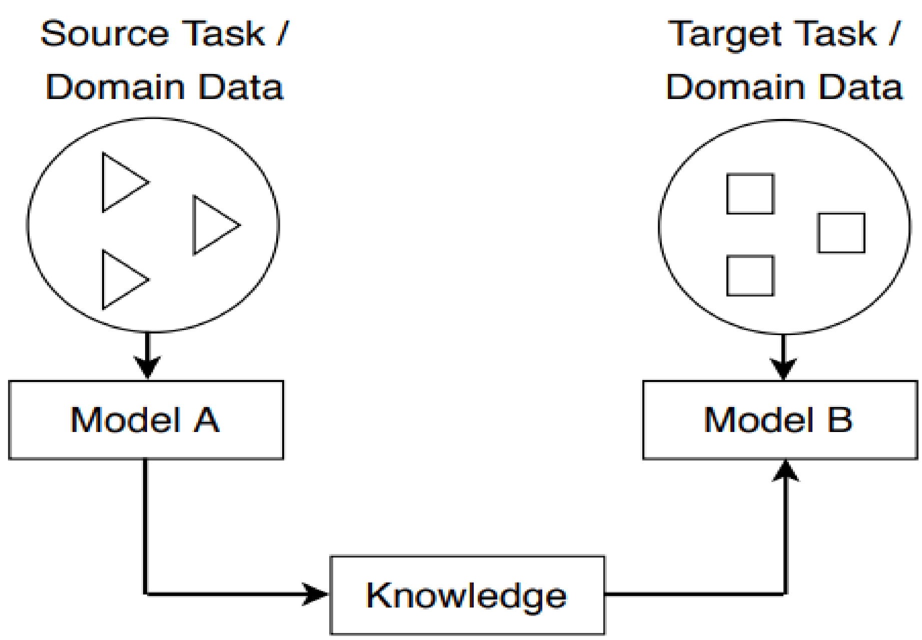

Figure 2-1: The transfer learning setup

While transfer learning involves freezing the pre-trained model's weights and only training the new layers, fine-tuning takes it a step further by allowing the pre-trained layers to be updated. This additional step is beneficial when the new dataset is large enough and similar to the original dataset on which the pre-trained model was trained. Fine-tuning involves the following steps:

- **Feature Extraction:** Similar to transfer learning, we use the pre-trained model as a feature extractor. We replace the final classification layers with new layers specific to our task and freeze the weights of the pre-trained layers.
- **Fine-Tuning:** In this step, we unfreeze some of the pre-trained layers and allow them to be updated during training. This process enables the model to learn more task-specific features while preserving the general knowledge acquired from the original dataset.

5.5.1 Key Differences between Fine-Tuning and Transfer Learning

Now that we have explored the implementation of both fine-tuning and transfer learning, let's summarize the key differences between the two techniques:

- **Training Approach:** In transfer learning, we freeze all the pre-trained layers and only train the new layers added on top. In fine-tuning, we unfreeze some of the pre-trained layers and allow them to be updated during training.
- **Domain Similarity:** Transfer learning is suitable when the new task or domain is somewhat similar to the original task or domain on which the pre-trained model was trained. Fine-tuning is more effective when the new dataset is large enough and closely related to the original dataset.
- **Computational Resources:** Transfer learning requires fewer computational resources since only the new layers are trained. Fine-tuning, on the other hand, may require more resources, especially if we unfreeze and update a significant number of pre-trained layers.
- **Training Time:** Transfer learning generally requires less training time since we are training fewer parameters. Fine-tuning may take longer, especially if we are updating a larger number of pre-trained layers.
- **Dataset Size:** Transfer learning is effective when the new dataset is small, as it leverages the pre-trained model's knowledge on a large dataset. Fine-tuning is more suitable for

larger datasets, as it allows the model to learn more specific features related to the new task.

It's important to note that the choice between fine-tuning and transfer learning depends on the specific task, dataset, and available computational resources. Experimentation and evaluation are key to determining the most effective approach for a given scenario.

5.6 Natural Language Processing (NLP) Techniques

Natural language or ordinary language is any language that naturally evolved in human. Involvement of human language comes through use and reputation without having proper and intentionally planned. Natural language is can be counted in different forms such as speech, singing, facial expression, signs and body gestures. Naturally developed language is actually human in habitant adoptions which are built on the basis of different words, signs, gestures and other activities. In recent years artificial intelligence is occupying important applications of human life. This made easy to come on new evaluation of technology with several new opportunities. Due to rise of importance of artificial intelligence many new sub-fields have arisen to contribute in human life. Many applications in this time arisen due to important contribution. Artificial intelligence is evolved in many fields of life such as education, health, and agricultural, natural language interpretation and also in all aspects of life. Rapid and efficient contribution of artificial intelligence shows greater importance in real life activities. Few of important fields of artificial intelligence include evolutionary computation, vision robotics, expert system, speech processing, planning, machine learning and Natural language processing. As this chapter is concern with natural language processing.

Natural Language processing (NLP) is subfield of artificial intelligence which focuses computational linguistics interpretation. This field encompasses several areas of textual and audio interpretation by integration of machine learning methods which behaves statistically. It is also covers the area of the pragmatic research of computational linguistics became very vast and powerful by implementation of various techniques. The increasing availability and capability of NLP techniques which improve computational language accuracy and improvement day by day. NLP and Machine learning are most focused areas of research. NLP is mostly influenced by other fields such as psychology, cognitive science, linguistics and many other fields. It is concern with computational models of engineering which processed to solve the human interaction and human language understanding. For this several software packages are developed for the language modelling areas for the interpretation of the computational language which human can interpreted easily. Here are 11 tasks that can be solved by NLP:

1) Sentiment analysis

Sentiment analysis is the process of classifying the emotional intent of text. Generally, the input to a sentiment classification model is a piece of text, and the output is the probability that the sentiment expressed is positive, negative, or neutral. Typically, this probability is based on either hand-generated features, word n-grams, TF-IDF features, or using deep learning models to capture sequential long- and short-term dependencies. Sentiment analysis is used to classify customer reviews on various online platforms as well as for niche applications like identifying signs of mental illness in online comments.

2) Toxicity classification

Toxicity classification is a branch of sentiment analysis where the aim is not just to classify hostile intent but also to classify particular categories such as threats, insults, obscenities, and hatred towards certain identities. The input to such a model is text, and the output is generally the probability of each class of toxicity. Toxicity classification models can be used to moderate and improve online conversations by silencing offensive comments, detecting hate speech, or scanning documents for defamation.

3) Machine translation

Machine translation automates translation between different languages. The input to such a model is text in a specified source language, and the output is the text in a specified target language. Google Translate is perhaps the most famous mainstream application. Such models are used to improve communication between people on social-media platforms such as Facebook or Skype. Effective approaches to machine translation can distinguish between words with similar meanings. Some systems also perform language identification; that is, classifying text as being in one language or another.

4) Named entity recognition

Named entity recognition aims to extract entities in a piece of text into predefined categories such as personal names, organizations, locations, and quantities. The input to such a model is generally text, and the output is the various named entities along with their start and end positions. Named entity recognition is useful in applications such as summarizing news articles and combating disinformation.

5) Spam detection

Spam detection is a prevalent binary classification problem in NLP, where the purpose is to classify emails as either spam or not. Spam detectors take as input an email text along with various other subtexts like title and sender's name. They aim to output the probability that the mail is spam. Email providers like Gmail use such models to provide a better user experience by detecting unsolicited and unwanted emails and moving them to a designated spam folder.

6) Topic modeling

Topic modeling is an unsupervised text mining task that takes a corpus of documents and discovers abstract topics within that corpus. The input to a topic model is a collection of documents, and the output is a list of topics that defines words for each topic as well as assignment proportions of each topic in a document. Latent Dirichlet Allocation (LDA), one of the most popular topic modeling techniques, tries to view a document as a collection of topics and a topic as a collection of words. Topic modeling is being used commercially to help lawyers find evidence in legal documents.

7) Text generation

Text generation, more formally known as natural language generation (NLG), produces text that's similar to human-written text. Such models can be fine-tuned to produce text in different genres and formats — including tweets, blogs, and even computer code. Text generation has been performed using Markov processes, LSTMs, BERT, GPT-2, LaMDA, and o

8) Grammatical error correction

Grammatical error correction models encode grammatical rules to correct the grammar within text. This is viewed mainly as a sequence-to-sequence task, where a model is trained on an ungrammatical sentence as input and a correct sentence as output. Online grammar checkers like

Grammarly and word-processing systems like Microsoft Word use such systems to provide a better writing experience to their customers. Schools also use them to grade student essays.

9) Information retrieval

Information retrieval finds the documents that are most relevant to a query. This is a problem every search and recommendation system faces. The goal is not to answer a particular query but to retrieve, from a collection of documents that may be numbered in the millions, a set that is most relevant to the query. Document retrieval systems mainly execute two processes: indexing and matching. In most modern systems, indexing is done by a vector space model through Two-Tower Networks, while matching is done using similarity or distance scores. Google recently integrated its search function with a multimodal information retrieval model that works with text, image, and video data.

PART-1: VERY SHORT QUESTIONS

1) What is the primary objective of deep learning?
2) Define Convolutional Neural Networks (CNNs) in brief.
3) What role do Recurrent Neural Networks (RNNs) play in sequential data analysis?
4) Explain the concept of Generative Adversarial Networks (GANs) briefly.
5) How do Transfer Learning and Fine-Tuning differ?
6) What are the key differences between Fine-Tuning and Transfer Learning?
7) Briefly describe the application areas of Transfer Learning.
8) What are some common Natural Language Processing (NLP) techniques?
9) How do CNNs and RNNs differ in their approach to processing sequential data?
10) Explain how GANs can be utilized in generating realistic images.

PART-2: SHORT QUESTIONS

1) What are the basic principles of deep learning?
2) How do convolutional neural networks (CNNs) differ from other types of neural networks?
3) Can you explain the architecture and working principles of recurrent neural networks (RNNs)?
4) What are the main components of a generative adversarial network (GAN)?

5) How does transfer learning differ from fine-tuning in deep learning?
6) What are some key differences between fine-tuning and transfer learning methodologies?
7) What are some common natural language processing (NLP) techniques used in deep learning?
8) How do word embeddings contribute to NLP tasks like sentiment analysis or language translation?
9) Can you explain the concept of attention mechanisms in NLP?
10) What are some challenges faced in deep learning for NLP tasks, and how are they addressed?

PART-3: LONG QUESTIONS

1) In the realm of Deep Learning Fundamentals, what are the underlying principles and key components that distinguish it from traditional machine learning methods, and how do these principles manifest in the architecture and training of deep neural networks?
2) How do Convolutional Neural Networks (CNNs) revolutionize the field of computer vision, and what are the fundamental building blocks and operations within CNN architectures that enable them to excel in tasks such as image classification, object detection, and semantic segmentation?
3) Exploring the domain of Recurrent Neural Networks (RNNs), what distinguishes them from feedforward neural networks, and how do recurrent connections facilitate the processing of sequential data, making RNNs particularly suitable for tasks like natural language processing, time series prediction, and speech recognition?
4) Delving into the realm of Generative Adversarial Networks (GANs), what are the underlying principles behind their architecture and training methodology, and how do GANs leverage the adversarial learning framework to generate realistic data samples, leading to breakthroughs in areas such as image synthesis, style transfer, and data augmentation?
5) When considering Transfer Learning and Fine-Tuning techniques in deep learning, what are the fundamental concepts underlying these approaches, and what are the key differences between them? How do practitioners leverage transfer learning and fine-tuning

to address challenges such as limited labeled data, domain adaptation, and model generalization across different tasks and datasets?

PART-4: MCQ QUESTIONS

1) Which of the following best describes deep learning?
- **a)** A type of machine learning that uses algorithms inspired by the structure and function of the brain
- **b)** A form of reinforcement learning that utilizes neural networks
- **c)** A technique for linear regression analysis
- **d)** An optimization method for gradient descent

2) What is the primary purpose of Convolutional Neural Networks (CNNs) in deep learning?
- **a)** Sequence prediction
- **b)** Image classification and recognition
- **c)** Text generation
- **d)** Speech recognition

3) What is the main advantage of Recurrent Neural Networks (RNNs) over traditional feedforward neural networks?
- **a)** Better performance for image classification tasks
- **b)** Ability to handle sequential data and variable input lengths
- **c)** Faster convergence during training
- **d)** Simpler architecture for implementation

4) Generative Adversarial Networks (GANs) consist of which two main components?
- **a)** Encoder and decoder
- **b)** Generator and discriminator
- **c)** Classifier and regressor
- **d)** Feature extractor and transformer

5) Which statement best describes Transfer Learning in deep learning?
- **a)** The process of training a model from scratch on a new dataset
- **b)** Fine-tuning a pre-trained model on a new dataset with a similar task
- **c)** Using a pre-trained model directly without any modifications
- **d)** Applying unsupervised learning techniques for feature extraction

6) What is the key difference between Transfer Learning and Fine-Tuning?

- **a)** Transfer Learning involves adjusting hyperparameters, while Fine-Tuning does not.
- **b)** Fine-Tuning involves training only the last few layers of a pre-trained model, while Transfer Learning trains all layers.
- **c)** Transfer Learning uses labeled data, while Fine-Tuning uses unlabeled data.
- **d)** Fine-Tuning requires retraining the entire model, while Transfer Learning does not.

7) Which of the following is NOT a common application of Natural Language Processing (NLP) techniques?

- **a)** Sentiment analysis
- **b)** Image recognition
- **c)** Machine translation
- **d)** Named entity recognition

8) Which NLP technique is used for converting words into their base or root form?

- **a)** Named entity recognition
- **b)** Lemmatization
- **c)** Stemming
- **d)** Part-of-speech tagging

9) What is the purpose of word embeddings in NLP?

- **a)** To convert text into a numerical representation
- **b)** To perform sentiment analysis
- **c)** To extract named entities from text
- **d)** To summarize large documents

10) Which of the following deep learning techniques is specifically designed for generating human-like text?

- **a)** Convolutional Neural Networks (CNNs)
- **b)** Recurrent Neural Networks (RNNs)
- **c)** Generative Adversarial Networks (GANs)
- **d)** Transfer Learning

1	2	3	4	5	6	7	8	9	10
a	b	b	b	b	b	b	b	a	b

CHAPTER 6

PRACTICAL APPLICATIONS AND FUTURE DIRECTIONS

6.1 Applications DOMAINS OF AI

Globally, due to the immense developments and technological transformations in various sectors, the need for AI-based products and processes are on the rise even in everyday applications. Given the rapid advances in AI, it is more likely that pathology and radiology images will be analyzed by intelligent agents in the future. AI agents in speech and text recognition are being employed for tasks like patient communication and recording of clinical notes. Figure 1.7 highlights the application domains of AI.

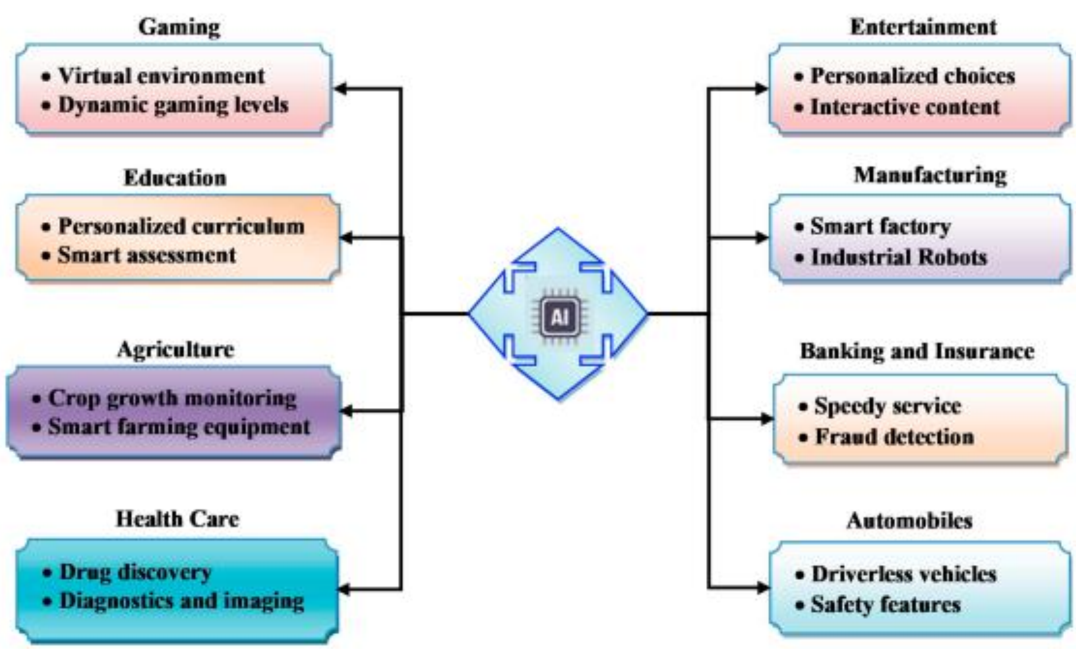

FIGURE 1.7 Application domains of AI (Govoni, 2012)

1. GAMING

Artificial Intelligence in the gaming industry was dated back to the 1950s when Arthur Samuel released the Checkers game powered by AI, which successfully demonstrated the self-learning capability of computer programs. This program has given tough challenges to even professional players and could even win them on many occasions. Today, AI finds a significant place in game development, as games with AI provides a highly realistic feel and involvement to the users. Games are naturally complex and require a human mind to think in countless ways beyond imagination. Different users have different assumptions, different levels of understanding, different styles, and skills while playing games. The AI entity in gaming has to look into all these factors, train itself by taking into consideration various human perspectives, and set nearly infinite strategies to tackle the human opponents. The AI program gains knowledge and learns a lot from each and every user playing the game. It creates a huge knowledge base of reference, which gets updated with every new game played and aids in making dynamic decisions during the game. Regression algorithms and machine learning techniques go hand-in-hand in predicting the game moves of the human opponent. The gaming industry provides a risk-free virtual environment for testing the intelligence of AI applications and enables us to explore creativity without any restrictions, though challenging.

2. EDUCATION

AI has a greater potential to change the teaching-learning process, assist teachers in devising better strategies in teaching, assist students in an adaptive and improved learning experience. AI can automate the administrative responsibilities of teachers and academic institutions. Extensive research and development works are being carried out to develop intelligent educational tools, which could save teachers time by assisting them in the maintenance of student attendance, evaluation of exam papers, assessment of assignments, and other supportive activities in education. AI in education is much focussed on identifying the subject knowledge and learning capability of each and every student through investigative testing and to develop personalized and student-specific curriculum. AI can be of much help in supporting the students who struggle to cope up with the common curriculum and combined teaching-learning practices.

Personalized learning experiences are expected to overcome the major shortcomings in the classic one-to-many educational models. Inclusive learning will become a reality with AI, where students from varied educational and societal backgrounds can participate in a classroom lecture and effectively engage in discussions. It is always a myth that the introduction of AI in education will lead to a replacement of teachers, but the actual fact is that teachers will be enabled through AI to perform better by providing individual attention and personalized recommendations to every student. AI can also customize the student assignments and exam question papers as well, thereby assuring a better environment for the students. Educational AI applications will facilitate students to learn in a conducive way, and the growth in this area will offer a wide range of prospective services to teachers and students.

3. HEALTHCARE

AI technology is revolutionizing the medical sector and offers multiple advantages over traditional analytics and medical decision-making practices. It can assist doctors and scientists in early detection and prevention of diseases, suggest personalized treatment plans for patients, unlocks various complex data sets to gain new understandings. Intelligent algorithms in AI can speed up and improve the precision in the analysis of medical data and images, which will allow physicians to gain more insights into disease diagnosis, treatment decision, and patient care. Automation of medical procedures through AI can expand healthcare access to millions of people who live in remote or underdeveloped regions where there is a shortage of trained medical as well as paramedical professionals. AI systems can also be used in taking X-rays, ultrasound, CT and MRI scanning, and many other diagnostic procedures which are in general performed by clinical support staff. AI and machine learning algorithms are capable to speed up the analysis of huge medical data, arrive at some meaningful inferences through predictions, provide early alerts about patient health conditions, recommend and support doctors in making decisions on the treatment to be given for critically ill patients. Artificial Intelligence (AI), combined with investigational technologies, is estimated to pave the way for the discovery of cost-effective, improved, and more successful drugs for various health complaints and diseases. AI will be helpful to automate and optimize the research and development in drug discovery procedures.

4. MANUFACTURING

Industry 4.0 is focused on bringing out a massive transformation in the manufacturing industry where Artificial intelligence serves as a core component in this revolutionary process. Artificial Intelligent technologies are capable of making the concept of “Smart Factory” a reality, which makes more productivity as well as staff empowerment. Andrew Ng, the co-founder of Google Brain and Coursera, says: “AI can efficiently accomplish manufacturing, ensure quality control, reduce the design time, cut down materials wastage, further production recycling, and reuse, do predictive maintenance, and much more”. Starting from materials procurement, production, warehousing to supply chain, sales, and maintenance, AI is aimed at changing the way every industry operates so far. The International Federation of Robotics has predicted that by 2025, there will be around 1.5 million industrial robots working in factories worldwide (Gonzalez et al., 2018). As more and more robots enter into the industrial shop floor along with human workers, there is a need to ensure efficient collaboration between robot and human. Advances in AI will enable robots to optimize industrial processes, handle more cognitive tasks, and make dynamic decisions based on the real-time scenario. AI algorithms play a significant role in the estimation of market demand, location and economic factors, weather patterns, consumer behavior, and much more.

5. BANKING AND INSURANCE

Artificial intelligence has gifted the banking and the insurance sector a whole new system to meet the customer demands with more convenient, smart, and safe methods to protect, spend, save, and invest their money. Artificial Intelligence will be the forthcoming trend in the banking sector as it is powered by the ability of data analytics to improve compliance, derive valuable insights, and tackle fraudulent transactions. AI can make use of the humongous data available in the insurance sector for more accurate predictions, determine trends, risks, save manpower, and ensure better information for future planning. An intelligent algorithm could realize anti-money laundering activities in no time compared to the time and effort to be spent by human resources. AI bots, digital payment consultants, and biometric fraud detection devices will reduce costs, ensure accurate and quick processing in banks, and offer highly improved quality of services to the customers. AI bots can instantly detect suspicious activities and security breaches concerning customer accounts and can alert the customers and companies well before the occurrence of fraud. Repetitive work processes can be automated, which allows human knowledge and time to be used for value-added functions, which definitely needs human expertise.

6. ENTERTAINMENT

Artificial intelligence serves as a powerful tool in the entertainment industry, bringing massive changes and thus reshaping the entertainment arena. AI along with augmented reality, data analytics, and deep learning technologies exhibit remarkable intelligence in interactive game design, innovative content production, movie design, and advertisement creation. AI has brought in an innovative style, creativity, and reality to content creation, delivery, and re-defined consumer engagement. In movie creation, AI employs massive data sets to analyze and explore the user preferences and to design scenarios, far beyond human capabilities. Various learning strategies are used by AI to learn from all possible external knowledge sources and self-experience to design interesting content. Companies use AI to monitor customer activity, assess customer behavior and to analyze customer sentiments on products, and use this analysis in improved as well as personalized service provisioning.

7. AUTOMOBILES

As autonomous vehicles are going to be the future, Artificial Intelligence is getting implemented in numerous ways in the design and operations of vehicles. Artificial Intelligence and machine learning have been successfully applied in the navigation of vehicles, monitoring of blind-spot, seats, mirrors, and temperature adjustment, and also in giving personalized suggestions. Various sensors controlled by AI can immediately respond to any dangerous situations by alerting the driver, applying the automated emergency braking system, or taking control of the vehicle and initiating communications to helplines. AI enables the detection of technical changes well in advance before it could affect the vehicle's performance and helps prevention of unexpected failures. Automated Guided Vehicle (AGV) is another path-breaking technology in the automobile industry, powered by AI. Without any human assistance, AGVs can identify the objects, find the optimal routes, pickup, and deliver goods to different parts of a designated location. Recently, many AI techniques are being tested and implemented in automobiles, aiming towards more effective automation and a driverless future.

8. AGRICULTURE

AI-assisted technologies can support the agricultural sector in improved crop yield, pest control, soil nutrition monitoring, crop growth monitoring, and many other tasks related to agriculture. AI can help the farmers to monitor their crops without the requirement to personally supervise and observe the farm. AI is changing the traditional agricultural practices, reduce the burden of farmers, and improve crop management. AI can also be utilized to test soil nutrient availability, nutrient deficiency, and other defects in the soil. This will enable the farmers to limit the use of chemical fertilizers as per the nature of the soil and crop needs. Implementing AI can also check crop defects and diseases at an early stage, thereby improving healthy crop production and controlled pesticide usage. AI-enabled applications are highly supportive of the farmers in forecasting the weather conditions, which play a vital role in crop planning and cultivation. Weather data also assists the farmer to take the precautionary steps to protect the crops based on the predicted rainfall or drought, with the help of AI. Furthermore, AI helps farmers to selectively identify the weeds, which helps to spray chemicals only on the weeds without affecting the crops. Implementing AI in agriculture will strengthen the agricultural sector to a remarkable extent and reduce the work of farmers by providing accurate and timely guidance.

6.2 AI in Healthcare and Medicine

Artificial intelligence is revolutionizing the field of healthcare, offering enormous potential to improve patient care, improve clinical decision-making, simplify administrative tasks and transform healthcare delivery. Here are some key areas where AI is used in healthcare:

- **Medical diagnosis:** AI algorithms can analyze massive amounts of medical data, such as medical images, lab results, and patient records, to help healthcare professionals diagnose diseases with greater accuracy and speed. For example, artificial intelligence can help radiologists detect early signs of breast cancer in mammograms or identify abnormalities in X-rays and CT scans.
- **Personalized treatment plans:** AI can analyze a patient's health data, including their personal information, medical history and lifestyle factors to develop personalized treatment plans. This can lead to more targeted and effective treatment approaches such as precision (personalized) medicine, which shapes treatment strategies based on an individual's unique characteristics.
- **Virtual health assistants:** AI-powered virtual health assistants, also known as " chatbots, " can provide patients with real-time health information, schedule appointments, and answer questions about medications, symptoms, and lifestyle recommendations. These virtual assistants can improve patient engagement, improve access to healthcare services, and reduce the burden on healthcare providers.

- **Predictive analytics:** AI can analyze large data sets to identify patterns and trends, enabling healthcare providers to make data-driven predictions and take preventative action. For example, AI can help identify patients at risk of developing chronic conditions such as diabetes or cardiovascular disease, enabling early interventions to prevent or more effectively manage these conditions.
- **Drug discovery and development:** AI can accelerate the drug discovery and development process by analyzing vast amounts of biomedical data to identify potential drug candidates, predict their efficacy and toxicity, and optimize their chemical structure. This can significantly reduce the time and costs associated with bringing new drugs to market.
- **Remote monitoring of patients**: AI can enable remote monitoring of patients with chronic conditions, allowing healthcare providers to collect and analyze patient data, such as vital signs, activity levels and medication adherence, in real time. This can help detect early warning signs, provide timely interventions and improve patient outcomes.
- **Health administration:** AI can simplify administrative tasks in healthcare, such as scheduling appointments, collecting co-payments from patients, or admitting patients. This can reduce the administrative burden on healthcare providers, improve operational efficiency and improve the overall patient experience.

important to note that the integration of AI in healthcare causes ethical, legal and regulatory problems. It is crucial to ensure that AI technologies are developed, validated and implemented responsibly and ethically, in accordance with existing health regulations and standards, in order to maximize their benefits and minimize potential risks. An example of the use of artificial intelligence in medical diagnostics is the field of radiology, where artificial intelligence algorithms can analyze medical images to help radiologists detect and diagnose various conditions. For example, AI is used in the diagnosis of breast cancer on mammograms. Breast cancer is one of the most common cancers in women, and mammography is a widely used tool for its detection. However, mammograms can be complex to interpret and false-positive and false-negative results can occur, leading to unnecessary follow-up tests or missed diagnoses. Artificial intelligence algorithms can improve the accuracy and efficiency of mammogram interpretation by helping radiologists identify potential abnormalities. The AI algorithm can analyze mammographic images and use deep learning techniques to detect subtle features that may indicate the presence of tumors such as microcalcifications or masses. The algorithm can then provide the radiologist with a computer-aided detection system (computer aided detection - CAD) which highlights suspicious areas for further evaluation. The radiologist can review the algorithm findings and make a final diagnostic decision. The use of artificial intelligence in mammography interpretation has shown promising results in research studies and clinical trials. It has the potential to improve the accuracy and efficiency of breast cancer detection, reduce false-positive and false-negative results, and help radiologists make more informed and timely decisions. This can ultimately lead to earlier detection of breast cancer, better patient outcomes and potentially lower healthcare costs.

AI algorithms for medical diagnosis, including breast cancer detection, are not intended to replace human radiologists. They are designed to increase the expertise of healthcare professionals and provide them with additional tools to help them make decisions. Radiologists continue to play a key role in reviewing and validating AI algorithm findings and making the final diagnosis based on their clinical judgment and experience.

Virtual health assistants Artificial intelligence-powered virtual health assistants are becoming increasingly popular in healthcare settings, providing patients with personalized care, information and support. Here are some examples of how AI is being used in virtual health assistants:

- **Symptom check.** Virtual health assistants powered by artificial intelligence can help patients assess their symptoms and provide preliminary diagnoses. By analyzing a patient's query and comparing it to a vast database of medical knowledge, a virtual health assistant can offer personalized recommendations for further assessment or self-care .
- **Medication management.** Virtual health assistants can help patients manage their medications by providing reminders for medication doses, monitoring adherence, and alerting patients to potential drug interactions or side effects. Artificial intelligence algorithms can also analyze patient data to optimize drug schedules and doses based on individual needs.

- **Health monitoring.** Virtual health assistants can collect and analyze patient-generated health data, such as heart rate, blood pressure and blood glucose levels, to provide real-time feedback and recommendations for managing chronic conditions such as diabetes or hypertension. AI can also identify patterns and trends in health data to alert patients and healthcare providers to potential health risks or changes in conditions.
- **Telehealth.** Virtual health assistants can help with scheduling appointments, providing reminders, and facilitating virtual communication between patients and healthcare providers. AIpowered virtual health assistants can also help patients prepare for telehealth visits by collecting relevant medical history, symptoms and other information that can be shared with healthcare providers.
- **Health education.** Virtual health assistants can provide patients with educational content, answering questions about medical conditions, treatments and healthy lifestyle habits. Artificial intelligence algorithms can analyze patient preferences and behaviors to provide personalized health education materials tailored to the needs and preferences of individual patients.
- **Emotional support.** Virtual health assistants can provide emotional support to patients by offering mental health resources, coping strategies and self-help advice. Artificial intelligence algorithms can analyze patients' reactions and behaviors to identify signs of distress or mental health concerns and make appropriate recommendations for support.
- **Health monitoring and training.** Virtual health assistants can help patients track their health goals, such as weight loss, exercise or sleep patterns, and provide personalized counseling and feedback based on their progress. Artificial intelligence algorithms can analyze patient data to provide insights and recommendations to optimize health outcomes.

AI-powered virtual health assistants have the potential to improve patient engagement, improve access to care, and support patients in managing their health and well-being. It is important to ensure that virtual health assistants comply with privacy and security regulations and that the information and recommendations provided are validated and verified by qualified health professionals.

6.3 AI in Finance and Business

- **Regulatory compliance – detection and prevention fraud:** With the increasing trend in ecommerce or online transaction the possibilities of fraud also increases exponentially. AI is based on the anti-fraud system which detects fraudulent activities, reports, and blocked such transactions. Banking and finance institutions have a Fraud Detection Software that patterns can be spotted by using predictive analytics without any knowledge to the human analysts and applying machine learning algorithms to detect the fraudulent transaction & minimizing fake decline.
- **Prediction of Stock Market and Trading system:** Several issues can cause obstacles in the trading system. AI systems provide a faster analysis of data not only the cause of failure be known, but also provided the solution related to that. A Computer system has been trained to forecast when trade shares to maximize the returns & to reduce the losses during the uncertainties & help the investors, institutions, companies to take quick decisions.
- **Increasing security:** In AI, Machine learning algorithms need a split minute to access fraudulent
- **transactions in real-time not spot them after the crime is committed.** Many of the organization are trying to implement the Artificial Intelligence to enhance the security in online transactions & related services.
- **Risk Management:** Many organizations led to the subprime mortgage crisis due to a lack of risk management. Traditional software applications focused only on the selected loan application and financial reports. But new machine learning technology focused on every fact related to the current market trend to prevent financial crime and financial crisis prediction by its credit-scoring tasks in real life environment. It also helps to minimize underwriting risks. In the field of loan, health, mortgage, or life insurance, it can help handle every risk. It also fits perfectly with the underwriting tasks that are so common in finance and insurance.
- **Credit Card and Loan Decisions:** In process of credit card and loan decisions, AI automatically assessing the profile which reduces the cost and efforts involved significantly and making the whole process fair and transparent.
- **Protect Client by Spending Pattern Prediction**: At present whole country is dependent on online transactions. In case if their card/Mobile is stolen or the account

is hacked AI is useful for client spending detection to prevent fraud or theft. It identifies the user & allows the transaction to happen.

- **Personalized Banking:** In banking, AI plays an important role to do all transactions online like payments, deposits where clients no need to rush banks. Even handle a majority of a client complaint and provide the clients with an efficient self-help interface. AI-based virtual supporters like Alexa, Google Assistant, Echo, etc. are already gaining popularity in the consumer markets. It presents true guidance to the prospective client and so that they can get accurate information and fast solutions to their problems.
- **Process Automation:** Process automation is central to boosting one's productivity and minimizing operational costs by doing its job in just a few minutes. AI reduce more than 50% repetitive task perform by human and minimize cost. Process automation effectively interpreted documentation, identify issue need human attention by its services like call center automation, chatbox (Robots do chatting and give instruction), paperwork automation, etc.
- **Security to World financial data** – Cyberattack and virus-like worms, Trojan are the main challenges in the modern era. Machine learning security solutions are capable of securing the world's financial data by providing the power of intelligent pattern analysis, combined with big data capabilities through security technology an edge over traditional and non-AI tools.
- **Marketing:** AI also shows its significance in finance domain people by predictive marketing analytics based on past behavior easily. It assists in accurately forecast sales by analyzing customer expectations. Web action can be properly supervised and cell phone app usage can be understood to discover trends and patterns.

6.3.1 IMPACT OF AI IN FINANCE SECTOR

PROS	CONS
Efficient in handling a large volume of information	Complex in nature need high production and maintenance cost

More efficient in forecasting assist business relationship strong and do advisory work as well	High-end fintech technology is too costly so each organization could not afford the premium application of AI
Eliminate bias from metrics	Due to rapid technology changes many experts issue warnings about the dangerous nature of AI
Better informative charts and graphs help to make a safe decision	Lack of regulatory scrutiny may present a problem in the upcoming period
Provide 24/7 hours service as compare to human resources.	Possibility of misuse of data cause serious losses like delivered to wrong hand can cause serious threats to humankind.
Quickly perform the task related to finance like Insurance, Trading, accounting, etc. Financial users get transaction records online and offline which saves time, money, and effort.	Wide-reaching unemployment as replaces workforce with machines and computers. Also, block the human mind and increase dependency on the machine (Arya, 2021).
Fraud detection is a smart card-based system with the use of AI.	Lack of creativity mind

6.4 AI in Autonomous Systems and Robotics

Artificial Intelligence has played a very major role not only in increasing the comforts of humans but also by increasing industrial productivity which includes the quantitative as well as qualitative production and cost-efficiency. Robotics and artificial intelligence (AI) are closely related fields, and when combined, they give rise to a discipline known as robotic artificial intelligence or simply “robotics in artificial intelligence.”

- Robotics in AI involves integrating AI technologies into robotic systems to enhance their capabilities and enable them to perform more complex tasks.
- AI in robotics allows robots to learn from experience, adapt to new situations, and make decisions based on data from sensors. This can involve machine learning, computer vision, natural language processing, and other AI techniques.

- Robots can use machine learning algorithms to analyze data, recognize patterns, and improve their performance over time. This is particularly useful for tasks where the environment is dynamic or unpredictable.
- AI-powered vision systems enable robots to interpret and understand visual information from the surroundings. This is crucial for tasks like object recognition, navigation, and manipulation.

The combination of robotics and AI opens up a wide range of applications, including autonomous vehicles, drones, industrial automation, healthcare robots, and more. The synergy between these fields continues to advance, leading to increasingly sophisticated and capable robotic systems. AI plays a crucial role in modern robotics, bringing intelligence and adaptability to these fascinating machines. Artificial Intelligence (AI) is used in robotics to enhance the capabilities of robots, enabling them to perform a wide range of tasks with increased autonomy and adaptability. There are several ways in which AI is applied in robotics:

- **Object Recognition:** AI-powered computer vision allows robots to recognize and identify objects in their environment. Computer vision helps robots understand their surroundings, create maps, and navigate through complex environments. This is essential for autonomous vehicles, drones, and robots operating in unstructured spaces.
- **Visual serving:** AI allows robots to track and precisely manipulate objects based on visual feedback, crucial for tasks like welding, painting, or assembling delicate components.
- **Human-robot interaction:** Robots can understand and respond to natural language commands, enabling more intuitive and collaborative interactions with humans.
- **Voice control:** Robots can be controlled through voice commands, making them accessible for a wider range of users.
- **Autonomous decision-making:** AI algorithms can learn from data and make decisions in real-time, enabling robots to adapt to changing environments and react to unexpected situations.

- **Reinforcement learning:** Robots can learn motor skills and control strategies through trial and error, allowing them to perform complex tasks like walking, running, or playing games.
- **Predictive maintenance:** AI can analyze sensor data to predict equipment failures and schedule preventive maintenance, reducing downtime and costs.
- **Sentiment analysis:** AI can analyze human text and speech to understand emotions and adjust robot behavior accordingly.
- AI algorithms process camera and sensor data to map surroundings, identify obstacles, and plan safe and efficient paths for robots to navigate.

6.4.1 Applications of AI in Robotics

The applications of AI in robotics are diverse and continually expanding as technology advances. Let's see few notable applications where AI plays a crucial role in enhancing the capabilities of robotic systems:

- **Manufacturing:** AI-powered robots automate tasks like assembly, welding, and quality control, improving efficiency and accuracy.
- **Healthcare:** Surgical robots assist doctors with minimally invasive procedures, while other robots help with patient care and rehabilitation.
- **Logistics and delivery:** Autonomous drones and robots deliver packages and perform warehouse tasks, optimizing logistics and reducing delivery times.
- **Exploration and disaster response:** AI-powered robots can explore dangerous environments, perform search and rescue operations, and assist in disaster recovery efforts.
- **Agricultural Robotics:** AI-enabled robots are used in precision agriculture for tasks such as planting, harvesting, and monitoring crop health.

6.5 Challenges and Limitations of Current AI Technologies

Like any technological developments, Artificial intelligence has both positive as well as negative impacts. Even though AI has a huge potential to serve mankind, there are certain challenges to be faced in real-time implementation. The following section discusses the major challenges of artificial intelligence in the working environment. Figure 1.8 shows the challenges of AI technology concerning various factors which include human bias, manpower, security, data genuineness, etc.

1. LOSS OF SELF-THINKING

The intelligence of one person may make a machine to behave smart and intelligent subject to the person's knowledge who feed intelligence to the machine. It does not mean that this constrained machine intelligence will enhance the user's selfthinking ability. Instead, this kind of someone else's intelligence may lead to negative impacts as well. For instance, a machine having limited intelligence in decision making will make a human to follow it as such, though there may be better decisions that could be arrived by the human by their own intelligence. For example, consider the scenario in which a machine having the intelligence to segregate the materials based on the color property. Assume the materials are in three different colors such as red, blue, and green and there are also other materials with a combination of the above three colors. The machine can perfectly segregate the materials with identical colors, but materials with composite colors and fading colors may be identified only through the program using color thresholding and this color thresholding is mostly static and user-defined. Sometimes, a human can do better segregation of color material than a machine that uses static intelligence. Such failure cases by intelligent machines are referred to as false positives and false negatives. Figure 1.9 shows the general representation of identical colors and degrading colors where the machine and human will be discriminated against in terms of their own intelligence.

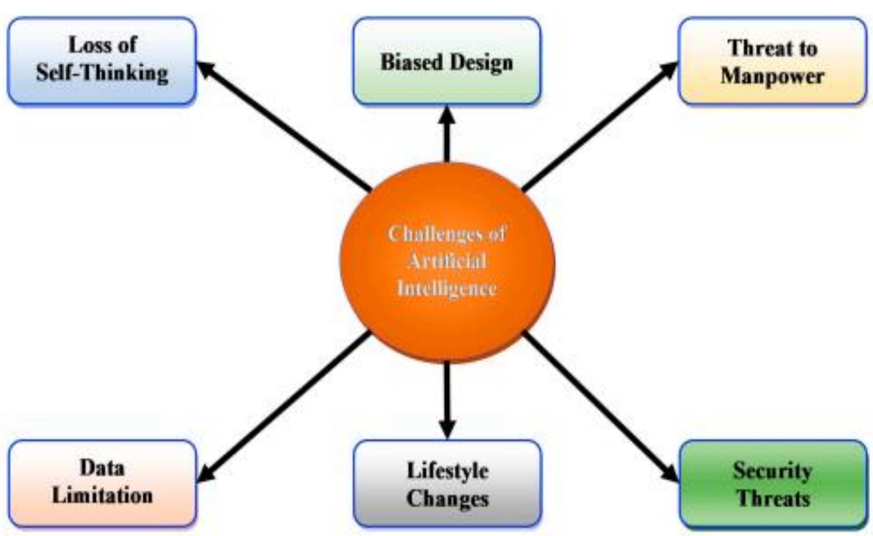

FIGURE 1.8 Challenges in AI (Govoni, 2012)

FIGURE 1.9 Representation of solid colors and composite colors (Govoni, 2012)

2. BIAS IN THE DESIGN OF ARTIFICIAL INTELLIGENCE

The question "Will it be a better model when one person's knowledge is adopted by all others?" is a great challenge for artificial intelligence developers. The answer to this question will make us understand the influence of "bias" in the design of artificial intelligence. Any machine designed with human intelligence and algorithms is primarily dependent on either the knowledge of a single person or a specific group and hence, the machine intelligence will be restricted based on their limited knowledge. This intelligence can be manipulated and controlled by the developer, which may not be favorable to all scenarios. This bias in design may become a threat to society to forcibly adopt a model, though it is not a perfect fit for everyone.

3. LIMITATION ON DATA

Availability of data plays a major role in justifying the performance metrics of any AI entity. Genuineness of the data is another major challenge to the developers of artificial intelligence as well as to the AI researchers. Most of the AI-based outcomes are primarily based on existing, dynamic data being continually collected. Several data pre-processing algorithms developed by researchers are available to smooth the data before developing any intelligence model. Now the question before AI developers is "How to find and fill up the missing data?" In general, AI developers will use mathematical and statistical models such as interpolations, regression, and correlation methods for fitting missing values with respect to existing data. These predicted and fitted values show higher influence in artificial intelligence models. The second question is "Will the mechanism used by AI developers for selection and rejection of data is perfect and suitable to all?" Figure 1.10 shows two different ways to cluster the data points, a simple illustration of two possible ways to construct AI models. In the first method, lower-right data points were considered and upper-left data points were excluded whereas in the second method, upper data points were selected and lower data points were excluded. Hence, the development of AI models based on these two methods will surely give two different kinds of understanding based on the corresponding selection of data.

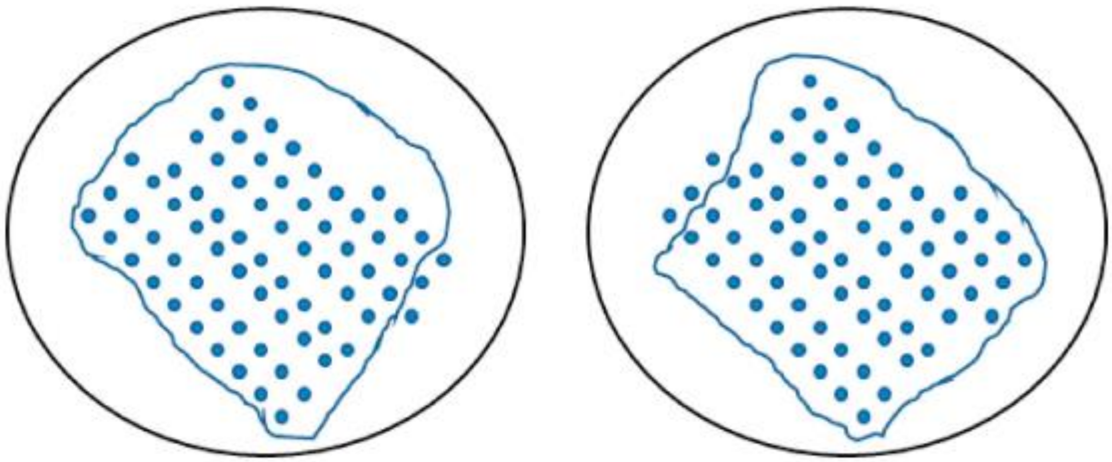

FIGURE 1.10 Two different types of clustering data to build AI model (Govoni, 2012)

4. THREAT TO MANPOWER

The goal of artificial intelligence is to reduce human errors by replacing them through machine intelligence. Job opportunities will be limited due to the growth and development of human free artificial intelligence models in society. This reduction in job opportunities due to the development of AI will indirectly influence the economy, as artificial intelligence gradually reduces manpower. Worldwide population growth is always on the rise, and hence the development of humanless technology may pose a big threat to human survival irrespective of the country.

5. LIFESTYLE CHANGES

The current lifestyle of the human being is incomparable with the traditional lifestyle due to the extensive use influence of technology. Technological development is also playing its own role as one of the factors which are affecting the health of the human being. For example, most of the traditional games were replaced by technology-based games where there is no physical exercise to the human. Some AI-based games are highly interesting not only to young children but also to old age people, where unknowingly their mind and brain are affected and addicted to the games. It is another big challenge where the users undergo immense stress and struggle to come out of the virtual environment, especially the younger generation.

6. SECURITY THREATS

AI has placed its footprints all over the world in smart product development and an integrated environment. The integrated environment will help society to access AIbased products from any corner of the world but on the other side, there is always a standing threat by intruders to do unauthorized access to these AI-based products. This leads to a major threat to society, as the intruder may get access and alter the functionality of the AI products. Think about the scenario where the AI machine designed to detect and remove the “weed” in the crop field starts to remove the crop instead of weed due to security malfunctioning. Such hidden threats are always there in most of the AI-based developments.

6.6 FUTURE PROSPECTS OF AI

AI is one of the significant and powerful breakthroughs which will have a huge impact on human in all walks of life and hence it needs continuous monitoring and attention to frame standards and policies for the upcoming years. Though initial efforts in AI is highly challenging, AI is expected to master all the domains in the future. The emphasis of AI should not only be on the capability of the technologies, but also the usefulness and implementation in the respective field. AI will undoubtedly empower the automation industry through a vast knowledge base and also infuse a high level of intelligence into the entire automation process, which will assist to prevent the associated cyber threats and contention. AI will become integral to all processes and operations and keeps evolving and innovating with time without considerable manual intervention. For widespread adoption of AI systems, regulations and standards must be set up by the competent authorities, provision for integration must be made available, sufficient training and knowledge must be given to the user base to make them clearer about their roles and the role of AI systems. Above all, the AI system must be constantly updated and to be incorporated with day-to-day advancements in the field. Future developments in AI has to be more focused on bias-free, eco-friendly, nonradioactive, carbon-neutral, and energy-efficient AI environment. Figure 1.11

presents the current scenario of manufacturing units, where robots assist humans in their work. Figure 1.12 shows the future scenario, where robots carry out the entire work under human supervision.

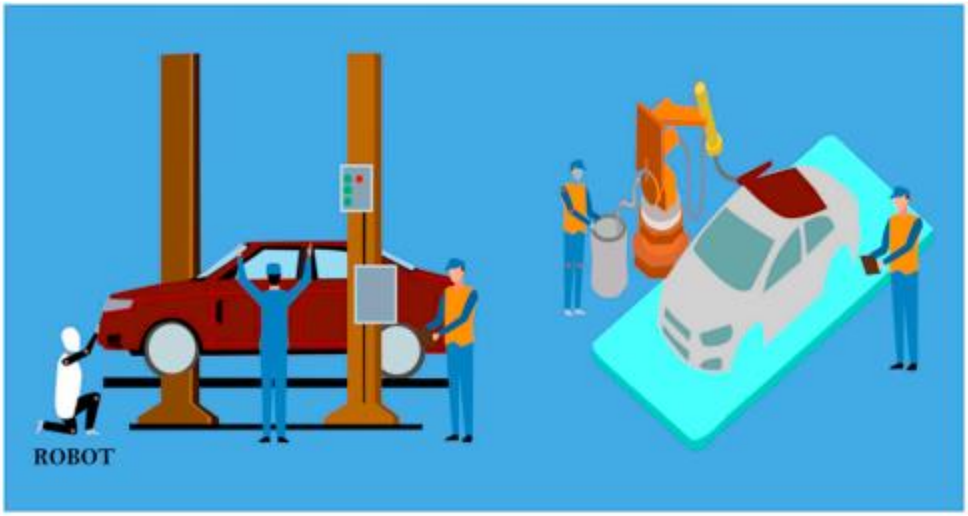

FIGURE 1.11 Present scenario of manufacturing unit (Govoni, 2012)

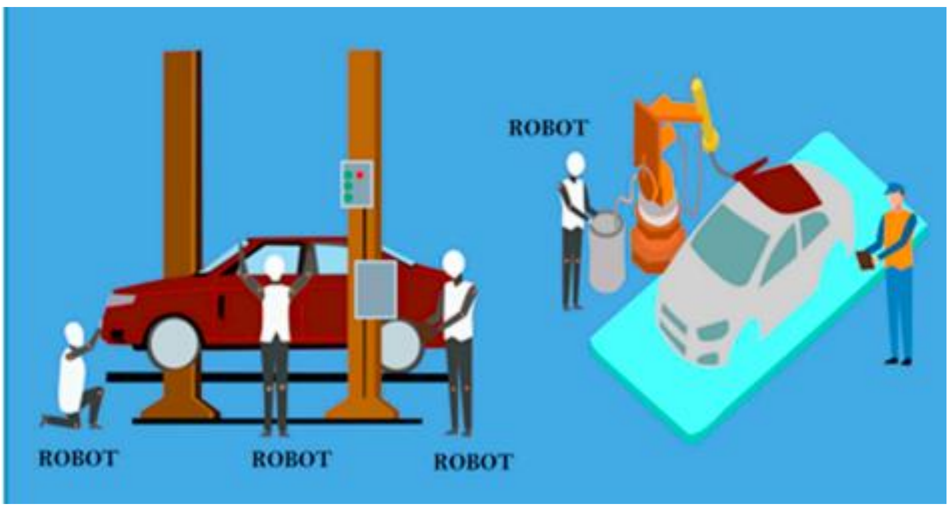

FIGURE 1.12 Future scenario of manufacturing unit (Govoni, 2012)

a) APPLICABILITY

Artificial intelligence models are being developed with the available, limited data based on few assumptions. Applying and testing the AI prototype to similar applications may result in similar results and interpretation. Also, applying the same prototype for slightly varied applications may not ensure proper decision making in all cases. Hence, the development of a flexible AI model to fit global requirements will be the focus in the future for AI developers.

b) DYNAMISM IN AI MODEL

Most of the AI applications are developed for the current technologies which keep updated on an everyday basis. Hence, an artificial intelligence–based system developed with today's capability may not be suitable in the future due to the dynamic change and growth in technology. Scalability in terms of functionality with respect to the current requirements is another bigger challenge for AI designers. All the AI models developed based on the present scenario should also have the ability and adaptability to support future scenarios.

c) ECONOMIC FEASIBILITY

The cost factor involved in the development of AI models is huge and not affordable by many. Even though introducing AI in a work environment have many positive footprints, the cost involved in developing and implementing such automated environments may not be economically feasible when compared with a traditional working environment. Hence, introducing this technology in small-scale industries and its applications may not be in the position to implement the same due to the higher influence of cost factor. More works are to be done in bringing down the cost incurred in the development and maintenance of AI systems.

d) USER TRAINING

Transformation in the workplace requires the user to have preliminary knowledge as well as intense training on AI models. Training on AI technology either before launching or after launching the AI products is mandatory to the user for effective usage of the AI system. For example, intelligent word editors and text-based applications can continue the word or subsequent words when the user tries to type half of the word itself. This word predictive and suggestive system needs a minimal level of training to the user for selecting such predictive words or sentences by pressing corresponding keys. Some users do not even know how to use such word applications even though users are using the word applications in their day-to-day working environment.

PART-1: VERY SHORT QUESTIONS

1) How is AI being applied in healthcare and medicine?
2) What are some examples of AI applications in finance and business?
3) What are the main impacts of AI in the finance sector?
4) How is AI utilized in autonomous systems and robotics?
5) What are some specific challenges in applying AI to robotics?
6) Can you name a few applications where AI is used in autonomous systems?
7) What limitations do current AI technologies face in robotics applications?
8) How is AI contributing to improving financial decision-making processes?
9) What are some potential future prospects of AI in various industries?
10) How is AI being used to enhance efficiency in healthcare processes?

PART-2: SHORT QUESTIONS

1) How is AI being utilized in healthcare and medicine to improve patient care and treatment outcomes?
2) What are some specific applications of AI in the finance and business sectors, and how do they impact operational efficiency?
3) Can you explain the significant impacts of AI in the finance sector, particularly regarding automation and decision-making processes?
4) What role does AI play in autonomous systems and robotics, and how is it revolutionizing industries like transportation and manufacturing?
5) What are some notable challenges faced in the application of AI in robotics, and how are researchers addressing them?
6) How does AI contribute to enhancing the autonomy and decision-making capabilities of robots in various domains?
7) What are the limitations of current AI technologies in achieving fully autonomous systems, and what advancements are needed to overcome them?
8) How do you envision the future prospects of AI in terms of its integration into everyday life and industries?
9) Can you elaborate on the potential benefits and risks associated with widespread adoption of AI in finance and business?

10) In what ways can AI further transform healthcare and medicine in the future, and what ethical considerations should be addressed

PART-3: LONG QUESTIONS

1) How is AI being utilized in healthcare and medicine to improve diagnosis and treatment methodologies, and what are the key challenges in integrating AI into this domain effectively, considering factors such as data privacy, ethical concerns, and regulatory compliance?

2) In what specific areas of finance and business is AI making the most significant impact, and what are the implications for traditional financial institutions and businesses in terms of competition, operational efficiency, and risk management? How can businesses effectively leverage AI technologies to stay competitive in this evolving landscape?

3) What are the primary ways in which AI is transforming the finance sector, from algorithmic trading to personalized financial advice and fraud detection? How do these advancements influence market dynamics, investor behavior, and financial decision-making processes, and what are the potential risks associated with overreliance on AI in finance?

4) How is AI driving innovation in autonomous systems and robotics, from self-driving cars and drones to industrial automation and space exploration? What are the key technical and ethical challenges that need to be addressed to ensure the safe and responsible deployment of AI-powered autonomous systems in various real-world scenarios?

5) What are the current applications of AI in robotics, and what are the main limitations and challenges faced by researchers and engineers in developing more advanced and versatile robotic systems? How might advancements in AI technologies such as reinforcement learning and natural language understanding shape the future capabilities of robots and their integration into diverse fields, from manufacturing to healthcare to space exploration?

PART-4: MCQ QUESTIONS

1) In which domain of AI would you find applications such as predictive modeling for disease diagnosis and treatment recommendations?

a) AI in Finance and Business

b) AI in Autonomous Systems and Robotics

   c) AI in Healthcare and Medicine
   d) Applications of AI in Robotics

2) What is a significant application of AI in the finance sector?
   a) Stock market prediction
   b) Crop yield optimization
   c) Weather forecasting
   d) Social media analytics

3) How does AI impact the finance sector?
   a) By eliminating the need for human intervention
   b) By reducing fraud and improving security
   c) By decreasing market volatility
   d) By increasing manual errors in transactions

4) Which field extensively utilizes AI for tasks like automated trading and risk management?
   a) Agriculture
   b) Marketing
   c) Finance
   d) Education

5) Autonomous cars and drones are examples of AI applications in which domain?
   a) Healthcare and Medicine
   b) Finance and Business
   c) Autonomous Systems and Robotics
   d) Future Prospects of AI

6) What is a primary challenge in the application of AI in robotics?
   a) Lack of computing power
   b) Limited availability of data
   c) Inability to understand human emotions
   d) Overreliance on human intervention

7) Which sector is expected to witness substantial growth due to the integration of AI?
   a) Retail
   b) Manufacturing
   c) Energy

d) Agriculture

8) What are some limitations of current AI technologies in healthcare?

a) Difficulty in interpreting complex data

b) Inability to perform repetitive tasks efficiently

c) Limited access to medical records

d) Lack of trained medical professionals

9) How does AI contribute to improving efficiency in business processes?

a) By increasing manual errors

b) By automating repetitive tasks

c) By reducing data analysis capabilities

d) By decreasing customer engagement

10) What is a potential future prospect of AI technology?

a) Decreased reliance on automation

b) Enhanced personal privacy protection

c) Increased human labor demand

d) Advanced human-computer interaction systems

1	2	3	4	5	6	7	8	9	10
c	a	b	c	c	b	b	a	b	d