Applied Deep Learning

Design and implement your own Neural Networks to solve real-world problems

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Dedicated to

My beloved parents:

Shri Krishan Lal Tekchandani

Smt. Kanta Tekchandani

and

My wife ***Varsha Tekchandani*** *and*

My son ***Tarun Tekchandani*** *and*

My daughter ***Medha Tekchandani***

My Brother ***Prakash Tekchandani***

— Dr. Rajkumar Tekchandani

My beloved parents

Late ***Shri Jai Singh***

Smt. ***Nachtro Devi***

&

My wife ***Palwinder Kaur*** *and*

My son ***Bhavik Nehra*** *and*

My daughter ***Anushka Nehra***

— Dr. Neeraj Kumar

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Hope this book brings wonderful joy and experience to readers worldwide.

Thanks & Regards

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Preface

This book covers many different aspects of deep learning and the importance of deep learning in the field of computer science and other allied areas. This book also introduces the importance of deep learning in the real world. It shows how the deep learning techniques are important for various aspects of computer science. This book solves the basic understanding of neural networks. It also gives importance to convolutional neural networks for the purpose of image-based classification. Moreover, all the deep learning concepts are implemented in hands-on sessions using Python's libraries. This book gives information about the usefulness of deep learning and machine learning worldwide.

This book takes theoretical as well as practical approaches for deep learning readers. It covers all the concepts related to deep learning in the simplest way with real-world examples. It will cover information on machine learning, deep learning techniques, Neural networks, and convolutional neural networks. It can be used for classification purposes in various domains. You can design your own neural networks by going through the entire book.

This book is divided into 08 chapters. They will cover the basics of artificial intelligence, machine learning, deep learning, the intuition of neural networks, CNN, object detection and localization, RNN, LSTM, and GANs. This book also includes review questions, MCQs, Web resources, and hands-on sessions using Python at the end of each chapter. for the readers to get more interest and joy in exploring deep learning techniques. The details are listed below:

Chapter 1: Basics of Artificial Intelligence and Machine Learning - Provide a brief idea about machine learning and its types with a proper explanation of classification and regression problems. In this chapter, there is a brief explanation of the clustering algorithms with solved examples. The readers will know the difference between binary and multi-class classification and the regression. The readers will understand the main concept of clustering and its types. Moreover, this will provide insights about various clustering algorithms along with its applications. Further, the basics of machine learning and artificial intelligence are implemented using python in this chapter.

Chapter 2: Introduction to Deep Learning with Python - Covers the basics of deep learning concepts along with the libraries and datasets used in Python. Furthermore, it also discusses various loss functions. In the chapter, a single-layer neuron is also covered. Additionally, the fundamentals of the SVM classifier and performance indicators are discussed.

Chapter 3: Intuition of Neural Networks - This chapter will focus on the intuition of neural networks in depth. In this chapter, we will learn from perceptron's activation functions. Moreover, we have discussed the working of gradient descent, cost functions, and the relationship between log-likelihood and MSE. Furthermore, gradient descent for linear regression and back-propagation in Neural networks with corresponding loss functions is described in detail. In this chapter, we have explored the effect of integration on the derivative of the cost function. At last, various computational graphs, along with gradients and different types of activation functions, are discussed with examples.

Chapter 4: Convolutional Neural Networks - This chapter will cover convolutional Neural Networks. In this chapter, we have explored various layers of CNN. We have discussed the concepts of padding, stride, and pooling in CNN with suitable examples, along with one- and two-dimensional convolution. We have also visualized the working of a three dimensional filter in 2-D convolution. Moreover, we have shown the working of CNN with an illustrative example under the section How CNN works? Finally, CNN case studies are discussed with their architectures with corresponding parameters. At last, the reader can build their own CNN model for image classification by going through the entire chapter.

Chapter 5: Localization and Object Detection - In this chapter, we explored various tasks related to computer vision, such as object detection, localization, classification, and segmentation. Furthermore, we have discussed extracting various objects from a scene or an image. We have also analyzed two parts of image segmentation, semantic and instance-based segmentation. In this chapter, we will understand the working of the widely used object detection algorithm as YOLO. Finally, you will study and compare various object detection algorithms using convolutional neural networks such as RCNN, Fast RCNN, and Faster RCNN. At last, you will explore the image segmentation algorithm as Mask RCNN on the COCO data set.

Chapter 6: Sequence Modeling in Neural Networks and Recurrent Neural Networks (RNN) - It mainly focuses on Recurrent Neural Networks. In this chapter, we have explored the basics of recurrent neural networks with the help of suitable examples and mathematical formulations. Further, we have realized recurrent neural networks with the help of three other neural networks. We have also visualized recurrence relationships in RNN using matrix augmentation. Moreover, we have illustrated the concept of backpropagation in time compared to RNN. Furthermore, various sequence predictions and applications of RNNs in the real world are discussed. At last, the reader can build their own RNN using hands-on sessions.

Chapter 7: Gated Recurrent Unit, Long Short-Term Memory, and Siamese Networks - It will focus on GRU, LSTM, and Siamese networks. In this chapter, we have discussed Simple Gated recurrent units with an understanding of input and cell update units. Furthermore, we discussed Full Gated Recurrent Units and showed the concept of relevance gate in full GRU. Furthermore, we covered the transition of GRU to LSTM. We have also seen various gates as input, output, and forget gate, and showed the importance of LSTM over RNN. Moreover, we comprehend the concept of back-propagation in LSTM. In this chapter, we have also discussed various applications of LSTM and types of long short-term memory networks such as vanilla, stacked, CNN, encoder–decoder, and bidirectional. Finally, Siamese networks and triplet loss function are discussed.

Chapter 8: Generative Adversarial Networks - The chapter will mainly focus on the intuition of GAN. We have discussed the architecture of GAN along with the generator and discriminator function. Moreover, we discussed the working of backpropagation during the training process of GAN for classification between real and fake images. Furthermore, this chapter has discussed various types of GAN, such as Cycle GAN, Pix GAN, Dual GAN, Stack GAN, and so on. Finally, various applications of GAN in the real world are discussed in detail.

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CHAPTER 1

Basics of Artificial Intelligence and Machine Learning

Introduction

Artificial intelligence is the demonstration of intelligent processes by machines, especially computer systems similar to human intelligence. The process of artificial intelligence includes learning, reasoning, and self-correction. This chapter covers the basic concepts related to artificial intelligence, such as patterns, classification, and regression problems. In this chapter, we briefly describe the basic concept of machine learning algorithms along with their types, such as deep learning and shallow learning techniques.

Structure

In this chapter, we will cover the following topics:

- Patterns
- Intra-class variability
- Intra-class variability
- Inter-class similarity
- Pattern analysis tasks
- Data and its types in machine learning

- Machine learning feature set
- Types of Regression
- Classification
- Clustering
- Agglomerative clustering
- Divisive clustering algorithms
- Clustering applications
- Hands-on session on AI and machine learning basics

Objectives

After going through this chapter, you will be able to understand the basic concepts of machine learning and its types. You will understand the types of classification and regression problems. You will get a brief idea about clustering algorithms and will be able to perform clustering algorithms in R.

Patterns

In the last few years, pattern analysis has been one of the emerging trends in the research community. A pattern can be termed as a type of theme of repeating events or elements of a set of objects. The elements repeat themselves in a manner which can be predictable. In the digital world, a pattern is almost everything. For example, the color of clothes, speech patterns, and so on. It can either be observed mathematically or physically by using some type of algorithm.

A pattern can be a proven solution in a specified manner for a common problem. In 1979, *Alexander* quoted *Each pattern is a three-part rule, which expresses a relation between a certain context, a problem, and a solution*. According to the *Gang of Four*, a pattern can be summarized into four different parts: a context where the pattern can be useful, the issues which are addressed by the patterns, the forces used for forming a solution and the solution that resolves those forces.

Example 1: Consider the following example and try to complete these patterns.

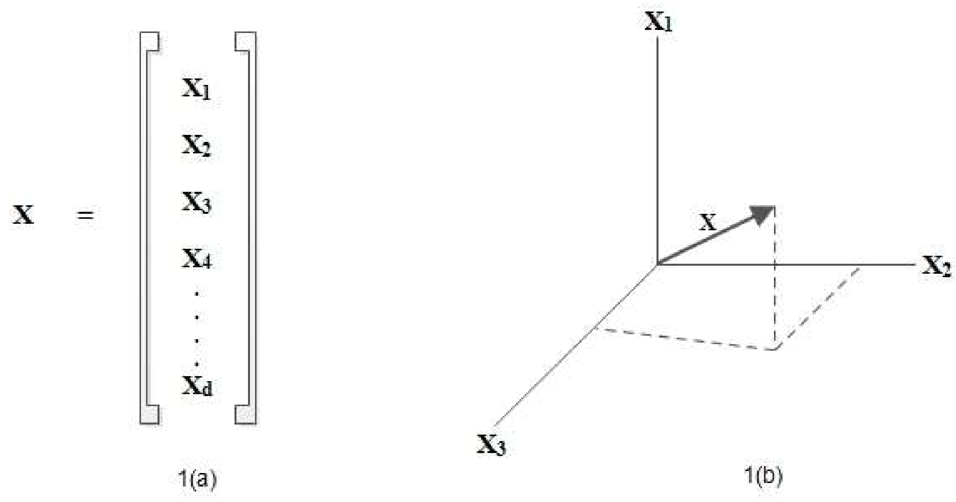
- 1,2,3,4,5,**6**,…,24,25,26,27,28.
- 1,3,5,7,9,**11**,…,25,27,29,31,33
- 2,3,5,7,11,**13**,…,29,31,37,41,43
- 1,4,9,16,25,**36**,…,121,144,169,196

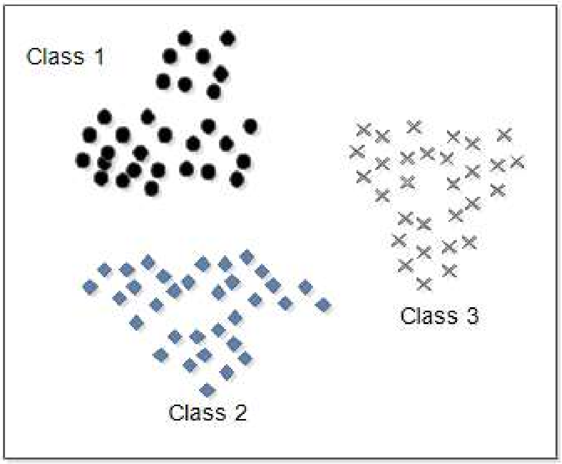
- 1,2,4,8,16,32,**64**,…,1024,2048,4096,8192
- 1,1,2,3,5,8,**13**,…,55,89,144,233,377
- 1,1,2,4,7,13,**24**,…,81,149,274,504,927
- 3,5,12,24,41,**63**,….., 201,248,300,357,419
- 2,7,12,17,22,27,**32**,…..,42,47,52,57,62
- 1,6,19,42,**59**,…,95,117,156,191,?

As per the preceding example, it is easy to fill the patterns initially, but as we progress downwards, it becomes a little bit complex. So, the pattern is defined as any regularity or structure in data and pattern analysis is the automatic discovery of patterns in data.

Pattern representation

In the field of computer science, a pattern is represented by using vector feature values. The feature is any distinct characteristic, quality, or aspect. Features can be numeric (for example, width and height) or symbolic. Suppose if there are **d** features of an object; then the combination of these **d** features can be represented as a column vector of dimension-d known as a feature vector. Space which is defined by the d-dimension feature vector, is called a **feature space**. Then, the objects are represented as some points in the feature space, and that representation is termed as a scatter plot. *Figure 1.1* shows various pattern representations:





1(c)

***Figure 1.1 (a)–(c)**: Pattern representation, dimension space of vector, and different classes of patterns.*

Figure 1.1(a)–(c) represents the vector of size ***d***, the dimension space of the vector and classes of patterns.

Analysis of patterns

It is a phase of pattern recognition that uses the existing knowledge present in data to uncover patterns using techniques of data analysis. Pattern analysis deals with the detection of patterns of the data from the same source automatically, making predictions of the data coming from the source. The information coming from the source can be of any form, such as text, images, family trees, records of commercial transactions, and so on.

The identification of the patterns from a finite data set has very distinctive and different challenges. So, in order to design an effective pattern analysis algorithm, one should consider three key features as follows.

Robustness

The first challenge for designing an effective pattern analysis algorithm is the fact that when it comes to real-time applications, data can be demolished by noise because of the randomness of the wireless channel or by virtue of human errors. So, while designing the algorithm, it must be kept in mind that the algorithms must identify the approximate patterns and can handle noisy data smoothly such that it should not affect the output of patterns or data analysis techniques. The algorithms that possess this property are considered robust.

Computational efficiency

As the amount of data is increasing enormously day by day, the designed algorithm must be able to handle larger datasets due to the enormous increase in data with time. So, if the algorithm works well for small objects, it should also work well for large datasets. Basically, computationally efficient algorithms are those whose resources scale increases polynomially with an increase in the size of the data.

Statistical ability

This property is the most basic property an algorithm should have, which states that the patterns that are identified by the algorithm are genuine and have an accidental relation with the data set attributes. We can define this property as if we apply the algorithm to the new data coming from the same source so that it should be able to identify a similar type of pattern. Thus, the output of the algorithm should be sensitive to the data source and not to the particular dataset. So, if the algorithm is sensitive only to a particular dataset, it can be termed as stable for short, and if the algorithm gives similar types of patterns from all the datasets coming from the same source, then such an algorithm can be termed as statistically stable.

Pattern classes

A pattern class can be defined as a collection of similar types of objects that may not be identical. A class consists of exemplars, prototypes, paradigms, and learning/ training samples. *Figure 1.2* represents different types of class variabilities:

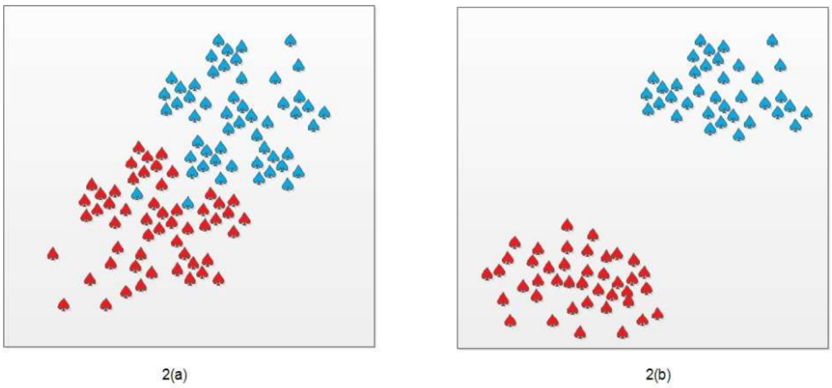


***Figure 1.2 (a)**: Low inter-class and high intra-class variability. (b) Low intra-class and high inter-class variability.*

There are the following two types of variability and one type of similarity in the pattern class:

- Intra-class variability
- Inter-class variability

Machine learning algorithms have to deal with these variabilities and similarities.

Intra-class variability

It refers to the deviations in the particular class score for a specific object which is not a part of the systematic difference. So, basically, it is within the class variability. It can be used to map different types of objects. If we talk about land covers, then bare soil, forests, and rocks can be mapped using intra-class variability. It is the variation that exists between all the samples of a particular class that are used to learn the machine.

Intra-class variability uses a tool named as ***feature space*** which predicts the patterns according to their features by using spectral signatures. So, according to the specific requirement, an appropriate feature space can be chosen.

Inter-class variability

Inter-class variability means the variability among the different types of classes in a dataset. It can be used in cases where one needs to separate different classes that exist in the dataset. Also, the accuracy of the classification of objects depends upon inter-class variability. *Figure 1.2(a)* represents the patterns having low inter-class and high intra-class variability, whereas *Figure 1.2(b)* represents the patterns having low intra-class and high inter-class variability. For an ideal clustering algorithm, the intra-class variability should be minimum, whereas inter-class variability should be maximum. This is an important criterion for getting classes of different patterns. In classification, there exists a labeled dataset, so inter and intra-class variability does not exist in supervised learning. The inter-class and intra-class variability is dependent on a distance metric.

Inter-class similarity

In inter-class similarity, the data is similar, almost nearest to each other and belongs to the same cluster. The outcomes are calculated as the ratio of the total summation distance to the summation of all the distances within one cluster of the dataset. Inter-class similarity can be seen in *figure 1.3*: