INTELLIGENT SYSTEMS AND APPLICATIONS IN COMPUTER VISION

Edited by

Nitin Mittal

Amit Kant Pandit

Mohamed Abouhawwash

Shubham Mahajan

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Intelligent Systems and Applications in Computer Vision

The book comprehensively covers a wide range of evolutionary computer vision methods and applications, feature selection and extraction for training and classification, and metaheuristic algorithms in image processing. It further discusses optimized image segmentation, its analysis, pattern recognition, and object detection.

Features:

- Discusses machine learning-based analytics such as GAN networks, autoencoders, computational imaging, and quantum computing.
- Covers deep learning algorithms in computer vision.
- Showcases novel solutions such as multi-resolution analysis in imaging processing, and metaheuristic algorithms for tackling challenges associated with image processing.
- Highlight optimization problems such as image segmentation and minimized feature design vector.
- Presents platform and simulation tools for image processing and segmentation.

The book aims to get the readers familiar with the fundamentals of computational intelligence as well as the recent advancements in related technologies like smart applications of digital images, and other enabling technologies from the context of image processing and computer vision. It further covers important topics such as image watermarking, steganography, morphological processing, and optimized image segmentation. It will serve as an ideal reference text for senior undergraduate, graduate students, and academic researchers in fields including electrical engineering, electronics, communications engineering, and computer engineering.

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About the editors

Nitin Mittal, received his B.Tech and M.Tech degrees in Electronics and Communication Engineering (ECE) from Kurukshetra University, Kurukshetra, India in 2006 and 2009, respectively. He completed his PhD in ECE from Chandigarh University, Mohali, India in 2017. He worked as a professor and assistant dean of research, ECE Department at Chandigarh University. Presently, he is working as skill assistant professor, department of Industry 4.0 at Shri Vishwakarma Skill University. His research interests include Wireless Sensor Networks, Image Segmentation, and Soft Computing.

Amit Kant Pandit is working as an associate professor and is Ex-Hod, DECE, in Shri Mata Vaishno Devi University (SMVDU), Katra (India). He is a senior member of IEEE and MIR labs member and has 19 years of academic experience.

Mohamed Abouhawwash received the BSc and MSc degrees in statistics and computer science from Mansoura University, Mansoura, Egypt, in 2005 and 2011, respectively. He finished his PhD in Statistics and Computer Science, 2015, in a channel program between Michigan State University, and Mansoura University. He is at Computational Mathematics, Science, and Engineering (CMSE), Biomedical Engineering (BME) and Radiology, Institute for Quantitative Health Science and Engineering (IQ), Michigan State University. He is an assistant professor with the Department of Mathematics, Faculty of Science, Mansoura University. In 2018, Dr. Abouhawwash is a Visiting Scholar with the Department of Mathematics and Statistics, Faculty of Science, Thompson Rivers University, Kamloops, BC, Canada. His current research interests include evolutionary algorithms, machine learning, image reconstruction, and mathematical optimization. Dr. Abouhawwash was a recipient of the best master's and PhD thesis awards from Mansoura University in 2012 and 2018, respectively.

Shubham Mahajan (Member, IEEE, ACM, IAENG) received the B.Tech. degree from Baba Ghulam Shah Badshah University, the M.Tech. degree from Chandigarh University, and the Ph.D. degree from Shri Mata Vaishno Devi University (SMVDU), Katra, India. He is currently employed as an Assistant Professor at Ajeenkya D Y Patil University, Pune. Dr. Mahajan holds ten Indian, one Australian, and one German patent in the field of artificial intelligence and image processing. He has authored/coauthored over 66 publications, including peer-reviewed journals and conferences. His research interests primarily lie in image processing, video compression, image segmentation, fuzzy entropy, nature-inspired computing methods, optimization, data mining, machine learning, robotics, optical communication, and he has also received the "Best Research Paper Award" from ICRIC 2019 (Springer, LNEE). Furthermore, Dr. Mahajan has been honored with several accolades, including the Best Student Award-2019, IEEE Region-10 Travel Grant Award-2019, 2nd runner-up prize in IEEE RAS HACKATHON-2019 (Bangladesh), IEEE Student Early Researcher Conference Fund (SERCF-2020), Emerging Scientist Award-2021, and IEEE Signal Processing Society Professional Development Grant-2021. In addition to his academic pursuits, he has served as a Campus Ambassador for IEEE, representing prestigious institutions such as IIT Bombay, Kanpur, Varanasi, Delhi, and various multinational corporations. Dr. Mahajan actively seeks collaboration opportunities with foreign professors and students, demonstrating his enthusiasm for international research partnerships.

Contributors

Sanjo J. Adwin
PSG College of Technology,
Coimbatore, Tamil Nadu, India

Mamta Arora
Chandigarh University,
Gharuan, Punjab, India

Mitali Arya
National Institute of Technology
Hamirpur,
Himachal Pradesh, India

Abhishek Bharane
Department of Information
Technology
Pimpri-Chinchwad College of
Engineering
Pimpri-Chinchwad, Maharashtra,
India

Vinay Bhosale
Department of Information
Technology
Pimpri-Chinchwad College of
Engineering
Pimpri-Chinchwad, Maharashtra,
India

Pranav Bongulwar
Department of Information
Technology
Pimpri-Chinchwad College of
Engineering,
Pimpri-Chinchwad, Maharashtra,
India

Jasmine Hazel Crasta
St Joseph Engineering College,
Vamanjoor, Mangalauru,
Karnataka, India

Soma Debnath
Amity Institute of Information
Technology, Amity University,
New Town, Kolkata, India

Priyanka Dhanasekaran
Department of Information
Science and Technology,
Anna University,
Chennai, Tamil Nadu, India

Chinmay Dixit
Department of Computer
Engineering and IT,
College of Engineering,
Pune, Maharashtra, India

Pulkit Dubey
Department of Computer Science,
Manav Rachna International
Institute of Research and Studies,
Faridabad, Haryana, India

S. P. Gautham
Department of Computer Science and Engineering,
St Joseph Engineering College, Vamanjoor, Mangalauru, Karnataka, India

A. V. Geetha
Department of Information Science and Technology,
Anna University, Chennai, Tamil Nadu, India

G. Gopisankar
Department of Computer Science and Engineering,
PSG College of Technology, Coimbatore, Tamil Nadu, India

Ashulekha Gupta
Department of Management Studies,
Graphic Era (Deemed to be University)
Dehradun, Uttarakhand, India

Manoj Kumar Gupta
School of Computer Science and Engineering,
Shri Mata Vaishno Devi University, Katra, Jammu and Kashmir, India

Medha Gupta
Amity Institute of Information Technology,
Amity University, Kolkata, Tamil Nadu, India

Nidhi Gupta
National Institute of Technology Hamirpur,
Himachal Pradesh, India

Pranesh Gupta
Indian Institute of Information Technology,
Una, Himachal Pradesh, India

H. N. Gurudeep
St Joseph Engineering College,
Vamanjoor, Mangaluru, Karnataka, India

Pai H. Harikrishna
St Joseph Engineering College,
Vamanjoor, Mangaluru, Karnataka, India

Anandaram Harishchander
Amrita School of Engineering,
Coimbatore Amrita Vishwa Vidyapeetham, Tamil Nadu, India

P. Muhamed Ilyas
Sullamussalam Science College,
Mallapuram, Kerala, India

A. Jayabharathi
PSG College of Technology,
Coimbatore, Tamil Nadu, India

Amit D. Joshi
Department of Computer Engineering and IT,
College of Engineering, Pune, Maharastra, India

Kapil Joshi
Department of CSE,
Uttaranchal Institute of Technology,
Uttaranchal University,
Dehradun, Uttarakhand, India

Ashima Kalra
Department of ECE, Chandigarh Engineering College,
Landran, Mohali, Punjab, India

Divneet Singh Kapoor
Kalpana Chawla Center for Research in Space Science and Technology,
Chandigarh University, Mohali, Punjab, India

K. Sheril Kareem
Sullamussalam Science College, Malappuram, Kerala, India

K. Karthik
St Joseph Engineering College,
Vamanjoor, Mangaluru, Karnataka, India

Nitish Katal
Indian Institute of Information Technology,
Una, Himachal Pradesh, India

Bobbinpreet Kaur
ECE Department, Chandigarh University,
Gharuan, Punjab, India

Talha Fasih Khan
Department of Computer Science,
Manav Rachna International Institute of Research and Studies, Faridabad, Haryana, India

Amit Kumar Kohli
Thapar Institute of Engineering and Technology,
Patiala, Punjab, India

Konda Hari Krishna
Koneru Lakshmaiah Education Foundation,
Vaddeswaram, Guntur District,
Andhra Pradesh, India

Rajesh Kumar
Meerut Institute of Technology,
Meerut, Uttar Pradesh, India

Vivek Kumar
Department of CSE, Uttaranchal Institute of Technology,
Uttaranchal University, Dehradun, Uttarakhand, India

Jyoti Lele
Dr. Vishwanath Karad MIT World Peace University,
Pune, Maharashtra, India

T. Mala
Anna University,
Chennai, Tamil Nadu, India

Onakar Mulay
Department of Information Technology
Pimpri-Chinchwad College of Engineering
Pimpri-Chinchwad, Maharashtra, India

Veronica Naosekpam
Indian Institute of Information Technology Guwahati, Assam, India

Naman Palliwal
Dr. Vishwanath Karad MIT World Peace University,
Pune, Maharashtra, India

Tanuja S. Patankar
Department of Information Technology

Pimpri-Chinchwad College of Engineering
Pimpri-Chinchwad, Maharashtra, India

Anuradha C. Phadke
Dr. Vishwanath Karad MIT World Peace University,
Pune, Maharashtra, India

M. Preethi
Department of Information Technology,
Sri Ramakrishna Engineering College,
Coimbatore, Tamil Nadu, India

Arjun Puri
Model Institute of Engineering and Technology,
Jammu, Jammu and Kashmir, India

R. Rajalakshmi
Sri Ramakrishna Engineering College,
Coimbatore, Tamil Nadu, India

Sahil Rajurkar
Dr. Vishwanath Karad MIT World Peace University,
Pune, Maharashtra, India

R. Ramya
Sri Ramakrishna Engineering College,
Coimbatore, Tamil Nadu, India

K. C. Ridhi
PSG College of Technology,
Coimbatore, Tamil Nadu, India

Nilkanta Sahu
Indian Institute of Information Technology
Guwahati, Assam, India

T. S. Saleena
Sullamussalam Science College,
Malappuram, Kerala, India

S. Sasank
PSG College of Technology,
Coimbatore, Tamil Nadu, India

Kiran Jot Singh
Kalpana Chawla Center for Research in Space Science and Technology,
Chandigarh University,
Mohali, Punjab, India

Anshul Sharma
Chandigarh University,
Mohali, Punjab, India

Pooja Sharma
I. K. Gujral Punjab Technical University,
Jalandhar, Punjab, India

Sheenam
CSE Deptt.,
Chandigarh University,
Gharuan, Punjab, India

S. Suriya
PSG College of Technology,
Coimbatore, Tamil Nadu, India

Gaurav Tewari
Gautam Buddha University,
Gr. Noida, India

Khushal Thakur
Kalpana Chawla Center for Research in Space Science and Technology,
Chandigarh University,
Mohali, Punjab, India

Vibor Tomar
Dr. Vishwanath Karad MIT World Peace University,
Pune, Maharashtra, India

E. Uma
Department of Information Science and Technology, Anna University, Chennai, Tamil Nadu, India

Yukti Upadhyay
Manav Rachna International Institute of Research and Studies,
Faridabad, Haryana, India

S. Vidhya
Sri Ramakrishna Engineering College,
Coimbatore, Tamil Nadu, India

Pavinder Yadav
National Institute of Technology Hamirpur,
Himachal Pradesh, India

Chapter 1

A review approach on deep learning algorithms in computer vision

Kapil Joshi, Vivek Kumar, Harishchander Anandaram, Rajesh Kumar, Ashulekha Gupta, and Konda Hari Krishna

1.1 INTRODUCTION

The topic of "computer vision" has grown to encompass a wide range of activities, from gathering raw data to extracting patterns from images and interpreting data. The majority of computer vision jobs have to do with feature extraction from input scenes (digital images) in order to get information about events or descriptions. Computer vision combines pattern detection and image processing. Image understanding comes from the computer vision process. The field of computer vision, in contrast to computer graphics, focuses on extracting information from images. Computer technology is essential to the development of computer vision, whether it is for image quality improvement or image recognition. Since the design of the application system determines how well a computer vision system performs, numerous scholars have proposed extensive efforts to broaden and classify computer vision into a variety of fields and applications, including assembly line automation, robotics, remote sensing, computer and human communications, assistive technology for the blind, and other technologies [1]. Deep learning (DL) is a member of the AI method family. Artificial Neural Networks (ANNs) get their name from the fact that they receive an input, analyze it, and produce a result. Deep learning is based on ANN. Because of the massive amount of data generated every minute by digital transformation, AI is becoming more and more popular. The majority of organizations and professionals use technology to lessen their reliance on people [2].

In machine learning, the majority of features taken into account during analysis must be picked manually by a specialist in order to more quickly identify patterns. DL algorithms gradually pick up knowledge from high level features. A part of machine learning called "further deep learning" is depicted in Figure 1.1. ANNs, which have similar capabilities to human neurons, are the inspiration for deep learning. The majority of machine

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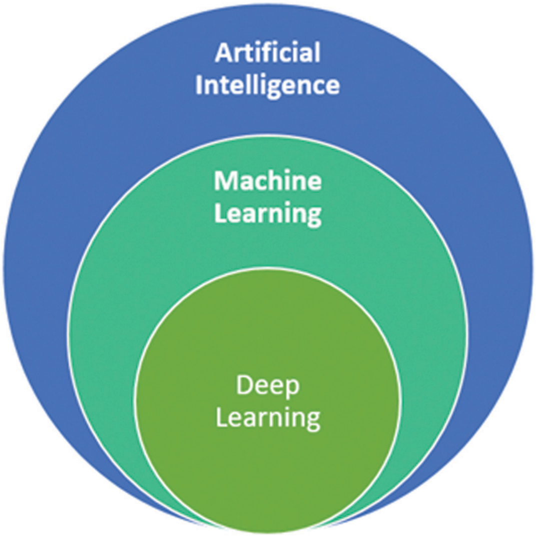

Figure 1.1 Deep learning, machine learning, and artificial intelligence.

learning techniques pale in comparison to ANNs because they can use learning that is supervised, semi-supervised, and unsupervised on a variety of different types of data.

The large family of algorithms known as "deep learning" includes supervised and unsupervised feature learning approaches that include neural networks and hierarchical probabilistic models. Due to their greater performance shown over prior state-of-the-art methods in a number of tasks as well as the volume of complex data from multiple sources, deep learning approaches have recently witnessed an increase in interest. Regarding their applicability in visual understanding, we will concentrate on three one of the key aspects of DL model types in this context: Convolutional Neural Networks (CNN), the "Boltzmann family," which includes Deep Bolzmann Machines, stacked (denoising) autoencoders, and deep belief networks [3]. Robots used in medical applications have been taught to distinguish between scanned and traditional images. Figure 1.2 [4] shows how DL algorithm input is broadly categorized.

For analysis, the DL algorithm needs input. Similar to how human vision works, images are considered in a variety of analysis applications.

Figure 1.3 displays categorization of the input data for the DL phases. But owing to the algorithm's variable inputs, considerable preprocessing is required to reduce the noise. to increase the accuracy of the algorithm.

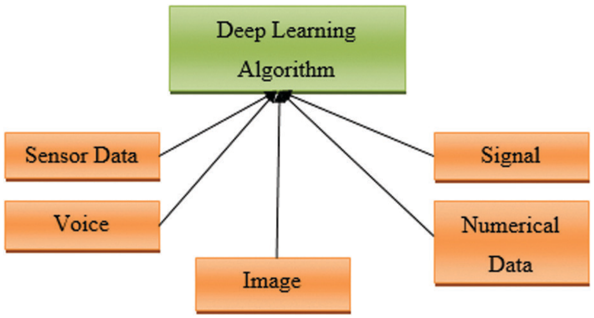

Figure 1.2 Deep learning algorithm's inputs.

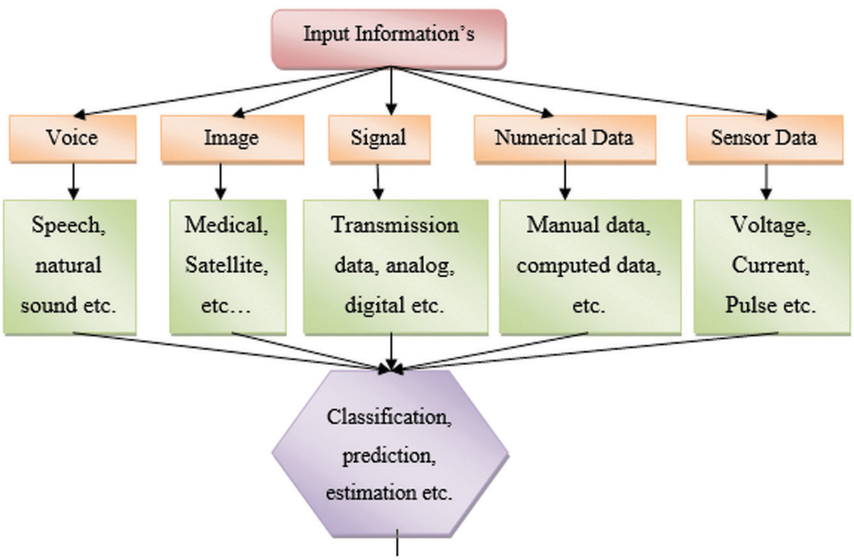

Figure 1.3 Outcome of deep learning algorithms.

1.2 DEEP LEARNING ALGORITHMS

Deep neural networks are challenging to train using back propagation because of the problem of vanishing gradient, which affects training time and precision. As determined by the net difference between the ANN expected output and actual output in the training data, ANNs calculate cost function [5]. After each step, biases and weights are modified based on the

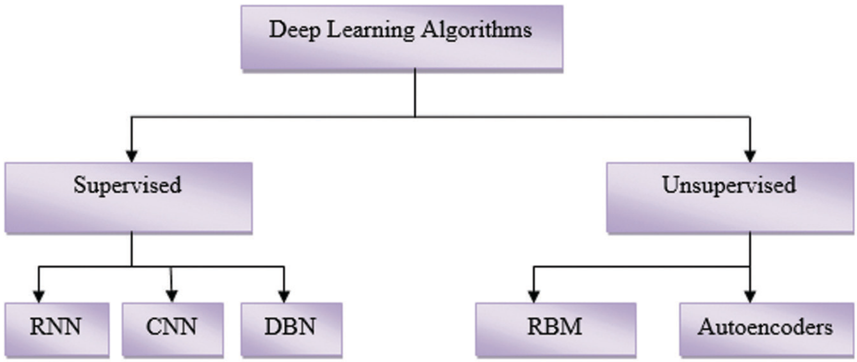

Figure 1.4 Algorithm classifications for deep learning.

cost. The price is as low as it can be. The rate at which cost will alter as a result of weight and biases is known as the gradient.

1.2.1 Convolutional neural networks

Convolutional Neural Network is a DL network for computer vision that can identify and categorize visual features. The structure and operations of the visual cortex had an impact on CNN architecture. It is intended to imitate the ways neurons are connected in the human brain [6]. Convolutional Neural Networks comprise numerous stages, including convolution layer, pooling layer, non-linear processing layer, and sub sampling layers, and it is capable of achieving spatial or temporal correlation in data [7]. Convolutional operations are carried out for feature extraction, and the resulting convolutional is then provided to the activation function. Since non-linearity produces a range of activation patterns for various responses, it is possible to learn the semantic differences across images. CNNs' ability to extract features automatically, which eliminates the requirement for a separate feature extractor, one of its main strengths. Figure 1.5 depicts the architecture of a CNN.

- **Convolution Layers**
  The convolution layer will calculate the scalar product between the weights of the input volume-connected region and the neurons whose output is related to particular regions of the input.
- **Pooling Layers**
  After that, it will simply down sample the input along the spatial dimension, further lowering the number of parameters in that activation [8].

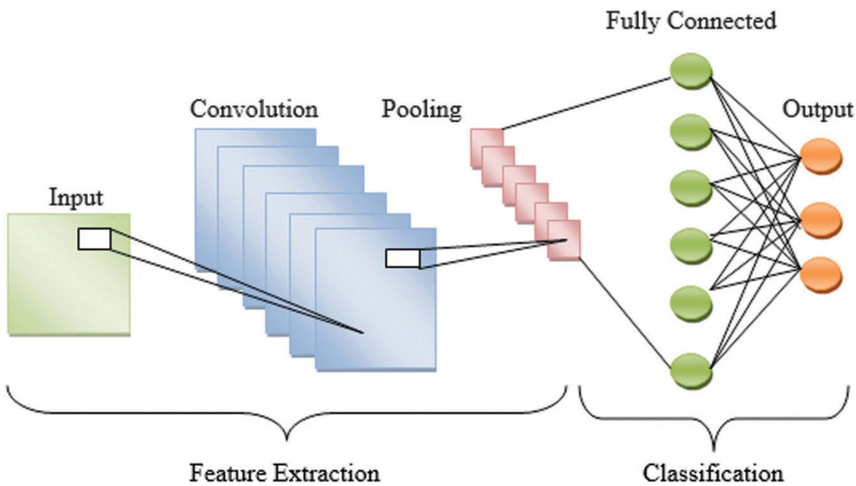

Figure 1.5 CNN architecture.

- **Batch Normalization**
  Batch Normalization is the method through which the activation nodes are scaled and adjusted to normalize the input layer neurons. The output from the preceding is normalized using batch normalization by dividing by the batch standard deviation after subtracting the batch mean [9].
- **Dropout**
  In order to avoid over-fitting, input units are set to 0 at random with a rate of frequency by the "dropout layer" at each training phase. The sum of all inputs is maintained by scaling up non-zero inputs by $\frac{1}{1-\text{rate}}$.
- **Fully Connected Layers**
  After that, it will carry out the same tasks as regular ANNs and try to create categorization scores from the activations. ReLu has also been proposed as a possible application between these layers in order to enhance performance.

1.2.2 Restricted Boltzmann Machines

Such an undirected diagrammatic and modeled depiction of the symmetrical layer, a visible layer, and a hidden layer link among the layers is called a "restricted Boltzmann Machine" (RBM). No relationship exists between

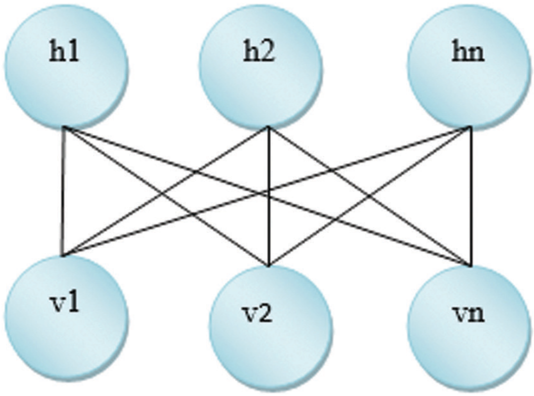

Figure 1.6 Restricted Boltzmann Machine.

an input and the hidden layer in RBM [10]. Restricted Boltzmann Machine exhibits strong feature extraction and representation capabilities. The Restricted Boltzmann machine is a probabilistic network that picks up on the hidden representation, h as well as the probability distribution of its inputs v. The two-layer, typical Restricted Boltzmann Machine method is shown in Figure 1.6. The fundamental benefit of the RBM algorithm is that there are no links between units in the same layer because all components, both visible and concealed, are separate.

The Restricted Boltzmann Machine algorithm seeks to reconstruct the inputs as precisely as possible [11].The input is modified based on the weights and biases throughout the forward stage before beginning to trigger the hidden layer. The hidden layer's activations are then modified based on the weight and biases and transmitted the activation layer's input layer afterward in the following steps: The input layer now searches for the updated activation as a reconstruction of the input, Compare it against the original input.

1.2.3 Deep Boltzmann Machines

In that they use the RBM as a learning module, Deep Boltzmann Machine, are DL models that are members of the "Boltzmann family." The Deep Boltzmann Machine (DBM) has undirected connections between its layers. With the help of the needed data, it accomplishes a layer-by-layer instruction approach that the unlabeled data is trained in, as well as allowing for precise customization. Teaching a stack of RBMs, which are then combined to build a DBM, constitutes pre-training for a DBM with three hidden layers,

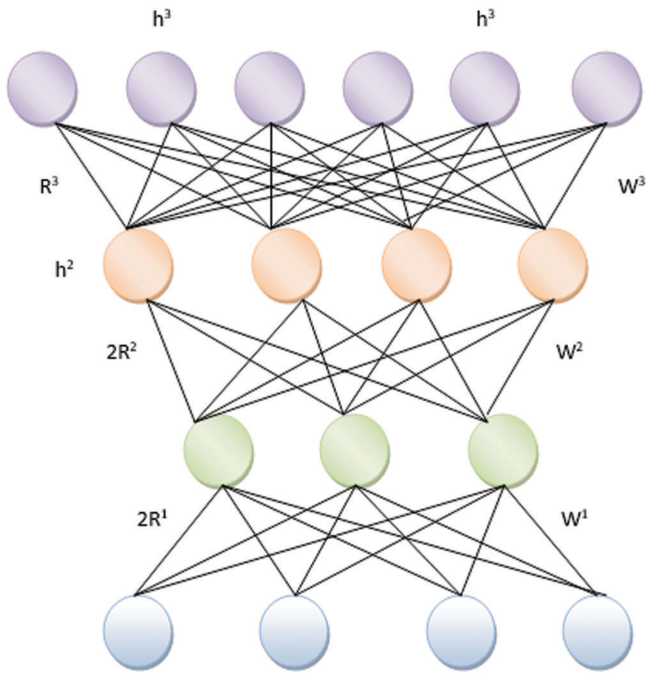

Figure 1.7 Deep Boltzmann Machine.

by defining its energy function to more clearly define the DBM's structure. In relation to the two-layer model as defined by Equation 1.1.

$$E_{DBM}(v,h^{(1)}, h^{(2)}; \theta) = -v^TWh^{(1)} - h^{(1)T}Vh^{(2)} - d^{(1)T}h^{(1)} - d^{(2)T}h^{(2)} - b^Tv \quad (1.1)$$

Where W, V, d(1), and d(2) are equal to. DBM can be thought of as a bipartite graph with two vertices.

Figure 1.7 DBM's R^1, R^2, and R^3 list the recognition that is intended. The Deep Boltzmann Machine (DBM), a deep generative undirected model, is composed of several hidden layers. In order to affect how lower-level characteristics are learned, it makes use of the top-down connection pattern. R^1, R^2, and R^3 are the recognition model weights, which are increased by two every layer to make up since there is not any top-down feedback [12].

1.2.4 Deep belief networks

A foundation for building models directly from what we see to what we wish to know is provided by DBM. In a way, the layer-by-layer structure

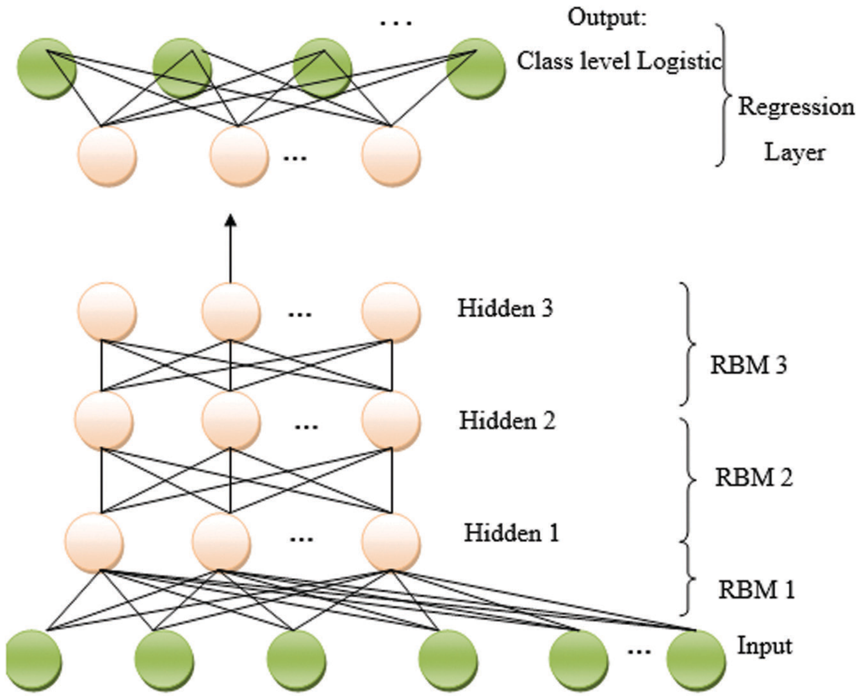

Figure 1.8 Deep Belief Networks.

represents features in a hierarchical manner. The feature-extracting component can be replaced with the self-adaptive network training method. After creating the network, a considerably smaller number of labeled the "back-propagation algorithm," is used to adjust the complete network using a sample set. Large unlabeled samples are used in the layer-by-layer training process [13]. As seen in Figure 1.8, a generative model called "deep belief networks" was produced by stacking several limited Boltzmann machines. An RBM is created by every two neighboring layers. Each restricted Boltzmann machine's visible layer is linked to its predecessor's hidden layer, and the first two levels are directional-less. The top-down between the upper layer and the lower layer with a directed connection are adjusted. In a deep belief network, the various layers of the Restricted Boltzmann Machine are trained in order: the lower Restricted Boltzmann Machines are first trained, followed by the superiors. Back propagation of features to the lowest layers after being extracted by the top Restricted Boltzmann Machine [14].

Pre-training and fine-tuning are the two stages of the deep belief network exercise procedure. Pre-training is a stage of unsupervised training that initializes the model to increase the effectiveness of supervised training. The supervised training stage, which modifies the classifier's prediction to fit the data's ground truth, can be thought of as the fine-tuning process [15].

DBNs can take one of two different forms:

- The deep belief network auto-encoder
- The deep belief network classifier

The auto-encoder deep belief networks are straightforward three-layer neural networks in which the input and output units are joined by a direct connection. Typically, there are a lot fewer hidden units than there are visible units.

There are two steps in the auto-encoding process:

- An input vector is encoded (compressed) to fit in a smaller form.
- It was reconstructed.

The recognition process makes use of the latter's architectural design to produce accurate classification results, with the input data vector represented by the first layer of a Deep Belief Networks' visible layer, the hidden layers the visible layer data, early detectors or reconstructors, and the classification labels represented by the softmax layer, which is the last layer of the Deep Belief Network [16]. Consequently, the classifier to guarantee that the results data is accurately tagged, deep belief network design demands that the last Restricted Boltzmann Machine be discriminative.

1.2.5 Stacked (de-noising) auto-encoders

Similar to how Restricted Boltzmann Machines are a component in Deep Belief Networks, the auto-encoder serves as the foundation of stacked auto-encoders. Therefore, before discussing the DL components of Stacked (Denoising) Autoencoders, it is vital to briefly go over the fundamentals of the autoencoder and its denoising variant.

1.2.5.1 Auto-encoders

A feed-forward neural network that learns a compressed, distributed representation of a dataset is a classic example of an auto-encoder. An auto-encoder is a three-layer neural network trained to reconstruct the inputs by utilizing the output as the input. For the data to be reproducible, it must learn characteristics that capture the variance in the data. If only linear activation functions are utilized and can be used for dimensionality reduction, it can be demonstrated that it is comparable to Principle Component Analysis (PCA). After training, the learned features are employed as the hidden layer activations, and the top layer can be ignored. Contraction, de-noising, and sparseness techniques are used to train auto-encoders.

In auto-encoders, some random noise is injected into the input during de-noising. The original input must be reproduced by the encoder. Regular neural networks will perform better in terms of generalization if inputs are randomly deactivated during training [17]. Setting the hidden layer's number of nodes in contractive auto-encoders to substantially fewer than the number of input nodes drives the network to do dimensionality reduction. As a result, it is unable to learn the identity function since the hidden layer does not have enough nodes to adequately store the input. By giving the weight update function a sparsity penalty, sparse auto-encoders are trained. The connection weights' overall size are penalized, and the majority of the weights have low values as a result. At each stage, old k-1 network hidden layers are used, and a new network with k+ 1 hidden layers is constructed, with the k+ 1th hidden layer using the k+ 1 hidden layer as input. The weights in the final deep network are initialized using the weights from the individual layer training, and the architecture as a

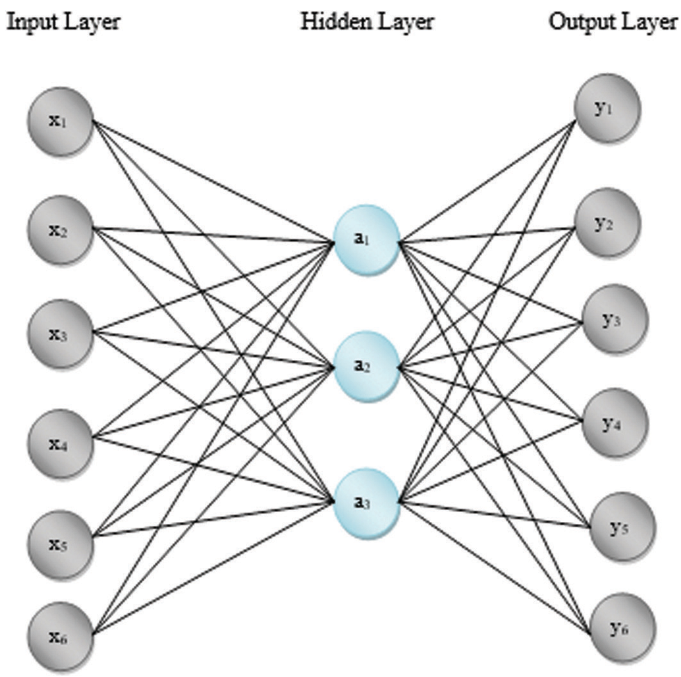

Figure 1.9 Autoencoders.

whole is then tweaked. On the other hand, the network can be tweaked using back propagation by adding an additional output layer on top. Deep networks only benefit from back propagation if the weights are initialized very close to a good solution. This is ensured by the layer-by-layer pre-training. There are also alternative methods for fine-tuning deep networks, such as dropout and maxout.

1.2.5.2 Denoising auto encoders

When given a contaminated input, the denoising auto encoder (DAE) is trained to reassemble a clear, "repaired," version of the input. This is accomplished by first using a stochastic mapping, w qD(w|x), to corrupt the initial input x into w. Then, as with the basic auto-encoder, corrupted input w is mapped to a hidden depicted y = f(w) = s(Ww + b), which we derived reconstruct a z = g(y). A diagram of the process can be found in Figure 1.10. The main modification is that instead of being a deterministic function of x, z is now one of w. The same as before, the reconstruction error is either the squared error loss $L_2(x, z) = ||x - z||^2$ or the cross-entropy loss L(x, z) = IH(B(x)||B(z)) with an affine decoder. Stochastic gradient descent is used to optimize parameters when they are randomly initialized [18]. It should be noted that qD(w|x) produces a separate corrupted version of each training example x that is shown.

Note that the reconstruction falls among a clean X and its reconstruction against Y is still being minimized by denoising auto-encoders [19, 20]. Therefore, this still entails maximizing a lower constraint on the mutual information between clean input x and representation y [21].The distinction is that y is now produced by using a faulty input with deterministic mapping f. As a result, it forces the acquisition of a mapping that extracts

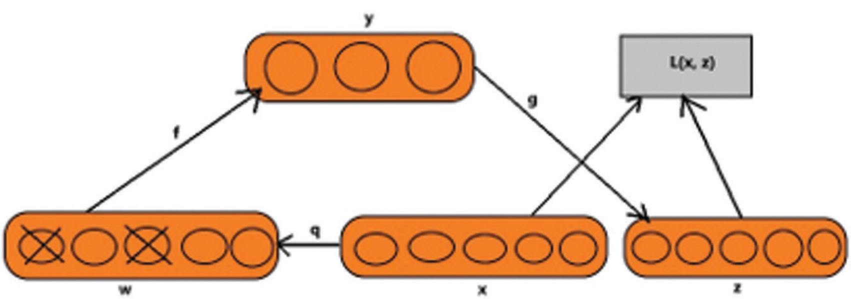

Figure 1.10 The architecture of the denoising autoencoder.

traits helpful for denoising and is significantly more intelligent than the identify [22].

1.3 COMPARISON OF THE DEEP LEARNING ALGORITHMS

Classification of learning, inputting data along with output details and multiple applications are compared in Table 1.1.

1.4 CHALLENGES IN DEEP LEARNING ALGORITHMS

Artificial intelligence, robotics, motion stabilization, virtual reality, automatic panorama stitching, and 3D modeling, scene comprehension, video processing, video stabilization, and motion capture are just a few of the many evolving problems in computer vision that cannot easily be applied in a differentiable system with deep learning [23]. Due to its critical importance in numerous applications, including robotics, surveillance, robotic identification of pedestrians, and real-time vehicle activity tracking, video-scene analysis is a contemporary study area. Despite its widespread use, video-scene analysis is still a difficult problem that calls for more precise algorithms. However, in recent years, improvements in DL algorithms [24] for video-scene study have caused an addressing of the issue of real-time processing.

1.5 CONCLUSION AND FUTURE SCOPE

Deep learning has rendered obsolete many of the computer vision techniques developed over the past 20 years. While machine learning may easily address problems with smaller datasets, deep learning methods are better suited for issues with enormous datasets. We contrast the various models applied to a number of issues, including object detection, object recognition, captioning, and other issues. A few of the most popular DL algorithms, including RBM and auto-encoder, which utilize unsupervised learning, and CNN, and deep belief network, which use supervised learning, are briefly examined. On the basis of their inputs, outputs, and fundamental operation, the algorithms are contrasted. Based on variables including input data, output data, and applications, we compare various algorithms. This study's findings suggest that CNN can successfully solve deep learning challenges involving image inputs. CNN, on the other hand, have substantial computational expenses.

Table 1.1 Comparisons between CNN, RBM, DBM and Auto Encoders

Parameter	*Convolutional Neural Networks*	*Restricted Boltzmann Machines*	*Deep Belief Networks*	*Auto encoders*
Type of Learning	Supervised	Unsupervised	Supervised	Unsupervised
Input Data	3-D Structured data	Any type of data	Text, Image	Any type of data
Output	Classified, predicted	Reconstructed output	Classified, predicted	Reconstructed output
Application	Image and voice analysis, classification, detection, recognition	Dimensionality Reduction/ Classification	NLP, dimensionality reduction	Dimensionality Reduction

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