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Deep Learning: Concepts, Architectures, Workflow, Applications and Future Directions

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Abstract

In recent years, deep learning (DL) has evolved into a statistical method in machine learning (ML) that produces surprising results in complex tasks, similar to human performance. Deep learning technology, derived from artificial neural networks (ANN), is a major advance in computer science because it allows learning from data. The ability to learn large amounts of data is one of the benefits of deep learning. In recent years, the field of higher education has grown rapidly and has been successfully used in many cultural fields. Deep learning outperforms well-known machine learning methods in a variety of fields, including cyber security, natural language processing, bioinformatics, robotics, and medical data tracking and management. To provide a better starting point from which to develop a comprehensive understanding of deep learning, this article also aims to take a closer look at even the most important aspects of deep learning, including current developments. In addition, this article highlights the importance of deep learning and explores different deep learning methods and networks.

In addition, it provides an overview of real-world application areas where deep learning techniques can be used. We conclude by outlining potential opportunities for future generations of deep learning modeling and making suggestions for research. On the other hand, this article aims to provide a comprehensive overview of deep learning modeling that can serve as a resource for academics and industry professionals. Finally, we provide new questions and recommended solutions to help researchers understand existing research gaps. This paper discusses various deep learning techniques, architectures, techniques and applications.

Keywords: Deep learning, Machine learning, Convolution neural network (CNN), Deep neural network architectures.

1. Introduction

Recently, machine learning (ML) has been researched and applied in various applications such as text recognition, spam detection, video streaming, image processing, and multimedia concept retrieval [1–6]. Among various ML methods, deep learning (DL) is commonly used in these applications [7-9]. Another name for DL is representation learning (RL). The constant emergence of new research in a vast and rare field is due to an unprecedented increase in data availability and significant advances in hardware technology. High performance computing (HPC) [10].

DL is based on a continuous neural network, but it is more important in terms of performance. The previous ones. In addition, DL uses semantic and functional tasks simultaneously to perform multiple

learning tasks. Modern improvements DL tasks performed well in a variety of tasks, including auditory and speech processing, visual processing, and natural language processing. Performance (NLP), etc. [11-14].

If intelligence is like the brain, then machine learning is the process by which intelligence acquires new cognitive abilities, and deep learning is the most effective personal training method available today. Machine learning is the study of computers that learn and evolve in ways that mimic or exceed human learning capabilities. Manufacturers train models to predict what they want from input. This knowledge represents past computer programs. The whole discipline of intelligence known as machine learning is based on the principle of learning by example, of which deep learning is the domain. Instead of giving the computer a long list of commands to solve the problem.

This is also how machine learning works, where the computer is trained using multiple instances of training data sets, the neural networks are then trained, and their paths are fine-tuned. The machine receives new input and creates something. Actual applications of this technology include spam filters in Gmail, Yahoo, and the True Caller app, which scans spam emails; Amazon's Alexa; and recommended videos that appear on our YouTube homepage based on the types of videos we've previously viewed. Tesla, Apple, and Nissan are among businesses developing autonomous technology based on deep learning. Deep learning is one of the methods of machine learning [9].

Relatively speaking, feature extraction is achieved in an automatic way throughout the DL algorithms. This is encourages researchers to extract discriminative features using the smallest possible amount of human effort and field knowledge [15]. These algorithms have a multi-layer data representation architecture, in which the first layers extract the low-level features while the last layers extract the high-level features. Note that artificial intelligence (AI) originally inspired this type of architecture, which simulates the process that occurs in core sensorial regions within the human brain. Using different scenes, the human brain can automatically extract data representation. More specifically, the output of this process is the classified objects, while the received scene information represents the input. This is process simulates the working methodology of the human brain. Thus, it emphasizes the main benefit of DL.

2. Background

To main aim of this review is to present the most important aspects of DL to make it easy for researchers and students to have a clear image of DL from single review paper. This review will further advance DL research by helping people discover more about recent developments in the field. Researchers would be allowed to decide the more suitable direction of work to be taken in order to provide more accurate alternatives to the field. Our contributions are outlined as follows:

- This is the first review that almost provides a deep survey of the most important aspects of deep learning. This review helps researchers and students to have a good understanding from one paper.
- We explain CNN in deep which the most popular deep learning algorithm by describing the concepts, theory, and state-of-the-art architectures.
- We review current challenges (limitations) of Deep Learning including lack of training data, Imbalanced Data, Interpretability of data, Uncertainty scaling, Catastrophic forgetting, Model

compression, Overrating, Vanishing gradient problem, Exploding Gradient Problem, and Under specifcation. We additionally discuss the proposed solutions tackling these issues.
- We provide an exhaustive list of medical imaging applications with deep learning by categorizing them based on the tasks by starting with classification and ending with registration.
- We discuss the computational approaches (CPU, GPU, FPGA) by comparing the influence of each tool on deep learning algorithms.

This study's main objective is to draw attention to the most important DL elements so that researchers and students may quickly and easily get a thorough grasp of DL from a single review piece. Additionally, it let people understand more about current developments in the area, which will enhance DL research. To provide more precise opportunities to the field, researchers would be allowed to select the best route of study to pursue.

This type of learning is at the heart of the fourth industrial revolution (Industry 4.0). The general contribution of this study is summarised as follows: To investigate several well-known ML and DL methods and provide a taxonomy reflecting the differences between deep learning problems and their applications. The main focus of the review that follows is deep learning, including its fundamental ideas and both historical and current applications in various domains.

This article focuses on deep learning workflow and modelling, that is, the ability of DL techniques to learn. This article helps developers and academics gain a broader understanding of DL methodologies; I have summarised numerous potential real-world application areas of DL

3. Why Deep Learning in Today's Research and Applications?

The main focus of today's Fourth Industrial Revolution (Industry 4.0) is typically technology-driven automation, smart and intelligent systems, in various application areas including smart healthcare, business intelligence, smart cities, cybersecurity intelligence, and many more [16]. Deep learning approaches have grown dramatically in terms of performance in a wide range of applications considering security technologies, particularly, as an excellent solution for uncovering complex architecture in high-dimensional data. Thus, DL techniques can play a key role in building intelligent data-driven systems according to today's needs, because of their excellent learning capabilities from historical data. Consequently, DL can change the world as well as humans' everyday life through its automation power and learning from experience. DL technology is therefore relevant to artifcial intelligence [17], machine learning [18] and data science with advanced analytics [19] that are well known areas in computer science, particularly, today's intelligent computing. In the following, we frst discuss regarding the position of deep learning in AI, or how DL technology is related to these areas of computing.

4. The Position of Deep Learning in AI

Nowadays, artifcial intelligence (AI), machine learning (ML), and deep learning (DL) are three popular terms that are sometimes used interchangeably to describe systems or software that behaves intelligently. In Figure 1, we illustrate the position of deep Learning, comparing with machine learning and artificial intelligence. According to Figure 1, DL is a part of ML as well as a part of the broad area AI. In general, AI incorporates human behavior and intelligence to machines or systems [20], while ML is the method

to learn from data or experience [21], which automates analytical model building. DL also represents learning methods from data where the computation is done through multi-layer neural networks and processing. The term "Deep" in the deep learning methodology refers to the concept of multiple levels or stages through which data is processed for building a data-driven model.

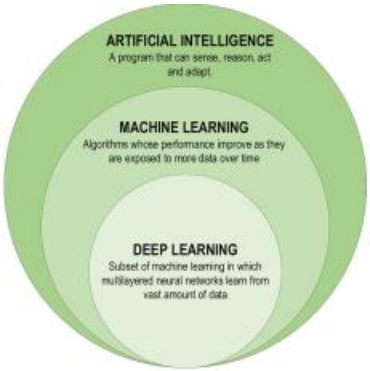

Figure 1 : Deep Learning Family

Thus, DL can be considered as one of the core technology of AI, a frontier for artificial intelligence, which can be used for building intelligent systems and automation. More importantly, it pushes AI to a new level, termed "Smarter AI". As DL are capable of learning from data, there is a strong relation of deep learning with "Data Science" [22] as well. Typically, data science represents the entire process of finding meaning or insights in data in a particular problem domain, where DL methods can play a key role for advanced analytics and intelligent decision-making [23]. Overall, we can conclude that DL technology is capable to change the current world, particularly, in terms of a powerful computational engine and contribute to technology-driven automation, smart and intelligent systems accordingly, and meets the goal of Industry 4.0.

5. Classifcation of DL approaches

DL techniques are classified into three major categories: unsupervised, partially supervised (semi-supervised) and supervised. Furthermore, deep reinforcement learning (DRL), also known as RL, is another type of learning technique, which is mostly considered to fall into the category of partially supervised (and occasionally unsupervised) learning techniques.

5.1 Deep supervised learning

This technique deals with labeled data. When considering such a technique, the environs have a collection of inputs and resultant outputs (xt, yt) ~ ρ. For instance, the smart agent guesses if the input is xt and will obtain as a loss value. Next, the network parameters are repeatedly updated by the agent to obtain an improved estimate for the preferred outputs. Following a positive training outcome, the agent acquires the ability to obtain the right solutions to the queries from the environs. For DL, there are several supervised learning techniques, such as recurrent neural networks (RNNs), convolutional neural networks (CNNs), and deep neural networks (DNNs). In addition, the RNN category includes gated recurrent units (GRUs) and long short-term memory (LSTM) approaches. Te main advantage of this technique is the ability to collect data or generate a data output from the prior knowledge. However, the disadvantage of this technique is that decision boundary might be overstrained when training set doesn't

own samples that should be in a class. Overall, this technique is simpler than other techniques in the way of learning with high performance.

5.2 Deep semi supervised learning

In this technique, the learning process is based on semi-labeled datasets. Occasionally, generative adversarial networks (GANs) and DRL are employed in the same way as this technique. In addition, RNNs, which include GRUs and LSTMs, are also employed for partially supervised learning. One of the advantages of this technique is to minimize the amount of labeled data needed. On other the hand, One of the disadvantages of this technique is irrelevant input feature present training data could furnish incorrect decisions. Text document classifier is one of the most popular example of an application of semi-supervised learning. Due to difficulty of obtaining a large amount of labeled text documents, semi-supervised learning is ideal for text document classification task.

5.3 Deep unsupervised learning

This technique makes it possible to implement the learning process in the absence of available labeled data (i.e. no labels are required). Here, the agent learns the significant features or interior representation required to discover the unidentified structure or relationships in the input data. Techniques of generative networks, dimensionality reduction and clustering are frequently counted within the category of unsupervised learning. Several members of the DL family have performed well on non-linear dimensionality reduction and clustering tasks; these include restricted Boltzmann machines, auto-encoders and GANs as the most recently developed techniques. Moreover, RNNs, which include GRUs and LSTM approaches, have also been employed for unsupervised learning in a wide range of applications. Te main disadvantages of unsupervised learning are unable to provide accurate information concerning data sorting and computationally complex. One of the most popular unsupervised learning approaches is clustering [22].

6. The Future Directions

To conclude our study and suggest future directions, a detailed review is presented. DL has difficulty comparing some complex types of data. A recent development in EAD is Multimodal EAD. Deep learning methods are important in the developing model for any area of problems related to information acquisition and learning quality. These data issues can cause low processing and false results, which is very serious. Appropriate data preprocessing methods are needed to be able to develop plans that suit the nature and characteristics of the data problem.

7. Summary and conclusion

Finally, a discussion summary is needed that gathers all relevant information gained from this in-depth research. We then provide a detailed analysis that complements our analysis and points to future directions.

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