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# Deep Structured Learning: Architectures and Applications

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***Abstract***

*Deep learning, a sub-field of machine learning changing the prospects of artificial intelligence (AI) because of its recent advancements and application in various field. Deep learning deals with algorithms inspired by the structure and function of the brain called artificial neural networks. This works reviews basic architecture and recent advancement of deep structured learning. It also describes contemporary applications of deep structured learning and its advantages over the treditional learning in artificial interlligence. This study is useful for the general readers and students who are in the early stage of deep learning studies.*

***Keywords:*** *Artificial Intelligence; machine learning; deep learning; deep belief network; deep neural network; deep structured learning; hierarchical learning.*

## 1. Introduction

Deep Learning (DL) is more commonly known as deep structured learning or hierarchical learning a subset of machine learning (ML), which is in fact a subset of artificial intelligence (AI). AI is the study of machines that observe their situation and define a sequence of action that will maximize its chance of achieving a given goal. In machine learning, machines learn way to complete a certain task without being explicitly programmed to perform the task. Deep learning algorithms are similar to how nervous system structured where each neuron connected each other and passing information. In deep learning tasks are broken-down and distributed onto machine learning algorithms that are organized in consecutive layers. Each layer builds up on the output from the previous layer. Together the layers constitute an artificial neural network (ANN) that impersonators the distributed approach to problem-solving carried out by neurons in a human brain. This is similar to the deep and layered learning process of the primary sensorial areas of the neocortex in human brain that automatically extracts features and abstractions from primary data. Basically, DL algorithms are more useful for dealing with large amounts of unsupervised data and naturally learn data representations in a greedy layer-wise method.

Inspired by the deep hierarchical structures of human speech perception and production systems, the concept of deep learning algorithms was introduced in the late 20th century. However, advances on on this arena was getting more attention since 2006 when Hinton proposed a novel deep structured learning architecture called deep belief network (DBN) Hinton [1]. Hinton proposed a training method called layer-wise-greedy learning that is supposed to be the birth of deep learning techniques. The basic concept of the layer-wise-greedy-learning technique is that unsupervised learning should be performed for network pre-training before the subsequent layer-by-layer training. The data dimension is reduced and a compact representation is hence obtained by extracting features from the inputs. Figure 1 shows the illustration of artificial intelligence, machine learning and deep learning and their timeline.

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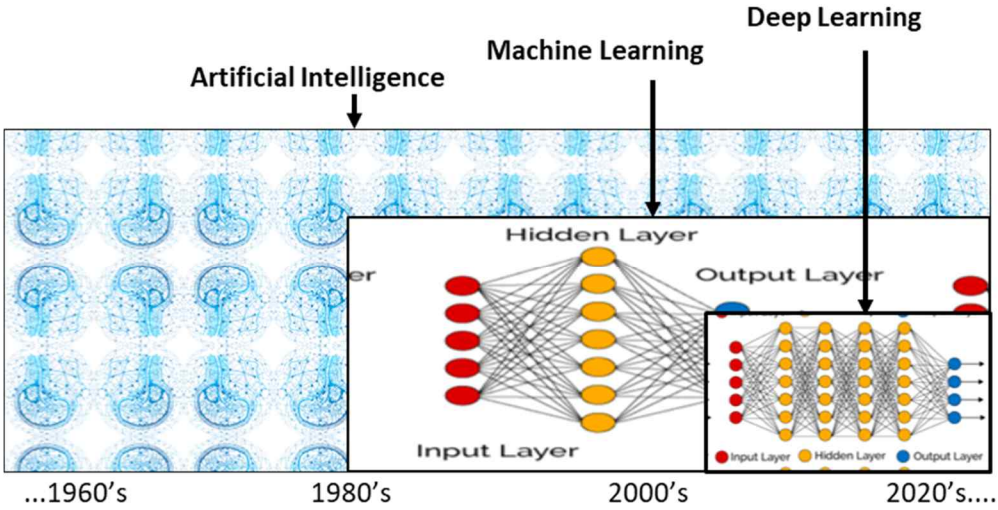


**Figure 1.** Artificial intelligence, machine learning and deep learning, subset and timeline illustration.

This work introduces deep learning techniques and its application. The rest of paper is organized as follows. Section 2 provides few learning architectures. Section 3 summarizes some of the major applications of deep learning. Finally, Section 4 concludes the paper.

## 2. Architecture of Deep Learning

There are four basic deep learning architectures: (a) restricted Boltzmann machines (RBMs), (b) deep belief networks (DBNs), (c) autoencoder (AE), and (d) deep convolutional neural networks (CNNs). In this section, we will discuss these architectures briefly.

**Restricted Boltzmann machines (RBMs):** RBMs are energy-based neural networks which are commonly used as the building blocks for deep-architecture neural architectures. This architecture is used to generate stochastic models of ANNs that can learn the probability distribution with respect to their inputs. It comprises a variant of Boltzmann machines (BMs) that can be interpreted as NNs with stochastic processing units connected bidirectionally. This architecture is widely used in deep learning because of their historical reputation and relative easiness.

**Deep belief networks (DBNs):** DBNs is a is a generative model with an input layer and an output layer, separated by many layers of hidden stochastic units, with connections between the layers but not between units within each layer. DBNs are more effective than ANNs when applied to problems with unlabeled data.

**Autoencoder (AE):** An autoencoder (AE), also commonly called as autoassociator, is a specific kind of unsupervised learning algorithm that provides compression and efficient data coding. Autoencoder learns an approximation to the identity function, which is a trivial function that tries to learn by placing some constraints on the network.

**Deep convolutional neural networks (CNNs):** Deep convolutional neural networks, also commonly known as ConvNet. CNNs comprised of one or more convolutional layers and then followed by one or more fully connected layers. The basic idea of CNNs is inspired by time-delay neural networks, in which the weights are shared in a temporal dimension that decreases computational complexity.

## 3. Application of Deep Learning

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### 3.1 Automatic Speech Recognition (ASR)

For so many years in the past, ML is used for acoustic modeling and automatic speech recognition [2]. Google started voice search using deep neural networks as a core technology for the last several years [3]. The ASR has to deal with many QoS parameters, such as, noise, accent, multi-model recognition and multilingual recognition, among others. Generally, data are preprocessed with noise removal algorithms (such as spectral amplitude estimation, spectral subtraction, and Wiener filtering) and ASR algorithm applied.

Recently many researchers are working on adding sounds to silent movies. Some applications are already on the shelf that used CNN and Long-short term memory (LSTM) recurrent neural networks. Models associate the video frames with a database of pre-recorded sounds in order to select a sound to play tat best matches what is happening in the scene. One very interesting application is forensic test, in which machine helps authorities to determine the synthesized or real sounds.

### 3.2 Image processing

Recently, the development in deep learning architectures has provided novel approaches in image processing, computer vision and pattern recognition. Due to the rapid development in digital industries, there are ever increasing requirements on the capability of information retrieval, processing and recognition, which brought new challenges in this domain.

Many applications such as event detection, scene reconstruction, object detection and recognition, image classification, segmentation, object posture estimation, image restoration, statistical learning, image editing and video enhancement can be optimized using deep learning. Some interesting real-world applications are auto colorization of black and white images, auto translation of text, auto translation of images, auto handwriting generation, auto image caption generation. Recently, deep learning algorithm, especially convolutional networks is rapidly applied for analyzing medical images [4].

### 3.3 Natural Language Processing (NLP)

Natural language processing deals with building machine learning algorithms to analyze and characterize human language automatically. Recently, deep learning methods have been successfully applied to a variety of language and information retrieval applications. It is one of the most vital technologies of the information age. With integration of deep learning, NPL methods are achieving advanced results on challenging machine learning problems such as translating text from one language to another, named entity recognition, part of speech tagging, word-sense disambiguation, question answering and sentiment analysis etc. There are a large variety of underlying tasks and deep learning models behind NLP applications. By exploiting deep architectures, deep learning techniques are able to discover from training data the hidden structures and features at different levels of abstractions useful for the any tasks. More recently, NLP-based systems enabled a wide range of applications such as Google's search engine, online assistant in various online stores, assistant in various virtual stores etc. Words in a sentence are not separated in some language like Chinese, Japanese, Korean and Thai. NPL is used for word segmentation in such languages. It can also be used in automatic summarization of text. Also, with the help of NPL, news aggregators can filter news based on sentiment. Recently, Young and et al. [5] published a detailed review of deep learning related models and methods that have been employed for numerous NLP tasks and a comprehensive understanding of the past, present and future of deep learning in NLP.

### 3.4 Recommender system

Recommender system is one of the most successful and widespread applications of deep learning system. When options are overloaded this cognitive process helps people who have a difficult time making a decision. Let n is the number of uses and m is the available items, we can get a large user-item matrix in recommender system to recommend from a large user–items $R \in R^{nxm}$, where, R is a sparse matrix. Some recently growing areas of interest of recommender system are music, news, fashion articles, and mobile apps recommendation.

### 3.5 Other various areas

Not only the categories mentioned above, several emerging areas are there where deep learning is used overwhelmingly, some examples are – clustering and spectrum decision in cognitive radio networks [8], bioinformatics [6], cancer research [7], drug delivery, drug discovery, toxicology, stock market prediction [9], consumer relation management, customer lifetime value, among others.

## 4. Conclusion

Recently, deep learning is one of the hottest topics in machine learning and data science. It is part of a broader family of machine learning, which a subset of artificial intelligence. Unlike machine learning, deep learning is mostly unsupervised. Because of technical advances in GPUs and libraries many layers are possible in neural networks. Since this is a fast-evolving arena in machine learning that is bringing breakthrough advances in many application areas, this work summarizes some of deep learning applications.

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