Bird's Eye View of Machine Learning, Deep Learning in Agriculture

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Abstract

Agriculture is the backbone of India as it is the source of food as well as one of the factors of economic development. The agriculture sector's contribution to the Indian economy is much higher than the world's average. Agriculture has several stages, such as soil preparation, crop selection, control of pests or insects, crop yield, and crop sales. Artificial Intelligence (AI) is one of the very emerging areas in the computer field. Applying AI in farming is now essential to increase crop production. Machine Learning (ML) and Deep Learning (DL) are sub-areas of AI. Though ML and DL follow their learning strategies. This paper gives an outline of ML and DL concerning agriculture. This paper also studies on comparison of ML and DL models with results. The majority of DL models are outperforming ML models. ML and DL are also applied in several other domains like medical, agriculture, business, transport (logistics), entertainment, education, and many more.

Keywords
Machine Learning, Deep Learning, Precision Agriculture,and Artificial Intelligence.

1.Introduction

India is one of the largest and oldest countries practicing farming for livelihood and also contributing 18% to the GDP of India. Farmers of India are facing a lot of problems at various stages of farming, starting from soil preparation to crop harvesting. Some problems can be solved by Artificial Intelligence. The requirement of Artificial Intelligence in Indian agriculture is essential to feed new information and increase the number of backend databases, it is used to accurately perform the tasks such as predictions of the crop, crop yield, weed detection, disease/pest detection, smart irrigation, etc. Artificial Intelligence (AI) is a leading and emerging research area in the computer domain. The word AI was coined by John McCarthy at the Dartmouth Conference in 1956 (Crevier 1993), defined as the science and engineering of making Intelligent Machines. The term artificial intelligence is applied when a machine mimics cognitive functions that humans associate with other human minds, such as the learning and problem-solving approach (Ongsulee 2017).

The central goals of AI research include reasoning, knowledge, planning, learning, natural language processing, perception, and the ability to move and manipulate objects. As AI evolved in the mid-1950, it has popularized in the early 2000 (S. D. Erokhin 2019) because of the availability of high-speed processors (CPU), Graphical Processing units, huge infrastructure, like a cloud environment, and good analytical procedures. Figure 1 is about the latest high-speed processor; Figure 2 is about the latest Graphical Processing Unit (GPU). Figure 1 is the comparison of various latest CPUs with respect to cores, threads, and processing speed. Figure 2 is a comparison of various latest CPUs with respect to memory bandwidth and base clock speed. These latest CPU and GPU data are taken from various sources on the internet. These latest CPUs and GPU help to analyze the data efficiently and accurately.

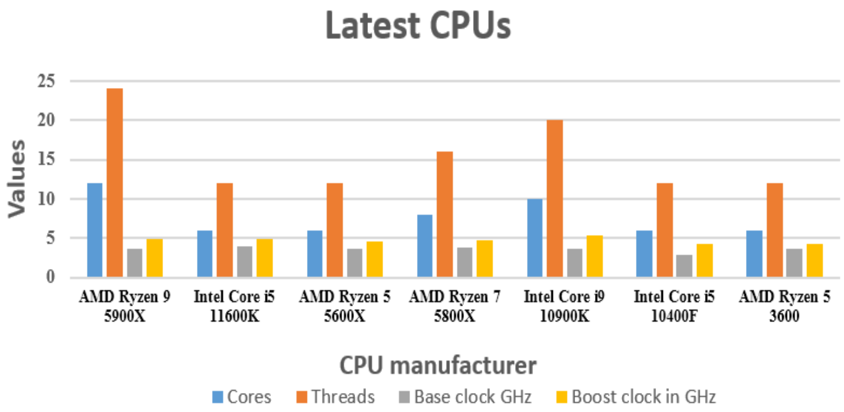

Figure 1. Latest Processors

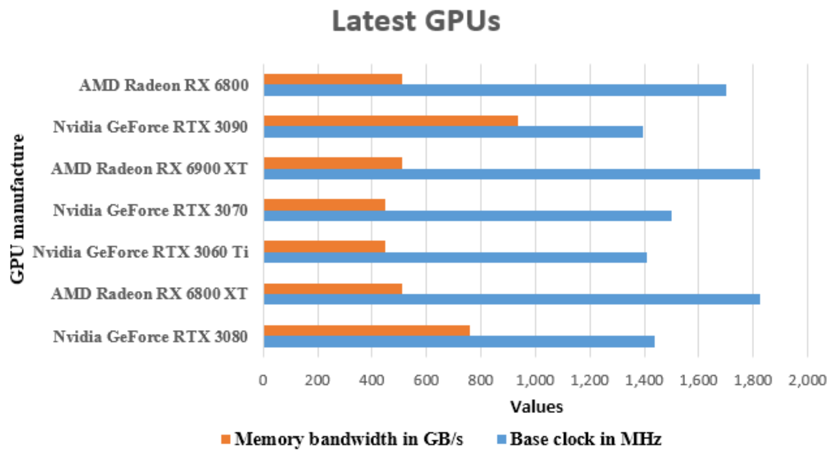

Figure 2. Latest Graphical Processing Unit

AI is a broad domain in computer science. Figure 3 shows the relationship between AI,ML, and DL. The DL is a subset of ML and ML is a subset of AI. Remaining, section 2 is about machine learning and its strategies, section 3 is about deep learning, and section 4 is about Feature learning of ML and DL. Section 5 is on the review of ML and DL on agriculture, and section 6 is the conclusion.

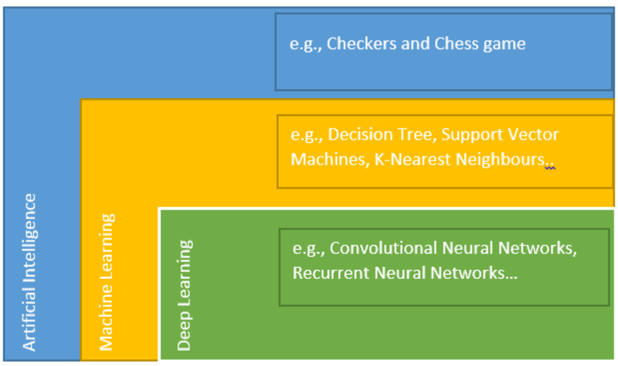

Figure 3. AI,ML, and DL

1.1 Objective

Though ML and DL are sub-areas of artificial intelligence, it is necessary to apply to agriculture to various stages of farming, like crop recommendation, disease detection, yield prediction, etc.,. DL techniques are better performance than ML techniques. Detailed comparison analysis of ML and DL is mentioned in further sections.

2.Machine Learning

Machine Learning (ML) was coined by Arthur Samuel, an American pioneer in the field of artificial intelligence in 1959. It is defined as a field of study that gives computers the ability to learn without being explicitly programmed (Muñoz, Andrés 2012). ML is one of the leading sub-domain of AI as it has a lot of scopes to design intelligent machines (Stanley Cohen 2021). ML involves machine identification to perform tasks without being exclusively programmed by humans. ML approaches to learning in traditionally categorized into three types, depending on the learning nature of the computer systems .Machine learning follows divided into three broad categories traditionally, depending on the kind of learning that takes place. Those are supervised learning, unsupervised learning, and reinforcement learning. Figure 4 is about the basic learning structure of machine learning.

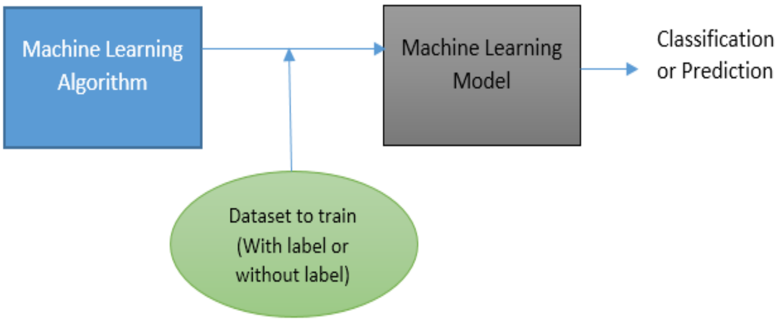

Figure 4. Machine learning structure

2.1 Supervised learning

Supervised learning imitates the learning strategy of a child monitored by parents, like how the child learns things or objects with names and detects or predicts objects later, here the model is presented with example inputs along with labels and their desired outputs, given by an instructor, and the goal is to learn a general rule that maps inputs to outputs. With supervised learning, the model can predict or classify the output.

Some supervised learning strategies for classification are Support Vector Machines (SVM), Naive Bayes, Nearest Neighbour, and Decision Trees. And a few supervised learning strategies for Regression: Decision Trees, Linear Regression, Logistic Regression, and Artificial Neural Networks.

2.2 Unsupervised learning

Unlike supervised learning, no labels of data are given to the learning algorithm, then left to its own to find similar features within given data as input. Unsupervised learning will be a goal in itself by finding hidden patterns or clusters in data. Some unsupervised learning strategies for clustering are the Apriori algorithm, K-means, and Gaussian Mixture.

2.3Reinforcement learning

A machine learning model or agent interacts with the random environment by performing an action and taking a reward strategy method to attain the goal, for example, a self-driving car or playing a game against an opponent. As it navigates its problem space, the program is provided feedback that's similar to rewards, which it tries to maximize. One of the reinforcement learning strategies is Q-learning.

3. Deep Learning

Deep Learning (DL) is a new subdomain of ML, which works like the human brain. DL requires a deep (more) neural network layer to train/process the data (model) and predict or detect the output. DL can apply to different areas like Speech recognition, Image recognition, Video analysis, Natural language processing, and smart devices.

Deep-learning methods are representation-based learning methods (LeCun et al. 2015) with multiple levels of representation, obtained by composing non-linear layers that each transform the representation at one level into a representation at a higher, slightly more abstract level. Very complex functions can be learned by the composition of such transformations. Figure 5 shows the process of deep learning methodology starts from input data to output, generally it is all happened in form of layer by layer from one level to the next level.

Figure 5. Deep Learning

Higher layers of representation accentuate characteristics of the input that are critical for discrimination and decrease irrelevant variations in classification tasks. For example, an image is made up of an array of pixel values, and the learned features in the first layer of representation usually indicate the presence or absence of edges at specific orientations and places in the image. The second layer recognizes motifs by spotting specific edge arrangements, even if the edge placements are somewhat different. The third layer may combine patterns into larger combinations that relate to components of recognizable things, with the following levels detecting items as a combination of these parts. The key aspect of deep learning is that these layers of features are learned from data using a general-purpose learning procedure.

The deep layer network transforms the input into representations that tend to capture a higher level of abstraction. Each hidden layer transforms the input into a representation that is increasingly different from the actual input and increasingly informative about the result. The representations learned help to distinguish between different concepts which in turn help to find out similarities between them. The deep layer network can be thought of as a multi-stage distillation information operation, where layers use multiple filters on the information to obtain an increasingly transformed form of information. Deep learning is on the rage and is gaining more popularity due to its supremacy in terms of accuracy nowadays. Major tech companies are investing heavily in deep learning as it has become necessary in every sector as a way of making intelligent machines. Google AlphaGo is just an example of deep learning that made the headlines when it crushed Lee Sedol, one of the highest-ranking Go players in the world.

3.1 Types of Deep Learning approaches:

3.1.1 Supervised deep learning:

Supervised learning, is a learning technique that uses labelled data for input and output. In the case of supervised DL approaches, the environment has a set of inputs and relevant outputs. The agent will then iteratively modify the network parameters to better approximate the desired outputs. After successful training, the agent can get the correct answers to questions from the environment. There are different supervised learning approaches for deep learning, including Deep Neural Networks (DNN), Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), Long Short Term Memory (LSTM), and Gated Recurrent Units (GRU).

3.1.2Unsupervised deep learning:

Unsupervised learning systems can occur without the presence of data in the form of labels. In this case, the agent learns the internal patterns or important features to discover unknown relationships or structures within the given input data. Often clustering, dimensionality reduction, and generative techniques are considered unsupervised learning strategies.Auto-Encoders (AE), Restricted Boltzmann Machines (RBM), and Generative Adversarial Networks (GAN) are a few models that come under unsupervised learning of deep learning.

3.1.3Reinforcement learning:

Deep Reinforcement Learning is a learning method for use in unknown environments. Depending upon the problem scope or space, one can decide which type of RL must be applied to solve a given task. If the problem has a more number of parameters to be optimized, DRL is the best way to implementation.

In nutshell, a deep learning network constructs options at multiple levels, with higher options created as functions of lower ones (Wani et al. 2019). it's an invasive field that circumvents the matter of feature extraction that is employed as a prelude by standard machine learning approaches. Deep learning is capable of learning the suitable options by itself, requiring very little steering by the user.

4.Feature learning of ML and DL

A key difference between traditional ML and DL is in how features are extracted from given data. Traditional ML approaches use handcrafted engineering features by applying several feature extraction algorithms and then applying the learning algorithms. Additionally, other boosting approaches are often used where several learning algorithms are applied to the features of a single task or dataset and a decision is made according to the multiple outcomes from the different algorithms. On the other hand, in the case of DL, the features are learned automatically and are represented hierarchically on multiple levels. This is the strong point of DL against traditional machine learning approaches. Table 1 shows the different feature-based learning approaches with different learning steps (Alom et al. 2019).

Table 1. Different Learning Strategies

S. No	Approaches	Learning Steps
1	Rule-based Learning	Input → Hand-design features → Output
2	Traditional Machine Learning	Input → Hand-design features → Mapping from features → Output
3	Deep Learning	Input → Simple features → Complex features → Mapping from features → Output

Figure 6 demonstrates that the performance of conventional ML approaches shows better performance for small amounts of input data. As the size of data increases beyond a certain point, the performance of conventional machine learning approaches becomes steady, whereas DL approaches increase with the increment of the amount of data.

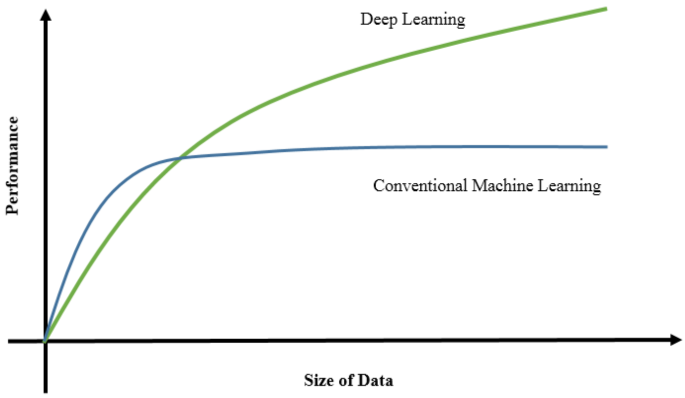

Figure 6. Performance of Deep learning to the amount of data

Major factors that need to consider, when we compare ML and DL are hardware requirements, execution time, the feature extracting procedure, problem-solving methods, and accuracy.
The differences between DL and ML are summarised in Table 2.

Table 2. DL and ML comparison

Element	Machine Learning	Deep Learning
Data	Performs well on small to medium size datasets	Performs well on large-size datasets
Hardware	Able to perform on CPU	Requires significant computing power e.g., GPU
Features	Features need to be manually identified	Learns features automatically
Training time	Quick to train	Consumes more time to train

5. ML and DL in Agriculture

In many countries, the majority of farmers rely on the traditional ways of farming which is based on the reliability of the suggestions from the elderly and their experience. Figure 7 presents a traditional crop step-by-step procedure. This method leaves farmers at the mercy of random climatic conditions which are already getting random due to global warming and uneven rainfall patterns. The manual spraying method for pesticides led to improper usage of resources and harms the environment. AI and IoT-enabled precision agriculture (Abdul Hakkim V.M et al. 2016) to remove the randomness and assist new-age farmers to optimize every step of the farming process.

Figure 7. Tradition Crop cycle

Now, agriculture is moving to widely adopting smart technologies like IoT and AI to efficiently cultivate organic products in limited land areas as well as to overcome the traditional challenges of farmers. And precision agriculture follows precisely by analysing data of soil.

Major steps of agriculture are soil preparation, seed sowing, adding fertilizer, weed or disease protection, and crop harvesting.

5.1 Review of ML and DL in agriculture

A lightweight multi-resolution Convolutional Neural Network-based deep-learning model compared with other CNN architectures and classical machine-learning models that have been adopted by transfer learning to the ultrasound images of Hepatocellular Carcinoma (HCC) for the binary classification tasks. Multi-resolution Convolutional Neural Network-based deep-learning model had given better performance over conventional machine learning models with 91% accuracy (Brehar et al. 2020). A graph convolutional neural network (GCN) is capable of a better prediction rate when compared to traditional machine learning methods like Bayesian, Decision Tree, and Random Forest. GCN predicts mouse liver microsomal with an accuracy rate is 83% (Renn, Alex et al. 2020). Analysed the X-ray images of watermelon seeds for the classification of whether seeds are viable and nonviable for germination by consideration of conventional machine learning and deep learning models (Ahmed et al. 2020). This deep learning model ResNet-50 has given a better accuracy of 87.3%.

Classify plant images and weed to spray herbicide exactly using CNN (Yashwanth et al. 2020). This classification technique is work with 96.3%. This can classify 8 plants to 9 weeds with the facility of computation model in Raspberry Pi. It helps to spray herbicides on weeds perfectly. The model developed different types of deep learning-based models weeds and classification with algorithms and datasets. And identified that still chance of improving the accuracy by considering big datasets (Moazzam et al. 2020).

Comparison of different deep learning models like Vgg16, Vgg19,ResNet50, ResNet50v2, and ResNet101v2, with two types of datasets, artificial data(readymade), Pakistan data(manually gathered), and compare results between them (Burhan et al 2020). In both categories, the accuracy of 73.98% and 86.79% were given by ResNet101v2. Disease detection in crops (Radovanović and Đukanovic 2020) is compared between traditional machine learning and deep learning models, by consideration of SVM, k-NN, FCNN, and CNN. Out of all considered models, CNN has given an accuracy of 99.3%. Multi-class Faster RCNN and Parallel Faster RCNN are proposed to estimate fruit quantity and quality by using CNN-based two models (Halstead et al. 2018). From that, Parallel RCNN, performed well in the detection of fruit. For the quality of fruit, Parallel RCNN has performed with 82.1%.

Analysed classification with different CNN hybrid models, such as CNN-ELM, CNN-KNN, CNN-GA, MLP-CNN, CNN-SVM, CNN-RNN, and CNN-LSTM. Classification done by CNN-LSTM gave 99% accuracy for hand written digits and breast cancer images (Suganthi and Sathiaseelan, 2020). A hybrid model approach(SVM+LSTM+RNN) (Agarwal and Tarar 2020) predicts crop yield based on factors of soil, PH and etc., given accuracy of 97%,when compared to the existing hybrid model(DT+ANN+RF) with an accuracy of 93%. A machine learning in precision agriculture, Decision Tree Ensemble has given an accuracy of 94.2% in comparison to the baseline colour analysis method which has given accuracy of 89.6% (Treboux and Gen 2018).

Deep learning models performed better in disease and weed detection (Sharma et al. 2021) and outperform machine learning models in precision agriculture for different tasks such as soil properties and weather prediction, crop yield prediction, disease, and weed detection, drip irrigation, and livestock production, and management, and intelligent harvesting. In machine learning in agriculture (Liakos et al. 2018), various machine learning models are reviewed for various agriculture applications like crop management, yield prediction, and disease detection.

Datasets help to identify suitable ones for research or project tasks (Lu et al. 2020) consideration of different datasets, which are 15 datasets on weed detection, 10 datasets on fruit detection, and 9 datasets on other applications. For deep learning-based techniques, which apply to various agriculture problems, such as disease detection, fruit classification, and fruit counting. And the majority of deep learning techniques surpass conventional machine learning techniques (Santos et al.2020). Statistical methods play a crucial role while considering the features of datasets. Comparison of regular statistical methods and machine learning methods with strengths (Kocian et al. 2020).

Classification methods (Mhaske et al. 2020) to the identification of fruit quality through RGB (Red Blue Green) and HSV(Hue Saturation Value) for classification based on fruit colour, fruit texture, and shape. A process for quality evaluation (classification) (Bhargava et al. 2018) of fruits and vegetables using computer vision, it describes the entire systematic procedure with various phases starting from pre-processing, segmentation, feature extraction, at end classification based on colour, size, texture, shape by using algorithms, such as Principal Component Analysis (PCA), Multi-class Support Vector Machine, Neural Network, etc.

6. Conclusion

Both Machine Learning and Deep Learning help to develop intelligent machines, which are useful to predict or detect output.ML and DL methods are necessary to apply in agriculture to gain profit by producing more yield. Though ML and DL are sub-areas of AI, the followed procedure is different. Compare to conventional ML models, DL models outperform in the majority of tasks like classification, detection, etc., with better accuracy. Depending on requirements of user, one can choose ML or DL. However, deep learning algorithms can be overkill for less complex problems because they require access to a vast amount of data to be effective.It means that the task with small datasets ML, and huge datasets DL is preferable.

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