Deep learning and its role in smart agriculture

V S Magomadov
Faculty of information technology, Chechen State University, 32 Sheripov Street, Grozny, 364024, Russia
E-mail: vmagomadov@gmail.com

Abstract: Deep learning is a data analysis and image-processing method, which has recently gained a lot of attention as a tool, which has great potential and promising results. There are many different fields that deep learning has been applied to and it is also being applied to the field of agriculture. The purpose of this paper is to explore deep learning in terms of agriculture and food production. The performance of deep learning in agriculture is the focus of this paper comparing it to other existing artificial intelligence models, which have been used in agriculture. In addition, several types of deep learning models are covered and their differences are explained. The paper explains why some deep learning models are better equipped to be used in the field of agriculture than other models.

1. Introduction
People often use artificial intelligence without even realizing it. Such services as Netflix, Pandora, Amazon Alexa, and many others have incorporated AI into their technology for them to be able to find out more about their users and what the preferences of those users are. By doing this, they can make the user experience more personalized because it is based on the learned patterns of behaviour of the users. Using this technology, video, and music streaming services can recommend to the users what they might like, and it is also possible for automated assistants to expect requests. The result of this all is that life is becoming more comfortable and homes smarter.

1.1. Benefits of AI
Natural language processing for reviewing documents – a company usually has thousands of documents that need to be checked by humans, which requires much effort and is very time-consuming. However, AI can be used for performing this task and classifying documents much quicker and there is no need to perform lookups across thousands of documents and create pivot tables. In addition, various types of data can be extracted from documents because the machine is able to recognize what kind of document it is dealing with based on the rules it has been taught.

Data extraction from documents – often data from many documents is required for various tasks within the company. It is difficult and time-consuming to extract data from so many documents. However, AI makes it easier to report because it allows automatic extraction of the data that the users are searching for.

Anomaly detection in data – machines are able to examine large amounts of data and automatically detect anomalies. This is how banks are able to detect unusual banking activity, which is an effective way to prevent consumer fraud.
Ability to learn from various types of data – AI’s ability to identify data and images in different kinds of documents and learn from them can be of great benefit for companies because it allows classifying these documents much more quickly. After the machine is presented with certain data to learn from, it can then deal with the same kind of data and classify it more accurately. Thus, the machine is capable of processing large volumes of complex documents in a matter of seconds while it would usually take humans hours of training.

Taking the information given above into account, AI is a great means for different industries to improve their business activities. AI is great at automating activities, which have historically been performed manually and combined with machine learning, AI can be a valuable instrument for businesses.

1.2. Deep Learning
Various industries right now are trying to incorporate artificial intelligence into their day-to-day operations. For example, it can be seen that manufacturing and automotive industries are using AI for certain tasks and it is expected that the use of AI will increase as we move forward. Agriculture is one of the industries, which is starting to apply AI in order to achieve a more effective and faster way of performing tasks. There is no doubt that agriculture is one of the most important parts of the world economy. The Environmental Protection Agency (EPA) states that agriculture is responsible for about 330 billion dollars in profit worldwide annually. The role, which is played by AI in agriculture, is going to be even more crucial because the world population is increasing and climate is changing [1].

Much effort has been put into building autonomous robots, which are capable of performing agricultural operations. These machines are better and faster at dealing with many agricultural tasks than humans are.

The DL based drone technology is also highly beneficial for farming because it makes it easier to monitor, scan and analyze the crops by providing high-quality images. This technology is useful in identifying the progress of the crops and assessing their health. For instance, based on the images provided by this technology, farmers can determine whether the crops are ready for harvest or not. DL and other machine learning technologies assist the farmers in determining the state of their soil [2].

Deep learning is also used in order to understand how water and nutrient need to be managed and determine the best time for planting and harvesting. This, of course, results in higher efficiency of farming and even ROI from certain crops can be predicted taking into account their price and margin within the market.

2. Methodology
This research consisted of two steps: 1) searching for previous work related to this subject and 2) an in-depth analysis of this work. As part of the first step, the data were collected by means of a keyword search in the scientific databases such as ScienceDirect and IEEE Xplore as well as the web scientific services such as Google Scholar and Web of Science.

The research papers found were then sorted out based on the following questions:
- What kind of agricultural problem were they trying to solve?
- What type of DL model did they use?
- What kind of data did they use?
- Did they use any data augmentation techniques?
- What was the performance?
- Were different datasets used for testing?
- Did they make any comparisons between DL and other techniques?

3. Deep learning
The human brain serves as the blueprint for designing a deep learning model, which is one of the types of machine learning. The purpose of a DL model, as its name suggests, is to learn from data, which originate from different places and make sense of this data without human intervention. Whether this
data is structured or not, a good DL model is capable of learning from it and make decisions based on its learning experience.

Search engines, social media, and other platforms generate enormous amounts of data on a daily basis, which a DL model has to be able to learn from. Big data is a term used to describe these vast amounts of data that anyone is able to easily access and use it according to their needs.

The main difference between traditional programs and DL based models is that DL allows processing data in a nonlinear fashion due to its hierarchical fashion. DL neural networks represent a web of connected nodes which looks like the human brain [3].

Figure 1 shows the architecture of DL which consists of a convolutional neural network (CNN) with fully connected and convolutional layers.

Figure 1. The architecture of DL.

CNN is a DL based algorithm the main use of which is natural language processing, speech recognition, face recognition and so on. It has convolutional and pooling layers, which are used for feature extraction while the fully connected layers serve as a classifier.

3.1. Convolutional Layer
If we have six convolution kernels $W$ (19) and use an RGB image as input $X$. The size of an image is a three-dimensional matrix $H \times W \times 3$. $h \times w \times 3$ is the size of the convolution kernel related to each convolutional layer. $b$ is the convolutional layer threshold. After calculating convolution, the size of the new image feature is $H_{\text{new}} \times W_{\text{new}}$. The number of inputs or the number of output feature maps is determined by the number of convolution kernels for each convolutional layer. The zero-padding method is used for identifying the edge information of an image and $P$ is the size of zero-padding. Setting a suitable size $S$ [4] for calculating convolution is also of the utmost importance when convolution is calculated in the convolutional layer.

3.2. Pooling Layer
The pooling layer is used for compressing the input tensor and reducing the input data size which means that each $n \times n$ submatrix of the input image is changed into specific element value. Maximum pooling and mean pooling are two of the most widely used pooling methods. As its pooled element, maximum pooling takes the maximum of the corresponding $n \times n$ area while mean pooling does the same with the average value of the corresponding $n \times n$ area. $W \times H \times D$ is the volume of the input for the pooling layer and $W_{\text{pooling}} \times H_{\text{pooling}} \times D_{\text{pooling}}$ is the volume of the output for the pooling layer [4]. In addition, two hyperparameters are necessary for the pooling layer which is the stride size $s$ and the special extent $f$.

3.3. Existing Architectures
If it is necessary to build DL models, researchers can make use of existing architectures instead of starting from scratch. Some popular existing architectures are CaffeNet, GoogleNet, AlexNet, and VGG. Each of these architectures has its advantages and drawbacks. They also have different scenarios in which they are more suitable for use. In addition, most of these architectures have previously been trained by some dataset, which means that their networks can be used to accurately classify certain problem domains. ImageNet and PASCAL VOC are the most popular datasets, which are used to pre-train DL models [5].

4. Smart agriculture and DL
Agricultural research is widely using CNN because of its strong image processing capabilities. Generally, plant and crop classification are the most common categories of DL applications, which are of great use in terms of yield prediction, pest control, disaster monitoring, robotic harvesting and so on. Plant disease detection consumes a great deal of time when performed manually. Fortunately, image processing can now be used for plant disease detection owing to the advances in AI. The models, which detect plant disease usually, employ leaf pattern recognition and image classification [6]. The Berkley Vision created a framework based on DL, which was used for developing a model for plant disease detection. This model is capable of recognizing 13 various types of plant diseases and it is also able to tell apart plant leaves and their surroundings [7]. Another research showed that the accuracy of a DL model in plant disease detection can go up to 95.8% after going through 100 iterations of training which can be further improved to reach 96.3% by more training. This indicates that DL outperforms manual plant disease detection [8].

In order to detect a lot of plant features, image recognition can be used which is why CNN has widely been used for weed detection and plant classification [9]. In 2017, to control and classify weed, a new method consisting of CNN and K-means feature learning was developed. The new method increased the accuracy of weed identification to 92.89% [10]. AlexNet is a pre-trained CNN architecture, which is commonly employed for classifying plants. The results of using this architecture at the Istanbul Technical University show that CNN is better than other machine learning algorithms based on hand-crafted features for the discrimination of phenological stages [7].

5. Discussion
Most of the recent technological achievements in the field of agriculture are related to production and other areas of agriculture in an attempt to improve crop productivity, minimize plant diseases and improve modern automated agriculture. Data classification and image recognition are what DL is usually used for. These two areas can be divided into the following categories: data collection and preprocessing, model testing, neural network training, and the analysis of the result.

For the first task, DL can be used in conjunction with other technologies such as radar, unmanned aerial vehicles, and Internet of Things, to provide image datasets of high quality. The DL applications are enhanced by these data making the resulting instruments more accurate.

There is a big number of agricultural applications not supporting new techniques, which means that agriculture still has a lot to explore in terms of DL. Despite the fact that some results indicate 95% accuracy, reliability and robustness remain major challenges.

6. Conclusion
This paper covers some major DL based technologies and their applications in the field of agriculture. It can be seen that DL has been applied in various areas of agriculture, for example, plant classification, plant disease detection, fruit counting, etc. The field of DL is a popular research topic these days and many applications have been developed. However, there is still much more to be done to realize the full potential of DL in agriculture. Smart agriculture has the potential for developing many DL based applications.

References
[1] Krishna P V and Gurumoorthy S 2018 Social Network Forensics, Cyber Security, and Machine Learning (Berlin: Springer) pp 59-60

[2] Kashyap P 2017 Machine Learning for Decision Makers. Cognitive Computing Fundamentals for Better Decision Making (Bangalore: Apress) pp 227-8

[3] Martinsanz G P 2018 Image Processing in Agriculture and Forestry (Basel: MDPI) pp 50-1

[4] Aggarwal C C 2018 Neural Networks and Deep Learning (Berlin: Springer) pp 101-2

[5] Ramsundar B 2018 TensorFlow for Deep Learning From Linear Regression to Reinforcement Learning (Sebastopol: O’Reilly) pp 71-2

[6] Khan S 2018 A Guide to Convolutional Neural Networks for Computer Vision (San Francisco) pp 53-4

[7] Sewak M 2018 Practical Convolutional Neural Networks (Mumbai: Packt Publishing) pp 37-8

[8] Zhongzhi H 2019 Computer Vision-Based Agriculture Engineering (Boca Raton: CRC Press) pp 81-2

[9] Goodfellow I 2016 Deep Learning (Cambridge: The MIT Press) pp 44-5

[10] Pantazi X E 2019 Intelligent Data Mining and Fusion Systems in Agriculture (Beijing: Elsevier Science & Technology) pp 53-4