

# Deep Learning In Smart Farming –Concepts, Applications and Techniques

Harjeet Kaur

School of Computer Science and Engineering, Lovely Professional University

Dr Deepak Prashar

School of Computer Science and Engineering, Lovely Professional University

Madhuri

School of Computer Science and Engineering, Lovely Professional University

## Abstract

One of the major factor influencing global economy is agriculture. In order to fulfil the needs of growing population in terms of food requirement, innovations and technological developments in agriculture is the need of hour. Farmers are still making use of traditional methods and their intuitions in farming which are not sufficient enough to provide full-fledged solution for problems like crop disease, unwanted weed, poor storage, ineffective pesticide management, inadequate water and soil management etc. More efficient farming practices can be attained using the recent technological advancements. Application of Artificial Intelligence across the farming sector has proven out to be more beneficial, efficient and sustainable than the way farming is done today. To further enhance the performance, Deep Learning (DL) algorithms may be applied in different aspects of agriculture. Presented work provides a crisp summary of concepts of popular Deep Learning algorithms and concludes how their application in the field of agriculture can support in improving productivity.

## 1. Introduction

Farmers all around the world specifically in countries where agriculture is the primary occupation of the people and a major factor contributing in their country's economy trust personal instincts and apply methods and techniques which demand huge amount of time and labour, for cultivating crops. This becomes a major reason for the loss of over 11 billion

dollars' worth revenue each year due to crop damage [1]. Cultivators are primarily relying on rainfall for harvest and all other subsequent activities. In such circumstance more efficient farming practices are required which make use of technological advancements and provide key for current restrictions in farming. Artificial Intelligence (AI), with the applications of Internet of things (IOT), drones, robots, different monitoring and predictive analysis, is adding new epitome in the field of agricultural. Global warming is leading to unexpected climate changes which consequently result in weak soil water equation and unpredictable rain falls. But AI enabled technologies gives precise reports on changes in climate of any location with suggestions to supervise farmers to take effective decisions in these conditions. With growing applications of AI in agriculture areas like drones, driverless tractors, plant health monitoring, automated irrigation systems are also expanding In 1983, a work done [2] listed down the applications of computers in the field of agriculture.

Problems in agriculture were studied and their solutions were proposed in different literatures beginning with databases till decision support systems [3,4]. Among all these solutions, AI enabled systems have established as excellent players as far as robustness and preciseness are concerned.

## **2. Smart Farming – key for sustainable agriculture**

Concept of Smart farming is all about the usage of technology in agriculture with objectives of increased quality and quantity in the field of agriculture. In this 21<sup>st</sup> century farmers have easy access Taxonomy of application of machine learning in agriculture is given in Figure 1. The work done here classifies applications of machine learning in five major areas – crop management, livestock management, field condition management,

pest management and weather tracing forecasting. Crop management is further split into sub categories including crop yield estimation, fruit counting, crop disease detection, weed identification, species recognition and crop quality. Field condition management includes soil and water management. Livestock management is categorized as livestock production and animal wellbeing.

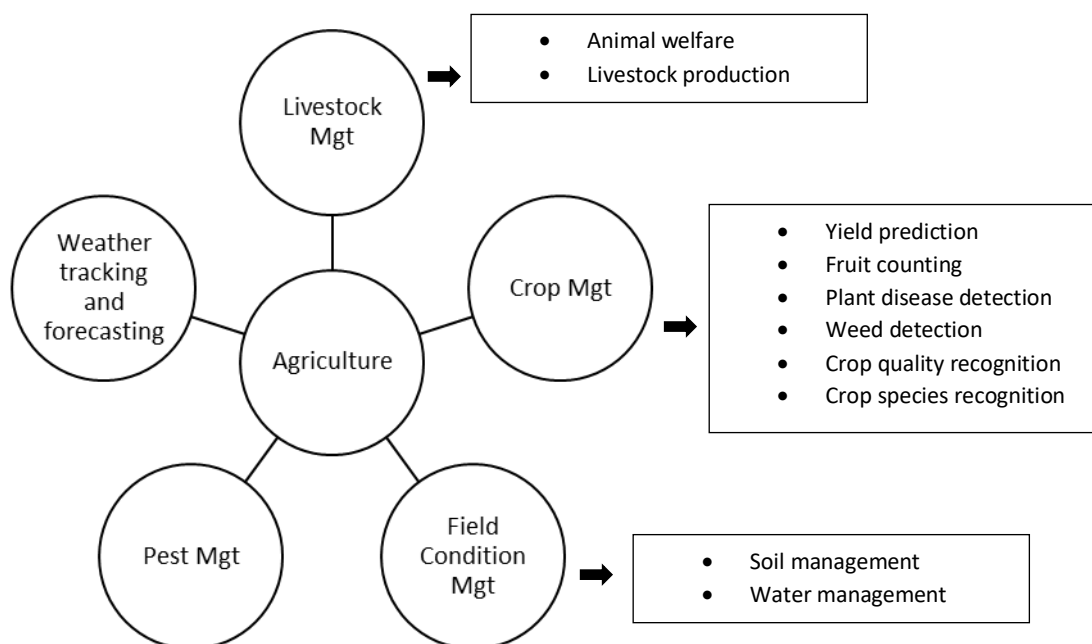


Figure 1: Taxonomy of application of Machine Learning in Agriculture

Precision agriculture includes high significant field yield prediction which directly effects the productivity. Yield prediction can further be divided into number of tasks such as yield estimation, yield mapping, supply and demand analysis of crop, and crop management for improved productivity. In work presented by authors of [5], applications of ML are included. It describes a low cost, non-destructive and efficient method for mechanically counting fruits on a coffee tree branch

Farmers make wrong decisions in choosing pesticides and fertilizers for pest control. But with the application of precision agriculture, variation within the field can be measured and farmers can change strategies accordingly. It results in better pest management. Not only in pest management, smart farming techniques helpful in monitoring the needs and health of

individual animals. Consequently their diet can be adjusted to make it more nutrient which protects them from unwanted diseases and enhances herd health.

The first proposal of using AI techniques in crop management was given by McKinion and Lemmon in their paper "Expert Systems for Agriculture" [6] in 1985. In doctoral thesis of Boulanger [7] corn crop protection expert system was proposed. Roach et al. suggested an expert system POMME for management of apple plantation [8] in 1987. Similarly for cotton crop management Stone and Toman came up with an expert system COTFLEX [9]. In the same lines Lemmon proposed another rule based expert system COMAX for cotton crop management [10].

Robotics, where robots use decision support system have also proved out to be very effective in digital farming. Figure 2 represents the application of robots in agriculture.

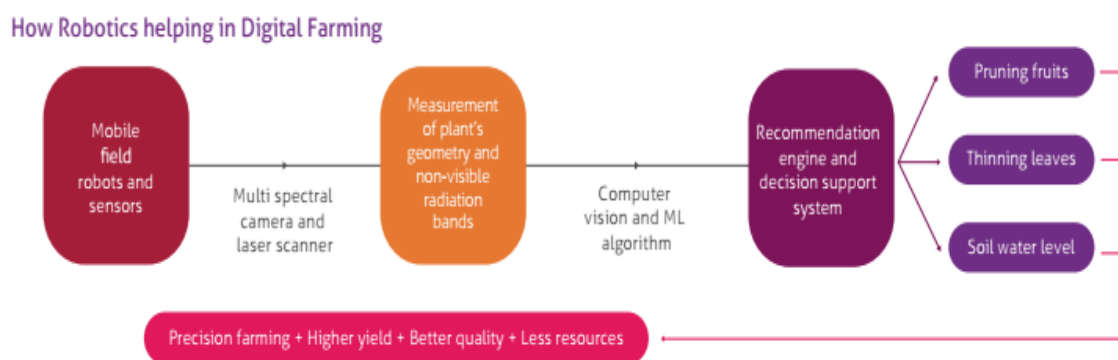


Figure 2: Use of robotics in fields. Source: <https://www.mindtree.com>

Some other prevailing technology solutions, along with their application areas, being used successfully in different parts of world and using machine learning in the field of agriculture are as described below

### **Blue River Technology for Weed Control**

Blue River Technologies are indulged in manufacturing smart farm machines to handle crops. Computer vision and Artificial intelligence in their smart machines can perform different categories of plant management efficiently. See and Spray robot developed by them can spray herbicides only when and where needed. This smart machine provides farmer with precise way of controlling and preventing herbicide resistant weeds. Sensors and cameras

used to detect weeds are using machine learning where the machine has been taught in different weeds.

### **Harvest CROO Robotics for Crop Harvesting**

Harvest CROO is working on agriculture robots. Certain farming areas in many countries are facing lack of labours which leads to significant revenue loss in these regions. Cost of harvest labours can be reduced by replacing them with robots which can pick and pack crops or fruits. It is one time investment. Robots developed by Harvest CROO Robotics are employed for picking and packing strawberries.

### **Plant Diseases Diagnosis App – Plantix**

Plantix App is developed by an agricultural tech startup PEAT in Berlin. It is used for detecting defects and deficiencies in soil. App makes use of images of plants to identify diseases. Collection of such images is kept in smart phone and are matched with image in server for diagnosis.

### **Prospera**

Prospera, a company for data analytics, is working on changing agricultural produce into a predictable and optimized assets. A cloud based solution is developed by them which combines all kind of data farmers are having such as data related to soil and water, images of crops etc. Prospera device makes sense of it all with the help of variety of sensors, computer vision and machine learning and makes predictions. It can be used in both open fields as well as in green houses.

## **3. Popular Deep Learning Algorithm**

This section describes the popular neural network algorithms used for deep learning, such as Feed-Forward Network with Back Propagation, Convolutional Network, Recurrent Network and Generative Adversarial Networks, which when implemented in technology solutions of problems in agriculture are

producing better results in context of farming. Applications of these deep learning algorithms are widely apparent in the field of agriculture.

### Feed-forward neural network and backpropagation (BP)

In the field of Artificial Neural Networks Feed-Forward Back Propagation algorithm is a supervised learning way of multilayer networks. Back propagation approach works on the principle of modelling given function by adjusting internal weights of input signals by considering error to produce expected output signal [11]. Figure 3 depicts the working in pictorial form. Training of the system is done with the help of supervised learning method where the error between the system's output and predefined expected output is back propagated in the system to modify internal weights

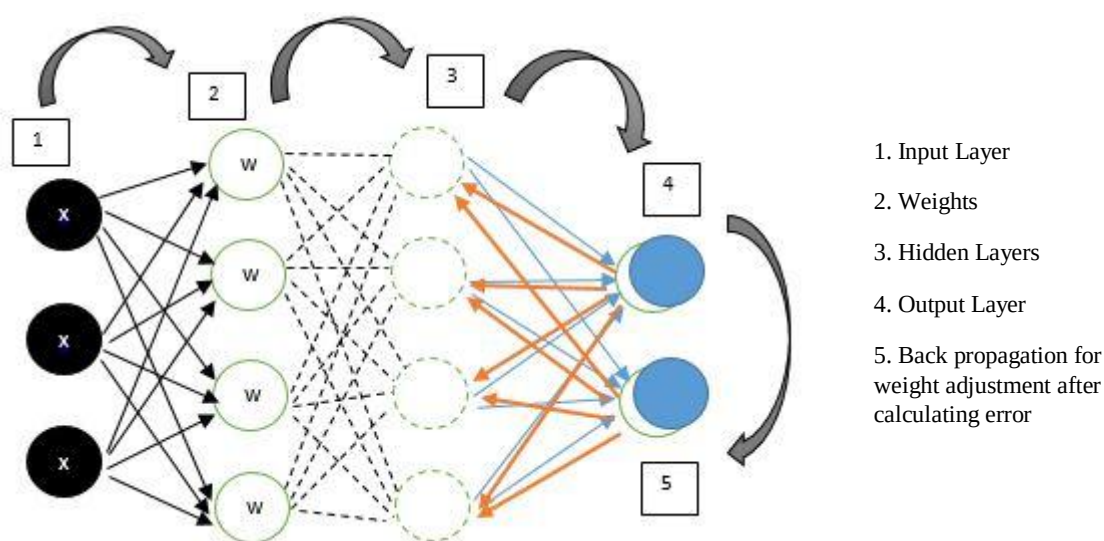


Figure 3: Simple Feed-Forward network with Back-propagation

### Convolutional neural networks (CNN/ConvNet)

Convolutional Neural Network, another deep learning algorithm, works on images as input. To these provided inputs, it gives learnable weights and biases to different identifiable objects in image. The basic architecture of CNN is inspired by the connectivity pattern of the Neurons in human

brain [12]. Receptive field is the restricted area of visual field where individual neuron give response to stimuli. The complete visual area is covered by collection of these fields overlap.

### **Recurrent neural networks (RNN)**

As name suggests in Recurrent neural networks output from last executed step is fed to current step [13]. In conventional neural networks all input and output are independent of one another. But many times it is required to remember the previous state. For example to predict the next word of the sentence, words written before are needed in order to give suggestions. This requirement of memory is fulfilled with the help of hidden layer in RNN. It is only this hidden layer used for remembering the state makes RNN different than other algorithms.

### **Generative adversarial networks (GAN)**

Under the category of unsupervised learning another powerful class of neural networks is Generative Adversarial Networks. It makes use of probabilistic models to generate data and thus is Generative. It is Adversarial as training is done under adversarial settings. And for training purpose it makes use of deep neural network algorithms [14]. GAN consists of generator and discriminator. Generator produces mock samples of image or audio data and aims to dodge discriminator. While discriminator is responsible for differentiating real and fake samples. Both, Discriminator and Generator are designed as neural networks and proceed in contest with each other during their training stage. The whole process is iterated numerous times and performance of discriminator and generator keeps on improving after each pass in loop.

## **4. Using Deep Learning in Smart farming**

Applications of Deep Learning has gained momentum in past few years and its applications are increasing day by day. Study of applications of DL

algorithm is becoming popular in recent works. Table 1 lists the application of deep learning algorithms in smart farming.

Table 1: List of applications of DL Algorithms in Agriculture

| Deep Learning Algorithm              | Applications                        | Examples                                                                                             |
|--------------------------------------|-------------------------------------|------------------------------------------------------------------------------------------------------|
| Back Propagation (BP)                | Pattern recognition, Classification | Leaf classification, Leaf disease detection, crop type classification etc.                           |
| Convolutional Neural Network (CNN)   | Image Processing                    | Plant disease detection, Fruit counting, yield prediction, weather forecasting etc.                  |
| Recurrent Neural Network (RNN)       | Time Series Analysis                | Phenotype identification, land cover classification, crop yield estimation, weather forecasting etc. |
| Generative Adversarial Network (GAN) | Image Generation                    | Recovery of lost features of images                                                                  |

### Applications of CNN in smart farming

CNN is most widely used in agricultural research and applications because of its strong capability of image processing.

Plant disease detection -Leaf image classification and pattern recognition are used in plant disease identification [15]. Berkley Vision and Learning Centre developed a deep learning framework to identify diseases in plants. The model was capable of identifying 13 categories of diseases in plants[16]. Similar kind of approaches have been used [17-21] to identify features of plants using image recognition. In all works CNN models have been used for image processing.

Fruit counting- Fruit counting is used in robotic harvesting and is most significant as far as yield prediction is concerned. Conventional methods of counting from mobile camera images or counting fruits manually is very

time consuming. A full convolution network has been proposed which uses blob detection method[21]

Weather Forecasting -Complete process of harvesting is dependent on weather conditions. For weather forecasting also CNN models are being used [22].

Yield prediction - Estimation of cost is significant for every stakeholder including farmers, consumers and government. Complete strategies for selling, purchasing and market are dependent on this. CNN models are used to predict crop yield in agriculture [23]. Use of CNN in yield prediction is not limited to crops only but can be applied on animals also to study their behaviors [24, 25].

### **RNN applications in smart agriculture**

Utility of Recurrent neural networks can be observed in time series data. It is currently being used in farming field for phenotype identification, land cover classification, leaf area index, crop yield estimation, soil moisture approximation, weather prediction and animal research. In addition, recurrent network models are applied to identify land cover classes but also to detect changes in land state [26].

Like convolution networks, recurrent networks are also used for estimation of yield. It makes use of time series data to reduce biasing [27]. Recurrent networks have also been applied in research on animals [28].

### **GAN applications in smart agriculture**

Not much literature is available depicting the application of GAN in smart farming. But GAN is very useful to solve the problem of feature loss due to poor samples. Mostly on compression features of an image are lost or become inaccurate and need of appropriate recovery is there. Ledig [29] demonstrated the use of GAN to resolve and regain the loss occurred because of poor sampling.

## **5. Frameworks/Libraries of Deep Learning training**

Deep Learning Frameworks consists of pre-defined and optimized components for designing deep learning models. These libraries and interface provide clear, easy, quick and concise way of defining models without getting onto details of underlying algorithms. Number of frameworks are available in market with their comparative analysis. Common deep learning frameworks are PyTorch on Python, Google's TensorFlow, Caffe, Keras, MATLAB, Amazon Machine Learning, Azure ML Studio and so on.

## **6. Discussion and Conclusion**

In currentwork, summary of applications of Deep Learning in agriculture, thus making it smart, has been presented. Brief review of concepts and techniques of DL applied in the field of yield prediction, fruit counting, crop disease detection, classification, weed detection, weather tracking and forecasting, animal welfare and behaviour classification is also given. Research with the applications of Deep Learning is growing with pace and the field is very diverse and vast. Work presented here has tried to bring out the usage of different DL algorithms in different areas and sub fields of agriculture. Finally it can be concluded that smart farming is more profitable, efficient and sustainable

## **References**

- [1] Burney J, Ramanathan V. Recent climate and air pollution impacts on Indian agriculture. Proceedings of the National Academy of Sciences of the United States of America. 2014;111(46):16319-16324.
- [2] D.N. Baker, J.R. Lambert, J.M. McKinion, —GOSSYM: A simulator of cotton crop growth and yield, II Technical bulletin, Agricultural Experiment Station, South Carolina, USA, 1983.
- [3] P. Martiniello, "Development of a database computer management system for retrieval on varietal field evaluation and plant breeding information in

agriculture," *Computers and electronics in agriculture*, vol. 2 no. 3, pp. 183-192, 1988

[4] K. W. Thorpe, R. L. Ridgway, R. E. Webb, "A computerized data management and decision support system for gypsy moth management in suburban parks," *Computers and electronics in agriculture*, vol. 6 no. 4, pp. 333-345, 1992

[5] Ramos, P.J.; Prieto, F.A.; Montoya, E.C.; Oliveros, C.E. Automatic fruit count on coffee branches using computer vision. *Comput. Electron. Agric.* 2017, 137, 9-22.

[6] J. M. McKinion, H. E. Lemmon. "Expert systems for agriculture," *Computers and Electronics in Agriculture*, vol. 1 no. 1, pp. 31-40, 1985.

[7] A G. Boulanger, —The expert system PLANT/CD: A case study in applying the general purpose inference system ADVISE to predicting black cutworm damage in corn, II Ph.D. Thesis, University of Illinois at Urbana-Champaign, 1983.

[8] J. Roach, R. Virkar, C. Drake, M. Weaver, "An expert system for helping apple growers," *Computers and electronics in agriculture*, vol. 2 no. 2, pp. 97-108, 1987.

[9] N. D. Stone, T. W. Toman, "A dynamically linked expert-database system for decision support in Texas cotton production," *Computers and electronics in agriculture*, vol. 4 no. 2, pp. 139-148, 1989.

[10] H. Lemmon, "Comax: an expert system for cotton crop management," *Computer Science in Economics and Management*, vol. 3 no. 2, pp. 177-185, 1990

[11] Goh A T C. "Back-propagation neural networks for modeling complex systems" . *Artificial Intelligence in Engineering*, 1995; 9(3): 143-151.

[12] Razavian A S, Azizpour H, Sullivan J, Carlsson S. "CNN features off-the-shelf: an astounding baseline for recognition" . *IEEE Conference on Computer Vision and Pattern Recognition Workshops (CVPRW)*, 2014

[13] LeCun Y, Bengio Y, Hinton G. "Deep learning. *Nature*" , 2015; 521(7553): 436

[14] Radford A, Metz L, Chintala S. "Unsupervised representation learning with deep convolutional generative adversarial networks" . *ICLR*, 2016

[15] Yalcin H, Razavi S. Plant classification using convolutional neural networks. *Fifth International Conference on Agro-Geoinformatics (Agro-Geoinformatics)*, IEEE, 2016.

- [16] Sladojevic S, Arsenovic M, Anderla A, Culibrk D, Stefanovic D. Deepneural networks based recognition of plant diseases by leaf imageclassification. Computational Intelligence and Neuroscience, 2016;Article ID 3289801, 11p.
- [17] Tang J L, Wang D, Zhang Z G, He L J, Xin J, Xu Y. Weed identificationbased on K-means feature learning combined with convolutional neuralnetwork. Computers and Electronics in Agriculture, 2017; 135: 63–70.
- [18] Srbinovska M, Gavrovski C, Dimcev V, Krkoleva A, Borozan V.Environmental parameters monitoring in precision agriculture usingwireless sensor networks, Journal of Cleaner Production, 2015; 88:297–307.
- [19] Ge Z Y, McCool C, Sanderson C, Corke P. Content specific featurelearning for fine-grained plant classification. CLEF (Working Notes), 2015.
- [20] Yalcin H. Plant phenology recognition using deep learning: 6<sup>th</sup>International Conference on Deep-Pheno. Agro-Geoinformatics, IEEE, 2017.
- [21] Chen S W, Shivakumar S S, Dcunha S, Das J, Okon E, Qu C, et al.Counting apples and oranges with deep learning: A data-driven approach.IEEE Robotics and Automation Letters, 2017; 2(2): 781–788.
- [21] I. Kavdir, and Daniel E. Guyer, "Apple grading using fuzzy logic," Turkish Journal of Agriculture and Forestry, vol. 27 no.6, pp. 375–382, 2004.
- [22] Salman A G, Kanigoro B, Heryadi Y. Weather forecasting using deep learning techniques. Advanced International Conference on Computer Science and Information Systems (ICACSIS), IEEE, 2015.
- [23] You J X, Li X C, Low M, Lobell D, Ermon S. Deep Gaussian processfor crop yield prediction based on remote sensing data. Proceedings ofthe Thirty-First AAAI Conference on Artificial Intelligence (AAAI-17), pp.4559–4665.
- [24] Kasfi K T, Hellicar A, Rahman A. Convolutional neural network fortime series cattle behaviour classification. Proceedings of the Workshopon Time Series Analytics and Applications. ACM, 2016.
- [25] Rahman A, Smith D, Hills J, Bishop-Hurley G, Henry D, Rawnsley R. Acomparison of autoencoder and statistical features for cattle behaviourclassification. In IEEE World Congress on Computational Intelligence(IEEE WCCI), 2016; pp.1–7
- [26] Lyu H, Lu H, Mou L. Learning a transferable change rule from arecurrent neural network for land cover change detection. RemoteSensing, 2016; 8(6): 506.

- [27] Minh D H T, Ienco D, Gaetano R, Lalande N, Ndikumana E. Deeprecurrent neural networks for winter vegetation quality mapping via multitemporal SAR Sentinel-1. *IEEE Geoscience & Remote Sensing Letters*, 2017; 99: 1-5.
- [28] Palangpour P, Venayagamoorthy G K, Duffy K. Recurrent neural network based predictions of elephant migration in a South African game reserve. *International Joint Conference on Neural Networks*, 2006: pp. 4084-4088.
- [29] Ledig C, Theis L, Huszar F, Caballero J, Cunningham A, Acosta A, et al. Photo-realistic single image super-resolution using a generative adversarial network. *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, Honolulu, Hawaii, USA, 2017; pp. 105-114