DEEP LEARNING IN AGRICULTURE

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CERTIFICATE

This is to certify that the Seminar entitled “DEEP LEARNING IN AGRICULTURE” submitted by AARYAN GUPTA (17BCE001), towards the partial fulfillment of the requirements for the degree of Bachelor of Technology inComputer Engineering of Nirma Universityis the record of work carried out by him under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination.

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ABSTRACT

This report focuses on the modernization of agricultural sectors with the implementation of deep learning. Agriculture is majorly dependant on a wide variety of variables and factors which cannot be predicted easily. The problems which arise due to these are not at all unprecedented but are faced by everyone involved in this sector. The report also encompasses some research papers from various fields in agriculture where the experiments conducted with upto 99% accuracy have shown that deep learning can play a crucial role in agriculture. A brand new sector known as precision agriculture has also been discussed which proposes endless future prospects which can make every agriculture activity predictable and efficient.

CONTENTS

1 INTRODUCTION

1.1 General

Deep learning is the most recent astounding development in technological field which has boosted the science of Artificial Intelligence by great margins. It comes with the prospect to improve every sector of the globe, making lives of people better simultaneously. Deep learning comes with the promise to initiate automation in every machine, even the learning process itself. Hence, it provides immense applications in every field.

1.2 Scope of Study

The study covers the prospects and applications of deep learning in various fields of agricultural sector. Following the introduction to deep learning and discussion of various factors which make the need of deep learning in agriculture imminent, we discuss the areas where deep learning has already left its marks. Thereafter, some research papers revolving around different aspects have been summarized.

2 LITERATURE SURVEY

2.1 General

The literature in this report mainly covers research papers which explain the implementation and prospects of deep learning in the agricultural sector. Some papers focused on deep learning algorithms helping in identification of diseases and species. One paper challenges the safety standards of current uses and another incorporates a wholly different field with deep learning and agriculture.

3 DEEP LEARNING

3.1 Definition

Deep learning is an advanced and a more specified sector of machine learning, or in broader terms, of artificial intelligence. It is a method to train a system to work like a human brain by developing artificial neural networks which mirror the functioning of the human brain, but of course, at a very high rate and precision. In very simple words, deep learning is a process which takes input a large amount of data and produces a prediction as the output, and simultaneously, keeps learning from the data.

3.2 Differentiating with Machine Learning

First of all, it’s important to know, on a basic notation, how deep learning differs from machine learning. Or how is deep learning better than machine learning, and what makes it a buzzword in this scientific world.

i. Deep learning can process unstructured and unlabeled data whereas machine learning cannot.
ii. Feature extraction has to be done manually in ML while DL deals with it automatically.
iii. Machine learning needs lesser data input and lesser time to get ‘trained’ as compared to deep learning.
iv. Deep learning, of course, is faster in testing.
v. More accurate, flexible and real-time results can be generated through deep learning algorithms as compared to the machine learning.

3.3 Working

Deep learning works on a sequence of layers and nodes. Data is passed from one layer to the next whilst getting processed further at each layer. These layers are structured as neural networks, which can be considered as a mathematical model of neuron to neuron information transfer in the human brain. The layers classify the data and converge it to produce the final output.

For example, 100000 dog images of different breeds are given as an input to identify a particular dog breed. Through image processing and other deep learning algorithms, the number of images at each layer in the neural network will keep getting reduced and hence at the final layer, the output will predict the breed of the given dog.

If we proceed to take the mathematical approach for deep learning, it largely revolves around linear and logistic regression and gradient descent. Regression is based on statistical data where the task is to generate a linear type of relationship between the variables and elements in a way which results in the least error. Linear regression is used for the study of data while logistic regression helps to determine which data is relatively true or false for a prediction. Other mathematical models used are activation function, weights, bias, errors, forward and back propagation, etc. When all these combine, they give rise to the neural network and thus a smart and efficient training.

3.4 Applications

From writing your forthcoming conversations to driving a car automatically, from playing your favourite music according to your mood to identifying your friends in a picture, deep learning can have infinite applications and perform scientifically magical tasks. It finds applications in fields like –

i. Healthcare
ii. Image processing
iii. Climatic predictions
iv. Translation of languages
v. Automatic text generation
vi. Smart systems
vii. Agriculture, etc.

Deep learning has not been lagging behind in making the primitive practices of sectors like agriculture much more advanced and predictable. It just does not appear in the news much because of the new tech-savvy audience. Hence, we will focus on this majorly hidden and less explored application of DL in agriculture, and explore how farther it could envision and revolutionize the agricultural sector.

4 NEED OF DEEP LEARNING IN AGRICULTURE

4.1 Macroscopic factors

The term agriculture has always been associated with primal and rudimentary practices. Even with enormous amount of technology amassed in today’s agriculture, the social perspective for agriculture remains as those basic methods of sowing, irrigation and harvesting crops, with generally simple machines and hand tools and henceforth, that “hard-working” and “drained” farmer selling his yield to the consumer market.

Ironically, the media and people are always seen grumbling around for the shortages of agricultural production, despite the fact that in a huge country like India, with annual population growth rate of 1.1%, the agriculture sector satisfactorily reaches production growth rate of 2.1%, which is almost twice as much.

Although, apart from these “social” issues, there are a lot of threats to the agricultural sector in the form of sustainability, quality and security because of factors such as deteriorating ecosystems and constantly differing climate. The ‘natural’ agriculture system works on a lot of variables and unpredictable factors. For example, the farmer cannot be aware of the amount of rain in the season, or if we talk on a smaller scale, he cannot know when cattle might enter his farm and ruin some of the production!

Hence, looking at the bigger picture, factors like productivity, food security, optimal demand-supply balance, environmental impact and sustainability are some agricultural challenges, may it be global or local. Surveys that have been conducted, explicitly mention an average drop of 30-50% in the quality of food in recent years. Since the population is ever increasing and the agricultural production too, but maintaining the availability of quality and nutritional food is a task which people struggle to accomplish.

4.2 Microscopic Factors

Apart from all these macroscopic highlights, some microscopic factors must be discussed too. Nowadays, organic farming is minimal and the use of various fertilisers and pesticides is widely accepted. May it be the seller or the farmer; they all know which pesticide works on which plants and what damage or improvement it offers. But this has resulted in a drastic depreciation of the quality of production. So, just imagine a scenario, where people can know the exact effects of these ‘medicines’ on a microscopic level and the revolution it might lead to in these agricultural sectors as well as scientific research. How even the slightest morphological change occurs in a vein of a leaf, the organic and inorganic interactions and most importantly, how it can all be converted into a pattern and hence a computer algorithm; now that sounds advanced!

5 DEEP LEARNING APPLICATIONS IN AGRICULTURE

5.1 Yield Prediction

Deep learning had been used for pre-mapping or estimation of yield in some crops and results were quite accurate and even provided details about which part of the crop was harvestable and which was not, or which was of low non-consumable quality.

For example, Coffee crop was monitored with DL and it provided accurate results regarding the branching, ripening and harvesting of the coffee beans.

5.2 Disease and Weed Growth Detection

Deep Learning algorithms have also proved very effective in analysing and detecting diseases and growth of weeds in the crops by processing changes in seed, leaf and root patterns of the crop and soil change patterns. Hence, it lets the farmer know when and where to put which pesticide. And the ultimate bonus of the technology is that it also helps in keeping a check on the environmental deterioration due to these pesticides and hence maintaining the efficient use of them.

For example, Wheat was kept under observation using ANN/XY-Fusion algorithms and changes in the leaves and seeds where recorded and thereafter, the results generated had approximately 98% accuracy, which is not possible by traditional means.

5.3 Quality Prediction

Quality, being the most important factor in agriculture, has also been consistently checked by the DL algorithms and even the slightest change patterns recorded, have helped to determine the impact of various environmental and human-ridden factors on the quality of the crop. This has thus helped to generate predictability in earlier unpredictable scenarios helped to distinguish between the quality and non-quality production.

For example, SVM models were used for quality check of Korla fragrant pears and the models had to categorize the pears on the basis of their quality. The result was an astonishing approximately 95% accurate.

5.4 Species Recognition

Every crop promotes the growth of weeds in large quantities. Also, there is never a 'pure' type of crop, i.e., all the seeds of exactly the same species in almost not possible. Hence, a lot of Deep Learning models have proved useful in recognition and differentiation in species of crops as well as weeds and thus generate a more pure crop and deploy pesticides more efficiently, respectively.

For example, in a legume plantation, CNN algorithms helped in determining the percentage of Soyabean, red beans and white beans with accuracy of upto 98% without taking any extra time. On the other hand, it would have taken days to do this task manually and used a lot of labour.

5.5 Livestock Management

Since livestock production and agriculture go hand-in-hand, various CNN and SVM models have contributed in optimizing the economic efficiency of the production system. They have also been used to identify diseases in the animals by analyzing the generated products and monitoring the behavioral changes. Apart from this, these behavioral patterns have also made the actions of various animals predictable that could harm the crops.

5.6 Soil Management

Nutrients and moisture levels of the soil must be pre-determined for more efficient production. There a lot of complex traditional ways available to test the soil suitability but the introduction of Deep Learning networks in soil management have resulted in better, cheaper and more accurate prediction and identification of soil properties.
For example, 140 soil samples were collected from an arable field in Premslin, Germany and conditions such as drying, temperature, pressure, and moisture of the soil were accurately measured upto 94% using KNN, ANN and SVM models.

5.7 Water Management

Evapotranspiration estimation helps to determine how much water is needed by the crops and when. Thus, since deep learning can provide this estimation accurately, it has led to a new generation of smarter irrigation systems which helps to stop any wastage of water and make irrigation more efficient and environment-friendly.

For example, Evapotranspiration and daily dew point temperature were checked for an arid region in India using ELM model which recorded changes in humidity, temperature, radiation, wind speed etc. and thus helped in forecasting more accurate environmental humidity conditions which in turn, helped in developing a better irrigation system.

6 Research Papers Study

6.1 Deep Learning for Plant Identification Using Vein Morphological Patterns

This research paper focuses on identifying a plant species on the basis of its leaf vein patterns by using deep CNN model. Three species of soybean are taken as test subjects and it has been shown that increasing the depth of the model improves the accuracy too.

Introducing to deep learning and how it can change agricultural sector, the paper proceeds to state that CNN model is used for image processing. The aim is to develop automatic plant identification as it is a laborious work if done manually amongst huge catalogs. The vein patterns of leaf are similar to fingerprints in humans; hence they are taken as the decisive component in plant identification.

Following stages of images were defined –

- Vein segmentation
- Central patch extraction
- Vein measures
- Classification

Figure 6.1.1 and 6.1.2 below are the schematic diagrams depicting what parts of the vein patterns were extracted and how the whole neural network was structured and various numbers of stages in each of its layer.

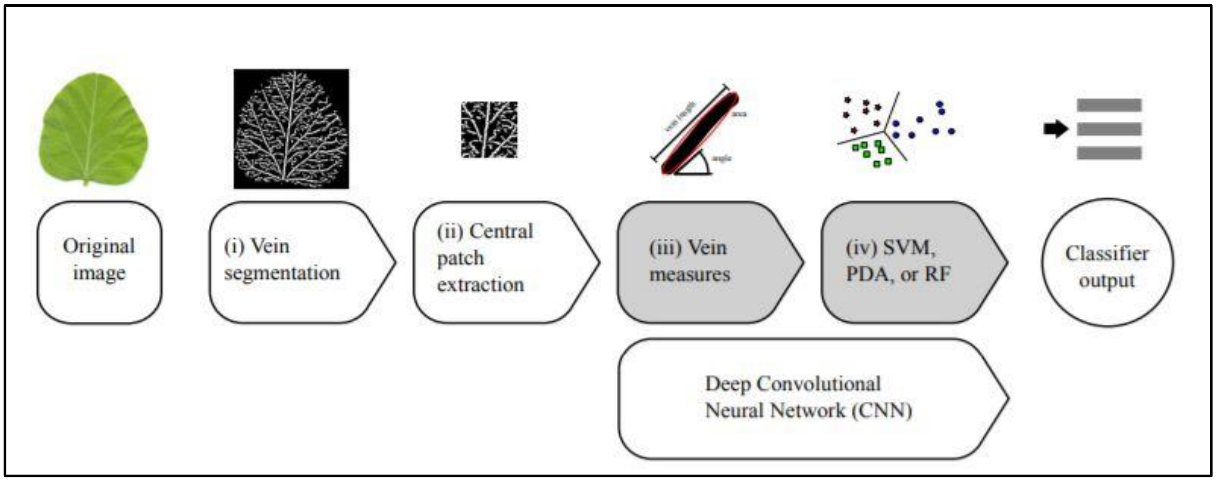

Figure 6.1.1

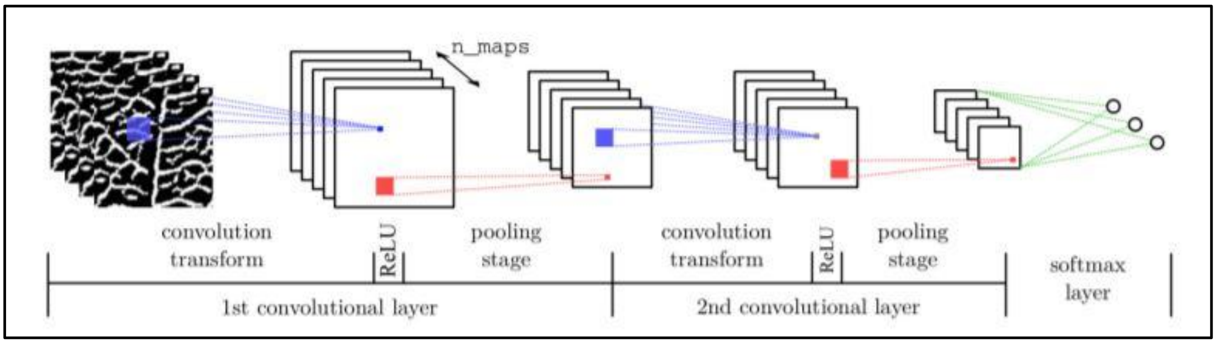

Figure 6.2.2

The results constituted of various observations.

- Final accuracy keeps on increasing with increase in depth of the model.
- Approximately 97% accuracy was achieved with just 5 layer model.
- The model can be extended to identify diseases at particular locations in the same species.
- Some varieties are harder to identify compared to others and more complex models are needed for them.
- Heat maps helped determine which parts of the leaf were more important for plant identification and which were not.

Overall efficiency was quite good because it used the standard models of deep learning. Only time needed in the beginning is the specification of feature extraction. Hence conclusively, it was a successful example of use of Deep Learning in agriculture.

6.2 Deep Learning Ontology: Dimensions in the Field of Agriculture, a Survey

This research paper brings up the topic of how agriculture can be revolutionized by adopting current trends of web ontology and deep learning. Analysing tons of data and then making decisions would definitely prove beneficial for the farmers. Currently there are three types of data-intensive technologies accessible –

- Farm Management Information System (FMIS), which is used to collect, store, process and broadcast data.
- A scientific domain to improve the returns and profits and also create lesser negative environmental externalities.
- Automation in agriculture.

Combined with Deep Learning and Big Data, success has been constantly achieved in terms of soil nutrition management, crop detection, disease protection etc.

Focusing further on the definition of ontology, the paper proceeds with various perceptions of the word. The author finally settles with defining ontology as a representation of heterogeneous data into a single collective space such that it provides integrated knowledge of the subject and easier analysis. Ontology follows some iterative steps –

1) Design
2) Develop
3) Integrate
4) Validate and feedback
5) Repeat

In agriculture, various aspects such as weather conditions, soil characteristics, inventory, hazards etc. have to be integrated to develop a functional system. All these data have enormous distinguished sources and hence would create a gargantuan database, which is almost impossible to do. Apart from this, the language is also a varying factor for farmers of different regions. To sort this out, deep learning with ontology can be the best practice.

The paper proceeds with a literature survey based on AGROVAC, which is a global standard agricultural vocabulary. A subset of it is Agricultural Activity Ontology (AAO), which follows a top-down approach and hence can be divulged into deep learning easily, starting from the top and going into depth at each step.

The Agri Nepal Data Project is a successful example of adoption of deep learning and ontology. Tamil Nadu regions also adopted a wireless sensor network, which worked on deep learning, and the ontological results guided farmers for better productivity. A separate ontological model known as OntoAgroHidro has been developed for agricultural impacts on water resources. All this has even given rise to an exclusively new sector of agriculture known as Precision farming.

6.3 Applying Deep Learning to Extract New Knowledge in Precision Agriculture Applications

This research paper focuses on the impact and accuracy driven sector of agriculture, known as precision agriculture, and how Deep Learning techniques can effectively be used to construct an automated decision support system by extracting knowledge automatically from various new and existing patterns. The major target of this research was to develop such system to determine the plant's conditions and the impact or stress of water on the plant.

Beginning with the introduction of Precision Agriculture (PA), the paper mentions about how it is a management system of variability in agriculture and how it can make agriculture more efficient and less degrading to environment. Emergence of wireless sensor networks has played a vital role in emergence of PA, allowing a finer and in-depth analysis by algorithms. Also, Data Mining helps to create a framework of unknown and potentially useful information, which provides a platform to identify patterns among huge data and apply the DL algorithms for the learning process of the system.

Proceeding with related works in PA, following systems have been corroborated in the paper –

- A computing model designed by looping sensor data with the help of actuators, which monitored even subtle signals in the plant or surroundings and helped in precise optimisation of the plant growth.
- Neural networks for smart irrigation systems.
- Applications of DL in farming activities in New Zealand, such as culling decisions in dairy herds, apple bruising determination, cows' behaviours during milking, etc.
- A quick and flexible control system using fuzzy controllers based on a lot of variable factors such as climate, pests etc.

Comparing with the above mentioned systems, the study in this paper is complementary to plant monitoring systems and an extension to the approach on current optimisation techniques.

Gaining insights from the genetic algorithms and neural networks, the paper establishes that they lack in modelling the knowledge in a comprehensible manner. Hence, standard rule learning algorithms have been implemented in this study instead. Deep learning is an essential part of the system because it integrates expert knowledge with rule sets, incorporates new knowledge, thus classifying and extracting more precise knowledge. A process model created by WEKA group in University of

Waikato, New Zealand has been used in this study. The derived rules were evaluated and cross-validated.

Satisfactory results were achieved and a comprehensible methodology for extraction of new knowledge was developed which can be used to make control system more precise. The system could also sort out the data sets with less informational value. It also provides an alternative to tackle dependency on sensors by defining other parameters to execute rules in case of damage to sensors. Overall, this study suggests that deep learning usage in PA applications can potentially deploy more effective and reliable control mechanisms.

6.4 Using Deep Learning to Challenge Safety Standard for Highly Autonomous Machines in Agriculture

This research paper goes through a CNN based deep learning algorithm, which detects a specific obstacle with an accuracy of 99.9%. Meanwhile, the authors argue over the fact that this particular algorithm does not detect the people around the obstacle at all, and hence when this algorithm is integrated in high-end autonomous machines, it poses a great threat to the safety standards. On a wider scale, the main focus here is to disregard the imaging sensors when it comes to ensuring safe operation.

The ISO/DIS standard is a set protocol for safety and operation of autonomous machinery if it has to be operated unsupervised. Further introducing the robust deep learning algorithm, the paper sets up the definition of the standardized obstacle for the machine to learn which can be seen below.

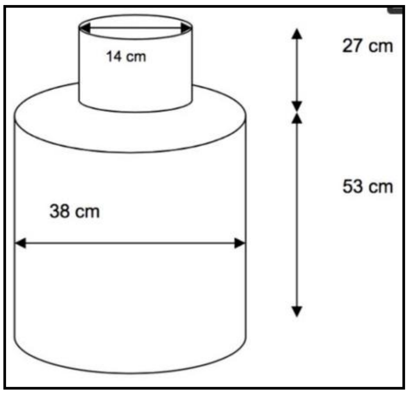

Figure 6.4.1

The data was collected from various sources which included images and recordings of a lot of obstacles including the standard one as in the figure 6.4.1, which acted as training data for the sensor kit. AlexNet model was then used to design the whole convolutional neural network and fine-tune each layer of the deep algorithm with respect to shape, colour, texture and other dimensions. It would also be taught to reject any other obstacles, ensuring foolproof performance. The whole algorithm worked on developing heatmaps of the images to detect the standardized obstacle, may it be of any size.

The results were obviously as precise upto 99.9% in detecting the obstacle from various distances and under varied light conditions. The precision did drop a bit in grassy areas though. But the main highlight is that the algorithm is unable to detect any humans in the image frame. Even with inputting images of life-like objects such as mannequins, the people could not be detected due to different heat signatures. Moreover, there could also be animals present in the fields. So, by far, such algorithm following automated machines will definitely comply with the ISO standards but they would just be one mistake away from causing incidents which would raise questions of the actual safety standards which should be followed. Such better standards have already been implemented in fields of automobiles etc. and same should be followed in agriculture too.

6.5 Deep Learning Models for Plant Disease Detection and Diagnosis

This research paper focuses on developing a deep convolutional neural network detection and diagnosis of diseases in plants. Only visual observations aren't enough for diagnosis of diseases as there are a lot of underlying factors too, which can be of even microscopic level. Often, this leads wrong conclusions and treatments. Having an automated and precise system for the complex diagnosis of diseases in plants would prove to be handy tool for the farmers. This system could also be incorporated into real-time high-end machinery being used nowadays.

After giving some basic information about Deep Learning and Convolutional Neural Networks, the paper lists down the data set of 87848 images featuring some common diseases in some common plants in both laboratory and field conditions. Following 5 CNN architectures were tested for the study using Torch7 machine learning computational framework –

- AlexNet
- AlexNetOWTBn
- GoogLeNet
- Overfeat
- VGG

The data set was split into 80/20 ratio for training and testing respectively. Various alterations were done on both the data sets like cropping; gray scaling etc. and they were implemented in various combinations.

Observations were made on the following points –

- Percentage of successfully classifying plant and its respective disease.
- Corresponding average error.
- Time at which best performances were achieved.
- Average time to train each model.

Fig. 1. Samples of images in laboratory conditions (up) and in field conditions (down) [From class c_49 – Tomato with Early blight]

Figure 6.5.1

VGG and AlexNetOWTBn provided the highest success rates, and on further testing and trainings, the VGG model was finalized with a precision of 99.53%. The training took 5.5 days time whilst classification of an image took just 2 ms, with certainty upto 100%. The observations do vary if training is done only with laboratory images and tested with field images and vice versa. Hence both types of images are crucial to be fed to this model.

This paper successfully concludes that CNN based deep learning algorithms are quite useful when it comes to automated detection and diagnosis of diseases in plants. Usage of field images successfully proves that this can be converted into a real-time model. Also the model is quite feasible in terms of GPU usage and cost and can be controlled via a small smart phone application too, resulting in an overall integrated disease identification system in plants in real agricultural scenarios.

7 SUMMARY AND CONCLUSION

7.1 Summary

In this report, we started the discussion with diving into the field of deep learning and how it actually works. Then moving on to its implementation in agriculture, the factors which caused its emergence and what all revolutions and benefits in various sectors they brought were discussed. We came along with the new sector of Precision Agriculture. The claims were validated by reviewing some research papers in the related field which provided an excellent insight on the topic from different perspectives.

7.2 Conclusion

Deep learning is the brand new state-of-the-art technology which has granted limitless boundaries to Artificial Intelligence. All activities in the world can be made simpler and automated by incorporating it with Deep Learning. Even the primitive sectors like agriculture have not been left untouched by Deep Learning. With more awareness and implementation, there is a promise of infinite positive future prospects and the agricultural sector would bloom like never before.

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Appendix – A List of Useful Websites

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