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Review Article

ARTIFICIAL NEURAL NETWORKS IN FARM MACHINERY

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Abstract: Artificial Neural Network (ANN) is becoming popular because it enables human capabilities-understanding, monitoring, reasoning, planning, communication and perception which has to be handled by software effectively, efficiently and at low cost. ANN plays a major role in the agricultural field especially in farm mechanization. The purpose of this review paper is about presenting different types of ANN, its application in mechanization and allied activities in agriculture.

Keywords: *Artificial Neural Networks, Farm mechanization*

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Introduction

An Artificial Neural Network (ANN) "is the piece of a computing system designed to simulate the way the human brain analyzes and processes information" [1]. A biological neuron consists of three main parts: dendrites- which receive information, soma- a cell body responsible for processing information received from dendrites and axon- a cable through which neurons send the information. An ANN consists of interconnected nodes similar to a network of neurons in the brain which helps in classification, prediction, decision-making, visualization, and others just by considering examples [2]. Unlike ordinary computers which work based on algorithmic techniques that contain some set of instructions, ANN works by its own logic which is unpredictable. It knows how to do tasks based on the data given for training or initial experience which is known as adaptive learning capability. Hence the method of problem solving is uncertain and they cannot be arranged to perform a specific task since all the interconnected nodes work simultaneously to resolve the problem [3]. In a commonly used ANN architecture, the neurons are organised in layers [4] which include: a) An input layer where the data is fed into the system, b) One or more hidden layers where the learning takes place, and c) An output layer where the decision/prediction is given [5]. An ordered set of predictor variables is fed into the input layer. Each input layer neuron distributes its value to all of the middle layer neurons. There is a connection weight along each link between input and middle neurons. Thus, the middle neuron receives the product of the value from the input neuron and the connection weight. Each middle-layer neuron adds up all of its weighted inputs and then applies a non-linear (logistic) function to it. The output from that particular middle neuron is then the result of the function. The output neuron is coupled to each middle neuron. There is a connection weight along each link between a middle neuron and the output neuron. As the final step, the output neuron takes the weighted sum of its inputs and applies the non-linear function to the weighted sum. The result of this function becomes the output for the entire ANN [4]. When an element fails, it can continue without any problem by their parallel nature. A neural network's basic rule is to learn that does not cause a problem of reprogramming.

ANNs are capable of learning and they need to be trained. There are several learning strategies such as supervised learning such as pattern recognition which involves a scholar who already knows the answers and feeds data to the ANN and it compares its guess with the scholar's correct answers and makes adjustments according to errors. Unsupervised Learning is used for hidden patterns. There is no pre-set example data with known answers. In this method based on some existing data set the elements are grouped to some unknown pattern. Reinforcement Learning is another method in which strategies are created based on observation. The ANN makes a decision by observing its environment and adjusts its weight accordingly.

The main advantages of artificial neural networks are it can do more than one job at a time known as Parallel processing abilities. In this Information is not stored in a database, instead stored on an entire network. It has the capability to learn and model complex relationships, which in turn helps in real life relations between input and output. Mistakes of one or more cells of ANN will not terminate the output formation- fault tolerance. The input variables can be placed without any restrictions [6], [7]. It has also got some disadvantages like its hardware dependency, shortage of rules for establishing appropriate network structure, need for numerical transformation since the system works based on the numerical information, and the lack of explanation on "why and how" of the solution may create less trust in the network [6], [7] . Hence ANNs have self-learning capabilities that enable them to produce better results as more data becomes available. ANN can be used for pattern recognition, fraud-detection, medical diagnosis, and data classification through the concept of learning process [2]. It has wide application in the agricultural field especially in farm mechanization. Mechanisation has been widely accepted in India as one of the prominent components of modernisation of agriculture [8]. One of the highly competitive and demanding markets is the agricultural machinery market, which provides innovative ideas in the agricultural sector. The manufacturers in this field need to supply quality and reliable products according to the necessity and demand of the farmers [9]. Modelling has been considered as an important tool [10] in this field. This review paper discusses the need of ANN in Farm mechanization, types of ANN, its current practices in the agricultural field and future scope.

Artificial Neural Network (ANN)

Types of ANN

There are different types of neural networks that are now available or are under development. They can be categorized based on their structure, data flow, neuron density, number of layers used and depth activation filters, *etc.*

ANN are executed based on the mathematical operations and a set of parameters needed to decide the output. Following are the types of neural networks widely used:

The Minsky-Papert perceptron model performs certain calculations in order to discover features or business intelligence in input data. It takes weighted inputs and uses the activation function to get the final result. Threshold Logic Unit (TLU) is another name for a perceptron. The main advantage is that Logic Gates such as AND, OR, and NAND can be implemented with perceptron. The disadvantages are that only linearly separable tasks, such as the boolean AND problem, may be learned using perceptrons. It does not work for non-linear problems like the boolean XOR problem [11].

Feed forward / Back propagation Neural Network – Artificial Neuron is the most basic and straightforward type of artificial neural network. The "feed forward" describes how this neural network processes and recalls Patterns and "back propagation" describes how this type of neural network is trained. Back propagation is a form of supervised training [12]. This ANN method is used for prediction of fertilizer required for the crop by analysing various parameters such as pH, nitrogen, phosphate, potassium, depth, temperature, rainfall. The Radial basis function Neural uses radial basis functions as activation functions. It can be used to approximate functions, predict time series, classify data, and control systems. Kohonen Self Organizing Neural Network is also known as Self-Organizing Feature Maps or Kohonen Maps and is an unsupervised learning model in Artificial Neural Networks. During model training, these feature maps are the generated two-dimensional discretized form of an input space (based on competitive learning). Recurrent Neural Network (RNN) – Long Short Term Memory is a deep learning architecture that uses an artificial recurrent neural network (RNN). It has feedback connections. The structured arrays of data such as images are processed using Convolutional Neural Network[13]. In the Modular Neural Network the various neural networks act as modules. The output is the summation of responses from the modules and it is done by an integrator [14].

ANN in Farm machinery

Farm mechanisation plays a vital role in expanding agricultural productivity. Agricultural mechanisation is a broad area which includes production, distribution, processing, storing and also utilization of many tools and equipment [15].

One of the main challenging features that can be related in agricultural mechanisation is the range of operations and conditions of the machines to perform in the field. There is always a problem of improper matching of the tractor and the implement used. This results in under loading of the tractor which causes reduced efficiency [16].

Also, the majority of the heavy implements like tractors, combine harvesters are all designed with a working range of bulk materials like crops, seeds and soils. Depending upon season and location, these materials may vary their properties. And these changes may affect the performance of the machine. The cohesive nature of the fibres could lead to blockage within the harvesting equipment and non-optimized cutting could result in poor quality crops and final product.

The draft of tillage implements plays a crucial role in designing more efficient tillage tools by choosing appropriate combinations of tractor and implement. Draft prediction models are required to predict the draft of tillage implements in different soil and operating conditions [16].

Another major problem with tillage equipment is that the blades are in frequent contact with soils. The conditions of soil may vary with different levels of compressibility and stickiness, even there is a chance of presence of harder materials like stones and rocks. All of these will create an impact on the blades and machines. Using ANN in this aspect for predicting how the equipment will be affected and perform under specific material may help to increase the performance of the machine. Even this will help to identify the possibility of wear on the tool and this will help the machine to perform as expected.

Grain augers that can be seen in combines and other agriculture areas which are generally used to transport grain is another example which highlights material handling can cause a challenge. It is important not to leave any material in the auger while transporting the seeds which may cause contamination of the product. Some wear occurring to the equipment may be due to the presence of certain type of grains or mixes which are abrasive in nature. This happens especially in continuous processes of transportation of materials. Optimizing the unloading of the auger is therefore crucia.

In all these examples, predicting the behaviour of materials and their impact on the machine is critical to achieve efficiency and performance; however, it is challenging due to the complexity and variability of the materials. Also testing using prototypes and other physical methods are expensive and limiting mainly in the field. In such a case, modelling has been considered as an important tool.

Taghavifar and Mardani (2014) [17] conducted a study to predict tire contact area and rolling resistance using artificial neural networks (ANN) modelling. It was considered that conventional models fail to investigate multivariate input and output relationships due to the complex and nonlinear interactions between soil and wheel. Experiments were carried out in a soil bin facility using a single wheel tester. Due to fast, precise and reliable computation, ANNs were found to be appropriate for soil-wheel interaction modelling.

Since agricultural systems and technologies are quite complex and uncertain, several researchers have focused on neural network methods for modelling different components of agricultural systems. This method was applied to predict noise level in tractor [18], performance of combine harvester [19], modelling of fuel consumption in wheat production using ANN [20] prediction of tractor fuel consumption [21] and predicting tire tractive performance [22].

Modern agriculture aims to have high production along with high product quality. This is mainly needed in crop production and livestock production. To achieve these requirements, advanced modes of data analysis are frequently used, which are deduced from artificial intelligence methods-one among them is Artificial Neural Networks [23]. They are widely used as a solution to many problems like classification, prediction tasks and now in agriculture too. They have become an essential part in the modern agriculture, mainly in precision farming.

Another important aspect is that Artificial Neural Networks can undoubtedly replace the classical method of modelling. It is considered as an alternative to traditional mathematical models. The range of applications of Artificial Neural Networks is very wide. Research is being carried out all over the world to use these tools in the agricultural field so that an increase in efficiency and high quality products can be obtained.

Zangeneh and Akram (2010) [24] used single hidden layer ANN for predicting the machinery energy ratio in potato production by analysing the energy input-output flow and consumption of power for various farming operations. The main hypothesis of the research is to be feasible to train an ANN model to establish a non-explicit function, which corresponds to the ANN network itself based on selected input parameters such as farm size and number of tractors owned, and the mechanization indicator as the outputs.

Using a regression method (Forward method) different ninety-four input items were selected for MER. The data were normalized using natural logarithm. Based on the response of ANN, 13 input parameters produced output. Different statistical measures such as coefficient of determination (R2), mean absolute percentage error (MAPE), mean squared error (MSE) and mean absolute error (MAE) were used to validate the performance of the developed ANN model with calculated value. The correlation of outputs between ANN and calculated value has a R2 value of 0.98 and MAPE sensitivity of 0.0001which indicates the accuracy of the developed ANN model. Sensitivity assessments were also conducted to determine the impact of each input item on the output value.

Chandel, *et al.,* (2019) [25] made an attempt to develop reverse feed ANN and statistical Multiple Linear Regression (MLR) models for estimating operating parameters of fluted roller metering devices. The fluted roller exposed length for urea, SSP and MOP fertilizers were satisfactorily simulated using MLR models during testing. MLR was inefficient at simulating flute diameter, bottom plate opening and speed of fluted roller. The respective maximum R2 values for urea, SSP and MOP fertilizer were 0.91, 0.85, and 0.85 during training and 0.91, 0.82 and 0.87 during testing for fluted roller exposed length. The performance prediction with ANN model for complete data validation of urea fertilizer was quite fine with a low RMSE value of 3.518 mm, compared to MLR for fluted roller exposed length (8.19 mm). The Nash–Sutcliffe coefficient (E) of tested fertilizer (urea, SSP and MOP) according to ANN model was close to 1 indicating high level of accuracy for all operating parameters except speed of fluted roller. The variation of exposed length was found most appropriate among all fluted roller parameters for variable rate application. The optimum flute diameter of 12mm and bottom plate opening of 10mm is recommended to be best for all types of fertilizer applications. However, lower rotational speeds resulted in higher pulsation amounting to irregular fertilizer metering. The reverse mapping using ANN models was quick enough due to significant reduction in adjustable variables to allow generation of numerous solutions from different initial conditions for the similar design objective.

The influence of peripheral speed and flute diameter on urea fertiliser application rate, particle damage, and particle per unit area. It shows that as the peripheral speed of the fluted roller increases, the application rate is reduced, while the amount of material discharge increases with the increase in flute diameter from 10 to 14 mm. The particle damage percentage was found to be increasing in proportion to the peripheral speed of the metering mechanism. The particle damage percentage was greater for metering mechanism with smaller flute diameter (10 mm) than that for larger diameter flute. Particle distribution per m2 of urea ranged 7–77, 10–94 and 11–117 for 10, 12, and 14mm flute diameter, respectively. These data sets were used for training the MLR and ANN models.

From the performance indices such as E, RMSE, R2, MAE and Pdv of the MLR and ANN models (for predicting the operating parameters), the model efficiency in case of MLR model was found close to zero. On the other hand, the model efficiency (E) of ANN was close to 1 for different performance indices except speed of fluted roller. The best ANN configuration for metering mechanism was obtained after the training process. Similarly, the same data set which was used for modeling ANN was also used to build the MLR model. Also, it was observed that for overall validation data sets, ANN model gave good prediction performance with the lowest RMSE of 3.518 mm, E of 0.91, MAE of 2.017mm and the highest R2 of 0.91. It was also observed that ANN model is better than the MLR model in terms of accuracy and coefficient of determination. The prediction by ANN was better as compared to MLR model due to its ability to fully capture the input–output relationship during training of the network and also due to its better generalization ability. It was observed that performance of MLR models was satisfactory for fluted roller expose length, whereas the ANN model performed very well for simulating relationship between metering device and operating parameters.

An effective model for predicting tractor drawbar power using artificial neural network models can be envisaged by [26]. Twenty important parameters under ballasted and unballasted conditions that affects the performance of tractor drawbar. Back propagation neural networks with 30 different network configurations were developed to select the best model for predicting the drawbar power. The process started with 15 neurons in the first hidden layer and no neuron in second layer (*i.e.,* single hidden layer network) upto 70 neurons in single hidden layer. After those two hidden layers were tested with 20 neurons in each hidden layer, which was increased step-by-step to 5 neurons in each layer every time, to 65 neurons in the first layer and 60 in the second layer.

The ANN with Levenberg–Marquardt training algorithm with two hidden layers, each with 35 neurons, presented better accuracy in simulation in terms of mean square error and coefficient of determination. Tangent sigmoid transfer function was used in the hidden layer, and linear transfer function for the output layer. During the training process the network weights were adjusted so as to minimize the error between the actual output and the predicted output from the network.

Applications of ANNs in agriculture

Introduction of artificial intelligence and its subunits in the field of agriculture has made an agricultural revolution. The main area where ANNs are widely used in agriculture is for solving various classification tasks and prediction tasks. Also, they are considered as a part of precision farming.

ANN models were used to monitor the water availability, anticipate the resource sustainability, usage of water in irrigation and also forecasting the seasonal variability[27] .ANN is used in the design of subsurface drainage [28] , forecasting groundwater level [29], prediction of groundwater quality [30].

Plant diseases and crop pests must be detected and classified early in order to manage and make decisions in the field of precision farming and plant protection. Many artificial neural network (ANN) approaches have recently been applied in agricultural classification tasks, which are task specific and need large datasets [31]. ANN was used by in image recognition and classification of crop and weeds. Plant protection UAV variable spray system was designed by Sheng, *et al.,* (2019) [32] based on Neural Networks. ANN was used by Bouasria, *et al.,* (2020) [33] to estimate soil organic matter. Agricultural data mining was done using ANN [34] to carry out the improved crop yield prediction [35]. Zeng and Chen (2021 [36] assessed susceptibility of shallow landslides using artificial neural networks.

Studies carried out by Talaviya, *et al*., (2020) [37] highlights the essential role of artificial intelligence and ANN for automated irrigation, spraying and weeding using some sensors, drones and other UAVs. Application of these technologies in the field has tremendously reduced the usage of excess pesticides and herbicides and thus increases the productivity and quality of the product.

A review work by Dongre and Gandhi (2016) [38] conveys that artificial neural network have important applications in the field of livestock and allied field. It includes prediction of various parameters like milk production, breeding values of cattle, mastitis, success rate of in vitro fertilization, detection of estrous, finding cows with difficulties in artificial insemination, calculation of nutrient content in manure etc.

For the prediction of soil organic matter [39] multilayer perceptron (MLP) with back propagation method with supervised learning was used and its results were compared with multiple linear regression (MLR) modeling. The ANN model was developed using MATLAB software. Soil sampling and laboratory analysis for physical and chemical analysis were done. Using wet combustion method soil organic carbon was determined. The NDVI which closely related to biophysical crop characteristics, such as absorption of photosynthetic active radiation and productivity was calculated using the remote sensing data such as Landsat ETM band 1, 2, 5 and band 7 and combination of bands 3 and 4. The dependent and independent variables decide the number of neurons in input and output layers. The network was designed with 5 parameters (*i.e*., the digital number of band 1, 2, 5 and 7 and NDVI) as input pattern and SOM as the output parameters.

The results showed that the MLR and ANN models explained 54 and 84 % of the total variability in SOM, respectively, in the rangeland site 77 and 91% respectively in forested area using remotely sensed data. The calculated Mean Arithmetic Error (MAE) and Root Mean Square Error (RMSE) values were 0.18 and 0.26 for the MLR model for SOM in rangeland and 0.09 and 0.13 for the forested area using MLR. ANN improved the MAE and RMSE to 0.09 and 0.12 for rangeland and 0.01 and 0.09 for forested land, respectively. Hence the ANN model provided better predictive performance when compared with the MLR model developed

Neural Network was used for predicting the appropriate crop to the farmer according to his field's climatic and soil information available. Parameters such as crop types, soil types, soil-PH value, crop disease and pesticides, seasonal parameters such as kharif, rabi and summer crops, zonal as well as district information, environmental parameters such as maximum and minimum temperature value and average rainfall were collected and normalized in the specified range. Then it is analysed by using feed forward back propagation ANN.

[40] conducted leaf disease classification using artificial neural networks. The leaf quality was assessed through three major procedures such as image acquisition, image processing, and classification. In image processing the input RGB image for the colour transformation structure was done using Hue Saturation Value (HSV) segmentation which is capable of detecting any colour. Based on the colour and shape, the leaf disease image was analysed and final classification was done using feed-forward Neural Network, which uses Back-propagation algorithm [41].

Conclusion

We live in a world where many of the newest digital technologies are assisting humans in discarding their abilities to learn, communicate and interact with real life. Artificial neural networks that have stepped into the world in the mid-20th century are rapidly developing.

This means that artificial neural networks will become an indispensable part of our lives and increasingly important.

Agricultural machine predicting models is not a mysterious trick or magic, but a set of well-defined models that collect specific data and apply specific algorithms to achieve expected results.

Application of research: Applications of these technologies in our farm machinery field can definitely help us in improving the efficiency and is surely a boon to the farmers, designers and for agricultural engineers.

Research Category: Artificial Neural Networks

Abbreviations: ANN- Artificial Neural Network, TLU- Threshold Logic Unit
Logic gates- AND, OR, NAND, XOR, RNN- Recurrent Neural Network
MLR- Multiple Linear Regression, SSP- Single Super Phosphate
MOP- Muriate of Potash, RMSE- Root Mean Square Error
E- Efficiency, R2- Coefficient of determination, MAE- Mean Absolute Error,
UAV- Unmanned Aerial Vehicle, NDVI- Normalized Difference Vegetation Index, HSV- Hue Saturation Value, SOM- Soil Organic Matter, RGB- Red, green, blue

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