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Artificial Neural Network Approach to Predict Milk Yield of Dairy Farm

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Abstract: ***Artificial neural networks have been widely used in various fields for prediction, classification, control system and pattern recognition. In this research, ANN is used to predict the milk yield of the next month based on the meteorological data. In this prediction, 26 input variables are considered. They are number of milking cows, Number of milking cows in each lactation stage (1 to 7), Number of milking cows in each milking month (1 to 13), Number of rainy days, Average Humidity-Day, Average Humidity-Night, Average Temperature and total rainfall amount. Two layered feed forward neural network is used with back propagation algorithm. Properly trained back propagation network tends to give reasonable answers when presented with inputs that they have never seen. Default back propagation algorithm Levenberg – Marquardt (trainlm) and scaled conjugate gradient (trainscg) are used in this work. The result is obtained with 11 neural network modals which are better than with the rest of modals. The best ANN modal is obtained by using seven combined ANN result. It gives 72% success in prediction with below 10% error and 94% success in prediction with between 15% error.***

Keywords: Dairy Farm, Meteorological data, Milk Yield Prediction, Neural Network

1. Introduction

Livestock production is one of the most important activities in Sri Lanka as a developing country. National livestock development Board (NLDB) engages in developing the livestock productions in Sri Lanka. There are number of farms under this board. Oyamaduwa is one of them where the research is conducted.

The main approach of this research is to predict about future milk yield by using neural network. It is said that Milk yield depends mainly on the meteorological data such as humidity, rainfall amount, number of rainy days and temperature. There are no witnesses to prove this fact but it is believed according to their experience and knowledge. Milk amount depends mainly on stress, food and nutrition of the animals. These factors are mainly depended on meteorological data. Increasing humidity directly affects to the stress of the cows. Staple food of cows is grass. Availability of food and the nutrition of grass increase with the rain. In addition, milk yield depends on lactation stage and milking month of the cow.

Generally, the management plans to achieve production targets of the next year. But they could not achieve the targets until now. Actual production is 60% behind the target production. Main objective is to find out either the relationship between the meteorological data and the availability of milk or not and if it is available to predict the future milk yield based on that.

2. Artificial Neural Network

Nowadays, ANN approaches are becoming increasingly popular. Many organizations are going to find solutions using ANN. It is a popular technique for prediction. It is able to capture and represent complex input and output relationships. The adaptive nature is very important feature of the ANN. ANN is trained to perform complex functions in various field including pattern recognition, prediction, identification, classification, clustering, regression, optimization and control systems. It can be trained to solve problems that are difficult for conventional computers or human beings. Main disadvantages of neural network are more time need and waste time. But trained neural network gives result fast.

ANN is an information processing system that has certain performance characteristics in common with biological neural networks. It is developed as generalizations of mathematical models of biological nervous systems. The basic processing elements of ANN are called artificial neurons, or simply nervous or neurons or nods. In a simplified mathematical model of the neuron, the effects of the synapses are represented by connection weights that modulate the effect of the associated input signals, and the nonlinear characteristic exhibited by neurons is represented by a transfer function. The neuron impulse is then computed as the weighted sum of the input signals, transformed by the transfer function. The learning capability of an artificial neuron is achieved by adjusting the weights in accordance to the chosen learning algorithm.

Number of types of ANNs is available for solving problems. Some of available ANNs are feed forward, linear filters, perceptron, radial basis and self-organizing. These ANNs are applied according to the nature of problem.

3. Related Work

There are few researches available in prediction of milk yield of dairy farms. Some of them are summarized here. Statistical methods, genetic algorithm and ANN can be used to predict the future milk yield of dairy farm.

3.1 Statistical Methods

The traditional approaches such as regression and time

series analysis can be used to predict the milk prediction. Although statistical methods are not available in milk yield prediction in much, there are many applications in prediction task.

In milk yield prediction task, a research work has been found using time series analysis [1]. In this research work, milk yield data is collected three times daily & used to create stochastic models for short-term forecasting of milk production. These models can be used in systems for automated registration of daily milk weights. Analyses are carried out on partial or complete lactation yield data from 513 lactations. Time series analysis is showed that the exponential smoothing function is the most appropriate model for both individual milking and daily yield data. Model parameters are influenced by parity, stage of lactation, occurrence of missed milking, and treatment for diseases. The model to forecast daily total yield performed equally well as the model to forecast individual-milking yield, since the variance of the residual errors of the forecast daily production was similar to the sum of the variances of the forecast errors of the individual milking.

Average parameter values from heifers and multifarious cows are not treated for diseases and without missing milk weights, are estimated and used to forecast next day milk yield. Average forecast errors preceding disease diagnosis are showed a sudden production decline in the case of clinical mastitis and a gradual production decrease in the case of clinical ketosis. Therefore, separate screening tests are needed when screening for these diseases with daily milk weight systems.

3.2 Genetic Algorithm

Genetic algorithm is not much used in prediction task. But there is one research work in milk yield prediction. According to this research [2], it achieves acceptable prediction results considering variables such as somatic cell count, parity, day in milk, milk protein content, milk fat content, and season.

3.3 Artificial Neural Network

There are many researches works available in prediction task using ANN. And also, some research works has been found about milk yield predicting. There is a research called weekly milk prediction on dairy goats. In this research [3], neural network has been used to predict next week's goat milk based on the current and previous milk yield. A total number of 35 goats are selected from a farm according to number of lactation, litter size, and body weight. Input variables are diet, milk yield, stage of lactation and days between partum and first control. Their approach was multilayer perceptron neural network with back propagation learning algorithm and sigmoid transfer function.

This study has been shown that ANN is a suitable tool for prediction of next week's milk yield from the collected parameters of goats. It is recommended that the further work is necessary to improve robustness of ANN modal.

3.4 Critical Analysis

I am going to predict monthly milk prediction according to the meteorological data on dairy cows. Although traditional approach is suitable for prediction, it is restricted by the missing or incomplete data and may not generate sufficient accurate results in the effort of milk yield prediction. Milk yield predicting matter is complex, nonlinear and continuous. Therefore, development of mathematical models by statistical methods for this effort may be difficult and complicate because of the lack of learning and adaptation in recognizing the behavior of dataset.

Genetic algorithm also can be used for milk yield predicting task. But number of parameters, relevancy of that parameters and complexity of genetic application in this problem, ANN is the suitable approach for this problem. The research work [3] shows the ANN approach is suitable for milk predicting. That research also mentions the area where it is conducted has no rainfall and high temperature. My research is also carried in dry zone. This research is specific for dry zone and also Sri Lanka because of monsoon pattern of our country. As a tentative approach to test the feasibility ANN analysis of milk yield prediction is based on meteorological data, ANN approach is selected for this research work. This is initial step to predict milk yield in dairy farm in Sri Lanka so feed forward neural network with back propagation algorithm is used as the first approach.

4. Methodology

In this research, ANN modals have been developed using the neural network tool box in scientific software package MATLAB (2008a).

My approach consists of seven steps:
1) Data gathering
2) Data preparing and preprocessing
3) Design ANN
4) Training ANN
5) Simulating ANN
6) Post processing Data

4.1 Data Gathering

The data gathered from Oyamaduwa farm Vilachchiya, Anuradhapura, Sri Lanka under the National Livestock Development Board (NLDB) is used in this research.

In this study, 26 parameters are considered that affect monthly milk yield (MY) namely; NMC (Number of Milking Cows), L1, L2, L3, L4, L5, L6, L7 (Number of Milking Cows in each Lactation stage), M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11, M12, M13 (Number of Milking Cows in each Milking Month), NRD (Number of rainy Days), AHD (Average Humidity-Day), AHN (Average Humidity-Night), AT (Average Temperature), TRA(Total rainfall Amount).

4.2 Data preparing and preprocessing

For testing the performance of the neural network, new data samples that are not used for creating neural network modal

is required. Original datasets are partitioned in to two parts one for constructing an ANN modal, consisting 80% and other one for checking the accuracy of the network for new data, consisting 20%.

When we divide original dataset in to two parts for Creating ANN and testing, data samples are selected randomly. Then our prediction is more accurate. MATLAB divider and function is used to divide data randomly. When neural network training, this function is applied default to separate training, validation and testing. Here this function is used to keep some datasets as new data samples which are selected randomly without any priority.

Dividing Dataset using divider and function:
Original data set is divided to 80% for constructing an ANN modal and 20% for checking new prediction result.

```
>>[trainV,valV,testV,trainInd,valInd,testInd]
=dividerand(data,0.8,0,0.2);
```

Neural network training can be made more efficient performing certain preprocessing steps on the network inputs and targets. Some of preprocessing functions are provided automatically when creating a network. Network input processing functions transform inputs into a better form for the network use. Processing functions associated with the network output transform target into a better form for network training, and reverse transformed outputs back to the characteristics of the original target data.

Two preprocessing functions are used in this research.
1) Mean and Stand. Dev. (mapstd)
2) Principal Component Analysis (processpca)

The original network inputs and targets are given in the matrices imilk and tmilk. The normalized inputs and targets are given in the matrices pimilk and milktarget.

```
>> [pimilk,ps1] = mapstd(imilk);
>> [milktarget,ps2] = mapstd(tmilk);
```

After the network is trained, these settings should be used to transform any future inputs that are applied to the network. They effectively become a part of the network. Hence test data should be transformed before applying the trained neural network.

```
>> pitestmilk = mapstd('apply',itestmilk,ps1);
>> testmilktarget = mapstd('apply',ttestmilk,ps2);
```

There are 26 parameters affecting the milk yield. Hence the dimension of the input vector is large. The components of the vectors may be highly correlated. It is useful in this situation to reduce the dimension of the input vectors. An effective procedure for performing this operation is principal component analysis.

In this analysis, it orthogonalizes the components of the input vectors (so that they are uncorrelated with each other), it orders the resulting orthogonal components (principal components) so that those with the largest variation come first, and it eliminates those components that contribute the least to the variation in the data set.

Processpca function in MATLAB performs a principal-component analysis. The input vectors are first normalized, using mapstd, so that they have zero mean and unity variance. This is a standard procedure when using principal components.

```
>> [pimilk,ps1]=mapstd(imilk);
>> [milkinput,ps3]=processpca(pimilk,0.02);
```

The second argument passes to processpca is maxfrac. Normally maxfrac is 0.02. This means that processpca eliminates those principal components that contribute less than 2% to the total variation in the data set.

After the network has been trained, these settings should be used to transform any future inputs that are applied to the network. So test data are also transformed.

```
>>pitestmilk=mapstd('apply',itestmilk,ps1);
>>testmilkinput=processpca('apply',pitestmilk,ps3);
```

MATLAB Complete Code for Data Preprocessing

```
>>[pimilk,ps1]=mapstd(imilk);
>> [milktarget,ps2]=mapstd(tmilk);
>> [milkinput,ps3]=processpca(pimilk,0.02);
>> pitestmilk=mapstd('apply',itestmilk,ps1);
>>testmilkinput=processpca('apply',pitestmilk,ps3);
>>testmilktarget=mapstd('apply',ttestmilk,ps2);
```

After the preprocessing, following variables will be available to design ANN.

Training Input : milkinput
Training target : milktaget
Test input : testmilkinput
Test target : testmilktarget

4.3 Designing ANN

When we design an ANN, we should consider for selecting suitable ANN architecture, training algorithm, number of layers, number of nodes in each layer, transfer function in each layer, network performance function.

4.3.1 Choosing ANN architecture

Feed forward network can potentially represent any input output relationship. Hence two-layer feed forward network shown in fig. 1 is used with back propagation algorithm to predict the monthly milk yield. Properly trained back propagation networks tend to give reasonable answers when presented with inputs that they have never seen.

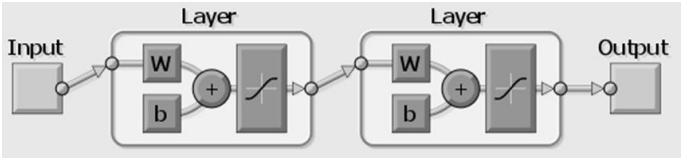

Figure 1: Two Layer ANN architecture

4.3.2 Choosing Training Algorithm

In this research, feed forward ANN uses the back-propagation algorithm. There are different back propagation algorithms. The basic implementation of back propagation learning updates the network weights and biases in the direction in which performance function decreases most rapidly, the negative of the gradient.

Default back propagation algorithm (trainlm) Levenberg-Marquardt is used in this research. This is fasted method in MATLAB neural network toolbox. In addition, scaled conjugate Gradient (traiscg) is used.

4.3.3 Choosing Number of layers

In this research two layers are used because any relationship can be found using two layers ANN. There is currently no theoretical reason to use ANN with any more than two layers.

4.3.4 Choosing Number of nodes in each layer

The number of nodes in the output layer is one since there is one output. The number of nodes in first layer is varying with each ANN. We are trained number of ANN to select best prediction ANN with varying number of nodes in layer

4.3.5 Choosing Transfer function in each layer

Tansig and logsig transfer function are used in the research. Multilayer networks often use the log-sigmoid transfer function logsig. The function logsig generates outputs between 0 and 1 as the neuron's net input goes from negative to positive infinity. Alternatively, multilayer networks can use the tan-sigmoid transfer function tansig. Transfer functions of the first and second layer are also varying with each ANN. Changing with transfer function is tried to design best prediction ANN.

4.3.6 Choosing Network performance function

During the training, weights and biases of the network are iteratively adjusted to minimum the network performance function. All algorithms use the gradient of performance function to determine how to adjust the weights to minimize the performance. I used default performance function of feed forward network called MSE(Mean Square Error). Fig. 2 is shown designing of ANN. Network architecture is selected as feed forward back propagation. Training function is selected as trainlm. Performance function is selected as mse. Number of layers is selected as two and number of nodes and transfer function of each layer can be selected clicking relevant layer.

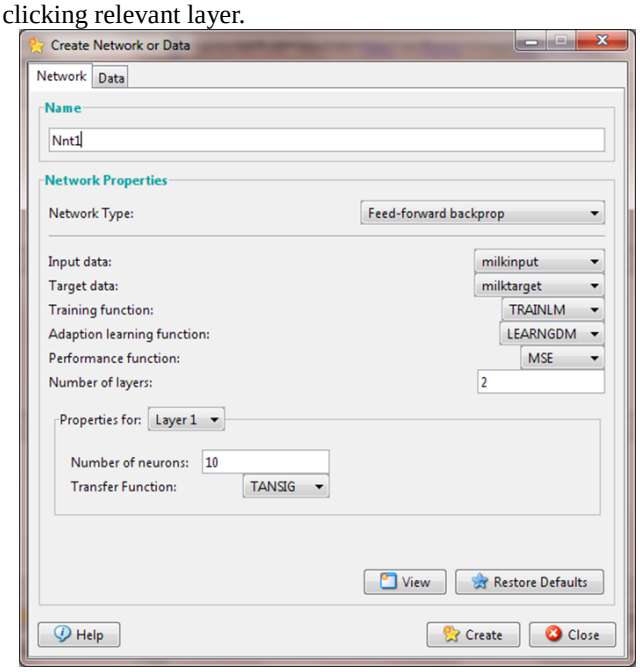

Figure 2: Designing window of ANN

4.4 Training ANN

The goal of training process is to find the set of weights values that will cause the output from the neural network to match the actual target values as closely possible. ANN can be trained in two modes: incremental mode and batch mode. Trainlm and Trainscg are batch mode training. Batch method is to compute the weight update for each input sample, but store these values during pass through training set called an epoch.

Using performance function mse find the performance of ANN modal. Weights are updated according to the selected training algorithm considering MSE. The training was terminated when the threshold of MSE=0.001 or when the number of iterations is equal to 1000(epochs) or validation error increased for six iterations which occurred at maxfail=6 in training.

4.5 Simulating ANN

For test the prediction, new data samples are applied to the ANN. Input data variable is testmilkinput. Target output is testmilktarget.

4.6 Post processing data

Mapstd was used to scale the targets, and then the outputs of the network are trained to produce outputs zero and mean and unity standard deviation. To convert these outputs back into the same units, post processing must be applied.

```
>>truesimoutputs=mapstd('reverse',nnt_simoutputs,ps2);
>>true_outputs=mapstd('reverse',nnt_outputs,ps2);
```

In order to compare the performance of the prediction of the modal, the prediction percentage was calculated below 5%, 10%, 15% and 20% error because prediction values cannot be achieved exactly. Standard deviation, maximum value, minimum value of actual outputs and predicted values of the test data calculated to compare the success of prediction.

5. Result and Discussion

Neural network modals were trained with changing number of neurons in layer 1, changing transfer function of each layer and changing training algorithm in back propagation as mentioned in methodology chapter.

135 neuron network modals were trained. As discussed in methodology chapter prediction success was calculated with below 10% and 15% error. Prediction success of below 5% and 20% error calculation was discarded due to difficult to select the best neural network from those values. Considering below 5% error prediction, most of ANN were failed to achieve success prediction that mean all ANN gave same success prediction. We couldn't find best ANN. Considering below 20% error prediction; most of ANN gave better prediction success. But percentage value of prediction success was in same range. Because of that reason, we couldn't select best ANNs with 20% error. Then we selected only 10% and 20% error to select best ANNs. Finally it is compared the results obtain from best ANN modals.

Table 2 shows the result of best 12 neural networks. Those tables show percentage of success in predicting. When calculating success of predicting, the target value below 10% error and below 15% error was considered. Because of exact value can't be achieved in prediction. Although we couldn't achieve accurate prediction, prediction percentage is considerable.

The Table 1 shows combined neural network details. Using seven neural networks combined another network. It gives 72 percentage forecasting prediction with 10% error of real value and 94 percentage forecasting prediction with 15% error of real value. This is best prediction other than single neural network prediction.

Table 1: Combined Neural Network structure and Predicting Result

Neural Network		Combined Result Analysis	
Name	Combined Neural Networks	10% Error Prediction (%)	15% Error Prediction (%)
Combined NN	Nnt53	72	94
	Nnt61		
	Nnt65		
	Nnt74		
	Nnt101		
	Nnt104		
	Nnt108		

In Fig. 3, line graph of combined neural network shows actual and forecast line more similar than the other graphs. There is only small deviation present there. Fig. 4 points are spread around the line goes through origin. So prediction is closer to actual values.

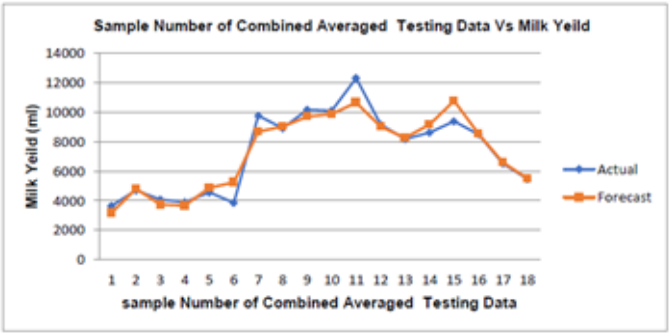

Figure 3: Sample Number of Testing Data Vs Milk Yields – Combined NN

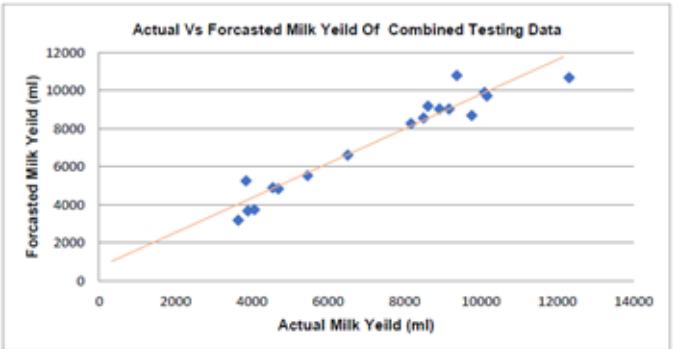

Figure 4: Actual Milk Yield Vs Forecasted Milk Yields – Combined NN

Table 2 summarizes the best 12 neural network modals and combined ANN among the 135 trained ANNs.

Table 2: Best 12 NN modal and combined neural network

Neural Network	Number of Nodes in Layer 1	Transfer function	Percentage of predicting success %	
			Error Below 10 %	Error Below 15 %
Nnt53	7	Trainlm	56	78
Nnt81	5	Trainlm	56	78
Nnt101	20	Trainlm	56	78
Nnt107	11	Trainlm	44	83
Nnt108	12	Trainlm	56	78
Nnt115	6	Trainscg	39	83
Nnt117	14	Trainscg	56	89
Nnt118	18	Trainscg	50	78
Nnt120	10	Trainscg	61	78
Nnt127	12	Trainscg	67	78
Nnt131	30	Trainscg	44	83
Nnt134	3	Trainscg	44	78
Combined NN			72	94

6. Conclusion

This research presents artificial neural network approach for predicting milk yield of dairy cows with the meteorological data. ANN is very helpful when developer does not have precise domain expertise from their domain and doesn't know any relationship. In this study two layer feed forward network was used because it can potentially represent any input output relationship. According to the results found from this research, neural network appears to be found good predicting for the milk yield of dairy cow.

This study has shown that ANN is suitable tool for the predicting of next month milk yield from cow factors recorded on the farm. Therefore, ANN allows one to take management decisions for the next month knowing the current farm situation. They also avoid waiting until the end of month to get a farm evaluation and take future decision. These results can also aid to improve milk yield and quality in dairy farm.

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