Advances and Applications in Mathematical Sciences
Volume 21, Issue 10, August 2022, Pages 6117-6128

PERFORMANCE COMPARISON OF ARTIFICIAL NEURAL NETWORK TRAINING ALGORITHMS FOR NOISE LEVEL PREDICTION IN INDUSTRIAL ZONE OF LUCKNOW

MINAKSHI MISHRA and RATAN KUMAR THAKUR

[1,2]Department of Statistics
School of Physical and Decision Sciences
Babasaheb Bhimrao Ambedkar University
(A Central University), Lucknow, India
E-mail: mmishra02sep@gmail.com
ratan.thakur.stats@gmail.com

Abstract

Long-term exposure to high noise levels causes lifelong hearing loss, stress, heart disease, and high blood pressure. For this study, we took into account climatic factors that have a negative impact on noise levels and endanger human life. In this study, a comparison of the three artificial neural network training methods, Bayesian Regularization, Scale Conjugate Gradient, and Levenberg-Marquardt, was conducted in order to determine the optimal training strategy for noise level prediction in Lucknow's Industrial Zone. The study reveals that Levenberg-Marquardt outperforms the other training algorithm for the noise level prediction in terms of high value of R^2 and low values of root mean squared error (RMSE), mean squared error (MSE), mean absolute error (MAE) and mean absolute percentage error (MAPE).

1. Introduction

Noise is defined as unwanted sound that causes aggravation, disrupts mental and bodily peace, and has negative psychological impacts on a person (Belojevic et al. [3]). Noise pollution has increased dramatically as a result of growing urbanisation, industrialisation, and environmental deterioration. As a result, predicting noise levels is critical in determining the true state of the

2020 Mathematics Subject Classification: 68T07.
Keywords: Noise level, Artificial Neural Network, Levenberg-Marquardt, Bayesian Regularization, Scale Conjugate Gradient.

Received March 23, 2022; Accepted June 15, 2022

situation caused by noise disturbances. Models for noise prediction are useful for urban planning, environmental management, and the creation of a healthy, noise-free environment. As a result, many academics are always on the lookout for approaches that are useful in properly estimating noise levels. As a result, it is critical to develop technologies that can be used to properly estimate noise pollution levels in metropolitan areas. Noise pollution is becoming more prevalent in metropolitan areas, posing a threat to quality of life and disrupting the working environment's calm.

Artificial neural networks (ANNs) are computational approaches and mathematical models that fall under the category of machine learning (Kelleher et al. [14]) and are widely used for prediction in the modern era. The advantages of using an ANN approach over traditional approaches are that they are faster and more reliable for multi-variable, non-linear, and complex computations. The Applications of ANN are very wide and as the time will go it will also go on very high demand because it gives a lot of benefits over a normal network that's why it is embedded. There are many applications of ANN in the real life such as image processing, speech processing, chat box for queries, natural language processing etc.

Many researchers have considered fuzzy soft computing techniques (Prakash et al. [23], Wang et al. [33], Rahman et al. [27], Singh et al. [29]), multiple regression techniques (Bhavyashree et al. [4], Rana et al. [25], Baffoe et al. [5] Dasarathy et al., [9]), genetic algorithm (Chen et al. [7], Refonaa et al. [24]), ARIMA technique (Garg et al. [11], Halliyavar et al. [13]) for the prediction purposes. The predictive strength of ANN technique is found to be more superior than other predictive models (Mishra et al. [18], Alsaawy et al. [1], Asogwa et al. [2], Ranpise et al. [28], Ramakrishna et al. [26], Zhang et al. [35]).

The main aim of the present work is to predict the noise levels in industrial zone of Lucknow by using LM, BR and SCG neural network training algorithm. The use of the ANN approach to anticipate noise levels has attracted considerable attention in recent years, and it has a wide range of applications in many real-world challenges. As a result, our research can assist policymakers in making more informed decisions about noise management in order to preserve low noise exposures and protect human health and well-being.

2. Materials and Methods

2.1 Study Area

The present study has been carried out considering Lucknow's Industrial Zone-Talkatora. Lucknow is situated on the north western bank of Gomti River, is not only the largest but also the capital city of Uttar Pradesh (Figure 1). This city is developing very fast due to rapid increase in urbanization, industrialization and population growth.

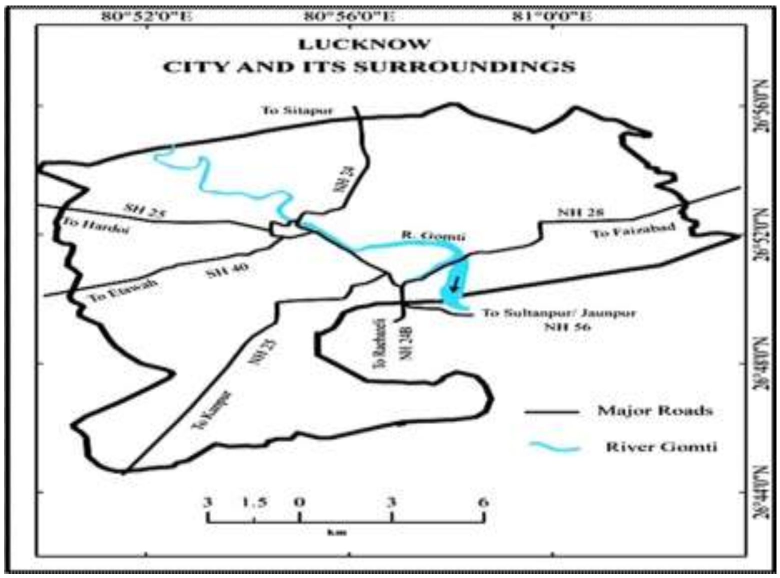


Figure 1. Location of Study Area.

2.2 Source of Data

The time series data of noise level (day and night time) was acquired for the period 2011-12 to 2015-16 from the www.indiastat.com and Uttar Pradesh Pollution Control Board. This study utilised meteorological data on weather factors such as maximum temperature (in °C), minimum temperature (in °C), relative humidity (in percent at 07 hrs), relative humidity (in percent at 14 hrs), wind speed (in km/hr), rainfall (in mm), and sunshine duration (hr/day) which were collected from the Indian Meteorological Department (IMD), Lucknow. The data analysis was carried out with the help of the MATLAB software and MS-EXCEL.

2.3 Artificial Neural Networks (ANNs)

Artificial Neural Networks are a special type of machine learning algorithms that are modelled after the human brain. That is, just like how the neurons in our nervous system are able to learn from the past data, similarly, the ANN is able to learn from the data and provide responses in the form of predictions or classifications. An artificial neural network (ANN) is a data processing system made up of non-linear, closely coupled processing components called neurons.

A single processing unit or neuron is shown in (Figure 2) [Dagli [8]; Fausett, [10], Haykin, [12].

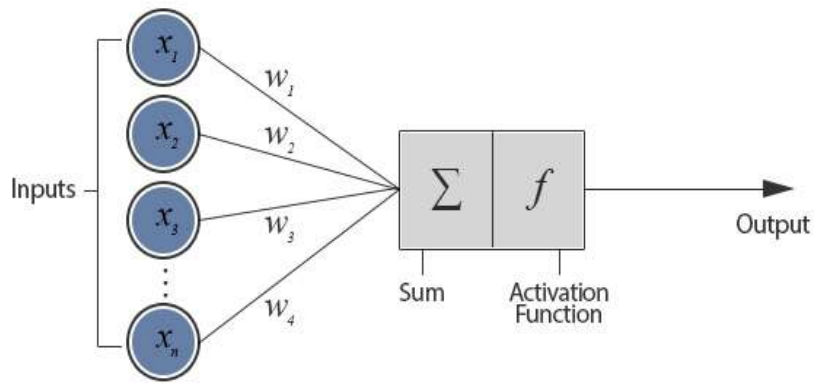


Figure 2. Architecture of Artificial Neural Network.

The general model of ANN (Figure 2), the net input can be calculated as follows:

$$y_m = x_1 \cdot w_1 + x_2 \cdot w_2 + x_3 \cdot w_3 + \ldots + x_n \cdot w_n. \tag{1}$$

i.e., net inputs

$$y_m = \sum_1^n X \cdot W; \text{ where } X = x_i \text{ and } W = w_i \tag{2}$$

$$i = 1, 2, 3, \ldots, n$$

The output can calculate by applying transfer function over the net input i.e.

$$Y = F(y_m) \tag{3}$$

Output = function net input calculated.

The most prevalent type of feed-forward network is the multilayer perceptron (MLP), which maps a set of suitable inputs to a set of suitable outputs. MLP is made up of three layers: an input layer that is used to feed data into the ANN model, a hidden layer that processes the data, and an output layer that is used to generate the best possible output from the ANN model as illustrated in (Figure 3).

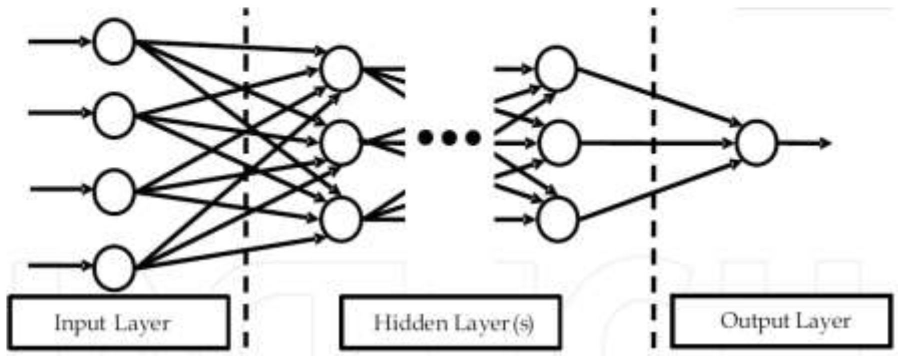


Figure 3. A Multi-layered preceptor (MLP) network.

2.4 Prediction of day time and night time noise levels using ANN model

The artificial neural network (ANN) is a huge parallel-distributed information processing system with certain performance characteristics. The 72 datasets were grouped into three categories: training, validation, and testing. Different network configurations with different numbers of hidden neurons are trained and their performance is tested using the GUI in the neural network toolbox in MATLAB. There are 50 training samples, 11 validation samples, and 11 testing samples in all. Three layers of ANN are used in this investigation (Figure 4),

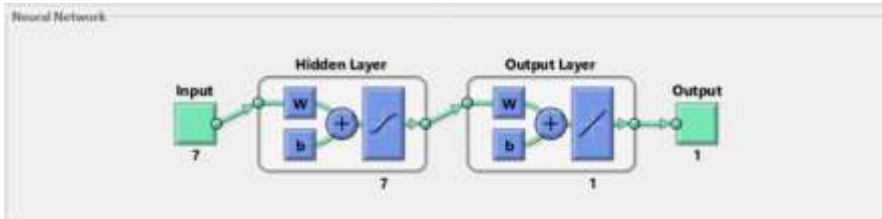


Figure 4. Abbreviated view of ANN model in MATLAB window.

where the first layer is input layer (7) which is triggered using the sigmoid activation function whereas the second layer is hidden layer (7) and the third layer is output layer (1) which is triggered using activation function.

2.5 Training Algorithm

The network is trained using Levenberg-Marquardt (LM), Bayesian Regularization (BR) and Scale Conjugate Gradient (SCG) algorithm.

(a) Levenberg-Marquardt Algorithm. Kenneth Levenberg and Donald Marquardt created this algorithm. This algorithm is conventionally known as damped least square methods which is used for solving non-linear least square curve fitting problems (Umar et al. [31], Nguyen et al. [21]). It is a hybrid of the Gradient Descent method and the Gauss-Newton method for minimization. The sum of squared errors is minimised in the gradient descent approach by updating the parameters in the steepest-descent direction. The sum of squared errors is decreased in the Gauss-Newton approach by assuming that the least square's function is locally quadratic in the parameters and finding the minimum of this quadratic. When the parameters are far from their optimal value, the Levenberg-Marquardt technique behaves more like a gradient-descent method, and when the parameters are close to their optimal value, it behaves more like the Gauss-Newton method (Litta et al. [17], Kayri [15]. It's the most extensively used optimization algorithm, and the results it produces are more reliable and precise (Nguyen et al. [21]).

(b) Bayesian Regularization Algorithm. The Thomas Bayes Theorem was used to create this method. This iterative training approach identifies the best combination of square errors and weights to build the neural network's weight parameters by minimising a linear combination of square errors and weights (Kayri [15]). It also modifies the linear combination, resulting in a network with high generalisation properties (Setiaji et al. [30]). It's a probabilistic network that uses posterior inferences to make decisions. The weights are updated using the greatest likelihood estimator. During the training phase, sample data is fed into the network, and weights are adjusted to get a closer match to the desired output (Usman et al. [32]). This algorithm is helpful in dealing with the problem of overfitting. The Bayesian regularisation method required longer to train than other neural network algorithms, but it has been widely employed to handle many challenging issues (Krishnasree et al. [16]).

(c) Scale Conjugate Gradient Algorithm. The SCG algorithm was developed by (Moller, [19]). It is a commonly used supervised learning algorithm in feed forward neural network. It belongs to the class of conjugate gradient methods. It is the widely accepted iterative algorithm which are regularly used in solving critical problems of linear equations (Othman et al., [22]). The major utility of SCG algorithm is that it avoids time consuming line search at each iteration which saves number of computations at each iteration (Xue et al. [34], Bulut et al. [6]). This algorithm utilises small amount of memory and does not include user dependent parameters, hence it is suitable for large scale problems and helpful for overcoming the problem of deciding a suitable step size.

3. Results and Discussion

In this section, a comparison of the predictive superiority of the Levenberg-Marquardt (LM), Bayesian Regularization (BR), and Scale Conjugate Gradient (SCG) neural network training algorithms has been carried out for the prediction of day-time and night-time noise levels in Lucknow's Industrial zone, as shown in tables 1 and 2.

Table 1. Comparison of LM, BR, SCG on the basis of model evaluation criteria for day-time noise level.

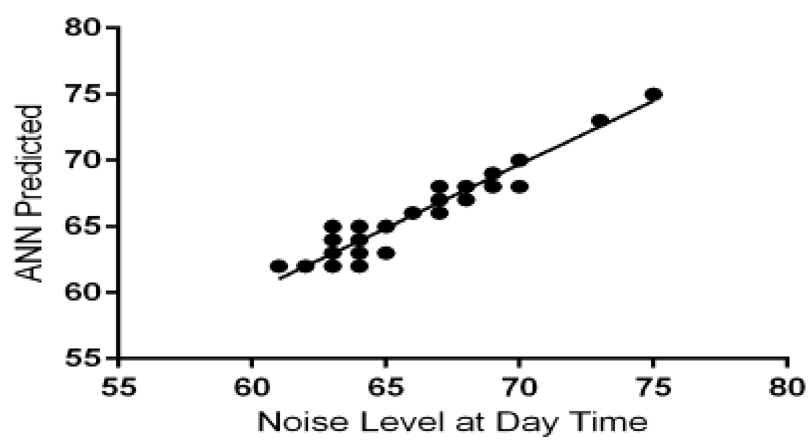
Model evaluation criteria	Levenberg-Marquardt Algorithm (LM)	Bayesian-Regularisation Algorithm (BR)	Scale Conjugate Gradient Algorithm (SCG)
R2	0.9149	0.8422	0.9054

MSE	0.7598	3.2747	1.5942
RMSE	0.8716	1.8096	1.2626
MAE	0.6397	1.1545	0.9717
MAPE	0.0099	0.0174	0.0149

Table 2. Comparison of LM, BR, SCG on the basis of model evaluation criteria for night time noise level.

Model evaluation criteria	Levenberg-Marquardt Algorithm (LM)	Bayesian-Regularisation Algorithm (BR)	Scale Conjugate Gradient Algorithm (SCG)
R^2	0.8679	0.8200	0.7078
MSE	2.0216	2.8384	4.8572
RMSE	1.4218	1.6847	2.2039
MAE	0.9483	0.9716	1.5549
MAPE	0.0161	0.0169	0.0263

Graphical Representation. In this section, we have shown the results graphically in order to clearly visualize the outcomes.



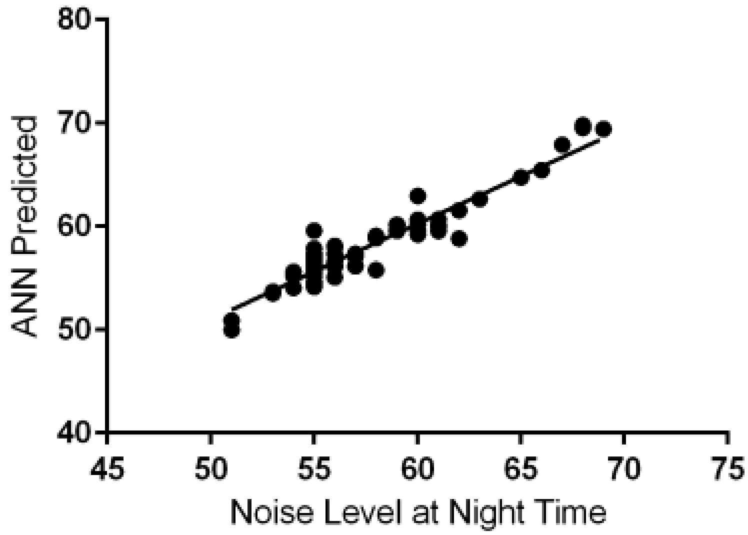


Figure 5. Actual and Predicted Noise level of day and night time using LM-ANN.

There exists a linear variation between actual and predicted noise levels which is observed in Figure 5. Hence it is proved that predictive noise level of day time and night time is directly proportional to actual noise level of day and night time.

4. Conclusion

The main goal of this research is to predict the day-time and night time noise level in Lucknow's industrial zone using multiple neural network techniques such as Levenberg-Marquardt (LM), Bayesian Regularization (BR) and Scale Conjugate Gradient (SCG) algorithm. The predictive performance of these algorithms was compared by maximum value of R^2 and minimum values of MSE, RMSE, MAE and MAPE. It was found that predictions done using LM-ANN algorithm are more robust and accurate than the other training algorithms. Hence, this work provides the basis for significance level of each metrological parameter contributing to the prediction of the noise level in industrial zone of Lucknow.

References

[1] Y. Alsaawy, A. Alkhodre, M. Benaida and R. A. Khan, A Comparative study of Multiple regression analysis and Back propagation neural network approaches for predicting financial strengths of Banks: An Indian Perspective, WSEAS Transactions on Business and Economics 17 (2020), 627-637.

[2] O. C. Asogwa, N. M. Eze, C. M. Eze, C. I. Okonkwo and K. C. Ojide, On the Efficiency of Multiple Linear Regression over Artificial Neural Network, International Journal of Statistics and Application 10(1) (2020), 1-9.

[3] G. Belojevic, B. Jakovljevic, V. Stojanov, K. Paunovic and J. Ilic, Urban road-traffic noise and blood pressure and heart rate in preschool children, Environment International 34 (2008), 226-231.

[4] S. Bhavyashree, M. Mishra and G. C. Girisha, Fuzzy regression and Multiple linear regression models for predicting mulberry leaf yield: A comparative study, International Journal of Agricultural and Statistical Sciences 13(1) (2017), 149-152.

[5] P. E. Baffoe and A. A. Duker, Evaluation of Two Noise Level Prediction Models: Multiple Linear Regression and a Hybrid Approach, Urban and Regional Planning 4(3) (2019), 91-99.

[6] M. Bulut, H. Tora and M. Buaisha, Comparison of three different learning methods of multilayer perceptron neural network for wind speed forecasting, Gazi University Journal of Science 34(2) (2021), 439-454.

[7] L. Chen, M. Jamal, C. Tan and B. Alabbadi, A Study of Applying Genetic Algorithm to Predict Reservoir Water Quality, International Journal of Modelling and Optimization 7(2) (2017), 98-104.

[8] C. H. Dagli, Artificial neural networks for intelligent manufacturing, Operating Research Journal 6(1) (1994), 1-26.

[9] A. K. Dasarathy, M. T. Selvi, C. Suresh and S. Ponkumarllango, Multiple linear Regression models for Leq estimation in noise emission measurement, Journal of critical reviews 7(04) (2020), 1255-1262.

[10] L. Fausett, Fundamentals of neural networks, Architectures, algorithms and applications, Prentice Hall, USA, 461 1994.

[11] N. Garg, M. K. Sharma, K. S. Parmar, K. Soni, R. K. Singh and S. Maji, Comparison of ARIMA and ANN approaches in time-series predictions of traffic noise, Noise Control Engineering Journal 64(4) (2016), 522-531.

[12] S. Haykins, Neural Networks: A Comprehensive Foundation, Macmillan Publishing, New York, 1994.

[13] D. Halliyavar, M. P. Shwetha, S. Puneeth and S. A. Chikop, Production analysis and prediction of TOP using ARIMA model, International Journal of Engineering Research and Technology 9(07) (2020), 945-949.

[14] J. D. Kelleher, N. B. Mac and A. D'Arcy, Fundamentals of machine learning for predictive data analytics: algorithms, worked examples, and case studies, Second Edition, MIT Press, 2015.

[15] M. Kayri, Predictive abilities of bayesian regularization and Levenberg-Marquardt algorithms in artificial neural networks: A comparative empirical study on social data, Mathematical and Computational Applications 21(20) (2016), 1-11.

[16] K. S. Krishnasree and M. R. N. Rao, Diagnosis of heart disease using neural networks-comparative study of Bayesian Regularization with multiple regression model, Journal of Theoretical and Applied Information Technology 88(3) (2016), 638-643.

[17] A. J. Litta, S. M. Idicula and U. C. Mohanty, Artificial Neural Network Model in Prediction of Meteorological Parameters during Pre-monsoon Thunderstorms, International Journal of Atmospheric Sciences, Article ID 525383 (2013), 1-14.

[18] M. Mishra and K. R. Thakur, Superiority of Artificial neural network model over multiple linear regression model for predicting broccoli yield, International Journal of Agricultural and Statistical Sciences 16(2) (2020), 757-762.

[19] M. F. Moller, A scaled conjugate gradient algorithm for fast supervised learning, Neural Networks 6(4) (1993), 525-533.

[20] A. Mansourkhaki, M. Berangi, M. Haghiri and M. Haghani, A Neural network noise prediction model for Tehran urban roads, Journal of Environmental Engineering and Landscape Management 26(2) (2018), 88-97.

[21] T. Nguyen, H. B. Ly, H. V. T. Mai and V. Q. Tran, On the training algorithms for artificial neural network in predicting the shear strength of deep beams, Complexity Article ID 5548988 (2021), 1-18.

[22] K. M. Z. Othman and A. M. Salih, Scaled conjugate gradient ANN for industrial sensors calibration, Bulletin of Electrical Engineering and Informatics 10(2) (2021), 680-688.

[23] T. N. Prakash and B. N. Veerappa, Interpretation of noise pollution effects of human being using fuzzy logic techniques, International Journal of Computer Science and Mobile Computing 14(4) (2015), 670-683.

[24] J. Refonaa, M. Lakshmi, R. S. S. Srinivasa Rao and P. E. Prasad, Rainfall Prediction using Genetic Algorithm, International Journal of Recent Technology and Engineering 8(2S3) (2019), 597-600.

[25] S. Rana, H. Elgohari and F. Islam, Temperature modelling of Rangpur division, Bangladesh: A comparative study between artificial neural network and linear regression models, International Journal of Agricultural and Statistical Sciences 15(1) (2019), 123-130.

[26] V. Ramakrishna, N. Saigiri, K. Chakribabu, S. Sultana and M. Dhanunjay, Modeling and Prediction of Traffic Noise Levels, IOSR Journal of Engineering 11(1) (2021), 1-13.

[27] M. M. Rahman, M. Shafiullah, S. M. Rahman, A. N. Khondaker, A. Amao and M. H. Zahir, Soft computing applications in air quality modelling: past, present, and future, Sustainability 12 (2020), 1-33.

[28] R. B. Ranpise, B. N. Tandel and V. A. Singh, Development of traffic noise prediction model for major arterial roads of tier-II city of Surat, India using Artificial neural network, Noise Mapping 8 (2021), 172-184.

[29] D. Singh, R. Upadhyay, H. S. Pannu and D. Leray, Development of an adaptive neuro fuzzy inference system based vehicular traffic noise prediction model, Journal of Ambient Intelligence and Humanized Computing 12 (2021), 2685-2701.

[30] P. Setiaji, B. Widjanarko, Y. Syahidin, H. Himawan, N. A. Siregar, L. Harmayani, Samboteng, N. A. Gul and R. Kartikaningsih, Best model and performance of Bayesian Regularization method for data prediction, Journal of Physics: Conference Series 1933 (2020), 1-9.

[31] A. O. Umar, I. M. Sulaiman, M. Mamat, M. Y. Waziri and N. Zamri, On damping parameters of Levenberg-Marquardt algorithm for nonlinear least square problems, Journal of Physics: Conference Series 1734 (2020), 1-11.

[32] S. M. Usman, N. P. Singh, T. Dutt, R. Tiwari and A. Kumar, Comparative study of artificial neural network algorithms performance for prediction of FL305DMY in crossbred cattle, Journal of Entomology and Zoology Studies 8(5) (2020), 516-520.

[33] Y. Wang, Y. Chen and J. Lian, Fuzzy Prediction for Traffic Flow Based on Delta Test, Mathematical Problems in Engineering Article ID 5128528 (2016), 1-13.

[34] W. Xue, P. Wan, Q. Li, P. Zhong, G. Yu and T. Tao, AIMS Mathematics 6(2) (2020), 1515-1537.

[35] X. Zhang, H. Kuehnelt and W. D. Roeck, Traffic noise prediction applying multivariate bi-directional recurrent neural network, Applied Sciences 11 (2021), 1-26.