International Journal of Advance Research and Innovation
Vol. 1(3), Jul-Sept 2013, pp. 118-123
Doi: 10.51976/ijari.131316

Article Info
Received: 10 Nov 2013 | Revised Submission: 25 Nov 2013 | Accepted: 30 Nov 2013 | Available Online: 15 Dec 2013

Application of ANN for Prediction of Surface Roughness in Turning Process: A Review

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ABSTRACT

Surface roughness, is the most specified customer requirements in a machining process. For efficient use of machine tools, optimum cutting parameters (speed, feed and depth of cut) are required. Therefore it is necessary to find a suitable optimization method which can find optimum values of cutting parameters for minimizing surface roughness. To predict the surface roughness many researchers used artificial neural network model. Comparison of the experimental data and neural network model results has shown that there is no significant difference and neural network model was used confidently. This paper deals with review study of works using Artificial Neural Networks ANN, in predicting the surface roughness in turning process. Some of the machining variables that have a major impact on the surface roughness in turning process such as spindle speed, feed rate and depth of cut were considered as inputs and surface roughness as output. The predicted surface roughness values computed from ANN, are compared with experimental data and the results obtained, conclude that neural network model is reliable and accurate for solving the cutting parameter optimization.

Keywords: *Artificial Neural Network; Surface Roughness; Turning; Cutting Parameters; Optimization*.

1.0 Introduction

Surface roughness is mainly a result of process parameters such as tool geometry (i.e. nose radius, edge geometry, rake angle, etc) and cutting conditions (feed rate, cutting speed, depth of cut, etc). The operating parameters that contribute to turning process are Cutting speed, Feed rate, Depth of cut. Vibrations, tool wear, tool life, surface finish and cutting forces etc are also in direct relation with values selected for process parameters. Hence to improve the efficiency of process and quality of the product it is necessary to control the process parameters. Therefore it is necessary to find a suitable optimization method which can find optimum values of cutting parameters for minimizing surface roughness. Surface roughness is with main focus, as it dictates the aesthetics and sometimes ergonomical characteristics of the product. Optimization of machining parameters not only increases the utility for machining economics, but also the product quality to a great extent. The dynamic nature and widespread usage of turning operations in practice have raised a need for seeking a systematic approach that can help to set-up turning operations in a timely manner and also to achieve the desired surface roughness quality. Statistical Design of Experiments may be used to reduce the total number of trials in order to save the time and resources without compromising the accuracy of prediction. These readings may be used to train and validate the Neural Network. ANN is found to be very useful with simulations tasks which have complex and explicit relation between control factors and result of process. Artificial Neural Network can be created using feed forward back propagation technique for simulation of the process .With assurance of accuracy of the predictive capabilities of the neural network; it may be then used for optimization.

2.0 Artificial Neural Networks

Artificial Neural Networks are can be used in several areas of engineering applications and eliminate limitations of the classical approaches by extracting the desired information using the input

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data. The advantage of the usage of neural networks as information processing systems for prediction is that they are able to learn from examples only and that after their learning is finished, they are able to catch hidden and strongly non linear dependencies, even when there is significant noise in the training set. Neural networks are composed of simple elements operating in parallel. These elements are inspired by biological nervous systems. As in nature, the network function is determined largely by the connections between elements. We can train a neural network to perform a particular function by adjusting the values of the weights between elements. Commonly neural networks are adjusted, or trained, so that a particular input leads to a specific target output. The network is adjusted, based on a comparison of the output and the target, until the network output matches the target.

Fig 1: Neural Network Architecture

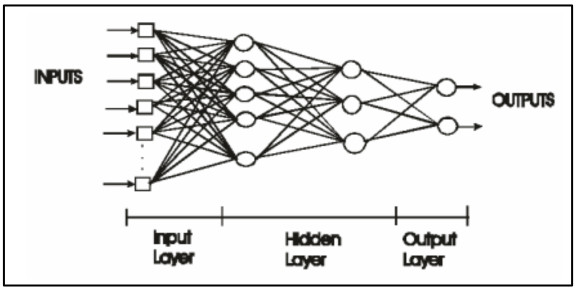
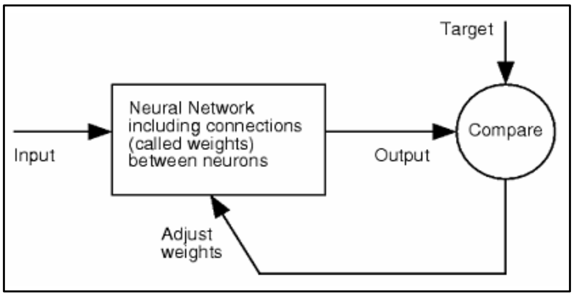


Fig 2: Feedback Control System in NN

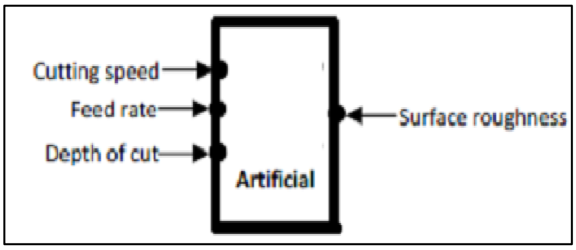


The network architecture/ topology or features such as number of neurons and layers are very important factors that determine the functionality and generalization capability of the network. Training of an ANN plays a significant role in designing the direct ANN-based prediction. Backpropagation is the most commonly used training method where the weights are adjusted according to the calculated error term using steepest descent method.

3.0 Literature Review

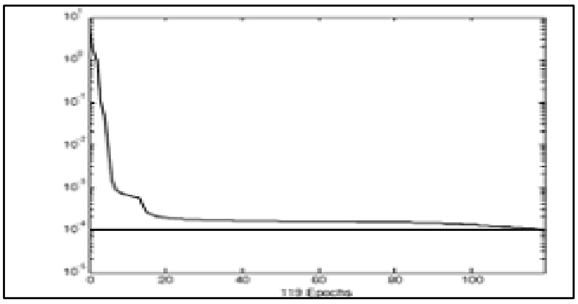
Diwakar Reddy V. et al, "ANN Based prediction of Surface Roughness in Turning", December 2011[4] have carried out machining process on Mild steel material in dry cutting condition in a lathe machine and surface roughness was measured using Surface Roughness Tester. To predict the surface roughness, an artificial neural network (ANN) model was designed through back propagation network for the data obtained. Comparison of the experimental data and ANN results show that there is no significant difference and ANN was used confidently. Three cutting parameters speed, feed, depth of cut have been considered .

Fig 3: Schematic Diagram of ANN for Ra. – Ref [4]



The machining tests have been carried out by straight turning of medium carbon steel (mild steel) on a lathe by a standard HSS uncoated and carbide insert with ISO designation-SNMG 120408 at different speed-feed and depth combinations. Details of the input/output parameters of the proposed ANN model are illustrated in Figure 3. ANN Training performance is shown in the Figure 4.

Fig 4: ANN Training Performance– Ref [4]



By using the MATLAB command „postmnmx‟ the network values have been predicted, regression analysis was adopted to find the coefficient of determination value (R2) for both training and testing phases to judge performance of each network. The multilayer feed forward network consisting of three inputs, 25 hidden neurons (tangent sigmoid neurons) and one outputs (network architecture represented as 3-25-1) was found to be the optimum network for the model developed in their study. They have, concluded from their results obtained that ANN is reliable and accurate for solving the cutting parameter optimization.

A. V. N. L. Sharma et al, "Parametric analysis and multi objective optimization of cutting parameters in Turning Operation of EN353-with CVD Cutting tool using Taguchi Method",2013[1] have studied prediction of surface roughness, using an Artificial Neural Network (ANN) model which was designed through back propagation network using MATLAB 7.1 software for the data obtained.

Experimental details and specifications used in their study are as

Machine tool : Engine Lathe Work material : Mild steel Cutting tool : High speed steel, Cemented carbide tipped tool

Cutting conditions: Dry environment Surface roughness measuring instrument Mitutoyo SJ-201P Traverse Speed: 1mm/sec Measurement : Metric/Inch

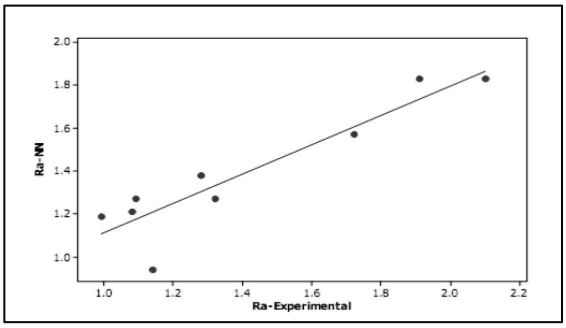
Three cutting parameters speed, feed, depth of cut have been considered .They have concluded in their studies that the approach is suitable for fast determination of optimum cutting parameters during machining, where there is not enough time for deep analysis.

B. Sidda Reddy et al, "Prediction of Surface Roughness in Turning using Adaptive Neuro-Fuzzy Inference System", December 2009[2] have developed surface roughness prediction model for machining of aluminum alloys, using adaptive neuro-fuzzy inference system (ANFIS). The experimentation has been carried out on CNC turning machine with carbide cutting tool for machining aluminum alloys covering a wide range of machining conditions. The ANFIS model has been developed in terms of machining parameters for the prediction of surface roughness using train data. The Experimental validation runs were conducted for validating the model. To judge the accuracy and ability of the model percentage deviation and average percentage deviation have been used. They have also applied the Response Surface Methodology (RSM) to model the same data.

They have concluded from their studies that the ANFIS results are superior to the RSM results.

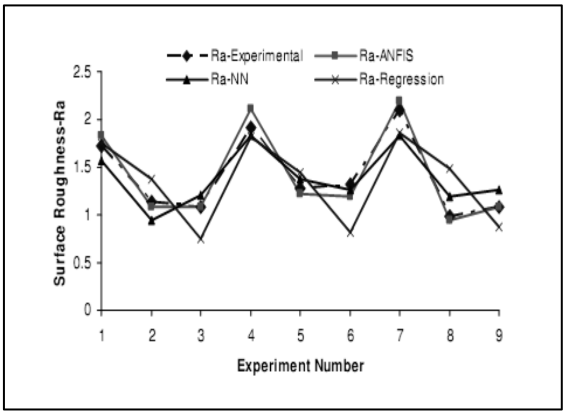
U. Natarajan et al, "On line automated surface roughness inspection for intelligent manufcaturing by machine vision using neuro fuzzy networks", [7] have analyzed the feasibility of fully automated futuristic actories. Their research studies deals with the use of machine vision techniques to inspect surface roughness of a work piece under a variation of turning operations. The surface image of the work piece is .first acquired using a digital camera and then the feature of the surface image has been extracted. A neural fuzzy network using a self organizing adaptive modeling method have been applied to constructing the relationships between the feature of the surface mage and actual surface roughness under various parameters of turning operations. They have, concluded from their results obtained that ANN is reliable and accurate for solving the cutting parameter optimization.

Fig 5: Prediction vs Measured Roughness Using NN Technique- Ref [5]



Sita Rama Raju K et al, "Prediction of surface roughness in turning process using soft computing techniques", 2012[5] have studied three soft computing techniques namely Adaptive Neuro Fuzzy Inference System ANFIS, Neural Networks NN and regression in predicting the surface roughness in turning process. The work piece material used was AA 6063 aluminum alloy .Here 27 data sets were considered for training and 9 data sets were considered for testing .The predicted surface roughness values computed from ANFIS, NN and regression are compared with experimental data.

Fig 6: Comparison of Experimental and Predicted Surface Roughness Values -Ref [5]



Based on the their experimental results they observed that, surface roughness value increases as the feed and depth of cut increases and as the spindle speed increases the surface roughness value decreases.

The minimum surface roughness value is observed at spindle speed of 150 rpm, feed of 0.05 mm/rev and a depth of cut of 0.2 mm respectively.

Zsolt Janos Viharos, "A general ANN model of Turning and its application for surface roughness estimation using acoustic emission signal", 1999[10] have applied ANN models to estimate the roughness of a given finishing operation.

They have used acoustic emission sensor as an information source to improve the estimation capability of the ANN model. To avoid the problem of overlapping and non-invertable dependencies they have used a new approach for building the ANN model. To estimate the surface roughness parameters describing the energy content of the Acoustic Emission signals sensor were used beside the three machining parameters depth of cut (a), feed per revolution (f) and cutting speed (v).Four parameters related to different frequency range are used to describe the energy content.

The frequency ranges were:

1. for E1: 50-750 [kHz]
2. for E2: 99-249.5 [kHz]
3. for E3: 249.5-400 [kHz]
4. for E4: 400-610 [kHz]

Fig 7: Machine parameters used to build up the ANN model. Ref [10]

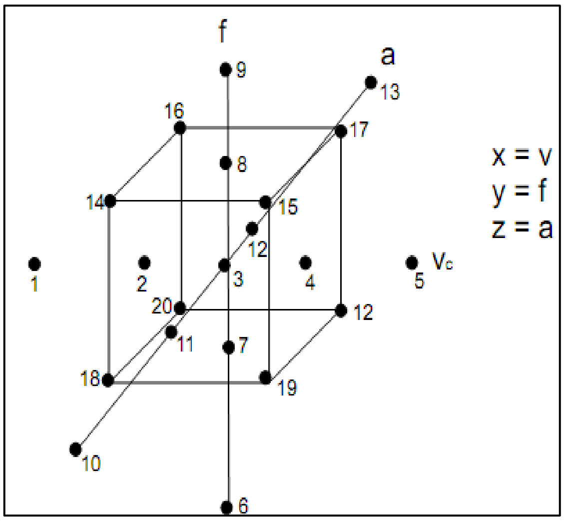
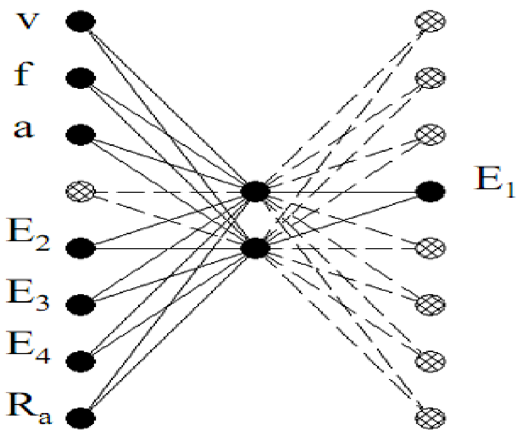
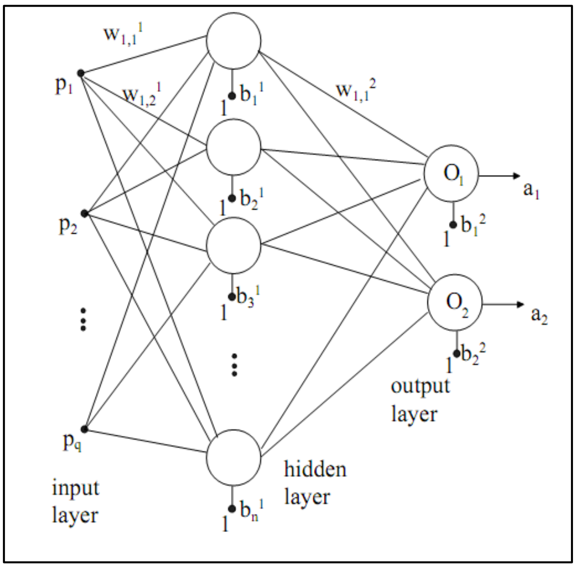


Fig 8: The resulted ANN Configuration with Two Hidden Nodes and with the Allowed Estimation Error of +/-2.5%. E1 Is the Only One Output of the ANN. Ref [10]



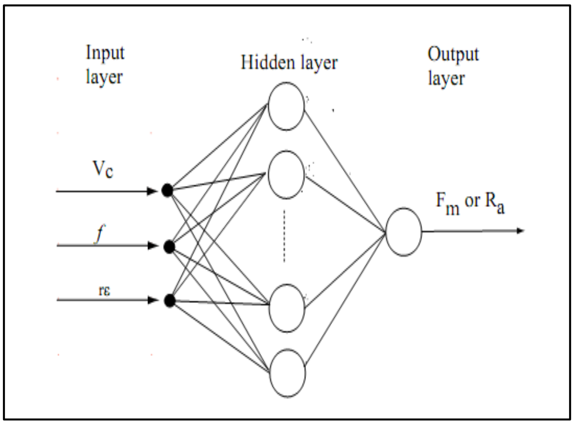
Tugrul Ozel et al, "Neural Network Process modelling for turning of steel parts using conventional and wiper inserts"(2006) [6] , have studied the effects of tool corner design on the surface finish and productivity in turning of steel parts. Surface finishing has been investigated in finish turning of AISI 1045 steel using conventional and wiper (multi-radii) design inserts. Multiple linear regression models and neural network models have been developed for predicting surface roughness, mean force and cutting Power.

Fig 9: Multilayer Feed-Forward Neural Network-Ref [6]



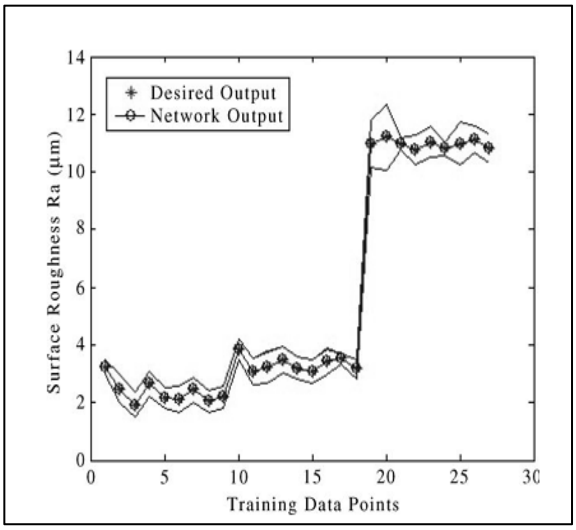
The Levenberg-Marquardt method is used together with Bayesian regularization in training neural networks in order to obtain neural networks with good generalization capability. Neural network based predictions of surface roughness are carried out and compared with a non-training experimental data. These results show that neural network models are suitable to predict surface roughness patterns for a range of cutting conditions in turning with conventional and wiper inserts.

Fig 10: Architecture of Multilayer Feed Forward Neural Network Used for Predictions -Ref [6]



Dejan Tanikic et al, "Metal cutting process parameters modeling: an artificial intelligence approach", June 2009, [3] have shown possibility of implementation of Artificial Intelligent based systems in metal cutting processes and used ANNs and ANFIS forpredictingtheres

Fig 11: Comparison Between Desired Outputs and FAN III Outputs- Ref [9]



Yue Jiao et al, "Fuzzy Adaptive Networks in machining process modeling: Surface roughness prediction for turning operations", (2004) [9] have used combined neural -fuzzy approach (fuzzy adaptive network, FAN), to model surface roughness in turning operations. The FAN network has both the learning ability of neural network and linguistic representation of complex, not well-understood, vague phenomenon.

A model representing the influences of machining parameters on surface roughness have been established and verified by the use of the results of pilot experiments.

4.0 Conclusion

Many authors have used ANN for predicting Surface Roughness in turning process. Some such recent works were studied and a literature review is presented in this paper. It has been observed that the cutting parameters considered for study by most of the authors is limited to three. Cutting Speed, Feed and Depth of cut.

The predicted surface roughness values computed from ANN, are compared with experimental data and the results obtained, conclude that neural network model is reliable and accurate for solving the cutting parameter optimization.

Almost all experimental studies suggest that ANN is a powerful tool and can be used for more accurate prediction of surface roughness.

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