FAULT DIAGNOSIS OF MECHANICAL SYSTEMS USING ARTIFICIAL NEURAL NETWORKS

Research Methodology (ME 0202) Term-Paper

SAMARTH NAYAK K. 4NI15ME135

VIKAS SONI 4NI15ME181

ABSTRACT

An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. ANNs, like people, learn by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. This is true of ANNs as well. This paper gives overview of Artificial Neural Network, working & training of ANN. It also explain the application and advantages of ANN.

Machine fault diagnosis (MFD) recovers all the studies that aim to detect faults automatically in the machines. This study aims to develop a sound based MFD system for drills using the pattern recognition techniques such as principal components analysis (PCA) and artificial neural networks (ANN).

1.INTRODUCTION

The concept of ANN is basically introduced from the subject of biology where neural network plays an important and key role in human body. In human body work is done with the help of neural network. Neural Network is just a web of inter connected neurons which are millions and millions in number. With the help of these interconnected neurons all the parallel processing is done in human body and the human body is the best example of Parallel Processing.

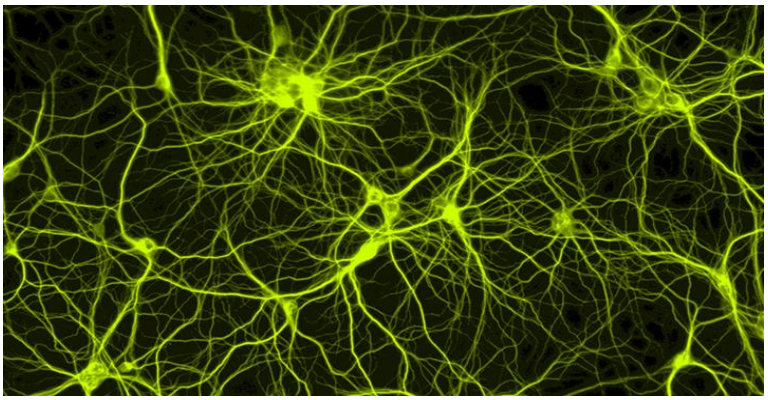


Figure 1: Neural Network in Human Body [1]

A neuron is a special biological cell that process information from one neuron to another neuron with the help of some electrical and chemical change. It is composed of a cell body or soma and two types of out reaching tree like branches: the axon and the dendrites. The cell body has a nucleus that contains information about hereditary traits and Plasma that holds the molecular equipments or producing material needed by the neurons. The whole process of receiving and sending signals is one in particular manner like a neuron receives signals from other neuron through dendrites. The Neuron send signals at spikes of electrical activity through a long thin stand known as an axon and an axon splits this signals through synapse and send it to the other neurons.

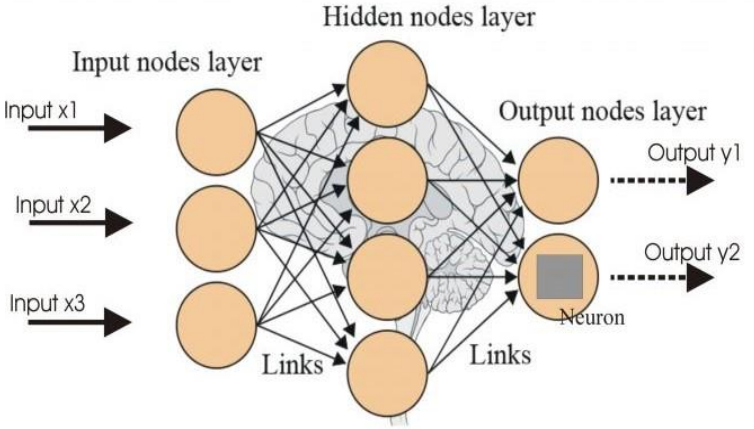


Figure 2: Multilayered ANN [1]

An Artificial Neuron is basically an engineering approach of biological neuron. It has device with many inputs and one output. ANN is consisting of large number of simple processing elements that are interconnected with each other and layered also.

There are various applications of artificial neural network. Every sector in this world wants a system which is it intelligent to solve any problem according to the inputs. Many applications have ability to predict any type of problem by its own with the help Artificial Neural Network phenomenon with the help of various algorithms like Perception Learning Algorithm, Back Propagation Algorithm, SOM Learning Algorithm and ART 1 Learning Algorithm. [1]

Neural networks NWA or simply RN neural networks, are now a data processing technique well understood and managed in several industrial fields, these techniques can extract, in many situations, the maximum of relevant information from the data it has: control processes, properties, predictions, modelling functions, pattern recognition and other industrial applications.

1.1 Basics of Artificial Neural Networks

An Artificial Neural Network (ANN) is a computational model that is inspired by the way biological neural networks in the human brain process information. Artificial Neural Networks have generated a lot of excitement in Machine Learning research and industry, thanks to many breakthrough results in speech recognition, computer vision and text processing. [2]

1.1.1 A Single Neuron

The basic unit of computation in a neural network is the neuron, often called a node or unit. It receives input from some other nodes or from an external source and computes an output. Each input has an associated weight (w), which is assigned on the basis of its relative importance to other inputs. The node applies a function f (defined below) to the weighted sum of its inputs as shown in Figure below:

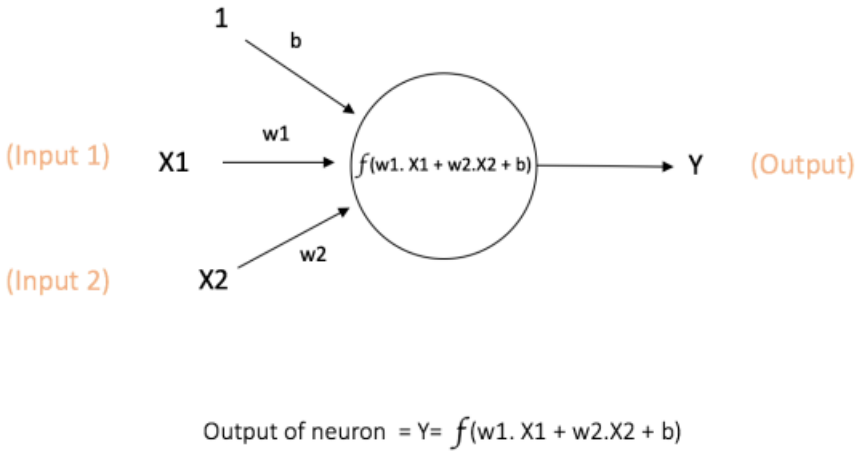


Figure 3: A Single Neuron [2]

The above network takes numerical inputs X1 and X2 and has weights w1 and w2 associated with those inputs. Additionally, there is another input 1 with weight b (called the Bias) associated with it.

The output Y from the neuron is computed as shown in the Figure 1. The function f is non-linear and is called the Activation Function. The purpose of the activation function is to introduce non-linearity into the output of a neuron. This is important because most real world data is non linear and we want neurons to learn these non linear representations.

Every activation function (or *non-linearity*) takes a single number and performs a certain fixed mathematical operation on it. There are several activation functions you may encounter in practice:

- **Sigmoid**: takes a real-valued input and squashes it to range between 0 and 1

$$\sigma(x) = 1 / (1 + \exp(-x))$$

- **Tanh**: takes a real-valued input and squashes it to the range [-1, 1]

$$\text{Tanh}(x) = 2\sigma(2x) - 1$$

- **ReLU** : ReLU stands for Rectified Linear Unit. It takes a real-valued input and thresholds it at zero (replaces negative values with zero)

$$f(x) = \max(0, x)$$

The below figure show each of the above activation functions.

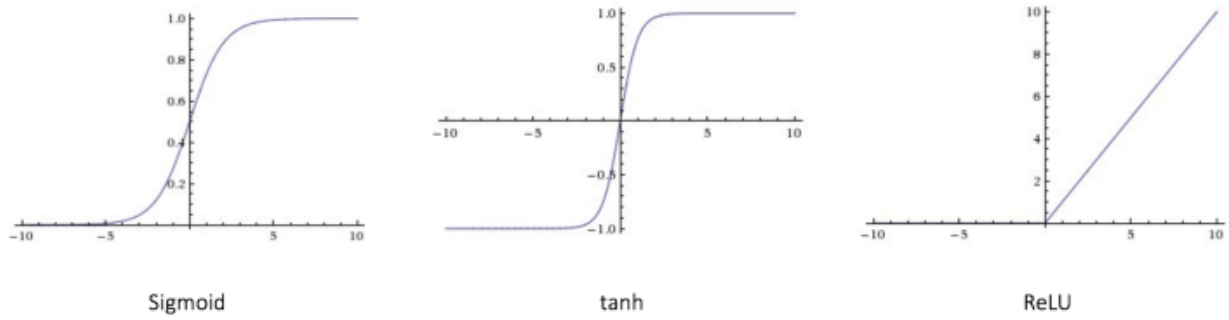


Figure 4: Different Activation Functions

Importance of Bias: The main function of Bias is to provide every node with a trainable constant value (in addition to the normal inputs that the node receives).

1.2 Feedforward Neural Network

The feedforward neural network was the first and simplest type of artificial neural network devised. It contains multiple neurons (nodes) arranged in layers. Nodes from adjacent layers have connections or edges between them. All these connections have weights associated with them.

An example of a feedforward neural network is shown in figure below:

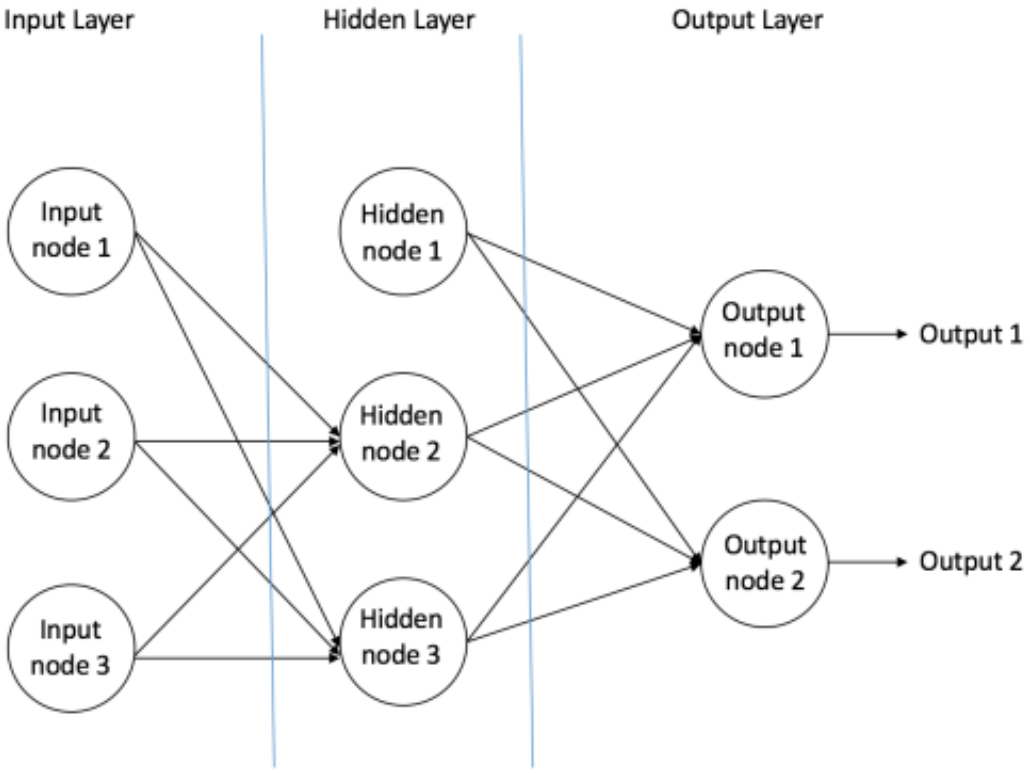


Figure 5: An Example Of Feedforward Neural Network [2]

A feedforward neural network can consist of three types of nodes:

1. **Input Nodes** – The Input nodes provide information from the outside world to the network and are together referred to as the "Input Layer". No computation is performed in any of the Input nodes – they just pass on the information to the hidden nodes.
2. **Hidden Nodes** – The Hidden nodes have no direct connection with the outside world (hence the name "hidden"). They perform computations and transfer information from the input nodes to the output nodes. A collection of hidden nodes forms a "Hidden Layer". While a feedforward network will only have a single input layer and a single output layer, it can have zero or multiple Hidden Layers.
3. **Output Nodes** – The Output nodes are collectively referred to as the "Output Layer" and are responsible for computations and transferring information from the network to the outside world.

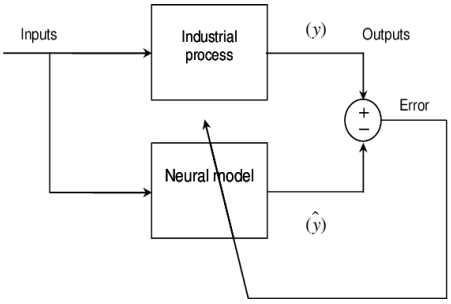
In a feedforward network, the information moves in only one direction – forward – from the input nodes, through the hidden nodes (if any) and to the output nodes. There are no cycles or loops in the network (this property of feed forward networks is different from Recurrent Neural Networks in which the connections between the nodes form a cycle).

Two examples of feed forward networks are given below:

1. **Single Layer Perceptron** – This is the simplest feed forward neural network and does not contain any hidden layer.
2. **Multi Layer Perceptron** – A Multi Layer Perceptron has one or more hidden layers. We will only discuss Multi Layer Perceptrons below since they are more useful than Single Layer Perceptons for practical applications today. [2]

2.LITERATURE SURVEY

Sl No	Author & Year	Title	Comments
1.	W.G. Lucking, M. Darnell and E.D. Chesmore	Acoustical Condition Monitoring of a Mechanical Gearbox Using Artificial Neural Networks.	• This paper is on the application of Time Encoded Speech (TES) to automatic speech recognition using Neural networks. The Neural Network has been applied for determination of irregularities such as Misalignment and Tooth Damage with the help of varying Amplitude and Frequency as an input to the network as many mechanical faults can be diagnosed through varying signal energy. A condenser microphone situated at a distance of 40 mm from the casing of the gearbox was used for the recordings. • When there is a misalignment or tooth damage, the output amplitude will be different from the ideal amplitude, thus giving a way to identify fault in the system. • For this the hidden layers of the Neural network has to be trained using number of datasets and then applying the network on previously unseen data. • Special emphasis was given to the selection of dataset to train the network so that the error is as minimum as possible. • The main conclusion to draw from these tests is that a well balanced data set not only produces a more generalised network solution but also requires less training time. • Difficulty Faced :- Deciding on the parameters of a good training set may become more difficult as the number of machine conditions to be classified increases.

2.	Mohamed Ben Rahmoune, Ahmed Hafaifa and Mouloud Guemana (IEEE)	Neural network monitoring system used for the frequency vibration prediction in gas turbine	• This paper propose the development of fault diagnosis system for the vibration detection and isolation using artificial neural networks, applied to a gas turbine system in order to secure the vibration frequency acquired by the sensors at the bearings and then predicting the behaviour of turbine shaft.  ***Fig 6. General Scheme Of Modelling*** • The neural model generates a neural observer for the modelling by Artificial Neural Network to compare the output of the process with their actual output (actual process output with the output of the neural network).
3.	Caleb Vununu and Ki-Ryong Kwon, Kwang-Seok Moon, Suk-Hwan Lee 2017 16th IEEE International Conference on Machine Learning and Applications.	Automatic Fault Diagnosis of Drills Using Artificial Neural Networks	• This paper aims to develop a sound based MFD system for drills using the pattern recognition techniques. • This study presents a fault diagnosis Investigation for drills using the sounds they produce during their active time. The principal damage considered in this study is the wear located on the tip of the drill. Data sounds were collected from both healthy and damaged drills using the effectiveness of the frequency domain based analysis. • The Fourier analysis provides useful tools for analyzing the data in the frequency domain. • Investigation of fault diagnosis system of drills using the sounds they produce. They have demonstrated the ineffectiveness of using the time domain based analysis because the time series of the sounds produced by the drills do not contain the health information of the drills.

4.	Hao Gang
	
	2016 IEEE
		Automobile Fault Diagnosis System based on Improved Neural Network	• This paper has dealt with automobile fault diagnosis system based on improved neural network.
			• Fault information is taken as training sample of neural network after the normalization. BP neural network is improved based on artificial fish swarm algorithm.
			• The process of improved BP based on artificial fish swarm
			  • Initialize the artificial fish parameters.
			  • Predetermine the original structure of BP neural network according to the actual situation.
			  • The algorithm starts .Choose the behaviour with the highest fitness value for execution..
			  • Determine whether neural network output error reaches set value. If it meets the condition, it outputs the optimal network structure and algorithm is over. Otherwise, the iteration times increases by one.
			  • Determine whether the iteration time has reached its maximum number of iterations. If it meets this condition, the optimal network structure is output.
			Simulation results show that engine fault diagnosis based on improved BP has better performance.

5.	Bo Liu, Hongxia Pan, Xiuling Li	An Expert System for Fault Diagnosis in Diesel Engine Based on Wavelet Packet Analysis Based Neural Network	• The vibration signal of diesel engine often gives much dynamic information of mechanical system condition. • In the experimental work, four conditions are designed to estimate the proposed fault diagnosis system. They include an engine without any fault, air leakage of the intake manifold, one cylinder misfiring, and two cylinders misfiring. The engine is run in the 1900 rpm. After the signal processing and feature extraction using WPA (Wavelet Packet Analysis), 80 groups of the data are used as the training set, the remaining 20 groups are used as the diagnosis test set samples.

6.	Huiqing JIANG, Suling JIA	Fault Diagnosis of Marine Main Engine Based on BP Neural Network	• This paper describes a fault diagnosis method for main engine based on Back Propagation neural network with the system fault classified according to fault tree analysis (FTA). • FTA is an effective method to analyze the reliability and security of a complicated system. It employs a top-down approach that begins with identification of an undesired event (top event, performs as root node) and ends with identification of all important events (child nodes) leading to top event. In order to easy the diagnosis, the fault degree is classified into 3 levels: non-fault, simple-fault and severe-fault. According to the output variable y, the result will be treated as follows: = If y is close to 0.5, it is simple-fault. If y is close to 1, it is severe-fault. Otherwise, there is non-fault. • This paper studies the fault and its diagnosis of marine main engine, and introduces a tree structure fault-classify method. The process could also be applied to the fault diagnosis of other components of the engine.
7.	Peng Wen (2009 International Conference on Measuring Technology and Mechatronics Automation)	Vibration Analysis and Prediction of Turbine Rotor Based Grey Artificial Neural Network	• In this paper, the management of the complexities of vibration reasons, a new method to predict the vibration and analyze the reliability of the turbine rotor is proposed. • Based on analyzing the vibration reasons, the measuring positions of vibration are obtained, and then the rotor will be periodic measured under the normal operation condition to get the test date, namely the amplitude of vibration. Based on the amplitude, the grey model optimized by Back Propagation (BP) neural network is established. • It could find vibration fault earlier in the operation of the rotor and determine the maintenance program which can ensure the secure reliability of the turbines.

8.	R. J.Howlett	Condition monitoring and fault diagnosis in a domestic car engine using a neural network.	• The fuel mixture strengths can be specified in terms of the excess air factor, also known as the λ ratio. • This is defined as follows :- $\lambda = AFR \backslash AFR_{st}$ where, AFR = the current air fuel ratio and AFR_{st} = the stoichiometric air fuel ratio. • The ignition system of a four-cylinder petrol-fuelled spark-ignition engine of the type used in many domestic motor-cars was adapted by the addition of a voltage test-point at the spark plug. Voltage waveforms were sampled and recorded for λ values of 1.0, 1.2 and 1.4 measured by analysis of the exhaust gas. A number of types of neural network were trained using this data and then tested on unseen data to determine their ability to correlate the unseen voltage with the λ.
9.	Wang Hongbo (2014 Fifth International Conference on Intelligent Systems Design and Engineering Applications)	Research on Active vibration control Based on Artificial Neural Network	• In this paper, magneto-rheological active vibration control was researched based on Artificial Neural System. • Artificial neural network (ANN) used numerical calculation method, carry on the active control research of passive vibration isolation system resonance suppression simulating the voice coil actuator, theory method of system vibration behavior is built. • The research adopted ANN as control method, which aimed at system natural frequency resonance suppression to passive vibration isolation platform, have clearly made a good vibration suppression effect, but, For the framework part of ANN, different network architectures can be adopted.
10.	Hardianto Dwi PA, Faza Alfaradin, Zaqiatud Darojah, Raden Sanggar D. (2015	Artificial Neural Network Based Identification System for Abnormal Vibration of Motor	• This paper reports an early work of machinery fault detection system module development. The system is developed and employed on a mechanical platform having a series of 3 aluminum rotating discs with unbalanced rotating mass to simulate an abnormal condition of a real machinery. • Artificial Neural Network (ANN) method is used to determine and to localize the

	International Electronics Symposium (IES))	Rotating Disc System.	abnormality by utilizing the vibration data. The method utilizes 3 features of time domain and 2 feature frequency domain signal characteristics. • After the ANN was trained, this detection system was able to identify the plant condition of 90% accuracy. • This detection system is intended to have a capability of either to give an early warning due to an abnormality of the machine vibration or to localize the position of such abnormality among the discs.
11.	Leo S. Bartolome, Argel A. Bandala, Cesar Llorente, Elmer P. Dadios	Vehicle Parking Inventory System Utilizing Image Recognition through Artificial Neural Networks	• An automated vehicle logging system is introduced in this paper. The system utilizes character recognition through images captured from the entrance of a parking area. • Character recognition engine is primarily implemented using feed forward neural networks. There are 50 input neurons which are defined by resizing each character into 25x25 pixel image and summing all the pixel values in each row and each columns resulting to 50 sums. • After which a numerical value will be produce and will signify a character equivalent. Characters are recognized separately. This process is done until all of the characters are recognized. • The system is trained using 5860 sets of training data yielding a system with 0.0001645724% error.
12.	Ogaji Stephen O.T, Professor Singh Riti	Advanced Engine Diagnostics Using Artificial Neural Networks	• In this paper, an artificial neural network system is trained to detect, isolate and assess faults in some of the components of a single spool gas turbine. • Determining the sensors to be monitored. This can be done by making use of the sensor information available for the given engine or applying such techniques as gas path analysis to determine the optimum combinations that would be effective to diagnose the desired faults.

			• The measurement patterns are classified into either faulty (F) or not faulty (NF) in class 1. If there is no fault detected in the patterns and if the network is sufficiently accurate, then there is no need for further diagnostic checks. If a fault is detected, the patterns are passed on to CLASS 2 where they are classified into either sensor faults (SF) or component faults (CF). If a sensor fault is detected, the pattern is passed on to an auto associative network (AUTOASSOC1), whose output has been constrained during training. If not then the patterns are passed on to another classification network called CLASS3 which classifies the patterns into any of the three categories i.e single component faults (SCF), dual component faults (DCF) and multi-component faults (MCF).
13.	Yang Xuhong (2014 IEEE)	Application of Artificial Neural Network to Fault Diagnosis in Nuclear Power Plant	This paper reviews on the various fault origins in a nuclear power plant water feed system. • The SOM artificial neural network possesses the full capability of unsupervised training and self adapting adjustment, so it can response differently according to different inputs and this is suitable for solving classification problems. The SOM network can automatically gather and sort data without pre-setting goals, thus it can solve fault diagnosis problems. • The SOM network is composed of input layer and output layer. Because of the lack of hidden layer, it is called single layer network. Each of the nerve cells in the input layer is connected bi-directionally to all the ones in the output layer, but with different weights. The training sample set is made up of symptom set and fault set. The symptom is the input of the sample while the fault set is the output. The output: “0” stands for ok while “1” stands for fault.

14.	S. Simani, F. Marangon, C. Fantuzzi	Fault diagnosis in a power plant using artificial neural networks: analysis and comparison	In this paper a model-based procedure of analytical redundancy via state estimation techniques for the diagnosis of faults regarding sensors of a dynamic system is presented. • The number of filters is equal to the number of system outputs, and each filter is driven by a single output measurement and all the inputs of the plant. The classification method is typically an off-line procedure where the fault mode is first defined and the data collected. In this situation, certain measurement patterns correspond to normal operation and other patterns correspond to faulty operations: the training of neural networks using this kind of information is called supervised. Multi Layer Perceptron (MLP) and Radial Basis Function (RBF) networks are typical examples of supervised trained network architectures.
15.	Maitha H. Al Shamisi, Ali H. Assi and Hassan A. N. Hejase	To Develop Artificial Neural Network Models for Predicting Global Solar Radiation in Al Ain City – UAE	Building reliable solar energy systems regardless whether the system is a photovoltaic or thermal solar energy system requires information on the GSR in the region where the system is to be built. • Different training algorithms were used with changes in the number of neurons and hidden layers. In addition, different transfer functions including the tangent sigmoid, log sigmoid and linear functions. Designing ANN models follows a number of systemic procedures. In general, there are five basics steps: (1) collecting data (2) preprocessing data (3) building the network (4) train (5) test performance of model. • Collecting and preparing sample data is the first step in designing ANN models. measurement data of maximum temperature (°C), mean wind speed(knot), sunshine (hours), mean relative humidity(%) and solar radiation (kWh/m2) then, (1) solve the problem of missing data, (2) normalize data and (3) randomize data.

			• During the training process, the weights are adjusted in order to make the actual outputs (predicated) close to the target (measured) outputs of the network.
16.	Simone Marinai, Marco Gori	Artificial Neural Networks for Document Analysis and Recognition	This paper deals with Artificial neural networks and their extensive application for document analysis and recognition. Most efforts have been devoted to the recognition of isolated handwritten and printed characters with widely recognized successful results. • To face document analysis and recognition and graphical item recognition tasks, one needs to select adequate neural architectures and learning schemes and to conceive appropriate representations of the data to be processed. • The first part is devoted to the analysis of neural methods related to pre-processing and segmentation of document images and graphs. • The second part covers the "reading" of written documents and includes OCR, graphical item. • Pixel classification was initially applied to the binarization of document images and graphs. The pixel class is computed by combining the MLP outputs. In this coding, one output unit is assigned to each class and all the outputs are set to 0, with the exception of the one corresponding to the correct class, which is set to 1.
17.	Kh Tohidul Islam, Ghulam Mujtaba, Dr. Ram Gopal Raj, Henry Friday Nweke	Handwritten Digits Recognition with Artificial Neural Network	In this study, they implemented a multi-layer fully connected neural network with one hidden layer for handwritten digits recognition. • The testing has been conducted from publicly available handwritten database. From that database, they extracted 28,000 digits images for training and 14,000 digits images for performing the test. Their multi-layer artificial neural network has an accuracy of 99.60% with test performance. • Overall, 99.60% of the predictions are correct

			and 0.40% are misclassifications in their experiment.
18.	Robert E. Uhrig	Application of Artificial Neural Networks in Industrial Technology	The paper suggests the basic principles involved while analysing the system using ANN is the same whether the application is to check a valve, rotating machinery, inspection for wear in mechanical system, or the evaluation of fatigue life. • Vibration Monitoring -Machine Fault Diagnosis Based on Vibration Analysis -Ball Bearing Fault Diagnosis from Vibration Analysis • Monitoring Equipment For Operability -Monitoring of Check Valves for Operability -Bearing Fault Diagnosis using Two Vibration Sensors -Control Rod Wear Recognition -Real-Time Estimation of Fatigue Life -Sensor Validation and Plant wide monitoring An inferential sensing system is defined as an instrumentation system which infers values of complex process variables by integrating information from multiple sensors. Inferential sensors, which often incorporate for process modelling is used for developing ANN.
19.	Purva Deshpande, Nilima Warke, Prakash Khandare, Vijay Deshpande	Thermal Power Plant Analysis Using Artificial Neural Network	The intention of this paper is to give an overview of using artificial neural network (ANN) techniques in power systems. Here Back Propagation Neural Network (BPNN) and Radial Basis Neural Network (RBNN) are used for comparative purposes to model the thermodynamic process of a coal-fired power plant, base on actual plant data and this works as the internal model for prediction of the Heat Rate and Boiler Efficiency. • Thus for heat rate nine variables and for boiler efficiency five variables are selected with 2246 rows for training and 750 rows for testing are selected. • Here for BPNN training has 2 hidden layer, [10, 10] neurons and RBNN training with spread as 1 and error goal as 0.0002.

			• Thus from the sensitivity results, it is seen that the most critical parameter affecting heat rate and boiler efficiency are condenser vacuum and gas temperature at air preheater outlet.
20.	Jesus De Lein, Edgar N. Sanchez	Mechanical System Tracking Using Neural Networks	In this paper they analyzed a control law, which forces an artificial output of a nonlinear system to behave like a linear one, allowing signal tracking; as an effect of this tracking, the system state converges to any selected equilibrium point. • Introduction of the structured neural networks estimate on-line a matrix required to calculate this control law. The applicability of the approach is illustrated by simulations results. • To estimate this matrix on-line, we considered the structured neural networks introduced in the system; whose learning and convergence properties are presented in matrix. These networks are very useful for solving matrix algebra problems in a highly parallel form, they constitute a simplified class of static feed forward neural networks, where the activation function is replaced by a simply identity function.

3.RESEARCH GAP

1. When we decide to take audio as an input to study the variation in amplitude as well as frequency, it becomes difficult for the sensor sensing a particular machine element to differentiate it with the other machine members. The unwanted background noises also make it difficult to get a pure input. So, studies have to be made for isolation of unwanted noise.

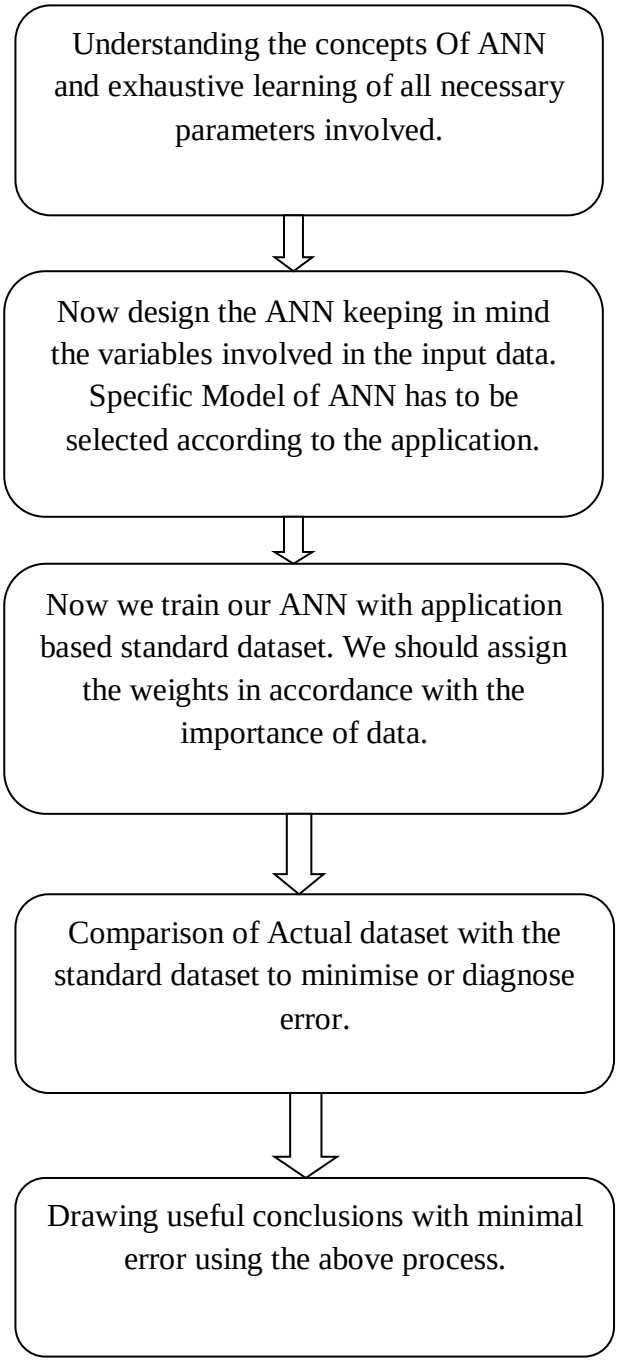
2. Deciding on the parameters of a good training set may become more difficult as the number of machine conditions to be classified increases.

3. The variables, whether dependent or independent have to carefully selected while training the Artificial Neural Network (ANN) for a particular application. Because ANN can be

applied in many fields of study, it becomes important to select the variables involved with utmost care.

4. As we encountered in many papers the input from a mechanical system was taken by audio recognition which result in mixing of unwanted background noises also. We propose to use specific sensors as an input source for ANN, such as a seismometer for vibration measurement, thermostat for temperature measurement, etc.

4.METHODOLOGY



5.CONCLUSION

We use Artificial Neural Network to minimise the error which might be caused while diagnosing an abnormality in a mechanical system. Neural networks are time efficient and when trained properly, provide results with minimum error. Because artificial neurons are structured in the form that human neurons are, they can constantly teach themselves by receiving new information, analyzing it and improving the result step by step. Of course, the more information the network gets, the more complicated it is to analyze, so the number of neurons in the network can exceed a few thousand, and the network's complicated structure is the reason for longer processing times.

But, if they get something for the first time, they commit it to memory and the machines gradually become smarter and smarter. Now it is time to look into how neural networks can be applied in any other kind of activity.

6.REFERENCES

1. A View of Artificial Neural Network, Manish Mishra and Monika Srivastava, IEEE International Conference on Advances in Engineering & Technology Research (ICAETR - 2014), August 01-02, 2014, Dr. Virendra Swarup Group of Institutions, Unnao, India.

2. https://ujjwalkarn.me/2016/08/09/quick-intro-neural-networks/

3. Acoustical Condition Monitoring of a Mechanical Gearbox Using Artificial Neural Networks W.G.Lucking, M.Darnel1 and E.D.Chesmore Hull - Lancaster Communications Research Group. The University of Hull, Cottingham Road, Hull, HU6 7RX

4. Automatic Fault Diagnosis of Drills Using Artificial Neural Networks, 2017 16th IEEE International Conference on Machine Learning and Applications

5. Fault Diagnosis of Marine Main Engine Based on BP Neural Network Huiqing JIANG, Suling JIA School of Economics and Management Beihang University Beijing, China

6. Automobile Fault Diagnosis System based on Improved Neural Network ,Hao Gang Shijiazhuang Vocational Technology Institute, Shijiazhuang, Hebei 050081, China

7. An Expert System for Fault Diagnosis in Diesel Engine Based on Wavelet Packet Analysis and Hybrid PSO-DV Based Neural Network Bo Liu, Hongxia Pan, Xiuling Li School of Mechanical Engineering & Automation, North University of China, Taiyuan, China

8. Neural network monitoring system used for the frequency vibration prediction in gas turbine - Mohamed Ben Rahmoune, Ahmed Hafaifa and Mouloud Guemana Faculty of Science and Technology Applied Automation and Industrial Diagnostics Laboratory University of Djelfa, Algeria

9. Vibration Analysis and Prediction of Turbine Rotor Based Grey Artificial Neural Network- Peng Wen Department of Production Harbin Turbine Company LTD Harbin, China

10. Condition Monitoring And Fault Diagnosis In A Domestic Car Engine Using A Neuralnetwork - R. J.Howlett

11. Research on Active vibration control Based on Artificial Neural Network Wang Hongbo Wulan Technology Co., Ltd. high tech Zone Ningbo,Ningbo Zhejiang , 315042, China

12. Artificial Neural Network Based Identification System for Abnormal Vibration of Motor Rotating Disc System -2015 International Electronics Symposium (IES)

13. Vehicle Parking Inventory System Utilizing Image Recognition through Artificial Neural Networks -Leo S. Bartolome, Argel A. Bandala, Cesar Llorente, Elmer P. Dadios Electronics Engineering Department De La Salle University.

14. Application of SOM Artificial Neural Network to Fault Diagnosis in Nuclear Power Plant- Yang Xuhong Faculty of Automation Engineering Shanghai University of Electric Power Shanghai China.