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Artificial Intelligence in Predictive maintenance to predict fault in machines

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Abstract

Artificial intelligence is one of the most widely used technologies in modern times. In terms of industrial AI, techniques such as artificial neural networks (ANN) are used maintenance industry for several fault and risk identification applications. In this paper, an overview of AI methods is described in addition with ANN technology. Predictive maintenance approach is evaluated from sets of data collected from literature survey. Fault detection of machines are analysed using different ANN algorithms. Basically the faults on pneumatic systems are tested out with 9 sets of different algorithm data. The results show that, ANN is a promising tool that can be used in predictive maintenance of machines. It helps in forecasting the targeted components of the machine before-hand and predicts their failures. This reduces the time and energy in the complete process.

Keywords: ANN, predictive maintenance, data sets, artificial intelligence, fault detection

I. Introduction

The areas and sectors of manufacturing as well as industrial applications around the globe are undergoing a massive increase in the demands to generate goods with optimum quality and maintaining their operating procedures with maximum efficiency. The production of typical items such as textiles, aircraft, automobiles and appliances require numerous complicated techniques and methods comprised of non-linear dynamic systems. Hence these methods are difficult to comprehend by scientific based approach and further they require experience for proper functioning.

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Failures taking place at the time of manufacturing or production, results in multiple implications in negative side for instance rise in the downtime, degraded productivity and often might cause risks to safety measures. Therefore, preventive based maintenance comes in to play. The technique utilized to identify the faults in machinery is inspired from preventive maintenance and is termed as condition based maintenance. This ensures that the production extends to its maximum capability. [1]

The modern day environment of industries all over the world needs solid, trustworthy and lean based production in order to complete the demands. This might be fulfilled by techniques such as Kanban systems and JIT planning. This can primarily mean that overproduction is estimated as a waste, the capacity of storage at the customer is neglected to essential stock in order to overcome the production for next few hours or even days..[2]

Because of the fact that any overproduction is non-desirable as well as the stock comprising the goods which are finished at the customer and the supplier is restricted to minimum. The raised demands are aimed on the process of production from the goods which are coming until the final item is completed. The Overall equipment effectiveness (OEE) is the most essential keys for production facilities in their performance as indicators and reflects the effectiveness of the operations utilized in manufacturing.[3]

A. Smart production and maintenance

The technology of production is undergoing the fourth leap covering the transition through the first three namely mechanization, electrification, andautomation. Quick and faster development in the technology generates a need required for the growth of any organization. As a result, in the present day, there is an experience of virtual world to the physical world in the field of production and maintenance. Depending on the above thoughts, a reasonable question arises as up to what extent the management in the production can be substituted based on artificial intelligence (AI). However, several implications arise as the optimality among the human made and machine made decisions. Who can set the target for the performance and how? What type of skill required in the line? Is there anyone targeted for errors? And lastly, up to what extent the decisions will be purely human made.?[4]

The primary constituents in the industry of AI might be featured as ABCDE. These

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are "(A) Analytical technology, Big data technology (B), Cloud or Cyber technology (C), Domainknowhow (D) and Evidence (E)." Analytics are the primary key of AI, that can incorporate value if the other factors are involved. Big Data as well as Cloud technology are important elements that incorporate the information source and thus provide a base for the AI. Further the Domain knowledge and Evidence are also important keys that are comprehended in this context. Domain knowledge is the essential aspect for the following. 1) "understanding the problem and focus the power ofIndustrial AI into solving it; 2) understanding the system so thatright data with the right quality can be collected; 3) understandingthe physical meanings of the parameters and how they are associatedwith the physical characteristics of a system or process; and4) understanding how these parameters vary from machine tomachine". Evidence is utilized in validation of industrial AI models and introduce them with cumulative ability of learning. With the help of producing patterns of data and its identification as evidence can improve the AI technology to get more precise results.[5]

II. Predictive maintenance

Predictive maintenance is the work carried out by common ideology by recording the indicators regarding the conditions of operation of the machines. The data will be available to confirm the maximum interval among the repairs and degrade the number as well as the cost regarding the non-scheduled outages taking place because of failure in the machine.[6]

The predictive maintenance utilized developed form of AI algorithms in the form of machine learning as well as artificial neural networks to idealize regarding malfunction of the working machinery parts. This helps in easy identification well as reduces the cost drastically for the unplanned downtime. This also helps in increasing the Remaining Useful Life (RUL) ofproduction machines and equipment. At the time where maintenance is non-avoidable, the working technicians are briefed on prior basis regarding the parts that needed checking and also which tool to be focussed along with the technique resulting in precise prediction of failure and repairs. This helps in scheduling beforehand..[1]

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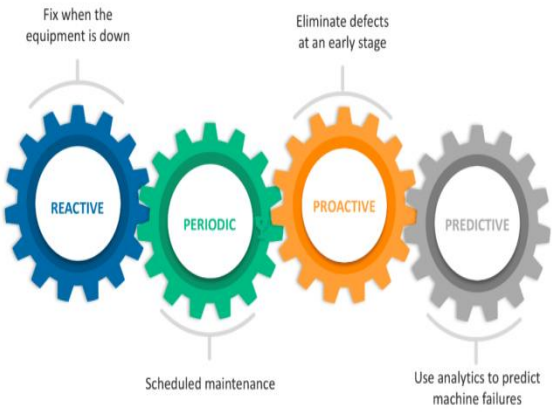

Fig.1: Predictive maintenance process

The maintenance in the industry might be corrective or else preventive. Corrective maintenance is carried out to rectify the errors after the breakdown of the machine. Preventive maintenance is carried out anything which is done prior to avoid breakdown of machine. The most simplified way of preventive maintenance is based on time where the components are repaired or else replaced as per the scheduled which is predetermined. This results in saving of time as well as cost as the complete machine is not inspected for replacements or repairs..[7]

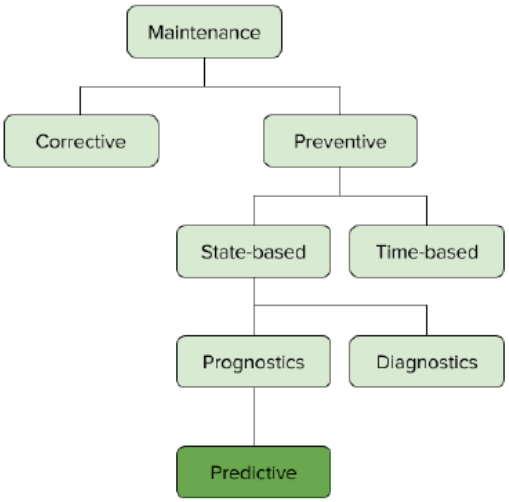

Fig.2: Different aspect of maintenance

When there are cultured techniques for capturing data, the sets of data generally contain ten thousand records. Whereas the application of preventive maintenance can be very costly and there is a need to utilize marginally statistical tools or even advanced form of data mining methods such as ANN. This also results in installation of complex tools and techniques.[8]

III. Artificial intelligence

Artificial Intelligence, is altering the methods by which a product is designed. One of the techniques is to feed the pre defined data related to the design and specification by the user or engineers into an AI algorithm (in thiscase referred to as “generative design software”). The input data can include limiting parameters for instance “material types, availableproduction methods, budget

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limitations and timeconstraints". The algorithm figures out every possible solution of configuration, prior to the delivery of best solution from the provided set of input data. The solution proposed can be further evaluated by means of machine learning, offering added highlights regarding the best design. This process can be carried out in a loop until an optimal solution is obtained. The key benefit of this approach is that "an AIalgorithm is completely objective – it doesn't default to whata human designer would regard as a logical starting point.No assumptions are taken at face value and everything istested according to actual performance against a wide rangeof manufacturing scenarios and conditions". [9]

A. ANN

Artificial neural networks are sub category of AI which has got a lot of attention and has multiple applications in engineering. It utilises analytical based approach to practical methods and provide quick and easy results. ANNs have depicted excellent potential for successful models with complicated input/output interconnection where the presence of non-linearity and inconsistent/noisy data severely impacts other approaches. ANN simulation models are robust and can bear faults. They can be applied with qualitative as well as quantitative type of data. All is required is to provide a data set in form of input in to an algorithm.[10]

B. Learning algorithms

The method of learning is primarily the manipulation of signal input weights to affirm the best results computed. At the time of designing the ANN model, the phase under test should have a data set. This data set is categorised in three parts:a training set, a validation set and atest set. The set for training is utilized for basic training regarding the networks. The set for validation is utilized for tunining the algorithm used in order to confirm the best result and the set of test is incorporated to evaluate the final results designed from the networks in the required algorithm. It becomes essential that every set includes varying sets of data. Two types of learning techniques are utilized: the supervised learning and the unsupervised learning. Generally the unsupervised learning is implemented for system optimization as it helps in minimizing the cost and energy and it is easier in application compared to supervised one.[11]

ANN might be implemented in predictive maintenance. Several sensory frameworks are available, such as simple capacitive and inductiveproximity sensors and photoelectric or laser sensors and vibration

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sensors to developed industrial systems such as thermographic cameras, vision systems, process control systemsand measurement sensors that can record huge amount of data from the machines which can be used in evaluations and analysis. ANN reflects assuring outcomes and a solid tool for calibration of these data so as to predict the activities under predictive maintenance. Several researchers have investigated and worked on ANN models. Multi-layerperceptrons (MLP) are one of the most utilized algorithms utilized for diagnosis of motors, valve checks, performance as well as degradation in the robotics engineering.[12]

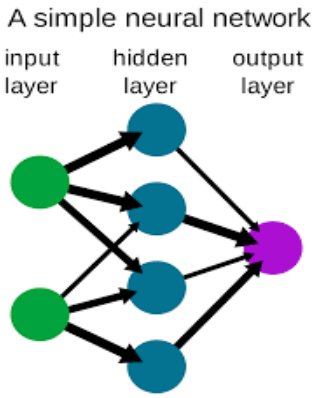

Fig.3: ANN Process

IV. Methodology

Infrared based thermography is a non-corrective technique utilized in maintenance in order to identify the distribution of heat in machine components. This is based on the fact that every object emits infrared radiations. In industrial maintenance, this technique is utilized to identify the heat zone areas of the machine components to detect the heat losses. Specifically used in electrical equipment, transformers' loads etc. The thermal imaging of electrical machines cabinets can rapidly depict the non-visible temperature uniformities regarding electrical devices such as circuit breakers,transformers, fuses, relays etc. Concentration of heat on such devices might cause faults or damage to the complete machinery. The identification can be carried out by simple observation of temperature contours in form of different color that show permissible temperature limits. The temperature ranges in 3 sections: "no defect with temperature differenceless than 5 °C; probable deficiency with difference above 5 °C and a defect withmajor discrepancy with temperature difference above 15 °C. This method develops from the fact, that it is solid in contrast to the variations of emissions of the subject and calibrating its temperature. The process of normalisation is carried out by converting the images in greyscale and the targeted areas were highlighted for observation and detailed analysis. The method used comparison of hotspot features like highest grey value, kurtosis,standard deviation, entropy, contrast, energy against the reference areas". In order to select the feature, they

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utilized a analysis of discriminant type so that the noise is degraded in the data and implemented tests for further analysis. The results showed that there was 83% sensitivity rate on the defects while parallel discriminant analysis prediction producedbetter results on specificity and accuracy.

A. Detection of faults on pneumatic systems

Pneumatic systems comprising of several pneumatic cylinders are utilized as cost effective and reliable components for machine having the driven parts and where there is no accurate location for positioning. The framework of pneumatic cylinder as well as the air valves obstruct was aimed. A station comprising testing units of linear potentiometerand proximity sensors (optical, capacitive and inductive) was used for the process of training as well as simulation of modes such as empty "magazine, dropped work piece, no pressure atvalve, low pressure with a conformity rate from 93 till 98 %. Few of the selected sensors were utilized with vacuum analogue pressure sensor, materialhandling arm pressure sensor where the data were classified into two classes, signalbelow or over the 3 V. The ANN applied was a type of adaptive resonance theory (ART) having the topology of back propagation. A total of 9 sets of fault modes were analysed in the study. However, it is recommended to reduce to 5 as per clarification and accuracy of results in maximum way possible.

V. Results and Discussion

The results were successfully evaluated. From the results a multi-layer perceptron ANN is obtained as shown in table 1. Several ANN models are utilized for the calibration of results including the MLP. It is involved because of its simplified application. It classifies the machine components and the failures as per the working conditions. In case of implementation of MLP for faultdetection caused by mechanical damage, it would be convenient to use boundary samplesin training phase.

Table 1: Outcomes from AI

Predictive maintenance task	**ANN Design**	**Achieved results**
crankshaft crack	RBF	95%
bearing condition	MLP	80%
bearing condition	GA	90%
bearing condition	MLP	96%
bearing condition	MLP	95%
bearing condition	FF ANN	81%
bearing condition	FF ANN	87%
electrical fault	MLP	92%
pneumatic system	ANN	94%

The utilization of artificially created damages and faults, it might result in non-recoverable damage" or fault at the initial

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stages to the other parts of the machine. This might result in progressive damage to the overall machine if the first wear or damage is not identified at correct location and time. This type of method can be beneficial where the assumed faults are to be made in a machine. In case of predictive maintenance is more useful to utilize with ANN technology which can provide the prediction of failure beforehand.

VI. Conclusions

Artificial neural networks depict robust potential in handling industry based applications. The present paper very well represents the need and theme of utilizing AI in industrial purposes specifically in maintenance and production. Because of computations of ANN, the human efforts is reduced in utilizing the mindset and skills in any operation. Detecting faults with help of machine learning is a modern technology whereby it reduces the time and cost. The results obtained are more accurate as well as precise compared to human evaluations. The results show that MLP design model using ANN algorithm shows 96% accuracy from the simulations. This is the maximum accuracy achieved out of all the nine algorithms used in the study. This also reflects that bearing conditions of the pneumatic systems needs to be checked regularly as the probability of failure in this component is maximum.

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