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IMPROVEMENT OF MACHINERY MAINTENANCE MANAGEMENT USING ARTIFICIAL INTELLIGENCE BASED VIBRATION ANALYSIS

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ABSTRACT
This study aimed to identify the benefits and challenges of applying Artificial Intelligence (AI) for Vibration Analysis to improve industrial machinery maintenance. The study identified that the quality of any Machinery maintenance management strategy depends on the accuracy of acquiring machinery operating condition data, accurately analyzing the data to determine any performance deviation, identifying incipient faults in any machine component parts and then presenting that information in a timely manner for maintenance actions to taken before failure occurs. Therefore, the process should be automated to eliminate delays due to human interventions. Based on this requirement, this research proposed a framework for AI based vibration condition monitoring and fault diagnosis for the improvement of industrial machinery maintenance management.

Keywords:
Artificial Intelligence, Vibration Analysis, Fault Diagnosis, Machinery Health Monitoring, CMMS

INTRODUCTION

Machinery health monitoring and fault diagnostic plays a key role in almost all industries. In today's commercial production industrial environment, there are increasing trend towards the need for higher and sustainable industrial machinery availability. Hence, accurate monitoring of industrial machinery health condition and proper fault diagnosis of any machinery fault and failure becomes very necessary. In recent times, some researchers have demonstrated that AI techniques has great potential to significantly enhance the quality of machinery health monitoring data processing and fault diagnosis. The main aim of vibration analysis and fault diagnosis is to follow up the machinery health and the remaining useful life (RUL) in industrial machinery. However, effective predictive health monitoring (PHM) methods are important to guarantee the required health state of the machinery. Thus, vibration analysis and fault diagnosis help to ensure the health state of the machinery are properly understood and to enable timely maintenance decisions to be taken. Industrial machinery, such as pumps, motors, gearbox, turbines, compressors, generators, and engines, are vital equipment in modern industrial applications and have to run efficiently, reliably, and safely (Omar, et al 2020). Vibration analysis is conducted to determine the operating and mechanical health condition of equipment. Vibration data is a widely measured parameter in many industrial applications and contains the most valuable information of machinery component faults. According to Arthur et al. (1992), of all the parameters that can be measured in industry today, none contains as much information as the vibration data. Even though proper condition monitoring of industrial equipment may require the measuring or monitoring of other parameters such as: temperature, pressure, flow rate, voltage, current, horsepower, torque, the fact remains that the vibration data in time and frequency domain contains more information about the machine's health and operating characteristics than any other parameter (Arthur et al. 1992).

Machinery health monitoring is a method of using sensors to acquire machinery operating information and analyzing this information to quantify the health condition of equipment Tobi et al. (2018). This is done so that potential problems can be detected and diagnosed early in their developmental stage and corrected by suitable recovery measures before they become severe enough to cause plant breakdown and other serious consequences (Williams et al. 1992). Fault diagnosis is vital in discovering the relationship between measured data and machine health conditions. However, engineers are constantly desirous to shorten the maintenance cycle and to improve the diagnostic accuracy. This could be achieved through the adoption of an automated process. Consequently, with the help of artificial intelligence (AI), fault diagnosis is expected to become smart enough to automatically detect and identify machinery health conditions timely to enhance quick maintenance decisions and resultant equipment reliability improvement and reduced maintenance and production cost.

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OBJECTIVES

The aim of this study is to develop the background research by investigating the practicality and the benefits of applying Artificial Intelligence (AI) for Vibration Analysis to improve industrial machinery maintenance. The following are the objectives of this study, (1) To investigate the impacts and factors to be considered at various stages of implementation of AI based vibration condition monitoring and fault diagnosis of industrial machinery. (2) To develop framework for implementation of AI based vibration condition monitoring and fault diagnosis and (3) To develop strategy that integrates AI based vibration condition monitoring and fault diagnosis into the computerized machinery maintenance management system.

METHODOLOGY

This research follows a review and understanding of condition monitoring and fault diagnostic processes of industrial machines. Over the years, Vibration analysis is used to determine the operating and mechanical condition of equipment. A major advantage is that vibration analysis can identify developing problems before they become too serious and cause unscheduled downtime. This can be achieved by conducting regular monitoring of machine vibrations either on a continuous basis or at scheduled intervals. The Process is mounting of sensors to monitor critical components of machines. Then, the acquired vibration signals from the sensors in time domain are transformed into frequency domain utilizing Fast Fourier Transform (FFT) to extract features from sensor signals. Every machinery fault has unique features in the frequency domain. The purpose of vibration analysis is to identify defects and evaluate machine condition. Vibration frequencies are used to relate machine faults to the time-varying forces, termed forcing frequencies, that cause vibration. This is a pattern recognition problem for which AI machine learning algorithm such as Artificial Neural Network ‘ANN’, the Support Vector Machine ‘SVM’ have proven successful.

Questionnaire was designed using the 5-Likert scale and was intended to capture the aim and of the study. Likewise, data were collected from Four engineering companies operating within the Southern part of Nigeria that are into Power Generation, Oil and Gas services, maintenance and machinery health monitoring and diagnosis.

The study suggested an automated framework that is able to monitor the state, predict and diagnose incipient industrial machinery faults using AI. The input of the model is vibration signal while the outputs is the health assessment of the monitored machine and the component fault diagnosis. First, signals are collected and preprocessed in order to reveal potential fault signatures. Then, features are extracted from the preprocessed signals around specific frequencies of interest related to machine and component faults. Finally, these features are used as inputs in pattern recognition models that can determine if a fault is present and in which component and severity of the fault. See the process flow diagram in Fig.1 below.

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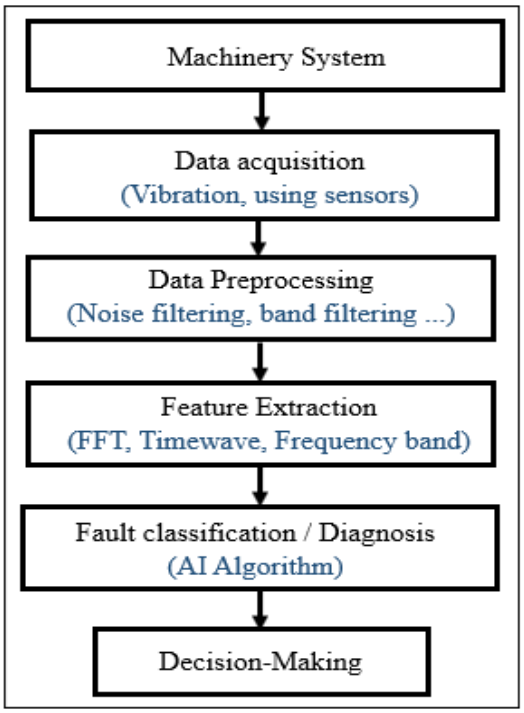

Fig. 1: Process flow of Condition Monitoring and Fault Diagnosis using AI

RESULTS AND DISCUSSION

The research through the various hypotheses tested shows that AI revolution can enhance machinery vibration condition monitoring and fault diagnosis effectiveness. Also, that Artificial intelligence (AI) approaches can improve industrial machinery maintenance management and invariably enhances machinery reliability and availability. Based on these findings, this research proposed a framework for AI based vibration condition monitoring and fault diagnosis for the improvement of industrial machinery maintenance management. The quality of any Machinery maintenance management strategy depends on the accuracy of acquiring machinery operating condition data, accurately analyzing the data to determine any performance deviation, identifying incipient faults in any machine component parts and then presenting that information in a timely manner for maintenance actions to taken before failure occurs. The process is automated and eliminate delays due to human interventions. With the development of sensor technology, powerful data processors and appropriate AI algorithm, desired improvement of machinery maintenance management strategy is achieved.

The framework is to acquire real time machinery performance vectors with permanently mounded sensors, in this case vibration sensors are attached at suitable locations on the machines to be monitored. However, other machinery performance data could be monitored depending on the complexity of the monitored machine. The acquired data is processed with appropriate data processors for sensitive features to be extracted. The features extracted are used as input signal to the AI model to perform pattern recognition and fault classification. The AI model is trained to be able to recognize deviations in the input data compared with the trained data and then be able to perform fault classification and diagnosis.

With this framework, machine operating deviation and fault is identified timely for accurate proactive maintenance actions to be taken before any functional failure occurs, thereby reducing machinery or system downtime. The proposed layout is shown in Fig, 4.1. below.

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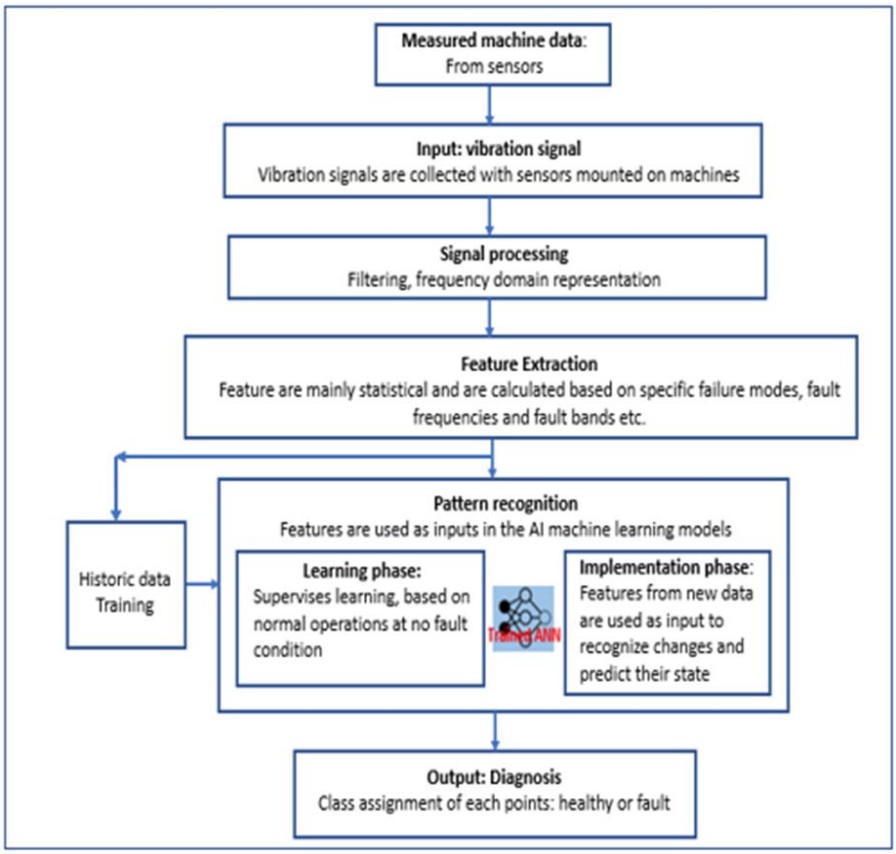

Fig. 4.1: Proposed flow diagram for the AI based condition monitoring and fault diagnosis management strategy.

Some organizations maintain a centralized computer database of information about the organization's maintenance operations and activities. It helps them to maintain clear oversight of all the assets maintenance management functions such as, scheduling maintenance activities, tracking Work Orders, Third Party Support, inventory and supply chain and cost management. This centralized computer database is known as Computerized Maintenance management System 'CMMS'.

For the AI based condition monitoring and fault diagnosis management system to improve the maintenance management of industrial machinery, it should be integrated and operated seamlessly within the Computerized Maintenance management System. Also, Internet of Things (IoT) have provided communication protocol to create a common communication basis between electronic devices. Therefore, the AI based vibration condition monitoring and fault diagnostic system can then be integrated into the computerized machinery maintenance management system through the Internet of Things (IoT) communication protocol for Device-to-Device connection.

The proposed integration of the AI fault diagnostic system with the Computerized Maintenance management System 'CMMS' will provide timely and actionable machinery health performance data, offer more measurable maintenance results, enhanced timely maintenance decisions, improved reliability, availability and safety, by eliminating catastrophic failure and reduced maintenance cost. The proposed layout for integration of the AI fault diagnostic system with the Computerized Maintenance management System 'CMMS' is shown in Fig. 2 below.

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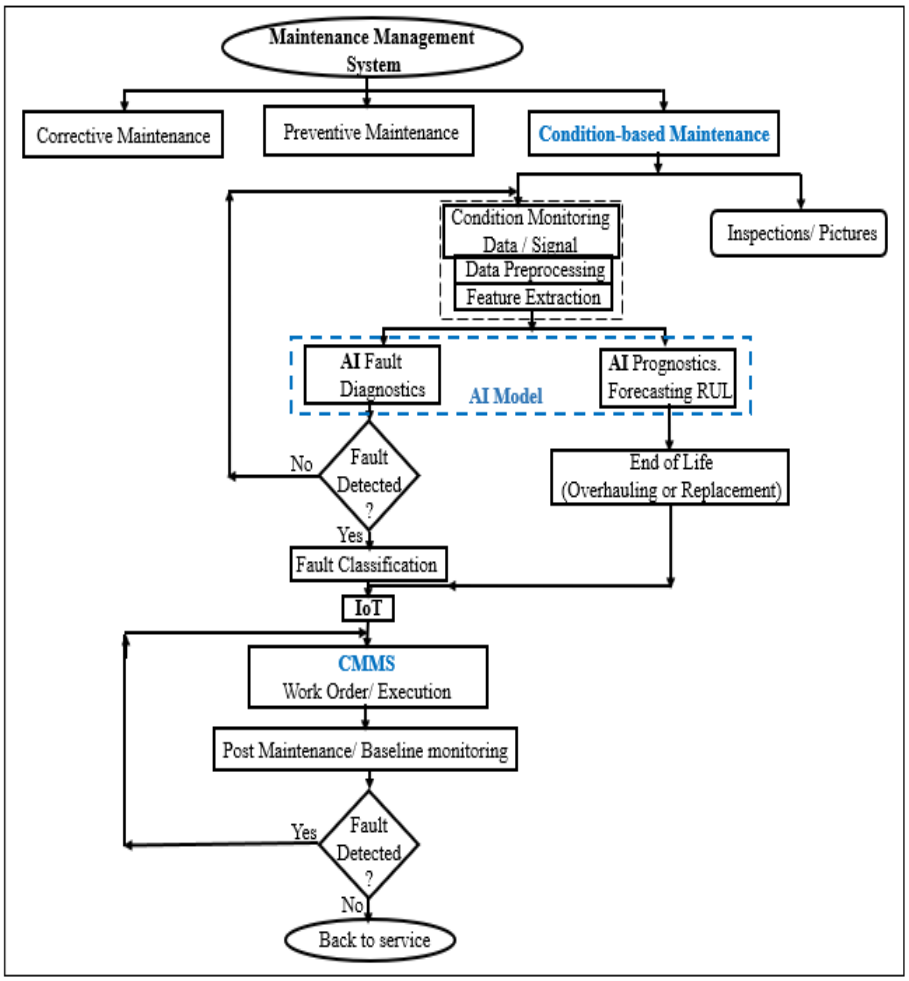

Fig. 2: Proposed framework for the integration of AI based vibration condition monitoring and fault diagnosis into the machinery maintenance management system.

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CONCLUSION

Enhancing the reliability, availability, and safety to reduce maintenance cost of modern industrial machinery is very crucial. Therefore, a robust and intelligent vibration analysis and fault diagnosis approaches are highly needed to enhance the quality of maintenance decisions and actions. The research developed a framework for artificial intelligence 'AI' method of vibration analysis and fault diagnosis of industrial machinery. With the rapid development in industrial sensor technology and the availability of powerful industrial computer processor, the stage is set for deployment of AI models for Condition Monitoring and fault diagnostic management of industrial machinery. The proposed AI based vibration analysis and fault diagnostic process will offer more measurable and notable maintenance results and provide better human/ machinery interaction for effective industrial machinery maintenance management. Machinery reliability and availability will be improved with consequential reduction in machinery unscheduled downtime and reduction in maintenance cost. The research developed a framework to integrate the proposed AI model for Condition Monitoring and fault diagnosis to operate seamlessly within the Computerized Maintenance management System.

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Also, the research indicated that 97.48% of all questionnaire respondents 'Strongly Agreed' that the AI support can offer faster, more accurate task execution of machinery condition monitoring and fault diagnostic management. However, some limitations and challenges were highlighted. 93.43% of questionnaire respondents were of the opinion that the AI support would require high technical skill to train the AI model before implementation and that the system will involve high initial investment cost, with challenges of protection of critical machinery information. Also, there are low awareness as respondents have not seen and have not used AI support for vibration condition monitoring and fault diagnosis of industrial machinery.

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