Cloud based AI approach for predictive maintenance and failure prevention

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Abstract: Every industry has utilized machines of various types for many functions. The manufacturing industry has utilized machines since the industrial revolution for mass manufacturing. Operating machines continuously can lead to faults and require maintenance and repairs. As computing power increased and various technologies such as embedded systems, artificial intelligence, deep learning, cloud computing etc. were developed, new systems were implemented to perform diagnostics on machines. In this paper, A conceptual system architecture of a cloud based AI system to predict potential failure of a component by analyzing data collected from various sources and develop inspection and maintenance schedules is proposed. The application of technologies such as Artificial Intelligence, Cloud computing and process mining in the system is discussed in detail. The operation of the system in a real world condition is discussed by developing a system architecture for maintenance and failure prediction of aircraft fan blades of an aircraft engine. The future application of the system with potential increase in capability is discussed.

Keywords: Artificial Intelligence, Process Mining, Cloud Computing, Predictive maintenance, MRO (Maintenance, Repair, Overhaul)

1. Introduction
Every day, people use machines and tools for various purposes. From the beginning of the industrial revolution to the current information age, machines have evolved from a series of mechanical components that perform a certain action when coupled together to a complex mechatronic system that can monitor itself, analyze and report any anomalies while performing its function. As the complexity of a design increased, the ability to identify a fault also increased resulting in long repair time. With the current level of computing power and the advent of embedded systems, many companies have developed and deployed diagnostic systems consisting of various sensors that monitor and store data in an onboard computer. The data from the sensors can be retrieved and analyzed to properly identify problems and devise solutions. In recent years, the development and implementation of Artificial Intelligence and cloud computing has enabled
identification of a potential failure region by analyzing the data collected by the sensors and thus preemptively perform repair before the fault causes major damage. This approach to maintenance and repair can also be applied to products that contain multitude of moving parts such as engines. Since engines are used in vehicles of various categories, failure while the vehicle is in operation can lead to a potential dangerous situation. This paper discusses a cloud based Artificial Intelligence architecture for maintenance and failure prevention and discuss a hypothetical network that monitors aircraft engine fan blades.

2. System Architecture
The proposed system uses technologies mentioned below
1) Cloud Computing
2) Artificial Intelligence
3) Process mining
The use of these technologies in the system is described in detail below

2.1. Cloud computing
Cloud computing is one of the leading technologies that are increasingly adopted across the industries. The availability of large data storage, powerful computational power and access to the user without any prerequisites in terms of infrastructure has led to the creation of new, innovative systems for various applications. In the proposed system, a cloud architecture is utilized as it provides flexibility in the collection of data. Data required can be collected from various sources around the world and still be available for analysis. The system also provides access to the end user for real time monitoring and decision making based on the collected data. If such a network is coupled with an analyzing algorithm, actionable information can be obtained which can be utilized for various purposes.

2.2. Artificial Intelligence
Artificial Intelligence is one of the leading technologies that is revolutionizing various industries. AI is used in various applications, from modelling drug interaction of various drug combinations to controlling unmanned military drones capable of performing missions deemed too complex for manned operation. The main advantage of AI is the ability to adapt to stimuli and dynamically change the algorithm employed, thus increasing the efficiency and accuracy of the algorithm. In the system proposed, AI analyses data stored in a cloud server from various sources and perform predictive analysis using data mining techniques such as process mining. Using the data, a predictive model is generated where the probability of failure of a particular part in a product is determined. The model is continuously updated as new data is entered. Based on the model, a predictive maintenance schedule is developed.

The following diagram depicts the general operation of the proposed system. The flow of data and processed information from sources and the artificial intelligence system respectively is shown.
2.3. Process Mining

A type of data mining technique, process mining generates information through analysis of event data that can be used for various purposes. Using the technique, one can identify a problem in the operation of a system, optimize the process to increase efficiency and lead to better design configuration. By analyzing the data using this technique, one can track the operation of a system, pinpoint potential failure areas and develop solutions to counter the problem. The effectiveness of the technique can be increased by combining it with technologies such as artificial intelligence. AI systems that use process mining can analyze large amount of data in a very short span and generate information for further processing. In the proposed system, process mining issued by AI to analyze data generated by various sources.

3. Related Work

Many researchers have conducted research and published work that cover various aspects of the system discussed in this paper.

- An end to end framework for monitoring the manufacturing process using deep learning was proposed by Ye Yuan et al. The framework utilizes deep learning to analyze data generated by sensors and extract information.
- A framework for a cloud-based health monitoring system is proposed by Shanhu Yang et al. The framework is designed to handle multitude of data from various sources and design a prognostic and health management system.
- An review of various algorithms used by artificial intelligence for fault diagnostics of rotary machines is conducted by Ruonan Liu et al. A literature survey of the algorithms used in the industry is conducted and limitations and implications of each algorithm is discussed.
- Various aspects of a new generation intelligence manufacturing system is discussed in detail by Zhou Ji et al. Different manufacturing paradigms and their application are analyzed and classified as digital manufacturing. The Use of AI in the new generation system and complex human-physical-cyber interaction is analyzed and discussed in detail.
4. Implementation of the maintenance system for fan blades of an aircraft engine
In this system, an AI based system is proposed to monitor the fan blades on an aircraft engine.

![Diagram of the maintenance system](image)

**Figure 2.** Architecture of the failure prediction and maintenance system for Fan blades of an aircraft engine

A cloud architecture is used where data about the fan blades from the manufacturer, the airline maintenance operators and the engine monitoring system is uploaded onto a cloud server. AI system continuously calculates the probability of failure of the fan blade and develop maintenance schedules for each blade. In an aircraft engine, various parameters that are related to an aircraft engine is recorded by the engine monitoring system on the aircraft. This data, along with the maintenance work done by the ground engineers and data from the manufacturer is fed into a cloud system. An AI system uses data mining techniques such as process mining to analyze the stored data and generates a predictive model that is updated continuously. The model calculates the probability of failure of a particular fan blade based on the data and generates a maintenance schedule.

5. Future applications
Since the system can predict a failure of a particular part of an aircraft engine, it can be used as an early warning system. It can also be used as a design optimization tool since data is collected form the manufacturing level to the user implementation level. By this way, a designer can evaluate the efficacy of the implemented design live as the product is used and can identify improvements at various levels. The airline can develop fleet wide maintenance schedule based on the analysis generated by the system. The overall safety of the aircraft is greatly improved as the predictive model can accurately calculate failure rate on an individual part basis and thus allow maintainers to conduct accurate inspections. Overall, the system can be adopted for a range of products and thus improve the quality, reliability and safety. The system is particularly effective for industries such as the airline industry, trucking industry shipping industry that operate large quantity of the similar products. The system can also be implemented towards potential military applications. Logistical operation can be better organized and vehicle readiness can be considerably increased.

6. Conclusion
In this paper, the architecture and application of a cloud-based AI maintenance system is discussed. From observing systems that employ cloud technology, we can infer that the system can be deployed at any
location without any complex infrastructure. The capability of the Artificial intelligence system can be expanded to diversify its application. Development of the concept and research into other similar fields shows a great potential towards wide range of applications in industries such as the automobile industry, electrical industry, Infrastructure development industry etc. Certain aspects of the concept require further development and refinement. With improvements in the process of the system, implementation of the system will be profitable and will improve overall safety and efficiency.

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