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Digital Twin and Predictive Maintenance of Hydraulic OR Pneumatic System

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Abstract **- Predictive maintenance is a technique for creating a more sustainable, safe, and profitable industry. One of the key challenges for creating predictive maintenance systems is the lack of failure data, as the machine is frequently repaired before failure. Digital Twins provide a real-time representation of the physical machine and generate data, such as asset degradation, which the predictive maintenance algorithm can use. Since 2018, scientific literature on the utilization of Digital Twins for predictive maintenance has accelerated, indicating the need for a thorough review. Hydraulic system has been the mainstream choice in large engineering equipment due to its smooth transmission, large bearing capacity, and small volume. However, because of the tightness and invisibility in hydraulic equipment, it is difficult to check and predict its faults. Common fault diagnosis and maintenance methods for the hydraulic system can be divided into two types: a signal analysis based on the mathematical model and a machine learning algorithm based on artificial intelligence. The first method can only diagnose specific faults based on the mathematical model, which is not universal, and the second one must rely on abundant history fault data, which is impossible to obtain in the early running stage. In order to address these questions, a digital twin framework is proposed which combines the virtual model with the real part to solve practical problems. As a concrete realization form of a five-dimension digital twin model, this framework provides a more feasible solution mode for fault diagnosis in the hydraulic system. Meanwhile, it expands the functions of faults prediction and digital model.**

Keywords: predictive maintenance, machine learning, Digital twin, smart manufacturing, Predictive Analytics.

I. Introduction

Predictive Analytics Process

Predictive analytics involves several steps through which a data analyst can predict the future based on the current and historical data. This process of predictive analytics is represented in figure 1 given below.

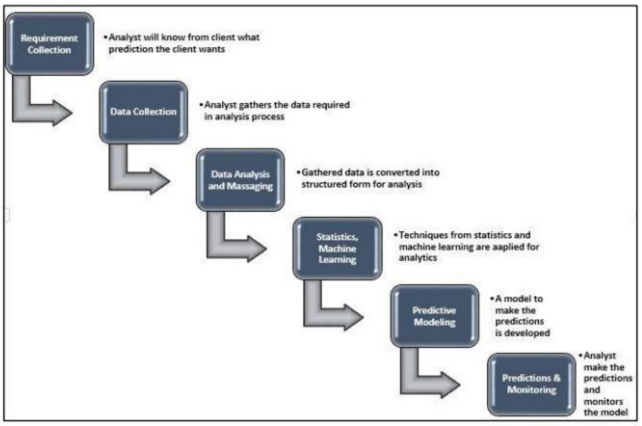

Figure 1: Predictive Analytics Process

II. Digital Twin

Digital twin is a process of building and managing the digital twin and its operating environment or system, which involves the whole life cycle of design, construction, operation and maintenance and scrapping. Digital twin is defined as the virtual representation of manufacturing elements in the manufacturing industry, such as the virtual representation of products, resources and processes. The digital twin is a dynamic model, which is constantly updated and changed with the changes of physical entities, and represents the equipment status, working conditions, geometry and resource status in the form of data synchronization.

Platform: Digital twin simulation platform is a development platform, which is specifically realized as a software development platform integrating data management, model management, real-time calculation and data simulation prediction. Through the digital twin simulation platform, the virtual entity can quickly and accurately reflect the state of the physical entity, so as to guide the behavior of the physical entity in time and make the system control more efficient. Visualization: Visualization technology is an effective means for people to efficiently understand information and make decisions. In the digital twin system, the three-dimensional (3D) visualization technology can give the operation and maintenance status of the system in the form of surreal, and carry out multi-scale virtual mapping for the key subsystems of the complex system, helping the personnel to quickly

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understand the relationship between physical entities and massive data.

III. Predictive Maintenance

To better grasp Predictive Maintenance, the authors have decided to initially define the concept. According to Oxford Learner's Dictionaries the adjective predictive is formally defined as Connected with the ability to show what will happen in the future and maintenance is defined as the act of keeping something in good condition by checking or repairing it regularly. Hence, combining the two will allow for the following definition of Predictive Maintenance the act and ability to keep something in a good condition by understanding what happens in the future.

IV. A Survey of Predictive Analytics Using Big Data with Data Mining

Big data is a term used for describing the exponential growth along with the structured and unstructured availability of data. As a promising term, it contains the following characteristics:

i. Volume: the amount of data generated.
ii. Variety: the category to which the big data belongs.
iii. Velocity: the speed of generation of data.
iv. Variability: the inconsistency which can be shown by the data.
v. Veracity: accuracy corresponding to the data is dependent over the truthfulness of the source data which are otherwise the quality of the data.
vi. Complexity: data management is becoming very complex when storing large volumes of data from different sources.

Big data analytics is the procedure for the investigation of big data so as to reveal hidden patterns, unknown relations and some other useful information which can be employed to make better decisions. Today, most of the companies store large volumes of diverse data (i.e. web logs, click streams, sensors and several other sources). The perceptions unknown within this 'Big Data' have significant business value. Several novel schemes have been developed to handle the challenges such as volume, variety, and velocity in big data.

i. Apache Hadoop software that is a cost-economic, hugely scalable platform for the analysis of big data. It can save and do the processing of petabytes of data, inclusive of every data type which is not suitable for traditional relational database management system (RDBMS).
ii. Not only structured query language (SQL) database lightens the restraints of the classical RDBMS to be capable of delivering a greater performance along with scalability SQL databases can then have the abilities of Hadoop clusters extended by yielding low-latency object retrieval or else other data warehouse (DW)-like functionality.
iii. Massively parallel-processing (MPP) appliances have the capacity of RDBMS-based data warehouses extended. These systems can save and then process petabytes of structured data.
iv. In-memory databases considerably can enhance the performance through the elimination of most data access latencies on the shuttling of data forward and backward between the storage systems and server processors.

In-memory databases can be considered to be an alternative in few of the MPP appliances of today for offering realistic performance for the applications that demand high. Predictive analytics is a type of analytics undergone on big data that deal with extracting information from data and predict the trends and behavior patterns. Predictive analytics determine the possible future result of an event or even the probability of a condition that can occur. It is one of the branches of data mining related to predict the future possibilities and their trends. Predictive analytics is useful for analyzing huge data automatically with multiple variables; it is inclusive of decision trees, clustering, neural nets, market basket analysis, regression modelling, hypothesis testing, decision analytics, genetic algorithms, and text mining etc.1 It contains different view approaches like integrated reasoning and pattern recognition along with predictive modelling. Many researchers have interest to build an automated reasoning tool for identifying future events and measures. Figure 1 indicates that the process of predictive analytics has to be consistent to guarantee efficiency and accuracy of the data prediction.

V. Data Analysis and Statistics

Data analysis is rooted in statistics, which has a pretty long history. It is said that the beginning of statistics was marked in ancient Egypt as it took a periodic census for building pyramids. Throughout history, statistics has played an important role for governments all across the world, for the creation of censuses, which were used for various governmental planning activities (including, of course, taxation). With the data collected, we can move on to the next step, which is the analysis of that data. Data analysis is a process that begins with retrieving data from various sources and then analyzing it with the goal of discovering beneficial information. For example, the analysis of population growth by district can help governments determine the number of hospitals that would be needed in a given area.

Types of data analysis

1. Exploratory data analysis

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2. Descriptive statistics
3. Predictive analytics
4. Prescriptive analytics
5. Regression analysis

VI. Common Faults in Pumping Systems

A centrifugal pump consists of several rotating and static components that has the task of displacing liquids. Due to the interaction of moving parts and liquids interacting with a solid and static surface, several errors can surface. A thorough investigation by Forbes resulted in a conclusion of dividing the main issues of a centrifugal pump into 13 types of faults. Each of the 13 types of faults could then further be divided into more specific reasons for the fault happening. Table 4 presents an overview of detectable errors with their corresponding data tags that might be of interest. To get a more detailed description of specific issues, the reader is recommended to visit Forbes. The main components of a simple centrifugal pump will consist of an impeller, a suction nozzle, a discharge nozzle, a shaft, a mechanical seal, and several bearings. Due to the nature of the pump, the pump faults can be categorized into three categories. Hydraulic, mechanical, and other failures. The hydraulic failures are caused by the liquid flowing within the piping. The state of the liquid can influence the performance of the pump, but also damage parts of the pump. Mechanical failures refer to the interaction of moving and static parts, this commonly causes wear or other types of fatigue. Finally, other type failures are a category for failures that do not directly fall into the two other groups. The power consumption of a pump can often be an indicator of whether the pump is performing desirably.

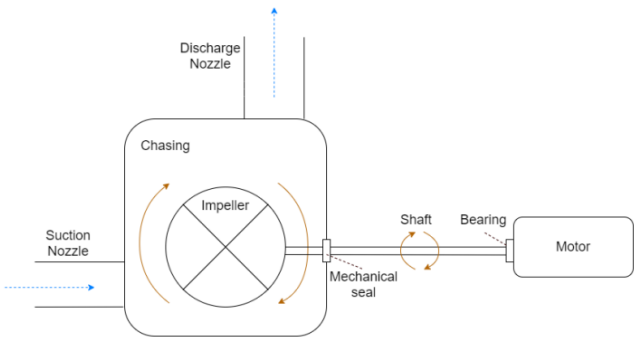

Figure 2: A simple figure of a centrifugal pump

From left to right; water enters the impeller through the suction nozzle, where kinetic energy will be applied to the liquid through turning of the shaft. The chasing keeps the water within the system, while the mechanical seals make sure there is no leakage. The bearing reduces the friction between the moving and stationary parts and is found in several places within a pumping system. The water exits at the discharge nozzle.

VII. Conclusions

The paper initially presented a thorough introduction to what predictive maintenance offers and gave a framework on how to prepare and develop predictive maintenance models. Here literature was recommended for further reading to deepen the understanding of how model construction could be done. Then literature with applications in various areas was introduced, this allowed for the identification of advantages and limitations of certain algorithms. It further allowed for identifying certain trends within the predictive maintenance field. This was compared to the specific domain of pumps and combined heat and power plants. Here certain gaps were identified, as limited material could be identified within the combined heat and power area. A set of challenges for predictive maintenance were then presented before outlining future trends. For future work, the authors recommend that a more exhaustive literature review is conducted as there are increasing amounts of literature being published at a rapid pace. General trends could be identified from the studied literature, but the paper would benefit from verification of the exhaustive search. This is especially related to domain-specific areas, as general literature does not seem to be lacking. Furthermore, the literature review should be extended to include literature of other types of models, such as physical and knowledge-based models.

After collection of data finds useful insights as follow as we've seen, data analysis and computer technology have been developing and affecting each other, ever since the advent of computing. As the collected data size gets larger, new methods of data analysis have been introduced in each stage, out of necessity. As data collection and computing gets even cheaper, we should continue to see breakthroughs in the area of big data.

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