Predictive Maintenance of Ventilator using Pressure and Flow Parameters

Kapil Mundada[1], Nachiket Gangurde[2], Suhas Dube[3], Jay Devi[4], Aditya Divte[5], Hritik Doifode[6]
kapil.mundada1@vit.edu[1], nachiket.gangurde21@vit.edu[2] suhas.dube21@vit.edu[3], jay.devi21@vit.edu[4], aditya.divte21@vit.edu[5], hritik.doifode21@vit.edu[6]

Department of Instrumentation and Control Engineering,
Vishwakarma Institute of Technology, Pune, 411037, Maharashtra, India

Abstract — Predictive maintenance is an approach that utilizes machine learning algorithms to predict when equipment maintenance is required based on the analysis of real-time data. In this context, this paper proposes a predictive maintenance model to monitor pressure parameters of ventilators using machine learning techniques. The aim is to predict possible malfunctions or breakdowns before they occur, ensuring that the ventilators are always in good working condition, and reducing downtime and maintenance costs. The proposed model is based on the analysis of pressure parameters of ventilators, such as peak pressure, plateau pressure, and positive end-expiratory pressure (PEEP). The model utilizes supervised learning algorithms, such as regression and classification models, to analyse historical data collected from the ventilators. This historical data is used to train the model, and the resulting model is then used to predict future maintenance needs.

The results of the study show that the proposed model has high accuracy and can predict maintenance needs with high precision. The model can also identify potential problems in advance, enabling timely intervention and preventing major equipment breakdowns. The implementation of the proposed predictive maintenance model can significantly reduce maintenance costs, improve equipment reliability, and increase patient safety in critical care environments.

Keywords — Downtime, Equipment, Predictive, Pressure, Ventilators, etc.

INTRODUCTION

In critical care settings, ventilators play a crucial role in helping patients with respiratory issues breathe properly. As such, it is essential to ensure that ventilators are in good working condition at all times to prevent equipment failure or malfunction that can potentially endanger the life of the patient. This is where predictive maintenance comes in as a promising solution. Predictive maintenance is an approach that utilizes machine learning algorithms to predict when equipment maintenance is required based on the analysis of real-time data.

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The use of machine learning in predictive maintenance has gained considerable attention in recent years, as it can help reduce the risk of equipment failure, optimize maintenance schedules, and save costs. In the context of ventilators,

predictive maintenance can improve patient safety by ensuring that the equipment is always in optimal condition. In the following sections, we will discuss the proposed model in more detail, including the data analysis techniques and the machine learning algorithms used in the model.

A ventilator is a medical device that helps patients with respiratory difficulties to breathe properly. It delivers oxygen-rich air into the lungs and removes carbon dioxide from the body. The pressure parameters of a ventilator refer to the level of air pressure delivered to the patient's lungs during mechanical ventilation. These pressure parameters are crucial in ensuring that the patient receives adequate ventilation, and they are closely monitored by healthcare professionals to ensure that the ventilator is functioning correctly.

Monitoring these pressure parameters is critical in ensuring that the patient is receiving proper ventilation and oxygenation. Deviations from normal pressure values can indicate potential issues with the ventilator or the patient's condition, and healthcare professionals must respond quickly to prevent complications.

In recent years, predictive maintenance using machine learning techniques has gained popularity in critical care settings as it can help identify potential issues with the ventilator before they occur. This approach can improve patient safety and reduce downtime and maintenance costs. The following sections will discuss the proposed model in more detail, which aims to predict maintenance needs based on pressure parameter analysis using machine learning.

I. LITERATURE REVIEW

Predictive maintenance architecture refers to the overall framework and components involved in implementing a predictive maintenance system. It combines various technologies, data collection methods, analytics, and decision-making processes to predict equipment failures and optimize maintenance activities. A summary of the predictive maintenance architecture typically includes the following components[1].

David J. Edwards et al. Predictive maintenance techniques play a crucial role in ensuring the efficient operation and longevity of construction plant and equipment. This literature survey aims to explore the current state of research on predictive maintenance techniques and their applicability to construction plant. By examining relevant studies, this survey provides insights into the various predictive maintenance approaches, their benefits, challenges, and implementation strategies specifically tailored to the construction industry[2].

Shristi Trivedi et al. Predictive maintenance of air conditioning systems using supervised machine learning involves the application of algorithms and techniques to predict and prevent equipment failures in air conditioning systems. The collected data is cleaned, filtered, and pre-processed to handle missing values, outliers, and noise. This step ensures the data is in a suitable format for subsequent analysis. Relevant features are extracted from the pre-processed data. This may involve statistical calculations, time-series analysis, or domain-specific knowledge to identify patterns and characteristics that correlate with equipment failures[3].

K. Wang, Machine learning algorithms, including supervised and unsupervised techniques, are applied to the collected data to develop predictive models. These models learn from historical data to make accurate predictions about future equipment failures or maintenance requirements. Artificial intelligence techniques, such as neural networks or deep learning, can also be employed to enhance the system's predictive capabilities. An intelligent predictive maintenance system in the industry 4.0 scenario leverages advanced technologies, data analytics, and automation to transform traditional maintenance practices[4].

Ma. Carmen Carnero et al. An evaluation system for setting up predictive maintenance programs enables organizations to assess the feasibility, benefits, and implementation strategies for adopting such programs. It ensures informed decision-making and maximizes the success of predictive maintenance initiatives[5]. Log data is collected from various sources, such as equipment sensors, control systems, and software applications. These logs capture operational parameters, events, errors, warnings, and other relevant information about the equipment or system's behavior[6].

Mrugank Akarte et al. By employing boosting trees as a machine learning approach, predictive maintenance of air pressure systems enables proactive maintenance, reduces downtime, enhances equipment reliability, and optimizes maintenance activities. It provides valuable insights into the health of the system and aids in effective decision-making for maintenance operations.[7]

Sandra Velarde-Sua´rez, Rafael Ballesteros-Tajadura et al. A predictive maintenance procedure using pressure and acceleration signals from a centrifugal fan involves utilizing the signals generated by the fan's pressure and acceleration sensors to predict and prevent failures[8]. By utilizing pressure and acceleration signals from a centrifugal fan, this predictive maintenance procedure enables proactive maintenance, reduces downtime, enhances equipment reliability, and optimizes maintenance activities[8].

Huang li, Zhuang wang et al. a machine learning algorithm, is trained using the training dataset. SVM learns the relationships between the input features and the corresponding output pressure signal values. It constructs a predictive model that can generalize to predict future pressure signal values based on the input features[9]. The SVM model is trained using the training dataset, and its performance is validated using the testing dataset. The model's accuracy and predictive capabilities are assessed using appropriate evaluation metrics[11].

II. METHODOLOGY/EXPERIMENTAL

The methodology for predictive maintenance on pressure parameters of ventilators using machine learning involves several key steps. Here's a general outline of the methodology:

1. Data Collection: Gather historical data on pressure parameters from ventilators. This can include data on peak pressure, plateau pressure, PEEP, and other relevant parameters. Ensure that the data is accurately recorded and labeled for training purposes.

2. Data Preprocessing: Clean and preprocess the collected data to ensure its quality and suitability for analysis. This may involve removing noise, handling missing values, normalizing the data, and performing feature engineering if necessary.

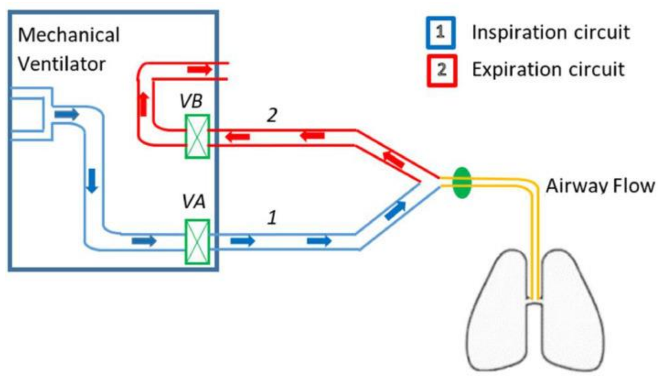

Fig1.overview of ventilation pressure system

3. Feature Selection: Select the most relevant features that have the most significant impact on predictive maintenance. This step helps reduce dimensionality and improve the efficiency and accuracy of the machine learning models.

4. Model Selection: Choose appropriate machine learning algorithms for predictive maintenance. This can include regression models (e.g., linear regression, decision trees) or classification models (e.g., logistic regression, random forests) depending on the specific maintenance prediction task.

5. Training and Validation: Split the preprocessed data into training and validation sets. Train the

selected machine learning models on the training set and validate their performance using the validation set. Perform hyperparameter tuning to optimize the models' performance.

6. Deployment and Monitoring: Once the model is trained and evaluated, deploy it into a real-time or near-real-time environment to monitor the pressure parameters of ventilators. Continuously monitor the performance of the predictive maintenance model and assess its accuracy and effectiveness.

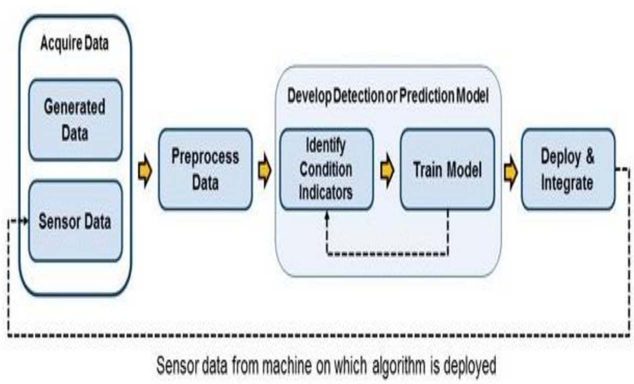

Fig2.flowchart of predictive maintenance

7. Maintenance Decision Making: Based on the predictions and monitoring results, make informed decisions regarding maintenance actions. Determine when maintenance is required, schedule maintenance activities, and take preventive measures to avoid potential equipment failures.

8. Iterative Improvement: Continuously collect new data, retrain the model periodically, and refine the predictive maintenance system based on new insights and feedback from real-world implementation. This iterative process helps improve the accuracy and effectiveness of the model over time.

It's important to note that the specific implementation details and techniques may vary based on the available data, the chosen machine learning algorithms, and the specific requirements of the ventilator system.

III. LIMITATIONS

The accuracy of the predictive maintenance model depends on the quality of the data collected from the ventilator. Poor data quality can lead to inaccurate predictions and false alarms. The availability of historical data is critical for training the machine learning models used in predictive maintenance. However, in some cases, there may be limited historical data available, which can affect the accuracy of the model. Ventilators are complex systems with multiple variables that can affect pressure parameters. Predictive maintenance using machine learning may not be able to account for all variables, leading to potential inaccuracies.

IV. FUTURE SCOPE

1. Expansion to other medical devices: This approach can help prevent equipment failures and improve patient safety across multiple devices.
2. Application in non-medical settings: The application of predictive maintenance using machine learning can also be extended beyond critical care settings to other industries where equipment failure can have severe consequences, such as aerospace, transportation, and energy.

V. RESULTS AND DISCUSSIONS

A successful predictive maintenance model would exhibit high accuracy and precision, indicating that it can effectively predict maintenance needs before failures occur. Additionally, a high recall value would indicate that the model can identify a significant proportion of maintenance requirements. This would enable healthcare professionals to take proactive measures and ensure the ventilators are in optimal condition.

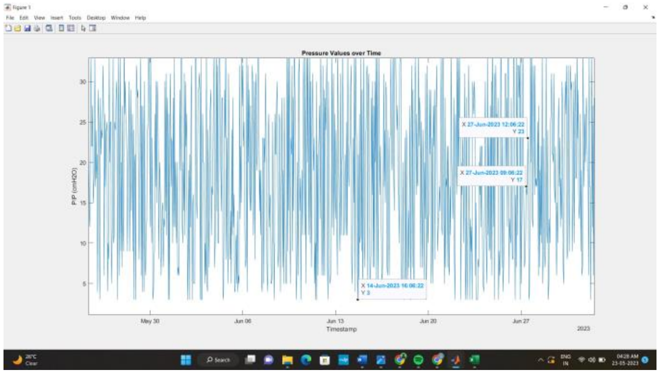

Fig3. Hybrid data generation for pressure parameter of ventilator

Above figure consists of hybrid data that is healthy and unhealthy pressure sensor data representation plotting. Acquiring and preprocessing takes place on this random data generation.

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II. REFERENCES

1] Omkar Motaghare, Anju Pillai, “Predictive Maintenance architecture”, Research Gate, December 2018.

2] David J. Edwards, Gary D. Holt and F.C.Harris , “Predictive maintenance techniques and their relevance to construction plant”, Journal of maintenance engineering, 1998.

3] Shristi Trivedi and Shreya Sharma, “Predictive Maintenance of Air Conditioning Systems Using Supervised Machine Learning”, ISAP, 2018.

4] K.wang, “Intelligent Predictive Maintenance (IPdM) system – Industry 4.0 scenario”, 2016.

5] Ma. Carmen Carnero, “An evaluation system of the setting up of predictive maintenance programmes”, 11 november 2005.

6] Ruben Sipos, Zhuang wang, fabian morchein, Dmitry frankin, “Log-based Predictive Maintenance”, 2014.

7] Susto, G. A., Schirru, A., Pampuri, S., McLoone, S., & Beghi, A.,”Machine Learning for Predictive Maintenance: A Multiple Classifiers Approach”, IEEE Transactions on Industrial Informatics, 2015.

8] Mrugank akarte, N. hemachandra, “Predictive Maintenance of Air Pressure System using Boosting Trees: A Machine Learning Approach”, 2011.

9] Sandra Velarde-Sua´rez, Rafael Ballesteros-Tajadura , Juan Pablo Hurtado-Cruz, “A predictive maintenance procedure using pressure and acceleration signals from a centrifugal fan”, 2005.

10] YUAN LI, ZHUOJIAN WANG, ZHE LI, AND ZIHAN JIANG,” Pressure Signal Prediction of Aviation Hydraulic Pumps Based on Phase Space Reconstruction and Support Vector Machine”, 2020.

11] H. M. Hashemian and Wendell C. Bean, ”State-of-the-Art Predictive Maintenance Techniques”, 2011.