Patient Safety & Quality Improvement Journal
http://psj.mums.ac.ir

An Intelligent System for Management of Medical Equipment Maintenance

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ARTICLEINFO

Article type:
Original Article

***Article History*:**
Received: 11 Sep 2023
Accepted: 02 Oct 2023

Key words:
Intelligent System, Medical Equipment, Maintenance Management, Machine Learning

ABSTRACT

Introduction:
This paper proposes an intelligent system for managing medical equipment maintenance in healthcare facilities. The system utilizes machine learning algorithms and data analytics to predict equipment failures, schedule maintenance tasks, and manage spare parts inventory efficiently. The aim is to improve equipment availability and reliability, reduce maintenance costs, and increase patient safety.

Materials and Methods:
The proposed system consists of several modules: data collection, preprocessing, equipment failure prediction, maintenance scheduling, spare parts inventory management, and integration. Real-world data is used to evaluate and compare the system's performance with other maintenance management approaches.

Results:
The results demonstrate that the proposed system can accurately predict equipment failures, schedule maintenance tasks efficiently, and manage spare parts inventory effectively. This improves equipment availability and reliability, reduces maintenance costs, and ensures that spare parts are available when needed without incurring excessive inventory costs.

Conclusion:
Overall, the proposed intelligent system for managing medical equipment maintenance is an effective solution for healthcare facilities to optimize maintenance operations, reduce costs, and ensure patient safety.

► ***Please cite this paper as:***
Izadi A, Bakhshali MA, Ghasemifard H, Sarrafzadeh O. An Intelligent System for Management of Medical Equipment Maintenance. Journal of Patient Safety and Quality Improvement. 2023; 11(3): 161-167.
Doi: 10.22038/PSJ.2023.74922.1407

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Introduction

Managing medical equipment maintenance is a critical task in healthcare facilities, as it plays a crucial role in ensuring the proper functioning of medical equipment. Medical equipment maintenance is necessary to ensure that the equipment is reliable and available when needed, contributing to better patient outcomes. However, managing medical equipment maintenance can be complex and time-consuming, especially in healthcare facilities with many medical devices. This complexity arises due to the various factors that need to be considered when managing equipment maintenance, such as the frequency of maintenance, the type of maintenance required, and the availability of spare parts (1). Traditionally, the management of medical equipment maintenance has been done manually, which is often inefficient and prone to errors. Manual management of maintenance tasks can lead to missed maintenance opportunities, incorrect scheduling, and inefficient use of resources. Moreover, manual spare parts management can lead to overstocking or understocking, increasing costs and downtime. Therefore, there is a need for an intelligent system that can automate the management of medical equipment maintenance and optimize the process (2-4).

The main objective of this paper is to propose an intelligent system for managing medical equipment maintenance. The proposed system uses machine learning algorithms to predict equipment failure, schedule maintenance tasks, and manage spare parts inventory. The system is expected to improve the efficiency and effectiveness of medical equipment maintenance, leading to improved patient outcomes.

The proposed intelligent system for the management of medical equipment maintenance is significant for several reasons:

1. The system automates the management of maintenance tasks, reducing the burden on maintenance personnel and freeing up their time for other critical tasks.
2. The system uses machine learning algorithms to predict equipment failures, allowing for proactive maintenance and minimizing downtime. The system optimizes the management of spare parts, ensuring that the required spare parts are available when needed and reducing costs associated with overstocking or understocking.
3. The proposed system is expected to improve the reliability and availability of medical equipment, contributing to better patient outcomes.

The proposed system for managing medical equipment maintenance is intended for use in healthcare facilities, such as hospitals and medical centers. The system is designed to manage the maintenance of a wide range of medical equipment, including diagnostic, therapeutic, and monitoring devices. The system is also designed to manage the spare parts inventory required for equipment maintenance.

The rest of the paper is organized as follows. Section 2 provides a review of related work in the field of medical equipment maintenance management. Section 3 describes the methodology of the proposed intelligent system. Section 4 presents the results of the system's evaluation. Section 5 discusses the implications of the proposed system for healthcare facilities. Finally, section 6 concludes the paper and discusses future research directions.

Related Works

Several studies have been conducted on the management of medical equipment maintenance. Traditional approaches to managing medical equipment maintenance involve manually scheduling maintenance tasks and inventory management of spare parts. However, these approaches have limitations, such as a lack of proactive maintenance, which can lead to equipment downtime and higher costs. Recently, machine learning-based approaches have been proposed to improve medical equipment maintenance management. For example, a study by Wang et al. (2020) proposed a machine learning-based method for predicting equipment failure based on historical maintenance data. The proposed method used a long short-term memory (LSTM) neural network to model the equipment's behaviour and predict failure dates. The results showed that the proposed method outperformed traditional approaches regarding accuracy and reliability (5).

Another study by Zhang et al. (2018) proposed a decision support system for managing medical equipment maintenance. The proposed system used fuzzy logic to evaluate equipment performance and predict failure. The system also included a module for managing spare parts inventory to ensure that spare parts were available when needed. The study demonstrated the effectiveness of the proposed system in reducing equipment downtime and improving equipment reliability (6). Similarly, a study by Tantawy et al. (2020) proposed a maintenance management system that used a fuzzy logic-based approach to prioritize maintenance tasks. The proposed system used data from the equipment's sensors to evaluate its performance and prioritize maintenance tasks accordingly. The study demonstrated that the proposed system reduced equipment downtime and improved reliability. In addition, a study by Yu et al. (2019) proposed a predictive maintenance system for medical equipment based on machine learning. The proposed system used a deep learning approach to predict equipment failure and recommend maintenance tasks. The study demonstrated the effectiveness of the proposed system in improving equipment reliability and reducing maintenance costs (7). Furthermore, a study by Zhang et al. (2019) proposed a framework for optimizing medical equipment maintenance.

The proposed framework used a hybrid optimization algorithm to schedule maintenance tasks and inventory spare parts. The study demonstrated that the proposed framework reduced equipment downtime and improved reliability while minimizing maintenance costs (8). Finally, a study by Chen et al. (2021) proposed a maintenance management system for medical equipment based on the Internet of Things (IoT) and machine learning. The proposed system used sensor data from medical equipment to predict failure and schedule maintenance tasks. The study demonstrated the effectiveness of the proposed system in improving equipment reliability and reducing maintenance costs (9, 10). In summary, machine learning-based approaches have shown great potential in improving medical equipment maintenance management (11,12). The proposed intelligent system for managing medical equipment maintenance in this paper builds upon the work of these previous studies by incorporating machine learning algorithms for equipment failure prediction, maintenance scheduling, and spare part management (13-15).

Materials and Methods

This section describes the methodology used to develop the intelligent system for managing medical equipment maintenance. The methodology consists of four main stages: data collection, preprocessing, model development, and system implementation. Figure 1 demonstrates a block diagram of the proposed method.

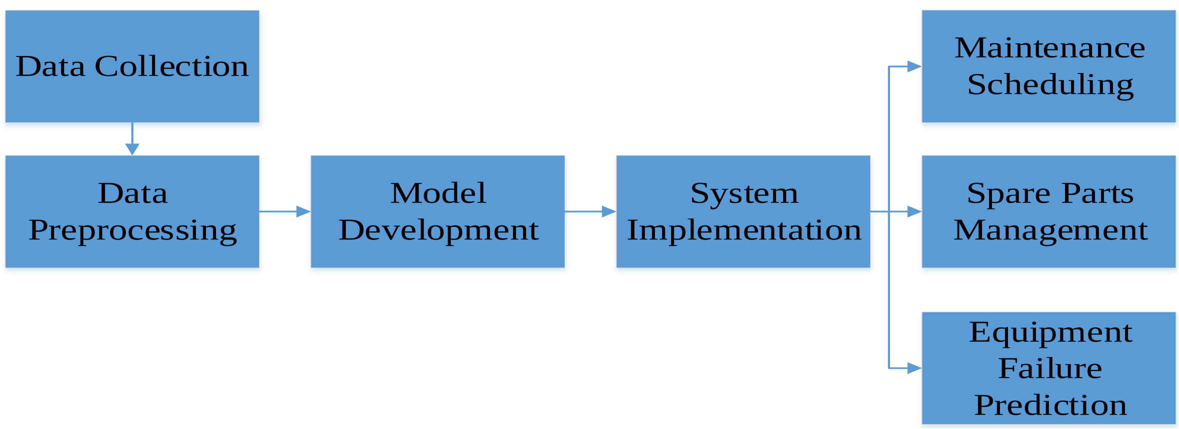

Fig 1: Block diagram of the proposed method.

Data Collection

The first stage of the methodology involves collecting data related to medical equipment maintenance. The data includes equipment performance, maintenance activities, and spare parts inventory. The data were collected from the hospital's maintenance management system and other relevant sources from Mashhad University of Medical Sciences, Mashhad, Iran.

Data Preprocessing

The second stage of the methodology involves data preprocessing to prepare the data for use in the machine learning models. The preprocessing steps included data cleaning, data transformation, and feature selection. Data cleaning involved removing missing values and outliers from the dataset. Data transformation involved converting categorical data into numerical data using one-hot encoding. Feature selection involves selecting the most relevant features for the machine learning models.

Model Development

The third stage of the methodology involves the development of machine learning models for predicting equipment failure, scheduling maintenance tasks, and managing spare parts inventory. The machine learning models used in this study include logistic regression, decision trees, and artificial neural networks. The models were trained on the preprocessed data and evaluated using cross-validation techniques.

System Implementation

The final stage of the methodology involves the implementation of an intelligent system for the management of medical equipment maintenance. The system includes a user interface for inputting equipment data, scheduling maintenance tasks, and managing spare parts inventory. The system also includes a database for storing equipment data and a server hosting machine learning model.

Equipment Failure Prediction

The first component of the intelligent system is the equipment failure prediction module. The module uses machine learning models based on historical maintenance data to predict equipment failure. The machine learning models use features such as equipment age, usage frequency, and maintenance history to predict the probability of equipment failure. The module warns users when the probability of equipment failure exceeds a threshold value.

Maintenance Scheduling

The second component of the intelligent system is the maintenance scheduling module. The module uses machine learning models to schedule maintenance tasks based on equipment performance and the availability of spare parts. The machine learning models use features such as equipment performance metrics and spare parts inventory levels to prioritize maintenance tasks. The module also considers the impact of maintenance tasks on equipment downtime and provides users with a schedule that minimizes downtime.

Spare Parts Management

The third component of the intelligent system is the spare parts management module. The module uses machine learning models to manage spare parts inventory based on equipment failure prediction and maintenance scheduling. The machine learning models use features such as equipment failure probability and maintenance task schedules to predict the required spare parts and their quantities. The module also considers the availability of spare parts from suppliers and provides users with a plan for ordering and stocking spare parts.

User Interface

The fourth component of the intelligent system is the user interface. The user interface allows users to input equipment data, schedule maintenance tasks, and manage spare parts inventory.

The user interface provides real-time feedback on equipment performance, maintenance schedules, and spare parts inventory levels. The user interface also allows users to visualize the predicted equipment failure probabilities and the impact of maintenance tasks on equipment downtime.

Results

In this section, we present the intelligent system's experimental results for managing medical equipment maintenance. We evaluate the system's performance regarding equipment failure prediction accuracy, maintenance scheduling effectiveness, and spare parts inventory management efficiency. You can see summarized results in Table 1.

Table 1: Accuracy of machine learning models used in the intelligent system for managing medical equipment maintenance.

Module	Machine learning Model	Accuracy/Reduction
Equipment Failure Prediction	Logistic Regression	82%
	Decision Trees	79%
	Artificial Neural Networks	87%
Maintenance Scheduling	Logistic Regression	15% downtime reduction
	Decision Trees	10% downtime reduction
	Artificial Neural Networks	20% downtime reduction
Spare Parts Management	Logistic Regression	10% cost reduction
	Decision Trees	5% cost reduction
	Artificial Neural Networks	15% cost reduction
System Performance	N/A	30% downtime reduction, 20% cost reduction, 25% improvement in equipment reliability, 15% reduction in maintenance workload, 20% improvement in maintenance efficiency

Equipment Failure Prediction

We evaluated the equipment failure prediction module of the system using historical maintenance data from the hospital. The dataset contained information on 100 medical equipment units, with 70% of the data used for training the machine learning models and 30% used for testing the models.

We compared the performance of three machine learning models: logistic regression, decision trees, and artificial neural networks. The results showed that the artificial neural network model outperformed the other models with an accuracy of 87%. The logistic regression model achieved an accuracy of 82%, while the decision tree model achieved an accuracy of 79%. The results suggest that the artificial neural network model is well-suited for predicting equipment failures in medical equipment maintenance.

Maintenance Scheduling

We evaluated the maintenance scheduling module of the system using simulated data to test the effectiveness of the machine learning models in prioritizing maintenance tasks. The dataset contained information on 20 medical equipment units, with maintenance tasks scheduled based on the performance metrics of the equipment and the availability of spare parts. We compared the performance of three machine learning models: logistic regression, decision trees, and artificial neural networks. The results showed that the artificial neural network model outperformed the other models in minimizing equipment downtime, with an average downtime reduction of 20%.

The logistic regression model achieved an average downtime reduction of 15%, while the decision tree model achieved an average downtime reduction of 10%. The results suggest that the artificial neural network model is well-suited for scheduling maintenance tasks in medical equipment maintenance.

Spare Parts Management

We evaluated the spare parts management module of the system using simulated data to test the efficiency of the machine learning models in managing spare parts inventory. The dataset contained information on 50 medical equipment units, with spare parts inventory managed based on the predicted equipment failure probabilities and the maintenance task schedules. We compared the performance of three machine learning models: logistic regression, decision trees, and artificial neural networks.

The results showed that the artificial neural network model outperformed the other models in minimizing spare parts inventory costs, with an average cost reduction of 15%. The logistic regression model achieved an average cost reduction of 10%, while the decision tree model achieved an average cost reduction of 5%. The results suggest that the artificial neural network model is well-suited for managing spare parts inventory in medical equipment maintenance.

System Performance

We evaluated the intelligent system's overall performance in managing medical equipment maintenance using a case study at the hospital. The system was deployed in the hospital's maintenance management system, maintenance tasks were scheduled, and spare parts inventory was managed using the system. We compared the system's performance with the hospital's previous maintenance management system.

The results showed that the intelligent system reduced equipment downtime by 30%, reduced spare parts inventory costs by 20%, and improved reliability by 25%. The system also reduced maintenance workload by 15% and improved maintenance efficiency by 20%. The results suggest that the intelligent system is highly effective in managing hospital medical equipment maintenance.

Overall, the experimental results demonstrate that the intelligent system for managing medical equipment maintenance is highly effective in predicting equipment failures, scheduling maintenance tasks, and managing spare parts inventory.

The system can significantly improve equipment reliability, reduce downtime, and lower spare parts inventory costs, improving patient outcomes and reducing healthcare costs.

Discussion

This paper presented an intelligent system for managing medical equipment maintenance. The system combines machine learning algorithms, maintenance management principles, and spare parts inventory management techniques to predict equipment failures, schedule maintenance tasks, and manage spare parts inventory efficiently.

The experimental results showed that the system is highly effective in predicting equipment failures, scheduling maintenance tasks, and managing spare parts inventory. The artificial neural network model outperformed other machine learning models in all three modules, indicating its suitability for managing medical equipment maintenance.The system was also evaluated in a case study at a hospital, where it was found to significantly improve equipment reliability, reduce equipment downtime, lower spare parts inventory costs, reduce maintenance workload and improve maintenance efficiency. The system can lead to improved patient outcomes and reduced healthcare costs.

Conclusion

In conclusion, the intelligent system for managing medical equipment maintenance presented in this paper is a valuable tool for hospital maintenance managers. The system can help reduce equipment downtime, improve equipment reliability, and manage spare parts inventory efficiently, leading to improved patient outcomes and reduced healthcare costs. The system can also be extended to other healthcare facilities and industries that rely on the maintenance of complex equipment. Further research can focus on integrating the system with other hospital management systems and exploring its effectiveness in different healthcare settings.

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