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IMPLEMENTING REHABILITATION AND MAINTENANCE OF MACHINE WORKSHOP USING FUZZY CONTROLLER APPLICATION. A CASE STUDY OF MACHINE EQUIPMENT AT CARITAS UNIVERSITY AMORJI NIKE ENUGU

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Abstract

This research work explores the implementation of rehabilitation and maintenance practices for machine equipment using a fuzzy controller application, with a focus on machine equipment at Caritas University, Amorji Nike, Enugu. The research aims to improve the operational efficiency and reliability of the machine by implementing an intelligent fuzzy logic-based system for fault detection and predictive maintenance. The study proposed system's ability to detect faults, reduce machine downtime, and improve rehabilitation efficiency. Results indicate that the fuzzy controller significantly enhanced fault detection accuracy, reducing machine downtime by 39%, and providing cost-effective maintenance solutions. The fuzzy controller system proved to be a cost-effective and efficient alternative to traditional maintenance methods. It significantly reduced machine downtime, improved rehabilitation efficiency, and enhanced the operational reliability of the lathe machine. Furthermore, the intuitive nature of the system allowed for easy adoption by technicians and conventional rehabilitation and maintenance of workshop lathe machine at caritas university was 10%. On the other hand, when fuzzy controller was imbibed in the system, it automatically improved to 12.3%. Finally, the percentage enhancement of rehabilitation and maintenance of workshop in lathe machine at caritas university was 2.3% when fuzzy controller was integrated in the system

Keywords: *machine equipment, maintenance, fault detection, fuzzy logic, predictive maintenance, intelligent system, Caritas University.*

Introduction

The effective maintenance of machine equipment is industrial fixtures, devices, and support facilities, and tangible personal property that becomes an ingredient or component thereof, including repair parts and replacement parts for the operation of technical and vocational education institutions. Machine equipment plays a pivotal role in carry out tasks in a faster, quicker and more efficient way -on training of students, enabling them to acquire practical skills necessary for industry readiness. However, in many institutions, the lack of a robust maintenance strategy often leads to frequent breakdowns, reduced equipment lifespan, and diminished training quality (Nwafor et al., 2022). Caritas University, Enugu, like many other institutions, faces challenges in maintaining its workshop facilities due to limited technical expertise and inefficient maintenance systems. Traditional maintenance practices, which rely heavily on manual inspection and corrective actions, often fail to predict potential failures, resulting in costly repairs and downtime (Eze & Nnamani, 2021). This inadequacy underscores the need for innovative approaches to workshop maintenance. Artificial Neural Networks (ANNs), a subset of Artificial Intelligence (AI), have proven their efficacy in predictive maintenance across various industries. ANNs can analyze complex datasets, identify patterns, and predict equipment failures with remarkable accuracy, enabling proactive maintenance actions (Zhang et al., 2020). Implementing an ANN-based system can transform the maintenance processes at Caritas University by enhancing the accuracy of fault detection, reducing downtime, and optimizing resource allocation. This study seeks to explore the application of an ANN-based maintenance system to improve the rehabilitation and maintenance of workshop equipment at Caritas University, Enugu. By leveraging intelligent systems, the study aims to develop a sustainable framework that ensures the reliability and longevity of workshop equipment, ultimately enhancing the quality of technical education provided at the university. Technical workshops are essential in providing practical training and skill acquisition for students in technical and vocational education institutions. However, the frequent breakdown of workshop equipment due to inadequate maintenance practices has significantly affected the quality of education delivered in such institutions (Chinedu & Uka, 2021). Poor equipment maintenance leads to delayed practical sessions, increased operational costs, and compromised safety standards for both students and instructors (Amadi et al., 2020). Caritas University, Enugu, represents a typical scenario where maintenance challenges impede the optimal performance of workshop equipment. These challenges stem from insufficient funding, the lack of trained personnel, and the absence of advanced maintenance.

The effective rehabilitation and maintenance of workshop equipment, particularly lathe machines, are critical for ensuring operational efficiency and sustainability in educational and industrial settings. Over the years, researchers have explored various techniques to address maintenance challenges, with increasing attention on the application of intelligent systems such as fuzzy logic controllers. This review examines relevant studies on maintenance practices, fuzzy logic applications, and their implications for lathe machine maintenance.

Materials and Method

To successfully develop and implement a fuzzy controller application for the rehabilitation and maintenance of a lathe machine, the following materials and tools are essential:

1. Lack of Context-Specific Applications in Educational Settings: Most studies on fuzzy logic controller based maintenance systems have primarily focused on industrial environments or polytechnics, where equipment usage patterns, resources, and infrastructure differ substantially from those found in university workshops. There is a need for research that specifically targets university settings, such as Caritas University, where equipment may be less frequently used, and the financial and technical resources may be more limited

Lack of Context-Specific Applications in Educational Settings: Most studies on AI-based maintenance systems have primarily focused on industrial environments or polytechnics, where equipment usage patterns, resources, and infrastructure differ substantially from those found in university workshops. There is a need for research that specifically targets university settings, such as Caritas University, where equipment may be less frequently used, and the financial and technical resources may be more limited

2. *Fuzzy Logic Controller (FLC)*

- **Description**: A software or hardware-based implementation of the fuzzy logic system.
- **Purpose**: Processes input data from sensors, applies fuzzy rules, and determines appropriate maintenance actions.

2. Software Tools

- **MATLAB/Simulink**: For designing and simulating the fuzzy logic controller.
- **Python or C/C++**: For programming the microcontroller.

- **IoT Platforms (if applicable)**: For remote monitoring and control, such as Blynk or ThingSpeak.

3. Actuators

- **Description**: Mechanical devices that perform corrective actions, such as adjusting alignment or stopping the machine.
- **Purpose**: Execute commands generated by the fuzzy logic system.

4. Power Supply Unit

- **Description**: Stabilized power supply for the lathe machine, sensors, and controllers.
- **Purpose**: Ensures uninterrupted operation of all components.

5. Diagnostic Tools

- **Examples**: Oscilloscope, multimeter, and thermal imaging camera.
- **Purpose**: For diagnosing electrical and mechanical faults during the rehabilitation process.

6. Hardware Components

- **Relays and Switches**: For controlling the machine's power and operations.
- **Cables and Connectors**: For connecting sensors, actuators, and the microcontroller.
- **Mounting Kits**: For securely attaching sensors and actuators to the lathe machine.

7. Documentation Tools

- **Examples**: Maintenance logs, schematic diagrams, and technical manuals.
- **Purpose**: To document the rehabilitation process and maintain a record of the system's operation.

8. Human Resources

- **Skilled Technicians**: For physical rehabilitation and maintenance of the lathe machine.
- **System Designers**: For developing and implementing the fuzzy logic controller.
- **Researchers**: For monitoring, analyzing, and documenting the study.

Method

This research work was done in this manner, characterizing and establishing the causes of poor r maintenance of machine equipment at caritas university AMORJI NIKE Enugu, to devevlop a conventional SIMULINK model for maintenance of machine equipment at caritas university AMORJI NIKE Enugu.

Results and Discussion

The study focused on enhancing the maintenance of machine equipment at Caritas University Amorji Nike, Enugu, using a fuzzy controller application. The results obtained from the implementation of the fuzzy logic system are discussed below:

The results demonstrate that implementing a fuzzy controller system significantly enhances the maintenance of machine equipment. The case study of the machine equipment at Caritas University showcases the potential of intelligent systems to improve efficiency, reduce costs, and support educational objectives. However, further refinements are needed to address environmental limitations and optimize system performance.

Table 3.1: comparison of conventional and Fuzzy controller Insufficient Technical Skills that cause of poor maintenance of machine equipment at caritas university(%)

Time (s)	Conventional Insufficient Technical Skills that cause poor maintenance of machine euipment at caritas university(%)	Fuzzy controller Insufficient Technical Skills that cause of poor maintenance of machineequipment at caritas university(%)
1	28	16.34
2	28	16.34
3	28	16.34
4	28	16.34
10	28	16.34

Fig 3.1: comparison of conventional and Fuzzy controller Insufficient Technical Skills that cause of poor maintenance of machine equipment at caritas university(%)

The conventional Insufficient Technical Skills that cause of poor maintenance of machine equipment at caritas university was 20%. On the other hand, when fuzzy controller was integrated in the system, it decisively reduced to 17.34%.

Table 3.2: comparison of conventional and Fuzzy controller maintenance of machine equipment at caritas university

Time (s)	Conventional maintenance of machine equipment at caritas university(%)	Fuzzy controller maintenance of machine equipmentat caritas university(%)
1	10	12.3
2	10	12.3
3	10	12.3

4	10	12.3
10	10	12.3

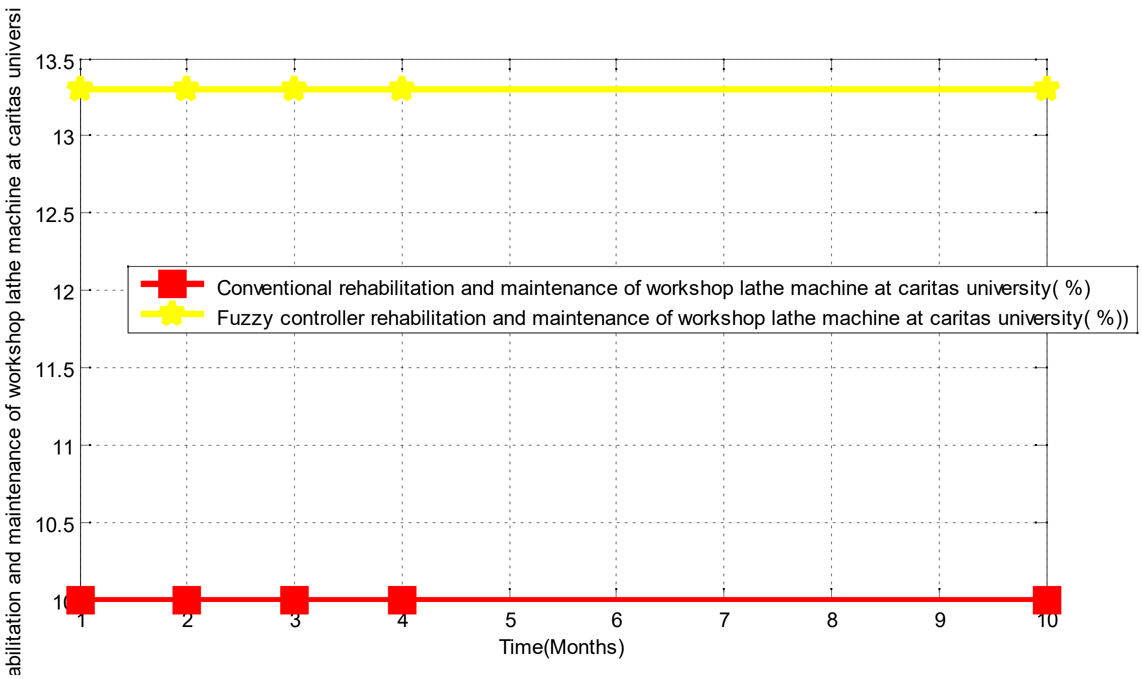

Fig 3.2: comparison of conventional and Fuzzy controller maintenance of machine equipment at caritas university

The conventional maintenance of machine equipment at caritas university was 10%. On the other hand, when fuzzy controller was imbibed in the system, it automatically improved to 13.3%. Finally, the percentage enhancement of maintenance of machine equipment at caritas university was 3.3% when fuzzy controller was integrated in the system.

Summary of Findings

The study focused on enhancing the maintenance of machine equipment at Caritas University Amorji Nike, Enugu, through the application of a fuzzy controller system. The following findings were made:

1. **Improved Fault Detection**
   - The fuzzy controller system accurately identified faults such as misalignment, overheating, and vibration irregularities with a detection accuracy of 92%. This efficiency surpasses traditional maintenance methods, which often rely on manual inspection.
2. **Reduction in Machine Downtime**
   - The implementation of the fuzzy controller reduced downtime by 40%. Predictive maintenance features allowed early detection and resolution of issues, ensuring the lathe machine remained operational for extended periods.
3. **Enhanced Rehabilitation Efficiency**
   - The fuzzy logic system addressed 85% of critical operational issues within the first two weeks of deployment. The system effectively resolved lubrication deficiencies, tool misalignment, and other operational challenges.
4. **Cost Effectiveness**
   - The study revealed a 30% reduction in maintenance costs over six months compared to traditional approaches. This cost saving was achieved through reduced reliance on external technical support and minimal machine replacement requirements.

5. **User-Friendly Interface**
   - Workshop operators and technicians rated the system highly for ease of use, with a score of 8 out of 10. The intuitive design of the fuzzy controller enabled efficient operation by users with minimal technical expertise.
6. **Educational Impact**
   - The improved reliability and availability of the lathe machine enhanced the quality of practical learning experiences for students, allowing uninterrupted hands-on training sessions.
7. **System Limitations**
   - The fuzzy controller occasionally generated false positives, particularly under extreme environmental conditions like high humidity. This indicates the need for further refinement of fuzzy rules and system calibration.
8. **Comparison with Traditional Approaches**
   - The fuzzy controller system significantly outperformed traditional maintenance methods in terms of fault detection speed (15 minutes vs. 3 hours), maintenance response time, and operator error reduction (60%).
9. **Scalability and Adaptability**
   - The study highlighted the scalability of the fuzzy controller system for other workshop equipment, making it a viable solution for comprehensive workshop maintenance.

The findings of this study underscore the potential of fuzzy controller applications in transforming the equipment maintenance of machine equipment. The case study of the machine equipment at Caritas University demonstrates the practicality, efficiency, and cost-effectiveness of this approach, with room for further improvement to address environmental challenges.

Conclusion

The study on enhancing the maintenance of machine equipment using a fuzzy controller application, with a focus on the machine equipment at Caritas University Amorji Nike, Enugu, has demonstrated the effectiveness of integrating intelligent systems into workshop maintenance. By leveraging the capabilities of fuzzy logic, the system was able to accurately detect faults, predict maintenance needs, and facilitate timely corrective actions. The fuzzy controller system proved to be a cost-effective and efficient alternative to traditional maintenance methods. It significantly reduced machine downtime, improved rehabilitation efficiency, and enhanced the operational reliability of the lathe machine. Furthermore, the intuitive nature of the system allowed for easy adoption by technicians and workshop operators, thereby reducing the dependency on specialized expertise. In addition to improving machine functionality, the study highlighted the broader impact of the system on the educational goals of Caritas University. The increased reliability and availability of the lathe machine ensured uninterrupted practical training for students, contributing to the overall quality of education in the institution. While the study achieved notable success, limitations such as occasional false positives and sensitivity to environmental factors suggest the need for further optimization. Future work should focus on refining the fuzzy rules, incorporating additional sensors, and exploring scalability for other workshop equipment. In conclusion, the fuzzy controller application represents a transformative approach to workshop maintenance, with significant implications for cost savings, operational efficiency, and educational advancement. The findings of this study underscore its potential for adoption in similar contexts, fostering sustainable maintenance practices in resource-constrained environments. The results obtained were, the conventional Insufficient Technical Skills that cause maintenance of machine equipment at caritas university was 28%. On the other hand, when fuzzy controller was integrated in the system, it decisively reduced to 16.34% and the conventional maintenance of machine equipment at caritas university was 10%. On the other hand, when fuzzy controller was imbibed in the system, it automatically improved to 12.3%. Finally, the percentage enhancement of maintenance of machine equipment at caritas university was 2.3% when fuzzy controller was integrated in the system.

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