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Development of a Machine Vision Based Non-Contact Metrology System for Inspection of Mechanical Components

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Abstract: Machine learning and automation have become an integral part of modern manufacturing industries, enabling faster, smarter, and more reliable production processes.
Industrial operations can now be automated using advanced machine learning algorithms combined with high-resolution imaging systems, driving the transition toward Industry 4.0. The central idea of this project is to automate the visual inspection process with high-precision defect detection.
One of the major challenges in today's factories is ensuring consistent quality inspection, as faulty components may still reach customers due to human error.
This project focuses on developing an AI-driven system capable of performing dimensional and structural analysis of mechanical components such as pinions, bolts, and nuts. A compact inspection setup is used with a high-resolution camera and precision platform.
The captured images are processed using image processing and machine learning techniques to extract parameters and detect defects accurately, ensuring consistency, reliability, and improved productivity.
Keywords: Machine Vision, Automation, Image Processing, Machine Learning, Quality Inspection.

I. INTRODUCTION

Modern manufacturing industries require high precision and consistency in quality inspection of mechanical components. Traditional manual inspection methods are time-consuming and prone to errors due to fatigue and subjective judgment. These limitations make manual inspection unsuitable for high-volume production environments.

Automated inspection using machine vision systems provides an effective solution by enabling fast, accurate, and reliable analysis of components. By integrating high-resolution imaging with intelligent algorithms, defects can be detected with greater precision and consistency.

The proposed system aims to eliminate human dependency, improve inspection efficiency, and ensure uniform quality standards across production lines.

II. SYSTEM METHODOLOGY

The proposed system is based on a machine vision approach for non-contact inspection of mechanical components. It consists of a backlit platform and a top-mounted high-resolution camera. The component is placed on the platform, and an image is captured under controlled lighting conditions to ensure high contrast.

The captured image undergoes preprocessing steps such as grayscale conversion and thresholding to simplify the data and enhance feature visibility. Image processing techniques including edge detection and contour analysis are then applied to extract important features such as shape, size, and dimensions.

These extracted features are analyzed using a machine learning model to classify the component and detect defects. The system compares measured parameters with predefined standards to determine whether the component is acceptable or defective.

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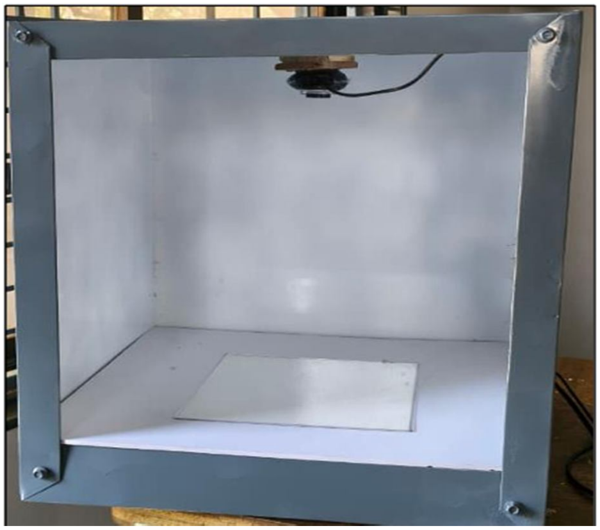

Fg. 1 Experimental Setup of Proposed System

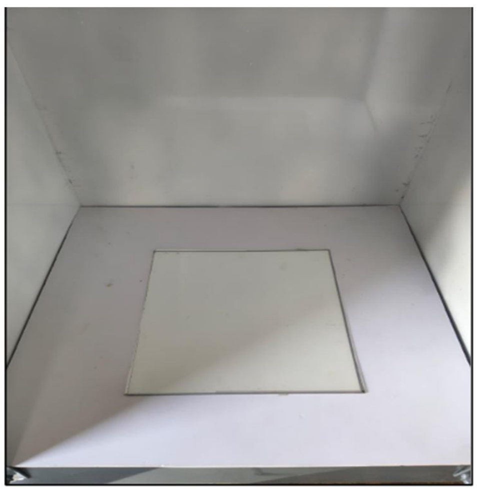

Fig. 2 Inside View of Experimental Setup

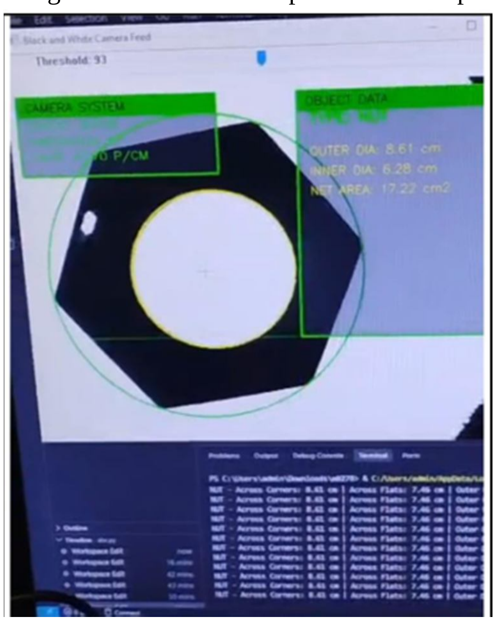

Fig. 3 Output of Inspected Component

III. RESULTS

The developed system successfully inspected mechanical components such as bolts, nuts, and pinions with high accuracy. The use of image processing and machine learning techniques enabled precise extraction of dimensional parameters and effective defect detection.

The system demonstrated consistent performance and significantly reduced inspection time compared to traditional manual methods. It proved to be reliable for continuous operation in industrial environments.

Key Results:

- High precision measurement of dimensions
- Reduced inspection time
- Improved consistency and repeatability
- Significant reduction in human error

IV. FUTURE SCOPE

The system can be further enhanced by integrating advanced deep learning algorithms for improved defect classification and pattern recognition. Incorporating IoT technology can enable real-time monitoring and remote control of the inspection process. Additionally, the system can be integrated with automated sorting mechanisms to instantly reject defective components, further improving efficiency. The use of multiple cameras and advanced sensors can also enhance inspection accuracy for complex components.

V. CONCLUSION

The proposed system provides an efficient and reliable solution for automated inspection in manufacturing industries. It enhances productivity by enabling fast and continuous inspection of components in real time. The system improves accuracy by eliminating human errors such as fatigue and inconsistency, while ensuring uniform and repeatable inspection results.

Additionally, it reduces dependency on manual labor and supports quick identification of defective components, thereby minimizing material wastage and improving overall process efficiency. Overall, the system contributes to better quality control and supports the advancement of smart manufacturing systems.

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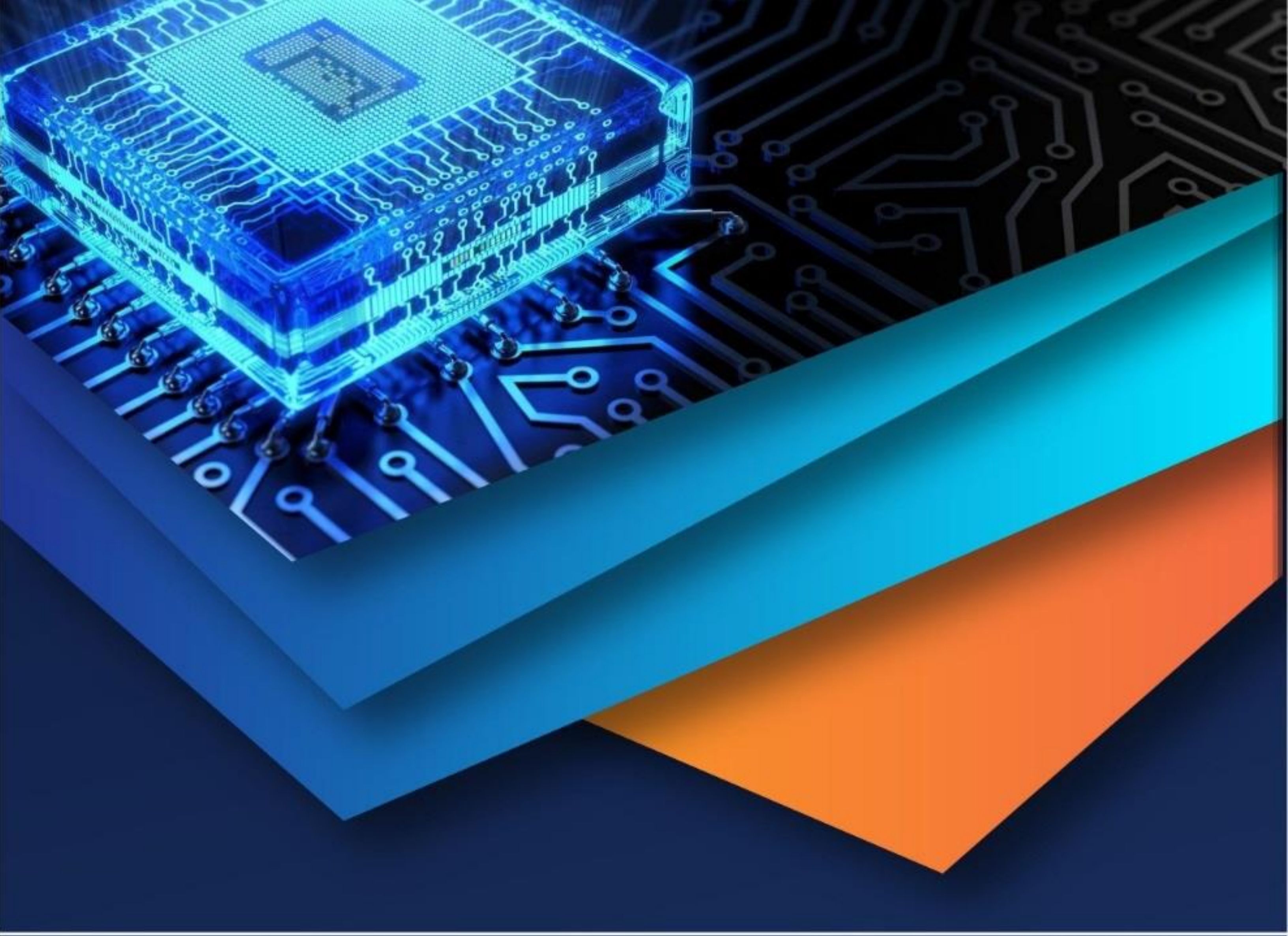

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