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AI QUALITY ANALYSIS OF "SPUR GEAR" BY IMAGE PROCESSING

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Abstract: This proposes approach to gear quality analysis using image processing techniques. The proposed method utilizes computer vision algorithms to extract features from gear images, which are then used to evaluate various quality parameters such as tooth wear, surface roughness, and dimensional accuracy. The system is designed to improve the efficiency and accuracy of gear inspection, reducing the need for manual measurement and human error. Experimental results demonstrate the effectiveness of the proposed approach in classifying gears as acceptable or defective, with a high degree of accuracy. This project has significant implications for the automation of quality control processes in the manufacturing industry.

Keywords: Gear quality, Tooth wear, Accuracy, Manufacturing, Gear inspection

1. Introduction

Gears are essential mechanical components used to transmit power between shafts. They come in various types such as spur gears, helical gears, and worm gears, and find applications in diverse machinery like automobiles, metal cutting tools, and marine power plants. The friction and losses in gear drives are minimal compared to other power transmission methods.

Our work utilizes MATLAB software for determining gear parameters, leveraging its accuracy and built-in functions. This user-friendly program simplifies design calculations, reducing errors and making gear design more efficient. In today's fast-paced computational world, industries increasingly rely on computers and algorithms for manufacturing tasks, including gear filtering and classification. Human labor is limited by time and cost, making automation crucial for efficiency.

Image processing technology, a subset of computer science, is integral to gear measurement and classification. By converting gear images to grayscale and developing algorithms, we accurately measure gear features such as outer and inner diameters, tooth count, tooth height, and pitch circle diameter. This approach streamlines the measurement process, ensuring gears meet specific size requirements.

Gear transmissions play a vital role in machinery, influencing motion properties through linear and rotary developments. Despite being an old technology, gear transmissions remain complex, necessitating accurate measurement of gear parameters. Specialized tools like tooth callipers are used for this purpose, considering variations in gear profiles, sizes, and tooth counts.

2. Literature Review

[1] Haque Nawaz and Himmat Ali: Published a paper titled "Gear Measurement Using Image Processing in MATLAB" in the International Journal of Innovative Technology and Exploring Engineering (IJITEE) in 2014. The study focused on measuring the area and counting the teeth of gear image objects using MATLAB and image processing techniques. The researchers converted the original gear image objects into grayscale to count the teeth using programming code. This work is significant as it aids in gear size limitation and guides further research in computer technologies like digital signal processing (DSP) and digital image processing (DIP).

[2] Cheng Pengfei and Feng Changyong: Published a paper in the Journal of Multimedia in 2013, discussing the extraction of characteristic values of gear defects through image processing. They utilized MATLAB's image processing toolbox for gear defect detection, leveraging image characteristics to identify different defect forms such as pitting and attrition. The paper highlights MATLAB's powerful data processing capabilities and its application in digital image processing for defect detection.

[3] Milica Babic et al: Conducted a comprehensive literature review on image-based quality inspection systems in the manufacturing sector (SMS) over the last decade. They focused on modern imagebased quality inspection systems, particularly in the context of Industry 4.0. The review discusses advancements in digital camera systems and analytics, including artificial intelligence and machine learning algorithms, for quality inspection of three-dimensional parts.

[4] H. Alkhadafe et al: Introduced the Automated Sensor and Signal Processing Approach (ASPS) for developing effective condition monitoring systems for gearbox fault diagnosis. The approach combines Taguchi's orthogonal arrays with automated selection of sensory characteristic features to optimize sensor selection and signal processing methods. The experiments demonstrated the effectiveness of the approach for gearbox fault diagnosis using multi-sensory signals and neural network classification models.

[5] Shivani Bhoir et al: Proposed a system for gear parameter checking using a conveyor belt, camera, and image processing techniques. The system checks each gear in a batch to ensure quality, preventing rejection of entire batches due to a single faulty gear. This approach improves quality control and efficiency in manufacturing processes.

3. Methodology

The initial step involves reading the original gear image with the tool, followed by converting it to grayscale. Subsequently, the image is thresholder, and the gear area is calculated. The region of interest is then highlighted to facilitate tooth counting, resulting in an accurate representation of the gear's teeth.

A. About MATLAB

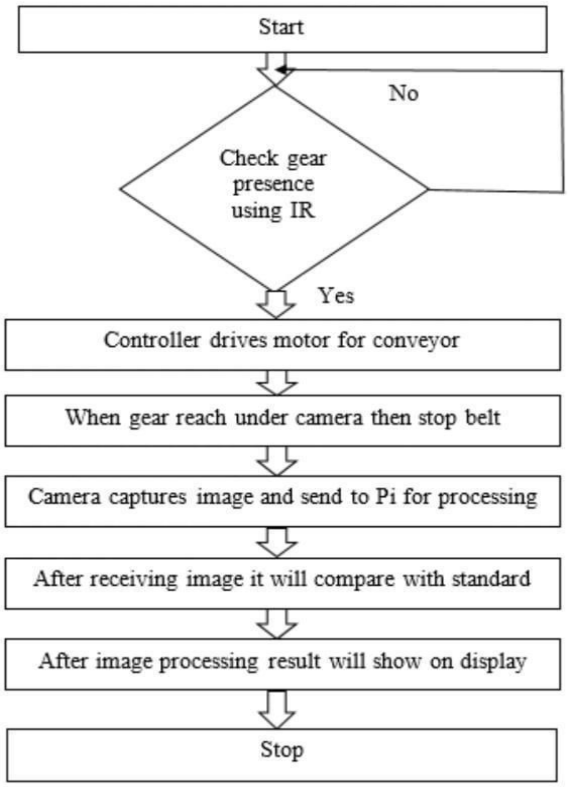
MATLAB, short for Matrix Laboratory, serves as an interactive platform tailored for matrix-based computation, primarily geared towards scientific and engineering applications. It stands out

as a high performance language suited for technical computing tasks. Offering a user-friendly environment, MATLAB seamlessly integrates computation, visualization, and programming, allowing users to express problems and solutions using familiar mathematical notations.

Common applications of MATLAB encompass math and computation, algorithm development, modelling, simulation, and prototyping, data analysis and exploration, as well as scientific and engineering graphics. Additionally, it facilitates application development, including the creation of graphical user interfaces.

As a software package specializing in high-performance numerical computation and visualization, MATLAB provides an interactive workspace equipped with an extensive array of built-in functions for technical computation, graphics, and animation. Moreover, its versatility extends to easy extensibility through its proprietary high-level programming language, making it a versatile tool for a wide range of technical tasks.

B. Construction



1) MATLAB serves as the core tool for image processing to compute gear parameters and count teeth accurately.
2) The project's central unit is the computer, interfacing with I/O devices via the parallel port.
3) Image processing involves analysing visual data to extract specific characteristics or parameters.
4) Standard image-processing techniques treat images as two-dimensional signals and apply corresponding signal-processing methods.
5) Material handling is facilitated by mounting rollers at predetermined distances and placing materials on a belt spanning these rollers.
6) The motor drive, coupled with the rollers, enables controlled movement of the belt and facilitates efficient material handling.
7) Adjustable time delays for material movement are managed through the motor drive.
8) Initially, the motor conveyor remains stationary until activated. ix) Gears are placed onto the conveyor belt and captured by a fixed camera positioned above the setup.
9) Captured gear images are transmitted to the computer for analysis using MATLAB algorithms. MATLAB algorithms process the images and present the results on the command window interface.
10) Accepted gears are sorted into a designated tray, while rejected ones are redirected using a DC gun motor.

A pushing rod, integrated with the DC gun through a hinge and spring mechanism, facilitates the movement of rejected gears into a separate tray when activated, and returns to its original position automatically.

C. Working

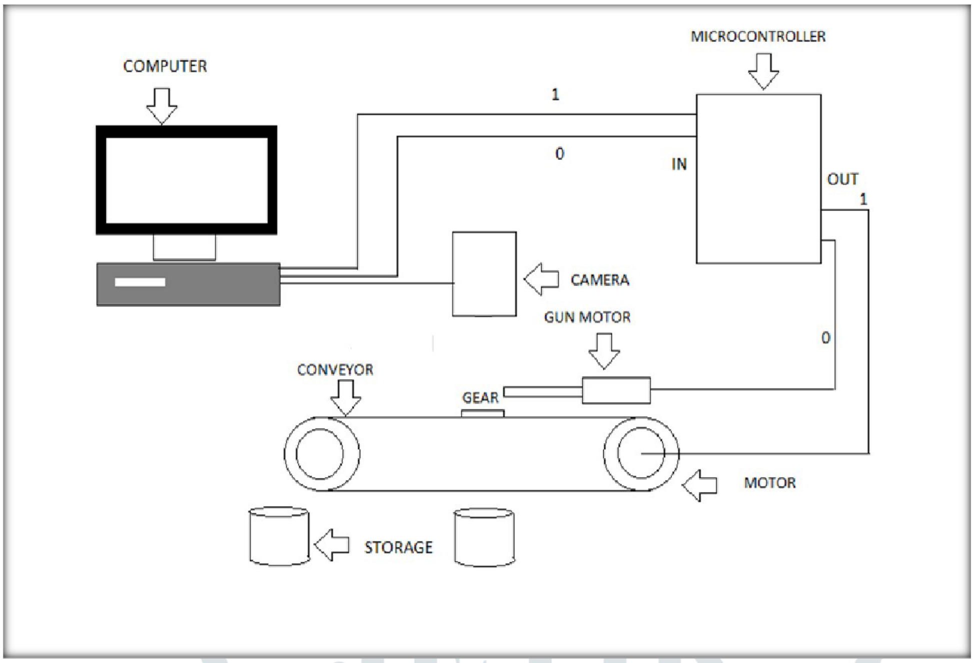


Fig 1. Model Setup

The MATLAB code developed for image processing begins by reading the original gear object image and converting it to grayscale. Then, it calculates the threshold value of the grayscale image to convert it into a binary image. The code includes steps to remove small objects from the binary image and fill any holes in the object to ensure accuracy.

After preprocessing, the code measures the properties of the image object regions and applies convex polygon conversion to these regions. Finally, it creates regions of interest and highlights them with red and yellow lines to indicate the teeth region of the gear object.

Through this process, the code is able to measure the area of the gear object and count the teeth using MATLAB. The code is designed to handle different gear objects by changing the object's name within the code.

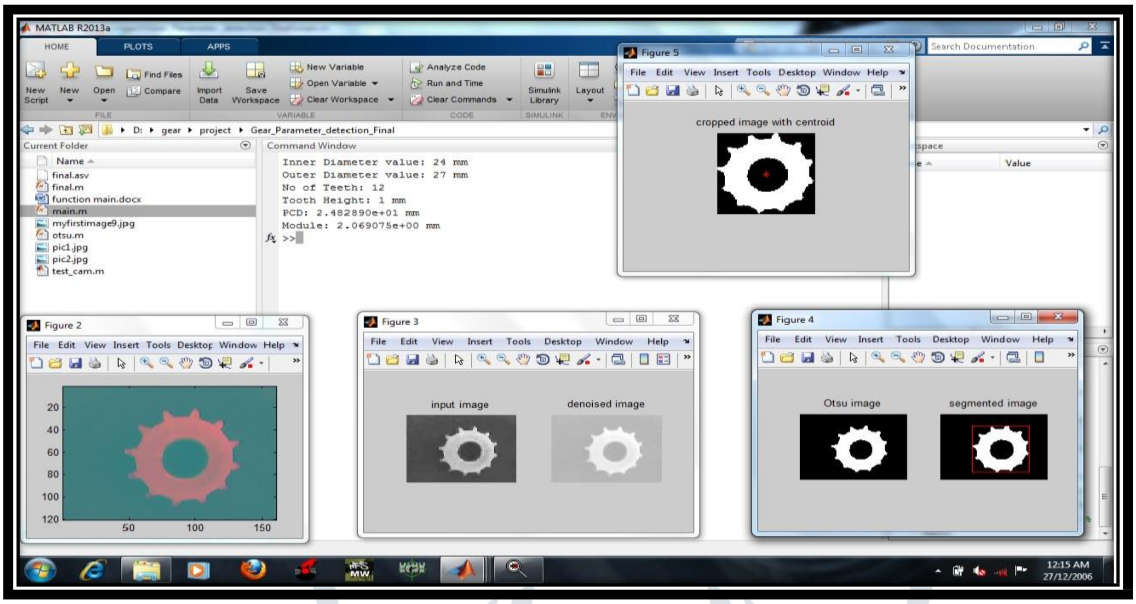
The results of the image processing are presented in the results section, showing measurements such as the outer diameter (addendum diameter), inner diameter (dedendum diameter), pitch circle diameter (PCD), module, number of teeth, and tooth height of the gear image object. The code effectively counts the teeth and provides detailed measurements for analysis and evaluation.

4. Results

Upon integrating a virtual terminal or similar component for displaying UART communication in our simulation, we can conveniently access it within the Proteus environment. Upon opening it, we'll encounter the initial prompt sent by the microcontroller, typically something like "Enter 1 or 0 to proceed." This message initiates the interactive testing phase of our simulation, allowing us to evaluate the functionality of the motors and UART communication.

Using the virtual terminal, we can transmit characters directly to the microcontroller. For instance, typing '0' or any other character and sending it through the virtual terminal prompts a response from the microcontroller. If '0' is entered, the microcontroller executes commands to activate the sorting motor and adjust the conveyor motor as per the specified code. Conversely, inputting any other character triggers corresponding logic within the code, thereby altering the behavior of the motors based on the input character.

a) Correct Gear Results:



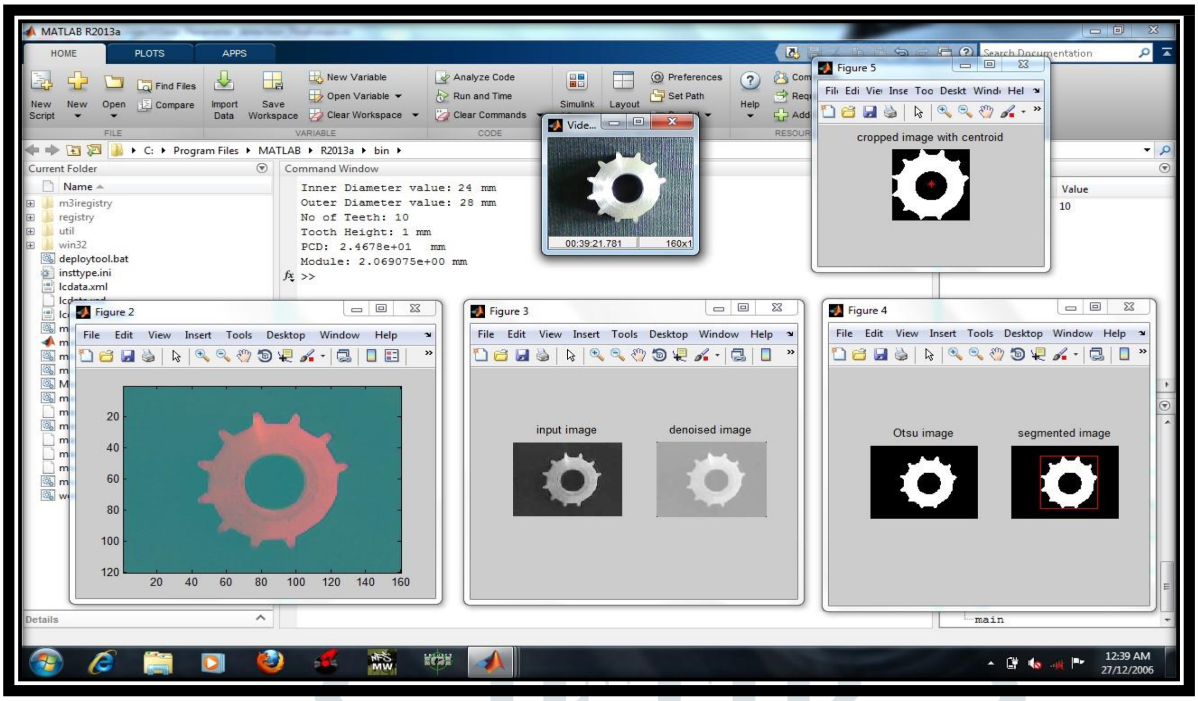
Input Data Validation: Begin by verifying the accuracy and appropriateness of the input data, including gear dimensions, tooth profiles, and other relevant parameters, ensuring they fall within acceptable ranges.

Gear Design Analysis: Utilize mathematical models and calculations to derive the anticipated gear parameters, such as gear ratio, tooth profile, pitch diameter, and other essential characteristics.

Simulation Using MATLAB: Employ MATLAB to conduct a comprehensive simulation of the gear system, incorporating the designed parameters and input conditions to simulate the system's behavior accurately.

Result Validation: Perform a thoough comparison between the simulation results and the expected values derived from the gear design analysis. This step confirms the functionality and correctness of the gear system based on the input data and design specifications.

b) Defective Gear Results:



Failure Identification: Begin by analyzing the simulation results using MATLAB to detect any deviations, anomalies, or failures in the gear system's performance that lead to incorrect or suboptimal functioning.

Root Cause Analysis: Utilize MATLAB for in-depth analysis, such as stress analysis, vibration analysis, and other relevant techniques, to pinpoint the root cause behind the identified failures or issues in the gear system.

Remediation Strategies: Develop and implement appropriate strategies to address the root cause of the issues identified in the gear system. This may involve redesigning components, adjusting operating parameters, or implementing other corrective measures as deemed necessary.

Validation of Remediation: Validate the effectiveness of the remediation strategies through additional simulations or physical testing, ensuring that the implemented changes have successfully resolved the identified issues and improved the overall performance of the gear system.

5. Conclusion

Gear area and tooth count are determined using image processing in MATLAB. Five gear images processed with MATLAB code show varying area and teeth count. This demonstrates MATLAB's capability in gear measurement via image processing.

Digital image processing, performed by computers using specific algorithms, holds promise across various fields. Its branches include image transformation, intensification, restoration, segmentation, analysis, and recognition. MATLAB's robust data processing abilities make it a valuable tool in digital image processing.

The combination of MATLAB and image processing technology enables efficient gear inspection, applicable in industries ranging from gear manufacturing to automobile and quality control departments. This technology can be utilized for circular component testing in both small and largescale industries.

In conclusion, image processing technology has wide-ranging applications in manufacturing, automobile, aerospace, medical, biological studies, remote sensing, and computerized photography, highlighting its effectiveness across diverse industries.

6. Acknowledgment

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