Smart Anomaly Detection and Classification for Validation Process of Watch Gears Using LABVIEW

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Abstract:

This project aims to automate the process of validation of miniature gears such as gears that are used in watches, clocks, etc., by using machine learning algorithms. These processes are carried out manually and hence the production speed is heavily dependent on the speed of validation of humans. This project aims to withdraw human support in this area by the use of machine learning. The gears are examined by using high-resolution cameras. The output of the camera is processed using NI LabVIEW's Vision Assistant which is pre-trained using ideal and defective gears. If the input gears are in coherency with those trained 'Ideal gears', such gears are sent for assembly. If the gears are defective, a signal is sent to an actuator (say a robot) to dispose of this defective gear for recycling. This way, the project when made as an industrial machine, could increase production and decrease the Cost-to-the-Company.

Keywords: Defect detection, image processing, computer vision.

1. INTRODUCTION

All manufacturing businesses try to create a variety of competitive products. The key determinants of competitiveness improvement are the productivity and quality of each industry's products. In this industry, defective items have resulted in numerous losses. Human inspection still detects the majority of faults that occur during the manufacturing process. Inspectors' work is arduous and time-consuming. Approximately 70% of defects can be identified manually. Furthermore, once a person becomes tired, the effectiveness of visual inspection decreases significantly. Because the bulk 2 of the gears are within a tenth of a millimetre of the specified size. Gear samples are increasingly being subjected to digital image processing techniques for product examination [1]. As technology advances, more and more products are being made with metals, particularly in robotics, which requires ultra-lightweight and modular components such as gears. Gears are composed of plastic material High-density polyethylene (HDPE) and other metals, according to industry statistics, which are prone to various sorts of defects (flash, warping, bubbles, empty portions, sink marks, ejector marks, and so on) when created using image processing

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[2]. As a result, we propose that a fully robust system based on image processing techniques (such as image segmentation and non-smooth corner detection) be investigated in order to develop a cost-effective solution for providing Total Quality Management in manufacturing units, allowing for a continuous monitoring and improvement eco-system while lowering costs [3].

Fig 1.1 – Clock Gears

A gear is a rotating circular machine element with carved or inserted teeth (called cogs) which meshes with another (suitable) toothed part to transfer (convert) torque and speed. In terms of the underlying notion, gear action is analogous to lever action. Different-sized gears create a mechanical advantage by generating a difference in torque owing to their gear ratio, and so may be regarded a fundamental machine [9,10]. Two meshing gears have different rotational 3 speeds and torques in proportion to their diameters. Both meshing gears have the same tooth shapes. The escapement, or wheelwork, of a clock is a set of turning wheels (gears) that transport motion from a weight or spring to the minute and hour hands. The accuracy of the wheels and pinions, as well as the tooth form, are critical for transferring power as consistently as feasible [11].

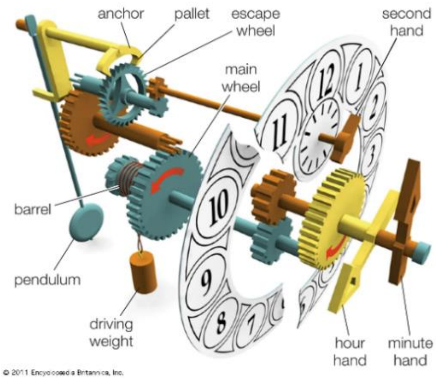

Fig 1.2 – A weight-driven clock featuring a pendulum's main components. Encyclopaedia Britannica, Inc.

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Before proceeding any further, let's have a quick glance at the common defects present in plastic materials like gears which is of course our material of interest [9]. The following are some examples of plastic gear faults that can be identified using image processing:

1. Flash: Excess moulding material that penetrates mould gaps, such as sliding push-out faces, inserts, and so on, is referred to as this fault.

2. Distortion: When the degree of shrinkage differs at different points inside the moulded component, this flaw causes deformation.

3. Bubbles: A manufacturing flaw has trapped an air bubble-like substance inside plastic gear.

4. Unfilled sections: This problem develops when injection moulding does not reach particular spots on the inside side of the die before solidifying.

5. Sink marks: On the outside surfaces of moulded components, they are markings or irregular patches on the surface.

6. Ejector marks: Flow markings are patterns left on the surface of moulded products by the flow tracks of molten plastic [4].

7. Missing Tooth: This fault refers to missing teeth/tooth in a plastic gear.

2. Existing Methodology

The existing methodology consists of examining and recording the condition of the functioning surfaces of gear teeth and bearings. Next, the gears are washed with solvents after the initial examination. The gears are again examined for defects. Because it is frequently the most essential aspect of the inquiry and may reveal vital information, this inspection is made as comprehensive as possible. For this investigation, a low-power magnifying lens and a pocket microscope are used.

A failure analysis report is made including all pertinent information discovered during the investigation, as well as inspections and testing, evidence weighing, findings, and suggestions. The information is thus documented in a concise manner, ideally in tables. The report normally includes suggestions for fixing the equipment or altering its design or operation to prevent future failures [5,6].

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Fig 2 - Manual gear validation

However, the above-mentioned methodology suffers from various drawbacks such as

1. To make a written account of any significant observations, including drawings and pictures as appropriate.
2. To clearly identify and designate each component (including gear teeth and bearing rollers) in the textual description, drawings, and images.
3. The speed of production is purely dependent on the validation speed of employed humans.
4. The Cost-to-the-Company in case of human is far greater in comparison to a well-maintained machine.
5. As humans are liable to errors but machines, the end product will be more reliable and the defective pieces to ideal pieces' ratio will be very low

Considering the above drawbacks, an automated methodology using image processing is proposed to simplify, increase and modernize the process of validation and production [7].

3 PROPOSED METHODOLOGY

The proposed methodology consists of a High-Resolution Camera along with LabVIEW's Machine Vision Module to automate the whole process of validation of the gears before assembly [8]. As soon as the process starts, the gears are passed on to the validation stage via the conveyor. The gears are then examined by the camera (A phone camera in our case). The resolution of the camera is 108MP. The description of the apparatus used is depicted below.

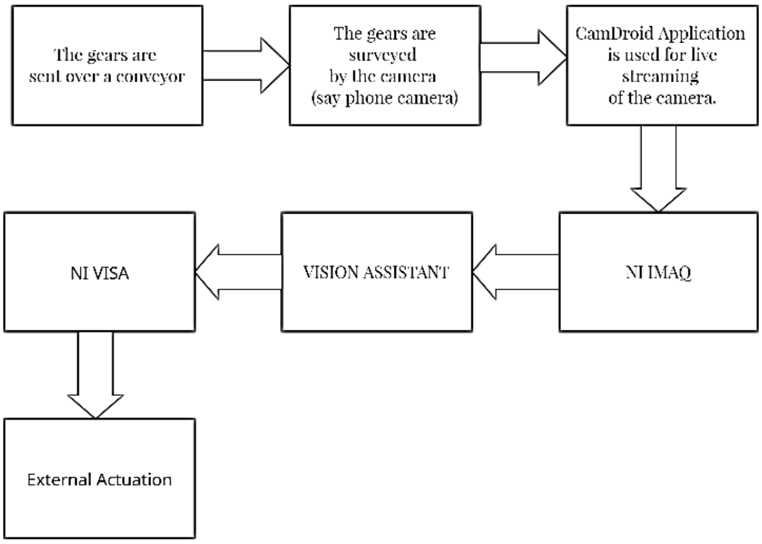

Fig 3.1 - Block Diagram of smart anomaly detection and classification for validation process of watch gears using LabVIEW

In order to decrease any noise, the camera is used under a dark environment. A flash is used to facilitate the imaging process. The image from the phone is telecasted to a Personal Computer with LabVIEW Software for further processing.

3.1 LabVIEW

The MAX and VISA toolsets include built-in support for NI hardware platforms including as Compact DAQ and Compact RIO. LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) is a platform and development environment for a visual programming language developed by National Instruments.

3.2 NI Vision Assistant

Vision Assistant is an image processing prototyping and testing tool. To design an image processing application, use the Vision Assistant scripting feature to create custom algorithms. The scripting feature records each stage of processing algorithm. The algorithm is saved as a script file that includes the processing functions and important parameters for the method you prototyped in Vision Assistant.

3.3 NI VISA

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VISA is an application programm**ing** interface (API) that allows a programme to communicate with GPIB, VXI, GPIB-VXI, and serial interfaces in a consistent manner. The VISA API can be used instead of having distinct APIs for each interface. This enables the programmer to create code that can easily be converted to various interfaces [16].

3.4 Data-set Collection

The Data-set for training our model is made ready by capturing the images of both ideal and defective gears. A few of the captured images are presented below:

Defective

(Damaged at the centre)

Defective

(Damaged at the curvature)

Ideal

(No Defects)

Ideal

(No Defects)

Defective

(Damaged at the centre and missing teeth)

Ideal

(No Defects)

Fig 3.2 – Gears Classification

The gears used for training model have their radii ranging from 1 cm to 1.75 cm. However, gears or parts of any dimensions can be trained effectively, as long as they are observable by the camera.

The defects which are currently observable by this project are missing teeth, dents, cracks, broken shaft and broken curvature.

The Work-Flow Diagram is presented below:

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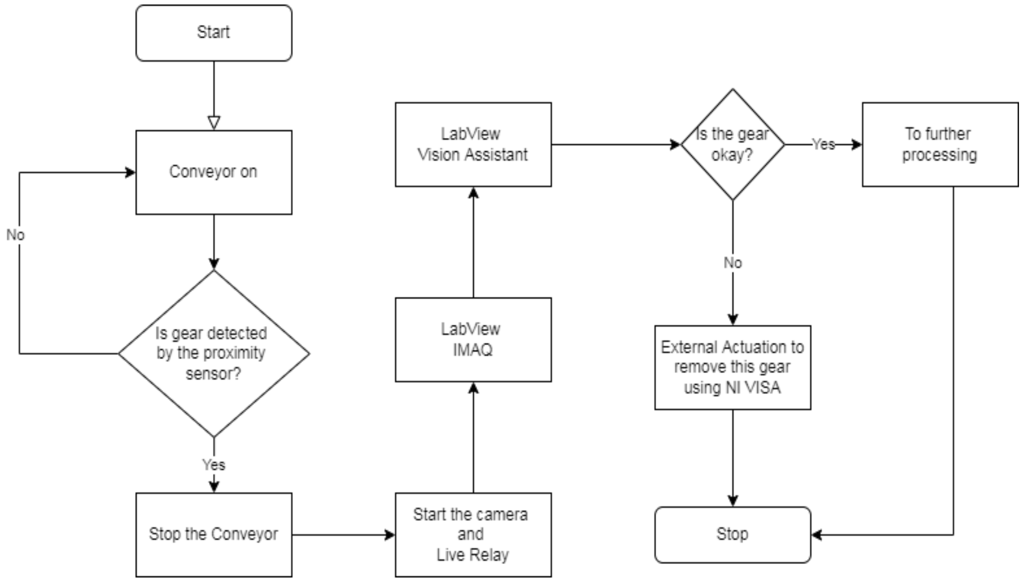

Fig 3.3 – Work flow chart of smart anomaly detection and classification for validation process of watch gears using LabVIEW.

The conveyor is loaded with the gears sequentially – one at a time. When the gear reaches the dark environment which can be focussed better by the camera, the proximity sensor outputs a signal to the controller which then stops the conveyor. The camera then live telecasts the gear to the LabVIEW using IMAQ module. This module grabs a frame from the live telecast and converts it into a binary image by extracting the luminance features present in the image. This extracted feature is sent to the Vision Assistant which is preloaded with the trained images of both damaged and ideal gears. The Vision Assistant then clusters the input data with the trained models and outputs a signal depicting whether the gear is ideal or damaged. If the gear is devoid of damages, it can be sent for further processing. If the gear is found to be defective, a signal is sent to the external actuator (say a pick and place robot) to remove the defective gear.

4 RESULTS AND DISCUSSION

The above proposed method is implemented in the Robotics Automation Laboratory in our institution viz. Sri Krishna College of Engineering and Technology and the results are obtained. The gear models are trained using K-Nearest Neighbour clustering algorithm.

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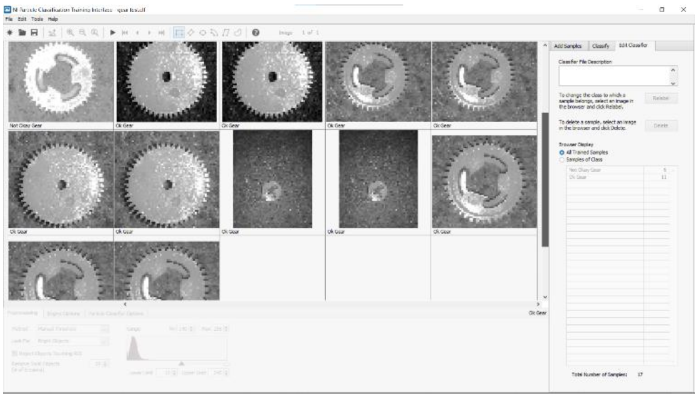

Fig 4.1 – Model Training

In Fig 4.1, the gear models used for training are depicted. For improving accuracy, one can train more models and classify them accordingly. Before training a picture, one has to choose the area of focus.

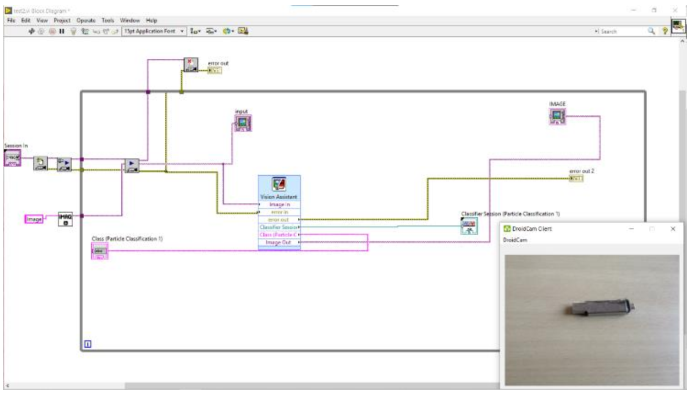

Fig 4.2 - LabVIEW Block Diagram

This can be done easily by adjusting the image histogram to select a particular feature such as luminance and omitting the others. The LabVIEW Block Diagram presented in Fig 4.2 has a NI IMAQ's Session in module via which the input camera which are connected to the PC can be selected. In our case, as we are using Droid Cam Client to telecast our phone camera to our PC. This telecasted phone camera is referred to as an external camera by the PC.

The next step which initializes the camera and grabs an image from the telecast, forwards the acquired image to the Vision Assistant Module. The forwarded image is visible to the user in the front panel. The image processed by the Vision Assistant is also visible to the user. These are shown in Fig 4.3.

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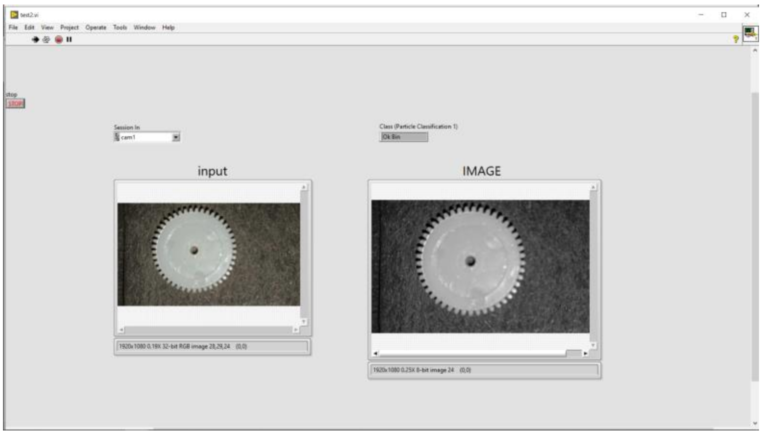

Fig 4.3 – LabVIEW Front Panel

The processed image is then classified based on the trained models and as seen from Fig 4.3, the Class (Particle Classification 1) string output shows "Ok Bin" meaning that the gear is free from defects.

Fig 4.4 Shows the Lab setup consisting of a conveyor, a ABB Robotic Arm, PLC and Servo Controllers and a PC with LabVIEW.

Let's have a look at the project's algorithm: One of the most essential Machine Learning algorithms is the K-Nearest Neighbour technique, which is based on Supervised Learning. When data has a high SNR, KNN is preferable to linear regression. The KNN method assumes that the new case/data and past cases are similar, and it allocates the new case to the category that is the most similar to the previous categories. The K-NN algorithm stores all available data and categorises incoming data points based on their similarity to existing data. This means that new data can be quickly sorted into well-defined categories using the KNN technique.

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Assume there are two categories: A and B, and you receive a new data item x1. This data point belongs in which of the following categories?

This type of challenge necessitates the use of a K-NN algorithm.

We can simply determine the category or class of a dataset with the help of K-NN [12].

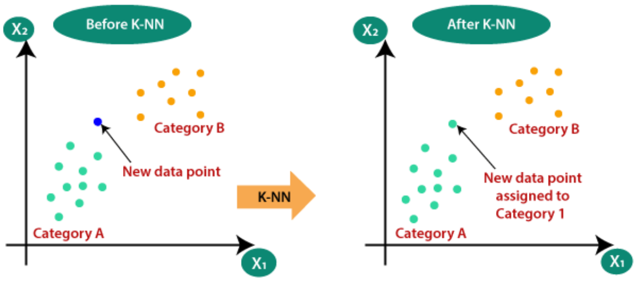

Fig 4.5 – K-NN

5 CONCLUSION

We can detect damaged gears with a number of teeth ranging from 64 to 120 using this proposed Methodology. The gear is declared defective and sent for recycling if the number of teeth is twisted, exceeds, or falls below the prescribed number. Second, using a range bound threshold that works on both colour and greyscale photos of the gears, we were able to identify some surface imperfections. This liberal technique can greatly limit the number of damaged gears transported to the assembly room by accident. Future approaches for improving the detection systems' performance include applying more complicated machine learning algorithms to identify problematic sections as they appear over time. The accuracy of the scenario machine techniques like as Support Vector Machine and neural network improves as a result of the adjusted parameter configuration. Thus, by automating a manually performed operation in an enterprise, the quality and quantity of output can be greatly enhanced.

6 FUTURE SCOPE

In future, the shaft radius and the gear radius can be included to the train model. If any part with radii different from that of the trained model is found, it would be classified as defective.

Currently, we were able to detect the defective gears with a specified number of teeth as mentioned above in this article. If the number of teeth is malformed or the gear is classified as defective by any means after processing by our system, a signal is sent to the robotic arm in the validation unit's conveyor in the future. The robotic arm is programmed to select and remove the faulty equipment based on the inputs given by LabVIEW [13].

For this purpose, we have planned to implement the above-mentioned process in the ABB Robotic Arm available in our institution's Robotics Automation Lab in Mechatronics Department. The image of the same is mentioned above: Fig 4.4.

If a defective part is found, reports can be generated automatically [14]. The report can withhold all the required information regarding the defective part such as defect classification, causes of the particular defect, number of defective parts with the same defect recognised so far etc. This information can be supervised by a manager which could facilitate improvising design and production methodologies to avoid faulty parts.

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