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Dimensional Fault Detection using Machine Vision

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Abstract-*Dimensional accuracy is the most important aspect when it comes to manufacturing of machine tools like drill bits, screws, etc. Deficiency of which causes heavy losses to the manufacturing companies. To avoid that, industries need a system at the end of manufacturing cycle, which would check the dimensional accuracy of each and every product, in a continuous manner, utilizing as less time as possible on each product. In this paper, we have designed such a system, in which we have used ML models to replicate the dimensions of each distinctive product and use them to detect the faulty products using machine vision. This system can detect the type of each product, declares the product as faulty if it doesn't match the dimensions of any product, within a specific tolerance.*

Index Terms-*Machine Vision, Machine Learning, OpenCV, Conveyor system, Computer Vision, Gaussian Blur, Grayscale Image, Contours, dimensional measurement, shape detection*

I. Introduction

With the various developments in the field of science and technology, the traditional manual testing and verification of dimensional accuracy of small automotive parts or machine tools has been unable to meet the needs of the modern technological advancements. Considering a drill bit, its overall diameter ranges from 0.05mm to 6.5mm which is quite difficult for dimensional accuracy testing by a human visual inspection on a repetitive basis. In industries, the quality inspectors traditionally inspect more than 10 dimensions of such small products using instruments like micrometres and microscopes. This is quite time consuming

and highly inefficient as it may lead to human errors on a large scale. Such errors cost various industries in millions. There are many articles on the internet depicting how some faults in industrial products can cause millions of losses to industries [1]. And why precision is so important in the manufacturing industries [2].

Presently, industries are being automized with the introduction of various advanced technologies. Efforts are being made to revolutionize the industries into completely automated i.e. as much less human intervention as possible. One such technology being majorly used is Machine Vision technology. Machine vision is the system which uses Computer Vision (CV) technology for the application of various processes like robotic guidance, basic inspection, gauging, identification, etc. The basic principle of machine vision is to analyze the measured target image obtained by the computer vision system so as to obtain the required measurement information, and determine whether the measured target complies with the specification based on prior knowledge [3].

This process includes capturing digital images of the products, image processing algorithms and actions taken based on the results. Models are created by detecting and analysing the patterns detected from the images. And hence in the same manner, same patterns are used to identify the faulty products from the industrial end products.

In this paper, we have described how we were inspired and got to know more about Machine Vision Technology and its marvels through different research papers in the second section. We described in short the overall structure of our system in the Proposed Method and the whole system briefly in the Methodology section. We achieved good results from the testing of our system, which we have discussed in the results section.

II. Related Works

Many researches have been made in this field, leading to many advanced technologies for inspection of machine tools. One such research refers to the inspection of wearing off of drill bits [4]. They have used a CCD (Charged Coupled Device) Camera to detect capture the images of the test bit and compare it with a normal drill bit. Based on this comparison, results are given out.

Another similar research is based on the inspection of the assembly of the industrial systems [5]. Through Computer Vision, minute details can be detected, which may not be much clear to the human eye. Similar research is based on the assembly of Geneva gear [12].

There have been many more interesting researches, which include Application of MV technology for medical syringe assembly [6]. They used 10 monochromatic cameras, capable of inspecting 5 syringes per 250 million seconds. We got an inspiration for designing our hardware system from their hardware assembly. Similar works can be seen in the research regarding tracking of large number of objects from multiple views [7]

We got highly inspired by the design of Low Cost systems [8] which can be applied as seen in the currently existing technology 'TM series 3000' [9], which have quite high cost, and less features.

Detection of exact shape of the object is not an easy task. From the research based on Penumbra analysis [10], we got an idea of how we can measure milimetric dimensions with a precision of tenths of a milimeter and to evaluate its distance to the plane with the same precision. They have used a MATLAB approach for this purpose. We did similar process through Python, which is quite easy as compared to MATLAB.

We did some detailed study aboutmany machine tools like screws, drill bits, we got to know a lot about drill bits from the works of M. Steinzig, D. Upshaw and J. Rasty [11]. This research what lead us to work for the dimensional fault detection of Drill bits, using MV.

III. Proposed Method

The system can be divided into various small processes. For the basic understanding, it can be mainly divided into 3 processes:

- Conveying
- Computer Vision
- Separation

In the conveying process, a conveyor system is used to carry the products from the Computer Vision process towards the separation.

The Computer Vision system consists of a camera, processing system and an IR sensor. IR sensor is used to detect the product and signal the conveyor to stop for few seconds for the image processing and fault detection process to complete. The CV process can be further divided into 2 main processes i.e.

- Training
- Testing

The separator system consists of a proximity sensor and an actuator to separate the faulty products from the rest.

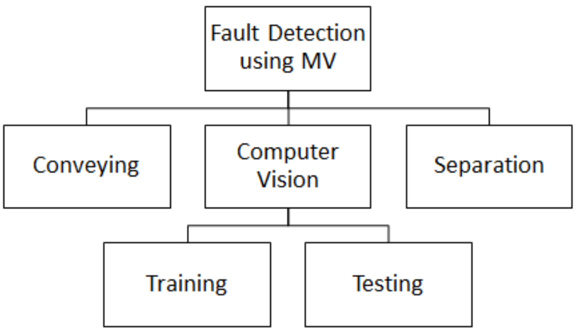

Figure 1: Proposed Method

IV. Methodology

A. Hardware Setup

A Conveyor can be used for the continuous conveying of drill bits.

The best suitable camera for purpose of Computer Vision would be Logitech HD Pro Webcam C920, Widescreen Video recording, 1080p Camera, Desktop or Laptop Webcam. Works in USB Video Device Class (UVC) mode. Compatible with Windows 7+, Mac OS 10.10+, Chrome OS and Android v 5.0 + with supported video calling clients.

Sensors like IR and Proximity sensor can be used to detect the drill bit.

According to which the conveyor can be stopped for CV process and actuator can be activated for the separated for the separation process.

Based on the length 2", 4" or more inch stroke actuator can be used, as shown in Figure 2.

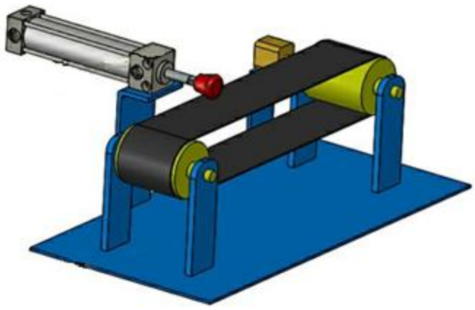

Figure 2: Conveyor and Separator

B.Computer Vision

For this process, the part of the hardware where the camera is fixed must be brought under complete darkness. A closed chamber needs to be created. As there's a need for illuminating the object inside the chamber, the position of the light source matters the most. The best position structure for the lightings would back lighting, as shown in Figure 3 below. This make the edges of the more clearly visible, hence enhancing the dimension detection process.

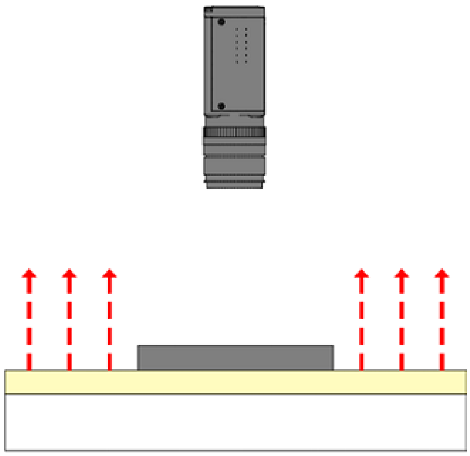

Figure 3: Back Lighting

In testing and the training processes, there are a series of similar steps to be performed, as depicted in Figure 4.

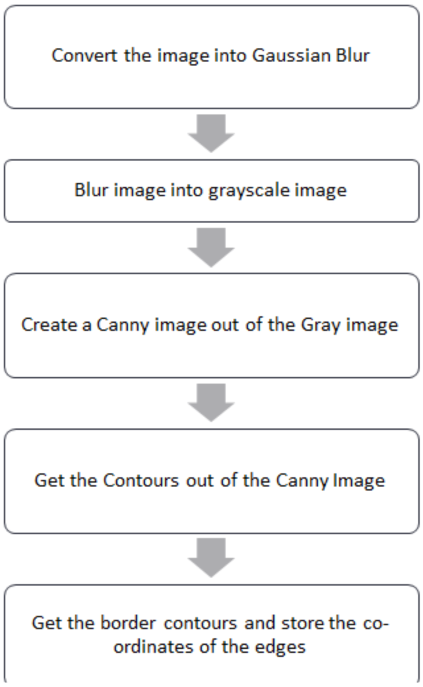

Figure 4: Image Processing steps

Initially, the image obtained from the camera is convolved with Gaussian Blur. Gaussian Blur is basically a low-pass filter, i.e. to remove the high frequency content which are basically noises. We get a smooth image at the output.
This smooth image is converted into Grayscale. As it makes it a binary image. Contours are extracted from this grayscale image. From these contours, the edges are detected and stored.

1)Training: In this process, the values of the edges of different images of same type of product is taken. A model is trained based on that data values using Keras. Here we purposely need an over trained model. Different models are trained and saved in this manner.

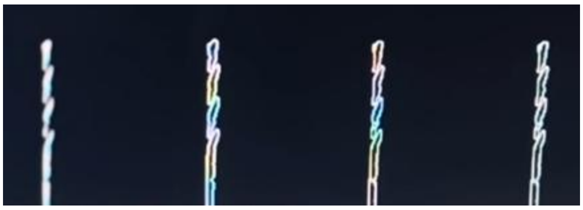

Figure 5: Contour detection of an image

2)Testing: After the image processing of the image, the values of edges are obtained. If all the values are within a specific tolerance of any one model, then that test model is declared of that type. If any one value doesn't match, then it is declared as faulty.

C.The Queuing Concept

In case of multiple products passing through the conveyor, it is really important that the separator system must recognize the faulty products which needs to be separated. To ensure this, we can make use of Queue Data Structure.
Basically, the queue is defined in the system before hand as an empty queue. Whenever a product passes the CV process, an integer is always enqueued into the queue. If case of a faulty product, an integer '0' is enqueued into the queue, as shown in Equation 1 and 3. And in case of a product which is not faulty, integer '1' is enqueued into the queue, as shown in Equation 2.

$Queue = [0] \ldots \ldots faulty(1)$

$Queue = [1,0] \ldots \ldots Notfaulty(2)$

$Queue = [0,1,0] \ldots \ldots Notfaulty(3)$

Hence, whenever the product reaches the proximity sensor of the separator mechanism, an integer is dequeued from the queue, as shown in equation 4. If the integer is '0', the Actuator is then activated to be start a single stroke after a certain delay of time of sending that product. This value of this delay is decided on the basis of run & error trails.

$[0,1,0] => Dequeue => [0,1] \qquad (4)$

And if the dequeued value is '1', then the actuator remains inactive and the product passes smoothly to the end of the conveyor.

IV. Results and Discussions

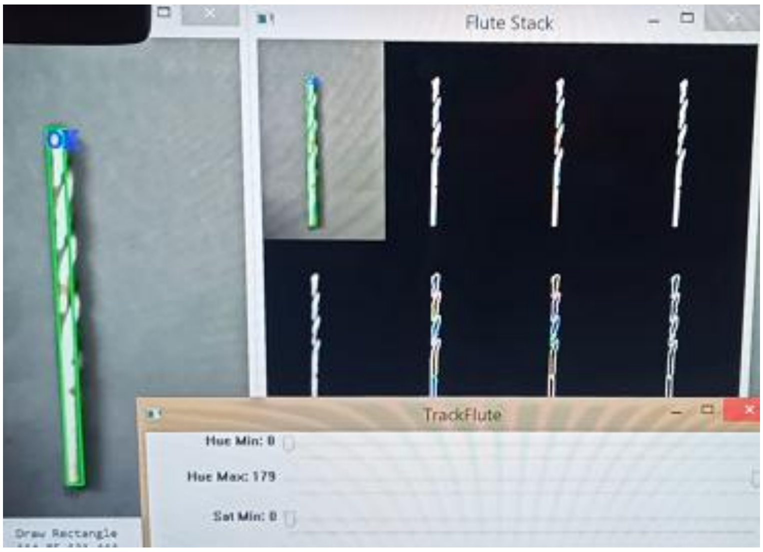

Figure 6: Detection of an indefective product

Out of 50 tests taken, the system was able to correctly detect the defectiveness of 45 products. As shown in Figure 6, a green bounding box is covering the dimensions of the test product. If this bounding box matches with that of any trained model, its displays the text as 'OK'.

And in case of mismatch in bounding boxes, it will display text as 'Faulty', as shown in Figure 7. The 10% inaccuracy was due to very minute defects in dimensions.

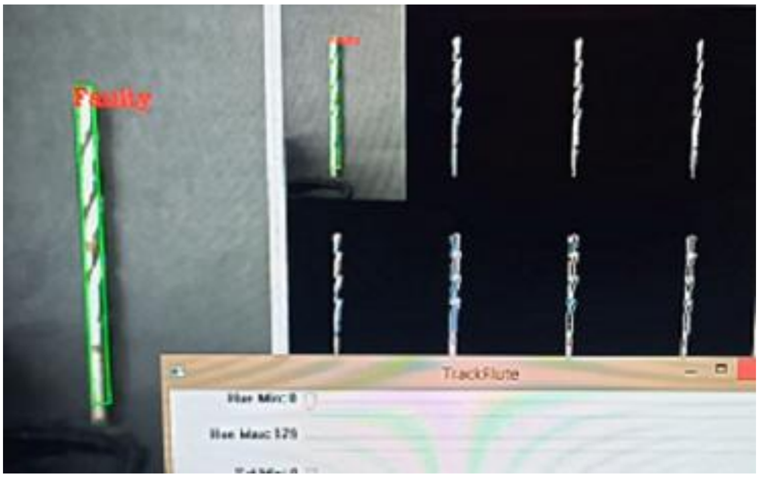

Figure 7: Detection of a defective product

After the testing of each product, a small summary is saved in notepad file. It conists of the test product number as the file name, timestamp of the test, and the fault status, as shown in Figure 8 below. This along with the captured image is stored in the local system, which can be deployed on any cloud platform.

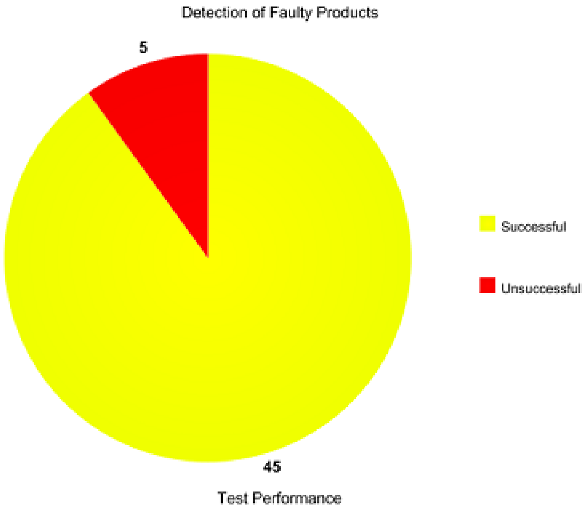

Figure 8: Test performance

Figure 9: Test report

V. Conclusion and Future Work

With this proposed system we were able to build a system, which was 90% efficient and cost effective. We look forward for a better efficiency, by reducing all the errors. This is a great leap towards preventing the faulty products as compared with the traditional human testing. As compared to the existing technologies like TM series 3000 [7], this system can be used for a long range of different products and is way much cost effective. We also look forward for introduction of 3d training and testing by adding more cameras and complex code to the system. By introduction of IOT, we can make this system remotely controllable and monitored.

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