Micro Level Dimensionality Measurement for Product Inspection using Machine Vision

Abstract—the incorporation of AI in the manufacturing industry has improved the efficiency and safety in, its operations, thereby reducing labor hardships. In order to facilitate automatic visual inspection on the objects that are manufactured daily, Machine Vision is used after the process of manufacturing. With the advancement in AI, it is possible to embed new processing units in the camera that can perform tasks which required dedicated servers earlier, with the aid of Deep Learning. In this work, our aim is to measure the geometric structure of screws and to identify the defects present in them. Finally, our results infers that irrespective of the micro level objects it outperforms the state of the art method with our novel photogrammetry approach which can be implemented in any industrial setup for the quality inspections of valves, engine spares etc. at the micro level

Keywords— *Machine vision, Deep Learning, Photogrammetry, Micro level inspection, Defect detection, Sub-Pixel processing, Image enhancement.*

I. Introduction

Today's manufacturing industry produces huge numbers of items every day. As we are in the 4th industrial Revolution and marching towards the 5th industrial revolution, the products are made using the automatic inspection line with less human intervention. Every machine in the production line will create a specific product based on its specified dimension within a certain error tolerance. The main goal of the manufacturers is to produce with less error tolerance, more accuracy, more quickly and to a higher standard which makes the quality of product to 100%. But one of the stumbling blocks in the manufacturing industry is measurement uncertainty in products. Uncertainty is the parameters associated with the result of the measurement process and explains how deviation in parameters from standard values affects the quality of products. Uncertainty is important with respect to measurement which influences quality, costs, decisions, and risks. Hence proper analysis of resulting measurement uncertainty allows making judgments about the quality of the object and it facilitates meaningful comparisons with other similar values through which prediction can be done. Thus Measurement uncertainty is an essential factor to assess the quality of the results stated to meet the established industrial accuracy requirements.

Hence our goal is to identify the techniques that perform measurement in images with highest possible accuracy based on mathematics and physics laws which must be the best toolkit for processing and analyzing the captured images which have manufactured objects at Micro-scale and Nano-scale with the help of machine vision. Image Enhancement, Edge Detection, and Dimensionality Measurement are stages of our project. During dimensionality measurement the dimension of objects are measured which is the result of our project based on which the further decision can be useful analyzing the manufactured product.

II. Literature Survey

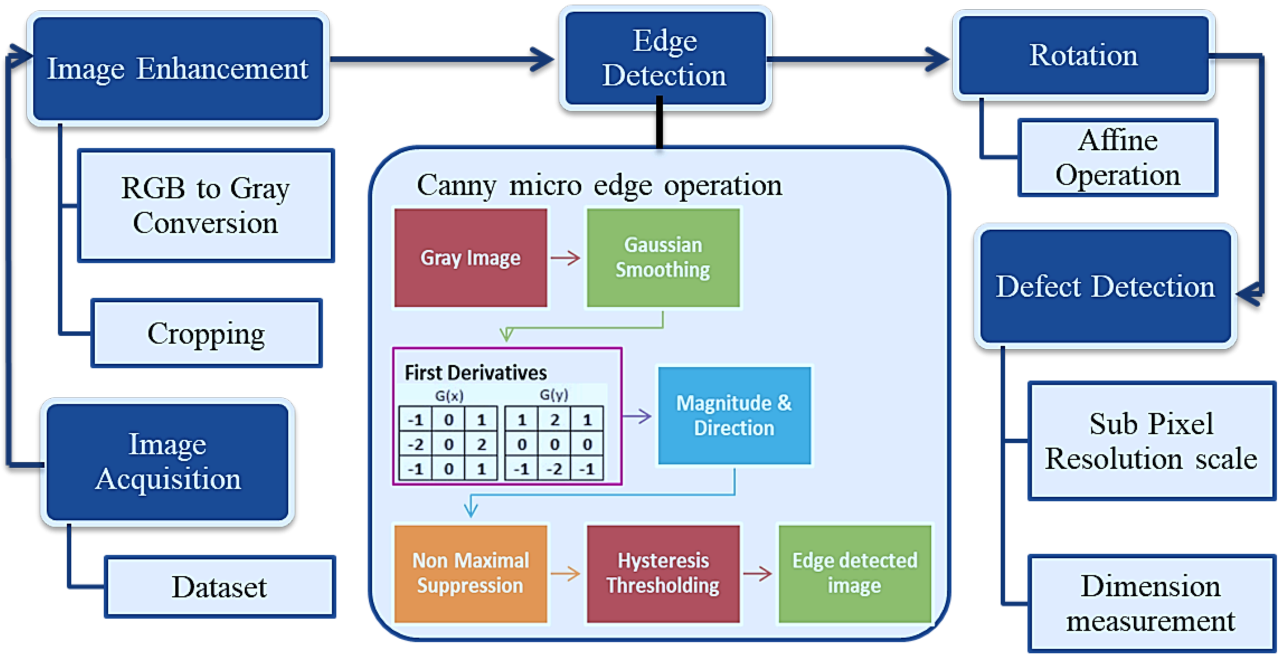
Structure of images based on the range of intensity. Edge detection is an important step of image analysis techniques in camera-based metrology for shape, size, position and defect measurement. Accuracy of the image analysis depends very much on the accuracy of the edge detection techniques used to extract the image features. Some of the techniques proposed for edge detection are described below. First technique uses a threshold value for a rough estimation of the edge position. Accurate techniques based on finding the first derivative of the intensity profile along the edge are presented. Standard edge detection algorithm based on canny operator which uses the local gradient maximum of the intensity profiles to find the position of the edge in pixel resolution is described. Another edge detection technique based on the correlation concept is suggested for images of features with high background noise, poor edge quality better results in extracting the edge positions at pixel resolution. At last in order to derive the position of edges at higher accuracy a multi-step algorithm was developed which is known as sub-pixel resolution. After finding the edges using the canny edge detector, the sub-pixel resolution technique is applied for accurate edge detection. According to the requirement and needs canny edge detection was used for detecting the edges for objects of interest in the image. The paper[] provides basic details from the structure of image to three case studies which helps in understanding the application of machine vision in the real world scenario in a more elegant and fruitful manner.

There might be cases where we do not obtain the closed edges of objects in the image using the edge detection algorithm, having gaps between the detected edges of the object. Also these types of situations mostly occur due to diffraction and aberrations caused while capturing the image. To reconstruct damaged regions of the edge obtained from the image, we have to use image restoration technique. Components representing and describing the region of objects in image such as skeletons, convex hull and boundaries are extracted using Morphological image processing, one of the techniques used in image restoration. Dilation, erosion, opening, closing, fill and majority operations are some of the well-known mathematical morphological operations. In this work [3] presented huge combinations of various morphological operations which have given best results on the monochromatic images such binary and gray scale for image restoration technique. The objects are expanded in dilation operation, thus small holes probably are filled and disjoint objects are connected. The objects are diminished in erosion operation with etching away (eroding) their boundaries. Therefore the article [5] has made our task less complex for choosing the correct image restoration technique which needs skill for selecting the necessary structuring element by experimenting and analyzing from the images.

III. Materials and Methods

The architecture diagram of our proposed work is depicted in the Fig.1.1. It explains the overall workflows that are carried out for the defect detection in the micro level inspection of the manufactured screw. Each phase of the entire work flow is explained in the following sections of this research article. The use of Image Acquisition, Image Enhancement, Edge Detection and Pixel Resolution are essential for the detection of dimension in small parts.

Architecture Diagram:



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A. Image Acquisition

The first step in any image processing technique is performing image acquisition. The purpose of image acquisition is to transform optical images into digital images. A digital image consists of a matrix of pixels where each pixel is associated with a certain intensity level. The image that is captured by a camera or a sensor is digitized using sampling and quantization processes. When light passes through the aperture of the lens of a camera, there's a possibility of diffraction due to the Heisenberg uncertainty principle. Based on the object of interest, different cameras are used for the image acquisition process. The image is scanned using a rectangular grid in order to retrieve the pixel intensity values and generating a 1-D vector that represents the integer values of gray scale intensities, which are obtained by the process of quantization.

Structure of images based on the range of intensity values:

a. Normalized gray scale image:

This is also called a Monochromatic image, where pixel intensity values lie in the range of 0 and 1.

b. Gray scale image:

The pixel values lie in between 0 and 255.

B. Image Enhancement

Since the binary model defines colors using only one component that is lightness, RBG images are to be converted to binary images. A binary image requires less available space and is faster, especially when we deal with complex computations. Lots of information which is irrelevant for processing the images are discarded when we convert an RGB image to a binary image. In case of a RGB scale image, for each of the component, i.e. RGB, image holds different intensity labels.

Since RGB images are represented by 3 channels, each of 8-bit length, the data to be stored and manipulated is huge. For several applications of image processing, color data does not facilitate us determining necessary edges or different options. If we do not want color, then we are able to contemplate it as noise. So, converting RGB to binary removes that noise. Code complexity increases when we use RGB images since additional color information is not useful for certain applications.

Techniques to Convert RGB to Gray scale:

1. *Lightness Method:*

The highest and lowest color components in a pixel are averaged to determine the gray scale value of a pixel, which is a pretty straightforward process.

$$G = \frac{(Red,Green,Blue) + min(Red,Green,Blue)}{2}$$

2. *Average Method:*

Another technique for converting gray scale images determines the average value of each of the three color components of a pixel.

$$G = \frac{Red+Green+Blue}{3}$$

3. *Luminosity Method:*

This is a more refined way to calculate the gray scale image than the mean approach. Instead of calculating the mean in this situation, based on the weighted mean of the color components is used to take into account human perception. Using this method, the gray scale value is computed as follows:

$$G = 0.299 * Red + 0.587 * Green + 0.114 * Bl$$

The third strategy was the one we thought was best out of all the options because studies on human eyesight have shown that our eyes respond differently to each particular color. Human eyes, in particular, are more sensitive to green than red and less sensitive to blue. The fact that the first two approaches don't take into account how sensitive the human eye is to color is also noteworthy.

C. *Edge Detection*

The main goal of edge detection is to identify the region of interest from the enhanced image. Here, the region of interest is the industrial manufactured object. There's a huge contrast between the background and the object of interest. So, the SNR ratio is high. Substantially the edges of the mechanical parts are of straight lines or bends. To identify the linear edges, linear regression with the least squares as cost function is used. The edge points of the straight line can be regarded as a set of vectors and they are set up directly using least squares linear regression method. The variables in fitting are the quantity of points and the noise involved that influences the accuracy obtained for the positioning of edges. High position accuracy is obtained for images with small noise and more points.

1. *Canny Operator:*

With the help of sobel operators, canny edge detection determines the edge's direction and intensity.

$$Magnitude = \sqrt{X_g^2 + Y_g^2}$$

$$Direction = \frac{Y_g}{X_g}$$

D. *Rotation*

In order to enforce uniformity in the calculation of the principal axes of the edge detected images, we have done the rotation of images in such a manner that all the images get aligned to the same position and from which the distances are calculated and then the principal axis will be the maximum distance value out of the calculated pairwise distances. The rotated bounding box is returned as a rectangle that occupies the maximum region covering the nail inside it. The current points of the image are updated by the given points in the rectangle. Then contour is drawn upon which the mid points between the top-left, top-right points, and bottom-left and bottom-right points. Then, the principal axes of the images are found by computing the pairwise distances, out of which the maximum distance is regarded as the principal axis. The image is inverted based on the threshold value that is computed based on the Gaussian adaptive thresholding mechanism. Wrap affine operation is performed by applying a certain threshold and taking into consideration the rotation matrix. This operation rotates the images with respect to a point which is the center of the image.

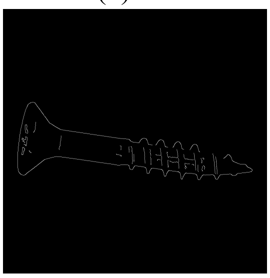
E. *Pixel Resolution*

Pixel resolution represents the details that the image holds. The pairwise Euclidean distances are computed between all the pixels that are present in the image. Resolution corresponds to the number of pixels present in the field of view. It is categorized into 4 types, namely, spatial, spectral, radiometric and temporal resolutions. Post the rotation operation, the principal axes are computed for all the images, whose values are then converted to millimeters by dividing the values by a reference value (125). The calculations are performed in a sub-pixel resolution scale, so that the accuracy of measurements gets enhanced. The principal axis is the distance between the 2 pixels which are far apart and whose intensities have maximum difference. Further, the measurement of the height of the screw is the length of the computed principal axis. The dimension of the intended object is then measured in millimeters scale.

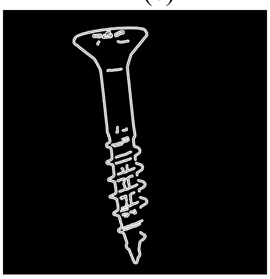
IV. Experimental results

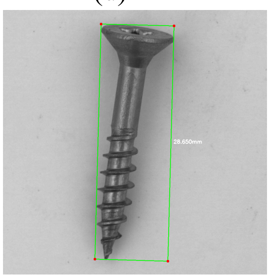
Thus we have successfully measured the dimension of the given manufactured objects. We have applied image processing techniques which made it possible to remove the noise from the images. Then, Gaussian blurring technique is applied before performing the edge detection techniques. We have done canny edge detection which more efficiently and accurately detects the edges that are present in the images of the given manufactured objects.

(a) (b)



(c) (d)





(e) (f)

Fig - 1 a) Dataset obtained after data acquisition b) After converting RGB to Gray scale image c) Result After Gaussian Blur applied d)Edge Detection using Canny operator e) Rotation of the screw f) Dimensionality measured screw

We have found the length of the principal axis of the image, which gives the maximum difference between the points that have the most different pixel intensities. We have also rotated the images in order to ease out the process of finding and measuring the principal axis' lengths of the images. We have done dilation and erosion in order to remove noise from the images completely. For rotation, we applied wrap affine transformation technique. Morphological operations are also performed on the images. We have calculated the dimensions in mm scale.

The role of illumination is to make the important features of objects visible which is the starting point of machine vision and can be achieved by image acquisition process. Then the image enhancement procedure is applied before processing to improve the quality and information content of the image, after which Edge Detection Algorithm integrated so well with binary images to identify the edges. Even though the dimension can be measured using the neural networks model, the need for a high performance computer for doing so, limits the implementation of the same. The Sub-Pixel edge detection is implemented to subdivide the pixels near the edge to achieve an accurate edge location. After recognizing the geometric features of the preprocessed image, defects on the object of interest are identified based on the object's measured dimensions.

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