A Literature Survey on Various Methods used for Metal Defects Detection Using Image Segmentation

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Abstract: *Segmentation partitions an image into distinct regions containing each pixel with similar attributes. To be meaningful and useful for image analysis and interpretation, the regions should strongly relate to depicted objects or features of interest. Segmentation can also be applied for detecting metal surface defects Surface quality of metals should be regularly tested before making them available in industries. Traditional testing methods are not such effective due to its low productivity and lower reliability. This paper presents a survey on various methods used for detecting metal surface defects using image segmentation.*

Keywords: Image Segmentation, Metal Defects, Guassian Filter, Canny Edge Detector, Fuzzy Logic, Principal Component Analysis (PCA).

1. Introduction

The defects found in metal products and intermediate products are distinguished on the basis of size and location, as well as nature and origin. Metal with surface defects are rejected at manufacturing time to avoid further errors. Early detection reduces damage and manufacturing cost of products. One of the most important and required operation on image is to recognize and categorize the various kinds of defects.

Automation plays an important role in any mass production manufacturing industries. Rejecting or accepting final component before delivery to customer depends on its correctness of required dimensions and other features. Automatic sorting and packing is in existence for a number of years to assure quality but such dimensions and features of final manufactured product checked by hand in almost all manufacturing industries. Manual examination is costly, time consuming, sometimes incorrect and manual inspection for some cases. Again human judgment depends on prior knowledge and experience. Quality checking is very important to withstand in market. To check quality of manufactured product it is necessary to identify fault in manufactured product to avoid defected product delivery to customer. Continuous inspection is required for quality enhancement [1].

Image Segmentation
Image segmentation is the division of an image into regions or categories, which correspond to different objects or parts of objects. Every pixel in an image is allocated to one of a number of these categories. A good segmentation is typically one in which pixels in the same category have similar grayscale of multivariate values and form a connected region, neighboring pixels which are in different categories have dissimilar values.

The term image segmentation implies dividing the image into smaller regions containing certain parts of the image. The number and properties of these regions vary dependent on the quality of the segmentation but also with the aim of the segmentation. In feature extraction, the aim of segmentation is to isolate an object without the background and determine certain properties of that region. There are a number of different image analysis methods available if the goal of the analysis is to find a specific object with distinct properties. One of these methods is for example, correlation. Image segmentation is a very important task when working with machine vision and there exist many different techniques to achieve good segmentation. In order to choose between the different methods it is advisable to look at the requirements of the segmentation, the properties of the object to be segmented and lastly, to try many different approaches as there is no "one best way" when dealing with image analysis [15].

2. Literature Survey on Defects Detection Techniques

Sr. No	Author and Year	Work	Methods / Algorithm	Tools / Parameters
1	John Canny 1986 [2]	Computational approach to edge detection	Feature Synthesis: Gaussian Operator	Edge points and profile
2	Mitra Basu [3]	Survey on Gaussian based edge detection method	Gaussian Filter	Edge Detection
3	Suzana and Zeljko, 2006 [4]	Colour and surface defect detection in ceramics tiles	Canny Edge detector and the sub-pixel corner locator method	Thresholds, minimum distance
4	D. Lu and Q Weng, 2007 [6]	Survey on techniques for improving image classification performance	Remote sensing, classification process.	Remote sensing and GIS
5	N. Senthil Kumaran and Rajesh 2009 [7]	Survey on Edge Detection techniques for Image Segmentation	Soft computing approach based on the Fuzzy logic, GA and NN	Edge Detection

Paper ID: ART20162357

6	Diwan P Ariana and Renfu Lu 2010 [8]	Evaluation of internal defect and surface color of whole pickles	Hyperspectral Imaging	Reflectance and Transmittance
7	H.Abdi and Williams [5]	Analysis of data from table	Principal Component Analysis	Points in maps
8	Domingo Mery, Vladimir Riffo, Ivn, Hans, Alvaro, Aldo,Jos [9]	Automated fish bone detection using X-Ray imaging	Image Acquisition, Preprocessing, segmentation	X-ray
9	T.Aarthi , M.Karthi, M.Abinesh [11]	Detection and Analysis of Surface Defects in Metals Using Wavelet Transform	Wavelet Transform	calculation of mean, variance, standard deviation, skewness and kurtosis from the acquired image.
10	S.Saqna Varhney, Navin Rajpal, Ravindar Purwar	Comparative study of Image Segmentation Techniques and Object Matching using Segmentation.	PCA	Back-Projection for object Recognition
11	Hema.L Chavan, Santhosh A. Shinde	Defective Product Detection using Image Processing	High and low pass filters, PCA, Euclidean Distance	Euclidean Distance
12	Mayuri Dharma Shinde	To detect and identify the defects of Industrial Pipe	Morphological, Dilation and Erosion Operations	Eccentricity
13	Jijina K.P, Sreeja.SS, Vinod.P.R	Real Time Detection and Classification of Metal Defects using Image Processing	Wiener Filter, GLCM, Neural Network	Geometric Features, gray-scale features.
14	Tiwari Priti Ramesh, Yashoda Bisht	Detection and Classification of Metal defects using Digital Image Processing	Back Propagation Neural Network, ROI	Morphological Operations
15	Y.Ramadevi, T.Sridevi, B..Poornima, B.Kalyani	Segmentation and Object Recognition using Edge Detection Techniques	EM Algorithm, Genetic Algorithm	Clustering the pixels
16.		Review of vision-based steel surface inspection systems	SVM, SOM, UDWT	

3. Related Work

In [1], the paper is to improve the quality of the industrial products using 2D or 3D image processing techniques. It proposes a novel 2D/3D image processing methodology for the quality control management for sensitive industrial products. High pass and low pass filters will highlight regions with high frequencies and smoothing the image and noise reduction. Pixels are classified as foreground, non-foreground and uncategorized pixels and using canny methods the edges are detected. PCA is used to extract features of stored and test images. Finally, Euclidean distance is applied to both the images and highest similarity is calculated. The formula used is:

Euclidean Distance
$$(\text{Img}_{ref}, \text{Img}_{test}) = \sqrt{Abs(\text{Img}_{ref}, \text{Img}_{test})^2}$$
$$\text{Matching} = \frac{2\,|A \cap B|}{|A| + |B|}$$

$$\text{Mis Matching} = 1 - \frac{2\,|A \cap B|}{|A| + |B|}$$

In [16], Tsai proposed a fast normalized cross correlation computation for defect application. A sum-table scheme is utilized, which allows the calculations of image mean, image variance and cross-correlation between images to be invariant to the size of template window. The proposed system is compared with traditional normalized correlation operation, which does not meet speed requirements, for industry applications. The computational complexity can be dramatically reduced. Since the proposed method is invariant to the window size, a user can select a proper window size to maximize the detection effectiveness for the object under inspection without trading off the computational efficiency.

In [1] Mayuri divided their work into three divisions. In the first section, preprocessing steps include gray scale conversion, threshold effect and noisy objects elimination. In the second section, the separation of pipe from image is performed by filling the regions by selecting points, interactively. In the third section, mathematical operations are done on the defected image and faults are detected. Dilation and erosion operations are performed and calculates the area and eccentricity of defected surface. Using the eccentricity value, the defect is classified accordingly.

In [17], the image is captured and smoothened during preprocessing stage. The target image is compared with the reference image and defect is detected with ROI. A weiner filter is used to filter the available noise. Defect is segmented using morphological operations. Finally, the defects are classified by the characteristics of defects including geometric ones, gray ones and texture features. With the help of neural network, defects are classified according to their classes.

Image Segmentation Methods

Image segmentation is done using various edge detection techniques such as Sobel, Prewitt, Roberts, Canny, LoG, EM algorithm, OSTU and Genetic Algorithm. Experimentation is performed on gray scale image using Matlab7.9.

In [12], the proposed method works mainly in three steps. In the first step, it converts the RGB image of the pipe i.e. acquired input image into a gray scale image. Secondly, it extracts the faults located on the pipe and finally it identifies the defect and classifies it into a major or minor defect.

According to this major or minor defect, decision can be taken on the defected pipe.

Manual inspection of end products slows down the entire process as it becomes costly, time consuming and also may impact the effectiveness of human labour due to the hazardous atmosphere of industry. Therefore, the process of inspection is also to be automated and inspection results should be fed back to the upstream manufacturing process for improvement of product quality. Surface defect is caused by many reasons such as poor quality of raw material or malfunction of rolling process. Simple surface defects like pits, bumps, scratches and holes create obvious problems for finishing operations, but more problematic is the fact that many times these defects do not become visibly noticeable until the operation is complete.

This method provides
- Earlier detection of metal defects saves valuable time and production
- Accurate classification of metal defects.
- Non destructive approach for the inspection of metal surface

In [13] morphological analysis for binary images are carried out and the defected areas undergo thresholding and Maximal similarity based region merging is used.

Morphological Image Analysis

The most fundamental morphological operators in image analysis are erosion and dilation. They both use a structure called a structuring element which controls the behavior of the operator. The structuring element is a matrix of 1s and 0s or as a set of background and foreground pixels. The structuring element has a fixed origin, and moving the origin within the structuring element usually creates a different behavior of the operator.

Morphological dilation is defined by

$$A \oplus B = \{ z \mid (Bz) \cap A \neq \varnothing \}$$

And erosion is defined by

$$\{ z \mid (Bz) \cap A^c \neq \varnothing \}$$

Where A is the image on which the erosion/dilation is applied and B is the structuring element Bz is the translation of set B by vector z. $\varnothing$ is the empty set, and $B \cap A$ is the intersection of set A and B, A^c is the complement of set A. The dilation of A with B is in other words the set consisting of all the structuring element origin locations where the reflected and translated B overlaps at least one element of A. It is clear from the definition that a dilation of an image will "thicken" its content (in the binary image). Erosion is the counterpart to dilation, the output image contains 1s in the structuring element origin locations where all elements of the structuring element overlaps positions with 1s. Opening and closing are two useful morphological operators that are commonly used to remove salt and pepper grain for example. Opening is defined as the erosion of A with B followed by the dilation of the result with B:

$$A \circ B = (A \oplus B) \oplus B$$

and morphological closing is defined as a dilation followed by erosion:

$$A \bullet B = (A \oplus B) \oplus B$$

Canny edge detector

The Canny edge detector uses a combination of different techniques to give a robust and accurate localization of edges in an image. The main benefit of the Canny edge detector over the more classical detectors such as Sobel or Previtt is that it is more accurate and less sensitive to noise. It should be said that the Canny method uses one of these classical methods within, but with pre- and post-processing methods to improve quality of the detections. The method was developed by John F. Canny in 1986 and follows the steps in the list below:

1) **Smoothening of the image**. This eliminates noise that otherwise would yield false edges. This smoothening is usually done with a spatial Gaussian low pass filter.
2) **Finding the intensity gradient of the image**. This can be done using one of many edge detector filters. Normally they filter the image in two directions, horizontal and vertical as they only can detect edges in one direction every pass. From the edge detectors it is possible to extract estimations of the edge gradient and edge direction.
3) **Non-maximum suppression**. An edge point is defined so that it is the local maximum in the direction of the gradient. These edges are marked and all pixels not belonging to the edge are set to zero.
4) **Double thresholding**. The pixels that remains after the non-maximum suppression still have their strength information. The double thresholding divides these into three categories, false edges, weak edges and strong edges. The pixels with intensity smaller than the low threshold are considered false, and are discarded as edge points. The pixels with a gradient intensity in between the low and the high thresholds are called weak edges and finally all pixels with a gradient intensity larger than the high threshold are called strong edges.
5) **Hysteresis tracking of the image gradient**. The strong edges are considered to be true edges and are all included in the output. The weak edges are only included if they are connected to a strong edge. The edge tracking can be performed in a number of different ways, one being to connect all edge pixels using 8-connectivity and saving all regions including at least one strong edge pixel. This results in a binary image.

Even though the Canny edge detector is fairly advanced and can yield very good results, it still has some limitations. It is a method that is based on thresholding and therefore the normal problems of deciding the threshold values apply. It is difficult to provide thresholds that always will give good answer, and so thresholds are strongly related to the fundamental challenges of the vision system.

Clustering-based methods

For each potential threshold **T**,
1) Separate the pixels into two clusters according to the threshold.
2) Find the mean of each cluster.
3) Square the difference between the means.
4) Multiply by the number of pixels in one cluster times the number in the other.

Using Genetic Algorithm

A genetic algorithm consists of three major operations: selection, crossover, and mutation. The selection evaluates each individual and keeps only the fittest ones in the population. The crossover recombines two individuals to have new ones which might be better. The mutation operator induces changes in a small number of chromosomes units. The process has the following procedure:

1) Select two bit strings (chromosomes), or in case of the genetic programming: select a branch of each parent.
2) Cut the chromosome (or branch) at a particular location.
3) Swap the bits/branches of the two parents.

In [14], the paper proposed that, Genetic algorithm exhibited normal segmentation effect on all types of images. Canny operator performed better than Sobel, Prewitt, Roberts and LoG.

4. Conclusion

This paper focuses mainly on the Image segmentation using various edge detection methods. This paper also gives a review on various methods and tools used for detecting surface defects on metals.

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