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Application of Enhanced Otsu method for Assembly Line Quality Analysis of Welded Structure

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Abstract: Experienced welders can take control on welding operations by simply observing the welded parts. This paper focuses on automation of the post welding quality inspection of the welded structure which was performed by the human welders in the past. The idea is to provide cost effective solution to the small scale manufacturing industries for automating there post welding operations and reduce the time required for these operations and increase the speed eventually. The proposed system has developed a GUI which can be used by non-technical workers and make their work easy. System uses basic Otsu method and enhances its performance with other methods that provide better results. Geometric parameters of the welded structure are calculated with the enhanced Otsu method which provides the required parameters for analyzing post welding quality inspection of the welded structure. Lot of research has been done in measuring characteristics of the welded structure. However, a limited research is done in the quality inspection and post welding operations efficiency performance check. An efficient GUI is developed to fulfill the required quality check.

Index terms: Enhanced Otsu, assembly line, quality inspection, automation, GUI(Graphical User Interface), area, entropy, contrast enhancement.

I. INTRODUCTION

In the recent years, there has been huge advancement in the field of wireless sensor networks, big data, Iot and mobile Internet that are entering the industrial sector, which builds the foundation for new industrial revolution i.e. industry 4.0. Namely, German technical academy and other institutions have jointly proposed the fourth generation of industry – which is designed to ensure the future competitiveness of German manufacturing industry. One of the crucial part of the manufacturing industries is welding which acts as a measure of industrialization level for which it has become a widely discussed topic today. Welding is an important joining technique which is widely used in industries. Experienced welders can observe the welded parts and analyze them accordingly which are few now-a-days. Welded structure geometrical parameters can be measured by processing images of the welding process from a vision system. Some researchers have already established vision systems and corresponding mathematical models to measure welded structure geometry. Various methods are proposed to extract the characteristics of welded structure like image processing, reversing, local threshold determination, fast Fourier transform and advanced morphological operations which obtains welded structure width [3]. A low cost system is developed using common commercial charge coupled device (CCD) camera and combined with a composite light filter. Welded structure image is captured clearly during constant-current gas tungsten arc welding (GTAW). Different image processing techniques are used to obtain a quality enhanced image [4]. An adaptive dynamic linear model is proposed [2] to model the dynamic welded structure geometry in GTAW process. A vision sensing system capable of measuring the welded structure characteristic parameters in real-time is utilized. Many of the researchers focused on measuring welded structure geometry by removing interferences like noise, grain and un symmetry overlapped with the welded structure region in images. The measurement is achieved through computer vision [5]. This paper presents a combination of methods with the purpose of developing an automation system for the post welding quality inspection of the welded structure, thus allowing for calculation of various geometrical parameters of weld like area, mean, standard deviation, entropy, contrast, kurtosis, skewness, IDM(Inprocess depth meter), variance, RMS(Root mean square), energy, correlation, homogeneity for analysis purpose. The proposed system works on images captured by CCD camera for GTAW process. These images are analysed for post welding process of quality inspection of the welded structure. Efficiency of the welding operations can affect the quality of the welded structure which can help an experienced welder to assess the quality inspection post welding operations. GUI was built which helped in automation of the post welding quality inspection process.

II. METHOD

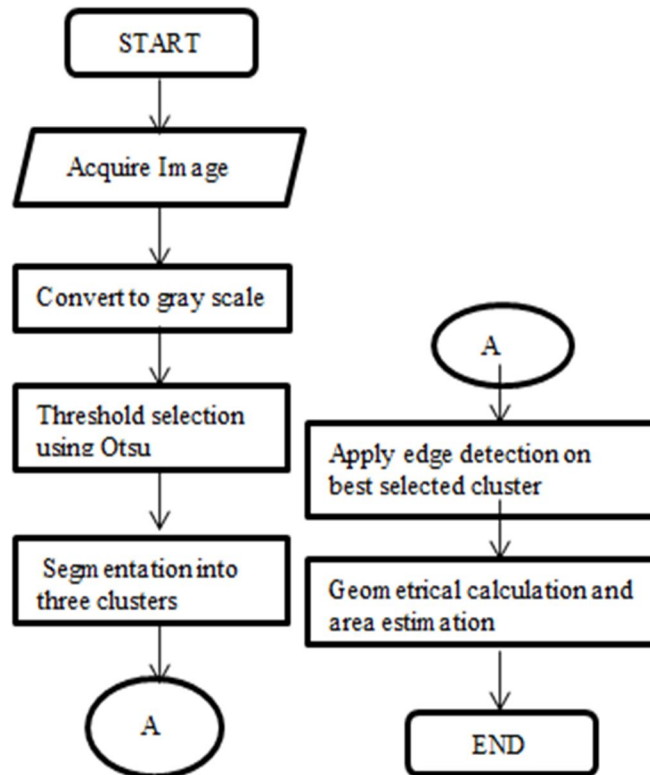


Figure 1: Basic flow of proposed system

In this section the innovative automation system for quality inspection post welding operations is briefly discussed. The basic flow of proposed system is shown in Figure 1. In this system images captured from the CCD (Common commercial Charge coupled device) camera are acquired first. After acquiring image it is converted into gray scale. Global thresholding is performed using Otsu algorithm explained in [5] which is the best compared to available thresholding algorithms.

Resultant image is then segmented into three clusters and edge detection is applied on the best selected cluster. Finally the geometrical parameters of welded structure are calculated and the results are analyzed.

The methods applied on the input image are (i) K-Means clustering, for a pre-segmentation of the image, (ii) Edge detection for reducing the image noise resulted from applying the K-Means clustering method and also removing the unnecessary details. This combination of methods is used to enhance the quality of the output image.

III. SEGMENTATION USING K – MEANS

We make use of K-means clustering algorithm, which is an unsupervised method, to provide us with a primary segmentation of the image. K-means clustering is used because it is simple and has relatively low computational complexity. We select number of clusters K to be 3. For the purpose of this paper we consider the objects to be the input image pixels and their features are their gray-level values. The algorithm has the following steps:

- A. We choose the number of clusters, K;
- B. We then randomly chose K pixels representing the initial group centroids.
- C. We assign each pixel to the group that has the closest centroid;
- D. When all pixels have been assigned, we recalculate the positions of the K centroids;
- E. Repeat Steps 2 and 3 until the centroids no longer move. This produces a separation of the pixels into groups from which the metric to be minimized can be calculated [11].

IV. EDGE DETECTION TECHNIQUE USING CANNY EDGE DETECTION

The algorithm runs in 6 separate steps:

1) *Smoothing*: Blurring of the image to remove noise

$$S = G_{\sigma} * I \quad G_{\sigma} = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

G_{σ} is Gaussian filter with a standard deviation of $\sigma = 1.4$

2) *Finding Gradients*: The edges should be marked where the gradients of the image has magnitudes

Compute x and y derivatives

$$\nabla S = \left[\frac{\partial}{\partial x} S \quad \frac{\partial}{\partial y} S \right]^T = [S_x \quad S_y]^T$$

3) *Direction Calculation*: To calculate the direction of edge we have to do following,

Compute gradient magnitude and orientation

$$|\nabla S| = \sqrt{S_x^2 + S_y^2}, \quad \theta = \tan^{-1} \frac{S_y}{S_x}$$

4) *Non Maximum Suppression*: Only local maxima should be marked as edges

5) *Double Thresholding*: Potential edges are determined by thresholding

6) *Edge Tracking by Hysteresis*: Final edges are determined by suppressing all edges that are not connected to very certain (strong) edge [12].

Canny edge operator is

$$\nabla S = \left[\frac{\partial G_{\sigma} * I}{\partial x} \quad \frac{\partial G_{\sigma} * I}{\partial y} \right]^T$$

V. EXPERIMENTS AND RESULTS

Implementation of the techniques was done on an image. Colored image was converted into gray scale image and then thresholding is done by using Otsu's method to get the accurate threshold value. Proposed enhanced Otsu that is a combination of contrast enhancement, segmentation by K-means and edge detection by Canny were applied on the image after global threshold selection. The Otsu and edge detection techniques were implemented using MATLAB R2013a. This paper use MATLAB to evaluate these algorithms by setting different thresholds. Otsu algorithm is applied on input image and results are obtained. Further enhanced Otsu is applied on image and results are obtained. Both the results are compared. The output images of Otsu and enhanced Otsu are shown in the next figures.



Figure 2: a) original image b) Otsu output image

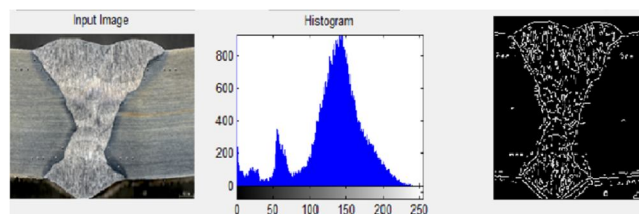


Figure 3: a) is input image, b) is Histogram of image and c) is output of enhanced Otsu.

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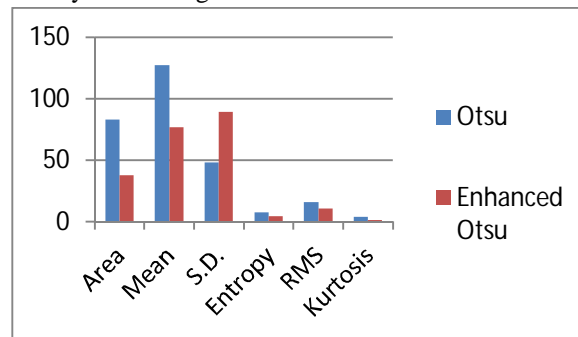
Following tables shows the results of geometric parameters calculation for Otsu and Enhanced Otsu.

Table I

Name	Area	Mean	S.D.	Entropy	RMS	Kurtosis
Otsu	82.78	127.37	48.27	7.28	15.62	3.63
Enhanced Otsu	37.65	76.58	89.01	4.46	10.78	1.48

The required parameters calculated are as shown in the Table I.

Following graph shows the comparative analysis for the geometric calculations.



VI. CONCLUSION

In this paper we have enhanced the basic Otsu's algorithm by using combination of techniques to suit for welded structure analysis. Otsu has performed well in case of thresholding. We compared the results obtained by Otsu with the proposed enhanced Otsu's results. We found that there was enhancement in the quality of the output image of the proposed method. Image noise is reduced and accuracy in geometric parameters calculations is significantly increased. Using canny edge detection, object picture of weld is clearly highlighted which helped in easy analysis of welded structure. Different geometric parameters are calculated which have different meaning and importance in welding. Taking all these points into consideration, the proposed enhanced Otsu has performed better than the basic Otsu in quality inspection of the welded structure post welding operations. This system can be further enhanced to make a dynamic system which works in real time analysis of welded structure.

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