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에지 향상과 활성 윤곽선을 이용한 용접 비드 영역화 알고리즘

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Welding Bead Segmentation Algorithm Using Edge Enhancement and Active Contour

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요 약 본 논문에서는 에지 향상과 활성 윤곽선을 이용한 용접 비드 영상의 영역화 알고리즘을 제안한다. 제안 방법에서는 에지 향상을 위하여 고주파 필터링과 대비개선을 수행하며, 이후 활성 윤곽선 방법을 적용하면 용접비드만의 영역을 얻을 수 있다. 제안된 알고리즘은 고주파 필터링을 통하여 에지를 검출하며, 대비 개선을 이용하여 검출된 에지를 강화한다. 이렇게 에지 정보를 향상시킨 후에 활성 윤곽선 방법을 적용하여 용접비드 영역을 추출할 수 있다. 제안 알고리즘은 용접 비드 영역화를 위한 기존의 방법들 보다 우수한 성능을 보였다. 제안된 알고리즘의 객관적 신뢰성을 위해 기존의 다양한 고주파 필터링 방법들과 비교하여 용접 비드 영역화가 우수함을 확인하였다. 제안된 방법은 영역화된 용접 비드에 대해 추가적인 절차를 통하여 용접 비드의 품질 평가를 하는데 있어 유용하게 사용될 수 있을 것이다.

• 주제어 : 용접 비드, 영역화, 에지 향상, 대비, 활성 윤곽선

Abstract In this paper, we propose an algorithm for segmenting weld bead images using edge enhancement and active contours. In the proposed method, high-frequency filtering and contrast improvement are performed for edge enhancement, and then, by applying the active contour method, only the weld bead region can be obtained. The proposed algorithm detects an edge through high-frequency filtering and reinforces the detected edge by using contrast enhancement. After the edge information is improved in this way, the weld bead area can be extracted by applying the active contour method. The proposed algorithm shows better performance than the existing methods for segmenting the weld bead in the image. For the objective reliability of the proposed algorithm, it was compared with the existing high pass filtering methods, and it was confirmed that the welding bead segmentation of the proposed method is excellent. The proposed method can be usefully used in evaluating the quality of the weld bead through an additional procedure for the segmented weld bead.

• Key Words : Weld bead, Segmentation, Edge enhancement, Contrast, Active contour

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Ⅰ. Introduction

Welding techniques are basics to modern manufacturing of tools in industries and they serve a significant role in multiple fields including robotics, mechanics, etc. With the increase in demand of automated production of materials in the field of robotics, various robots are developed to perform the activities that were previously done by human. This procedures have served humans from the side effects of welding processes. In order to obtain good and reliable instruments from welds, the welding manipulators should operate at high efficiency and accuracy. If the accuracy results are very small then we need to detect which part is good or bad, long or short, correctly or wrongly welded etc. Additionally, welding efficiency and quality is referred to as a key indicator of performance in welding processes. Therefore, in this work we aim at segmenting the welding beads on the images and determine whether the beads are correctly welded.

Image segmentation is literally defined as image classification at pixel level whereby the every individual pixel is allocated, labelled, classified, and localized depending on the relational properties with the other pixels. There are several methods that have been proposed by different scholars for the segmentation of welding bead materials as detailed in [1]. These methods include active contours, graph-based (connected components), snake algorithms, random walker, geodesics, and morphological snakes. Also, this work is motivated by Haffner et al., [2, 3] who proposed a system for automatic weld evaluation. The authors' work achieved promising results however, the detected edges of the segmented weld beads were not well smooth. In this work, we apply an active contour algorithm with high pass filtering for the segmentation of the welding beads.

Active contour model which is also called snakes; is a framework in computer vision introduced by Kass et al., in [4] for detecting and segmenting an object from a possibly noisy image. The snakes model is popular in computer vision, and recently is widely used in applications like object tracking, pattern and shape recognition, segmentation, edge detection and stereo matching. Generally, a snake is an energy that minimizes deformable shapes by the influence of constraints and image forces [5]. The image forces pulls the object in an image towards the object contours while the internal forces resists deformation of the contour objects. Additionally, snakes are also termed as a special case of the general technique for matching a deformable model to an image by employing energy minimization [6].

Even though, the snake algorithms are very famous for solving various segmentation problems but they do not solve the entire problem of finding contours in images, because the algorithm requires prior information of the desired contour based on the shape of the object to be segmented. Rather, they depend on various mechanisms such as user interaction, combination with some higher level image processing techniques, etc.

This work is organized into five sections whereby the second section presents the related works, third section presents the proposed work. The experimental results and discussion are in fourth section while the last section describes the concluding remarks.

Ⅱ. Related Work

Segmentation of welding beads in the field of computer vision is trending because of its essence and significances in terms of technological advancements. There are several algorithms that have been introduced to segment welding beads as mentioned in [7] who presented an algorithm for general welding detection from radiographic images. The authors described and proposed an algorithm that segments digitized radiographic images image processing techniques named as histogram analysis, contrast enhancement, and image thresholding. Awang et al., in [8] proposed a machine learning algorithm that overcomes the problem of detecting and localizing defects on welding beads by using a decision tree-based algorithm of colored images. The results from this work were promising however, the algorithm was slow due computational costs.

There are several models and algorithms that have been invented to realize and recognize welding bead detection and segmentation in the field of computer vision. Haffner et al., in [3] proposed a method that does weld segmentation and evaluation using image entropy. The authors' proposed algorithm used image processing techniques like image entropy, blurring, thresholding, morphological opening, and closing for bead segmentation. The purpose of using statistical image entropy function is to obtain the texture characteristics of the image while ignoring spatial structures. This algorithm achieved reasonable results however, it was affected by computational complexities and it was affected by the regions with pixels that have higher intensities.

High and low pass filters can be used to enhance images for the purpose of achieving outstanding results during image analysis. The high pass filters include Sobel, Laplacian, Prewitts, and Inverse gaussian but to mention a few, while the low pass filters include mean filtering, median filtering etc [9]. The high pass filters normally make the image sharper than its original image whereas low pass filters do the opposite. High pass filtering works in exactly the same way as low pass filtering; it just uses a different convolution kernel. Low pass filtering smoothen out noise while high pass filters normally enhances the brightest part of the image [10].

Ⅲ. Proposed Work

The motivation of this work stems from the drawbacks experienced in the work of Haffner et al., in [10-11]. The authors algorithm was challenged by the local minima states whereby the convergence of the segmented curve depends on the maximization of the local minima constraints. The edges of the images are not easily captured by this algorithm.

In this work we propose an active contour model that adaptively search for the minimum state of the image features. This algorithm applies external forces that acts upon the object to be segmented by incorporating Laplacian filtering in the image energy function. It can also be used to segment objects with mixed pixel intensities. This algorithm is based on energy formulation for a simple elastic contour with n points v_i for $i = 0, 1, 2, 3, \ldots, n-1$. We define the internal energy as E_i and the external energy as E_e. Therefore, the energy function of the snake is the sum of the external energy and the internal energy.

$$E^*_{snake} = \int_0^1 E_{snake}(v(s))ds \qquad (1)$$

The expression in Eq. (1) can be expanded as shown in Eq. (2).

$$E^*_{snake} = \int_0^1 (E_i(v(s)) + E_{im}(v(s)) + E_{cn}(v(s)))ds \qquad (2)$$

where E_{im} is the energy from the image, E_{cn} is the energy from the contour.

The image energy (E_{im}) is the function which is described by the image features. For the image $I(x, y)$, the lines, edges and terminations are present in the image, therefore the general function of the energy is given in Eq. (3).

$$E_{im} = w_l E_l + w_e E_e + w_t E_t \qquad (3)$$

where the w_l, w_e and w_t are the weights of the features (line, edges, and terminations) of the image.

We define the line function in terms of intensity values as $E_l = I(x, y)$ where the sign of the w_l will determine the line to be attracted to either dark lines or light lines. We then apply the Laplacian filter for smoothing or noise reduction by applying a laplace transform L where $E_l = L(I(x,y))$ and the edge function will be as

$$E_e = -|\nabla I(x,y)|^2 = -\left|G_\sigma . \nabla^2 I\right|^2 \qquad (4)$$

where G_σ is the gaussian with the standard deviation σ and the minima of this function $G_\sigma . \nabla^2 I$ is the one that defines the image edges.

From E_l we normalize the filtered image. $E_l = g(x,y) = \frac{L(I(x,y)) - \min(L(I(x,y)))}{255-0} * 255$

The above procedure is summarized in the following workflow of the proposed algorithm as shown in Fig. 1.

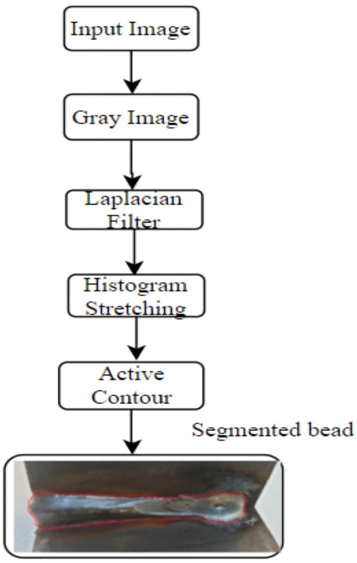

Fig. 1. Workflow of the proposed algorithm

The proposed algorithm in Fig. 1. has six blocks whereby the first block inputs an RGB image which is converted to gray scale in the second block. The output from the second block is then smoothened by a laplace filter to determine the dark and light lines where the gradient approaches to zero, positive or negative. The output from the Laplacian filter is then normalized by using the histogram technique to yield the normalized results that are used for segmentation in the active contour block. The essence of applying Laplacian filter is to detect the edges of the input image by computing the second derivative of an image. The active contour algorithm in the fifth block yields the output in the last block as shown in the proposed algorithm.

Ⅳ. Experimental Results

The experimental setup and procedures of this work were done via a computer with GPU operating on windows installed with python under "skimage" library. We used five colored images for the whole experiment. To evaluate our proposed algorithm, we compared the obtained results from various high pass filters. The following figure indicates the procedure of the proposed algorithm as shown below.

In Fig. 2., image (a) is the RGB image, image (b) is the gray image, image (c) is the gray image processed by Laplacian filter and image (d) is the normalized image of the filtered image in block 4 of the proposed algorithm. The normalized image is then assigned a region of interest on the location where the bead is located and the resulting Fig. 3 represents the segmented bead.

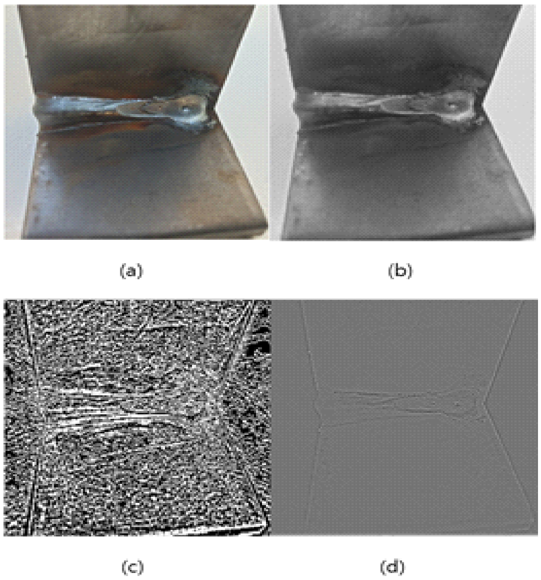

Fig. 2. Shows image (a)-(d) for the proposed algorithm

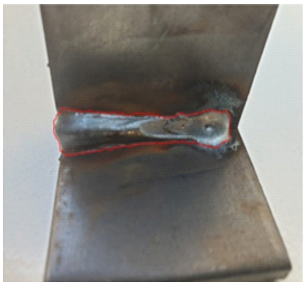

Fig. 3. Segmented bead from the preprocessed image

We compared the proposed algorithm with other high pass filtering techniques and found than the proposed algorithm works better than isotropic Sobel and Prewitts filters as shown in figure (Fig. 4-6).

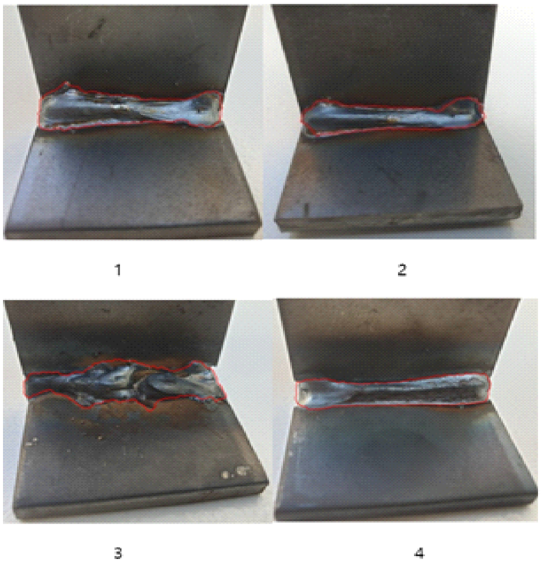

Fig. 4. Segmented images filtered by Laplacian filter

From Fig. 4 to Fig. 6, there are four images labeled 1 up to 4. The image 2 is smoothly segmented by active contour algorithm when processed by Laplacian filter. Its edges were not well captured by the algorithm when processed by the isotropic Sobel and Prewitts filters. Likewise, for image 1, 3, and 4, the edges were not well captured by the active contour algorithm. Among all the compared high pass filters, the Laplacian filtering enhanced the brightness of the images to yield good segmentation results.

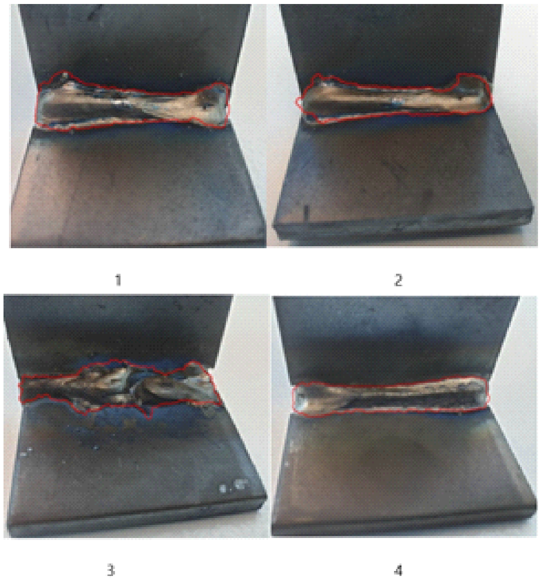

Fig. 5. Segmented images filtered by Isotropic Sobel filter

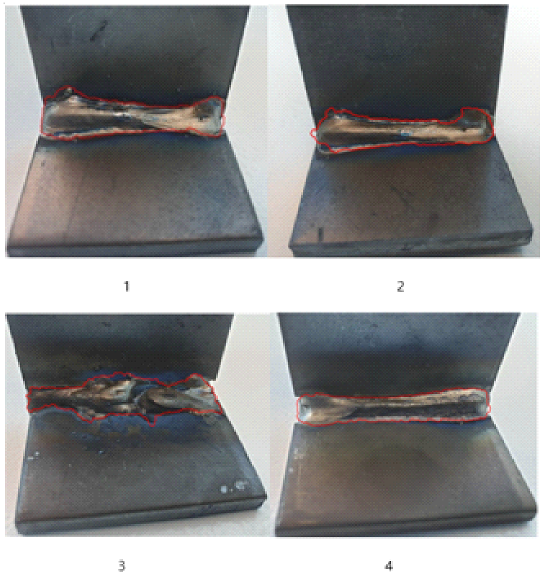

Fig. 6. Segmented images filtered by Prewitts filter

Based on the experimental results, the images processed by Laplacian filters yield good segmentation results compared to other results that were processed by the rest of the filter. The weaknesses for the segmentation results of the images processes by isotropic Sobel and Prewitts filters are the segmented bead is not smooth in the edges of the welding bead.

Ⅴ. Conclusion

We proposed an active contour algorithm that uses high pass filters to process the images for segmentation of welding bead. The proposed algorithm initially converts the RGB image to a gray scale image. The gray scale image is then filtered by a Laplacian filter to sharpen the pixel intensities. The filtered image is then normalized by the histogram stretching technique to increase the global contrast of an image to be localized and segmented.

Based on the experiments conducted in this work, the segmentation results from the images filtered by Laplacian filter yielded promising results compared to those filtered by isotropic Sobel and Prewitts filters. Additionally, edges obtained from the images processed by Laplacian filter are clear compared to those obtained by isotropic Sobel and Prewitts filters. For the segmentation of weld bead images we recommend the Laplacian filter and histogram stretching as the main preprocessing techniques that will yield good segmentation results of the weld beads.

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