Software System Designs of Real-Time Image Processing of Weld Pool Dynamic Characteristics

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Abstract. In this paper, welding pool image processing software is developed to measure the weld shape parameters in different images. Firstly the visual sensing system was established according to the principle of the passive visual image sensing. Next, the image processing and pattern recognition techniques are discussed to get a clear contour of the pool and measure its size. Finally, in order to testify the efficiency of the software, an image of aluminum alloy welding pool is used and validating results indicate these techniques can be applied practically.

1 Introduction

To realize real-time closed loop control of penetration and weld seam forming, the weld pool shape should be obtained. Therefore, the goal of image processing is to gain the topside width and the backside width of the pool which are associated more closely with penetration.

Many researches have been done in weld pool image processing algorithm in resent years. The sensing systems can be divided into 2 types according to the source: the active mode (imaging with supplementary high-intensity light source) [1,2]and the passive mode(imaging with arc light illumination). Some previous studies indicated effectiveness of the passive visual method for monitoring weld pool, which is more close to simulate a welder observing behavior during his welding operations, furthermore, it is a key technology for intelligentized robotic welding [3,4,5,6]. S.B.Chen and G.J.Zhang developed a narrowband filtering for low carbon weld pool [9] and J.J.Wang developed a wideband filtering for Al alloy weld pool [5] during pulse GTAW and both of the above method is in a simultaneous double-sided visual image sensing system. [3,4].

The bead-on-plate welding was conducted on low carbon steel during pulsed GTAW; a typical low carbon weld pool images is obtained and the algorithms for extracting geometry parameters of the topside and backside images of the weld pool was developed by Y.J.Lou [3]. The calculating time for a frame image was less than 50ms for the top image and 30ms for back image.

J.J.Wang developed the algorithm for Al alloy weld pool during pulsed GTAW process. Based on proper welding conditions for taking fine images of Al alloy weld pool during pulsed GTAW process, a frame of typical images of the topside and backside weld pool were captured. The real-time image processing algorithms were developed to deal with three types of weld pool images, namely the intact image, the fragmentary image and the degenerative image [5].

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It should be pointed out that all the above work is independent with each other for certain kind of material, certain size of welding pool image and certain processing condition. But all-purpose image processing software is necessary to deal with weld pool image in different conditions in real time for further study in intellectualized welding robot system. Therefore, in this paper, software is designed to process various weld pool images during pulsed GTAW.

2 The Architecture of Welding Pool Image Processing Software

The system is specially designed to deal with weld pool image, so as to gain information of the size of weld pool which indicates penetration of the material.

2.1 General Functions of the Software

A series of factors including current polarity inversion, arc instability, workpiece reflection, curtain off from nozzle, etc., causes deformation and distortion of the image. The software is designed to function: preprocess of image, edge detection, binary processing and post-process of image. The architecture of the software is shown in Figure 1.

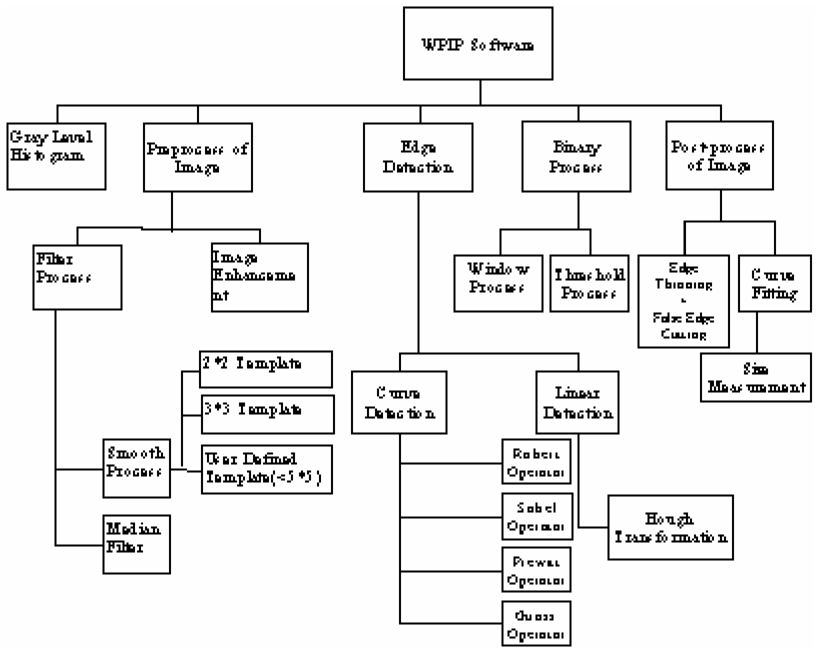


Fig. 1. Architecture of the software

2.2 Design of the Main Modules in the Software

All the functions are encapsulated in the function library for easier function call. Some of the algorithms are selected to discuss as follows:

2.2.1 Preprocess of Image

This part offers two functions namely filter processing and image enhancement.

Filter is necessary because in the unprocessed image there is a lot of noise such as uniform noise, pulse noise, Gusss noise. Guass noise comes into being due to the influence of high temperature in CCD; uniform noise due to random factors and pulse noise due to halt in data transmission. So in the software smooth processing of different template is designed for Guass noise and uniform noise; while median filter is designed for pulse noise. [5]

Meanwhile, image contrast is intensified by gray stretch for easier treatment in the following steps. The equation (1) is used in the enhancement, where x is the original gray value and $f(x)$ is the output gray value.

$$f(x) = \begin{cases} \frac{y_1}{x_1} x & x < x_1 \\ \frac{y_2 - y_1}{x_2 - x_1}(x - x_1) + y_1 & x_1 \le x \le x_2 \\ \frac{255 - y_2}{255 - x_2}(x - x_2) + y_2 & x > x_2 \end{cases} \tag{1}$$

2.2.2 Edge Detection

The aim of edge detection is to enhance the contour of the image so that it can be easily recognized by the machine. In an image, edge is where a significant local change in the gray level occurs. The traditional edge detection operators are to differentiate the pixels in 8 neighborhood of the current with different weight.

However, the edge has different contrast against the background in different areas. So in this paper an improved algorithm is added to deal with the output of traditional edge detect operator. Specifically, the gray level difference is replaced with the sum of that to enhance the contour in the part where contour is not so clear. And the algorithm is as follows:

1) calculate the output value of operator(M) in both row and column
2) for each current pixel (x, y), set the width of its neighborhood as N(where N is odd) and we calculate the difference between the current pixel and it neighborhood pixel ΔG,

$$\Delta G = \sum_{i=-\frac{N-1}{2}}^{\frac{N-1}{2}} \sum_{j=-\frac{N-1}{2}}^{\frac{N-1}{2}} |(f(x, y) - f(x+i, y+j))| \tag{2}$$

where i and j are nonzero integers

3) calculate the new gray level of current pixel point *g(x,y)*

$$g(x, y) = \Delta G + M \tag{3}$$

2.2.3 Threshold Processing

The goal of threshold processing is to set a threshold so as to separate the pool contour from the background more clearly on one hand and to reduce the time of calculating on the other. It is analyzed that different images have different gray level. Hence an adaptive algorithm is necessary here to gain the threshold automatically by the machine. And statistics is introduced to get the threshold. The algorithm is discussed in detail as follows:[6]

1) Set the neighborhood width of the current pixel as N(N is odd), and calculate the probability of pixels $P(k)$ whose gray level equal to k ;

$$P(k) = \frac{m}{N^2} \tag{4}$$

Where m is an integer less than N^2, and represent the number of pixels whose gray level is k , $k = 0,1,\cdots\cdots 255$.

2) Calculate the expectation of pixels ($E(x, y)$)in the neighborhood:

$$E(x, y) = \sum_{k=0}^{255} k \cdot P(k) \tag{5}$$

Set the adaptive threshold T_d and the fixed threshold T

$$T_d = rE(x, y) = r\sum_{k=0}^{255} kP(k) \quad (r > 1) \tag{6}$$

In the expression of T_d , the coefficient r is added to prevent the threshold in some image from being too low and thus lead to wide contour.

2.2.4 Measurement

After the binary-value image is obtained, edge thinning, false edge removing and curve fitting is needed to get a smooth and closed curve of the pool. Then, define the pool's maximal width and pool's length as the image's characteristic parameters, see figure 2.

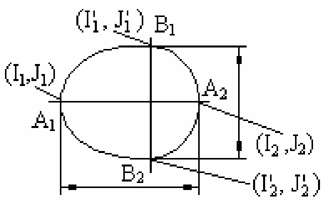


Fig. 2. Principle of measurement

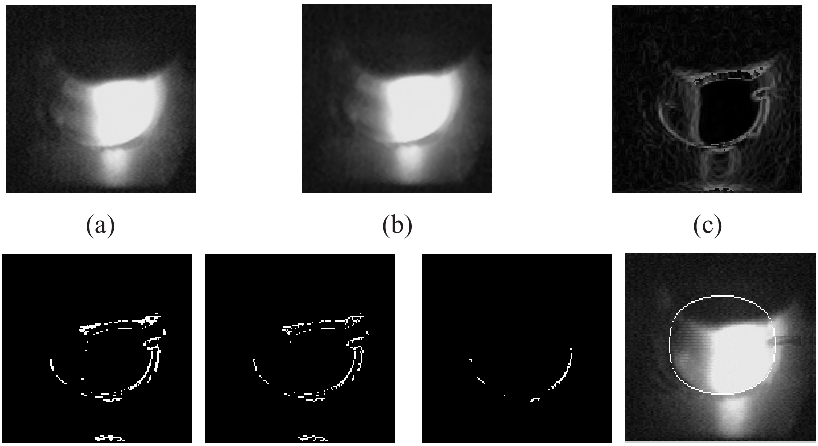
3 Algorithm Validations

To show the efficiency of the software, an image of aluminum alloy weld pool is presented. As is known from practice, weld pool of aluminum alloy is difficult to deal with due to its special characteristics such as high reflection, low contrast between the pool and background in comparison with low carbon steel and stainless steel. Moreover, a series of factors including current polarity inversion, arc instability, work-piece reflection, curtain off from nozzle etc. add difficulties for common algorithm to deal with the image. And as the backside image is comparably easier to deal with, only the topside image is discussed here.

3.1 Image Processing

For aluminum alloy, image is processed in the following steps, filter processing, image enhancement, edge detection, binary processing, edge thinning, false edge removing and curve fitting.

When filter processing, median filter is selected. As most of the noise in the image is dotting randomly in the image, median filtering is quite efficient for white noise without removing the image details. And a weighted median filter was designed to further improve the effect. In the process of edge detection, Prewitt operator is chosen. Among the traditional algorithmic operators, Prewitt operator is more suitable compared with Sobel operator which produces a wider contour with Guass operator which is more noise sensitive. During binary processing, the value of r is set by experiment, and in this paper, $r = 1.3$. Meanwhile a fixed threshold is necessary to prevent from false edge, and in this paper $T = 144$. During curve fitting, as the upper half of the contour is actually the nozzle and the welding wire, and the lower half is what we really care about, only the lower half is preserved after removing the false edge. And consider of the axial symmetry of the image, we can recover the image by mirror processing. Meanwhile, the LS fitting is chosen because firstly, the ellipse equation can approximate the actual edge well; secondly, local adjustment can be made by LS method.



(a) (b) (c)

(d) (e) (f) (g)

Fig. 3. Process flow chart of an entire pulsed image a) Original Image b) median filtered Image c) sharpened Image d) transformed threshold Image e) fined Image f) Image after false edge cutting g) Image after curve fitting

3.2 Result Discussion

The contour of the pool after processing is satisfying compared with the original image except for some roughness in the rear part of the pool where the edge is not so clear and few points are left after edge detection. More research is necessary if we want to recover the whole weld pool edge.

4 Conclusions

This paper presents efficient and practical software of welding pool edge detection. An image preprocessor, an edge detector, a binary processor and an image post-processor are included in the software. Because of the good symmetry of the image, the whole edge of the image can be recovered well.

However, more algorithms in the aspects of filtering, image strengthening and edge detection should be developed so as to strengthen the robustness of software in dealing with different materials. Moreover, in consideration of the roughness in the rear part of the fitted curve, it is necessary to improve the curve fitting algorithm in order to get a smoother curve.

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