Title	Image Processing for On-Line Detection of Welding Process (Report II) : Binary Processing for the Image of Arc Welding Process(Welding Physics, Processes & Instruments)
Author(s)	Inoue, Katsunori
Citation	Transactions of JWRI. 1980, 9(1), p. 27-30
Version Type	VoR
URL	https://doi.org/10.18910/7216
rights	
Note	

Image Processing for On-Line Detection of Welding Process (Report II)†
–Binary Processing for the Image of Arc Welding Process–

Katsunori INOUE*

Abstract

The application of the BIP is described continuing the previous report.

The image which is picked up from the arc welding process progressing part with TV camera is processed with the BIP and the necessary information for the arc welding automation is extracted. The procesis consist of adjustment of the threshold value, reading the image data, the smoothing and the differential operations, extraction of the required parts and detection of their positions. These procesis are combined together, the algorithm for the real-time detection is composed.

The image obtained during welding is processed, the real-time detection is performed successfully by this algorithm.

KEY WORDS: (Automatic Control) (Measurement) (Television) (Computers) (Joint Preparation) (CO_2 Welding)

1. Introduction

It was reported previously that the image obtained by observing the arc welding process progressing part with a suitable optical device had various useful information.[1) ~ 6)] We can extract more reliable information if the similar image is processed with the BIP, on which the report was also made previously.[7)]

In this report, the image processing algorithm is described by adducing an example of application of this method to butt welding of square groove joint. The usefulness and effectiveness of this method are also proved by showing the result of real-time extraction of the necessary information for arc welding automation from the actual image which is picked up during welding.

2. Image of Arc Welding Process Progressing Part

When we look down obliquely from the front of the arc welding process progressing part, whose schematic illustration is shown in **Fig. 1**, with TV camera, the image as shown in **Fig. 2(a)** can be obtained. On picking up this image, the TV camera was laid on its side in order to be convenient for processing the image with the BIP. On such an image, the necessary values for arc welding automation are shown in **Fig. 2(b)**. The parts indicated as **a** and **b** correspond to the groove face, the distance **W** between them expresses the groove width, and the parts indicated as **c** and **d** correspond to the outer circumference of the electrode wire, the distance **E** between the center of **a**, **b** and that of **c**, **d** corresponds to the wire

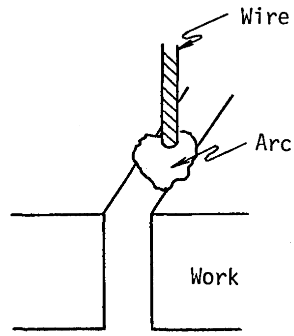
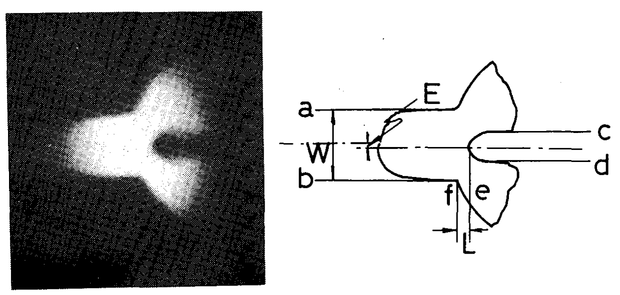


Fig. 1 An illustration of the arc welding process progressing part.



(a) (b)

Fig. 2 (a) An example of the image, picked up with TV camera, on a monitor.
(b) Schematic illustration of the necessary values for arc welding automation in the image.

deviation from the weld line respectively in this figure. In addition to these values, the distance **L** between the lower end of the wire **e** and the part **f** which corresponds to the front edge of the molten pool is an important factor

† Received on March 29, 1980
* Professor

Transactions of JWRI is published by Welding Research Institute of Osaka University, Suita, Osaka, Japan

which has an effect on the weld result.

The other values than described above are also related to the result of the weld, however, the author makes no mention of them. In this report, the measurement of **W** and **E** values is only described as follows.

3. Image Data Reading and Processing

3.1 Adjusting threshold value and reading image data

It is possible to read the image data with the BIP by the same method as reported previously[7]. When the image is converted into binary data with the BIP, the threshold value of the BIP must be set suitably so as to fit the brightness of the image. The configuration of binary image data, which is converted from the stationary image like as the photograph of Fig. 2(a) with several levels of threshold values, is shown in **Fig. 3**, where the levels are

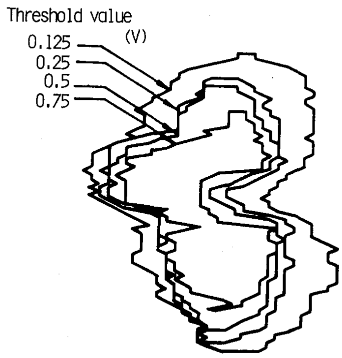


Fig. 3 An effect of the threshold value of the BIP on the outline of the image data.

expressed as voltage and the video signal from TV camera or VTR is adjusted so that its white and black levels may become 1 and 0 volt respectively, therefore, all the levels are within the grey level. The image in this example is so high contrasty that the level change of the threshold value does not affect the shape of the binary image to measure **W** and **E** values. Such image of good quality can not always be obtained, so we must measure the necessary value only in the case the good quality image is obtained.

The setting and adjustment of the threshold value is as follows; First, the initial threshold value is assumed, then, the image data are read in and the summing up value $\sum_{I=1}^{N} B_I$ of the bright data B_I (for B_I ($I=1 \sim N$), refer to the previous report) is obtained. The value $\sum_{I=1}^{N} B_I$ is compared with the preset value and, if the difference between them is not within the allowable limit, the threshold value is adjusted according as the amout of the difference.

3.2 Preprocessing – Smoothing operation

The image of arc welding process progressing part is unstable due to momentarily flickering of welding arc and fluctuation of molten pool. In some cases, the noise is generated at the horizontal scanning in TV camera due to heavy current of welding, and is superposed on the video signal. Therefore, the outline of the image which is

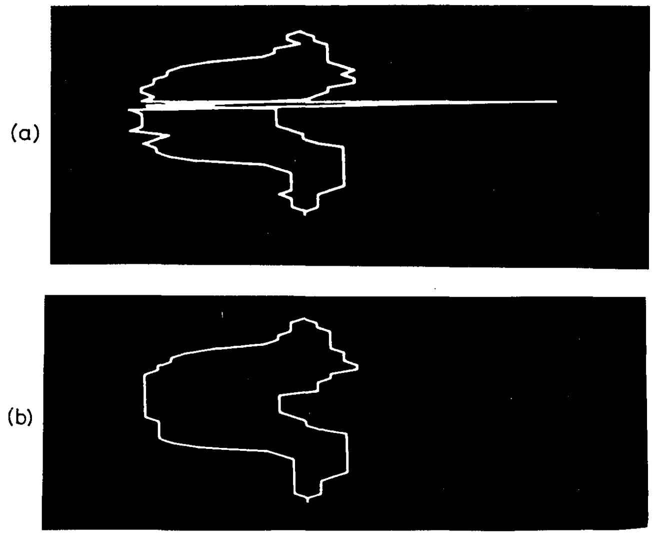


Fig. 4 (a) Outline of the image before the smoothing operation.
(b) Outline of the image after the smoothing operation.

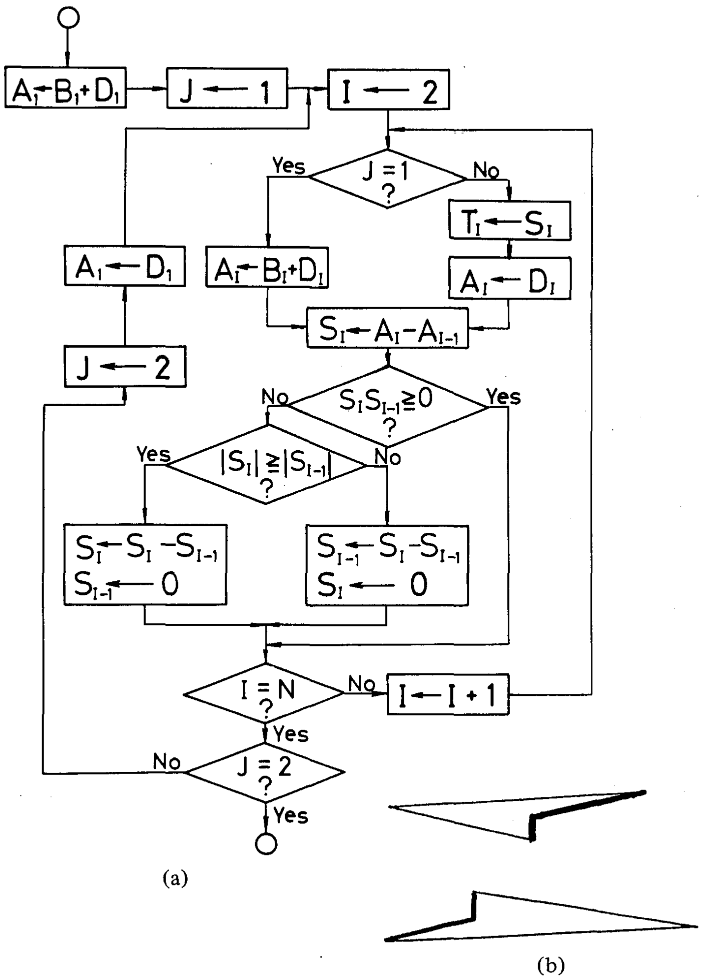


Fig. 5 (a) Flowchart for the smoothing operation.
(b) Elimination of a projecting part by the smoothing operation.

obtained by processing with the BIP has the large projecting part, which should not exist originally, and the small ripples as are seen in **Fig. 4(a)**. They are harmful for the differential operation described later, so they must be removed.

The smoothing operation, whose algorithm is shown in **Fig. 5(a)** as a flowchart, is performed to remove these harmful parts. (The reader may refer to Fig. 4 of the previous report for B_I and D_I in this flowchart.) The projecting part which may exist on the outline of an image and is drawn as a thin line in **Fig. 5(b)** can be changed to a thick line by drawing the image on the basis of S_I and T_I values ($I=2 \sim N$) which are obtained by the smoothing operation. The outline of the image shown in Fig. 4(a) is also changed into that of **Fig. 4(b)** by removing the projection and the ripples in the same way.

3.3 Differential operation – Extraction of required parts

It is necessary to search the processed image data S_I and T_I in order to find out the suddenly changing points on the outline and to obtain **a, b** and **c, d** positions which are illustrated in Fig. 2(a) and correspond to the groove face and the circumferential of the wire.

First, the differential operation is performed on the image data for this purpose. Equation (1) is applied to the image data S_I and T_I.

$$\left.\begin{aligned} C_I &= S_{I+2} + 2(S_{I+1} + S_I) + S_{I-1} \quad \text{(right side)} \\ &= T_{I+2}\ 2(T_{I+1} + T_I) + T_{I-1} \quad \text{(left side)} \end{aligned}\right\} \qquad (1)$$

, where S_I and T_I are defined in the flowchart of Fig. 5(a)

The processing result on applying equation (1) to the image data of the left and right outlines in Fig. 4(b) is shown in **Fig. 6**. The right outline does not show so

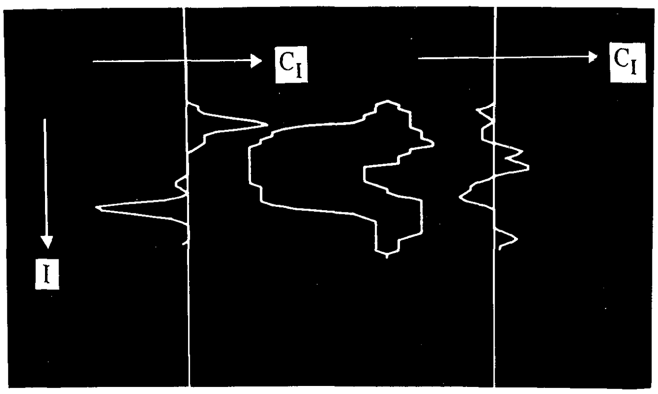


Fig. 6 The result of the differential operation for the image data.

suddenly changing (that is to say, the image of the wire is not so clear) that C_I value has not a sharp peak, however, its maximum and minimum points correspond to the wire position. Searching left and right C_I values from top to bottom ($I=3 \rightarrow N\text{-}2$), finding out the position of positive and negative absolute value maximum points and defining them as **a**, **b**, **c** and **d** points, **W** and **E** values can easily be calculated.

4. Real-Time Processing

4.1 Algorithm for real-time processing

The algorithm, with which the above mentioned processis such as adjusting threshold value, reading image data, smoothing and differential operations can be performed one by one continuously, must be composed in order to measure **W** and **E** values in real-time from the continuously picked up images during welding process. In addition, the routine for examining the reliability of the measured **W, E** values is necessary.

An example of such algorithm is shown in **Fig. 7** as a flowchart. As is seen in the figure, the flowchart is

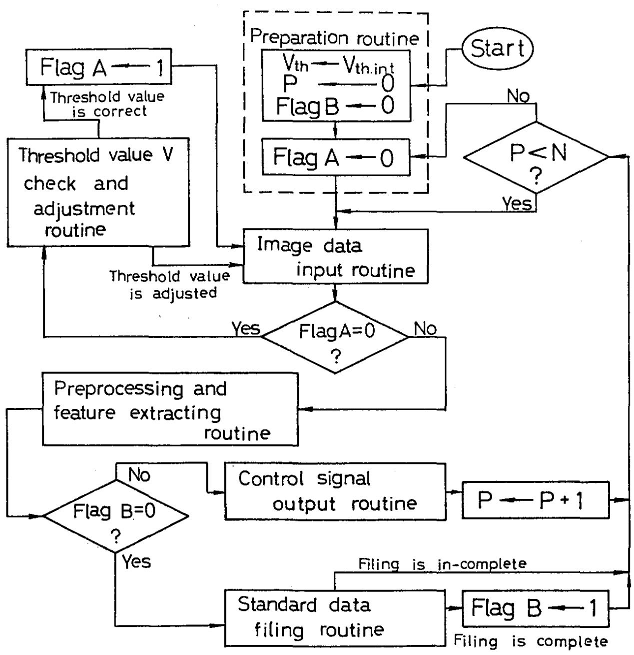


Fig. 7 Flowchart for the real-time detection of wire and groove.

composed of several routines and the branch to any routines is judged by examining flag A and B. The outline of the algorithm is as follows;

The initial values for the threshold and flags are set and reading the image data is performed at first stage. In the next stage, the threshold value is examined by the way described in the section 3.1 and adjusted according to the prescribed algorithm if it does not pass the examination. In case of passing, the flag A is changed. After that, the data are read again in both cases. In case of correct threshold value (in case of flag A=1), the flow branches to the preprocessing and feature extracting routine, the above mentioned smoothing and differential operations are practiced and the required position is detected. The flow, then, may branch to the standard file routine according to flag B. The order and distance among the positions of **a**, **b**, **c** and **d** points are examined whether they are proper and within the prescribed allowable limit or not at the standard file routine, the only data which pass the examination are registered in the standard file. When the standard file is completed, the flag B is changed. Since then, the flow branches to the control signal output routine, where the detected points are examined by comparing with the standard file data, the **W** and **E** values are calculated on the basis of the measured values and they are sent to the control system of an welder if the result of the examination is proper. At the same time, the oldest data in the standard file are replaced with these new measured values, thus, the file is renewed. In case of not passing the examination in the control signal output routine, the **W** and **E** values are calculated on the basis of the stored data in the standard file. After the flow passes this route at the alloted times, the flag A is changed again and the same procesis are repeated.

As described in the section 3.1, it is unnecessary to adjust the threshold value so severely in this application of the BIP, we have only to adjust it in the intervals of detection as shown in the algorithm of Fig. 7.

It is indispensable to such an unstable image like as the example reported here to make a standard file. It is desirable that the number of the file data set is of 2^n (n is equal to 4 or 5 usually) from the view point of easiness for arithmetic operation.

4. 2 Result of real-time detection test

Two examples of the real-time detection test result are shown in **Fig. 8** together with the objective images. These images were obtained during CO_2 arc welding under the condition of 30(V), 400(A) and 300(mm/min). The groove width of the work piece is wider than the wire diameter in the upper image and narrower in the lower image. The detection results are output about every 70(ms) on an average and displayed as the relative positions of **a**, **b**, **c** and **d** points at every time. In both examples, the relative position of the wire to the groove can be measured exactly, the weld automation system can obtain necessary information.

It can be concluded that the result is satisfactory.

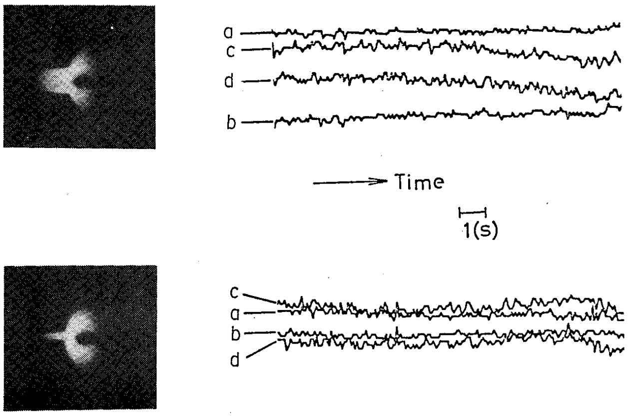


Fig. 8 The results of the real-time detection.

5. Summary

This report is summarized as follows:

(1) It is shown that the useful information for arc welding automation can be extracted from the image of the arc welding process progressing part.

(2) Algorithm for processing the image to extract the necessary information and to detect the required values is described and the examples of the result at each processing stage are shown.

(3) The real-time detection algorithm for this image obtained during welding and its test result are shown. It can be concluded from the result that the method described in this report is useful to obtain necessary information for the arc welding automation.

References

1) Y. Arata and K. Inoue: Trans. JWRI, Vol. 1 (1972), No.1, p. 99 – 113.
2) Y. Arata and K. Inoue: Trans. JWRI, Vol. 2 (1973), No.1, p. 87 – 101.
3) Y. Arata and K. Inoue: Trans. JWRI, Vol. 4 (1975), No.2, P. 205 – 208.
4) Y. Arata and K. Inoue: Trans. JWRI, Vol. 5 (1976), No.1, p. 77 – 85.
5) Y. Arata and K. Inoue: J. of JWS, Vol. 48 (1979), No.7, p. 493 – 498.
6) Y. Arata and K. Inoue: J. of JWS, Vol. 48 (1979), No.9, p. 695 – 700.
7) K. Inoue: Trans. JWRI, Vol. 8 (1979), No. 2, p. 169 – 174.