Study for Submerged Arc Welding Tracing Based on Hopfield Neural Network

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Abstract. This paper presents a new method based on Hopfield neural network to find out the welding center. The method transforms the problem of image processing into an optimization problem for searching the welding center. The energy function is constructed to meet the properties of welding image such as great noise. The algorithm combined with median filtering and neural network is also put forward. Examples show that the algorithm is practice and effective in detecting the welding center.

1. Introduction
The problem of searching the welding center fleetly and exactly is the key of automatic welding system. The welding quality can be ensured by using stepper motor to adjust the position of the welding torch. Because there is a large number of weld medicine around the welding torch in the actual production site of the submerged arc weld, the welding position is unable to been seen directly. In order to detecting the actual position of welding real-time, the study for welding tracking technology about the submerged arc welding robot have been researched at home and abroad. Which visual sensing technology is a hot [1]. With the widespread application of the visual sensor CCD, people use it to identify the location of the welding seam and construct a variety of welding tracing system [2]. Many meaningful works has been done [3]. Gao Xiangdong, Huang Shisheng applied the Adaptive Resonance Theory (ART) for welding recognition [4]. Qu Wentai, Zhu Jing used Gauss wavelet for welding detecting [5]. Xie Zhimeng, Gao Xiangdong employed the Canny operator to carry on the welding edge image extraction [6].

In this article, it was proposed to utilize Hopfield neural network for identification of welding center. Welding images can be obtained by using visual sensor CCD. The problem of the welding center images has been transformed into an optimization problem to be solved in this method. It is indicated that the method has higher accuracy and stronger noise immunity through the illustration.

2. Analyses about Actual Welding Image
Being the particularity of the submerged arc weld, the welding image is unable to be captured by the camera directly in the actual production. In the automatic welding system, it is general that the welding center has been identified before the weld, and then to adjust the welding torch according to this center. The welding image of the steel pipe in submerged arc weld is as shown in Fig.1.

It can be showed in Fig.1 that the grayscale contrast ratio of the welding image is relatively low and there is a rather strong interference on site. So it is difficult to determine the position of the welding center accurately by using conventional methods for image processing. It also can be presented that the welding image is symmetrical about the welding center.In view of this characteristic, it has been
proposed using Hopfield neural network to identify the welding center and transforming image processing problems into an optimization solution in this article.

![Image of welding image with and without light](image-url)

**Fig. 1** The original welding image of submerged arc weld

3. **Hopfield Neural Network**

3.1. Neural network model

In order to find out the welding center as exact as possible, we need to establish the neural network model showing the optimal state. In this article the grayscale of the pixel point (i,j) in a N×M gradation picture can be expressed as f(i,j). The neural network model established is as shown in Table 1.

Each unit is indicated with $v_{ij}$ in Table 1. The model is arranged in a matrix of dimensions N×M, corresponding to the size of the grayscale image. In Table 1 only one element is equal to 1 while the rest are equal to zero in each column. The element with value 1 indicates that the pixel points corresponding to the unit is located on the welding center. The element with value zero indicates that the pixel points corresponding to the unit is not located on the welding center. For example, In Table 1 its output indicates the welding center is located on the second column of the pixel point in weld image.

|   | 1   | 2   | …   | M   |
|---|-----|-----|-----|-----|
| 1 | 0   | 0   | …   | 0   |
| 2 | 1   | 1   | …   | 1   |
| … | …   | …   | …   | …   |
| N | 0   | 0   | …   | 0   |

Table 1 The model of neural network

After the establishment of the neural network models for the optimization state, the energy function is defined by:

$$E = E1 + E2 + E3$$  \hspace{1cm} (1)

In which:

$$E1 = \frac{A}{2} \sum_{j=1}^{M} \left( \sum_{i=1}^{N} v_{ij} - 1 \right)^2$$  \hspace{1cm} (2)

$E1$ is the first item of energy function. $E1$ is adopted to make each column have only one element with value 1 while the rest are equal to zero. This means that the output of the calculation for welding center is unique.

The grayscale of the welding image presents the obvious symmetry about the welding center. We can define $H_i$ as the position of the welding center. Then the second item of energy function can be represented as:
\[ E2 = \frac{B}{2} \left( \sum_{j=1}^{M} \sum_{i=H-WD}^{M} f(i,j)(i-H)\left(1-v_{ij}\right) \right)^2 \]  

(3)

Where

\[ H_i = \sum_{j=1}^{N} v_{ij} \cdot i \]  

(4)

Equation (3) is utilized to ensure that the elements with a value of 1 are located in the welding center. \( H_i \) indicate the position of column on which the element is equal to 1 in the output of ith row in neural network, it also is the welding center.

In order to ensure the welding center being a straight line, and at the same time in order to make energy function has a fairly strong noise immunity ability, the third energy function can be described as:

\[ E3 = \frac{C}{2} \sum_{j=1}^{M} \sum_{i=H-WD}^{M} \sum_{l=2}^{N} \left( v_{ij} - v_{(i+l)j} \right)^2 \]  

(5)

The original Hopfield model often plunged into invalid solution. The improved dynamic equation is proposed in reference[7]

\[ \frac{du_{ij}}{dt} = -\frac{\partial E}{\partial v_{ij}} \]  

(6)

We can use equation (1) and equation (6) to study the tracing problem of welding center image. The dynamic equation is derived from equation (5) based on the establishment of energy function (1). It can be expressed as:

\[
\begin{cases} 
\frac{du_{ij}}{dt} = -A \left( \sum_{o=1}^{M} v_{oj} - 1 \right) + \\
+ B \left( \sum_{j=1}^{M} \sum_{i=H-WD}^{M} f(i,j)(i-H)\left(1-v_{ij}\right) \right) f(i,j)(i-H) \\
- C \sum_{l=2}^{N} \left( v_{ij} - v_{(i+l)j} \right) \\
v_{ij} = \frac{1}{2} \left( 1 + \tanh \left( \frac{u_{ij}}{u_r} \right) \right) \end{cases}
\]  

(7)

In which, \( u_{ij} \) is the input of neuron; \( u_r \) is the normalized coefficient which makes neural output being Sigmoid function, 0.001 can be given to \( u_r \).

It can have the solution by using Euler method for equation (7).

3.2. Algorithm

Because of stronger interference of grayscale image on site, welding center defined by only using Hopfield neural network is not to be straight. The accurately algorithm can be used as following.

1) Median filtering by using 3x3 template;

2) Solving using Hopfield neural network

3) Recording the number of neuron which output is equal to 1 in each column. Finding out the two column including the most neuron and records its columns as \( L_1, L_2 \)

4) The welding center can be determined by equation (8)

\[ L_0 = \frac{L_1 + L_2}{2} \]  

(8)
Where, $L_0$ is the number of columns on which the pixel point of welding center; According to the information of welding center, we can adjust welding torch position and ensure the quality of welded pipe.

### 3.3. Illustration

Still take Fig. 1 as the example, the welding boundary and the center line obtained by using the proposed algorithm are as shown in Fig. 2. The accurate calculation for the median line can be carried out by Hopfield neural network. Even the light source is not ideal situation.

![Fig. 2 The processed welding image of submerged arc weld](image)

(a) with light  
(b) without light

### 4. Conclusion

In order to identify the median line of the welding seam, a new method based on Hopfield neural network is showed in this article, and the algorithm is combined with median filtering and neural network to wipe off noise and find the welding center effectively. It has the following advantages over many exiting methods for image processing: good noise immunity, accuracy.

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