A Study on the Welding Gap Detecting Using Pattern Classification by ART2 and Fuzzy Membership Filter

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Abstract

This study introduce to the fuzzy membership filter to cancel a high frequency noise of welding current. And ART2 which has the competitive learning network classifies the signal patterns for the filtered welding signal. A welding current possesses a specific pattern according to the existence or the size of a welding gap. These specific patterns result in different classification in comparison with an occasion for no welding gap. The patterns in each case of 1mm, 2mm, 3mm and no welding gap are identified by the artificial neural network.

These procedure is an off-line execution. In on-line execution, the identification model of neural network for the classified pattern is located on ahead of the welding plant. And when the welding current patterns pass through the neural network in the direction of feedforward, it is possible to recognize the existence or the size of a welding gap.

1. Introduction

This thesis propose to detect a welding gap under the arc sensing system. Among the position-sensing methods available, the arc sensor that utilizes the electrical signal obtained from the welding arc is one of the most prevalently used methods. Its advantages are that no particular sensing device is necessary and a real-time sensing of the groove position directly under the arc is possible.[1]~[6] In this study, fuzzy membership filter(or moving average method) is used to cancel a high frequency noise and to smooth a raw current signal. This scheme was contrived from the principle of FIR filter which armed with a moving average method. This algorithm contain very simple mathematical process to obtain a value of average signal so that it takes very short time to calculate the result.

ART2(Adaptive Resonance Theory2), a kind of neural network, which has the competitive learning network classifies the signal patterns for the filtered welding signal. A signal processing method based on the artificial neural network(ART2) was proposed for discriminating the current signal patterns when a welding gap occurs from the current signal patterns when a welding gap don't occur[7]. A welding current possesses a specific pattern according to the existence or the size of a welding gap. The patterns in each case of 1mm, 2mm, 3mm and no welding gap was acquired in off-line process. A neural network which has two hidden layer learned to identify the classified current patterns in off-line process. Finally, TDNN(Time Delayed Neural Network) has to be selected as an on-line type of identification neural network, seeing that a real welding signal get to the input node of neural network continuously.

2. Fuzzy Membership Filter

Fig. 1 represents a concept of the fuzzy membership filter. a_i, $i=1, 2, \cdots, n$, are the discrete sample data of a continuous input and μ_j, $j=1, 2, \cdots, m$, are the membership grade of each input data, a_i, which is assigned to a fuzzy membership. Width of a fuzzy membership can be varied and as width grow wider, the filtered output become more smooth. As long as new input data occur, fuzzy membership has to be shifted to the next m-tuple data and the calculation to acquire a output should repeated in the same manner. Fuzzy membership is divided into odd numbers for the convenience of calculating, accordingly, Fuzzy grade of a central location of the divided points is always 1.0. Seeing that the left side and right side of fuzzy membership is located on the symmetrical area, their grades have the equal value.

For instance, when a triangular fuzzy membership is divided into 9 points, each grade of all points is a0=0.0, a1=0.25, a2=0.5, a3=0.75, a4=1.0, a5=0.75, a6=0.5, a7=0.25, a8=0.0 from the extreme left side to the extreme right side.

From now on, the simple procedure of this

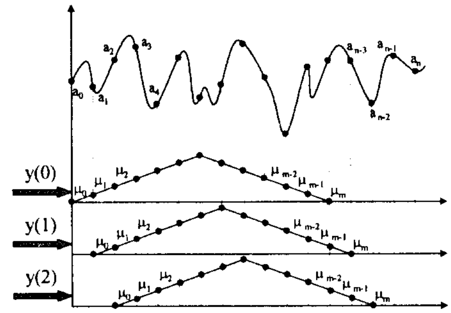


Fig. 1 Fuzzy membership filter

method is represented. Above of all, a division number for fuzzy membership has to be chosen, it could be varied as the case may be, then all of grade divided into division number are aggregate. This is represented Equation (1) and the aggregated value is constant if a division number is once chose.

$$\sum_{i=0}^{m} \mu_i = \mu_0 + \mu_1 + \mu_2 + \cdots + \mu_{m-1} + \mu_m \qquad (1)$$

where m is a division number and μ_i is a fuzzy grade.

Next, it is necessary to obtain each production between the sample input, as many division number, corresponding with the grade and the assigned grade. Then all of each production is aggregated. This procedure divided by Equation (1) makes Equation (2) and this equation brings about the output of the fuzzy membership filter.

$$y(k) = \frac{\sum_{j=0}^{m} \mu_j \cdot a[(k - \frac{m-1}{2}) + j]}{\sum_{i=0}^{m} \mu_i} \qquad (2)$$

3. Simulation

3.1 Selecting Welding Current

The specification of selected welding signal to be simulated as follows:

- welding speed : 3~5 mm/sec
- weaving width : 10 mm
- welding voltage : 25 V
- wire feed speed : 118.5 mm/sec
- flow rate of CO2 : 18 l/min

- thickness of workpiece : 10mm

To obtain the reliable result, the experiments must be implemented repeatedly. The off-line process is represented in Fig. 2. A raw welding current signal brought about the welding plant is filtered with a low pass filter and fuzzy membership filter and then ART2 classifies the filtered welding signal.

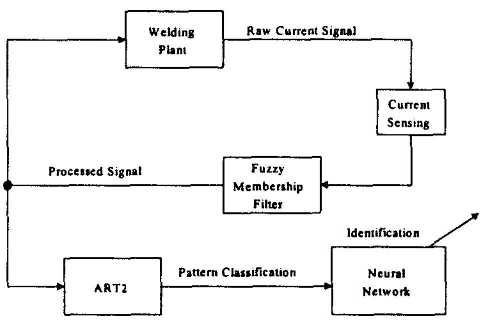


Fig. 2 Off-line Process

3.2 Filtering of the welding current

The material for a simulation is shown Fig. 3. In Fig. 3, welding current signal which has 3200 sample data when the torch weaves eight times is represented for convenience sake.

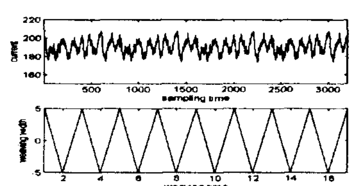
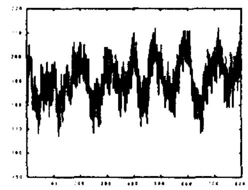


Fig. 3 Welding current and weaving motion

The random noised signal of welding current is filtered by fuzzy membership filter which has nine division number. A reason for choosing nine division number of fuzzy membership is that it shows best output than other division number. The fidelity of filtered output is depend upon division number and the choice of it can be altered in accordance with purpose. For example, to get a average signal of weaving motion or torch height, division number should be increased so that a average signal for the wider area is acquired. This method can be used as a simple software filter or as a kind of moving average scheme.



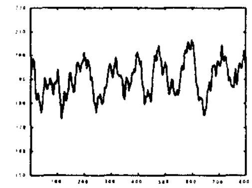


Fig. 4 Filtered signal by fuzzy membership filter

For the welding gap in case of 0mm, 1mm, 2mm and 3mm, raw signal is generated individually and each signal is filtered by fuzzy membership filter with nine division number. The results is represented from Fig. 4.

3.3 Pattern Classification Using ART2

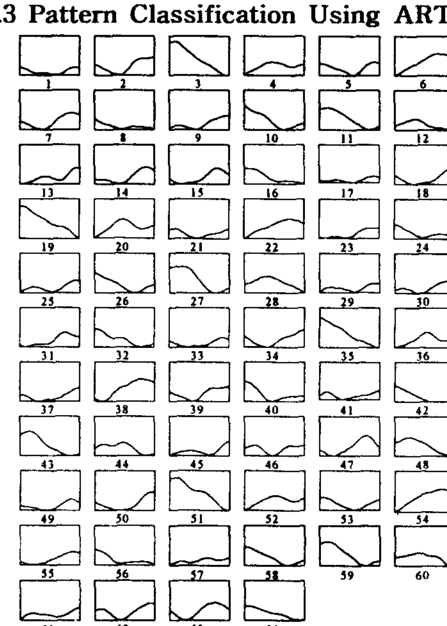


Fig. 5 Patterns for 0mm gap

Filtered welding signal by fuzzy membership filter or another algorithm must be classified to detect a welding gap. Before anything else, to recognize the difference between 0mm welding gap and 3mm welding gap, ART2 was implemented for 64 patterns of each case.

The classification result of 0mm welding gap is represented in Fig. 5.

As the same approach, the classification result of 3mm welding gap is shown Fig. 6. We can assume that when the cluster of 3mm welding gap is compared to the cluster of 0mm welding gap, if there is a new cluster in 3mm welding gap, it must express that there is some variation in case of 3mm welding gap.

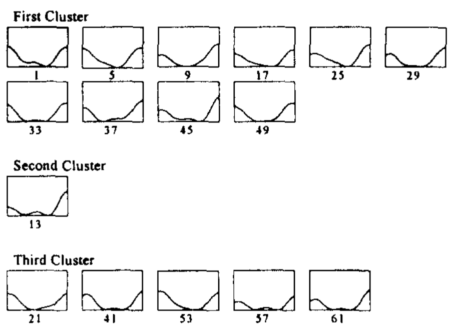


Fig. 6 Clusters of 3mm gap

By the way, all the welding parameters, material of workpiece, welding voltage, weaving width etc., is equivalent in this experiment. Furthermore, the variation of welding current signifies that some abnormal state, the welding gap, lies in the workpiece. Namely, The presence of the welding gap was revealed apparently.

We can tell the difference between the clusters of 0mm and 3mm welding gap partly because some clusters of both are identical, and partly because some clusters of both are substantially the same. The reason why some clusters of both are not identical is that several patterns are separated from due to the presence of welding gap. For example, when we consider the second cluster of 3mm welding gap in comparison to the second cluster of 0mm welding gap, 9th and 49th pattern were excluded due to welding gap.

The same procedure is applied to detecting 2mm and 1mm welding gap. The classification results are represented in Fig. 7 and Fig. 8.

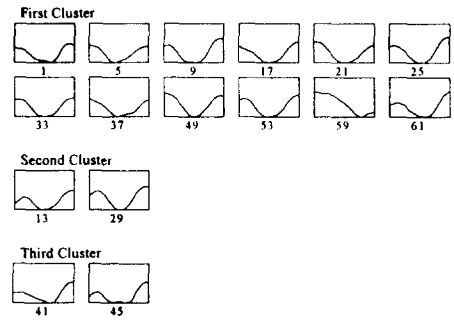


Fig. 7 Clusters of 2mm gap

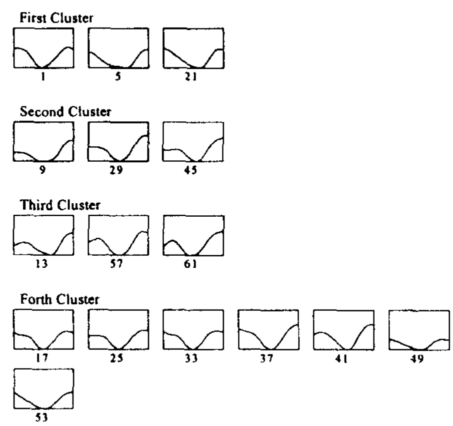


Fig. 8 Clusters of 1mm gap

3.4 Identification of classified patterns

It is indispensable to identify the welding gap because it is too insufficient to recognize the welding gap with only patterns in previous section. Numerous patterns for welding gap have to be acquired through the extensive experiments, it could make us convince whether the welding gap occur or not.

In this simulation, EBPA(Error Back Propagation Algorithm) which has two hidden layer is used. Architecture of this neural network is that it has 20 input nodes, 40 first hidden nodes, 40 second hidden nodes and one output nodes. The classified patterns for respective welding gap are used as the input patterns and each case of welding gap has its own desired value.

The specification of this neural network is following:

- Input nodes : 20
- First Hidden nodes : 50
- Second Hidden nodes : 40
- Output node : 1
- Learning rate : 0.03
- Steepness of activation function : 0.1

The identified neural network is used in on-line process. The current signal is processed by a low pass filter and fuzzy membership filter and the filtered signal comes into the identified neural network in real-time. In practice, this type of neural network must be a TDNN(Time Delay Neural Network) as the sampled signal turn in the TDNN piece by piece in temporal series.

4. Conclusion

This method has an advantage in being realizing at a low cost and is not restricted by space. First and foremost, since the majority of welding automation at present employs the arc sensor system, we will not be able to add a vision system to existing facilities. Thus we have no other way but to choose this method to detect the welding gap. Using the welding current signal in detecting the welding gap is decidedly superior to the vision sensing system in many aspects. But it has a limitation in precision, This limitation will be improved all the more when a signal processing technique is developed.

In future research, a adaptive controller using fuzzy-neuro approach will be completed. It is high time that a welding gap controller should be developed.

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