Usage of GA with Multilevel Thresholding to Detect Ice Thickness of Iced Conductor

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Abstract. Ice load on the electrical transmission line (ETL) can change the aerodynamics of the lines, causing galloping and faults, for example short circuits. If enough ice load forms, the weight of ice on the line can cause the electrical lines to collapse and then it can cause loss of load. Thus electrical energy of some consumers may be cut for days. So, ice load must be monitored continuously to prevent this case. Image processing can be used to monitor ice load and to determine ice thickness of iced conductor. Ice thickness of iced conductor can be determined by using image segmentation, and image segmentation makes according to optimum threshold value. Optimum threshold value can be determined bi-level threshold method or multi-level threshold method. It was seen in literature that multilevel threshold method is an effective method in object recognition. Multilevel thresholding can be made by Otsu method. But determination of optimum threshold level is difficult process. In this study, multilevel threshold method was used and its optimum threshold level was determined with genetic algorithm. Objective function of genetic algorithm is determined by Otsu method.

Keywords: Ice load, electric transmission line, image processing, multilevel.

1 INTRODUCTION

At cold and humid weather, ice occurs on the conductors of transmission line and it is called as ice load. Ice load occurs generally at between 2˚C and -8˚C temperature and at least 95% humidity. Ice load amount on conductor increases at low temperature and high humidity and if its amount increases excessively, transmission line pole may be bending or conductor may be breakage. Ice load can be monitored continuously to decrease its effect of ice load. Image segmentation was used to determine ice thickness of iced conductor in this study. There are lot image segmentation methods. It was seen in literature that bi-level threshold method is not enough for some object identification. Thus multilevel threshold method was used for image segmentation studies. Multilevel threshold can be made Otsu method. But detecting of optimum threshold level is difficult. The optimum threshold level can be determined by using artificial intelligence methods for multilevel threshold.

Particle swarm optimization (PSO) method was often used in literature. When PSO is used with Otsu method, its results are better than traditional Otsu method results. Two-dimensional Otsu method is suggested for segmentation of low-contrast iced conductor. The result of two-dimensional Otsu method is good but algorithm speed is low level. Multilevel threshold was made with maximum entropy and developed PSO (DPSO). Convergence of the suggested method is faster than convergence of traditional PSO, and 5 threshold levels were used but the best level for segmentation was not defined.

When transmission line monitoring was made with video processing, two-dimension Otsu method was used to eliminate noise of image. The best simulated annealing PSO (SA-PSO) was used with two-dimension Otsu method to detect the best threshold level. But single level

threshold was made. When hybrid PSO-GA was used with OTSU method, noise of image was eliminated, and threshold number and the best threshold level is not indicated. Slope-line search algorithm was used to determine ice thickness. This method is different the other methods. In this method image segmentation was made with single level threshold. If multilevel threshold can be used, the better results may be obtained. Support Vector Machine (SVM) and Artificial Neural Network (ANN) were used as different method to detect ice thickness of iced conductors. SVM and ANN were used to classify image. When SVM and ANN were compared, the result of SVM is better than the result of ANN. But ice thickness of SVM and ANN were not indicated.

In this study, multilevel thresholding was used to determine ice thickness of iced conductor. Multilevel thresholding was made by using Otsu method. The optimum threshold level was determined by using Genetic Algorithm (GA). The result of Otsu-GA methods were compared at the end of this study.

2 PROBLEM FORMULATION

Otsu indicated between-class variance method for image segmentation. In this method, variance of different classes is maximum value. When an image is divided as two classes, these classes can be defined as C_0 and C_1. If threshold level of C_0 and C_1 is determined as t, C_0 includes the gray level from 0 to t-1, and C_1 includes the gray level from t to L. gray level probabilities are defined as w_0 and w_1, and distribution of gray level probability of classes as follows ;

$$C_0 = \frac{p_0}{w_0}, ..., \frac{p_{t-1}}{w_{t-1}} \text{ and } C_1 = \frac{p_t}{w_t}, ..., \frac{p_L}{w_L} \quad (1)$$

$$\text{where } w_0 = \sum_{i=0}^{t-1} P_i \text{ and } w_1 = \sum_{i=t}^{L} P_i \quad (2)$$

The mean levels of classes are defined as μ_i. the mean levels of image are defined as μ_T.

$$\mu_0 = \sum_{i=0}^{t-1} \frac{i.P_i}{w_0} \text{ and } \mu_1 = \sum_{i=t}^{L} \frac{i.P_i}{w_1} \quad (3)$$

$$\mu_0.w_0 + \mu_1.w_1 = \mu_T \text{ and } w_0 + w_1 = 1 \quad (4)$$

Otsu's method which is based on between-class variance is defined as follows;

$$f(t) = \sigma_0 + \sigma_1 \quad (5)$$

$$\text{Where } \sigma_0 = w_0.(\mu_0 - \mu_T)^2 \text{ and } \sigma_1 = w_1.(\mu_1 - \mu_T)^2 \quad (12)$$

In bi-level threshold studies, optimal threshold level (t) is determined by Otsu method as follows;

$$t = \arg\max\{f(t)\} \quad (6)$$

Multilevel thresholding of an image can be extended between-class variance function.

$$f(t) = \sum_{i=0}^{m} \sigma_i \tag{7}$$

The number of threshold is m (t_0,t_1,t_2,.....,t_m), and the number of classes in original image is m (C_0,C_1,C_2,.....C_m).

Where
$$f(t) = \sigma_0 + \sigma_1 + \sigma_2 + ... + \sigma_m \tag{8}$$

$$\begin{aligned} \sigma_0 &= w_0.(\mu_0 - \mu_T)^2 \\ \sigma_1 &= w_1.(\mu_1 - \mu_T)^2 \\ \sigma_2 &= w_2.(\mu_2 - \mu_T)^2 ... \\ \sigma_m &= w_m.(\mu_m - \mu_T)^2 \end{aligned} \tag{9}$$

The optimum threshold levels (t_0,t_1,t_2,....,t_3) are determined as follows;

$$(t_0, t_1, t_2, ..., t_m) = \arg\max \{ f(t) \} \tag{10}$$

3 BRIEF DEFINITON OF PROPOSED METHOD

In this study, iced conductor image which is shown Fig. 1 was used for ice load monitor study. This iced conductor belongs to ETL which was harmed by ice load. Primarily image segmentation must be made properly. If image segmentation is made properly, target object can be detected correctly.

After this image was converted to gray level, average filter was used to determine ice thickness of conductor. Unnecessary object images on image of iced conductor were eliminated with average filter. After average filter was implemented to the gray level image, its histogram was obtained. Optimal threshold point can be determined by using the obtained data from histogram.

Fig. 1. Iced conductor.

It seen in literature that the results of multilevel thresholding are better than the results of bi-level thresholding for image segmentation. Therefore multilevel thresholding was preferred in this study. Multilevel threshold can be made Otsu method. But detecting of optimum threshold values is difficult. Thus GA was used to detect optimum threshold values for image segmentation. When Otsu method was used with GA, objective function was determined

equation (10). So $t_0,t_1,t_2,\ldots t_m$ values which is on gray value histogram can be determined easily by using Otsu method with GA. $t_0,t_1,t_2,\ldots t_m$ values is shown Fig.2.

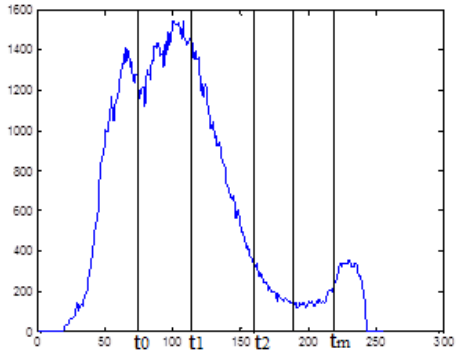

Fig. 2. Histogram of gray level image

After threshold level and threshold values are determined, edge detection can be made. There are a lot edge detection methods in literature. These methods can be defined as two topics. These topics are first-order and second-order edge detection operators. First-order edge detection operators are Roberts Cross, Smoothing, Prewitt, Sobel, and Canny. Second-order edge detection operators are Laplacian, Zero-crossing and Laplacian of Gaussian. Marr–Hildreth algorithm was used for edge detection. Marr–Hildreth algorithm is based on the zero-crossings of the Laplacian of the Gaussian operator.

4 GENETIC ALGORITHM

Find the optimum threshold levels is difficult process by using only Otsu method. Thus genetic algorithm was used in this study. Genetic algorithm is one of the powerful algorithms to solve optimization problems.

Working principle of genetic algorithm as follows:

1. Chromosome population is occurred as random according to iteration number and genes numbers. Genes are $t_0,t_1,t_2,\ldots t_m$.
2. Fitness value of chromosome is calculated by objective function, and affinity value is calculated. Objective function is determined by Otsu method. Chromosome selection process for crossover operation is made according to affinity value. In this study tournament selection method was used as the selection process, and the selected population was occurred for crossover. Two chromosomes are selected and affinity values of chromosomes are compared in tournament selection process. If chromosome affinity value is good another chromosome affinity value, it is selected for crossover process. Tournament size determines according to population size.
3. Crossover is made after the selection process. Crossover is made according to crossover rate (Pc). The number is produced random between 0 and 1 for any chromosome which will be selected for crossover. If the number (or ID) of chromosome is less than Pc, it is selected to crossover. After the crossover population is created, chromosomes are selected as pair, and mutual gene exchange is made between pair chromosome. If the selected chromosomes are shown as C=(C(1),C(2),C(3),..,C(m)) and K=(K(1),K(2),K(3),..,K(m)), crossover can be shown by equation (11) for each gene.

$$\mathrm{Cn(i)} = \beta.C(i) + (1-\beta).K(i) \quad \text{and} \quad \mathrm{Kn(i)} = \beta.\mathrm{K}(i) + (1-\beta).\mathrm{C}(i) \tag{11}$$

So new chromosomes are produced as Cn and Kn. i which is produced randomly is a number according to gene number. β is produced random between 0 and 1. Change of the number of genes is determined as randomly.

4. Mutation is made when radical change need in genes. Mutation provides variation in population and is made according to mutation rate. The number is produced random between 0 and 1 for any bit which will be selected for mutation. If the number is less than mutation rate, this bit is selected for mutation process. The selected bit is changed with a random number

5 EXPERIMENTAL RESULTS

At least three threshold levels were selected to determine ice thickness of iced conductor which is shown Fig.1. Ice thickness was determined by using Otsu method with GA. Ice thickness of ice conductor is determined according to number of pixels which is obtained after edge detection process. Different threshold levels were used to determine ice thickness of iced conductor. When Otsu-GA method was used to determine ice thickness, Table 1 and Fig. 3

Table 1. Font sizes and styles.

Threshold Level	The Number of Pixels	Threshold Values	The Fitness Value of GA
3	52	82 121 177	1943
4	48	73 103 135 186	2004
5	45	69 96 122 153 197	2035
6	44	58 80 103 127 158 202	2055
7	42	58 79 101 123 146 173 205	2069

The most accurate result was obtained when threshold level was 7. This result can be seen in Fig. 3.

Fig. 3. The result of Otsu Method with GA

6 CONCLUSION

Image processing is used generally in ice monitoring method. In this study, ice thickness of iced conductor was determined by using image processing and Genetic Algorithm. The good results are obtained by using multilevel thresholding method in literature. Thus multilevel thresholding was used to determine ice thickness. Otsu method was used for multilevel thresholding, and GA was used to find optimum threshold level. When the results of Otsu-GA which is shown in Table 1 were examined, 7 level thresholds were determined as the best result, and total thickness of iced conductor was found 42 pixels. This value can be acceptable level.

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