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DE-Otsu Method to Eliminate Ice Load Effect

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ABSTRACT

The ice causes additional burden on Electric Transmission Line (ETL) conductor, and it is called as ice load. Tension of ETL can be increase due to ice load. If tension of ETL increases extremely, conductor breakage or bending of power pole can be shown, and electric energy of some consumers may be cut several days. Therefore, ice load must be urgently eliminated, but primarily ice thickness of ice load must be determined. Monitoring of ETL can be made to prevent effect of ice load. When multilevel threshold image segmentation is used as ice monitor method, ice thickness of ETL can be determined accurately. In this study, Otsu method can be used as multilevel threshold method but finding of optimum threshold levels with Otsu method is difficult. Therefore differential evolution algorithm (DE) was used to find optimum threshold level, and maximum threshold number were selected as 8 levels.

KEYWORDS: Ice load, Electric Transmission Line, Image Segmentation, Multilevel Threshold, Otsu Method.

INTRODUCTION

Power quality is an important issue for electric transmission lines (ETL). Power outage adversely affects to power quality, and it can occur due to different reasons. Ice load which is one of these reasons extremely harms to ETL. Ice load occurs generally at between 2˚C and -8˚C temperature and at least95% humidity. If amount of ice load excessively increases, transmission line pole or tower may be bending or conductor may be breakage. Thus it can cause to power outage for days, and property damages on a large-scale. Ice monitoring method is one of the effective methods to prevent effect of ice load. Image segmentation can be used as ice monitoring method, and threshold value is important to make good segmentation. Thus bi-level and multilevel image segmentation methods were developed in literature. It was indicated in literature that the result of multilevel image segmentation is better than the result of bi-level image segmentation.

Multilevel threshold can be made Otsu method but detecting of optimum threshold levels is difficult with traditional Otsu Method. Thus artificial intelligence methods have been used to detect optimum threshold levels in literature. One of these artificial intelligence methods is Particle Swarm Optimization (PSO). It was seen that when PSO-Otsu method was used, its algorithm speed is faster than traditional Otsu method [1].Two-dimensional Otsu method can be used in segmentation of low-contrast iced conductor studies. Algorithm speed of two-dimensional Otsu method is low speed. This case is disadvantage for two-dimensional Otsu method [2]. Thus 2D Otsu was developed with genetic algorithm, and genetic algorithm was developed with simulated annealing. But in [2], threshold level is low. Convergence of traditional PSO can be developed with developed PSO (DPSO). In image segmentation studies with multilevel threshold method, the good results were obtained with DPSO. [3]. But in [3], maximum threshold levels are 5. These threshold levels may be not enough for some application. Video processing can be used to monitor transmission line, but noises of image are important problem. When 2D Otsu method was used with PSO, noises which are on image were eliminated [4]. But single level thresholding was made in [4]. When hybrid PSO-GA method was made with Otsu method, noise of image was eliminated [5]. But in [5], the best threshold levels are not indicated. Slope-line search algorithm is another method to determine ice thickness of iced conductor. In this method, ice thickness which is on aerial line conductor can be determined by using slope-line search algorithm [6]. But in [6] study single level threshold was used with slope-line

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search algorithm. Image classification method can be used to determine ice thickness. In literature, determination of ice load was made using image classification methods. Support Vector Machine (SVM) and Artificial Neural Network (ANN) methods were used as classifier. When the result of SVM was compared with the result of ANN, the result of SVM was better than the result of ANN [7]. But ice thicknesses of these methods were not indicated.

In this study, iced conductor thickness which belongs to ETL will be determined by multilevel thresholding. Otsu method will be used as multilevel threshold method. Since computational time of traditional Otsu method is long, this method will be accelerated with differential evolution algorithm (DE). So, optimum threshold level can be determined by DE. Maximum threshold levels are defined as 5 levels in literature, but these levels are not enough to determine iced conductor thickness. Thus maximum threshold levels have been determined as 8 levels in this study.

2Problem 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 andw_1, and distribution of gray level probability of classes as follows [8];

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

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

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;

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

$$\sigma_0 = w_0.(\mu_0 - \mu_T)^2 \text{ and } \sigma_1 = w_1.(\mu_1 - \mu_T)^2 \quad (6)$$

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

$$t = \arg\max\{f(t)\} \quad (7)$$

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

$$f(t) = \sum_{i=0}^{m} \sigma_i \quad (8)$$

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

$$\text{Where } f(t) = \sigma_0 + \sigma_1 + \sigma_2 + \ldots.. + \sigma_m \quad (9)$$

$$
\begin{aligned}
\sigma_0 &= w_0 . (\mu_0 - \mu_T)^2 \\
\sigma_1 &= w_1 . (\mu_1 - \mu_T)^2 \\
\sigma_2 &= w_2 . (\mu_2 - \mu_T)^2 ... \\
\sigma_m &= w_m . (\mu_m - \mu_T)^2
\end{aligned} \quad (10)
$$

The optimum threshold levels ($t_0,t_1,t_2,....,t_3$) are determined as follows [8];

$$(t_0, t_1, t_2, ..., t_m) = \arg\max \{f(t)\} \quad (11)$$

3 Definition of Proposed Method

In Figure 1, iced conductor of ETL has been shown. This ETL is damaged by extreme ice load. In this study, iced conductor image which is shown Figure 1 will be used for ice thickness determination. Determination of ice thickness of iced conductor will be made image segmentation method. Thus threshold level must be determined properly. Multilevel threshold method will be used to determine optimum threshold level but primarily gray level histogram of this image must be obtained. After this image was converted to gray level, average filter will be used to eliminate unnecessary object images on image of iced conductor. After average filter will be implemented to the gray level image, its histogram will be obtained. Optimal threshold points can be determined by using the obtained data from histogram.

Figure 1. Iced Conductor

Multilevel threshold will be made Otsu method. But detecting of optimum threshold values is difficult. Thus DE algorithm will be used to detect optimum threshold values for image segmentation. DE objective function is Equation (11). So $t_0,t_1,t_2,\ldots t_m$ values which are on gray value histogram can be determined easily by using DE-Otsu Method. $t_0,t_1,t_2,\ldots t_m$ values are shown Figure 2.

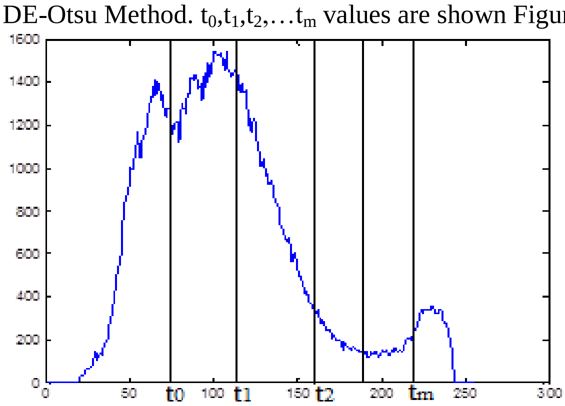

Figure 2. Histogram of Gray Level Image

After threshold level and threshold values are determined, edge detection can be made. There are many 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 will be used for edge detection in this study. Marr–Hildreth algorithm is based on the zero-crossings of the Laplacian of the Gaussian operator [9].

4 Differential Evolution Algorithm (DE)

DE algorithm is one of the important o[illegible] algorithms. Its working principle is similar to working principle of Genetic Algorithm. Crossover, mutation and selection operators which are used in Genetic Algorithm are used in DE. DE algorithm will be used with Otsu method to find optimal threshold level in this study. After histogram of image is obtained, DE-Otsu Method will be applied for multilevel threshold. DE algorithm steps are defined as follows [10];

Step 1: Initial population is occurred. Chromosome number of initial population must be at least 4. In this study, population number is 256.

Step 2: Target vector and base vector are selected, and different two vector which are different target vector and base vector. Namely different four vectors are selected in population.

Step 3: Weighted difference vector is calculated with difference two vectors.

Step 4: Addition of weighted difference vector with base vector is made to occur mutant vector. F value is between 0 and 2. After mutation operation is applied to each vector, mutant population is occurred.

$$\forall j \leq D : n_{i,j,G+1} = x_{j,r_3,G} + F.\,(x_{j,r_1,G} - x_{j,r_2,G}) \tag{12}$$

Step 5: Crossover operator is applied between initial population and mutant population. Crossover is made according to crossover rate (RC). RC value is determined randomly between 0 and 1, and the number is produced random between 0 and 1 for each gene of chromosome. If the number is small than RC, gene is taken from mutant population chromosome. Otherwise, gene is taken from initial population chromosome. But at least one gene must be taken from mutant population. So, new trial vector is occurred.

$$If\ rand\,[0,1] \vee j = j_{rand}$$

$$\forall j \leq D : x_{j,u,G+1} = \begin{cases} x_{j,n,G+1} & \\ x_{j,i,G} & Otherwise \end{cases} \tag{13}$$

Step 6: Objective function value of target vector and objective function value of new trial vector are compared to select the best vector for new population.

$$\forall i \leq NP : x_{i,G+1} = \begin{cases} x_{u,G+1} & \\ x_{i,G} & Otherwise \end{cases} \tag{14}$$

$$If\ f(x_{u,G+1}) \leq f(x_{i,G})$$

These processes which are between Step 2 and Step 6 are applied each chromosome. Namely primarily after1th chromosome is selected as target vector, these processes which are between Step 2 and Step 6 are applied. Subsequently, 2th chromosome is selected as target vector and these processes are applied. Thus, a new solution is produced for each chromosome. So, new population is occurred. This loop continues until the best solution is found or when iteration number is reached. In this study, iteration number is 100.

4 EXPERIMENTAL RESULTS

DE-Otsu method was used to determine iced conductor thickness which is shown in Figure 1. DE-Otsu method is faster than traditional Otsu method. In literature maximum threshold levels are determined as 5 levels, but these levels are not enough to determine iced conductor thickness which is shown in Figure 1. Thus in this study, maximum threshold levels were determined as 8 levels, and minimum threshold levels were determined as 3 levels. The iced conductor thickness was determined according to pixel number of image. The result of DE-Otsu Method is shown in Figure 3 and Table 1. Figure 3 belongs to 7 levels threshold.

Table 1. The result of DE-Otsu Method

Threshold Levels	The Number of Pixel	Threshold Values	The Fitness Value of DE
3	52	82 121 177	1943
4	50	73 104 135 183	2002
5	48	63 89 113 142 190	2034
6	47	57 83 110 139 164 192	2048
7	44	58 84 105 136 158 175 203	2058
8	38	57 79 95 124 133 163 188 218	2067

Figure 3. The Result of DE-Otsu Method

5 Conclusion

Ice load faults are important issue for power quality studies. Primarily iced conductor thickness must be determined to prevent ice load effect. In this study, DE-Otsu Method was used to iced conductor thickness. The results of DE-Otsu Method are shown in Figure 4 and Table 1. In literature, maximum 5 levels were made but 5 levels are not enough to determine ice thickness. The result of 7 levels thresholding is closest to the real image size. It was shown in Figure 3. This result is enough to determine ice load on conductor. Thus DE-Otsu Method can be used with 7 levels thresholding in application of ice thickness determination.

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