Multilevel Threshold and PSO for Ice Load Detection on Aerial Lines

Bahadır Akbal, Musa Aydın

Department of Electrical and Electronics Engineering, Selçuk UniversityKonya, TURKEY

ABSTRACT

If amount of ice load extremely increases on conductor, electric tower bending or conductor breakage can be seen. So, ice load must be eliminated urgently to prevent faults of Aerial Lines. But primarily ice thickness of ice load must be determined. Image processing is proposed because image processing is one of the best methods for image recognition. In literature, Bi-level Thresholding (BLT) and Multilevel Thresholding (MLT) have been used for image recognition studies. The result of MLT is better than the result of BLT. So, MLT was used in this study. Otsu method was used as MLT. But determination of optimum threshold levels with traditional Otsu Method is difficult. PSO was used to determine optimum threshold levels. In literature, maximum threshold levels are 5 levels, but these levels aren't enough for this study. So, maximum threshold levels were determined as 8 levels threshold to obtain the most accurate results.

KEYWORDS: Ice load, image processing, multilevel thresholding, Otsu method, PSO.

1 INTRODUCTION

Ice load damages to conductor and pole or tower of aerial lines. The reasons which cause increase of ice load are humidity, radius of conductor and air temperature. Ice load occurs generally at between 2˚C and-8˚C temperature and at least 95% humidity. If diameter of conductor increases, ice load increases. Thuselectric transmission lines (ETL) are effected by ice load because diameter of ETL conductor is bigger than electric distribution lines. If amount of ice load increases excessively, transmission line tower may be bending or conductor may be breakage. Especially in winter, this case is not desired by customers. Turkey, Canada, China were adversely affected by ice load, and power cut have been seen for days in some regions which belong to these place. For example, in Adıyaman which belongs to Turkey, 122 pieces electric pole were collapsed by ice load. Therefore power cut was seen for days in winter. Thus ice load must be eliminated urgently, but primarily iced conductor thickness which belongs to ETL must be determined. One of the ways of ice thickness determination is ice monitoring. Ice monitoring can be image processing, meteorological sensor or different method, but image processing has more accurate results. Image segmentation can be used as ice monitoring method. There are different applications of image segmentation in literature. These applications are generally related to image recognition. Thus bi-level and multilevel threshold methods were developed to make good image recognition. It was defined in literature that multilevel threshold method is better than bi-level threshold method. 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 levels are 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

***Corresponding Author:** Musa Aydın, Department of Electrical and Electronics Engineering, Selçuk University Konya, TURKEY. aydin@selcuk.edu.tr,

image are important problem. When 2DOtsu 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, noises of image were eliminated [5]. But in [5], the best threshold levels are not indicated. Slope-line search algorithm is another method to determine iced conductor thickness. 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 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. It was seen that 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 thickness was not indicated.

Determination of ice thickness is first step to prevent ice load effect on ETL. If ice thickness is determined properly, elimination of ice load will be easy. In this study, multilevel threshold method and Particle Swarm Optimization will be used to determine ice thickness. Otsu method will be used as multilevel threshold method, but determination of optimum threshold level with traditional Otsu method is difficult. Thus PSO-Otsu method will be used. PSO-Otsu method was used in literature but maximum threshold levels are 5 levels. It was seen in made studies that this levels are not enough to determine ice thickness. Ice detection which is closest to real image will be tried raising threshold levels. Thus maximum threshold levels have been selected as 8 levels.

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

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

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

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

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

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

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

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

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

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

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

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

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

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 $f(t) = \sigma_0 + \sigma_1 + \sigma_2 + ... + \sigma_m$ (9)

$$\sigma_0 = w_0 . (\mu_0 - \mu_T)^2$$
$$\sigma_1 = w_1 . (\mu_1 - \mu_T)^2$$
$$\sigma_2 = w_2 . (\mu_2 - \mu_T)^2 ... \qquad (10)$$
$$\sigma_m = w_m . (\mu_m - \mu_T)^2$$

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

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

3 DEFINITION OF PROPOSED METHOD

In this study, iced conductor thickness which belongs to damaged ETL will be determined multilevel threshold method. Histogram of gray levels image must be obtained. So, some image process application must be applied to iced conductor image. Primarily image is converted to gray image, and then average filter is implemented to eliminate unnecessary objects on image. After these processes are implemented to image which is shown in Figure 1, gray levels histogram can 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 PSO will be used to detect optimum threshold values for image segmentation. PSO objective function is Equation (11). So $t_0, t_1, t_2, ... t_m$ values which are on gray value histogram can be determined easily by using PSO-Otsu Method. $t_0, t_1, t_2, ... t_m$ values are shown Figure 2.
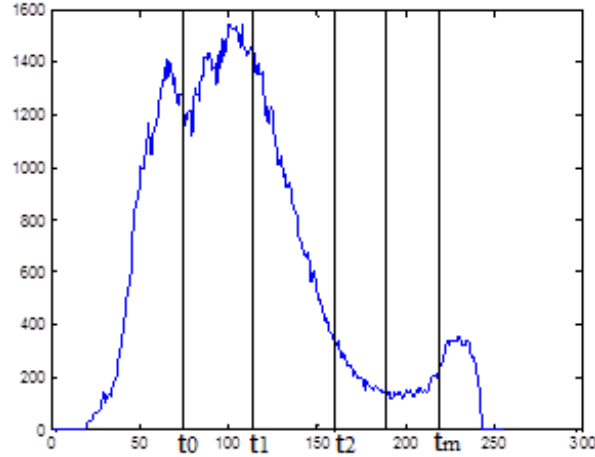
Figure 2. Histogram of Gray Level Image

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. Marr–Hildreth algorithm is based on the zero-crossings of the Laplacian of the Gaussian operator [9].

4. Particle Swarm Optimization

PSO is algorithm based on swarm intelligence. Each individual in PSO is defined a particle. Each particle has a position and a velocity. There are not cloning, crossover and mutation operators in PSO. The swarm moves through search space according to position of particles to find optimum result. If swarm consists of i unit particle in D dimensional space, i-th particle position is $X_i = (x_{i1}, x_{i2}, x_{i3}, ..., x_{iD})$, velocity is $V_i = (v_{i1}, v_{i2}, v_{i3}, ..., v_{iD})$. Each particle has a memory. The best previous position of particle is saved in memory at the end of iteration. Memory is defined as $pbest = (p_{best1}, p_{best2}, p_{best3}, ..., p_{best.i})$. The best position is selected through in the swarm at the end of iteration. This position is defined as $gbest_i = (g_{i1}, g_{i2}, g_{i3}, ..., g_{iD})$. The optimum result is searched according to g_{best} and p_{best}. Velocity of each particle is updated with equation (12), and also positions of each particle are updated with Equation (13) as follows [10]:

$$v_{id}(t + 1) = v_{id}(t) + c_1.r_1(pbest_{id} - x_{id}) + c_2.r_2(gbest_{id} - x_{id}) \quad (12)$$

$$x_{id}(t + 1) = x_{id}(t) + v_{id}(t + 1) \quad (13)$$

Where r_1 and r_2 are random numbers between 0 and 1, c_1 and c_2 are learning coefficient. Particles are directed with these coefficients towards p_{best} and g_{best}. c_1 and c_2 usually are selected as $c_1+c_2 = 4$.

In this study, algorithm works as following:

1. Position of particles is determined randomly. In first iteration, value of velocity is zero. Each particle occurs from real value codes of $t_0, t_1, t_2, ... t_m$.

2. The fitness value of position of particle is calculated with objective function. Since this problem is a maximization problem, the best position is determined according to particles which have high objective function value. The best position of particle is stored in p_{best}. At each iteration, current fitness value is compared with the best previous fitness value of particle in p_{best}. If current fitness value of particle is better than the best previous fitness value of particle, $p_{best}t(i,d) = x(i,d)$. Otherwise $p_{best} (i,d)$ do not change. Also in 1 thiteration $p_{best}t(i,1) = x(i,1)$.
3. The best particle in p_{best} is called as g_{best}. g_{best} is selected for all particles .
4. If optimum solution is found, program is stopped and gbest is saved. Otherwise new position and new velocity is calculated for each particle according to g_{best}. Namely particles are updated according to gbest. And go to 2-nd step. This process continues until maximum iteration number or optimum value.

4. EXPERIMENTAL RESULTS

PSO-Otsu method can be one of effective method to apply multilevel threshold method. Maximum threshold levels of made studies in literature are 5 levels, but it is seen that high levels thresholding are required to determine iced conductor thickness which is shown Figure 1. So, threshold levels were increased to detect ice thickness which is closest to the real image. Maximum threshold levels were determined 8 levels, and minimum threshold levels were determined 3 levels. Iced conductor thickness was determined according to pixels number of image. The results of PSO-Otsu Method are shown in Figure 3 and Table 1. Figure 3 belongs to 7-level thresholding.

Table 1. The results of PSO-Otsu Method

Threshold Level	The Number of Pixels	Threshold Values	The Fitness Value of PSO
3	56	81 116 1174	1731
4	50	74 102 133 183	1784
5	47	70 96 115 148 188	1813
6	45	66 89 111 128 156 193	1832
7	40	62 80 101 123 142 164 202	1844
8	38	41 65 83 98 117 1139 170 207	1850

Figure 3. The Result of PSO-Otsu Method

5.CONCLUSION

Ice load causes to long-term power outages. Many methods were developed to eliminate iceload, but primarily ice thickness of ice load must be determined. In this study, PSO-Otsu method was used to detect iced conductor thickness. In literature PSO-Otsu method was used for different applications, and maximum threshold levels were suggested as 5 levels. But it is seen at the end of this study that 5 levels threshold are not enough to detect 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. 7 levels threshold PSO-Otsu method can be used to detect ice thickness.

REFERENCES

1. Zhiwei, Y, Hongwei C and Jinping LZ, "Automatic threshold selection based on Particle Swarm Optimization algorithm", in Proc. International Conference on Intelligent Computation Technology and Automation, 2008.

2. Fengjie S , He W and Jieqing F, "2D Otsu Segmentation Algorithm Based on Simulated Annealing Genetic Algorithm for Iced-cable Images", in Proc. International Forum on Information Technology and Applications, 2009.

3. Hongmei T, Cuixia W, Liying H and Xia W, "Image Segmentation Based on Improved PSO", in Proc. International Conference on Computer and Communication Technologies in Agriculture Engineering, 2010.

4. Sun F, Yang Z and Fan J, "Study on the Preprocessing Algorithm of Transmission Lines Video Monitoring Image", in Proc. 2nd International Conference on Information Engineering and Computer Science, 2010.

5. Sun F and Tian Y, "Transmission Line Image Segmentation Based GA and PSO Hybrid Algorithm", in Proc. International Conference on Computational and Information Sciences, 2010.

6. Lu J, Luo J, Zhang H and Li B, "An Image Recognition Algorithm Based on Thickness of Ice Cover of Transmission Line", in Proc. International Conference on Image Analysis and Signal Processing, 2011.

7. Jiao R, Li B and Li Y, "Detection of Cladding Ice on Transmission Line Based on SVM and Mathematical Morphology", in Proc. International Congress on Image and Signal Processing, 2010.

8. Akay B, "A Study on Particle Swarm Optimization and Artificial Bee Colony Algorithms for Multilevel Thresholding". Elsevier Applied Soft Computing 2013; 13(6):3066-3091.

9. Nixon M S andAguado A S, "Feature Extraction and Image Processing", Newnes, India, 2002.

10. Storn, R and Price K, "Differential evolution a simple and efficient heuristic for global optimisation over continuous spaces". Journal of Global Optimization 1997; 11(4):341-359.