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Research Article

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GSA-Kapur Method for the Iced Conductor Thickness Determination Studies

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Abstract In this study, image processing is used to detect the iced conductor thickness. Ice load occurs at night under and heavy fog ambient conditions. If ice load determination studies are made by using image processing, dark and heavy fog conditions should be considered. Multilevel threshold method is used as image processing method to solve these problems in this study, but threshold levels of multilevel threshold method should be increased to exceed these problems, but computational time of multilevel threshold method increases at high level thresholds. Therefore artificial intelligence methods are used to find the optimum threshold levels. In this study, Kapur Method is used as multilevel threshold method, and Gravitational Search Algorithm (GSA) is used as artificial intelligence method. When GSA-Kapur Method is used together, its result is close to the real value.

Keywords GSA-Kapur Method, Iced Conductor Thickness

Introduction

Power cut is important issue for electric plants. Power cut can be seen as conductor breakage, animal contact, electric pole or tower bending and insulator faults. One of the causes of power cut is ice load. Heavy fog and cold air conditions cause formation of ice load on transmission line conductor. If ice load amount increases on transmission line conductors, conductor breakage or tower bending can be seen, so power cut occurs in transmission lines. The iced conductor is shown in Figure 1, and the bended transmission line tower is shown in Figure 2. Therefore ice load must be eliminated before ice load amount extremely increases. Ice load can be melted by using thermal method. In literature, AC and DC current methods are used as thermal methods, but primarily ice load amount thickness should be determined. Ice load generally occurs in night and heavy fog air conditions because air temperature of night is less than daytime temperature. In this study, image processing is used to determine the iced conductor thickness. However detection of the iced conductor diameter is difficult with image processing under heavy ambient conditions. Multilevel threshold method is used to solve these problems.

Figure 1: The iced conductor

Figure 2: The bended transmission line tower

Kapur and Otsu methods are used as multilevel threshold method. Kapur indicated maximum entropy method, and Otsu indicated between-class variance method for image segmentation. If the iced conductor thickness is determined under heavy ambient conditions, threshold levels of multilevel threshold methods should be increased. When threshold levels are increased, computational time of multilevel threshold methods increases. Therefore artificial intelligence methods are used to find the optimum threshold levels and to reduce computational time. Particle swarm optimization (PSO) is one of the powerful optimization methods. Otsu method was used with PSO to obtain fast results [1]. Maximum threshold levels are 5. 5-level thresholding cannot be enough for ice load detection studies. Therefore performance of the suggested method should be testes at high level thresholds. When Kapur Method was used with PSO, the local optimum problem occurred. Modified PSO (MPSO) was used to solve this problem [2]. Different methods are used to improve convergence of artificial intelligence methods. One of the methods is Developed PSO (DPSO). PSO was improved to use multilevel image segmentation methods [3]. Threshold level of the suggested method is 5. This level cannot be enough for ice load determination studies. Also the best level for segmentation was not defined. If image clarity is improved, image segmentation quality increases. So, hybrid PSO-GA algorithm was used with Otsu method to solve this problem [4]. In [4], causes of noise were not defined. Two-dimensional Otsu method was used to solve low-contrast iced image [5]. This method algorithm speed is low. If the proposed method is used with an artificial intelligence method, its speed can increase. Ice load monitoring was made with video processing in some studies. Two-dimensional Otsu method can be used in video processing studies for ice load monitoring [6].The best simulated annealing PSO (SA-PSO) method was used in [6] to find optimum threshold level. One of the different methods for ice thickness determination studies is slope line search algorithm [7]. Support Vector Machine (SVM) and Artificial Neural Network (ANN) are powerful classification algorithms. These algorithms were used for image segmentation of iced conductor, and the obtain results were compared. It is seen that the results of SVM is better than the results of ANN [8]. Multilevel thresholding and artificial intelligence methods were used together in different studies, but heavy air conditions were ignored [9,10,11]. In the studies which are made in literature, night and heavy fog conditions were not considered. In this study, these conditions were considered, so the climate cabinet was used to create ice load. Iced conductors in climate cabinet are shown in Fig. 3.

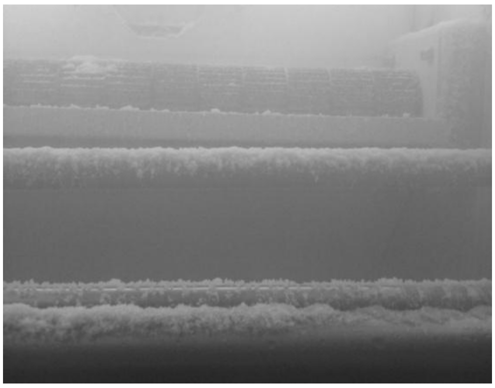

Figure 3: The iced conductors in climate cabinet

The iced conductor image was taken by using outdoor camera in the climate cabinet under heavy fog and dark ambient conditions, and it is shown in Fig.4. Kapur method is used to determine the iced conductor thickness. When threshold level were increased, computational time of Kapur Method increased. Thus Gravitational Search Algorithm (GSA) was used with Kapur Method to detect the optimum threshold level and decrease computational time. Namely, the suggested method is GSA-Kapur Method.

Figure 4: The iced conductor in the climate cabinet in dark and heavy fog conditions

After gray level histogram of image is obtained, multilevel threshold method can be implemented. Gray level histogram of the iced conductor thickness which is shown in Fig. 3 is shown in Fig. 5. If threshold level is m, $(t_0, t_1, t_2, \ldots t_m)$ are values of thresholding levels.

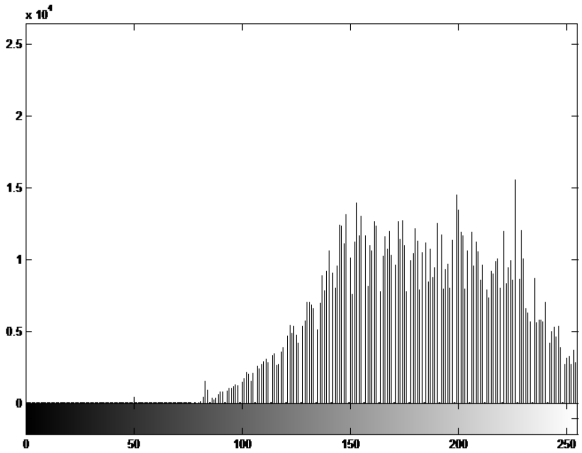

Figure 5: The gray level histogram of the iced conductor

Kapur Method

Kapur's method which is based on maximum entropy is proposed to make formulation of optimal thresholding problem. Kapur indicated maximum entropy method for image segmentation. After gray level histogram of image is obtained, the optimal threshold value can be obtained. Image is indicated with L gray levels (0, 1,...,L-1). i^{th} probability is defined p(i) as follows [12];

$$p(i) = \frac{h(i)}{\sum_{i=0}^{L-1} h(i)} \tag{1}$$

h(i) is called the number of pixels of gray-level i. Kapur's entropy can be described for bi-level threshold as follows:

$$H(0) = -\sum_{i=0}^{t-1} \frac{p(i)}{\omega_0} \ln \frac{p(i)}{\omega_0}, \quad \omega_0 = \sum_{i=0}^{t-1} p(i) \tag{2}$$

$$H(1) = -\sum_{i=0}^{t-1} \frac{p(i)}{\omega_1} \ln \frac{p(i)}{\omega_1}, \quad \omega_1 = \sum_{i=t}^{L-1} p(i) \tag{3}$$

If the sum of the class entropies is maximum value, the threshold level is optimum. This case is shown in Eq.(4) [9]:

$$t = \arg\max(H + H) \tag{4}$$

Multilevel threshold can be made with Kapur entropy when Eq. (5) is used [13].

$$\begin{aligned}
H(0) &= -\sum_{i=0}^{t_1-1} \frac{p(i)}{\omega_0} \ln \frac{p(i)}{\omega_0}, \omega_0 = \sum_{i=0}^{t_1-1} p(i) \\
H(1) &= -\sum_{i=t_1}^{t_2-1} \frac{p(i)}{\omega_1} \ln \frac{p(i)}{\omega_1}, \omega_1 = \sum_{i=t_1}^{t_2-1} p(i) \\
H(2) &= -\sum_{i=t_2}^{t_3-1} \frac{p(i)}{\omega_2} \ln \frac{p(i)}{\omega_2}, \omega_2 = \sum_{i=t_2}^{t_3-1} p(i) \\
H(j) &= -\sum_{i=t_j}^{t_j+1} \frac{p(i)}{\omega_j} \ln \frac{p(i)}{\omega_j}, \omega_j = \sum_{i=tj}^{t_j+1} p(i) \\
H(m) &= -\sum_{i=t_m}^{L-1} \frac{p(i)}{\omega_m} \ln \frac{p(i)}{\omega_m}, \omega_m = \sum_{i=t_m}^{L-1} p(i)
\end{aligned} \tag{5}$$

Sum of entropies must be made maximum to obtain the optimal threshold levels values. This is shown with Eq. (6):

$$(t_0, t_1, t_2, ..., t_m) = \arg\max(\sum H(i)) \tag{6}$$

In this study Gravitational Search Algorithm (GSA) is used as artificial intelligence method to find the optimum threshold levels. Namely objective function of GSA is Kapur method. Also, GSA is new algorithms in this area.

3. Gravitational Search Algorithm

Gravitational search algorithm is used to solve maximization or minimization problems. Find of optimum threshold level in Kapur Method is a maximization problem, and objective function of GSA-Kapur is Equation (6).

GSA is based on Gravitational law which was found by Newton. Each particle is defined as agent in GSA. According to gravitational law, the other particles are attracted by gravitational force of each particle. Gravitational force is affected by particles masses. The particle which has heavier mass attracts the other particles, and the other particles move towards the particle. In this study, if agent has heavier mass, fitness value of agent is higher value because Kapur Method is a maximization problem, and it is near to optimum solution. Each agent has four features. These feature are position (X_{ii}), inertial mass (M_{ii}), active gravitational mass (M_{ai}) and passive gravitational mass (M_{pi}). $M_{ai} = M_{pi} = M_{ii}$ is calculated with Eq. (7) [14].

$$m_i(t) = \frac{fit(t) - worst(t)}{best(t) - worst(t)} \tag{7}$$

$$M_i(t) = \frac{m_i(t)}{\sum_{j=1}^{N} m_j(t)} \qquad i = 1, 2, ...N \tag{8}$$

If agent number is N in search space, each agent position can be defined by Eq. (9).

$$X_i = (x_i^1 ... x_i^d ... x_i^n) \qquad i = 1, 2, ...N \tag{9}$$

n is agent dimension, and agents occur x_i^d particles. Namely, x_i^d is defined as variable of agent. F is gravitational force between i[th] agent and j[th] agent at the t time. Gravitational force is shown in Eq. (10).

$$x_i^d(t+1) = x_i^d(t) + v_i^d(t+1) \quad (10)$$

M_i is mass of i[th] agent, M_j is mass of j[th] agent, $R^{ij}(t)$ is the Euclidian distance between i[th] agent and j[th] agent, and it is defined Eq. (11). G(t) is gravitational constant and is defined Eq. (12).

$$R_{ij}(t) = \left\| X_i(t), X_j(t) \right\|^2 \quad (11)$$

$$G(t) = G_0 . e^{-\beta(t/t_{\max})} \quad (12)$$

G_0 is an initial value, β is constant value, t is the current iteration number, t_{max} is maximum iteration number, and total force on i[th] agent is defined with Eq. (13) at t time.

$$F_i^d(t) = \sum_{j \in K_{best}, j \neq i}^{N} rand_j . F_{ij}^d(t) \quad (13)$$

r and $_j$ is random number between 0 and 1, K_{best} is the first agents which have the best fitness value. Acceleration of agent is calculated with Eq. (14). Velocity and position are updated with Eq. (15) and Eq. (16) according to acceleration of agent at the t time.

$$a_i^d(t) = \frac{F_i^d(t)}{M_{ii}(t)} \quad (14)$$

$$v_i^d(t+1) = rand_i . v_i^d(t) + a_i^d(t) \quad (15)$$

$$x_i^d(t+1) = x_i^d(t) + v_i^d(t+1) \quad (16)$$

$x_i^d(t)$ is position of ith agent, $v_i^d(t)$ is velocity of agent, and $rand_j$ is random number between 0 and 1 at the t time. Working principle of GSA as follows [14]:

1- Initial population is occurred, and positions of agents are determined as randomly.
2- Fitness values of agents are calculated.
3- Best and worst agents are selected in population, and G is updated.
4- M and a of agents are calculated, and velocity and position of agents are updated.

After these steps are implemented, fitness values of the updated agents are calculated. If optimum value is found, or the maximum iteration number is reached, program is stopped. Otherwise, the steps which are between 2 and 4 are continuously implemented.

4. Experimental Results

Detection of the iced conductor diameter is difficult process under the heavy ambient conditions. Hence GSA-Kapur method was used in this study. Different threshold levels were tried to determine the iced conductor thickness. These threshold levels and their results are shown in Table 1. It is seen in Table 1 that threshold levels of GSA-Kapur Method should be increased to obtain sensitive results. If Table 1 is examined, the most sensitive result is obtained by 20 threshold levels, and its result is shown in Fig. 6. The detection ice load thickness on original image is shown in Fig. 7.

Table 1: The Results Of GSA-Kapur Method

Threshold Level	**Iced Conductor Thickness (pixels)**	**Threshold Values**
5	510	126 141 176 197 218
10	411	37 75 111 125 160 182 197 204 219 224
15	310	27 56 60 94 96 108 108 120 145 172 184 209 221 229 250
20	260	8 13 93 102 135 146 155 166 172 176 182 194 199 203 215 219 227 227 245 252

Dark and heavy fog ambient conditions are an important problem for image processing because dark and heavy fog air conditions reduce image contrast. This case can be seen in Fig.4. These problems were solved by using GSA-Kapur method in this study, and its threshold levels should be increased to obtain the most accurate result which is the closest to the real iced conductor thickness measure. The most accurate result was obtained at 20 levels thresholding, and its error is only 1 pixel. If threshold levels are more than 20 levels, the local optimum falling occurs. Therefore ice load detection program is interrupted by the local optimum falling. Also increasing of threshold levels is unnecessary because the error is only 1 pixel.

Figure 6: The result of 20-level GSA-Kapur Method

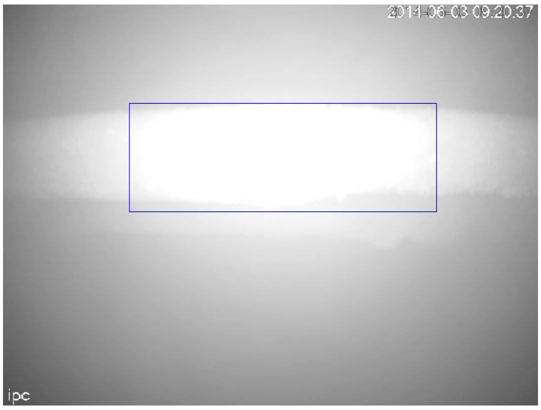

Figure 7: The detection ice load thickness on original image

Conclusions

In literature, AC and DC currents are generally used for ice load elimination studies. If ice load amount is not accurately determined, ice load melting current is not accurately determined. Therefore ice load determination studies is very important study for the ice load elimination. Image processing is useful method for ice load determination study, but ice load occurring conditions which are dark and heavy ambient conditions is important problem for image processing. Usage of multilevel threshold and artificial intelligence method is suggested in this study. GSA is used as artificial intelligence method, and Kapur method is used as multilevel threshold method. GSA and Kapur methods were used together to detect the iced conductor thickness which is shown in Fig. 4. Also, the iced conductor is obtained under real icing conditions in the climate cabined. When GSA-Kapur Method whose threshold levels are 20 is used to detect the iced conductor thickness, the very good result is obtained, and its error is only 1 pixel. Therefore GSA-Kapur Method is suggested for the ice load thickness determination studies.

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