Determining of Iced Conductor Thickness Using CSA-Kapur and GA- Kapur Methods

Bahadır AKBAL, and Musa AYDIN

Abstract**—**The occurred ice on conductor is called ice load. Ice load causes additional loads on aerial lines. So, aerial line pole bending or conductor breakage has been seen. There are many methods in literature to eliminate ice load, but primarily ice load amount must be determined. One of the effective methods is ice monitoring method for ice load determination studies. In this study, the iced conductor thickness was determined with image monitoring method, and ice monitoring was made multilevel thresholding method due to high humidity. Kapur Method was used as multilevel thresholding method and was used with GA and CSA because determination of the optimum threshold level with traditional Kapur is difficult. The iced conductor thickness was determined with CSA-Kapur and GA-Kapur methods according to different thresholding levels. The best result of CSA-Kapur method and the best of GA-Kapur method were compared at the end of this study.

Keywords**—** CSA, GA, image segmentation, ice load, Kapur Method, multilevel thresholding.

I. Introduction

Transmission and distribution of electrical energy are generally made with aerial lines, and they are called Electric Transmission Line (ETL) and Electric Distribution Line (EDL). So, faults of aerial lines must be taken into account to provide energy stability. Environmental factors are important fault causes of aerial lines. These factors can be sorted as ice load, wind load, wild animals and lighting. When aerial lines are designed, wind load and ice load are taken into account. There are certain ice and wind loads of each region in world. In recent years, ice load caused important aerial line faults because aerial lines are designed according to its region conditions. If ice load on conductors of aerial line exceed to ice load of its region which is used at aerial line design, additional ice load on conductor increases, and aerial line pole bending or conductor breakage is seen. Cause of this case can be climate change. Important ice load faults were seen in Turkey, China and Canada. Ice load which occurred on electric transmission line conductor is shown in Fig. 1. ETL pole which is damaged by ice load is shown Fig. 2. So, additional ice load must be eliminated. In literature, Joule effect method has been proposed to eliminate ice load, but ice load amount must be known to use this method. Because in Joule effect method, current have been used to melt ice load. If ice load amount is not known as correctly, ice melting current is not determined exactly. Ice load monitoring method has been used to determine ice load amount. Ice thickness of iced conductor can be used as ice load monitoring method. Image segmentation method is one of the most effective ice thickness determination methods. Because ice load occurs at high humidity and low temperature, high humidity causes decrease of clarity of iced conductor image, and traditional image segmentation method cannot enough to solve this problem.

Fig. 1 Ice load on ETL conductor

Multilevel threshold method can be used to solve this problem, but optimum threshold levels determination with traditional multilevel threshold methods is difficult. So, artificial intelligence method can be used to determine optimum threshold levels.

Fig. 2 The damaged ETL pole

Otsu and Kapur Methods have been used as multilevel thresholding method. Otsu indicated between-class variance method for image segmentation. In this method, variance of different classes is maximum value. Kapur indicated maximum entropy method for image segmentation. Particle swarm optimization (PSO) is one of the powerful optimization methods. Otsu method was used with PSO to obtain fast result [1]. Maximum threshold levels are 5. 5-level thresholding cannot be enough for some image segmentation studies. When Kapur Method was used with PSO, the local

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optimum problem occurred. Modified PSO (MPSO) was developed to solve this problem [2]. Different methods were used to improve convergence of artificial intelligence methods. One of the methods is Developed PSO (DPSO). PSO is improved to use multilevel image segmentation methods [3]. 5-level thresholding with DPSO was made but high level thresholding was not made. 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 are 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 has been 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 was seen that the results of SVM is better than the results of ANN [8].

High humidity and low temperature are causes of occurring of ice load, and high humidity is important problem for image segmentation. High humidity was ignored in most studies which were made to detect ice load. In this study, the climate cabinet was developed, and ice load image was taken with 3 megapixel night vision outdoor camera during high humidity to detect the iced conductor thickness. Multilevel thresholding method will be used to solve high humidity problem. Kapur method was selected as multilevel thresholding method. Genetic Algorithm and (GA) and Clonal Selection Algorithm (CSA) were selected to determine optimum threshold level, and the results of these algorithms will be compared.

II. PROBLEM FORMULATION

Multilevel thresholding can be made 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;

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

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

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

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

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

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

Multilevel threshold can be made with Kapur entropy when (5) is used [9].

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

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

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

III. THE PROPOSED ARTIFICIAL INTELLIGENCE METHODS

GA and CSA have been used to solve optimization problems. These algorithms are powerful algorithm. So, in this study, GA and CSA were proposed to determine optimum threshold levels for multilevel thresholding method.

A. Clonal Selection Algorithm

One of the effective artificial intelligence methods to solve optimization problems is Clonal Selection Algorithm (CSA). When clonal selection algorithm (CSA) was used to solve electrical engineering optimization problems, the good results were obtained. So, CSA will be used to detect the most appropriate threshold level and optimum threshold values. Antigens and antibodies are the basic elements of the CSA. Antigens are defined by optimum value of function. Antibodies are used to find optimum value of the function. To find the best antibody should be used operators of clonal selection algorithm.

Clonal selection algorithm operators occur from cloning and mutation. In cloning operation, antibodies are cloned by multiplying coefficient which is calculated according to affinity of antibodies. So, population of cloned antibodies is occurred (C). Then according to mutation rate, mutation process is applied to population of cloned antibodies.

Mutation rate is inversely proportional to affinity. Namely antibody having high affinity is mutated less according to antibody having low affinity. In Fig. 3 is shown the block diagram of CSA optimization algorithm [10]-[11]-[12].

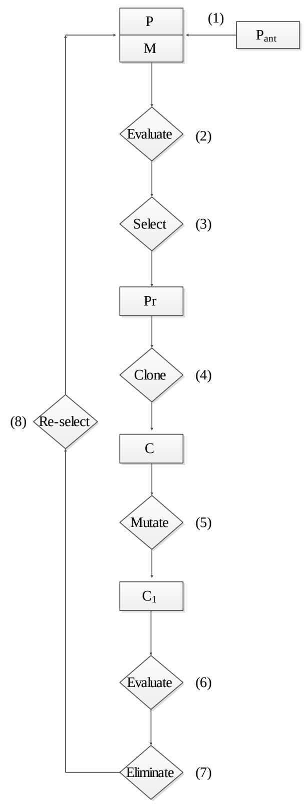

Fig. 3 Flow chart of CAS

1. Antibody population is occurred as random.
2. The fitness values of all the individuals are calculated in Population P. Affinity is determined according to the fitness value. Equation (6) is used as objective function of CSA.
3. According to affinity value, the best antibodies are selected and P_n population is occurred.
4. These antibodies are cloned and C population is occurred.
5. Mutation process is applied to C population which occurs from cloned antibodies. Generate a mutated antibody pool (C_1). The mutation rate of each individual is inversely proportional to its fitness.
6. The fitness values of all the individuals are calculated in Population C_1.
7. Similar antibodies in C are eliminated and C_1 is updated.
8. To select advanced antibodies, reselect process is applied to C_1.

New generated individuals are combined with random generated individuals. Thus new antibody population is occurred. This process prevent local minimum fitting event. Thus various results may be found in this algorithm.

B. Genetic Algorithm

GA is based on natural selection process, and the important operators of GA are crossover and mutation. So, GA has been used to solve complex optimization problems. The flow chart of GA is shown in Fig. 4 [11].

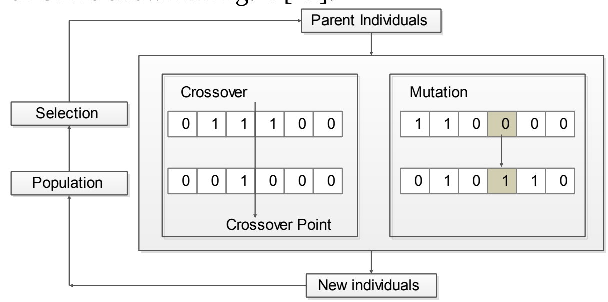

Fig. 4 Flow chart of GA

Working principle of genetic algorithm as follows [13]:

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 (6). Chromosome selection process for crossover operation is made according to fitness 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 (P_c). 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 P_c, 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 (7) and (8) for each gene.

$$\mathrm{Cn(i)} = \beta.C(i) + (1-\beta).K(i) \quad (7)$$

$$\mathrm{Kn(i)} = \beta.\mathrm{K}(i) + (1-\beta).\mathrm{C}(i) \quad (8)$$

So new chromosomes are produced as C_n and K_n. 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.

IV. Material and Method

Ice load amount must be known to eliminate it. For example, if joule effect method is used to eliminate ice load, ice load amount must be known to determine ice load melting current. In this study, ice load will be determined with the iced conductor thickness, and it will be made image segmentation method. Multilevel thresholding method will be used because high humidity is major problem for image segmentation studies, and optimum threshold levels will be determined by CSA and GA. The climate cabinet was designed to provide the real ice load conditions. Also an outdoor camera has been used to take photograph of iced conductor in humid weather. The obtained image is shown in Fig. 5.

Fig. 5 The iced conductor

The obtained iced conductor image must be converted gray level, and gray level histogram must be obtained to use multilevel threshold method. The gray level histogram is shown Figure 6. If threshold level is m, $t_0,t_1,t_2,\ldots t_m$ are values of thresholding levels. After threshold levels are selected, the optimum values of threshold levels $(t_0,t_1,t_2,\ldots t_m)$ are determined with CSA and GA separately. After these operations is applied the obtained iced conductor, edge detection is made, and ice thickness of iced conductor is determined.

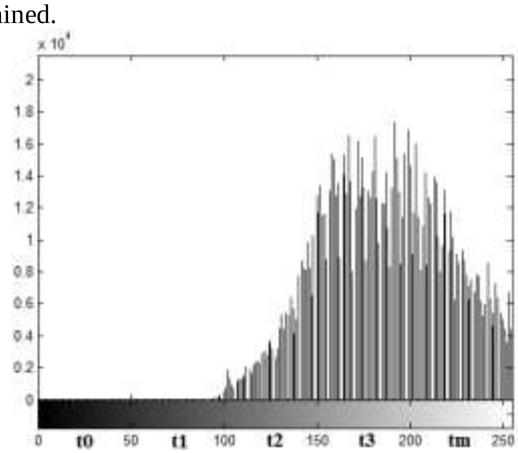

Fig. 6 The gray level histogram of the iced conductor

V. Experimental Results

Ice thickness of iced conductor which is shown in Figure 5 was determined by CSA-Kapur and GA-Kapur method. Minimum threshold levels are determined 3, and maximum threshold levels are determined as 10. When CSA-Kapur method was used, Table I and Fig. 7 were obtained. Threshold level and the determined iced conductor thickness which are obtained threshold levels are shown in Table I. Boundaries of the detected iced conductor thickness according to the most appropriate threshold levels are shown in Fig. 7.

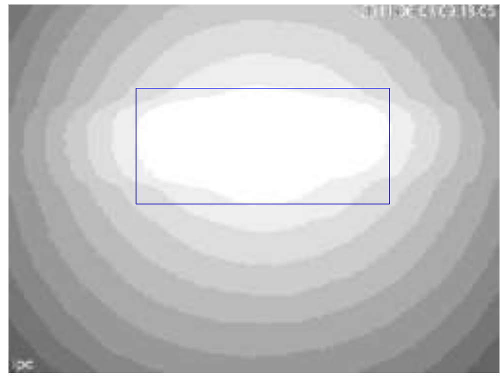

Fig. 7 The better result of CSA-Kapur Method

TABLE I
The Results of CSA-KApur Method

Threshold Level	Iced Conductor Thickness (cm)	Threshold Values
3	12.6	130 168 207
4	10.4	124 149 181 215
5	9.5	119 144 174 198 220
6	8.7	117 140 161 182 203 224
7	7.1	121 140 157 178 197 217 232
8	6.8	112 130 148 166 183 201 216 233
9	6.5	110 124 140 158 173 188 204 220 236
10	5.64	101 112 127 142 154 165 181 204 228 241

When GA-Kapur method was used, Table II and Fig. 8 were obtained. Threshold level and the determined iced conductor thickness which are obtained threshold levels are shown in Table II. Boundaries of the detected iced conductor thickness according to the most appropriate threshold levels are shown in Fig. 8.

TABLE II
The Results of GA-KApur Method

Threshold Level	Iced Conductor Thickness (cm)	Threshold Values
3	12.2	130 167 207
4	11.3	120 148 180 212
5	9.35	118 142 168 194 221
6	8.5	116 136 158 180 202 225
7	6.5	116 136 157 178 200 217 236
8	6.3	112 130 149 169 189 205 222 237
9	5.9	112 130 150 167 182 196 211 224 239
10	4.9	112 130 148 164 180 192 204 216 230 245

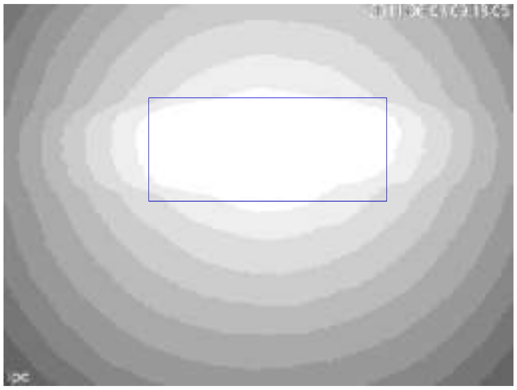

Fig. 8 The better result of GA-Kapur Method

VI. CONCLUSION

There are many ice load elimination methods in literature, but primarily, ice load amount must be determined to eliminate ice load. In this study, ice load amount was determined with iced conductor thickness. Multilevel image segmentation method was used to determine iced conductor thickness which is shown in Figure 5. CSA-Kapur and GA-Kapur methods were used to determine ice thickness. The optimum threshold levels are determined as 10 levels according to the results of these methods. Total iced conductor thickness was determined with CSA-Kapur method as 5.64 cm, and it was determined with GA-Kapur method 4.9 cm. When the results of these methods were compared, it was seen that GA-Kapur method results is more close to the real iced conductor thickness. Iced conductor thickness could not be fully determined but it was approximately detected.

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