IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

Hybrid radial basis function with firefly algorithm and simulated annealing for detection of high cholesterol through iris images

To cite this article: A Anjarsari *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **546** 052008

IOP Conf. Series: Materials Science and Engineering **546** (2019) 052008 doi:10.1088/1757-899X/546/5/052008

Hybrid radial basis function with firefly algorithm and simulated annealing for detection of high cholesterol through iris images

A Anjarsari[1], A Damayanti[1,*], A B Pratiwi[1], E Winarko[1]

[1]Department of Mathematics, Faculty of Science and Technology, Universitas Airlangga, Surabaya, Indonesia

*Corresponding author: aulid@fst.unair.ac.id

Abstract. Cholesterol is a lipid (fat) produced by the liver and is required to build and maintain cell membranes. Cholesterol is also important for the metabolism of fat soluble vitamins. This important lipid is found in human blood. Excess cholesterol (high cholesterol) can cause health problems such as being a factor of coronary heart disease that responsible for the heart attacks, liver or kidney disease. Observation of iris pattern can detect several types of diseases, one of which is high cholesterol. The purpose of this research is to detect whether someone is exposed to high cholesterol or not, through iris images based on firefly algorithm, simulated annealing, and radial basis function. Firefly algorithm and simulated annealing are used in the unsupervised learning process in radial basis function neural networks. The stages of high cholesterol detection process are images processing namely grayscale process, thresholding, histogram equalization, segmentation, and detection process is using radial basis function neural network. The percentage success rate of the recognition pattern of iris images for detecting high cholesterol is 89% .

1. Introduction

Iridology is the science of reading the markings or signs in the iris (the colored part of the eye) to determine the functional state of the various components of the body [1]. This method can give information to doctors or health practitioners based on signs in the lining of the eye, reflex conditions of various organs and anybody systems. These signs give images detail of the body integration, including the strength of its constitution, areas of blockage or accumulation of toxins and the strengths and weaknesses inherent in them [2]. One disease detected through the iris is the state of cholesterol in the human body. Cholesterol is a waxy substance made by the animal liver also available in food through animal products such as meat, poultry, fish, and dairy products. Cholesterol is both good and bad. High Density Lipoprotein (HDL) is a good cholesterol and Low-density lipoprotein (LDL) is bad cholesterol. High cholesterol in serum is a major risk factor for cardiovascular disease in humans such as coronary heart and stroke [3]. In Indonesia, there are about 25 out of 1000 people died because of this health problem. The number of people with cholesterol leading to heart disease or stroke has increased since 2009-2011 [4].

The Artificial Neural Network (ANN) is a learning method used to recognize the characteristics of data. The advantage of the artificial neural network lies in the learning ability. The ability of the artificial neural network to solve complex problems has been demonstrated in various types of research [5]. The artificial neural network has several architectures, one of them is Radial Basis

Function (RBF). The RBF training method almost resembles the Multilayer Perceptron (MLP) method. But RBF uses Gaussian matrix calculation on the radial hidden layer function, while the MLP uses the sigmoid function [6]. This neural network has advantages including a simple RBF network structure and faster learning speed so that iterations run fast. However, RBF still needs to optimize its weight, therefore, RBF training process becomes faster. In the previous studies, several metaheuristic algorithms were conducted as training in the process of classifying diseases with the neural network Radial Basis Function method [7]. In 2015, Alweshah and Abdullah conducted a study to solve classification problems with artificial neural networks in hybrids with Firefly Algorithm (FA) and Simulated Annealing (SA) which is shown better results than using artificial neural networks.

In this study, hybrid RBF neural network with FA and SA is applied to diagnose high cholesterol through iris images and it was hoped that the built system could recognize the pattern of iris images well so that the diagnosis was more accurate.

2. Methodology

The steps taken in this study include preprocessing, image reduction process and detection process based on hybrid RBF neural network with firefly algorithm and simulated annealing.

2.1 *Preprocessing*

Preprocessing is an initial process in the image that aims to improve image quality. In this study, the preprocessing process is grayscale, thresholding, and histogram equalization.

2.1.1. Grayscale

Grayscale is the stage of taking all pixel data in the image in the form of three-color information (red, green, blue) into three different matrices with values represented between 0 and 255. To change the image to be grayscale it will be done by looking for the average value of the three colors that have been taken. The grayscale calculation formula is shown in equation 1 [8].

$$S = \frac{r+g+b}{3} \tag{1}$$

where:
r = value on red layer
g = value on green layer
b = value on blue layer

2.1.2. Thresholding

Thresholding is used to adjust the number of grayscale in the image as desired. For example, if you want to use 16grayscale, then just divide the grayscale by the value 16. Basically, the thresholding process is the process of changing the quantity of the image. The thresholding calculation formula is shown in equation 2 and 3 [9].

$$x = b.int\left(\frac{wk}{b}\right) \tag{2}$$

$$b = int\left(\frac{256}{a}\right) \tag{3}$$

where:
wk = gray degree value before thresholding
x = gray degree value after thresholding
a = threshold value

2.1.3. Histogram Equalization

Histogram equalization is a histogram smoothing process, by reading each pixel of RGB and making it an input on the histogram, then the results are levelled with reference values around it. The formula for calculating histogram equalization is shown in equation 4 [10].

$$w = \frac{c_w th}{n_x n_y} \tag{4}$$

where:
w = gray value results from histogram equalization
c_w = cumulative histogram of w
th = image size
n_x and n_y = size image

2.2 *Image reduction process*

Image reduction process is a process to reduce the pixel size of an image, and segmentation is used in this study. The stages in the segmentation process are, for each segment of an image, the segment average is the number of intensities or grayscale levels of all pixels in a segment divided by the number of pixels of the segment. So that each segment consists of pixels that have the same grayscale level [9].

2.3 *Radial Basis Function*

Radial basis function neural network is a multilayer neural network model that uses the hybrid learning method in its training, namely unsupervised learning from the input layer to the hidden layer and supervised learning from the hidden layer to the output layer.

Each activation function of neurons in the hidden layer will be a Gaussian function which is indicated by the average vector of the centre (ci) and the distribution of parameters (αi) with i = 1, 2, ..., so that the activation function is given as follows [11]:

$$Z_i(x) = (-Z_{in\_i})\ ) \tag{5}$$

with $Z_{in\_i} = \alpha_i . \|x_i - c_i\|^2$ is an input signal from the input layer to the hidden layer. (6)

The output unit values at the Y output layer are as follows:

$$Y = \frac{1}{(1+e^{-Y_{in}})} \tag{7}$$

with $Y_{in} = \sum_{i=1}^{I} w_{i1} Z_i + b$ is an input signal from the hidden layer to the output layer. Where w_{i1} is the weight between hidden layer i-unit with first unit of output layer and b is bias for output layer units. (8)

To calculate the error of the difference in output values and target values, it is necessary to obtain a minimum Mean Square Error (MSE) [7].

$$MSE = \frac{1}{N} \sum_{k=1}^{N} \|t(x_k) - y(x_k)\|^2 \tag{9}$$

with $t(x_i)$ and $y(x_i)$ is the desired output vector and the actual output vector for the training sample xi, while N is the number of training samples.

2.4 *Firefly Algorithm*

Firefly Algorithm is an algorithm inspired by the behavior of fireflies, where each firefly is interested in moving closer to a firefly that emits a brighter light than it. There are important main things in firefly algorithm, namely light intensity, attractiveness, distance, and movement [12].

2.5 *Light Intensity*

The light intensity is obtained from the value of the objective function. The value of the light intensity is obtained from the formula as follows:

$$I(x_i) = \frac{1}{f(x_i)} \tag{10}$$

where :
$f(x_i)$: objective function value
x_i : firefly-i

2.6 *Attractiveness*

Attractiveness is the second most important thing in the Firefly Algorithm. Where the attractiveness value is obtained from a formula as follows:

$$\beta = \beta_0 e^{-\gamma r_{ij}^2} \tag{11}$$

where :
β_0 : initial value of attractiveness
γ : light absorption coefficient at intervals [0, ∞]
r_{ij} : distance between i-firefly and j-firefly

2.7 *Distance*

Distance is the distance between 2, i and j fireflies, at their xi and xj respective positions. Distance can be calculated using the formula:

$$r_{ij} = \| x_i - x_j \| = \sqrt{\sum_{k=1}^{d} (x_i^k - x_j^k)^2} \tag{12}$$

where :
x_i^k : k-element from x_i or firefly i

2.8 *Movement*

Movement is a movement carried out by i firefly because of interest in other j firefly, whose light intensity is brighter. With the movement, the firefly position or solution from firefly will change according to the following formula :

$$x_i^{new} = x_i + \beta_0 e^{-\gamma r_{ij}^2} (x_i - x_j) + \alpha \, (rand - \tfrac{1}{2}) \tag{13}$$

where :
α : random parameter coefficient
rand : random numbers at intervals [0,1]

2.9 *Simulated Annealing*

Simulated annealing is a probabilistic method proposed in Kirkpatrick, Gelett, and Vecchi (1983) and Cerny (1985) for finding the global minimum of a cost function that may possess several local minima. The simulated annealing process is the following:

a. Initialize the initial temperature T.
b. Initial solution x initialization.
c. Calculates the fitness value of the initial solution (x).
d. Modify the initial solution to a new solution x' and recalculate the fitness value from the new solution $f(x')$.
e. If the new solution's fitness value is better than the previous solution's fitness value, then x' will replace x. If not, then r random numbers are generated at intervals [0,1]. Calculate the probability of $P = \exp(-\Delta f / T)$ with $\Delta f = f(x') - f(x)$, where P is the probability that a new, better solution will not be accepted as a temporary solution. If $P > r$ then x' will replace x.
f. Calculate the temperature change $T = \beta T$ with $0 < \beta < 1$. Do it again from step d to the final temperature.

2.10 *Network training uses radial basis function with firefly algorithms and simulated annealing*

In the RBF training process, it used hybrid RBF with firefly algorithm and simulated annealing to obtain optimal weight and bias. The steps of the training are the following:

a. Input the normalized matrix and the parameters used in RBF-FA-SA. There are temperature drop factor (β), $T_{initial}$, T_{final}, population of fireflies, β_0, γ, α, error limit and maximum iteration.

b. Generate initial population in FA randomly at intervals [0,1] and change individual in FA become weight and bias in RBF.
c. Calculate the Mean Square Error (MSE) with the RBF process as the initial determination of FA fitness.
d. Check whether the MSE value obtained is less than the error limit or whether it has reached the maximum iteration limit. If the iteration has reached the maximum iteration or the MSE obtained is less than the error limit, then firefly individuals are considered optimal. If not, the process is continued by calculating the fitness value of each individual firefly and determining the intensity of the Firefly light by maximizing fitness values. The fitnness value for each Firefly is determined by equation (14).

$$f(x) = \frac{1}{1+MSE} \tag{14}$$

e. Comparing the value of the light intensity of each Firefly with other Firefly, the light intensity of firefly which is brighter will be approached by the value of the other firefly intensity. Then calculate the movement value of fireflies in fireflies that have high brightness intensity values.
f. Determines the worst firefly as the initial solution in the simulated annealing process.
g. Modify the worst firefly and calculate the firefly's light intensity.
h. Compare the light intensity of the initial solution and the new solution. If the new solution is better then proceed to step i. But if not, then a real number is generated randomly r at the interval [0,1]. Calculate the probability of acceptance (P). If P ≥ r then the new solution is accepted as a temporary solution.
i. Reducing temperature. If it reaches the maximum iteration, the process stops and continues to step j. If not, then go back to step g.
j. Combine all solutions obtained.
k. Determines the best firefly that is firefly with the highest light intensity.
l. Make the best firefly moves and it will get a new population on Firefly, then do step (c) again.
m. Check whether the MSE value obtained is less than the error limit or the maximum iteration. If it has met the error limit or the maximum iteration, then the weight and bias are optimal. If not, then repeat step (d).

All training process can be seen at flowchart in figure 1.

3. Results and discussions

The data used in this study are 60 iris images of patients taken from Doctor Abdul Hamid Arif Eye Clinic, SpM consisting of 42 iris images of high cholesterol and 18 normal iris images. This image is in the .jpg format and The size is 125 x 125 pixels. In the training process, 42 iris images were used, consisting of 29 iris images of high cholesterol and 13 normal iris images. While the validation test used 18 iris images consisting of 13 iris images of high cholesterol and 5 normal iris images. Examples of iris images used in this study can be seen in Figure 2.

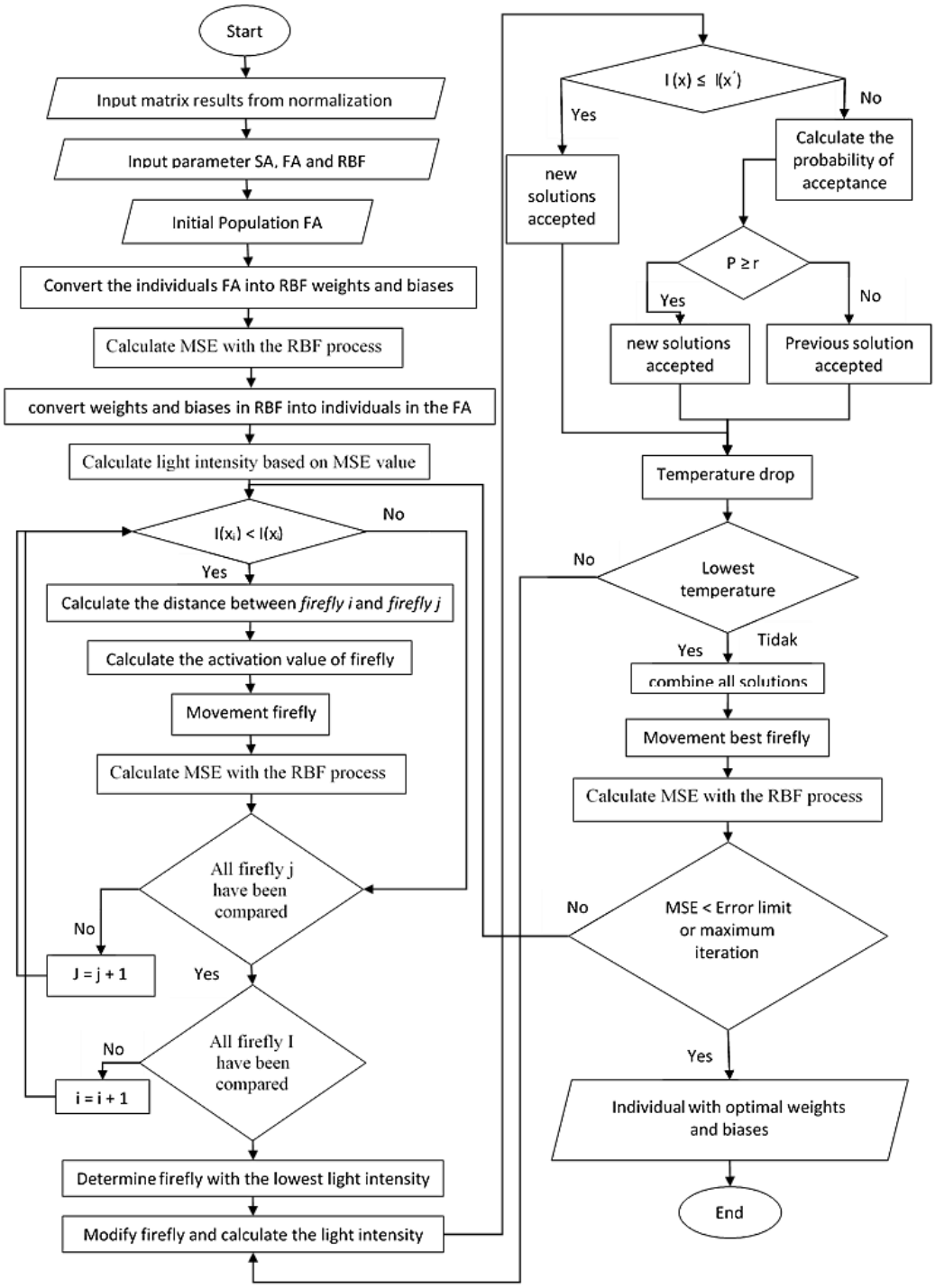

Figure 1. Flowchart of RBF-FA-SA training process.

(a) (b)

Figure 2. The iris images, (a) high cholesterol image, (b) normal image

In this study, there are 3 stages that must be done, namely the pre-processing, the image reduction process and the detection process. In the first stage, namely pre-processing, all the iris images used will go through the grayscale, thresholding, and histogram equalization processes. The second step is the reduction image process, which is to change the image size from 125 x 125 pixels to 25 x 25 pixels. Figure 3 shows the result of the preprocessing and reduction process.

(a) (b) (c) (d) (e)

Figure 3. Image processing result: (a) original image; (b) grayscale image; (c) thresholding image; (d) histogram equalization image; and (e) segmentation image.

The third stage is the process of detecting high cholesterol in the iris image using RBF-FA-SA which consists of the training process and the validation test process. The RBF network architecture used consists of 3 layers, I thought this was supposed to be input layer with 625 neurons, hidden layers with 25 neurons, and output layer with 1 neuron. In the process of training the RBF network, the use of FA and SA is to obtain optimal weight. There are several parameters used for each methods/algorithm, namely, individuals number, air coefficient, random value coefficient, and initial activation value for FA, the temperature drop factor, initial and final temperature for SA, and the error limit and maximum iteration for RBF. Variation of parameters used in the RBF training process can be seen in table 1.

Table 1. Variation of parameters used in RBF network training

Number of Individuals	Air Coefficient	Random value coefficient	Initial attractiveness	Initial temperature	Finale temperature	Drop temperature factor
10	0.5	0.2	0.5	50	1	5
30	1	0.5	1	100	1	5
50	1.5	0.8	1.5	150	1	5

In the testing process of training data using optimal weights from the training results with several variations in parameter values, the best results obtained can be seen in Table 2.

Tabel 2. The best training testing results

No.	Number of Individuals	Air Coefficient	Random value coefficient	Initial attractiveness	MSE	Iteration	Percentage test result
1	30	0.5	0.5	1	0.55752	8	100 %
2	30	1	0.2	1	0.52707	8	100 %
3	50	1	0.8	0.5	0.14779	30	100%

The process of validation testing was carried out on 18 iris images using some optimal weights which the results can be seen in table 3.

Tabel 3. Validation test results

No.	Number of Individuals	Air Coefficient	Random value coefficient	Initial attractiveness	MSE	Iteration	Percentage test result
1	30	0.5	0.5	1	0.55752	8	89 %
2	30	1	0.2	1	0.52707	8	70 %
3	50	1	0.8	0.5	0.14779	30	89%

In Table 3 there are 2 types of parameter variations with a percentage of 89% test results but the smallest MSE value is 0.14779, so the optimal weight used is when the individual is 50, air coefficient 1, random value coefficient of 0.8, and initial activation value 0.5. And graph of MSE changes can be seen in Figure 4.

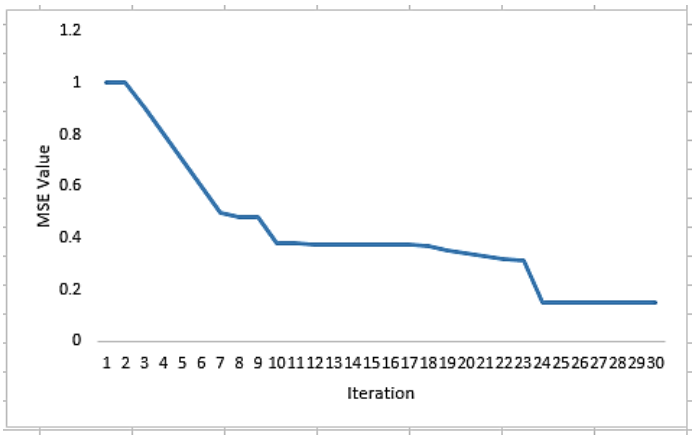

Figure 4. Graph of MSE changes when individual 50, air coefficient 1, random value coefficient 0,8 and initial activation value 0.5.

4. Conclusion

Based on the discussion above, some conclusions can be drawn, implementation of Firefly Algorithm and Simulated Annealing in training of Radial Basis Function networks can detect high cholesterol through the iris image. In the network training process the data used were 45 iris images, the smallest MSE was 0.14779, so the optimal weight used were 50 individuals, air coefficient 1, random value coefficient of 0.8, and initial activation value of 0.5 obtained from the iterations of 30 iterations can detect images with 100% accuracy. In the process of validation testing with 25 images that have never been used during training, the program can detect validation test data with a validity percentage of 89%.

References

[1] Kriege, T., 1975*, Fundamental of Iris Diagnosis*, Trans A. Priest, London: Fowler Co.
[2] Sibuea, A., 2006, *IRIDOLOGY - iris analysis (Basic Course),* Medan: Gemari.
[3] Tabas, I., 2002, *Cholesterol in Health and disease*, J Clin Invest, 110, 583.
[4] Wahyuni, T., 2015, *Gaya Hidup*, Retrieved from CNN Indonesia: https://www.cnnindonesia.com/gaya-hidup/20150916165846-255-79191/kadar-kolesterol-orang-indonesia-sama-dengan-orang-amerika
[5] Brace, H., 1997, *Pengantar Psikologi,* Jakarta: Edition 11, Jilid 2.
[6] Orr, L. J., 1996, *Introduction to Radial Basis Function Neural Network For Pattern Recognition*, Scotland: University of Edinburgh.
[7] Horng, M.-H. Y.-X.-C.-J., 2012, *Firefly Meta-Heuristic Algorithm for Training the Radial Basis Function Netwrok for Data Classification and Disease Diagnosis, Theory and New Applications of Swarm Intelligence*, Shanghai, China: InTech China.
[8] Kanan C. and Cottrell G. W., 2012, *Color to Grayscale: Does the Method Matter in Image Recognition?.*7(1)
[9] A. Basuki, J. P., 2005, *Pengolahan Citra Digital Menggunakan Visual Basic,*Yogyakarta: Penerbit Graha Ilmu.
[10] Dwipayana M, Arnia F, Musliyana Z., 2017*, Histogram Equalization smoothing for determining threshold accuracy on ancient document image binarization*.
[11] Setiawan, K., 2003, *Paradigma Sistem Cerdas,* Surabaya: Sekolah Tinggi Teknik.
[12] Yang, X. S., 2010, *Engineering Optimization: An Introduction with Metaheuristic Application,* New Jersey, USA: Wiley & Sons, Inc.
[13] Kirkpatrick, S., Gelett, C.D. and Vecchi, M. P., 1983, *Optimization by simulated annealing*, *Science* 220 621-630.
[14] Cerny, V., 1985, *A thermodynamic approach to the traveling salesman problem: An efficient simulation*, *J. Optim. Theory Appl*. 45 41-51.