# Iris Recognition using Multi-Resolution Frequency Analysis and Levenberg-Marquardt Back-Propagation

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***Abstract***—In this paper, we suggest an Iris recognition system with an excellent recognition rate and confidence as an alternative biometric recognition technique that solves the limit in an existing individual discrimination. For its implementation, we extracted coefficients feature values with the wavelet transformation mainly used in the signal processing, and we used neural network to see a recognition rate. However, Scale Conjugate Gradient of nonlinear optimum method mainly used in neural network is not suitable to solve the optimum problem for its slow velocity of convergence. So we intended to enhance the recognition rate by using Levenberg-Marquardt Back-propagation which supplements existing Scale Conjugate Gradient for an implementation of the iris recognition system. We improved convergence velocity, efficiency, and stability by changing properly the size according to both convergence rate of solution and variation rate of variable vector with the implementation of an applied algorithm.

***Index Terms***—Levenberg-Marquardt Back-Propagation, Multi-Resolution Frequency Analysis, Conjugate Gradient.

## I. INTRODUCTION

The area between the pupil and the white of the eye is called the iris and everyone has his own different biological features such as long-belted net made in the iris, the red fiber, the eyelash-shaped process, winding blood vessel system and ring-shaped circles, corona-shaped ligament surrounding the pupil, the original color of the iris and spot [1][2].

According to existing researches on the iris recognition, Using 1-D feature of the iris is Boles method which uses corrugation in the outline of the iris in the iris image. While this method has advantage of rapid process and small amount of calculations since it uses 1-D features, it has also disadvantage of decreased amount of comparative data by neglecting each different iris pattern except for iris wrinkle pattern [3]. In addition, method using 2D feature uses iris pattern of 2D image as feature value. Its typical case is the research of the iris recognition by Daugman, where Daugman detected the boundary between the pupil and the outside in the iris image, extracted features of the iris pattern using 2D Gabor filter and then compared them [4]. Researches related to the iris recognition have been performed in Korea and there was a research similar to that by Daugman and there were researches applying new algorithms [5].

In particular, back-propagation which is the basis of recognition researches has used general method to get the solution of weight and critical value related to multiple perceptron. When small learning rate is used, it belongs to very stable minimum gradient descent, but it has a disadvantage of slow convergence. Addition of moment terms and application of variable learning rate can be considered as the means to enhance the performance of back-propagation.

Other means to get the solutions of weight and critical value apply very complex algorithms and most of these are based on Newton's method, but in practical application, compromise plan of Newton's method and minimum gradient descent is used and scale conjugate gradient (SCG) is mainly used. However, conjugate gradient which is the non-linear optimization method is not suitable to solve the optimization problem because of its slow convergence. Also, back-propagation algorithm using SCG property has the restrictions more than one in convergence speed and solidity depending on set of learning parameter and has not ensured the minimum convergence.

Since conventional neural network required impractical time to extract features depending on structure and learning algorithm or failed to extract the exact features, researches of new techniques to settle these problems are urgently required. Therefore, if an efficient learning algorithm is proposed for improving these restrictions, neural network for the iris recognition will be better utilized. For the performance test of system from such a viewpoint, existing papers confirmed FAR and FRR. This study is to enhance convergence speed after enough learning and test using LMBP technique.

Learning convergence speed is improved and efficiency and stability can be obtained simultaneously by changing size according to degree of solution convergence and change of variable vectors with the application of Levenberg-Marquardt BP method proposed in this study. This study consists of the following;

Chapter 2 is on how to recognize the iris image. Chapter 3 describes implementation method and performance analysis of iris recognition system, chapter 4 deals with implementation of this system and experimental results and chapter 5 explains conclusions and future research tasks.

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## II. RECOGNITION METHODS OF IRIS IMAGE

### *A. Pocessing of Iris Image*

When the iris image is obtained, it passes through preprocessing to extract features. Major preprocessing processes are detecting the boundary of the pupil and changing iris area except the pupil area into polar coordinate system.

(Fig. 1) is the conceptual diagram of the process to detect the center of the pupil as the shape of the pupil.

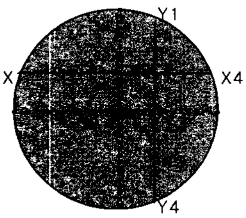


Fig. 1 Detect the center of the pupil

First, random point T (x,y) is set within the pupil. When the position of point T = (x0, y0) is decided, coordinate values are increased or decreased toward x, y direction respectively and distance to outline is measured. I(x,y) is the image information in x, y coordinate, the pixel value.

$$
\begin{aligned}
&\text{if } I(x0+incx,\ y0) < thresholdOfPupil, incx^{++}\\
&\text{if } I(x0-decx,\ y0) < thresholdOfPupil, decx^{++}\\
&\text{if } I(x0,\ y0+incy) < thresholdOfPupil, incy^{++}\\
&\text{if } I(x0,\ y0-decy) < thresholdOfPupil, decy^{++}
\end{aligned}
$$

If end points are defined as X1, X4, Y1 and Y4 respectively, X3 value, central coordinate value of x axis from X1X4 and Y2 value, the central coordinate of y axis from Y1Y4 can be obtained. If x coordinate value of X3 and y coordinate value of Y2 are taken respectively, actual center of the pupil, C-(x1,y1), can be obtained. When the center of the pupil, C, is obtained, radius r1 (radin) and radius r2 (radout) are obtained with the boundary of pupil outline and that of the black and white of the eye from the center.

$$
\begin{aligned}
&\text{if } I(x1+radin,\ y1) < thresholdOfPupil, radin^{++}\\
&\text{if } I(x1+radout,\ y1) < thresholdOfLimb, radout^{++}
\end{aligned}
$$

When internal and external boundaries are detected, 60% of distance between internal and external boundaries are taken as the iris pattern and it is converted into polar coordinate as shown in Equation (1). 60% is experimentally set to take the most iris patterns[6].

$$
\begin{aligned}
&I(x(r,\theta), y(r,\theta)) \rightarrow I(r,\theta)\\
&x(r,\theta) = (1-r)x_p(\theta) + rx_s(\theta)\\
&y(r,\theta) = (1-r)y_p(\theta) + ry_s(\theta)
\end{aligned}
\tag{1}
$$

$(x_p(\theta), y_p(\theta))$: Coordinate rotated toward + direction as $\theta$ from horizontal axis on the pupil.

$(x_s(\theta), y_s(\theta))$: Coordinate toward the a given distance from horizontal axis on the pupil

### *B. Extrction Technique of Iris Features*

Wavelet conversion has the advantage of processing the signal at the various frequency bands by converting sample frequency input with multiple resolution systems into sample frequency of other forms. Sampling frequency of input signal can be segmented with 2 down-sampling and it is very available in analyzing signal by multiplying Wavelet function and scaling function with input signal and dividing frequency bands into high and low frequencies. Frequency segmentation features of Wavelet function are varied according to the kinds of mother wavelet. In particular, in case of Haar Wavelet, its shape has the advantages of its simple shape and quick operation speed [7].

### *C. BPN (Back propagation neural network)*

Error back propagation learning algorithm which is learning method of multi-layer perceptron is based on teacher's signal. Learning is composed of forward part getting actual output and back propagation part getting error of actual output and teacher signal and revising weight with delta rule. The basis of delta rule is adjusting weight by reducing error between actual output calculated with current weight and desired output. But, when neural network is multi-layered, there may be a problem how weight which is not connected to output neuron is adjusted. Error back propagation learning algorithm selects the method of sharing liabilities to all neurons and weights within neural network in order to solve these problems. Liability of error between actual output and desired output makes back propagation for error of output neuron to electric neuron, shares liability and repeats its process till back propagation reaches input neuron [8][9]. (Fig. 2) indicates back propagation neural network algorithm.

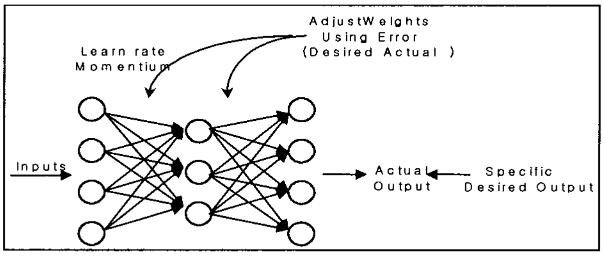


Fig. 2 Back-Propagation Algorithm

Error function used in back propagation neural network algorithm is shown in Equation (2).

$$
E = \frac{1}{P \cdot N_m} \sum_{s=1}^{P} \sum_{i=1}^{N_m} [d_{s,i} - y_{s,i}^{M}]^2 \tag{2}
$$

$d_{s,i}$ , $y_{s,i}^{M}$ are desired output value and actual output value of *sth* learning data respectively and $N_m$ is the number of output neurons.

### *D. Levenberg-Marquardt method*

One of minimum square technique to solve non-linear problems is adding Largrange multiplier to major diagonal component of matrix and getting the stable solution by preventing divergence of solution.

When Jacobian matrix of model reaction in model variables is Z, differential vector of measured value and model reaction is g, variable change vector per repetition in Marquardt is given with Equation (3).

$$\delta = (Z^T Z + \beta I)^{-1} Z^T g \quad \text{Equation} \quad (3)$$

Where, $\beta$ is Largrange multiplier and I is unit matrix. If $\beta$ is 0, it is identical with Newton-Raphson method and the calculation speed of solution is very fast, but it has the problems such as divergence of solution or instability. While there is infinity, it is the same as the maximum gradient method and its convergence is good, but convergence spped is very slow. Therefore, Levenberg-Marquardt can achieve efficiency and stability simultaneously by changing the size according to degree of convergence of solution, that is, degree of changes in variable vector [10].

This study applied the secondary approximate method Levenberg-Marquardt Back-Propagation to the iris recognition system, changes the size properly according to the degree of convergence of solution and change of variable vector and obtained efficiency and stability simultaneously.

## III. SUGGESTED IMPLEMENTATION METHOD OF IRIS RECOGNITION AND LMBP PERF ORMANCE ANALYSIS

### *A. Extraction of Haar Wavelet Conversion Based Feature Vector*

Process of extracting feature parameter using wavelet conversion divided two input image signals into polar coordinate system and feature area using edge distribution, performs Haar wavelet conversion and obtains coefficient matrix. It is to obtain wA8 which keeps most of information of original image in the state of reducing the size of image information to 1/4 in the process of general segmentation of Haar wavelet. Original image can be restored with wA8 part and three remaining values. To reduce the size of information, wavelet conversion frequency was repeated and proper frequency was designated as four because image was reduced in more than four times as information was lost. This study used 4-level wavelet conversion coefficients because feature of reduced information more than 4 times lost its meaning. In conclusion, it has the features of image signal since it is feature vector made on the basis of restorable values with information of original image. When 4-level wavelet conversion of feature area of iris image used in this paper is performed, coefficient matrices wA8, wH8, wV8 and wD8 can be obtained. wA8 is 4-level low frequency coefficient level, wH8 is horizontal high frequency coefficient matrix, wV8 is vertical high frequency coefficient matrix and wD8 is diagonal high frequency coefficient matrix. After analyzing their distribution characteristics, feature vector is extracted. Absolute value of four coefficient matrices is obtained and then each feature vector of wA8, wH8, wV8 and wD8 is extracted. (Figure 3) is one of original image samples used as experimental data and (Figure 4) indicates the images of coefficient matrices wA8, wH8, wV8, wD8 after 4-level wavelet conversion and shows the concentration of original image information on these four coefficient matrices. Feature extraction selected 10 learning samples of original image, converted them into 4-level wavelet and obtained wA8, wH8, wV8 and wD8. After analyzing data distribution of these coefficient matrices, feature vector was extracted, normalized and used as input vector of neural network. (Figures 5,6,7 and 8) indicate feature distribution of sample image of original images.

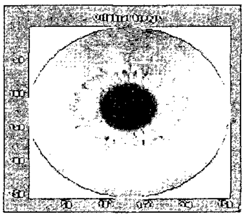
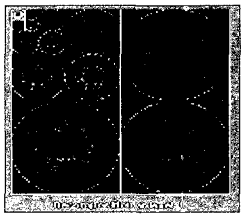

Fig. 3 original image samples used as experimental data
Fig. 4 Iris images of after 4-level wavel conversion

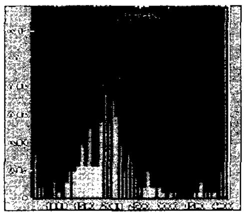
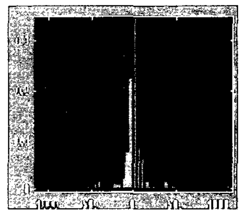

Fig. 5 Feature distribution of wA8
Fig. 6 Feature distribution of wH8

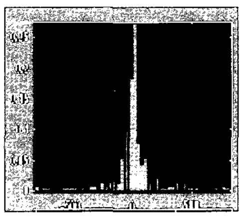
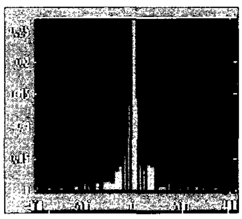

Fig. 7 Feature distribution of wV8
Fig. 8 Feature distribution of wD8

### *B. Suggested Levenberg-Marquardt Function Back-Propagation*

Back-propagation which was researched used general methods to get the solutions of weight and critical value related to multi-layer perceptron repeatedly. This method belongs to minimum gradient descent which is stable when small learning rate is used, but it has the disadvantage of slow convergence and in particular, it is not suitable to solve optimization method with Scale Conjugate Gradient method which is the non-linear optimization method because of its slow convergence speed.

Therefore, this study changed the size properly according to degree of convergence of solution and of change of variable vector in the iris recognition discrimination system using Levenberg-Marquardt and obtained efficiency and stability simultaneously with fast learning convergence speed. The following is Levenberg-Marquardt function algorithm.

### C. Neural Network for the Iris Recognition

Neural network learning using normalized feature vector should be designed. The number of input and output layer nodes is preset according to the form of learning pattern, but the number of hidden layers and nodes can be set randomly by the degree of learning. The iris recognition system suggested in this paper makes 64 coefficient values obtained through wavelet the input nodes of neural network.

It used 8 output nodes, 120 hidden nodes and neural network of 64×120×120×8 with two hidden layers.

Activation function between input node and hidden node,

obj fn $E(a)=\sum_{i=1}^{m} f_i^2(a)$

Algorithm

1. $\lambda \leftarrow 10^{-3}$ ; $a(0)=a_0$
2. Compute $E(a(k))$;
3. Compute Jacobian $J_k$;
4. $a(k+1)\leftarrow a(k)-\lambda^k(J_k^T J_k+\lambda I)^{-1} J_k^T f(a(k))$;
5. Compute $E(a(k+1))$;
6. if $E(a(k+1)) > E(a(k))$ then $\lambda\leftarrow 10\times\lambda$ and goto 4;
7. if $E(a(k+1)) > E(a(k)) < 10^{-4}$ then stop

   if $E(a(k)) - E(a(k+1)) < 10^{-3}$ (4 × consecutively) then stop;
8. $\lambda\leftarrow 0.1\times\lambda$
9. $a(k)\leftarrow a(k+1)$; goto 2;

and hidden node and output node used bipolar Sigmoid function and nodes between each layer.

## IV. IMPLEMENTATION AND EXPERIMENTAL RESULTS

### A. Learning of Neural Network

This experiment used 64 coefficient values using 4-level wavelet conversion for 512×512 iris image as input pattern of neural network and images used for the experiment were 10 respectively for total 50 persons.

10 of obtained images were used as learning data for neural network learning and the 10 remaining images were used as experimental data for measuring recognition rate of learned neural network. In the recognition of this iris image, 64 input nodes, 8 output nodes and 120 nodes were used and neural network of 64×120×120×8 with two hidden layers was used. Learning method using designed neural network Scale Conjugate Gradient learning algorithm which is learning algorithm of general neural network and Levenberg-Marquardt BP suggested in this study.

Learning pattern is coefficient feature vector obtained through 4-level wavelet conversion and the number of the whole learning patterns using 10 iris images of total 50 persons is 500. Both SCG and LM learning methods experimented learning hours and recognition rate using learning rate 0.4, momentum 0.7 and learning error 0.01. The frequency of repeated learning is set to 500 times and learning ended when learning error value is reduced below 0.01 of learning error. Neural network completed after stabilization learning is used as neural network of the iris recognition. Learning is not always completed within the range of the same learning on characteristics of neural network learning and at the worst case, there may be a situation that learning is not run.

This study indicated mean learning convergence speed of two learning methods such as LM and SCG through 10 times. When learning through total 10 times was run, LM learning method achieved the success of learning for 8 times and the learning frequency except for non-performance of learning was converged within the error range at the mean 20.24 times and learned ended. In SCG learning, the frequency of success of learning was mean 7 times, learning error was converged within error range after repeated learning through mean 40.72 times and learning ended, and SCG learning showed unstable reactions from once to 12 times. Accordingly, when the frequencies of mean repeated learning with success cases of learning were compared, it is considered that LM learning algorithm was learning method suitable to the iris learning pattern. <Fig. 9> compares mean convergence speeds after running neural network learning.

For the iris recognition rate of test pattern, recognition of 500 iris image patterns of 50 persons except for patterns participating in learning was tested. In case of test pattern, performing recognition with LM neural network achieved the success in recognition of 451 image of total 500 patterns and SCG neural network recognized 412 images exactly.

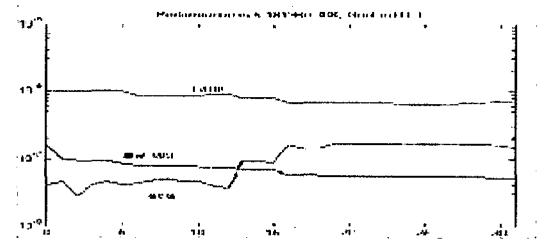

Fig. 9 compares mean convergence speeds after running neural network learning

The whole mean recognition rate showed the recognition rates of 90% and 82% respectively. This study is to get NMSE which is normalized MSE to show the recognition iris image. Neural network results of LM and SCG were compared with MSE, NMSE (normalized mean squared error). Its results were shown in <Table 1>.

Table.1 Compared with LMBP, SCGBP

| Performance | LMBP | SCGBP |
|---|---|---|
| MSE | 0.00692 | 0.00877 |
| NMSE | 0.16267 | 0.18610 |
| Recognition rates | 0.9084(90%) | 0.8210(82%) |

As described in the results of <Table 1>, LM neural network applied in this paper is suitable learning because learning ended within the range of learning error of test pattern. But it showed error recognition of the exact iris recognition when it is image with lighting, eyelash is not removed in preprocessing or there is a lesion in the iris.

## IV. CONCLUSIONS

This study used neural network which speeds up convergence of iris recognition with Levenberg-Marquardt Back-Propagation. Designed neural network algorithm was learned through LMBP algorithm and SCGBP algorithm. The number of 10 learning patters of 50 persons was 500 and used learning rate 0.4, momentum 0.7 and learning error 0.01. When the frequency of learning repetition was set 500 times and error value of designated learning was reduced below 0.01, it was considered that learning ended. As a result of measuring the frequency of learning, it was found that LMBP algorithm was more suitable to iris recognition learning pattern, rapid performance speed and learning pattern showed recognition rate of 90% and test pattern also showed the recognition rate of 89%. It was confirmed that images which were not recognized included those having lesion in the iris, having light or lowered eyelashes. Future research tasks are to analyze the features of the factor which can cause physical diseases like jaundice, find out features that unique iris code is made and used directly and improve its reliability.

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