# FAST NON-LINEAR NORMALIZATION ALGORITHM FOR IRIS RECOGNITION

Wen-Shiung Chen, Jen-Chih Li, Ren-He Jeng
*VIPCCL, Department of Electrical Engineering, National Chi Nan University, Puli, Nantou, Taiwan*

Lili Hsieh
*Department of Information Management, Hsiuping Institute of Technology, Dali, Taichung, Taiwan*

Sheng-Wen Shih
*Department of Computer Science and Information Engineering, National Chi Nan University, Puli, Nantou, Taiwan*

Keywords: Biometrics, Non-linear Normalization, Law of Cosine.

Abstract: In biometrics, human iris recognition provides a high-level security. However, the size of eye pupil always varies with different illumination, resulting in the iris texture deformation. Thus, how to precisely predict the deformation degree of the iris is an important issue. A fast algorithm simply using the law of cosine is proposed to make Yuan and Shi’s non-linear normalization model used in iris recognition suitable for real-time personal authentication applications.

## 1 INTRODUCTION

In biometric-based automatic identity authentication techniques, the iris recognition is one of the most reliable methods. Iris texture possesses a lot of distinctive information helpful for discriminating people's identity. Nowadays the existing iris recognition systems have a very good performance (J. Daugman, 1993; R. Wildes, 1997; L. Ma *et al.*, 2003; L. Ma *et al.*, 2004). However, the iris texture can be deformed due to variation of pupil size resulting from different illumination. How to compensate the effect of pupil size variation becomes an important issue. In most of the iris recognition techniques, a normalization process is always performed.

In general, the human eye pupil's diameter is of about 1.5mm ~ 7mm, and always varies with different illumination from exterior into eye. The human iris is an annular region circumjacent the pupil, and having the width of around 12mm. The iris is an enormous complex meshwork of pectin ate ligament tissue resulting in patterns of almost infinite variety. The pupil size varies with different illumination, as a result the iris deforms, such as contract or expand, even torture, caused by papillary variations. The purpose of normalization is to facilitate the subsequent processing (e.g., feature extraction), and most importantly, to restore precisely various degrees of deformation of the iris structure in a minimal state of distortion. Among the normalization methods, The approach, proposed by Daugman (J. Daugman, 1993), is the most popular and widely used in many systems, in which iris is assumed to be homogenous 'rubber-sheet' model. In this approach the annular iris region is linearly mapped or transformed into a fix-sized rectangular block via the following formulas:

$$\begin{cases} x(r,\theta) = (1-r)x_p(\theta) + rx_i(\theta) \\ y(r,\theta) = (1-r)y_p(\theta) + ry_i(\theta) \end{cases} \quad (1)$$

where $\left(x_p(\theta), y_p(\theta)\right)$ and $\left(x_i(\theta), y_i(\theta)\right)$ are the polar coordinates of the inner and outer boundary points in the direction $\theta$, $(x, y)$ are the Cartesian coordinates. However, the model is not entirely accurate since it assumes the stretch of iris tissue in radial direction is linear as the pupil size changes.



Chen W., Li J., Jeng R., Hsieh L. and Shih S. (2010).
FAST NON-LINEAR NORMALIZATION ALGORITHM FOR IRIS RECOGNITION.
In *Proceedings of the International Conference on Computer Vision Theory and Applications*, pages 507-510
DOI: 10.5220/0002840905070510

Under the environment with uniform illumination, the size of pupils varies slightly so that the performance can be good. However, on the other hand, a non-uniform illumination scenario always results in the variation of pupil size vastly. In such case, the linear mapping cannot correctly predict the deformation so that the performance becomes degraded. Therefore, to develop a non-linear normalization method for resolving iris texture deformation is necessary.

H. J. Wyatt's work (H. J. Wyatt, 2000) focuses on the construction of a meshwork of 'skeleton' that can minimize 'wear-and-tear' of iris as pupil size varies. By following, Yuan and Shi adopted the idea in (H. J. Wyatt, 2000) as a basic model. They simplified it and developed a non-linear normalization model for iris recognition (X. Yuan *et al.*, 2005). The modified approach was applied to overcome the non-linear deformation on the iris texture caused by pupil variations in iris recognition. It has been shown that this modified approach achieves a relatively good performance. However, the model needs to solve two simultaneous equations so that it is complicated to get the sampling points and the time complexity is high. When the size of image needed to be normalized increases, the computing time becomes too large. The iris recognition system must be realized in real-time for the authentication applications. Therefore, it needs to propose a fast algorithm which can construct the nonlinear normalization model quickly for implementing iris recognition.

## 2 NON-LINEAR NORMALIZATION REVISITED

In 2005, Yuan and Shi proposed a non-linear normalization model (X. Yuan *et al.*, 2005), as shown in Figure 1, with the prior defined parameter $\lambda_{\mathrm{ref}}$ through the solution of two simultaneous equations to solve the iris deformation caused by pupillary variations problem. First of all we construct the gap of 90-degree between points P and I′ that is connected by the arc(PI′). Such an arc defined in the H.J. Wyatt (H. J. Wyatt, 2000) is known as "fiber." Then we define the virtual pupil radius $r_{ref} = \lambda_{ref} R$ that constructs the same arc between the points P′ and I′ connected by the arc(P′I′).

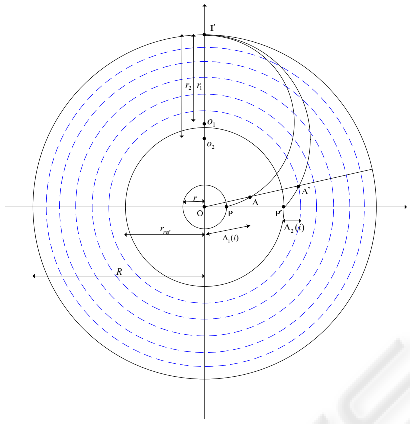

Figure 1: The non-linear normalization model proposed by Yuan and Shi.

The arc(PI′) is part of the circle of:

$$x^2 + (y - y_1)^2 = r_1^2 \tag{2}$$

where

$$y_1 = (R^2 - r^2)/2R \tag{3}$$

and

$$r_1 = (R^2 + r^2)/2R, \tag{4}$$

and arc(P′I′) is part of the circle of:

$$x^2 + (y - y_1)^2 = r_2^2 \tag{5}$$

where

$$y_2 = \left(R^2 - r_{ref}^2\right)/2R \tag{6}$$

and

$$r_2 = \left(R^2 + r_{ref}^2\right)/2R. \tag{7}$$

Then the arc(P′I′) is uniformly sampled along the radial direction. When the pupil radius changes from $r$ to $r_{ref}$, the non-linear relationship between arc(PI′) and arc(P′I′) is used to solve the non-linear deformation of the iris texture patterns.

Suppose the point A′ is on the $i$-th sampling circle. Then $A'_x$ and $A'_y$ can be solved by:

$$\begin{cases} x^2 + y^2 = \left(r_{ref} + \Delta_2(i)\right)^2 \\ x^2 + (y - y_2)^2 = r_2^2 \end{cases} \tag{8}$$

where

$$\Delta_2(i) = \frac{i\left(R - r_{ref}\right)}{(m-1)}, i = 0,1,2,\ldots,m-1. \tag{9}$$

Its corresponding point A on the arc(PI′) can be solved by:

$$\begin{cases} y - A'_y = k(x - A'_x) \\ x^2 + (y - y_1)^2 = r_1^2 \end{cases} \tag{10}$$

where

$$k = A'_y / A'_x. \tag{11}$$

By solving these two simultaneous equations (4) and (5), the Cartesian coordinates, $A_x$ and $A_y$, of the point A are obtaind. Since it needs to solve two equations simultaneously, the computing time must be high. In the next section a simple and fast approach is then proposed to reduce the computing time tremendously.

Algorithm 1: Non-linear Normalization Algorithm.

```
for i ← 0 to m − 1 do
begin
    Generate eq.(4);
    Solve eq.(4) by newton's method;
    Generate eq. (5);
    Solve eq.(5) by newton's method;
end
```

## 3 FAST ALGORITHM OF NON-LINEAR NORMALIZATION

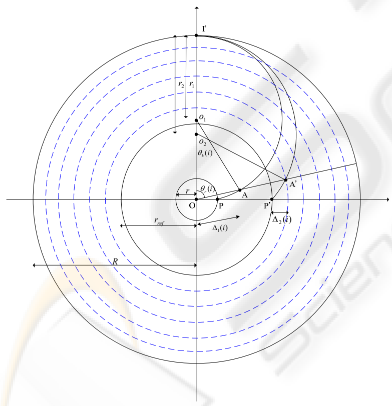

Figure 2: Observation.

According to the non-linear normalization model mentioned above, we realize that the final goal is to find out the Cartesian coordinates $A_x$ and $A_y$ of the sampled point $A$, indirectly by first knowing the coordinates of the virtual point $A'$. If we know the length of $\overline{OA}$ between the point A and the pupil center $O$, and the angle $\theta_r(i)$ between $\overline{OA'}$ and $y$-axis, the coordinates of the point A may be determined. It is observed from Figure 1 that the two points $A'$ and A are colinear, so $\overline{OA}$ and $\overline{OA'}$ have the same angle $\theta_r(i)$. Obviously, the three points, the point $A'$, the pupil center $O$ and the center $o_1$ of $\mathrm{arc}(P'I')$, form a triangle $\Delta A'Oo_1$, as shown in Figure 2. Since the lengths of three sides of the triangle are known, the angle $\theta_r(i)$ can be determined according to the law of cosine.

Similarly, the three points, the point A, the pupil center $O$ and the center $o_2$ of $\mathrm{arc}(PI')$, form another triangle $\Delta AOo_2$, as shown in Figure 2. In this triangle only $\overline{OA}$ is unknown. According to the law of cosine and the law of sine, the length of $\overline{OA}$ may be determined from $\theta_k(i)$ which might be obtained from $\Delta A'Oo_1$. Trivially, the coordinates, $A_x$ and $A_y$, of the sampled point A are computed by

$$\begin{cases} A_x = \Delta_1(i)\sin(\theta_r(i)) \\ A_y = \Delta_1(i)\cos(\theta_r(i)) \end{cases} \tag{12}$$

where

$$\theta_r(i) = \cos^{-1}\left[\frac{y_2^2 + \left(r_{ref} + \Delta_2(i)\right)^2 - r_2^2}{2y_2\left(r_{ref} + \Delta_2(i)\right)}\right] \tag{13}$$

and

$$\Delta_1(i) = \left(r_1^2 + y_1^2 - 2y_1 r_1 \cos(\theta_k(i))\right)^{1/2}.$$

Finally, we adopt the Cartesian coordinates of all of the sampled point A on $\mathrm{arc}(PI')$ to construct a non-linear normalization model directly. The detailed procedure is shown in algorithm II.

Algorithm 2: Fast Non-linear Normalization Algorithm.

```
for i ← 0 to m − 1 do
begin
  Compute θr(i);
  Compute Δ1(i);
  Ax = Δ1(i)sin(θr(i));
  Ay = Δ1(i)cos(θr(i));
end
```

## 4 EXPERIMENTAL RESULTS

In this section, two different non-linear normalization algorithms are compared.

### 4.1 Speed Comparison

The time consumption of Yuan's algorithm and proposed algorithm in computing 32 sampling points of fiber are shown in Table 1.

Table 1: Computing Speed Comparison.

| | Yuan and Shi's algorithm | The Proposed algorithm |
|---|---|---|
| Speed | $100(ms)$ | $0.14(ms)$ |

Figure 3 shows the relationship of the sampling point of fiber and the computing time in different algorithms.

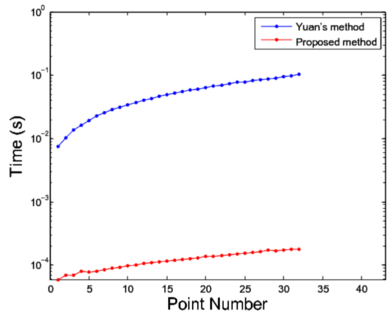


Figure 3: The relationship of the number of sampling points of fiber and the computing time of different methods.

## 4.2 Performance Comparison

We implemented two iris recognition systems in which the same pre-processing, feature extraction, classification, except the normalization, are used. We collected an iris image database (denoted as DB1) in different illumination. It contains 18 classes and each class contains 9 images. The image samples of three subjects are shown in Figure 4.

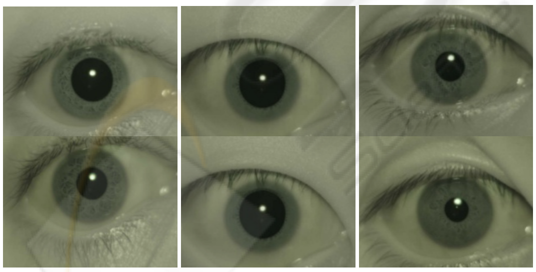

Figure 4: The eye image samples.

Then we evaluate the performances with linear and non-linear normalization on DB1. The ROCs (receiver of operating curves) are shown in Figure 5.

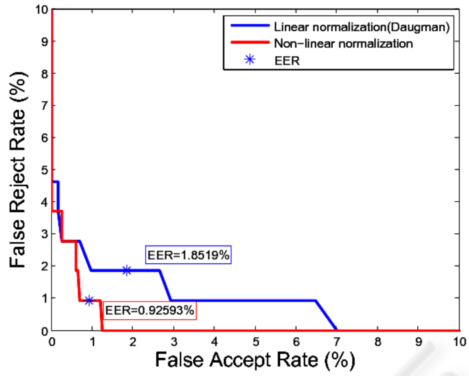


Figure 5: ROC curves with linear and non-linear normalization.

# 5 CONCLUSIONS

In this paper, we proposed a fast and simple non-linear normalization algorithm. Even if the normalization of image size increases, the computing time is not increased rapidly, and it is also very simple and easy to achieve. The experimental results show the computing time is reduced by 100 ms, and the equal error rate (EER) is decreased by 0.94% as compared with linear normalization.

# REFERENCES

J. Daugman, 1993. High confidence personal visual recognition of person by a test of statistical independence. *IEEE Trans. on Pattern Analysis and Machine Intelligence*, vol. 15, no. 11, pp. 1148-1161.

R. Wildes, 1997, Iris recognition: An emerging biometric technology. *Proceedings of the IEEE*, vol. 85, no. 9, pp. 1348-1363.

L. Ma, T. Tan, Y. Wang and D. Zhang, 2003. Personal identification based on iris texture analysis. *IEEE Trans. on Pattern Analysis and Machine Intelligence*, vol. 25, no. 12, pp. 1519-1533.

L. Ma, T. Tan, Y. Wang and D. Zhang, 2004. Efficient iris recognition by characterizing key local variations. *IEEE Trans. on Image Processing*, vol. 13, no. 6, pp. 739-750.

H. J. Wyatt, 2000. A 'minimum-wear-and-tear' meshwork for the iris. *Vision Research*, vol. 40, pp. 2167-2176.

X. Yuan and P. Shi, 2005. A non-linear normalization model for iris recognition. *Advances in Biometric Person Authentication*, pp. 135-141.