# Orientation Recognition of Iris Pattern

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**Abstract.** An iris recognition system that employs a rotation spreading neural network (R-SAN net) has been proposed. R-SAN net is suitable for the orientation recognition of concentric circular patterns such as the iris pattern. The orientation recognition characteristics of R-SAN net for the iris pattern have been investigated. However, it has not yet been understood how the orientation recognition performance of R-SAN net is better than that of other methods employed for orientation recognition.

In this study, we evaluated the effectiveness of the orientation recognition performance of R-SAN net by comparing its orientation recognition characteristics with those of the moment (MO) method. The standard deviation of the orientation recognition error in the MO method is larger than that in R-SAN net. For an arbitrary input orientation, R-SAN net showed a fairly good orientation recognition performance as compared to the MO method.

## 1 Introduction

An iris recognition system that employs a rotation spreading neural network (R-SAN net) has been proposed [1], [2]. For orientation recognition, R-SAN net requires a two-dimensional input pattern to be converted from the Cartesian coordinate system to the polar coordinate system. Thus, R-SAN net is suitable for the orientation recognition of concentric circular patterns such as the iris pattern. In personal authentications through cellular phones, a change in the rotation of the iris pattern occurs due to the use of an unfixed camera, and this causes a decrease in the iris recognition rate. In order to solve such problems, the change in the rotation is corrected by using the recognized rotation angle obtained by R-SAN net. The correction of the change in the rotation prevents the decrease in the iris recognition rate. In the previous study, the orientation recognition characteristics of R-SAN net were investigated. However, it has not yet been understood how the orientation recognition performance of R-SAN net is better than that of other methods employed for orientation recognition.

In this study, we evaluated the effectiveness of the orientation recognition performance of R-SAN net by comparing its orientation recognition characteristics with those of the moment (MO) method, which is a typical technique employed for orientation recognition.

## 2 Orientation Recognition by R-SAN Net

### 2.1 Outline of R-SAN Net

The structure of R-SAN net is shown in Fig.1. R-SAN net consists of orientation and shape recognition systems. In the operation of this network, the input pattern ($300 \times 300$

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pixels) is converted into a pattern in polar coordinates. This transformed pattern is input to the spreading layer and a spread pattern is obtained.

In the learning process, the orientation memory matrix is obtained by generalized inverse learning. In the recollection process, the output of orientation recognition neurons is obtained by multiplying the spread pattern and the orientation memory matrix. The orientation is recognized from the output of the orientation recognition neurons by using the population vector (PV) method.

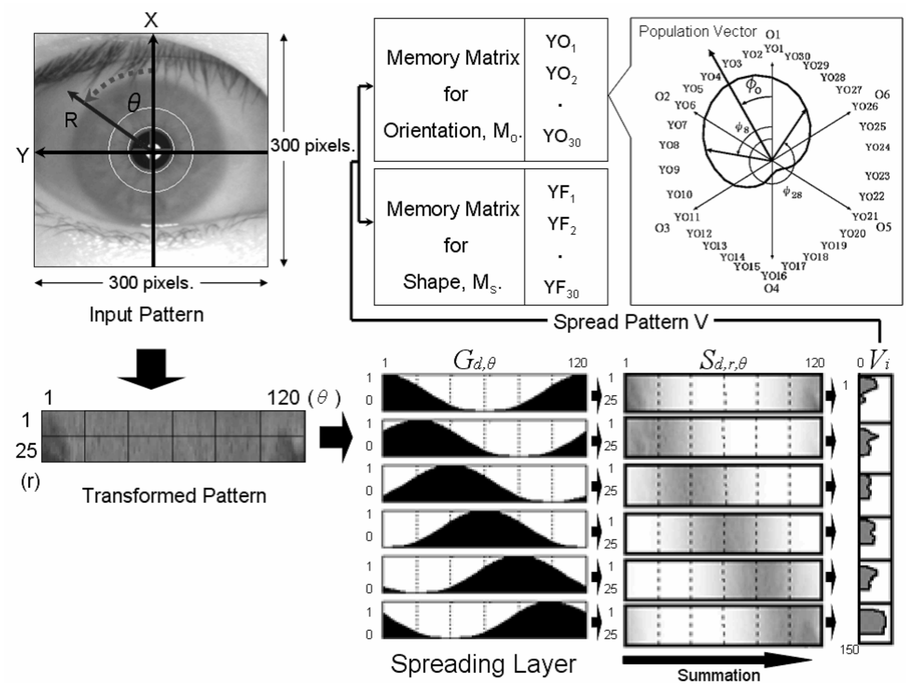


**Fig. 1.** Structure of R-SAN net

## 2.2 PV Method

The orientation recognition of the iris pattern is realized by using the PV method along with the output of the orientation recognition neurons [3]. This method provides the orientation of an object by synthesizing the continuous spectra of the outputs of the orientation recognition neurons. The arrangements of the orientation recognition neurons and the population vector are shown in Fig.2. Each orientation recognition neuron $YO_i$ has a representative orientation $\psi_i$ that characterizes the best orientation for the optimal response in Eq.(1). The length of the vector is proportional to the neuron's output. The population vector orientation $\phi$ is calculated by the vectorial summation of 30 orientation neurons arranged at intervals of $12°$, as shown in Eqs.(2) and (3).

$$\psi_i = \frac{2\pi}{30} \times (i-1)[rad] \qquad (i = 1, 2, \cdots, 30) \tag{1}$$

$$x = \sum_{i=1}^{30} YO_i \cos\psi_i \quad , \quad y = \sum_{i=1}^{30} YO_i \sin\psi_i \tag{2}$$

$$\phi = \tan^{-1}\left(\frac{y}{x}\right) \tag{3}$$

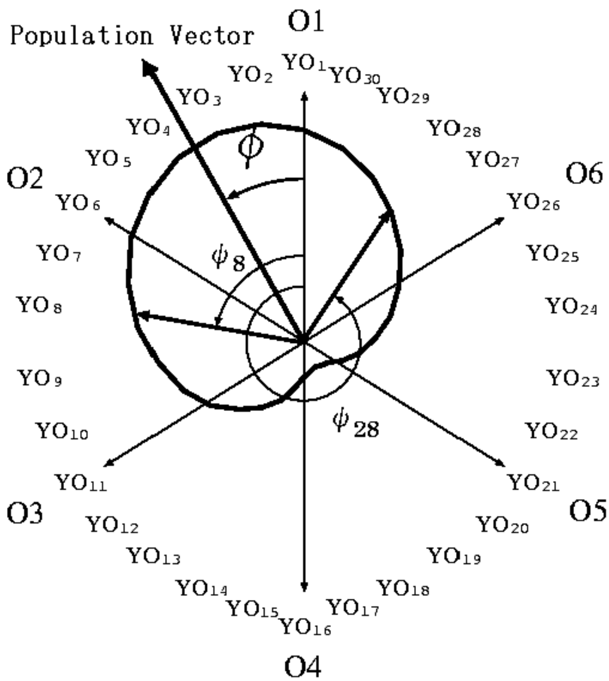


**Fig. 2.** Orientation recognition with the PV method

## 2.3 Process of Orientation Recognition Using R-SAN Net

The process of orientation recognition using R-SAN net is performed as follows. In the learning process, the iris pattern is captured by a CCD camera. The original pattern for learning and recollection processes is a gray-scale pattern of 300 $\times$ 300 pixels. The origin for the polar and Cartesian coordinates is the central position of the pupil. The transformed pattern is obtained by sampling the original pattern in polar coordinates $(r, \theta)$ at intervals of 3° for $\theta$ and at equal intervals ranging from 30 to 55 pixels for $r$, excluding the pupil region. Next, the spread pattern is obtained by multiplying the transformed pattern with the spreading weight, which is a periodic Gaussian function in the

$\theta$-direction. The summation of each pixel value of the spread pattern in the $\theta$-direction provides the spread pattern vector. The orientation memory matrix is obtained by associating the spread pattern vector with the desired outputs of the orientation recognition neurons.

In the recollection process, the spread pattern vector is obtained in a manner identical to that of the learning process. The outputs of the orientation recognition neurons are obtained by multiplying the spread pattern and orientation memory matrix. The orientation of the input iris pattern is recognized by using the PV method along with the outputs of the orientation recognition neurons.

## 3 Orientation Recognition Using the MO Method

### 3.1 Moment Characteristics

The moment characteristics are one of the important factors for representing the shape of an object [4], [5]. The second-order moment around the center of gravity describes the degree of concentration. The moment characteristics around an arbitrary axis of an object show the degree of extension. In the MO method, the direction along which the object extends is used to define the orientation angle.

### 3.2 MO Method

In the present study, the orientation recognition characteristics of R-SAN net are compared with those of the MO method. The orientation recognition performed using the MO method is as follows.

The $(p+q)$-order moment $M_{pq}$ of pattern $f(m,n)$ around the center of gravity is given by Eq.(4). When the center of gravity $(m_G, n_G)$ is set as the origin $(0,0)$, the $(i+j)$-order moment $\mu_{ij}$ is given by Eq.(5). In addition, the second-order moment $\mu_\theta$ around the straight line passing through the origin with an inclination $\theta$ is defined by Eq.(6). The angle $\theta$ for the minimum value of $\mu_\theta$ defines the principal axes of inertia and represents the direction along which the object expands. The orientation of the object is calculated by using $\theta$, as shown in Eq.(7).

$$M_{pq} = \sum_m \sum_n (m - m_G)^p (n - n_G)^q f(m,n) \tag{4}$$

$$\mu_{ij} = \sum_m \sum_n m^i n^j f(m,n) \tag{5}$$

$$\mu_\theta = \sum_m \sum_n (m\cos\theta - n\sin\theta)^2 f(m,n) \tag{6}$$

$$\theta = \frac{1}{2}\tan^{-1}\left(\frac{2\mu_{11}}{\mu_{20} - \mu_{02}}\right) \tag{7}$$

### 3.3 Process of Orientation Recognition Using MO Method

The orientation recognition of the iris pattern by using the MO method is as follows. In the learning process, the iris image is extracted from the original image from a radius of 30 to 55 pixels, excluding the pupil region. The MO method provides the iris orientation by using the extracted image of the iris pattern. The orientation of the iris image is obtained by calculating the second-order moment around the center of gravity. The calculated orientation is stored as the criteria angle $\theta_L$ of the registered iris. In the recognition process, the recognized orientation $\theta_{MO}$ of the iris image is obtained by subtracting the registered angle $\theta_L$ calculated in the learning process from the orientation angle $\theta_R$ calculated in the recognition process, as shown in Eq.(8).

$$\theta_{MO} = \theta_R - \theta_L \tag{8}$$

## 4 Orientation Recognition Experiment

### 4.1 Experimental Method

In order to evaluate the orientation recognition performance of R-SAN net and the MO method, the orientation recognition experiment was conducted by using 35 iris patterns. In the recognition process, the iris image was recaptured. The orientation recognition results were obtained by rotating the iris pattern at intervals of $10°$ based on the pupil center. For the $p$-th input of the iris pattern at $\theta_i$, the recognized orientation errors $E^{R-SAN}_{o,\theta_i,p}$ (in R-SAN net) and $E^{MO}_{o,\theta_i,p}$ (in the MO method) are calculated by Eqs.(9) and (10), respectively. The average $\bar{E}^{R-SAN}_{o,\theta_i}$ and standard deviation $SD(E^{R-SAN}_{o,\theta_i})$ in R-SAN net and the average $\bar{E}^{MO}_{o,\theta_i}$ and standard deviation $SD(E^{MO}_{o,\theta_i})$ in the MO method are calculated for each input angle $\theta_i$ $(= 0°, 10°, \cdots, 360°)$ for all the iris patterns $(p = 1, 2, \cdots, 35)$. The average $\bar{E}^{R-SAN}_o$ and standard deviation $SD(E^{R-SAN}_o)$ in R-SAN net and the average $\bar{E}^{MO}_o$ and standard deviation $SD(E^{MO}_o)$ in the MO method are calculated by using $E^{R-SAN}_{o,\theta_i,p}$ and $E^{MO}_{o,\theta_i,p}$ in all values of $\theta_i$ $(= 0°, 10°, \cdots, 360°)$ and $p$ $(= 1, 2, \cdots, 35)$. These values are used for the evaluation of the orientation recognition performance.

$$E^{R-SAN}_{o,\theta_i,p} = \phi_{\theta_i,p} - \theta_i \qquad (\theta_i = 0°, 10°, \cdots, 360°, p = 1, 2, \cdots, 35) \tag{9}$$

$$E^{MO}_{o,\theta_i,p} = \theta_{MO,\theta_i,p} - \theta_i \qquad (\theta_i = 0°, 10°, \cdots, 360°, p = 1, 2, \cdots, 35) \tag{10}$$

### 4.2 Orientation Recognition Result

The orientation recognition characteristics of R-SAN net are shown in Fig.3. The horizontal axis represents the input orientation angle $\theta_i$ of the iris pattern, and the vertical axis denotes the recognized orientation angle. The characteristics for ideal orientation recognition are represented by a solid line. The circle shows the average $\bar{E}^{R-SAN}_{o,\theta_i}$ of the recognized orientations of 35 iris patterns. The vertical bar shows the standard deviation $SD(E^{R-SAN}_{o,\theta_i})$. The recognition result for R-SAN net shows good linearity between the

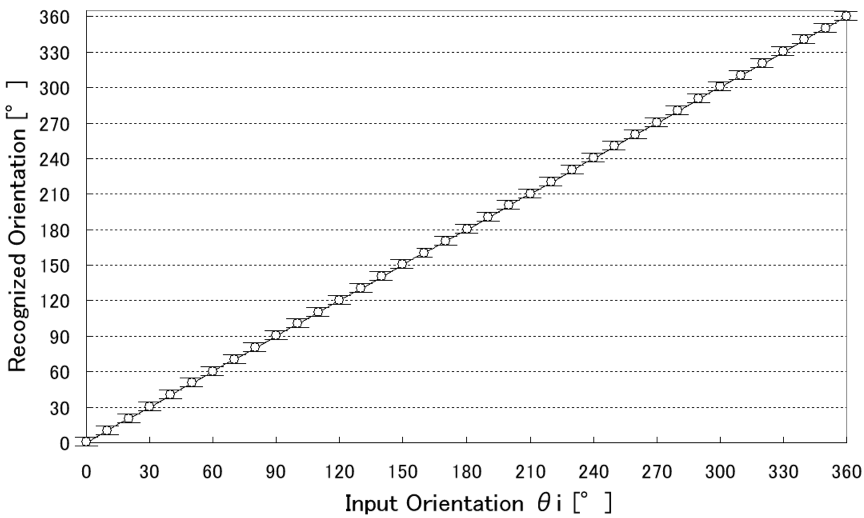


**Fig. 3.** Orientation recognition characteristics obtained using R-SAN net

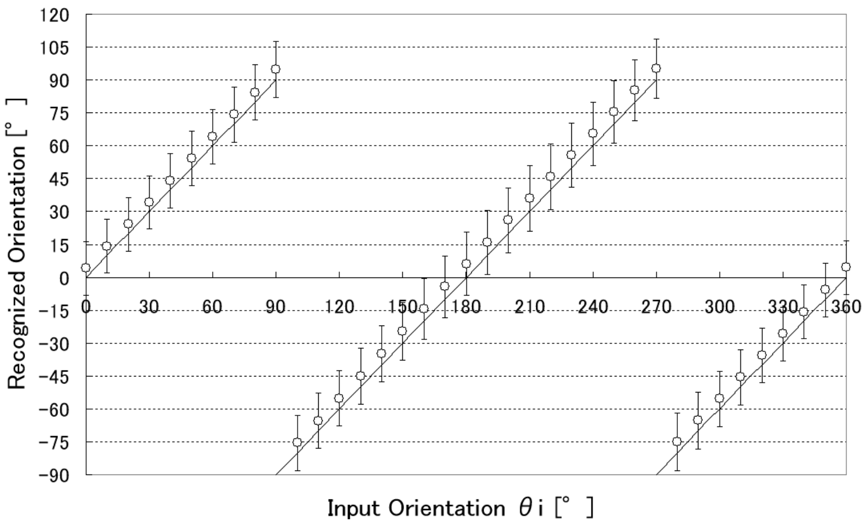


**Fig. 4.** Orientation recognition characteristics obtained using the MO method

orientations of the input and recognized iris patterns. The average $\bar{E}_o^{R-SAN} \pm$ standard deviation $SD(E_o^{R-SAN})$ is $0.46° \pm 2.88°$. R-SAN net can correctly recognize the iris orientations for arbitrary input orientations.

The orientation recognition characteristics of the MO method are shown in Fig.4. The horizontal axis represents $\theta_i$ for the iris pattern, and the vertical axis denotes the recognized orientation angle. The characteristics for ideal orientation recognition are represented by a solid line. The circle shows the average $\bar{E}^{MO}_{o,\theta_i}$ of the recognized orientations of 35 iris patterns. The vertical bar shows the standard deviation $SD(E^{MO}_{o,\theta_i})$. The average $\bar{E}^{MO}_{o}$ $\pm$ standard deviation $SD(E^{MO}_{o})$ is $4.87° \pm 12.99°$. The standard deviations $SD(E^{MO}_{o,\theta_i})$ and $SD(E^{MO}_{o})$ are considerably large. The deterioration in the orientation recognition performance of the MO method is due to a slight variation in the pixel value, which results from a change in the rotation of the input iris pattern or a change in the pixel value of the iris pattern that occurred during the image recapture. Thus, it is clarified that orientation recognition by the MO method is easily influenced by a slight change in the pixel values.

## 5 Conclusion

In this study, we evaluated the effectiveness of the orientation recognition performance of R-SAN net by comparing its orientation recognition characteristics with those of the MO method. From the experimental result, it was observed that R-SAN net exhibited fairly good orientation recognition performance for an arbitrary input orientation as compared to the MO method. The MO method is vulnerable to slight changes in pixel values. The orientation of the iris pattern was correctly recognized by R-SAN net for arbitrary input orientations.

In a future study, we will investigate the orientation recognition characteristics for the iris pattern captured by a rotating camera.

## References

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