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ANALYSIS OF PARTIAL IRIS RECOGNITION

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ABSTRACT

In this paper, we investigate the accuracy of using a partial iris image for identification and determine which portion of the iris has the most distinguishable patterns. Moreover, we compare these results with the results of Du *et. al.* using the CASIA database. The experimental results show that it is challenging but feasible to use only a partial iris image for human identification.

Keywords: 1D iris identification, partial iris, iris recognition

1. INTRODUCTION

The iris (Fig. 1) is a protected internal organ behind the cornea which gives color to the eye [1]. Ophthalmologists Flom and Safir first noted that the iris is very unique for each person and remains unchanged after the first year of human life [2]. For each person, the left eye is distinctive from the right eye [2]. In 1987, they described a manual approach for iris recognition based on visible iris features. In 1994, Daugman invented the first automatic iris recognition system [3]. Since then, various algorithms have been proposed for iris recognition [3-11], which include Daugman's quadrature 2D Gabor wavelet method [3] and a one-dimensional iris recognition approach [4, 5, 11] by Du *et. al*.

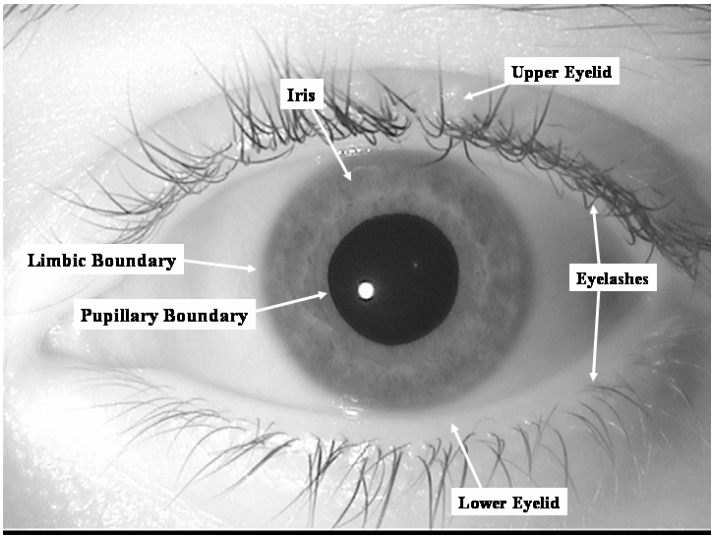


Figure 1: An iris image.

Currently, iris recognition systems require a cooperative subject [12]. Partial iris recognition algorithms would be very important in surveillance applications where capturing the entire iris may not be feasible. Little research has been performed in this area.

In this paper, we investigate the accuracy of using a partial iris image for identification and determine which portion of the iris has the most distinguishable patterns. Moreover, we compare these results against with the results of Du *et. al.* using the CASIA database [13] reported in [14]. The experimental results show that it is challenging but feasible to use only a partial iris image for human identification.

2. PARTIAL IRIS GENERATION

To analyze the partial iris recognition performance, we generated a collection of partial iris images from full iris images. For our experiments, we generated four different kinds of partial iris images. Fig, 2 provides an example, with Fig. 2(a) being the original full iris image. From this image, we created the following:

- Left-to-Right: The “Left-to-Right” model gradually exposes the iris beginning at the left limbic boundary and concluding at the right limbic boundary (Fig. 2(b)).
- Right-to-Left: The “Right-to-Left” model gradually exposes the iris beginning at the right limbic boundary and concluding at the left limbic boundary (Fig. 2(c)).
- Radial Outside-to-Inside: The “Radial Outside-to-Inside” model starts radially at the outer limbic boundary and gradually exposes the iris pattern in concentric rings moving toward the pupil (Fig. 2(d)).
- Radial Inside-to-Outside: The “Radial Inside-to-Outside” model gradually exposes concentric rings beginning radially at the pupillary boundary and concluding at the limbic boundary. (Fig. 2(e)).

The percentage of the iris patterns used in the identification is calculated by:

$$\text{Partial percentage} = \frac{\text{Area of the Partial Iris}}{\text{Total Area of the Iris}} \times 100\% \qquad (1)$$

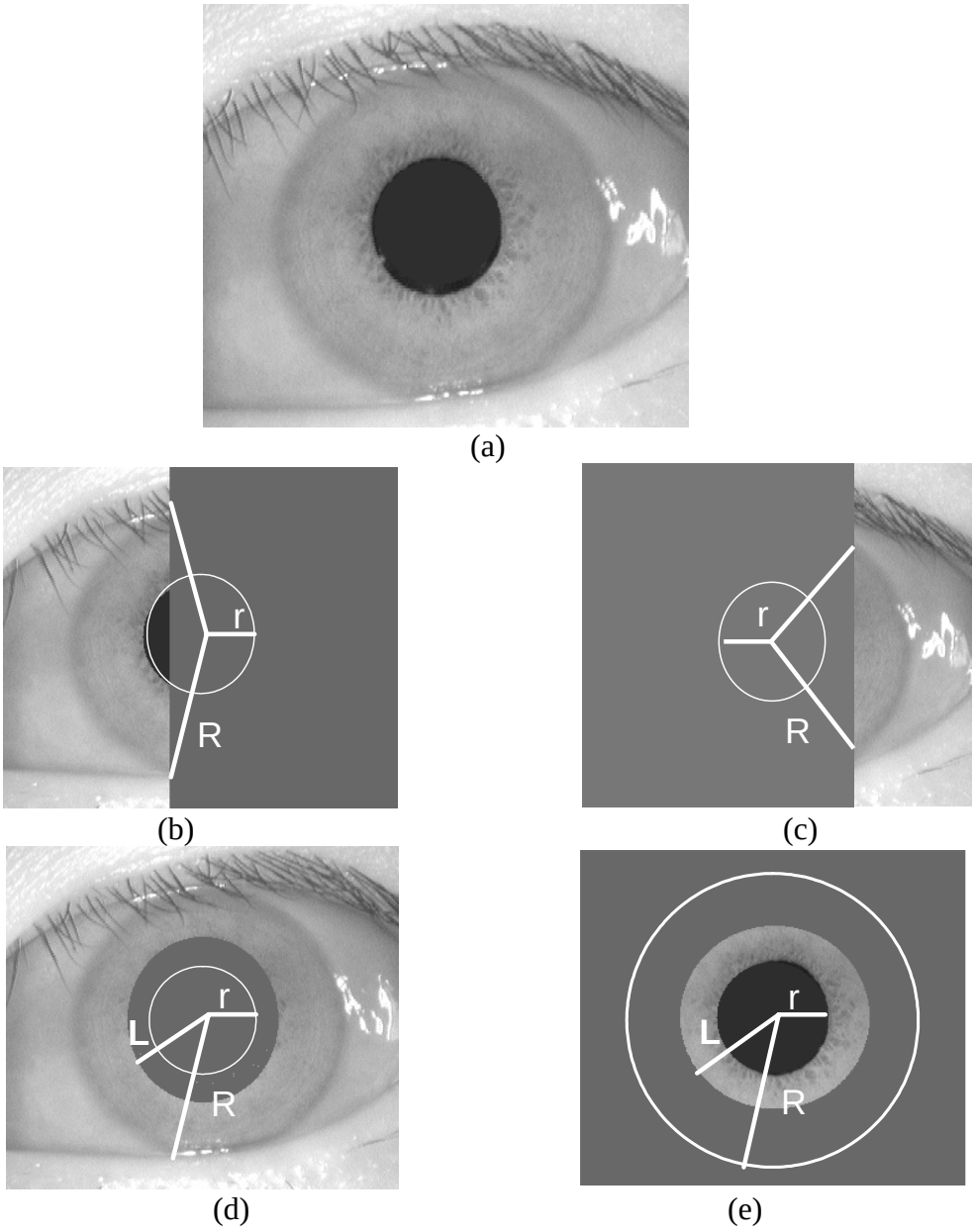


Figure 2. An example of generated partial iris images. (a) The original iris image, (b) Left-to-Right, (c) Right-to-Left, (d) Radial Outside-to-Inside, (e) Radial Inside-to-Outside. (r, R, and L are pupil, limbic, and partial radius respectively.)

With the partial iris images generated in Fig. 2, we can analyze four different kinds of situations:

- Tear Duct-to-Outside: The "Tear Duct-to-Outside" model gradually exposes the iris beginning at the near tear duct side and concluding at the far duct side. For the subject's left eye, This corresponds to the "Left-to-Right" model; for the subject's right eye, it would be the "Right-to-Left" Model.
- Outside-to-Tear Duct: The "Outside-to-Tear Duct" model moves in the inverse direction of the "Tear Duct-to-Outside" model.

- Radial Outside-to-Inside: Uses the "Outside-to-Inside" model for analysis.
- Radial Inside-to-Outside: Uses the "Radial Inside-to-Outside" model for analysis.

3. 1D IRIS IDENTIFICATION ALGORITHM

Fig. 3 shows the 1D Iris Identification System, which is used to analyze potential iris recognition. This algorithm is explained in detail in [4], and the functionality of the block diagram of Fig. 3 is briefly described in the following.

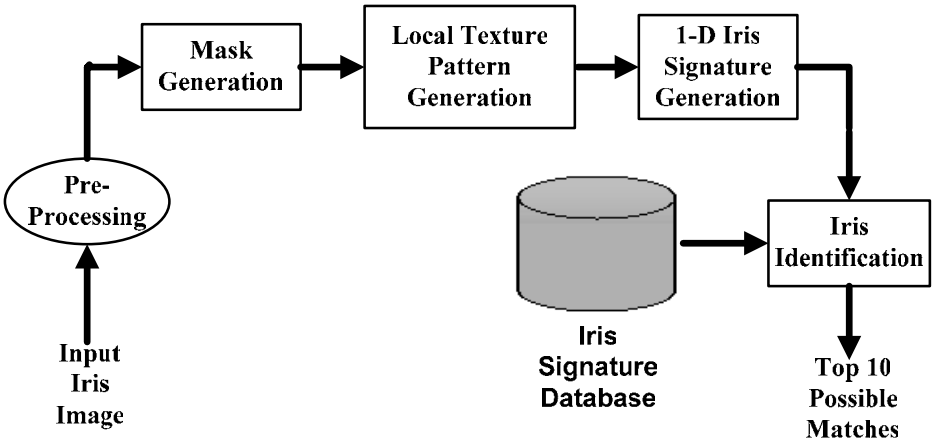


Figure 3. 1D Iris Identification System

The Preprocessing Module finds the pupillary boundary, the limbic boundary, the eyelids, and the eyelashes in the input raw iris image. The Mask Generation Module isolates the iris pixels and normalizes the distance between the limbic boundary and the pupillary boundary to a constant pixel size. The LTP Module generates the local iris patterns by using overlapped windows to calculate the local variances. The Iris Signature Generation Module builds a one-dimensional signature for each iris image by averaging the LTP values of each row. The Iris Signature Database stores the one-dimensional iris signatures in the database. The Iris Identification Module matches the iris signature generated from a newly input iris image with the enrolled iris signatures in the database. The matching score is based on the Du measurement [5]. The output of this module is the ten closest matches from the database.

The merit of this one-dimensional method is that it relaxes the requirement of using a major portion of the iris, which can enable partial iris recognition. In addition, this approach generates a list of possible matches instead of only the best match. In this way, the users could potentially identify the iris by another level of analysis.

The partial iris images are used to produce the iris pattern (signature). For a partial iris image, depending on the percentage of the iris image used it would be very difficult or even impossible to detect the pupil, the limbic boundary, the eyelids and eyelashes. The purpose of the paper is to analyze the partial iris identification performance. Therefore, in this system, we first preprocess the input raw full iris image to identify the iris area and determine pupil center, pupil radius, and limbic radius. In addition, eyelids and eyelashes are detected.

4. EXPERIMENTAL RESULTS

In our database, we have collected 1520 iris images from 106 different eyes. These iris images include those with contact lens and eyeglasses. In this analysis, we only use iris images from bare eyes (iris images without eyeglasses or contact lens). In addition, blurred iris images were eliminated from the experiment. Overall 818 iris images were used, 395 from left eyes and 423 from right eyes.

In this experiment, the accuracy rate for partial iris recognition is defined as:

$$\text{Accuracy rate} = \frac{\text{Number of Correctly Identified Iris Images}}{\text{Total Number of Iris Images Tested}} \times 100\% \tag{4}$$

Here "the correctly identified iris images" means the algorithm correctly placed the iris images within the top 10, or top 5, or top 1 (also called rank 10, rank 5 or rank 1). The testing results coincide with intuition; as more of the iris pattern is available for analysis, the probability of a correct match increases.

Fig. 6 shows the iris identification results for the "Tear Duct-to-Outside" model. Here, the Rank 10 and Rank 5 curves increase sharply until approximately 35% of iris pattern exposure, which is the reflection point of the curves. After this point, the two curves increase very slowly. However, the Rank 1 curves increases gradually and consistently throughout the exposing of the iris patterns. From Fig. 6, we find that exposure of 30% of the iris patterns is good enough to achieve over 95% accuracy for a Rank 10 system and over 90% accuracy for a Rank 5 system; while accurate identification (Rank 1) needs far more information.

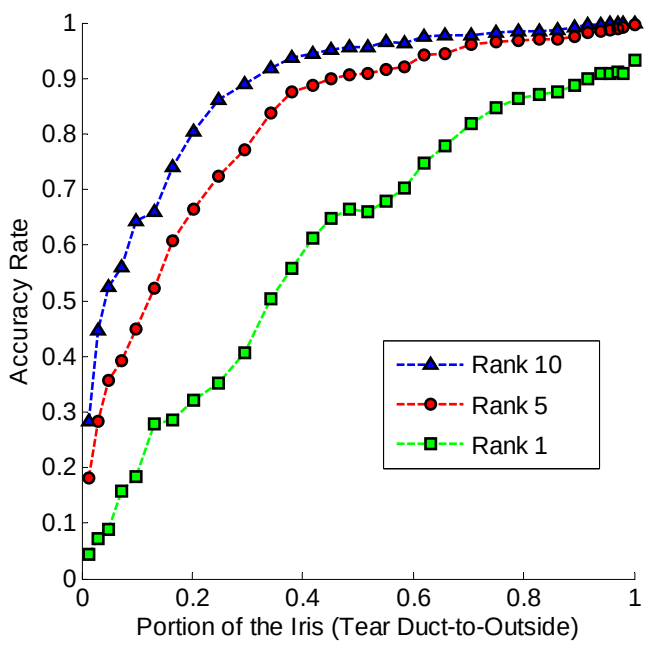


Figure 6. Partial iris identification performance for the "Tear Duct-to-Outside" model.

Fig. 7 shows the iris identification results for the "Outside-to-Tear Duct" model. In Fig. 7, the curves increase gradually and consistently until approximately 40% of iris pattern exposure. The curves remain fairly flat between approximately 40%-60%, correspondingly to regions covered by the eyelids and eyelashes. Once the pupil is fully exposed and more of the iris pattern is again added to the image, the accuracy again increases, as expected.

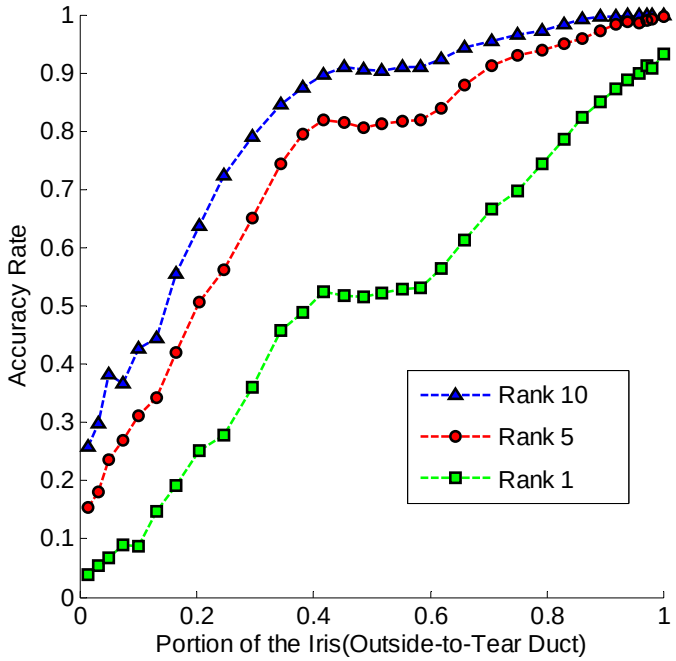
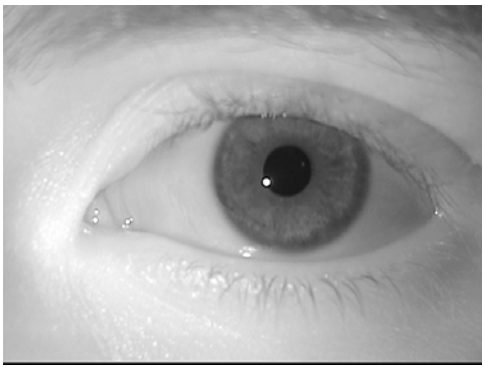


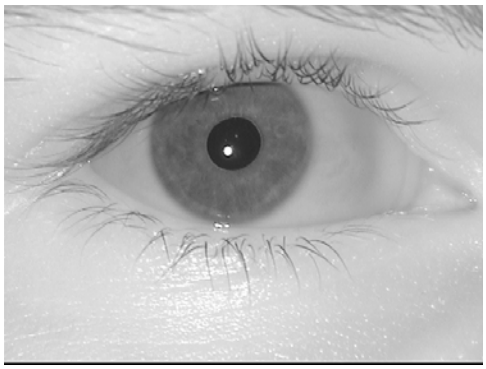
Figure 7. Partial iris identification performance for "Outside-to-Tear Duct" model.

Comparing Fig. 6 and Fig. 7, the Tear Duct-to-Outside model uses a smaller portion of the iris pattern to achieve the same accuracy rate as that of the "Outside-to-Tear Duct" model. For example, to achieve a 90% accuracy rate in the Rank 10 system, the "Tear Duct-to-Outside" model needs 25% while the Outside-to-Tear Duct model needs 45%. For 50% of iris pattern exposed, the "Tear Duct-to-Outside" model can achieve 70% identification (Rank 1) accuracy while the "Outside-to-Tear Duct" model can only achieve 50% accuracy.

The differences between these two models are reasonable and expected. They result from the shape of the eyelids. The eyelids tend to cover more of the Outside half than the Tear Duct side (Fig. 8). From the above analysis, we see that using these iris patterns to do partial identification is more challenging but feasible by using a Rank 10 or Rank 5 system.



(a) A left eye



(b) A right eye

Figure 8. The shape of the eyelids

Because the iris images in the CASIA database do not label the left or right eye and it cannot always be visually determined (some eye images are clipped in the left and right side), we cannot compare the Tear Duct-to-Outside and Outside-to-Tear Duct models. Du *et al.* has used the "Left-to-Right" model to analyze the CASIA database [14]. The "Left-to-Right" model can be looked on as an average of the "Tear Duct-to-Outside" model and the "Outside-to-Tear Duct" model. In the CASIA database, the curve remained steady between approximately 45%-55% exposure. This observation matches the simulation results using our own database.

The performance of partial iris identification for the "Radial Inside-to-Outside" Model is shown in Fig. 9, while the curves for the "Radial Outside-to-Inside" model are shown in Fig. 10. In Fig. 9, the accuracy rate increases much more dramatically than the other methods, and as a result, the "knee" for this model is located at approximately 20% of iris pattern exposure. In Fig. 10, the accuracy rate increases quickly up to 20%, then increases at a slower rate.

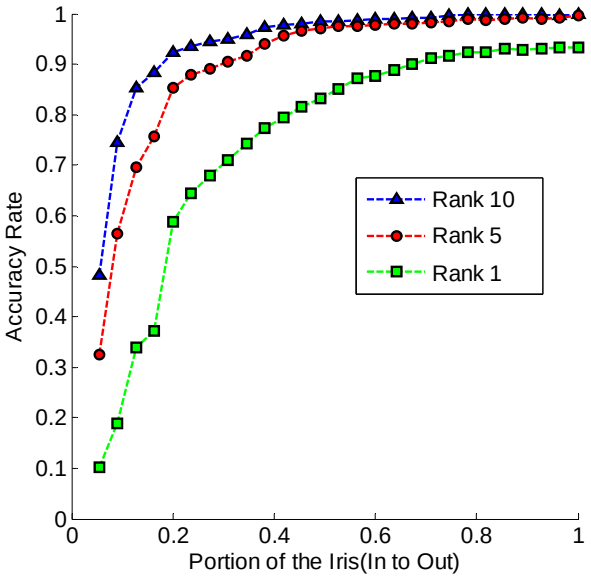


Figure 9. Partial iris identification performance for "Radial Inside-to-Outside" model.

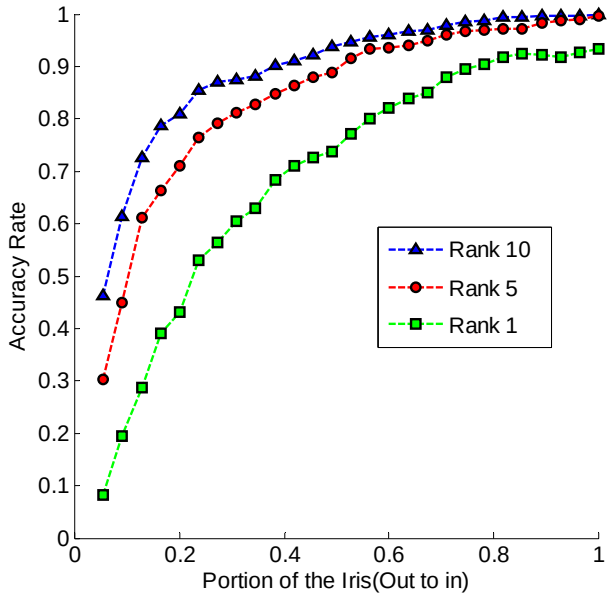


Figure 10. Partial iris identification performance for "Radial Outside-to-Inside" model.

By setting a threshold for acceptance at a 95% accuracy rate (for rank 10 matching), the "Radial Outside-to-Inside" model requires at least 60% of the iris pattern to be present. Conversely, only 25% on the iris pattern needs to be exposed for the "Radial Inside-to-Outside" model to achieve the same accuracy rate. These experimental results support the conjecture that a more distinguishable and individually unique signal is found in the inner rings of the iris.

In all cases (Figs. 6,7,9,10), with 40% of the iris, a 90% accuracy rate can be achieved for rank 10, a 80% accuracy rate for Rank 5, and a 45% accuracy rate for Rank 1. It shows that the partial iris recognition is promising for use in human identification using a rank 10/5 technique. However, it did not perform well enough for rank 1 identification

5. CONCLUSIONS

In this paper, the performance of partial iris recognition is analyzed. The experimental results show that a more distinguishable and individually unique signal is found in the inner rings of the iris. Also, as expected, the experimental results show that the eyelids and eyelashes detrimentally affect the iris recognition result. For surveillance, it is more likely that the eye (away from the tear duct) would be captured. This is the more challenging scenario but the results show that it is still feasible. Finally, the results show that a partial iris image can be used for human identification using rank 5 or rank 10 systems.

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REFERENCES

[1] J. Forrester, A. Dick, P. McMenamin, and W. Lee, *The Eye: Basic Sciences in Practice*, W B Saunder, London, 2001.

[2] L. Flom and A. Safir, United States Patent No. 4,641,349 (issued February 3, 1987), *Iris Recognition System*, Washington D.C.: U.S. Government Printing Office.
[3] J. Daugman, "How Iris Recognition Works", *IEEE Transactions on Circuits and Systems for Video Technology*, Vol. 14, No. 1, pp. 21- 30, 2004.
[4] Y. Du, R. W. Ives, D. M. Etter, T. B. Welch, and C.-I Chang, "One Dimensional Approach to Iris Recognition", *Proceedings of SPIE Volume 5404*, pp. 237-247, Apr., 2004.
[5] Y. Du, R. W. Ives, D. M. Etter, and T. B. Welch, "Use of One-Dimensional Iris Signatures to Rank Iris Pattern Similarities", submitted to *Optical Engineering*, 2004.
[6] R.P. Wildes, J.C. Asmuth, G.L. Green, S.C. Hsu, R.J. Kolczynski, J.R. Matey, and S.E. McBride, "A Machine Vision System for Iris Recognition", *Mach. Vision Application*, Vol. 9, 1-8, 1996.
[7] W.W. Boles and B. Boashash, "A Human Identification Technique Using Images of the Iris and Wavelet Transform", *IEEE Transactions on Signal Processing*, Vol. 46, No. 4, 1998.
[8] Y.-P. Huang, S.-W. Luo, E.-Y. Chen, "An Efficient Iris Recognition System", *the First International Conference on Machine Learning and Cybernetics*, pp. 450-454, 2002.
[9] Y. Zhu, T. Tan, and Y. Wnag, "Biometric Personal Identification Based on Iris Patterns", *15th International Conference on Pattern Recognition*, Vol. 2 , pp. 801 –804, 2000.
[10] L. Ma, Y. Wang, and T. Tan, "Iris Recognition Using Circular Symmetric Filters", *16th International Conference on Pattern Recognition*, Vol. 2 , pp. 414-417, 2002 .
[11] Y. Du, R. W. Ives, D. M. Etter, and T. B. Welch, "One-dimensional Iris Signature for Identification", U.S. Patent Pending, (Navy case number: 96,365), 2004.
[12] Y. Du, R. W. Ives, and D. M. Etter, "Iris Recognition", a chapter on biometrics, *the Electrical Engineering Handbook*, 3rd Edition, Boca Raton, FL: CRC Press, 2004 (in press).
[13] CASIA Iris Image Database, http://www.sinobiometrics.com
[14] Y. Du, B. Bonney, R. W. Ives, D. M. Etter, and R. Schultz, "Partial Iris Recognition Using a 1-D Approach: Statistics and Analysis," *IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP)*, May 2005.