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 against 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.

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 [3]. For each person, the left eye is distinctive from the right eye [3]. In 1987, they described a manual approach for iris recognition based on visible iris features. In 1994, Daugman invented a first automatic iris recognition system [2]. Since then, various algorithms have been proposed for iris recognition [3-10], which include Daugman’s quadrature 2D Gabor wavelet method [2] and one-dimensional iris recognition approach [4, 5, 13] by Du et. al.

Figure 1: An iris image.
Currently, iris recognition systems require a cooperative subject [11]. 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 [14] reported in [15]. The experimental results show that it is challenging but feasible to use only a partial iris image for human identification.

2. PARTIAL IRIS

To analyze the partial iris recognition performance, we synthetically generated partial iris images. Fig. 2(a) is an example iris image. The Partial Iris Generation Module will select a portion of the iris based on a particular experiment. In our experiments, we synthetically generate four different kinds of partial iris images:

- **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. 3(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. 3(c)).
- **Outside-to-Inside**: The “Outside-to-Inside” model starts at the outer limbic boundary and gradually exposes the iris pattern in concentric rings moving toward the pupil (Fig. 3(d)).
- **Inside-to-Outside**: The “Inside-to-Outside” model gradually exposes concentric rings beginning at the pupillary boundary and concluding at the limbic boundary. (Fig. 3(e)).

The percentage of the iris patterns used in the identification is calculated differently for these three different approaches.

For Fig. 2(b)-(c), the percentage is calculated by:

\[
\text{Partial percentage} = \frac{\text{Area of the Partial Iris}}{\text{Total Area of the Iris}} \times 100\% 
\]

(1)

for Fig. 2(d),

\[
\text{Partial percentage} = \frac{R-L}{R-r} \times 100\% 
\]

(2)

for Fig. 2(e),

\[
\text{Partial percentage} = \frac{L-r}{R-r} \times 100\% 
\]

(3)

Where r, R, and L are defined as shown in Fig. 2.
Figure 2. An example of generated partial iris images. (a) The original iris image, (b) Left-to-Right, (c) Right-to-Left, (d) Outside-to-Inside, (e) 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 left eye, it would be “Left-to-Right” model; for the right eye, it would be “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.
- Outside-to-Inside: Uses the “Outside-to-Inside” model for analysis.
Inside-to-Outside: Uses the “Inside-to-Outside” model for analysis.

3. 1D IRIS IDENTIFICATION ALGORITHM

Fig. 3 shows the 1D Iris Identification System. This system is comprised of the following modules: the Preprocessing Module, the Mask Generation Module, the LTP Module, the Iris Signature Generation Module, the Enrollment Module, the Iris Identification Module, and the Iris Signature Database Module.

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 constant pixels.

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 inside the database. The matching score is based on the Du measurement [5]. The output of this module is the 10/5/1 closest matches from the database.

The merit of this one-dimensional method is that it relaxes the requirement of using a major part 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 image by another level of analysis.

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 eye-glasses. In this analysis, we only use iris images from bared eye (iris images without eye glasses 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.

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 will be very hard 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 iris image and identify the iris area to determine pupil center, pupil radius, and limbic radius. In addition, eyelids and eyelashes are detected.

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

\[
\text{Accuracy rate} = \frac{\text{Number of Correctly Identified Iris Images}}{\text{Total Number of Iris Images Tested}} \times 100\% \quad (4)
\]

Here “the correctly identified iris images” means the algorithm correctly placed the iris images within the rank 10/5/1 ranks. The testing results coincide with intuition; as more of the iris pattern is available for analysis, the probability of correct match increases.

Fig. 6 shows the iris identification results for the “Tear Duct-to-Outside” model.

![Figure 6. Partial iris identification performance for the “Tear Duct-to-Outside” model.](image)

In Fig. 6, 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 reflection point, the two
curves increase very slowly. However, the Rank 1 curves increases gradually and consistently through out the exposing of the iris patterns. From Fig. 6, we find that exposure of 30% of the iris patterns will be 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) will need far more information.

![Figure 7](image.png)

**Figure 7.** Partial iris identification performance for “Outside-to-Tear Duct” 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 steady 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 percent change that the test case matches the original increases, as expected.

Comparing Fig. 6 and Fig. 7, the Tear Duct-to-Outside model uses much lesser portion of the iris pattern to achieve same accuracy rate as that of the Outside-to-Tear Duct model. For example, if we want to achieve 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, Tear Duct-to-Outside model can achieve 70% identification (Rank 1) accuracy while the Outside-to-Tear Duct model can only get 50% accuracy.
The differences between these two models are reasonable and expected. They are resulted 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.

Because the iris images in the CASIA database do not label the left or right eye, 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 [15]. 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 “Inside-to-Outside” Model is shown in Fig. 9, while the curves for the “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 fast before 20%, but the curve continues to increase.

![Figure 9. Partial iris identification performance for “Inside-to-Outside” model.](image)
By setting a threshold for acceptance at a 95% accuracy rate (for rank 10 matching), the “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 “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.

From Figs. 6-7 and 8-9, we can also see that using only 40% of the iris can achieve more than 90% accuracy rate for rank 10, 80% accuracy rate for Rank 5, and 45% 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 would be very challenging to use in 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.

6. ACKNOWLEDGEMENT

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7. REFERENCES


CASIA Iris Image Database, http://www.sinobiometrics.com