Impact of Resolution and Blur on Iris Identification

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Abstract

Iris recognition is increasingly employed as a biometric modality to improve the security across the government, public, and private sectors; however, the limitations of iris recognition are yet to be fully understood. Several approaches have been previously proposed that allow performing a reliable identification of a person based on iris information. However, resulting iris identification systems are limited in their ability to correctly identify a person because of the imperfectly acquired iris images. Two iris image properties – resolution and blur - significantly impact the identification performance. The impact of these two iris image properties on correct recognition rates have been explored and summarized in this work in an attempt to provide clarity for challenges related to iris biometrics.

1. Introduction

As the level of security breaches and transaction fraud increases, the need for highly secure identification and personal verification technologies is becoming apparent. This need for biometrics can be found in federal, state, and local governments, in the military, and in commercial applications. It is clear that every entity which provides access to private information can greatly benefit from a secure identification and personal verification system.

Many systems have been proposed as a solution for such a need including but not limited to fingerprinting, palm printing, vascular pattern recognition, hand geometry, dynamic signature, voice recognition, facial recognition, and iris identification [1].

1.1. Motivation of Iris Identification

In order for a human characteristic to be used as a biometric, it must meet specific criteria. Any potential biometric characteristic is analyzed against the biometric rubric. This rubric consists of qualifiers: universality (each person should have the characteristic), uniqueness (how well the characteristic separates individuals), permanence (how well the characteristic resists aging and other time dependent variances), collectability (ease of acquisition for measurement), performance (accuracy, speed, and robustness of the technology used), acceptability (degree of approval of a technology), and circumvention (ease of use of a substitute for the characteristic) [2].

Irises are perceived to be one of the best characteristics to use as a biometric trait because the error rate of iris recognition is one of the lowest among known biometric traits [3]. Majority of people have two irises from birth until death. No two irises are considered to be the same [3]. Irises can contain many distinctive features such as arching ligaments, furrows, ridges, crypts, coronas, freckles, and zigzag collarets [4]. The iris has the great mathematical advantage that its pattern variability among different persons is enormous [5]. Irises remain stable from six months of age until death [6]. Since the iris is an internal organ that can be seen externally, iris identification systems can be noninvasive [5]. Burch's initial proposal of using the iris as a pattern for identification has become a reality [6]. The iris pattern is considered to be difficult to reproduce [7], however even commercial iris recognition systems have frequently accepted reproduced irises as legitimate irises [8].

Regardless of the contemporary research on iris recognition, important questions regarding robustness of iris identification in various usability scenarios remain. Among those there are questions concerning the limitations of iris identification for cases of extreme degradation of image quality. The objective of this paper is to provide a better understanding of the impact of captured iris dimensions and image blur on corresponding identification accuracy.

1.2. Related Work

Many solutions have been proposed for answering the demand for an iris identification system. Improvements have been proposed to these systems in an attempt to optimize their performance. However, precious little is written concerning some of the limitations associated with all iris identification systems, namely image resolution and image blur.

Although the non invasive nature and high variability of irises make them a promising biometric, high quality photographs with high resolution and good contrast are needed for today's iris identifying algorithms to perform well. This is not a problem if the iris is photographed at very close range with a cooperative subject, but if the subject is farther away and possibly even walking, photographing the iris for identification becomes more challenging [9].

According to Daugman, a minimum radius of 70 pixels (140 pixel diameter) is required in order to capture the rich details of the iris pattern [10]. However, ISO/IEC has set the standard of a required minimum 200 pixel diameter across the iris for high quality iris images [10]. Hollingsworth's research in how dilation of the pupil affects biometric performance suggests that the diameter of the iris is an inadequate way to measure the total amount of iris available. She asserts that the annular width of the iris is a more correct measure of the iris size [11].

Algorithms have been proposed to de-blur images [12]. These algorithms are employed when an image is found to be sufficiently blurry, cannot be re-acquired, and whose correct iris identification is less than sufficient. Some proposals are designed to select the best quality iris image from a set of images [13]. Studying the effect of severe image compression on iris recognition performance has been pursued [14]. The compressed images may be perceived to be blurred although there is a significant difference between a blurred image and a compressed image. To the best of our knowledge, there is no published work that investigates in detail the relationship between image blur and correct iris recognition.

2. Objectives

The objective of this research is to investigate the relationship between: 1) Image Resolution and Identification Performance and 2) Image Blur and Identification Performance.

3. Methodology

Four components are required to test the effect of the iris size and image blur on iris recognition rates: 1) An iris database 2) Correct recognition rate definition 3) The ability to alter the image resolution 4) The ability to alter image blur 5) Iris identification software.

3.1. Iris Database

The UBIRIS.v1 database [15] was selected among other databases (CASIA-IrisV3-Interval [21], MMU iris [22], etc.) because it provides high quality iris images with minimized noise factors and is widely accepted among iris recognition researchers.

3.2. Correct Recognition Rate Definition

Correct Recognition Rate (CRR) was defined as a true accept rate [20] of a biometric system.

3.3. Image Resolution

Our goal was to test iris image resolution requirements. In order to define the effect of image resolution on iris recognition, several datasets of varying iris image resolutions were created. The initial dataset was simply the raw first session recorded UBIRIS.v1 database. This dataset was then copied twelve times. The resolution of each copy's iris images were then decreased. Microsoft Office Picture Manager was used to alter image resolution. Microsoft Office Picture Manager allows the resolution of multiple images in multiple folders to be changed simultaneously.

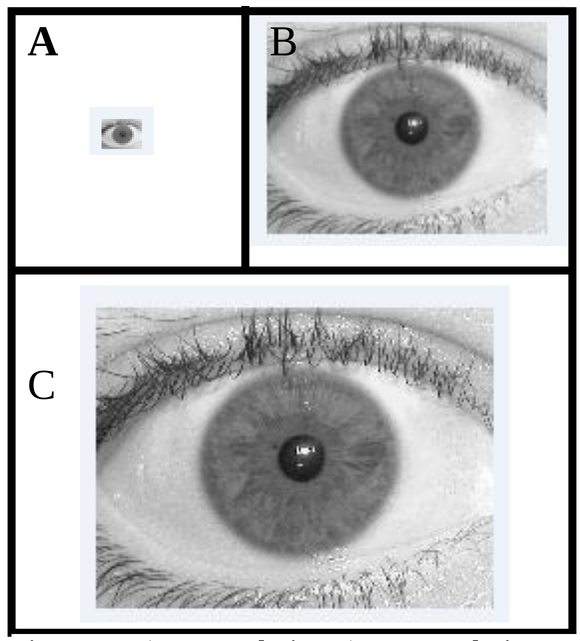

Figure 1 : A) 1% resolution B) 50% resolution C) 100% resolution

The above iris resolutions were created starting with a very small resolution and reaching maximum available size. Table 1 presents tested resolution levels.

Iris Annular Width	Sample Iris Diameter	Image Width	Image Height	Pixels
3	8	20	15	300
7	20	45	34	1530
10	28	63	47	2961
14	40	89	67	5963
17	49	110	82	9020
19	56	126	95	11970
22	63	141	106	14946

24	69	155	116	17980
26	75	167	125	20875
28	80	179	134	23986
29	85	190	142	26980
31	90	200	150	30000

Table 1: Iris Image Resolution Information

3.4. Image Blur

Our goal was to blur the image in the same way as done by an out of focus camera. In photography, bokeh is the blur or aesthetic quality of the blur [16, 17]. Bokeh can be simulated by convolving the image with a kernel that corresponds to the image of an out-of-focus point source taken with a real camera. Gaussian blur is less computationally expensive and produces a softer effect than convolution.

The Gaussian blur filter uses a Gaussian function for computing the alteration applied to each pixel. The equations of a Gaussian function in one and two dimensions:

Equation 1: 1-Dimensional

$$G(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2}{2\sigma^2}}$$

Equation 2: 2-Dimensional

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

In order to apply a Gaussian function to an image, a C++ program was developed that can apply a Gaussian blur to multiple images in multiple directories. Librow's Gaussian filter implementation was used [18]. This filter is based on a *window*. As the window size increases, so does the blur.

To produce the largest possible blur for our database, we searched for the lowest window size corresponding to a CRR of 0%. We found that the lowest window size which produced a CRR of 0% was 85 (σ=85). The window size of 0 represents 0% blur which corresponds to the original dataset. Twenty-six unique window sizes were selected between those extreme points to represent the whole range of possible blur levels. A dataset was created for each of the 26 selected window sizes. Table 2 presents tested blur levels.

Window Size (σ)	% Blur
0	0.00%
1	1.18%
3	3.53%
5	5.88%
7	8.24%
9	10.59%
11	12.94%
13	15.29%
15	17.65%
17	20.00%
21	24.71%
25	29.41%
33	38.82%
39	45.88%
43	50.59%
47	55.29%
51	60.00%
59	69.41%
61	71.76%
65	76.47%
67	78.82%
71	83.53%
77	90.59%
81	95.29%
83	97.65%
85	100.00%

Table 2: Iris Image Blur Information

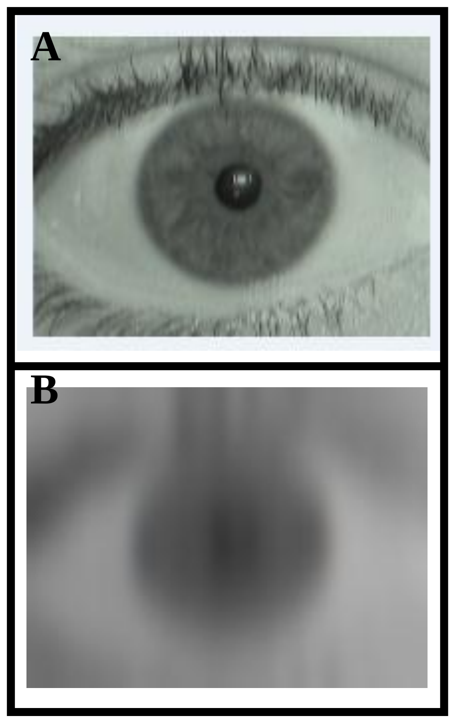

Figure 2: A) Window size 9
B) Window size 85

3.5. Iris Recognition Software

The software suite that was selected was GIRIST, a free iris recognition system [19]. GIRIST performs comparably to the commercial systems deployed today [23]. GIRIST is able to compute CCR to assess accuracy of identification.

GIRIST produces 96.8% CRR on average when tested on the following databases: CASIA-IrisV3-Interval [21], UBIRIS.v1 [15], MMU iris [22].

4. Results

4.1. Resolution Impact

Figure 3 presents CRR results for the iris resolutions represented by Table 1.

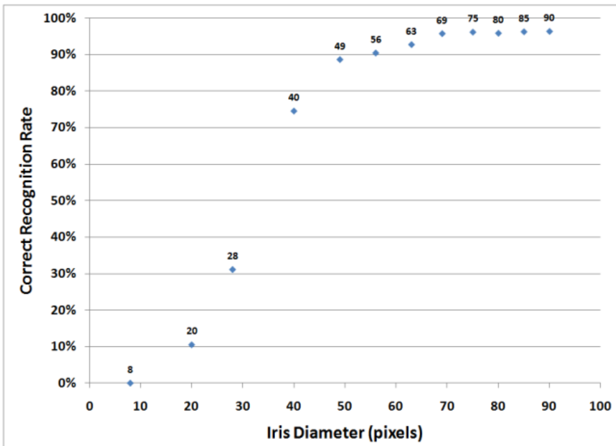

Figure 3: Correct Recognition Rate as a function of Iris Diameter

The CRR decreases sharply when iris diameter approximately becomes 70 pixels (Figure 3). The next drop off point occurs at sample iris diameter 49. These saturation points are important because increasing beyond the resolution suggested by those points does not seem to provide a substantial increase in identification accuracy.

4.2. Resolution Impact

Figure 4 presents CRR results for the iris blur represented by Table 2.

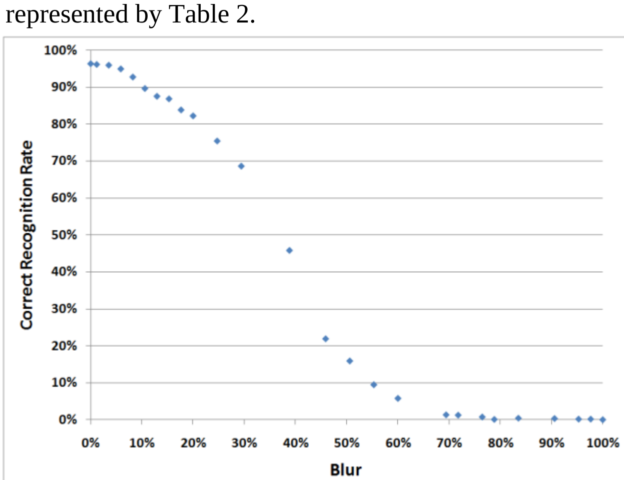

Figure 4: Correct Recognition Rate as a function of Gaussian Blur Window Size

Figure 4 shows that as blur increases, CRR decreases. CRR only drops ~1.5% as blur increases from 0% to 5%. The recognition rate decreases linearly as blur increases from 10% to 30% (~10% blur ≈ ~90% CRR, ~20% blur ≈ ~80% CRR, ~30% blur ≈ ~70% CRR). A big drop occurs near 30% blur. Unfortunately, this drop is not extremely significant because the CRR has already decreased substantially and therefore the behavior past this point is trivial.

This graph demonstrates very clearly that it is possible for researchers to sacrifice a small amount of blur on the entire image in an attempt to reduce the image's high frequency components.

5. Limitations

5.1. Image Blur

The Gaussian blur is an emulation of depth of field blur found in common photographs, and thus the inferences we may make from this research may not pertain to all blur situations. Therefore further research is necessary to define the relationship between motion blur and correct iris identification.

5.2. Iris Recognition Software

GIRIST was selected largely because of its performance and its availability. While it is not open source, the executable is free. No other iris recognition software was used to corroborate our results. Other iris recognition software may produce different results.

5.3. Image Database

A single database was used in this research [15]. Therefore the limits are limited to this single database. For example, the diameters of the irises in these images are around 90 pixels. We are limited by this maximum resolution. The behavior of CRR for iris diameters above 90 pixels is unknown. Another example is that the images contained within this database are not color. The effect of color images is unknown.

6. Conclusion & Future Work

Iris recognition is increasingly employed as a biometric modality to improve the security across the government, public, and private sectors; however the limitations of iris recognition are yet to be fully understood. This work explored the impact of image resolution (with corresponding iris width) and image blur on correct recognition rates.

Results received as a part of the iris resolution investigation indicate the iris width may be significantly smaller than what was previously perceived to provide acceptable levels of recognition. The image resolution analysis saturation points provide evidence that resolution may be sacrificed at the expense of perhaps a more economical camera, a more portable camera, a more convenient camera such as a webcam, or data storage. Though saturation points are apparent in the preceding data, it is uncertain whether there are further saturation points at increasing resolution levels. This necessitates further research into the relationship between image resolution and correct iris identification.

Quantitative analysis indicates that a small amount of blur can be employed to reduce potential image noise without losing a significant amount of identification accuracy.

We feel that the presented results are useful for the practitioners that use iris-identification systems because they allow better understanding of the limitations and capabilities or such systems.

Additional research should be conducted to understand the impact of different types of blur including motion blur, resolution degradation on a wider range of iris recognition techniques, and image databases.

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