A New Biometric Database Based on Corneal Topography

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Introduction

Biometrics refers to identity recognition of persons according to their physical or behavioral characteristics. Many physical body parts and personal features have been used for biometric systems: fingers, hands, feet, faces, irises, retinas, ears, teeth, veins, voices, signatures, typing styles, gaits, odors, and DNA. Person recognition based on biometric features has attracted more attention in designing security system. In this paper we propose a new biometric database based on corneal topography. The cornea is the outer transparent part of the eye, and covers nearly a fifth of the eyeball surface, with an average diameter of 11 mm (see Figure 1). Corneal topography is a non-invasive medical imaging technique to assess the shape of the cornea in ophthalmology. Figure 2 shows typical corneal topographies (images) of the anterior surface elevation from 2 different subjects. These images (a.k.a. elevation maps) show the measured height with respect to a reference (best-fit) sphere with pseudo-colors where warm colors depict points higher than the sphere and cool colors correspond to lower points. One can easily see that these maps are different from one individual to the other (uniqueness). The idea of using this physical characteristic for biometrics also comes from its long-term stability of many years (permanence).

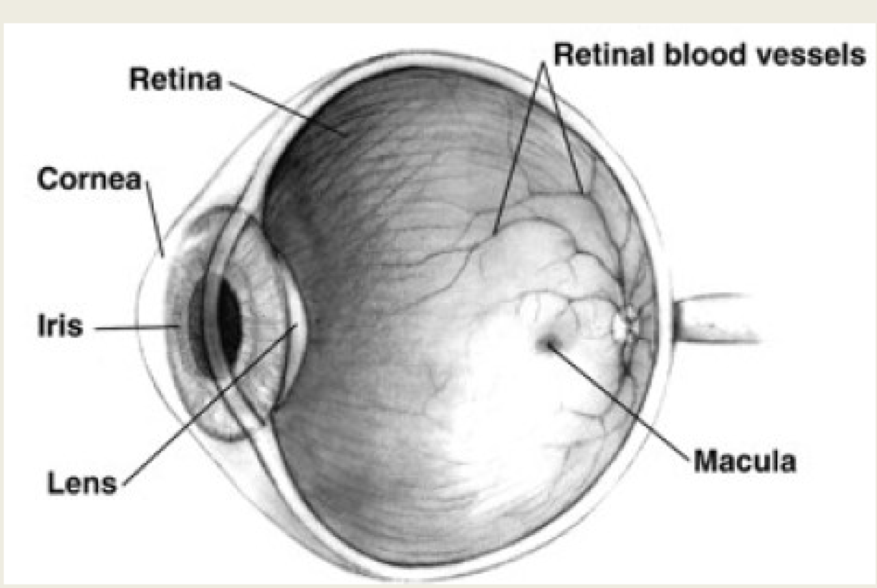

Figure 1: Sectional view of the eyeball [National Eye Institute – NEI]

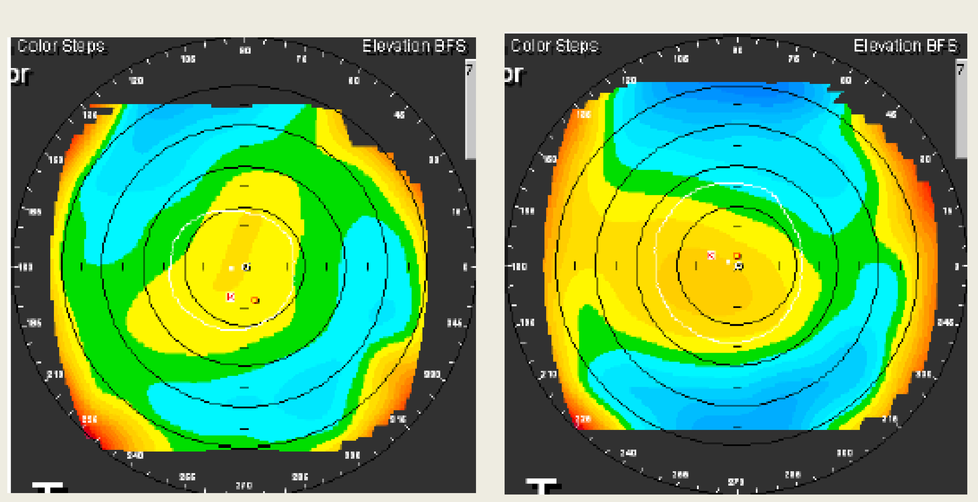

Figure 2: Typical topographies of 2 individuals (anterior surface elevation maps).

Aim

Our goal is to use cornea as a new biometric trait for identity authentication by modeling its 3D geometry. For this reason, we propose to realize a new corneal biometric database.

Materials & Methods

The database was done at the Department of Ophthalmology, Maisonneuve-Rosemont Hospital, Montreal, by using a Pentacam Topographer (Oculus) see Figure 3. The Pentacam measurement process takes less than two seconds and minute eye movements are captured and corrected simultaneously. By measuring 25,000 true elevation points, precise representation, repeatability and analysis are guaranteed. The data points are then used to generate corneal maps used for diagnosis and treatment. Our Database contains 312 corneal topographies captured from 39 different people of different ages using a both eyes. For each eye, we captured two sessions of corneal topography. The time interval between the two sessions was equal or greater than one month. In each session; 8 corneal topographies (4 left eyes end 4 right eyes) were captured. The corneal shape was recorded as a uniformly spaced (X-Y) grid (image) of raw elevations (Z). This elevation can be represented with an appropriate mathematical model such as a Zernike polynomial expansion.

Figure 3: Pentacam Topographer Acquisition

The Zernike polynomials are a set of functions $Zn\pm m\ \rho,\theta$ that are orthonormal over the continuous unit circle. They have been used extensively for phase contrast microscopy, optical aberration theory, and inter ferometric testing to fit wave-front data. These functions are characterized by a polynomial variation in the radial direction ρ (for $0 \le \rho \le 1$) and a sinusoidal variation in the azimuthal direction θ. The polynomials are defined mathematically by

$$Z_n^{\mp m} = \begin{cases} \sqrt{2(n+1)}R_n^m(\rho)\cos m\theta\ for\ +m \\ \sqrt{2(n+1)}R_n^m(\rho)\sin m\theta\ for\ -m \\ \sqrt{(n+1)}R_n^m(\rho) \qquad for\ m=0 \end{cases} \qquad (1)$$

$$R_n^m(\rho) = \sum_{s=0}^{\frac{n-m}{2}} \frac{(-1)^s (n-s)!}{s!\left(\frac{n+m}{2}-s\right)!\left(\frac{n-m}{2}-s\right)!}\rho^{n-2s} \qquad (2)$$

Results & Discussion

Our proposed Database was tested for person recognition. The corneal height data were decomposed into a linear combination of the Zernike functions, we took the first 36 Zernike coefficients as a feature vector for one cornea. To show if corneal topography can be a good biometric alternative, two sets of comparison were processed, 741 matching comparisons (same subjects) and 1092 non-matching-comparisons (different subjects) by computing the absolute difference (AD) between all Zernike coefficients. Figure 4 shows the mean AD for each coefficient for the two tests. The more the difference between green (same subjects) and red bars (different subjects) for a particular coefficient, the more this coefficient is selective for a biometric application. The figure clearly shows the potential of Zernike coefficients for biometrics and that some coefficients are more discriminating than others. This is also coherent with the work of N.D. Lewis (PhD thesis 2011, U. of Arizona). In the future, we plan to use this database to identify the best combination of the most informative coefficients, e.g. with Linear Discriminant Analysis (LDA), for biometric applications.

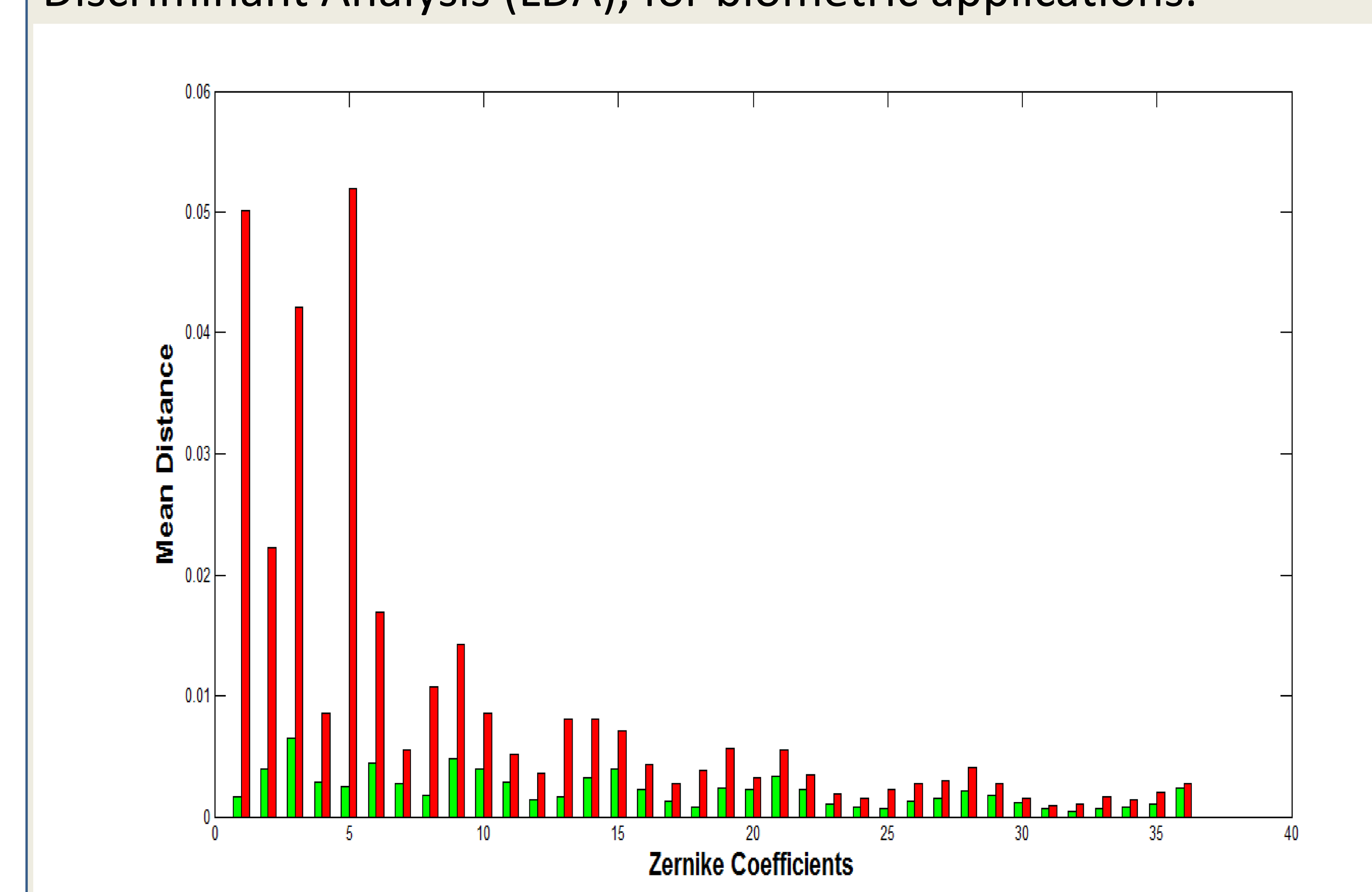

Figure 4: Mean difference for each Zernike coefficients within (green) and between (red) classes.

Conclusion

The objective of this work was to investigate corneal topography as an accurate biometric modality using shape discriminating features. The results obtained confirm that corneal topography could be an effective biometric method.

Acknowledgements

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