Isolating Iris Template Ageing in a Semi-controlled Environment

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Abstract

Apparent template ageing effects are often attributed to changes during acquisition rather than the natural ageing of the iris. In this paper we attempt to remove apparent ageing effects by using a semi-controlled environment (selecting a best subset from a larger database) and controlling as many factors as possible in the biometric tool-chain. This includes manual segmentation and the use of a non-linear biomechanical model to alleviate influence of pupillary dilation on the results.

Main Results

- AGESEG database, as a subset of CASIA v5 with segmentation ground truth: `http://wavelab.at/sources/Hofbauer16d`
- There is apparent template ageing. Segmentation is not the problem.
- There is a change in pupillary dilation. Normalization based on a biomechanical model cannot fix it.

The Casia Iris Ageing Database

The database is a subset of the upcoming CASIA v5.0 Iris Database. The user images are from video recordings of both eyes and span four years (2009 and 2013).

Based on

P. Wild, J. Ferryman, and A. Uhl, "Impact of (segmentation) quality on long vs. short-timespan assessments in iris recognition performance," *IET Biometrics*, vol. 4, no. 4, pp. 227–235, 2015

and their quality based assessment of the database we chose the following userse and sessions

- 2009: We based the selection of users on session 1 (images without glasses).
- 2013: Again we used the session without glasses.

We still had to remove some individuals as follows:

- 0023,1067: No data for user in 2009.
- 1004: No images without glasses in 2013.
- 0190,0191: No data in 2013.

The database originally contained 120 images from an video sequence per eye (2009) and 20 images from a video sequence per eye (2013).

Since the images are from a video sequence of the eyes, temporal proximity resulted in almost equal images. Keeping in mind that manual segmentation would be performed, we chose ten images per eye, spaced apart as fas as possible in the temporal domain. Images in which large parts of the iris were occluded by the eyelids due to blinking were eliminated.

The resulting database consists of 47 users with two eyes per user for a total of 1880 images. There are 10 images per eye and year. The manual segmentation is done by a single Operator 'A' (*OpA*).

The inner and outer iris boundaries are segmented using elliptical boundaries and the lower and upper eyelids use polynomial boundary.

Database—Acquisition Effects

Before we begin the experimental analysis of the database let us first consider a number of other circumstances which can lead to apparent template ageing. The objective is to minimize external influence which could lead to ageing-like results, within the possibilities determined by working with a fixed database.

Specifically the following possible influences were considered.

- *Rotation* see Figure 2. This is compensated for in all tests.
- *Sensor ageing* is not an effect with any significant influence as shown by Bergmüller *et al.* [2]. The database they used for their research is a superset of the database we are using, so the results clearly apply. They extracted an ageing model of the sensor based on the four-year gap and applied the effects of an artificial sensor-ageing to the images, which produced a negligible influence for up to 96 years of sensor-ageing.
- The *obfuscation of the iris by the eyelid*, due to blinking or similar effects, was minimized by selecting images from the database where this did not occur.
- *Obfuscation of the iris by glasses*, which might introduce additional reflections and distortions, was prevented by choosing images of subjects without glasses from the database.
- The *recording conditions* seem relatively stable over the two yeara, mainly a 1-bit shift is visible. Figure 1 shows the two histograms.
- There are some *blurring effects*, presumably due to the recording modalities and motion, as well as visible interlacing. These effects appear in both the 2009 and the 2013 images and thus introduce no clear bias towards either.

  The biometric quality is considered good since we used the analysis by Wild *et al.* [1] as a guide to select the subset. Regarding image quality, utilizing BRISQUE a no-reference image quality assessment tool from Mittal *et al.* [3], we get a very similar range of qualities for both years. For 2009 we get average $\mu_{09} = 57.800$ and standard deviation $\sigma_{09} = 18.288$ while for 2013 we have $\mu_{13} = 58.960$, $\sigma_{13} = 18.254$.

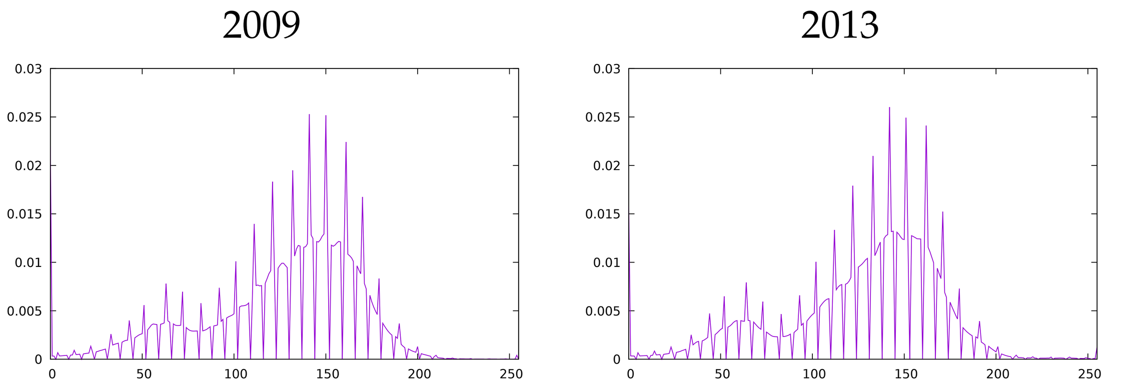


Figure 1: Aggregate histogram of 2009 and 2013. The overlap coefficient between the aggregate histograms of 2009 and 2013 is 73.13% (no shift) and 94.83% (correcting the 1-bit shift).

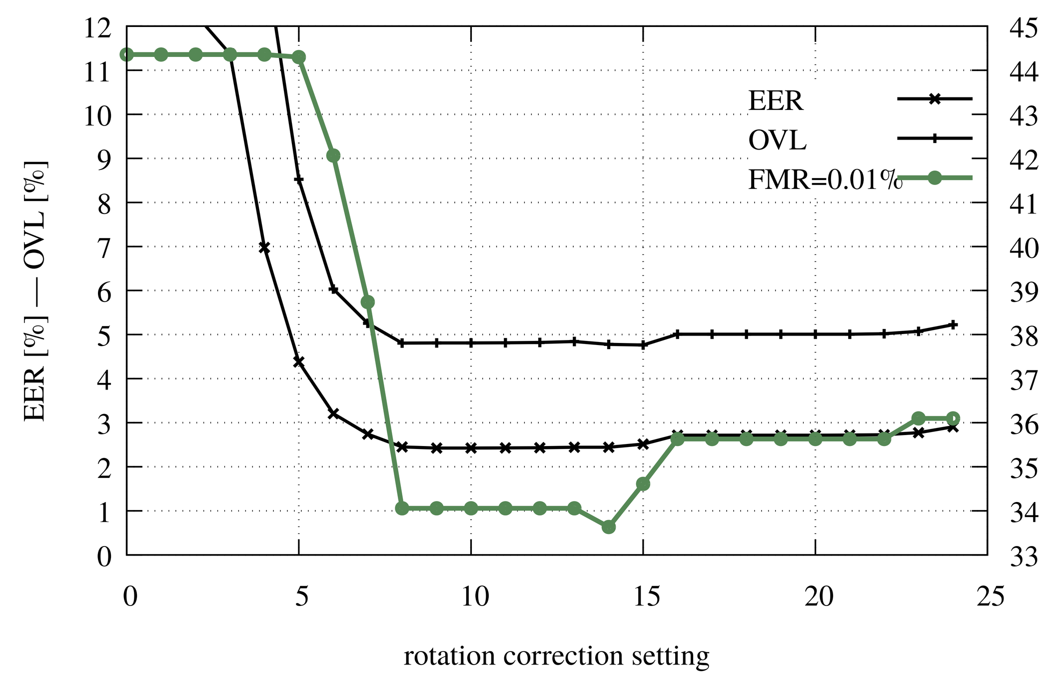


Figure 2: Rotation compensationi is set to to ±14 bits,i.e.,the rotational range in the database is approximately in the range ±10°.

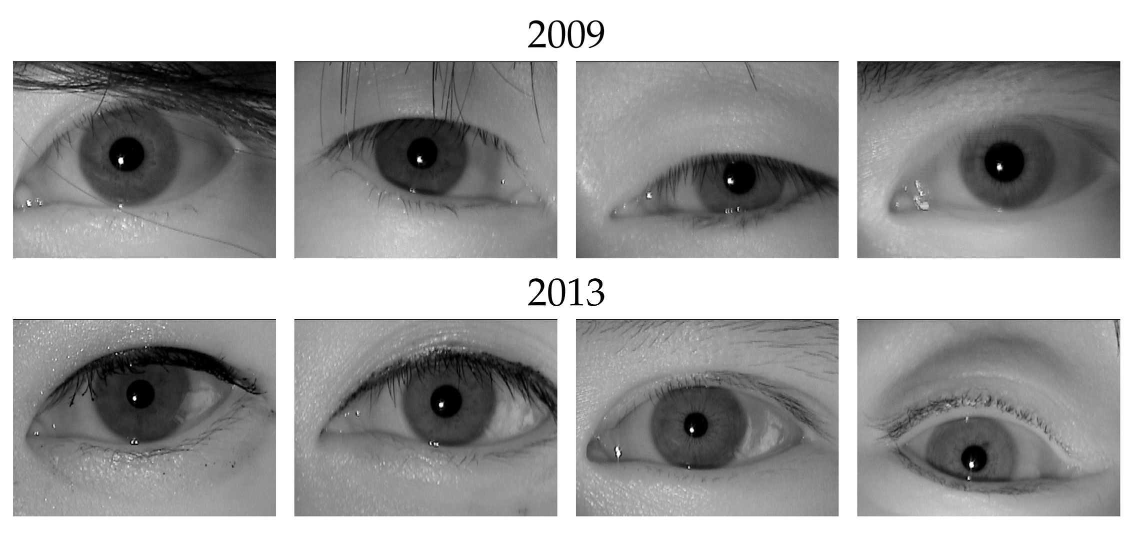


Figure 3: Range of image quality from 2009 and 2013.

Apprent Ageing and Segmentation

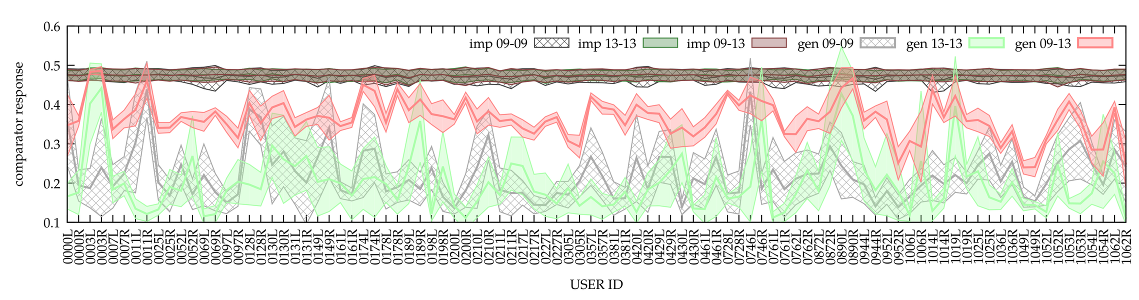
- USIT `caht` and `manual` segmentations with `lg` features.
- Commercial segmentation and features extraction method (Neurotec Verieye).
- Comparison for each year (in-year tests) and between years 2009 and 2013 (inter-year test).

→ If there is template ageing the in-year tests should show clearly better performance than the inter-year test.

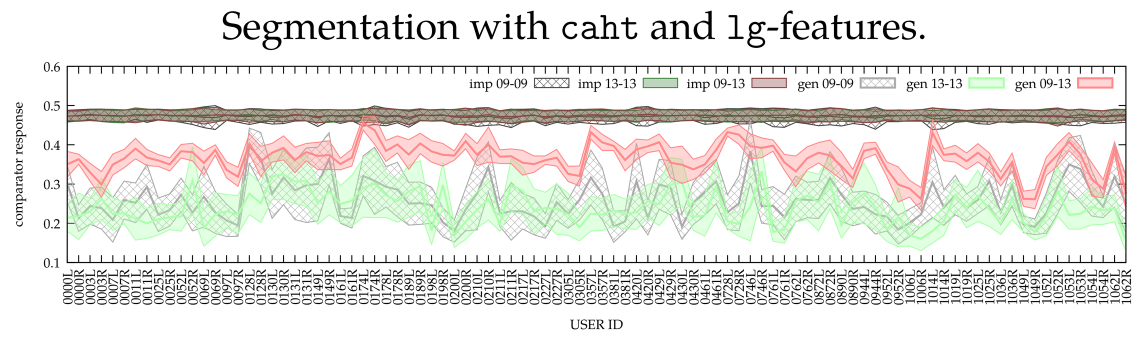
	Manual		caht		Verieye	
comparison	EER [%]	OP 0.01 [%]	EER [%]	OP 0.01 [%]	EER [%]	OP 0.01 [%]
2009–2009	2.512	13.197	4.184	9.722	1.346	2.458
2009–2013	3.531	55.442	8.810	56.722	1.678	3.864
2013–2013	0.312	1.532	5.135	6.327	0.709	0.709

In- and inter-year performance given as equal error rate (EER) and the FNMR at operation point FMR=0.01% (OP 0.01). VeriEye by Neurotechnology uses its own segmentation and features.

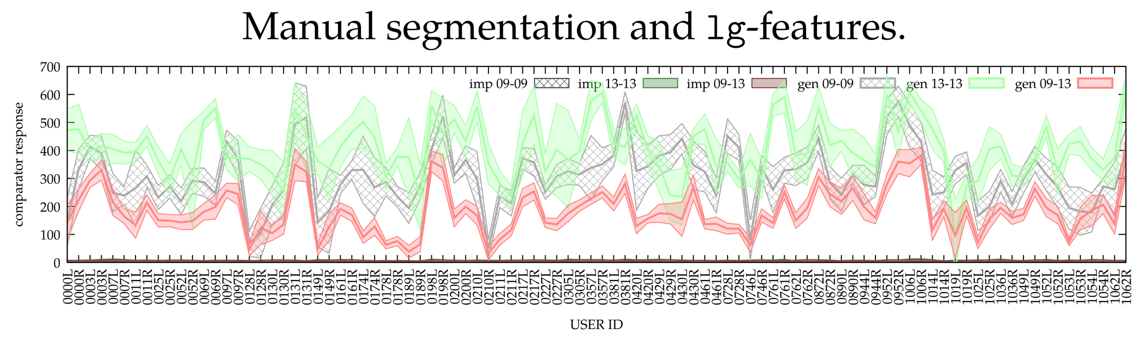
- Manual segmentation leads to a better performance than algorithmic segmentation.
- For all version the inter-year has lower performance than in-year.



Segmentation with `caht` and `lg`-features.



Manual segmentation and `lg`-features.



Neurotechnology VeriEye.

Hamming score of genuine and imposter scores, given as mean plus/minus one standard deviation grouped per user.

- `caht` segmentation does not simply degrade all results; rather, there seem to be specific users for which the segmentation fails. ID 0003: the `caht` segmentation clearly introduces errors. ID 0007: the difference between `caht` and manual segmentation is negligible.
- The use of a manual segmentation does not remove the apparent template ageing effects.

Apparent Ageing and Pupillary Dilation

- Does the change in pupillary dilation influence the recognition rate?
- Use a biomechanical model (**BMM**) to offset the non-linear normalization modification due to dilation based on

  I. Tomeo-Reyes, A. Ross, A. D. Clark, and V. Chandran, "A biomechanical approach to iris normalization," in *Proceedings of the IAPR/IEEE International Conference on Biometrics (ICB'15)*, 2015

  – Normalization based on change in dilation.
  – Only an increase in dilation can be changed (one-way compensation).
  – The BMM was shown to perform well for large dilation changes (positive displacement).
- Compare the result of the BMM to the Daugmans rubersheet model (**RSM**)
- Use manual segmentation to prevent segmentation errors.

Experimental setup (compare in-year and intra-year):

- ***BioC*:** The first experiment assumes that only iris codes are stored in the gallery, i.e., only the query images can be normalized using the BMM. All query images, regardless of dilation ratio, are normalized using the BMM.
- ***BioI*:** The second experiment stores the iris images in the gallery, and the BMM is applied to the gallery or query image, depending the dilation degree, making it possible to account for dilation and constriction.

	Rubersheet		*BioC*		*BioI*	
comparison	EER [%]	OP 0.01 [%]	EER [%]	OP 0.01 [%]	EER [%]	OP 0.01 [%]
gallery–2009	1.773	9.235	1.843	13.404	2.178	12.191
gallery–2013	2.548	46.393	4.778	62.281	2.979	53.813

Performance comparison of RSM and BMM normalization,with both *BioC* and *BioI* setup. The table gives the equal error rate (EER) and the FNMR at operation point FMR=0.01% (OP 0.01).

- In-year:
  – *BioC* BMM does worse than RSM. Dilation should be stable (minor changes only).
  – *BioI* BMM is worse, the BMM is ineffective for small differences.
- Inter-year:
  – *BioC* BMM does a lot worse than RSM. Dilation change is probably constriction,i.e., not what the BMM was designed for.
  – *BioI* BMM is slightly worse than RSM and better then *BioC*. This further substantiates the constriction theory.

Dilation—Amount and Direction

- Analysis of the experiments and actual iris dilation.
- Is the change significant and what is the direction of change?

	rubber sheet	biomechanical	total
gallery–2009	53.43%	46.57%	79524
gallery–2013	87.87%	12.13%	88360

Number of times the images were normalized with the RSM (constriction) or BMM (dilation) for the *BioI* test.

- Relatively stable in in-year environment ('coin-flip' between constriction and dilation)
- Clear constriction between years, i.e., constriction over time (88%).

The finding that dilation constricts with age is also supported byt he following medical study:

J. R. Peterson, L. S. Blieden, A. Z. Chuang, L. A. Baker, M. Rigi, R. M. Feldman, and N. P. Bell, "Establishing age-adjusted reference ranges for iris-related parameters in open angle eyes with anterior segment optical coherence tomography," *PloS ONE*, vol. 11, no. 1, p. 12, 2016

Analysis of change in dilation ratio between years:

- The one-way analysis of variance was calculated per eye:
  – 72 of 94 are significant for $p^* = 10^{-6}$.
  – 87 of 94 are significant for $p^* = 0.01$.
  – The change in dilation ratio between years is $\mu_{\Delta D} = -0.125$ with $\sigma_{\Delta D} = 0.081$.
- No relevant in-year change.
- Relevant inter-year change.
- BMM was designed for large change in dilation, due to constant illumination the dilation is age based and to small for BMM to handle.
- It is likely that the apparent ageing does not stem, solely, from dilation changes.