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Face Image Analysis in Mobile Biometric Accessibility Evaluations

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***Abstract*— Smartphones cameras are widely used for biometric authentication purposes. This enables more and more users experience face recognition in different common scenarios (e.g., unlocking phones, banking, access controls). One of its advantages is that face recognition requires low interaction with the systems (by simply looking at the smartphone's screen). Thus, it may be useful for people affected by mobility concerns. For this reason, researchers recently started to conduct mobile biometric evaluations recruiting accessibility populations. The aim is to analyse all those factors that, depending on the users' capabilities, influence the biometrics recognition process. In this paper we focus our attention on sample quality, analysing the face images collected during a mobile biometric accessibility study. Results obtained enable us to understand how the users' accessibility concerns influence the biometric sample quality and discuss possible solutions for eradicating this inconvenience. This assessment had been conducted following the recommendations of the ISO/IEC TR 29794-5.**

Keywords: mobile biometrics, face recognition, face image quality, accessibility.

I. Introduction

Motor and cognitive concerns affect the 15% of the world's population [1]. This means that, today, around 1 billion of people must deal with several accessibility barriers.

Technology has always provided products to support people in everyday life, helping users with accessibility problems in many scenarios. Regarding the mobile environment, biometrics seems to be a useful technological solution to eradicate all those obstacles that arise when accessing smartphones' applications. For example, biometric recognition is currently the widest authentication method used to unlock mobile phones or even to access banking apps. Thus, all the inconveniences related to having to remember and type a password or a PIN are, thanks to biometrics, cancelled.

Nowadays almost all the newest smartphones have a finger sensor and therefore fingerprint recognition is considered the most common biometric modality. But, following the release of face identification on Apple and Android devices[2][3], also face recognition is becoming more popular among the users. Additionally, this modality could be an easier authentication alternative for people with accessibility concerns. This because it generally takes less interaction between the user and the mobile system. For example, presenting the face to the camera of the smartphone requires less effort than holding the device and, at the same time, touching the fingerprint sensor. Before addressing this modality to a widest population of users (including elderly and people with mobility concerns) several aspects that could affect the performance, the usability and the accessibility of the face recognition process must be analysed.

In this paper, we focus on assessing the quality of the face images samples collected during an accessibility evaluation. The scenario of the experiment requires the users to authenticate themselves by means of face recognition using a mobile phone. We recruited 48 users belonging to two main groups: control population and accessibility population (affected by mobility and cognitive issues). By comparing the quality scores between these populations, it will be possible to understand and discuss how the accessibility concerns affect the samples' quality in a mobile face authentication process. This scenario evaluation had been designed following the directives of the ISO/IEC 19795-2[4], while the ISO/IEC TR 29794-5[5] had been applied for reporting the face image quality scores.

The rest of the paper is organized as follows: Section II provides a snapshot of the main works conducted in this area; the evaluation set up is presented in Section III. The methodology is defined in Section IV, while the results are presented in Section V. Finally, in Section VI we report the conclusions about our work.

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II. Related Works

In recent years, the image quality samples for mobile face recognition has been analysed by a number of researchers.

In 2017, Wansik et al.[6] collected a database of more than 6000 selfie photos taken by 101 volunteers using smartphones. The aim of the authors was to propose a new approach for assessing the pose and the illumination in face images. This approach, based on the vertical edge density, was applied to analyse their database besides the traditional quality metrics [5]. Results obtained let the authors foresee a future application of their approach as a new facial image quality metric.

Lunerti et al.[7] in 2017 investigated the environmental effects on face recognition in mobile phones. Their evaluation aimed to analyse how the variability of brightness and background could affect the face samples' quality and the performance of a mobile face authentication systems. 53 participants were enrolled in the evaluation. During the first part of the evaluation, they were required to store their facial photos (1 taken by a reflex camera and 5 using a mobile device). Later on, they were provided by a smartphone (Google Nexus 5) and asked to complete 3 sections of 30 minutes each. The task to complete during the sections was to take at least 5 face images as selfies in 10 different locations (indoor and outdoor). Analysing the face image metrics [5], all the samples presented a good Facial Dynamic Range. Outdoor photos had better brightness levels, while the indoor images obtained better background scores. Regarding the performance, the matching scores were higher indoor than outdoor. Finally, according the users' feedbacks collected after the test, the level of easiness of use and confidence in taking the selfies were higher in the indoor scenarios.

In 2018, the authors in [8] conducted a study on samples quality collecting a database of face images and video recorded by a iPhone 6S. For the experiment they recruited 201 participants and asked them to perform 6 sessions in 5 months. Besides, they also assessed other 4 database of facial images (2 database of photos acquired with smartphones and 2 acquired with cameras). The assessment had been conducted applying deep learning neural networks (DNN). Their study had demonstrated that deep learning architectures are the most precise solution to classify the quality features of the photos taken with mobile devices.

To date, the image quality of face recognition systems had been analysed just to evaluate its impact on the authentication process. In this paper, we aim to assess the extent to which users' accessibility problems can affect the quality of images.

III. Evaluation Setup

In this work, we analysed a database of facial images collected during accessibility evaluation of a biometric-based access control system. The participants, enrolled in the test, were asked to authenticate themselves by means of mobile face recognition to access a door. This system had been developed to support people affected by mobility and cognitive issues. For this reason, during the evaluation we recruited two main populations of user for testing the accessibility of this mobile system.

The first group was composed of 31 users without any kind of concerns (control population). 23 of them were aged between 19 and 49 y/o; while the remaining 8 belonged to an older-adult subgroup (aged more than 49).

The second group gathered 17 users aged between the 19 to 60 years, with different kind of cognitive and mobility issues (3 users were affected by leg concerns, 4 affected by arms disability, 1 with temporary accessibility concerns in her hands and 15 affected by cognitive concerns).

The experiment (Fig. 1) was divided in two sessions, 7 days apart. For logistical reason, the door's opening had been simulated through a tablet device (Sony Xperia Tablet Z). During the first session, users accepted the experiment's condition and they were provided by a One Plus 3T smartphone in which we installed an Android application developed for this experiment. Though the app, participants enrolled their faces storing 5 selfies photos as reference templates. Later on, the application required them to take other 5 face photos to achieve 5 verification attempts. Each time the application recognized the face of the participant, a Bluetooth signal was sent from the smartphone to the tablet showing an open door on the screen. Finally, during the second session participants just repeated the verification part.

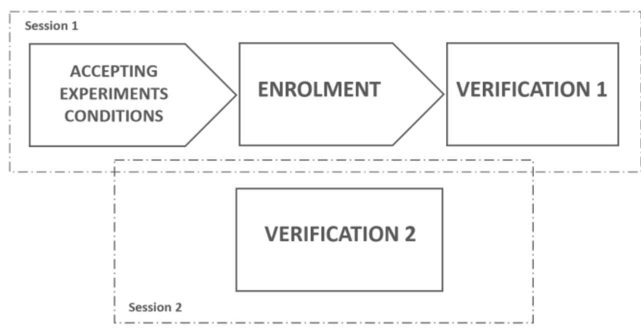

Fig. 1. Workflow of the experperiment.

IV. Methodology

The ISO/IEC TR 29794-5 ("Biometric Sample Quality – Part 5: Face Image Data Sample Quality – Technical Report") [5] defines all the directives useful to test the face image quality. According to this report, we analysed the facial images collected in the evaluation under two main aspects: i) subject's behaviour; and ii) the brightness and background of the samples acquired.

A. Subject's behaviour

This aspect had been assessed to report all those details useful to understand the users' feelings while completing the experiment's task. As specified in the ISO/IEC TR 29794, the *"typical characteristics that are related to the subject's behaviour include:*

- *Closed and open eyes*
- *Closed and open mouth*
- *Any kind of expression*
- *Head pose"*

For our quality assessment, we focused on the expression and emotion of the users (neutral, surprise, anger etc.). Additionally, we also analyse the head pose checking the compliance with the ICAO[9] frontal pose requirements.

The aim of this analysis is to understand if there are any correlations between the behaviour of the participants and their belonging group. In our specific case, this means understand whether accessibility concerns also influence participants' feeling performing a biometric recognition process.

B. *Brightness and background analysis*

Regarding the characteristics of the image acquisition, the standard [5] suggests analysing the illumination intensity, the image brightness and contrast. Thus, for all the images collected in our database we report the following brightness scores:

- The number of bits contained in the face region of each image (Facial Dynamic Range). Through this value we can understand how the face region is illuminated in the collected photos.
- How bright is the facial region of each photo (Facial Brightness).
- Level of contrast in the eye region of each photo (Eye Contrast). It represents the ratio between the darkest and brightest point of the eye region.

Besides these data, we analysed the background though the following value:

- The extent to which the colours vary in the background of the face image (Background Uniformity). This value depends exclusively on the environment in which the photo is taken and not on the user's capacity. However, it has been calculated to report a complete analysis of the image quality.

V. Results

In the sections below the results of our analysis are provided.

VeriLook SDK[10], a Neurothecnology[11] software, had been used to assess all the details related to the subjects' behavior. While, we used Preface SDK (Aware)[12] to analyse the brightness and background of the facial images.

In order to understand if even age could affect the face image quality in a biometric recognition process, we reported the results of the control population considering separately the older-adult subgroup.

A. *Subject's behaviour*

a) Facial expression

Verilook SDK detects in each face image the facial expression of the users (e.g., happiness, surprise, neutral, fear, disgust, anger and sadness).

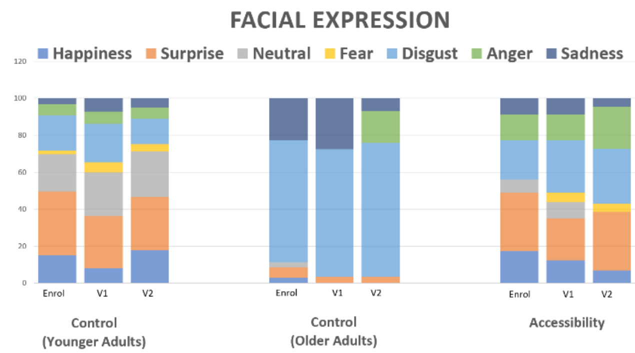

Fig. 2. Percentage distribution of the facial expressions. For each population we reported separatenly the results of each phase: enrolment (Enrol), first verification (V1) and second verification (V2) sessions.

In the figure 2, the percentage distributions of the facial expressions of participants are shown. The results are divided among the populations and the experiment's phases. Positive facial expressions, such as happiness, surprise and neutral, were predominant in all three phases among the control population. While, in the accessibility population there was a prevalence of disgust and anger especially in the second visit. This was probably due to the stress of not remembering how complete correctly the tasks. Regarding the older-adults subgroup, negative facial expressions prevailed (e.g., disgust, anger and sadness) in each session. Those feelings demonstrated that the elderly people were not at ease in completing a task they were not used to (taking selfies).

b) ICAO Frontal Compliance Check

The International Civil Aviation Organization (ICAO) is responsible to define all the guidelines for passport photos to be readable in travel checks. The following table (Table I) shows the percentages of photos that respect the ICAO frontal pose requirements:

TABLE I. ICAO Compliace

Population	**ICAO Frontal Compliance Check**		
	Enrolment	***Verification 1***	***Verification 2***
Control	94,68%	98,93%	91,49%
Older Adults	85,71%	68,57%	88,57%
Accessibility	61,4%	77,2%	68,18%

The percentage of compliant samples increased between enrolment and the first verification for control and accessibility populations. This shows that the participants belonging to these classes have acquired skills in presenting their faces for biometric recognition. This does not happen in the older-adult population, where the samples that respect the ICAO frontal requirements decreased between the enrolment and the first verification. This is probably due to the users' tiredness at the end of the first session.

B. Brightness and Background scores

In this section, we are going to report the values of brightness and background scores separately for each group of users.

The populations are significantly different considering the p-values obtained with the ANOVA. Analysing the variance between the quality scores reported for the tree populations, the p-value for each metrics are: 0,01 for the Facial Dynamic Range; 0,004 for the Facial Brightness; 0,006 for the Eye Contrast and 0,00012 for the Background Uniformity. Since these values are lower than the 0,05 we can conclude that it exists a significant difference between the three groups.

a) Brightness scores

For each photo analysed, Preface returns specific values corresponding to the Facial Dynamic Range (FDR), the Facial Brightness and the Eye Contrast.

The values for the Facial Dynamic Range are between 7 and 8, where 7 is the minimum acceptable value and 8 the optimal value. Whereas, the Facial Brightness is expressed in percentage from the 25% (facial region too dark) to the 75% (facial region too bright). Finally, for the Eye Contrast values are between 1 and 5 (where 3 is the acceptable value, 5 the optimal).

In the following Tables (Tables II, III, IV), we reported the mean and the standard deviation of the brightness scores obtained during each session from the three populations.

TABLE II. BRIGHTNESS SCORES FOR CONTROL POPULATION

Brightness	**Control (Younger Adults)**		
	Enrolment	***Verification 1***	***Verification 2***
Facial Dynamic Range	7,73 ± 0,2	7,88 ± 0,06	7,58 ±0,28
Facial Brightness	53,5 ± 5,8	53,49 ± 5,07	54,3 ± 6,67
Eye Contrast	4,3 ± 0,52	4,5 ± 0,5	4,5 ± 0,51

Younger Adults obtained acceptable scores for all the three metrics. Additionally, there is an increasement of the FDR between enrolment and first visit (users gained experience in taking the selfies).

TABLE III. BACKGROUND SCORES FOR CONTROL - OLDER ADUL POPULATION

Brightness	**Control (Older Adults)**		
	Enrolment	***Verification 1***	***Verification 2***
Facial Dynamic Range	7,82 ± 0,08	7,73 ±0,121	7,57 ± 1,16
Facial Brightness	52, 69 ± 8,9	50,7 ± 8,82	52,28 ± 5,8
Eye Contrast	4,76 ± 0,42	4,64 ± 0,47	4,8 ± 0,4

Older-Adults group reported a decrease of FDR between the enrolment and the verification 1, probably due to the users' tiredness (as already supposed for the ICAO Frontal Compliance results).

TABLE IV. BRIGHTNESS SCORES FOR ACCESSIBILITY POPULATION

Brightness	**Accessibility Population**		
	Enrolment	***Verification 1***	***Verification 2***
Facial Dynamic Range	7,67 ± 0,15	7,77 ± 0,16	7,72 ± 0,18
Facial Brightness	51,92 ± 4,9	49,65 ± 11,82	51,37 ± 4,67
Eye Contrast	4,39 ± 0,53	4,36 ± 0,48	3,41 ± 1,06

Even for the accessibility population, we obtained FDR scores very close to the optimal values. Moreover, respect the other groups, accessibility population obtained lower scores of facial brightness probably because of their attitude in taking selfie (approaching too much the device to the face).

Finally, the Eye Contrast scores are generally quite close to the optimal value (5). We just obtained a lower value (3,41) for during the verification 2 of the accessibility population.

b) Background scores

Regarding the background scores, Preface expresses the Uniformity by percentage values (100% is the optimal score).

In the following Tables (Table V, VI and VII), for each population we report the mean and the standard deviation of the Background Uniformity scores obtained during the different parts of the evaluation.

TABLE V. BACKGROUND SCORES FOR CONTROL

Background	**Control (Younger Adults)**		
	Enrolment	***Verification 1***	***Verification 2***
Background Uniformity	82,55 ± 13,85	84,1 ± 17	79,32 ± 21,12

TABLE VI. BACKGROUND SCORES FOR CONTROL - OLDER ADUL POPULATION

Background	**Control (Older Adults)**		
	Enrolment	***Verification 1***	***Verification 2***
Background Uniformity	84,19 ± 14,58	87,20 ± 5,5	83,51 ± 15,49

TABLE VII. BACKGROUND SCORES FOR ACCESSIBILITY POPULATION

Background	**Accessibility Population**		
	Enrolment	***Verification 1***	***Verification 2***
Background Uniformity	92,15 ±8,76	88,87 ± 15,47	83,58 ± 11,77

The Background Uniformity reached acceptable values in all the cases. The accessibility population obtained higher values compared to the others. This result could be addressed to the difference of the environment where the accessibility group performed the experiment.

VI. Conclusions

The work presented in this paper analysed the quality of face images collected while evaluating the accessibility of a mobile biometric system. The participants recruited in the test represent a heterogeneous population of users which can benefit from mobile biometric applications. In order to understand how age and accessibility issues affect the sample quality of a face recognition process, we separated the users into three different groups (younger adults, older adults and accessibility).

Results obtained analysing the face images demonstrated that the user's age and capability influenced the sample quality under different aspects. This is notable, especially, analysing the users' behaviour. Young adults performed the face recognition mostly with a happy or neutral expression, while the other populations showed quite different emotions in completing the task.

Especially in the elderly subgroup, we noticed that participants mostly presented expressions of disgust and sadness. Thus, we conclude that this population represent a class of users that still have many interaction issues while performing a mobile biometric authentication. We do argue that elderly population should be taken more into account in future accessibility evaluations. In order to design mobile biometric application easy-to-use even for older adult users.

Regarding the accessibility population, we underline the results obtained checking the ICAO compliance. Reporting the percentage of compliant samples, the accessibility population reached lower levels compared to the other two groups. This could be addressed to the mobility concerns of the users. For instance, several participants (especially with legs concerns) could not have a straight posture. In our next accessibility evaluations, we will intent to assess how this aspect of the face image quality could affect the outcome of the mobile face recognition process. By resolving all those factors that influence the face recognition on smartphone, in future it will be possible to provide accessible biometric applications not just for private contexts but even for public scenarios (for example Automated Boarder Controls and access systems).

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