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Correcting the planar perspective projection in geometric structures applied to forensic facial analysis

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ABSTRACT

The process of forensic facial analysis may be founded on several scientific techniques and imaging modalities, such as digital signal processing, photogrammetry and craniofacial anthropometry. However, one of the main limitations in this analysis is the comparison of images acquired with different angles of incidence. The present study aimed to explore a potential approach for the correction of the planar perspective projection (PPP) in geometric structures traced from the human face. A technique for the correction of the PPP was calibrated within photographs of two geometric structures obtained with angles of incidence distorted in 80°, 60° and 45°. The technique was performed using ImageJ® 1.46r (National Institutes of Health, Bethesda, Maryland). The corrected images were compared with photographs of the same object obtained in 90° (reference). In a second step, the technique was validated in a digital human face created using MakeHuman® 1.0.2 (Free Software Foundation, Massachusetts, EUA) and Blender® 2.75 (Blender® Foundation, Amsterdam, Nederland) software packages. The images registered with angular distortion presented a gradual decrease in height when compared to the reference. The digital technique for the correction of the PPP is a valuable tool for forensic applications using photographic imaging modalities, such as forensic facial analysis.

1. Introduction

Forensic facial analysis consists of a scientific procedure to compare morphometric information obtained from the human face [1,2]. This procedure is founded on the hypothesis that the morphology of the human face varies among subjects [1]. Consequently, it enables to distinguish subjects based on their facial traits—even if these traits are expressed bidimensionally (2D) [1]. The comparison between images is the basis of this analysis, which is performed matching a target face (unknown subject) with a reference face (known subject) [1,2]. Ideally, the target and reference faces should be registered contemporarily, but in most of the cases they are obtained in different moments. In this context, some facial structures are modified following the ageing process (e.g., the human skin, due to dehydration and collapse); while others trend to remain stable, especially in the adulthood (e.g., the diameter of the iris and the distance between pupils) [1,2].

Several scientific techniques for image acquisition and analysis may be applied to study the human face. Facial photo-anthropometry arose as an option to explore the morphometric information of stable facial structures registered in photographs [3,4]. Specifically, this technique quantifies the morphological relation between landmarks, dimensions, angles and proportions calculated from photographs of the human face, avoiding a direct qualitative comparison of the facial structures [3,4]. On the other hand, a limitation in this technique is found when photographs acquired with different angles of incidence are provided for comparison [3,4]. This situation is often observed when the images are obtained from security cameras, which are usually installed in a high position invariably registering the suspect distorted in relation to the camera.

The present study aims to overcome this limitation in photo-anthropometry for forensic facial analysis, exploring an approach

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to correct the planar perspective projection (PPP) in geometric structures traced from photographs of the human face.

2. Material and methods

In the first study part, the sample consisted of two geometric structures—1 isosceles triangle (measuring 45 × 45 × 62 mm with thickness of 20 mm) and 1 rectangle (measuring 40 × 45 mm with thickness of 20 mm) confectioned in wood. Both structures were photographed using a Canon 1100D® (Canon®, Tokyo, Japan) DSLR (Digital Single-Lens Reflex) camera with a Canon® 18–55 mm VR lens. The photographs were taken from a distance of 20 cm from the geometric structures, in 4 different angulations in relation to the horizontal plane (90°, 80°, 60° e 45°), using iSetSquare (Plaincode®, Stephanskirchen, Germany) software package. The images were scaled to life size and the correction of the PPP was performed using plug-ins of ImageJ® 1.46r (National Institutes of Health, Bethesda, Maryland) software package. The correction itself is performed in this software using algorithms of linear projection, which calculates the projection matrix based on the landmarks selected in the distorted image and determining their ideal position in the corrected image (commands: Plugins – GeometricMappings – Projective Mapping). The angulation of 90° was considered as reference for correcting the distortions of 80°, 60° and 45°. The distorted objects were corrected considering their largest diameter. The photographic distortions were quantified as the difference in the width and height of the geometric structures, expressed in pixels.

In the second study part, the technique was validated in a photograph of a human face obtained using MakeHuman® 1.0.2 (Free Software Foundation, Massachusetts, EUA) software package imported into Blender® 2.75 (Blender® Foundation, Amsterdam, Nederland) software package. The same angular distortions were used to generate different PPP. In this case, the frontal photograph of the human face (90°) was used as reference to correct the other distortions. Each image was landmarked in the *subnasale* and *cheilion* points, located in the columella and bilaterally on the lip commissure, respectively. The images were scaled to life size and superimposed using these 3 landmarks (triangle) as references. The obtained outcomes were exposed as descriptive statistics.

3. Results

In the first study part, loss of vertical dimension was observed in the distorted images of both the triangle and the rectangle compared to the reference. The difference in vertical dimension became gradually more pronounced with the increase in distortion (height of the triangle and the rectangle evidenced in Table 1). These differences are observed more clearly superimposing the reference (A: 90°) and the target (B: 80°, C: 60°, D: 45°) images of the triangle and the rectangle after the correction of the planar perspective projection (Figs. 1 and 2). The same trend was observed validating the technique in a digital human face (Figs. 3 and 4).

Table 1
Width and height of the triangle and the rectangle expressed in pixels.

	Width	Height
Triangle		
90°	1170	612
80°	1170	609
60°	1170	606
45°	1168	586
Rectangle		
90°	852	764
80°	852	738
60°	852	732
45°	850	678

Different values for the width and height of the geometric structures are distributed according to the distortions in the planar perspective projection.

4. Discussion

The face is the body part that better represents the human being [5]. The analysis of the human face may be approached with several purposes, such as for artistic sculpture and painting, anatomy, anthropology, and therapeutic procedures [3]. The cephalometric landmarks used to perform this analysis translate the facial traits into geometric structures, such as triangles and rectangles [3]. Early studies within facial analysis were simply based on the direct and qualitative comparison of morphological traits [6]. The facial analysis improved over the time, implementing quantified information obtained from morphological proportions, symmetry and geometry. The trend for a more objective approach was triggered by artistic investigations that measured of the human face in the search for facial beauty [6]. In the forensic sciences, this analysis is mainly performed founded on the principle of uniqueness of the human face [7,8]. In this context, the techniques that contribute for the improvement of the facial analysis also contribute for the process of facial identification [4].

Despite not used commonly, the term “identification” applied to forensic facial analysis denotes a more scientific and systematic pathway towards the comparison between suspects [4]. On the other hand, forensic facial “recognition” comprehends a more subjective and less scientific approach. Both the objective and subjective forensic facial analysis are often explored in the field of forensic Biometrics, which also includes the analysis of patterns from the human voice, iris and retina [4]. Technological advances in computer sciences improved the field of Biometrics over the last years, especially concerning the development of algorithms for the automation of comparative procedures in facial analysis [9–11].

Currently, the forensic facial analysis enables the comparison between human faces registered in 2D images [1]. An important limitation of this technique consists on the need for comparing facial images registered in the same position [2,12]. Additionally, other factors associated with technical image acquisition may also influence the comparative outcomes [13,14]. When the images are distorted, a more subjective approach takes place, leading to the qualitative comparison of morphological traits [15,16]. However, when aligned properly, the facial images may be analyzed objectively and compared using quantitative procedures [15].

Digital image processing, craniofacial anthropometry and photo-anthropometry comprehend the technical pathways for the potential systematization and quantification of the forensic facial analysis. Specifically, the last consists on the acquisition of metric data from morphological measurements performed in photographs [3]. Differently from the qualitative comparisons founded on the morphological facial similarities, the photo-anthropometry aims is to retrieve metric information from structures registered in 2D and compare proportions between photographs [3,15,17–20]. On the other hand, the literature reports difficulties applying this technique in the field of forensic identification/recognition [4,15]. As mentioned previously, these difficulties are justified by the geometric distortions in the photographs. The present study proposed a correction of the PPP, enabling a more precise comparison of facial photographs. In specific, the presented outcomes indicated that geometric structures traced from the human face my guide the correction of the PPP through a precise and potentially more reliable way compared to the arbitrary correction of image distortions (e.g., rotating and re-sizing the photographs).

In this context, the correction of the PPP reverses the distortion, providing a target image similar to the reference. This correction