Three-dimensional measurement of human face with structured-light illumination

[1]J.Čarnický, [2]D. Chorvát Jr.

[1]Department of Nuclear Physics and Biophysics,
Faculty of Mathematics Physics and Informatics, Comenius University,
Mlynská dolina, 842 15 Bratislava, Slovakia
Email: carnicky@ilc.sk
[2]International Laser Centre, Ilkovičova 3, 812 19 Bratislava, Slovakia
Email: dusan@ilc.sk

Abstract: *The potential of three-dimensional scanning with structured-light illumination was evaluated for measurement of human face geometry. The aim was to create virtual human face models from the data scanned on real people, and to characterize the precision of such measurements. The quality of scanning with structured light proved to be sufficient to let us quantitatively parametrize the human face for anthropometric purposes. Values resulting from the distance measurements between the selected landmarks on obtained models were in agreement with the published data.*

Keywords: 3D scanning, structured light, face anthropometry

1. Introduction

For many applications like facial recognition, historical research, delict investigation, telecommunications or even games, a new trends emerged to measure and evaluate 3D facial models. For the past decades three dimensional facial data were obtained mostly by direct anthropometric measurements [1]. Landmarks have been used for over a century by antrhopometrists interested in qualifying cranial variation [1, 2, 3, 4]. A great body of work in craniofacial anthropometry is that of Farkas who established a database of anthropometric norms by measuring and comparing more than 100 dimensions (linear, angular and surface contours) and proportions in hundreds of people over a period of many years. These measurements include 47 landmark points to describe the face [1, 3, 4]. Recently, a large variety of non-contact methods to measure three-dimensional facial geometry have been developed, such as laser scanning, stereo-photogrammetry, infrared imaging or computed tomography. However, most of these methods has inherent limitations (X-ray or laser radiation exposure, lack of precision/speed, etc.), therefore none of them is in common clinical use.

2. Subject and Methods

In this paper we discuss three-dimensional scanning of human face using structured-light illumination [5]. Application of this method for scanning and anthropometric measurement of the model human head has been recently described in details by Enciso et al. [2]. However, scanning of human face in real situation is more experimentally demanding and involves more uncertainities than repeatedly scanning of the mannequine model. Therefore, the main objective of our study was to broaden the application of this technique to the creation of a virtual human face from the data scanned on real people, and to characterize the precision of such measurements.

For the three-dimensional face scanning we used non-contact optical scanning system ShapeCam (Eyetronics). The core of the ShapeCam system comprised of a source of the structured-light (customized Canon Speedlite 550EX flash with projection grid) and a professional digital camera Canon EOS D60 (with 6 Mpixel CMOS detector). To obtain three dimensional models from acquired photographs we used the software bundles ShapeSnatcher and ShapeMatcher (Eyetronics). Snapshots were taken from the distance of 2-3 m with Canon EF 70-200 mm zoom lens. The orthogonal grid structure was projected onto the object and photographed with 1/250 s exposure (Fig. 1). Scanned persons were instructed to stay in natural position and to avoid moving the mimic muscles during scanning. The measurement took approximately 2 minutes, resulting in 4-8 scans from different directions. 15 (of 25 scanned) faces were digitized with closed eyes to reduce the glance of the eyes and thus to increase the scanning precision.

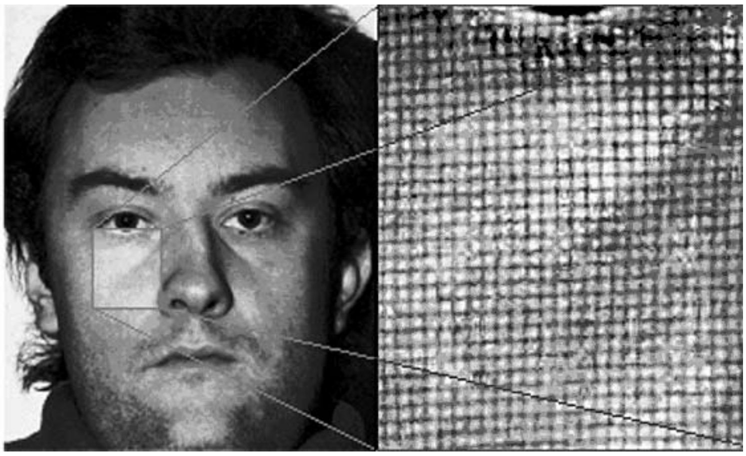

Fig 1. Detail of the ShapeCam photograph with gridline projection.

In the first step, calibration matrix for the 3D-reconstruction was computed from the snapshot of the calibration box. Then, the ShapeSnatcher software was used to evaluate the deformations of the grid lines projected on the surface of the object, and to calculate the 3D geometry of the visible part of the face according to the calibration matrix. Before processing a single photograph, we often needed to manually edit or erase areas with badly detected grid (mostly eyes and hairy structures like eyebrows). After processing the images from several different points of view, the 3D-snapshots were stitched together with the ShapeMatcher software forming a complete virtual model of the face (Fig. 2) containing 25.000 to 55.000 triangles.

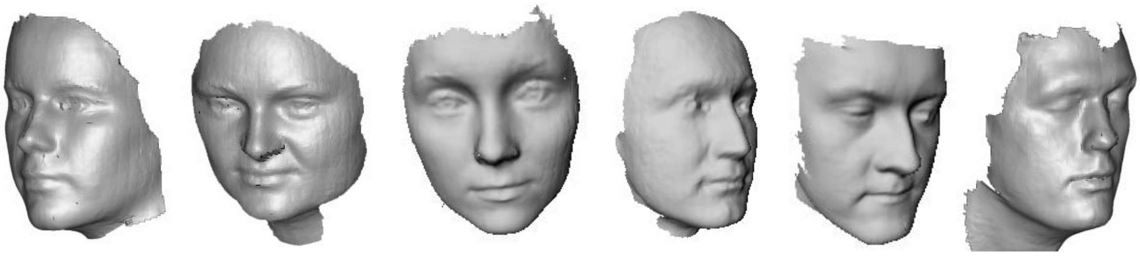

Fig. 2 Selected examples of the scanned virtual face models

The 3D models were exported either to VRML data format (for presentation), or to STL data format (for measurement). In the first case we were able to extract and preserve the face geometry with texture, forming a complete virtual model of the scanned person. In the second case we used the Magics RP software (Materialise) to measure distances between selected Farkas's anthropometric landmarks on obtained virtual models (9 men, 16 women).

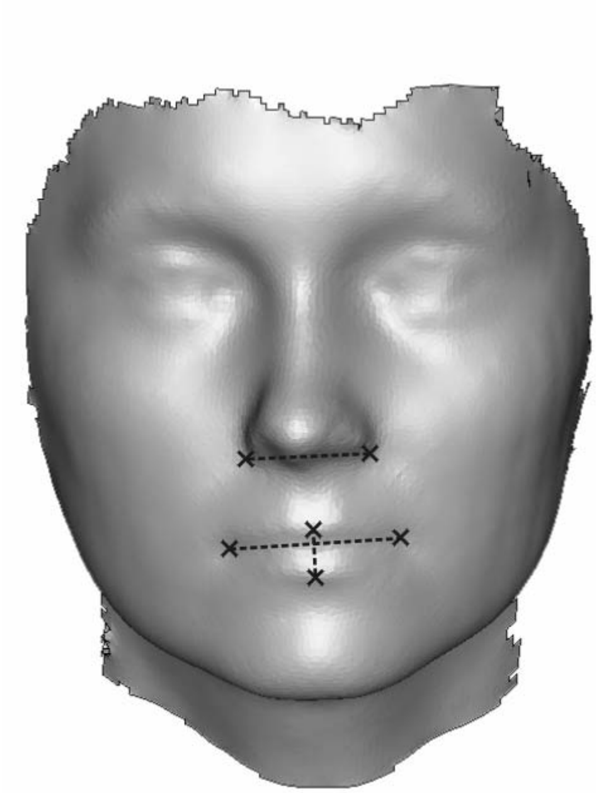

Fig.3 Selected subset of Farkas's points, used for distance measurements

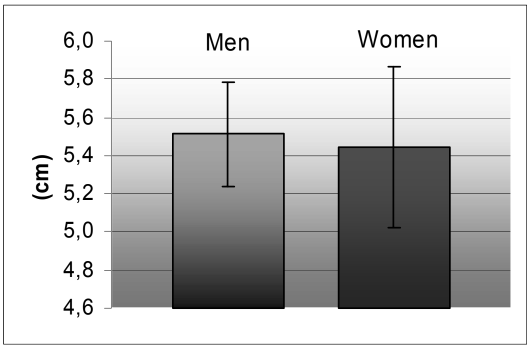

Fig.4 Mouth width

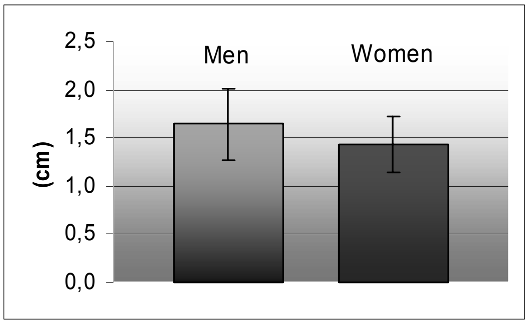

Fig.5 Vermilion height

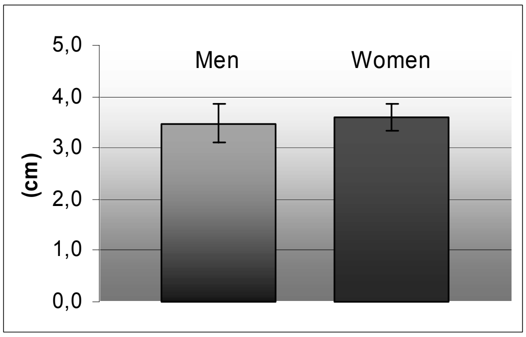

Fig.6 Nose width

3. Discussion

We scanned and created 25 models of human face, and measured 3 linear distances between 6 selected Farkas's anthropometric landmarks on each model. Selected subset of Farkas's landmarks is shown at Fig.3. We evaluated the average values of mouth width /vermilion heigh /nose width of men to be 55 ± 2 mm / 16 ± 4 mm /35 ± 4 mm; for women we obtained values 54 ± 2 mm /14 ± 3 mm / 36 ± 3 mm (Fig. 4-6). These results are in good agreement with the values reported by Ferrario et al. [8]. However, the differences in obtained values between men and women were not significant in our case, in opposite to the findings reported in [8]. This fact could be interpreted mostly in terms of the lower number of scanned persons (25, compared to 180 by Ferrario et al.), as well as different population sampling in our case. Enciso et al. [2] characterized the mean absolute error of the ShapeCam (Eyetronics) imaging system to be 0.50mm, with the standard deviation of 0.40mm, variance of 0.16mm and maximum error of 1.55mm. Comparison of our results to the measurements of Ferrario et al. suggests that the quality of ShapeCam scans is sufficient to provide quantitative parametrization of the human face geometry, and higher uncerntainity observed during scanning of real people is most probably caused by the natural variance of anthropometric parameters in screened population.

One of the most pronounced advantages of our measurement method is that it is based on fast and non-contact process, so the skin surface is not deformed during scanning [4, 6]. The scanned person also need not to stay without moving for a prolonged time, because of the short time of acquisition [1, 5]. Another advantage of creating virtual model and measuring the point-to-point distances afterwards is that we only choose each landmark once, and not in every measurement [4, 7].

4. Conclusions

We showed the possibility to reconstruct three dimensional virtual models of human face by noncontact scanning based on structured light illumination. The quality of used method proved to be sufficient to let us quantitatively parametrize the human face for anthropometric purposes. Values resulting from the distance measurements between the selected Farkas's landmarks on our face models were in agreement with the data published previously, with standard deviation within the range of 2-4mm.

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