3D Scanning System for In-Vivo Imaging of Human Body

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1 Introduction

Optical technologies for measuring the human body shape without contact have gained popularity in the recent years. In particular, techniques based on fringe projection have demonstrated a good performance for generating three-dimensional (3D) topographies of the human body. For the 3D digitization of the human body, the technique has found various applications in different fields, including relevant cosmetic and medical applications such as 3D back shape detection in scoliosis [1], 3D shape measurement of pectus excavatum [2], 3D intra-oral dental measurements [3], or 3D measurement of the topography of human skin [4, 5, 6]. In the latter, optical measurement of the skin surface by means of fringe projection provides a less invasive, faster and more accurate result than the obtained with traditional methods established in the cosmetic industry based on skin replicas of silicone, which are applied along several minutes on the person, and therefore are more sensitive to errors associated with unintentional movements of the person due to breathing or muscle contractions.

In this work we present a scanning system for measuring in-vivo the 3D topography of the human body. The system has been designed for taking 3D measurements over 180 degrees of different parts of the body, ranging from the knees to the face of the person. The scanner has been developed to meet the requirements of the cosmetic industry for the evaluation of the effectiveness of cosmetic products applied to reduction of volume in large size skin zones, as cellulite, abdomen and breast volume changes.

This paper is organized in three sections: in section 2 the 3D scanner prototype developed is presented. Section 3 shows some preliminary 3D measurements obtained with the scanner. Finally, section 4 briefly summarizes the conclusions of the work.

2 Development of the 3D Scanner Prototype

A scanner prototype for measuring the 3D topography of different parts of the human body has been developed. The measuring principle is based on the

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well-known techniques of stereovision combined with the projection of fringe patterns. Four shifted fringe patterns are projected onto the skin surface to get the corresponding phase map, and then common phases are identified for each pair of cameras, so finally 3D data is obtained by triangulation based on the well-known epipolar geometry. This final step of triangulation which retrieves the metrological 3D data from 2D images requires a previous calibration of the scanner with a reference object, in order to compute the transformation from image coordinates to real world coordinates. In our case, the calibration is performed using the technique proposed by Tsai [7] with a calibration rigid board featuring a black and white checkerboard pattern.

The scanning system has been designed to measure the 3D topography of the human body over 180 degrees. Two lateral sensing units (placed right and left of the patient), each with a DLP-based projector to project the sinusoidal fringe patterns and a pair of megapixel color cameras in an standard stereo geometry, scan sequentially the left and right sides of the patient, which is placed at a one meter distance in front of the units. Finally, the 3D data measured from the left and right views are stitched together to get the complete 3D topography, with the aid of the intrinsic and extrinsic calibration parameters previously computed for both units. Both cameras and projectors are low-cost off-the-shelf commercial components with low price and easy availability for a quick replacement in case of damage. The scanner prototype is thus very affordable and with great potential of mass production in subsequent industrialization stages. In addition, a motorized vertical unit enables to move up and down the scanning units and subsequently to scan the different parts of the body with this single device (e.g. face, breast, hip, backbone, etc.). Figure 1 shows the 3D scanner prototype developed.

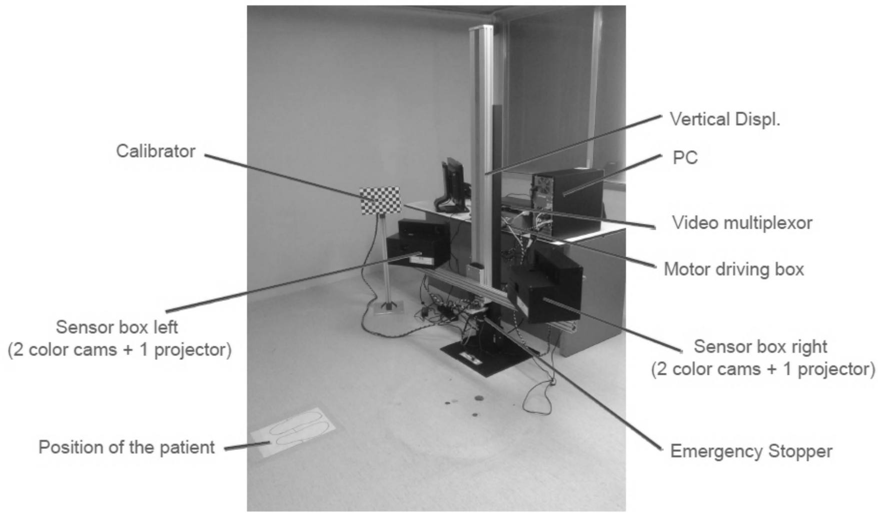

Fig. 1 3D scanner prototype developed to measure large parts of the human body over 180 degrees. All the hardware components included in the scanner are identified in the figure.

In addition to the abovementioned hardware system, a user-friendly software interface to operate the complete instrument has been developed. The interface allows controlling the hardware of the system in a friendly and interactive way by a professional of the cosmetic and beauty industry with a non-engineering background. The interface enables the automatic calibration of the system, the automatic measurement of the 3D skin surface, and the management of the patient personal data and 3D data measured. In addition, a matching tool has been also included within the features of the interface for repositioning the patient in comparative measurements. The matching tool enables a precise comparison in real-time between the position of the patient in past and present times, in order to ensure that the skin area scanned is the same in both acquisitions. This is a complex issue in practice in this kind of measurements, although it is key to accurately quantify the effectiveness of e.g. a given skin volume reduction product.

3 Preliminary Results

The 3D scanner prototype has been designed to perform the measurements with an acquisition time of 4 seconds, a field of view of 0.4 x 0.3 square meters, and spatial resolution of 0.3 mm. The scanner has been built to reconstruct the 3D shape of the object together with the associated RGB colour texture superimposed. This is also very useful in beauty industry applications, where the aesthetics of the image is mandatory. Besides, the combination of 3D data plus the RGB characteristics provides a strongly realistic representation of the digitized human body.

An in-depth validation procedure of the scanner has been carried out by measuring a set of reference objects with well-known shapes. Plane objects with a rectangular shape and spherical objects with well-know dimensions have been measured in an initial validation phase. Results obtained shown a good quality of measurement with accuracy in height (Z) below 0.5 mm RMS for all cases analyzed, and almost perfect repeatability data, only limited by camera noise.

Furthermore, the prototype has demonstrated a extremely good performance when scanning people. Different human body parts, ranging from the knees to the head, have been successfully scanned in 3D on a number of patients. As an example, figure 2 displays a 3D measurement of the face of a male together with a horizontal profile extracted at the middle of the face, where the width of the nose is clearly measured as an example. Other parts of human bodies (face, male breast and legs) and dummies (female breasts) scanned with the system are depicted in figure 2.

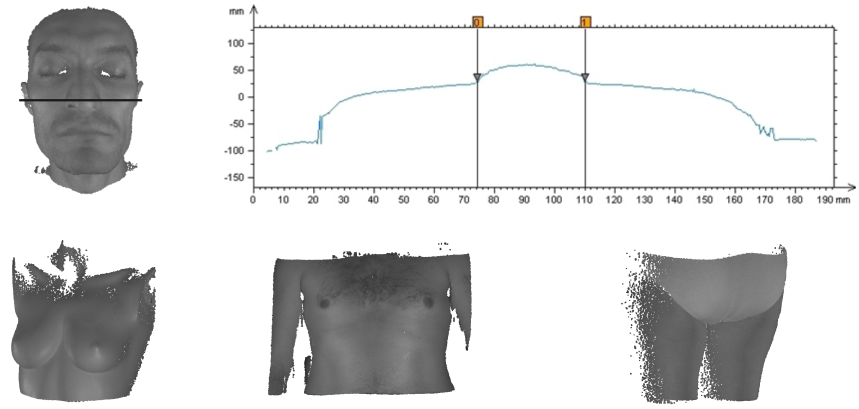

Fig. 2 (top) 3D scanning of a face and horizontal profile extracted where the width of the nose is highlighted, (bottom) different parts of the body scanned with the system

4 Conclusion

A 3D scanner measuring large areas of the human body, incorporating 3D information of the human body with superimposed colour texture data has been developed for evaluation of cosmetic applications. The system includes repositioning tools for ease of operation.

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