Photogrammetric fringe projection for in-vivo skin topography measurements

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ABSTRACT:

Profilometry of skin topography at different scales allows quantitative analysis of medical and cosmetic procedures which otherwise remain qualitative. The use of surface profilometry parameters in measurements of skin allows a better characterization of the effects of cosmetic treatments and a better insight in its effects. This paper describes the practical application of a fringe projection system for 3D topography of human skin, involving two cameras which allow photogrammetric reconstruction of the corresponding phase maps. The system has been designed and built using simple off-the-shelf optical elements and a simple user interface has been developed. Projected fringe patterns are accurately evaluated using phase-shifting methods, and a further triangulation step allows the final reconstruction of the topography of the sample. Preliminary experimental results showing the applicability of the unit to evaluate in vivo methodology for accurate measurement of skin topography are presented.

Keywords: Fringe projection, 3D reconstruction, skin topography, fringe projection, phase shifting, skin profilometry, dermatology, cosmetics

1.- Introduction

The research in the cosmetic and dermatology industry is devoted to the development and enhancement of a number of beauty and skin treatments. Interest in quantitative evaluation of in vivo skin features is of evident technical and economical interest as, jointly with sensorial evaluation, becomes the measure of success of a given treatment or process. As skin is an easily reachable, optically diffusive surface, the information which may be obtained from 3D measurement procedures (from surface roughness to Fourier analysis of microstructures [1,2]) becomes a very interesting source of information for quantitative evaluation purposes.

Different techniques have been used with this purpose along the years, including reflectometry, mechanical techniques, laser profilometry and transmission methods [3]. However, a large number of non-contact optical topography techniques are available [4] and are becoming increasingly popular for characterizing skin surface topography in vivo.

Among these techniques, we propose a novel approach to the classical fringe-projection technique [5] where a double camera system is implemented. This allows a very good combination of sensitivity, lateral resolution and field of view.

In the next section we will describe the basics of the measurement technique. Section 3 will briefly discuss the experimental setup implemented. Section 4 will present the first results obtained with the current setup, showing the capabilities of the measurement technique. Section 5 will point out the main conclusions and future work to be done.

2.- Measurement principle

In photogrammetric techniques, two cameras are used In order to recover height measurements out of the geometrical positioning of the cameras and their relative fields of view. In our case, we will retrieve the height data out of the correspondences of two phase maps obtained at each of the cameras, using the setup presented in Figure 1.

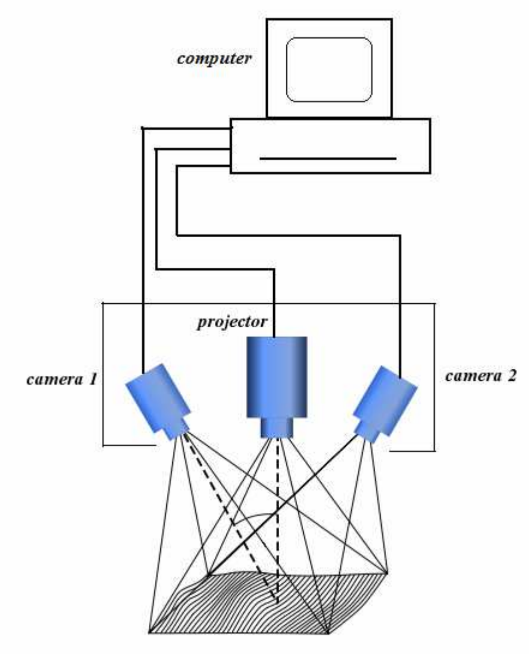


Fig. 1: Schematic diagram of 3D imaging system

A sinusoidal fringe pattern is projected onto the sample under test. This sinusoidal signal is registered on the cameras as a sinusoidal intensity pattern which has the topographic information of the sample embedded, in the shape of the deformation of the fringes in the images.

Phase-shifting techniques [6] are well known enhancement techniques in interferometry, used for accurate phase determination allowing resolution enhancements of two orders of magnitude. In our case, a series of four fringe patterns are projected onto the surface under test with a known 90º phase delay between them introduced. Under this conditions, the phase modulo 2π of the signal may be recovered out of

$$\tan\varphi(x,y) = \frac{I_4(x,y) - I_2(x,y)}{I_1(x,y) - I_3(x,y)} \qquad (1)$$

where $I_i(x,y)$ is the spatial distribution of intensity in the ith fringe pattern registered in the cameras. A final phase-unwrapping procedure yields the unwrapped phase map of the surface for each of the cameras.

Finally, photogrammetric triangulation techniques are used to recover the height values of the surface out of the known geometric arrangement of the setup, retrieving the topography of the sample under test.

3.- Experimental setup

The general setup of the instrument includes the sensor unit (including cameras and a projection system, which are described next), mounted in a common box. The box has a series of degrees of freedom in position to allow optimum positioning relative to a chinrest where the panelist is placed.(Figure 2)

Fig.2: General experimental setup

The sensor unit consists of a projection unit with two commercial CCD cameras is enough to perform reliable measurements, so yielding a very cost-effective setup. The projector includes a commercial LCOS unit with HDTV definition (1920x1080pixels) for control of the fringe projection system, and a self- designed optomechanical system. Cameras are CCD units with 1280x

960pixels each and a lens adjusted to the field of view and resolution required for the measurement is used.

The camera and LCOS unit are synchronized so projection of consecutive fringe patterns and its acquisition are ensured, and performed in the minimum required time. It is obvious that optimized times for data acquisition procedures are essential for skin profilometry of in-vivo patients. Present measurement times are just of some seconds. A self-developed user interface (Figure 3) manages the acquisition process, the file management and parameterization of the different acquisitions, and the data analysis procedures.

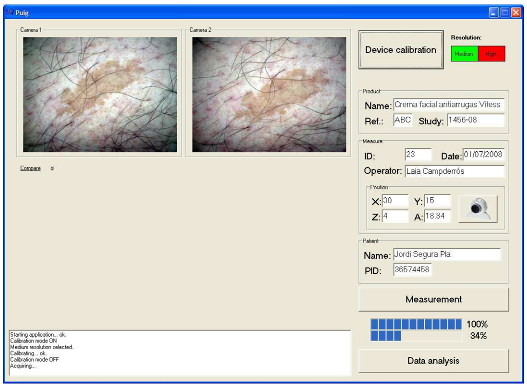


Fig. 3:Self-developed user interface

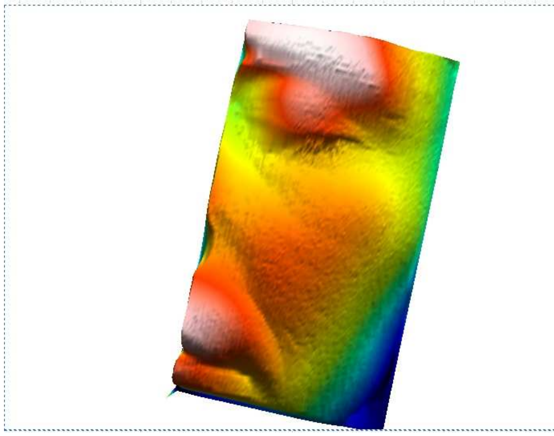
4.- Experimental results

Figure 4 shows the first results of the measurement setup. In fig 4a we see the user positioned in the measurement moment, with the square spot of light where fringes will be projected. Fig.4b shows the measured profile of skin, allowing measurement of a number of different features and line profiles. Figure 4c shows some possible data analysis features. In this example, the roughness profile along a given section of the topography is extracted.

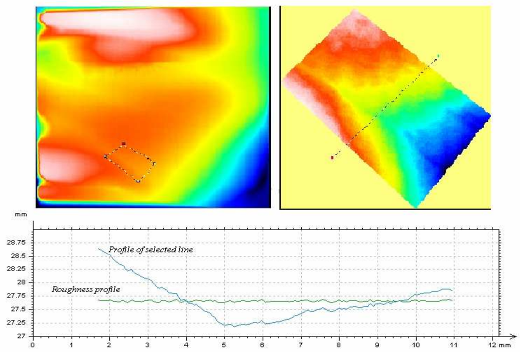
5.- Conclusions

A photogrammetric fringe-projection system for the measurement of diffusive surfaces, in particular of skin topography, has been presented and described. The system combines phase-shifting procedures usual in fringe projection techniques with the use of triangulation techniques normally used in photogrammetric techniques to achieve fast, high resolution profilometry measurements of skin topography.

(a)



(b)



(c)

Fig4: a) User in measurement position; b) Measured topography of skin; c) Profile and extraction of roughness profile of a section of the topography section using data analysis

The technique allows detailed data analysis of different roughness parameters of skin, enabling its use in a number of applications related to dermatology, cosmetics, and skin elasticity.

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