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A STUDY ON TWO COST EFFECTIVE SCANNING AND MODELING TECHNIQUES USED FOR THE FABRICATION OF AN ORTHOTIC MASK

BY

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Abstract. The facial orthosis is used in the treatment of facial burns to minimize hypertrophic and deforming scarring. The paper approaches the most cost effective solutions for the 3D scanning and 3D modeling of anatomic surfaces and discusses the feasibility of these solutions for the modeling of facial orthoses. The structured light scanning technique and single camera photogrammetric technique were approached and discussed. The head of person was scanned, 3D reconstructed and processed in order to obtain the 3D model of a customized face mask. Results showed that single camera photogrammetric scanning techniques is the most cost effective but has some drawbacks in the reconstruction of the 3D mesh. Other scar rehabilitation studies have shown that surface scanning results in a better fitting mask than manual fabrication and without anxiety-provoking.

Key words: orthosis, 3D modeling, facial burns.

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1. Introduction

Facial burn treatments involve removing the damaged tissue followed by grafting and other recovery procedures. Seriously burnt patients often have complications such as scarring, speech problems or tissue deformities.

The main objectives in burn tissue recovery are functions restoration, comfort and skin aesthetics. Prevention of scarring should be one of the most important aims of burn recovery. Hypertrophic scarring, Keloid scarring, scar contracture, loss of parts of the body and change in color of skin are the major outcomes of a thermal injury.

The hypertrophic scars are provoked by the increased blood flows that appear in the burn tissue. The burn tissue forms sometimes granulation tissue, containing fibroblasts that produce collagen fibers. The excessive multiplication of collagen fibers during the normal healing process produces the hypertrophic scar (Beranek & Clevy, 1986), (Chait & Kadwa, 1988), (Rockwell *et al.*, 1989).

The modern manufacture of orthotics masks needs high-resolution surface scanning, CAD/CAM or Rapid Prototyping technologies and devices for thermoplastic material deformation (Keating & Knox, 2008), (Cheah & Chua, 2003), (Whitestone & Richard, 1995), (Lin & Nagler, 2003), (Pilley & Hitchens, 2011). The methodology of facial orthosis fabrication and preliminary results from the use of the most cost efficient technical solution are described in this article.

Two modeling methods were used in this study. Firstly, a structured light scanning technique and secondly, a single camera photogrammetric scanning technique were approached. Results were discussed in order to reveal some characteristics.

2. Scanning and Fabrication Methods

The manual methods for creating orthotic masks have many drawbacks including the intensive work, time-consuming and imprecise process which may affect the treatment. Mainly, pressure mask fabrication with computer aided technologies contains next steps:

- A) Facial scanning;
- B) 3D digital model construction;
- C) Pressure masks fabrication by Rapid Prototyping.

The manual methods consist of: facial impression (most disturbing for a patient), fabrication of moulage, pulling the face mask, finishing touches and fit assessment (Nakamura, 2010). The use of the new computer aided technologies is often faster and decreases the amount of practitioner time required for each visit to patient.

A. Facial scanning

There are a lot of commercial solutions for noninvasive face scanning: using laser scanners; using structured light scanners; using video cameras and markers; using single camera photogrammetry.

Last solution, known as photo-based scanning, looks more appropriate in this case having two major advantages: it is the most cost-efficient (about ten times cheaper structured light scanning) and does not use disturbing or dangerous light (passive method).

Photo-based scanning is based on photogrammetric techniques. This scanning system includes software capable to calibrate cameras and to determine the position of the camera when shooting photos.

B. 3D digital model construction

Computer programs (known as scanning software) are used to perform the 3D digital construction. The main goals of the 3D scanning software are to import the photos from the digital camera and to transform 2D photos to 3D digital model.

The scanning software compares photos patch by patch to find the matches and when these matches are found, the position data of the photographs is used to assemble the patches in 3D space.

C. Face mask fabrication by Rapid Prototyping

CAD/CAM and Rapid Prototyping are indispensable tools for the technological improvement in the conception and manufacturing of customized prostheses and orthoses. 3D printing is a low-cost alternative to traditional rapid prototyping for fabricating customized components. 3D printing is a process of making 3D solid components from digital models using additive techniques and creating by laying successive layers of material.

In the final step, the model of the face mask is transferred to the 3D printer software, in order to convert 3D model to 3D print data.

3. Results

In the first approach, a study was performed in order to scan and to reconstruct the head of a person using the structured light scanning technique. A commercial Artec MH scanner as in Fig. 1 was used to extract data of head.

Fig. 1 − The Artec MH scanner.

The Artec MH 3D Scanners use video camera technology and projects structured light onto the face of patient and capture a multitude of frames. The frames are combined automatically (in the scanner software) into a single 3D mesh, in the 3D reconstruction phase. The mesh represents the 3D surface model of the face.

Fig. 2 shows the 3D mesh model of the patient head obtained after 3D scanning and 3D reconstruction.

Fig. 2 – The 3D mesh of the head.

Several image processing were applied to the 3D model in CAD software in order to obtain the face mask.

First step is model preparation for Boolean intersection. A 3D box is superposed over the 3D model of the head as in Fig. 3. Both models are made by surfaces.

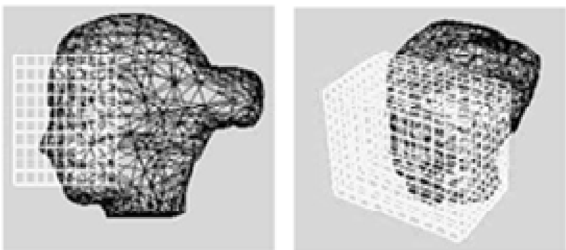

Fig. 3 – Superposing a box over the 3D model.

The result of surfaces intersection is a thin surface presented in Fig. 4 (left).

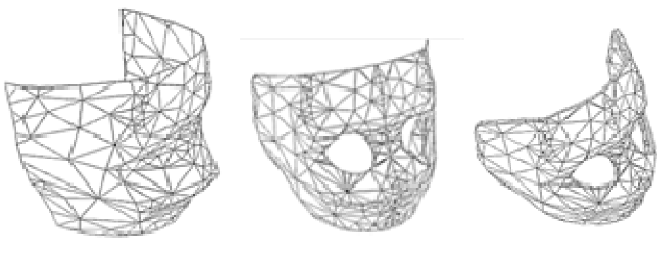

Fig. 4 – The mask after the Boolean intersection (left), after adding holes (center) and after adding thickness (right).

A Boolean operation is applied in order to obtain eye holes. Two cylinders were subtracted from the mask surface and the result is presented in Fig. 4 (center). In a last operation, thickness was added to the surface of the mask as in Fig. 4 (right).

There are tools for this operation in almost all CAD software. Finally, the 3D model has to be saved in STL format, useful in Rapid Prototyping

The mask model is prepared in order to be manufactured using a 3D printer and a transparent material.

In the second approach, a study was performed in order to test the feasibility of photogrammetric scanning and 3D reconstruction for customized face mask fabrication.

The face of a person was scanned using a single camera photogrammetry technique and 3D virtual reconstruction in order to prepare a future 3D printing of the mask. Fig. 5 shows a set of photos took during single camera scanning.

Fig. 5 - Taking photos from different directions.

The next phase is transforming 2D images into 3D model using dedicated software.

There are three ways to approach the 3D construction phase with photogrammetric software: using open source software (Insight); using free online services for 3D construction (www.hypr3d.com, www.123dapp.com, www.my3dscanner.com etc.; using commercial software (PhotoModeler, 3DSOM, D-Sculptor, iModeller etc).

Fig. 5 contains photos shouted according to 3DSOM software. In this case, there is a calibration sheet mounted around the neck, printed according to software instructions. The calibration sheet aim is to determine the camera orientation and position and to facilitate the creation of the 3D model. This calibration sheet is not mandatory and photo-based software has solutions for assembling photos without calibration sheet.

Transformation from 2D to 3D will be performed after the insertion of photos in the software. Transformation may contain two major operations (depending on chosen software): background elimination and 3D model assembling. Background elimination refers to the masking of the background around the photo subject as in Fig. 6. Software has some tools for this operation.

Fig. 6 - Background elimination.

3D model assembling of photos was automatically performed using 3DSOM software and the results are presented in Fig. 7.

The scanning software used in this study compares all images patch by patch to find the matches and when these matches are found, the position data of the photographs is used to assemble the patches and to form a 3D model.

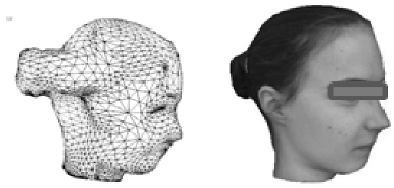

Fig. 7 - The 3D digital model of the head (left: 3D mesh model and right: textured model).

The 3D model is close to the model obtained using structured light scanning technique but some indentations are not well defined.

4. Discussion

The manual methods for creating facial orthoses have many drawbacks including the application of a plaster material directly to the patient's face. The method created discomfort for the patient, making him to wait until the plaster had dried. New studies have shown that head or neck scanning results in a better fitting orthotic mask than conventional fabrication (Lin & Nagler, 2003), (Pilley & Hitchens, 2011).

In this study, time consumed during taking photos of a head was about 15-20 minutes. Structured-light or laser scanners took about 10 minutes for a similar task but produce disturbing light.

In the case of patients with severe burns and having reclined head, it is sufficient to take photos only for 180° around the head. The final model will reconstruct precisely only the frontal part of the head, sufficient for obtaining the facial orthosis.

Results of the scanning and reconstruction study showed that the structured light scanning and photogrammetric scanning and reconstruction techniques furnished apparently good 3D meshes.

Analyzing the photogrammetric approach forms, the textured model visible on the right side of Fig. 7 has good details but very few details in some areas with indentations of the 3D mesh model as shown in left side of Fig. 7.

Most visible indentations are placed at: the corner between eye, nose and forehead; the intersection line between nose and face; the inner spaces of the nose; the inner shape of the ear.

5. Conclusions

The study showed that the best results of the scanning and modeling techniques of the facial orthosis for patients with facial burns were produced by the structured light scanning and reconstruction technique.

The modeling of the facial mask needs the assistance of other CAD or computer graphics software.

Single camera photogrammetric scanning technique remains the most cost-effective solution for prostheses and ortheses modeling and fabrication but is restricted to anatomic surfaces without indentations.

The pressure masks may be scanned and manufactured with 3D printers starting from a 3D model of the face and the pressure area can be easily modified during the process of 3D modeling or 3D printing.

Scar recovery studies (Richard *et al*., 1986), (Shons *et al*., 1981) have shown that surface scanning results in a better fitting mask than conventional fabrication, without the intensive manual work, time-consuming, and imprecise process, which may delay treatment effects. The conventional process is slow and anxiety-provoking, and often require anesthesia.

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UN STUDIU ASUPRA A DOUĂ TEHNICI DE SCANARE ŞI MODELARE UTILIZATE PENTRU FABRICAREA UNEI MĂŞTI ORTETICE

(Rezumat)

Lucrarea de faţă prezintă un studiu realizat asupra a două tehnici de scanare şi modelare a suprafeţelor anatomice în vederea fabricării unei măşti utilizate la prevenirea cicatricilor hipertrofice care pot apărea în arsurile feţei.

Soluțiile de scanare si reconstrucție 3D abordate se bazează pe tehnica scanării cu lumină structurată şi pe fotogrammetria cu o singură cameră foto, tehnici care au cele mai reduse costuri. Este analizată posibilitatea utilizării acestor soluţii in modelarea măștilor ortetice utilizate in recuperarea arsurilor.