A 3D BIOMECHANICAL MODEL OF THE HUMAN FACE

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INTRODUCTION

TIMC Laboratory, in collaboration with the Plastic and Maxillo-facial surgery Department of Grenoble (France), has developed a simulator for orthognathic surgery, based on a 3D cephalometric analysis of the patient's head bone structures (Mollard *et al*., 1998). The main idea was to provide surgeons a virtual 3D model of the patient's skull, in order to simulate osteotomies, propose a diagnosis, and plan surgery. This simulator concerns only bone structures repositioning, without any references to the soft tissues connected to those structures, namely skin tissues, muscles, nerves and veins. The next stage of this project is thus to couple the simulator with a biomechanical model of the face, realistic from an aesthetic and functional point of view.

This paper presents the biomechanical model of the face that was recently developed. Face anatomy and the retained volumetric geometry of the model are first described. Then, the modeling of soft tissues (skin and muscles in that case) is explained. Finally, results of the dynamic simulations of face deformations under muscles actions are presented.

FACE ANATOMY

Facial skin has a layered structure composed of the epidermis (a superficial 0.1 mm thick layer of dead cells), dermis (0.5 - 3.5 mm thick) and hypodermis (fatty tissues connected to the skull). Many facial muscles are inserted between those skin layers and the underlying bone structure. In the case of maxillo-facial surgery, the great majority of interventions act on the upper and lower maxilla. This is the reason why our main focus for skin face modeling was dedicated to the lower part of the face, with a special emphasis on soft tissues surrounding human lips.

More than ten muscles act on lips shape, the great majority of them being pair muscles along the sagittal plane. Most of them are dilators (with a distended action like skeletal muscles), and are gathered around the lips. They all have same kind of insertions : one into skull bone, and the other one inside the lips, onto a constrictor muscle, namely the orbicularis oris (figure 1).

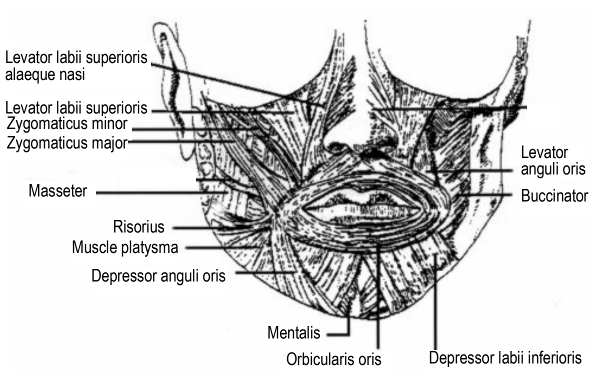

Figure 1 : Face anatomy

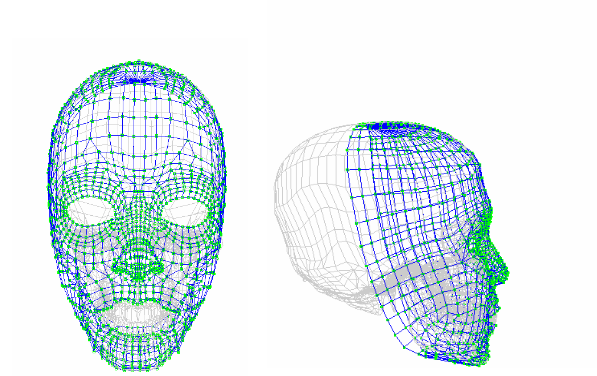

Figure 2 : 3D face mesh fixed to the skull

DEFINITION OF THE VOLUMETRIC MESH

We started from a 3D mesh surface of face skin (Guiard-Marigny *et al.*, 1996) which was originally proposed in the framework of computer animation. This 3D mesh was used to build two other surfaces, in order to simulate a volumetric mesh : the first one is just scaled from the skin mesh, while the other one corresponds to its projection onto the skull (figures 2). A volumetric mesh is thus built, modeling a skin structure composed of two thicknesses of material. This mesh defines the 3D geometry of our biomechanical model of the skin, *i.e.* is used to discretized the linear elasticity equations in the framework of the Finite Element (FE) Method.

MECHANICAL PROPERTIES AND MUSCLES

As a starting point, the volumetric face mesh was modeled as an isotropic linear FE structure, with biomechanical characteristics chosen in order to replicate observations made on human face skin. Young's modulus corresponds to the small-deformation slope of the skin stress-strain relationship (Fung, 1993), while Poisson's ratio value is close to 0.5, in order to model skin tissues quasi-incompressibility. Then, muscles were defined by making some "holes" inside the global 3D mesh, and by inserting other FE structures with biomechanical properties modeling muscles characteristics (orthotropic FE structures, with a symmetry along muscle axis). Sliding relations were simulated by imposing no penetration between muscular FE structures and the rest of the global face mesh. Figures 3 and 4 (top) respectively show the insertions of a dilator muscle (zygomaticus major), mainly responsible for smiling action, and a constrictor one (orbicularis oris), the main actuator of lips protrusion. Figures 3 and 4 (down) illustrate face deformation, under the action of those two muscles (results from the dynamical resolution of FE partial differential elasticity equations, with a linear time activation pattern, *Castem 2000* package).

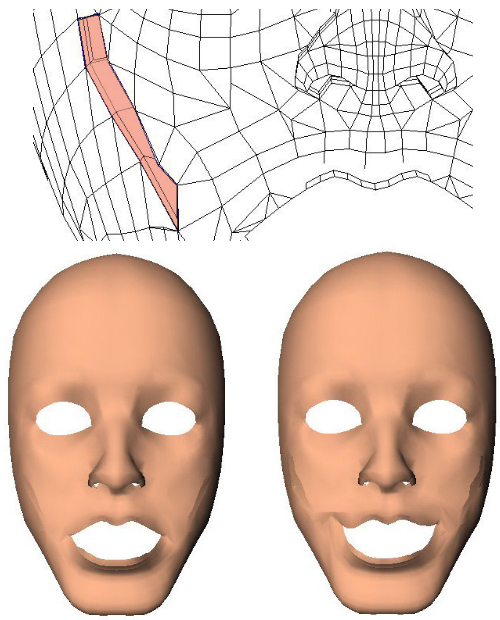

Figure 3 : Zygomaticus major muscle action

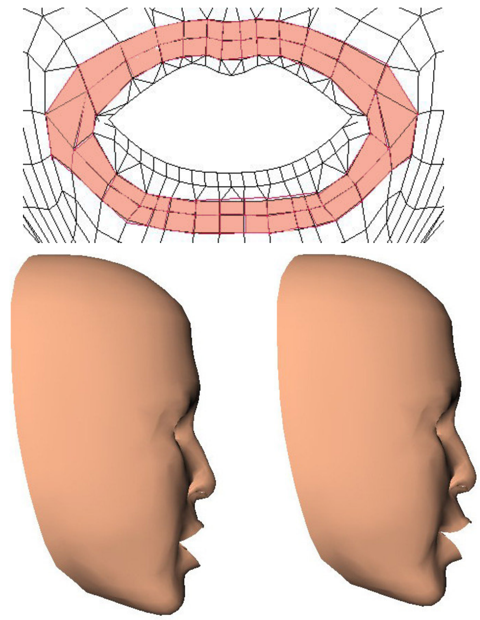

Figure 4 : Orbicularis oris muscle action

CONCLUSION

A preliminary version of a biomechanical FE model of the human face was presented. It has now to be completed and integrated into the global plastic and maxillo-facial surgery simulator.

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SPEAKER INFORMATION

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