3D Dynamic Representation System for the Human Head

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Abstract—The human head representations usually are based on the morphological – structural components of a real model. Over the time became more and more necessary to achieve full virtual models that comply very rigorous with the specifications of the human anatomy. Still, making and using a model perfectly fitted with the real anatomy is a difficult task, because it requires large hardware resources and significant times for processing. That is why it is necessary to choose the best compromise solution, which keeps the right balance between the details perfection and the resources consumption, in order to obtain facial animations with real-time rendering. We will present here the way in which we achieved such a 3D system that we intend to use as a base point in order to create facial animations with real-time rendering, used in medicine to find and to identify different types of pathologies.

Keywords—3D models, virtual reality.

I. INTRODUCTION

STARTING with the '90 years, when the first 3D facial animations appeared, it showed to be necessary to create systems capable to simulate as good as possible the muscular interactions from the real world.

The system's realism degree is directly correlated with the level of anatomic knowledge involved; anyway, it is necessary to know the shape, the structure, the position of the components and, more important that everything, the interactions between them. The position of the system's components (in our case, the human head) is described according with 3 reference plans:

- The lateral-median plan (or the sagital plan): divides the head in two halves – left – right;
- The coronal plan: divides the head in two halves – front and back;
- The transversal plan (or the horizontal plan): perpendicular on the other two plans.

In order to start the building of our 3D model, we also took in consideration the following elements:

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- The human head structure: skull (lat. Cranium), facial muscles (lat. M. faciales et masticators), ocular globes (lat. Oculi), teeth (lat. Dentes) and tongue (lat. Lingua);
- The skull's number of bones: 7 bones stiff connected; the facial skeleton's number of bones: 15 small bones also stiff connected, in a mosaic shape – excepting the mandible, which is mobile;
- The facial muscles: 3 groups – the muscles that sustain the facial expressions (on 2 layers, one superficial and one deeper); the muscles for mastication and mandible's movements and the muscles for the tensioning / relaxing of the facial skin tissues.

II. MATERIAL AND METHODS

The skull's modeling started using some reference pictures: 5 main reference pictures and a few more as secondary pictures. The main pictures represented a skull's projections on the 3 references plans (also known as axonometric plans): front – back, top – behind, left – right (Figs. 1 – 5). We considered that the left and the right sides were perfectly symmetrically – therefore it wasn't necessary to use here 2 reference pictures.

Fig. 1-2 The reference skull pictures: front – back projections

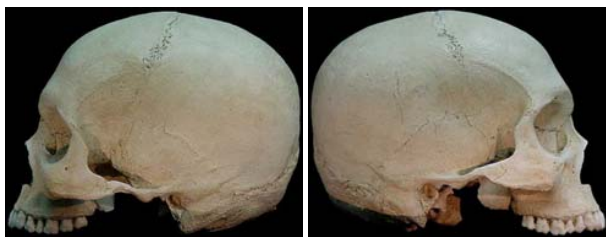Fig. 3-4 The reference skull pictures: top – behind projections

Fig. 5 The reference skull pictures: left – right projections
(taken as perfect symmetrically)

In order to achieve and to show the surfaces, we used the nurbs technology (the level curves), and, after this step, we used the editable polygons techniques [1]. The inter-bone ditches were showed using bump textures – in order to keep the number of polygons as low as possible. The bone, muscles and skin colors were showed using color textures.

In order to represent the muscles we created 3D objects [1] that also respect the symmetry principle. These basic structures were transformed further, to obtain an aspect very similar with the anatomical and topological shapes. In order to get more details, we increased the number of polygons, adding also the texture maps. We also modified the structures using the 3D functions of scale and translation [1], applied at each logical level of the 3D objects: point, edge, polygon, object – until the object satisfies acceptable the anatomical demands.

The skin surface was simulated using a mesh type 3D object that respects the proportion of the anthropometrical measures for a female Caucasian prototype. The skin was build in order to cover, without interactions at this stage, the bone, muscular and cartilages layers (Fig. 6).
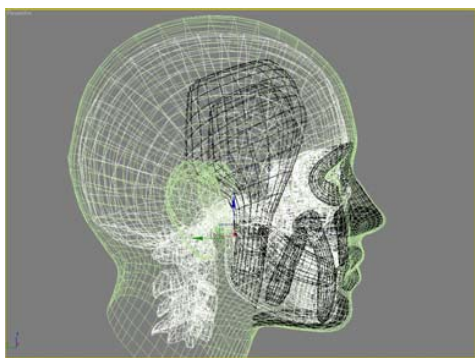

Fig. 6 Lateral projection of the 3D model in its last stage

Elements about the System's Dynamics

In order to simulate the face's dynamics, we started with Hooke's formula [2]:

$$\frac{\Delta l}{l_0} = \frac{1}{E} \cdot \frac{F}{S_0}$$

$$F = k \cdot \Delta l$$

where: l_0 = the initial length; Δl = the difference between the final and the initial lengths; E = the elasticity constant; F = the deformation force.

Therefore, an elastic surface like skin is an edges network (as 3D object) which interconnects the points. The skin's elasticity and its dynamics are obtained applying a resort on each edge of the object. Starting with the hypothesis that, locally, the skin has a constant elasticity coefficient, we can think that the elasticity constant according to which the system is distorted is the same in certain areas. In order to study this constant, we took its approximate values and the areas where it is different. For the objects which are modified during the process of facial mimicry we apply a system of resorts (Fig. 7).
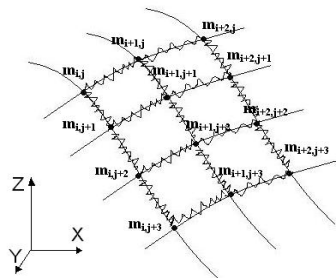

Fig. 7 The system of resorts for facial mimicry

In this way, the dynamics for a single object and its distortions can be calculated using the Newtonian physics laws – we parse the 3D files, we extract the coordinates for the set of points that compose the object and for the set of paired points corresponding to the edges, and, therefore, it is not difficult to attach resorts on the given object.

The problem becomes more complicated when the system contains more than one object, because they must interact without interferences – or having common volume areas (Fig. 8).
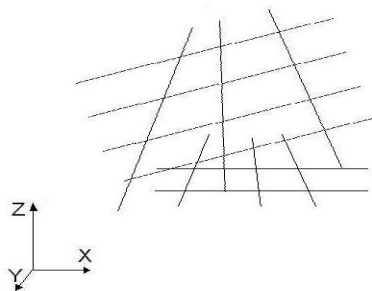

Fig. 8 The case of two objects interaction

The difficulty is to choose the pair of points $(m_i, o_j) \in M*O$, $(m_{i'}, m_j) \in M*M$, $(m_i, p_j) \in M*P$ and $(p_i, o_j) \in P*O$, where M, M', O, P are set of surface point of an object having the muscle, bone and respectively, skin type.

Starting with the anthropometrical points (Fig. 9), we will divide the system's surface in a few regions named after the corresponding points.
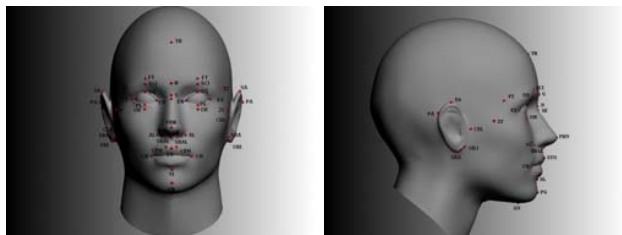
Fig. 9 The anthropometrical points

For example, for the TR region, the problem is to choose the resorts (Fig. 10) – and this problem can be solved using algorithms to calculate the minimal flux into a network, or algorithms to find the minimal cost paths – the cost being defined as the distance between 2 points,

$$\cos t = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2}$$
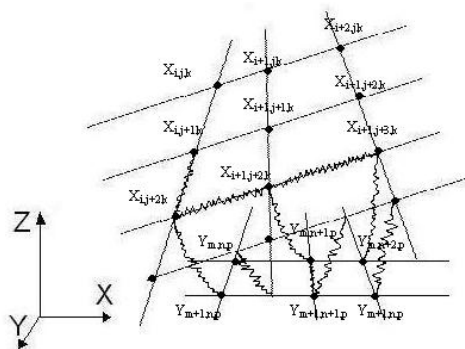

Fig. 10 The problem to choose the resorts in case of interaction between 2 objects

Using the condition that the distance between 2 points that make a pair must be minimal, it is necessary to solve the problem of calculating the minimal flux on a given network where we added another 2 points t and s, by adding all the edges from t to each point in the set with the biggest number of elements and from each point in the set with the smallest number of elements to s. It is also possible to interpret this problem as a problem of maximizing the flux on the chosen network, where we applied a bijective function – the capacities on edges in the maximization problem corresponds in this way with the values given by the algebraic inverse.

The algorithm that makes the connections necessary to add a minimal number of resorts on the 3D wire-frame system – the resorts being chosen with the smallest length is further presented (it derives from the Ford and Fulkerson algorithm [2] to find the maximal value flux):

1:       Choose x = (x$_{ij}$) the initial flux (ex. the null flux)
   Label s with (0,…,∞)
2:       **while** (there are unsearched labeled points) **do**
   { "Choose" a labeled and unsearched point i;
       labelling (i);
       if (t is labelled)   **then**

   { Change the flux on the path given by the labels;
       Delete all labels;
       Label s with (0,…,∞)
   }
   }
3: S←{i | i∈V, i is labelled}
   T←V←S
X = the maximal value flux
(S,T) = the minimal capacity section.

With this resorts system, we can solve the problem of interactions between 3D bone objects or 3D muscle objects (Fig. 11).

The only difficulty that remains is to simulate the skin's elasticity. To do this, our idea is to use an auxiliary system with rigid properties, identical with the skin surface in the number of points, edges and polygons, in which we will frame the 3D skin object.
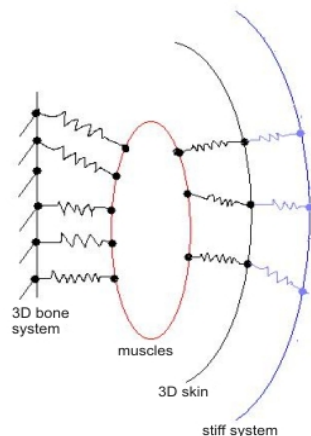

Fig. 11 The resort system to solve the interactions between objects

III. RESULTS

The system used for modeling and texture was an Intel Core Duo 6320 – 1.86 GHz, 4 GB DDR2 RAM, HDD Maxtor 250 GB SATA 2, video card: ATI Radeon X1600 Pro 512 MB DDR3 RAM. The modeling was made in 3D Studio Max 2008, and for textures we used Adobe Photoshop CS2.

The face's musculature was achieved using the Box object [3]. The insertion points and the muscles shape were defined according to the medical references we consulted in this purpose. We created each muscle separately – in order to obtain independent movements and appropriate interactions with the other muscles and the surrounding tissues.

In the first stage, we put the four vertex of the box in the insertion points of each muscle. Then, we added more details to the object by inserting some new wedges and moving them in anatomic position [4]. Generally, in order to obtain the muscle's thickness, we used the "extrude" tool (Fig. 12).

Fig. 12 The muscles modeling in our system

In the last stage, at the end of the modeling, we achieved the muscles texture. We decided to avoid using a real texture, and to create instead a personalized texture "by hand" – using a program for photo editing, Adobe Photoshop in our case – in order to obtain a improved muscles visualization [5]. Each muscle has 2 types of texture – color texture, for its color, and bump texture, for striations and all the other details (Fig. 13).
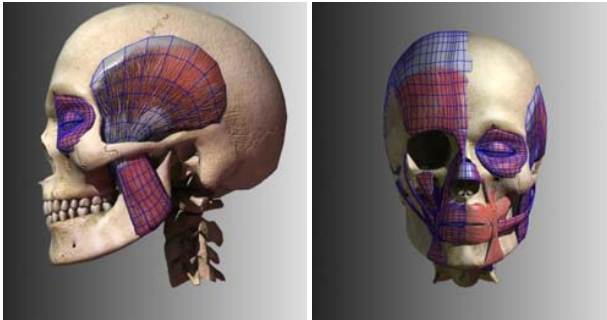

Fig. 13 The muscles in the final stage of modeling

The muscles were created perfectly symmetrically in sagital plan. The human face's asymmetry will be achieved later, by compressing some muscles or relaxing the others. We tried to make the muscles with the smallest possible number of polygons, in order to optimize their animation in real time. In the final stage, the face's muscles have 7950 polygons and, respectively, 6679 vertexes. The most muscles don't have polygons on their inner face, because this face doesn't influence, visual or technical, the final animation. In the cases of two or more overlapped muscles which interact between them, we modeled the muscles on the both faces.

IV. CONCLUSION

We paid an increased attention to the anatomical details of the facial muscles. Using the large amount of anatomical references from the Internet, we think that we succeeded to create a model very close with the reality (Figs. 14 - 16).
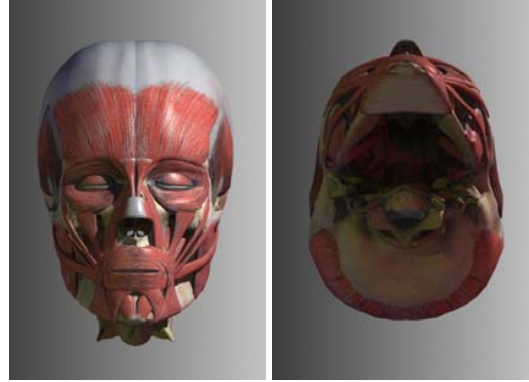

Fig. 14 The front and bottom views of our model

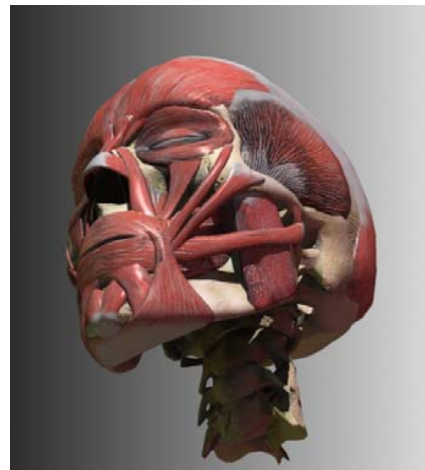Fig. 15 The left view of our model

Fig. 16 A perspective view of our model

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