face reconstruction,
forensic anthropology,
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Rafal STEGIERSKI, Pawel MIKOLAJCZAK *

FACE RECONSTRUCTION. SELECTION OF VERTICES ACCORDING TO CYLINDRICAL PROJECTION. FAST DEFORMATION METHOD.

Nowadays exist many different methods of computer assisted face reconstruction. Part of them are based on the deformation of the model face. Article presents this kind of method which incorporates the fast methods of deformation of the triangle mesh and vertices selection.

1. PREFACE

Importance of the forensic face reconstruction with no doubt is known for everyone. When other methods of identification of the victim of crime failed forensic anthropologist could help to solve the case. These matters are much often present in computer visualisation papers but yet there is not available good enough complex solution.

Nowadays personal computers are fast enough and have enough memory to run complicated algorithms which could quickly solve problems of analyzing large data sets. In addition, compilers are day by day better and generate more optimal programs. Time is a very important aspect in a computer reconstruction and visualization systems, even more important than quality.

There are few different approaches how to do a face reconstruction. Some of them try to just copy the methodology of the traditional clay face reconstruction [1]. There is also a lot of methods which use deformable models of face [3]. All of them as a base of the reconstruction use a 3d triangle mesh model of skull generated by segmentation and triangulation of CAT scans or from 3d scanners

2. ANATOMICAL LANDMARKS

In the computer assisted reconstruction like in the traditional method one of the most important factors is the set of properly placed markers. Each marker should be set in the characteristic anatomical landmark of the skull. The number of landmarks depends on a chosen method and includes from one dozen to several dozen places. The solution proposed here uses 21

* University of Marie Curie Sklodowskiej, Lublin, Poland. {ulv,mikfiz}@goblin.umcs.lublin.pl

landmarks taken from the most popular anthropological tables of human skin thickness [4,5,7]. 27 triangles for each half of the face, which are used in the selection of face the part of the head skin, are based on these landmarks (fig. 1).

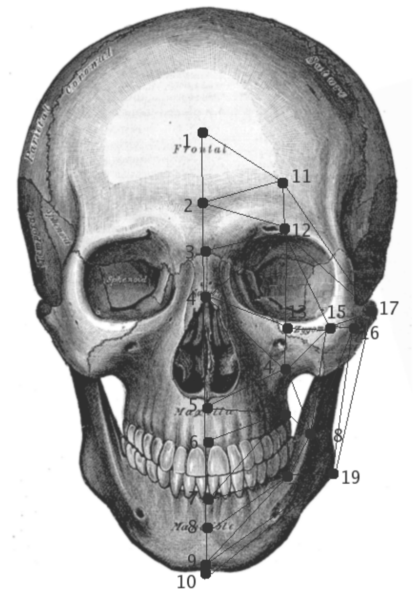


Fig. 1. 27 triangles build on the landmarks.

All the landmarks are put on the computer model of the skull in Klayman system developed by the author. It is the longest and most important in the stage of whole reconstruction and lasts from a few to several minutes.

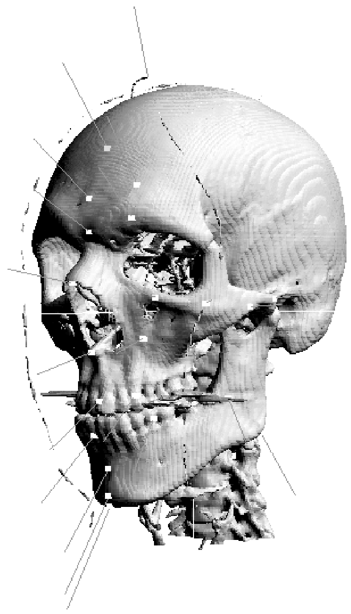


Fig. 2. The landmarks set on the 3d model of the skull.

3. CYLINDRICAL PROJECTION

The next step is the creation of the height map according to 3d coordinate of each vertex of a triangle mesh of the skull. It is made by conversion which is based on a modified cylindrical projection. For all the vertices it is necessary to calculate all the coordinate in a cylindrical coordinates [2] which is related to Cartesian coordinates as:

$$r = \sqrt{x^2 + y^2}$$

$$\Theta = \begin{cases} \arcsin(\frac{y}{r}), \; dla\, 0 \leq x \\ \pi - \arcsin(\frac{y}{r}), \; dla\, x < 0 \end{cases}$$

$$H = z \tag{1}$$

Each skull represented in the system is normalized and mounted with the top of the head in z direction, its left side in x direction and the front in y direction. Now coordinate Θ after scaling is X of the height map and coordinate H is Y. The points values of height map are calculated on the basis of the value of the coordinate r of each vertex of triangles.

All landmarks are treated in the same way and their cylindrical coordinates are calculated. It is able to select the areas of face from the skull now and cut out a face area from the triangle mesh of the skin.

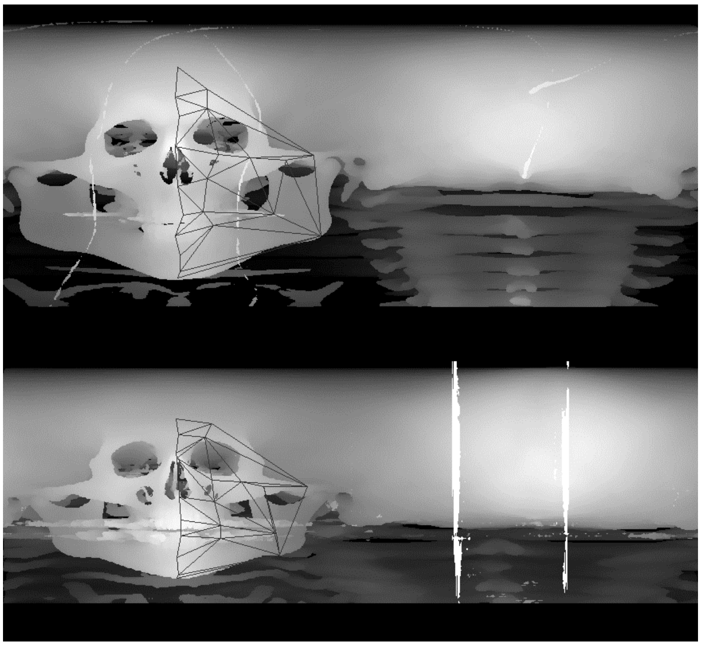


Fig. 3. Height maps for two different skulls

All of the vertices of the mesh of the skin which are inside 27 triangles built on the anatomical landmarks are selected. The algorithm is based on the 2d representation of the triangle meshes of the skull and skin because we only use coordinates *Θ* and *H*. To find out all the required of vertex in the face area it is necessary only to calculate 6 times simplified[1] cross product and 3 times dot product per vertex, so it is a much faster way than in 3d space.

3. PARAMETERS OF THE DEFORMATION. SHEPARD'S METHOD.

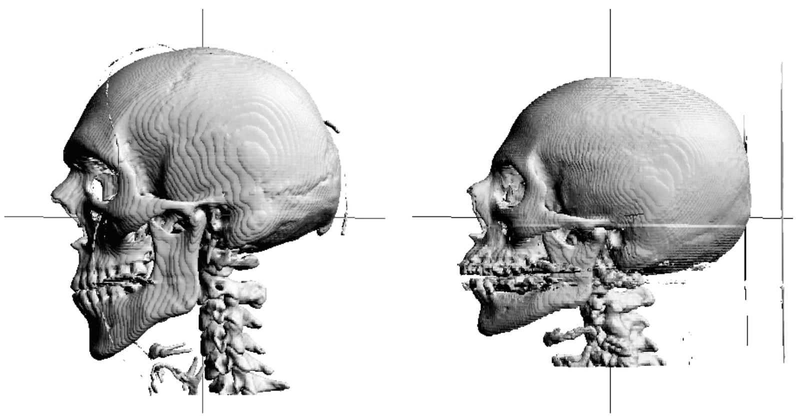
The triangle mesh of the model skull and mesh of the skull of an unknown person have the markers set in the anatomical landmarks and according to these coordinates the value of ΔX shifts is calculated. Then for all the vertices of the face areas a new position is found. Based on ΔX the value of ΔX_i is interpolated. For this reason Shepard's [6] method generalized to three dimensions is used.

$$\Delta X_i = \sum_{i=1}^{n} w_i f_i$$

where:

$$w_i = \frac{h_i^{-p}}{\sum_{j=1}^{n} h_j^{-p}}$$

The values h_i and h_j are a distance in Euclidean metric between the analyzed vertex and knot which is at the marker position. The value p, called power parameter, defines the weight of the knots by its distance and the author used the standard value $p=2$.



[1] We use only the sign of the result not the value

Fig. 4. The model skull (left) and an unknown person's skull

The first version of the algorithm calculates the value ΔX_i for vertex according to coordinates of 3 knots in the anatomical landmarks which build one of 27 triangles to which vertex belongs. This attempt was too rigid and triangle mesh get as a result was very distorted (fig. 5). When all of the marks are used as knots the result is proper, all the calculations are simple and this change doesn't affect the time of execution significantly.

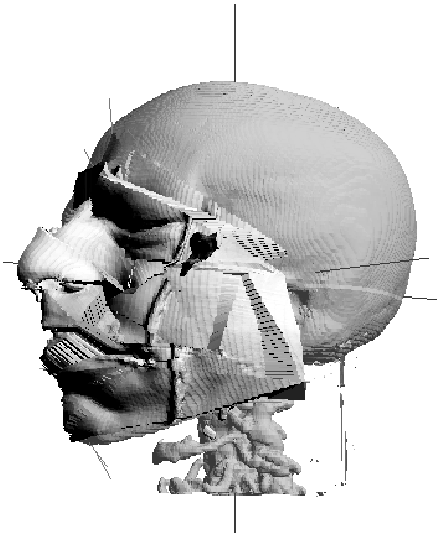


Fig. 5. Result of improper deformation

4. CONCLUSIONS.

The result of deformation, despite of the relatively simple method, is proper. The quality of the triangle mesh is good without any artefacts. The proportions and the shape of the generated face fulfil the proportions and the shape of an unknown skull (fig. 6 and 7).

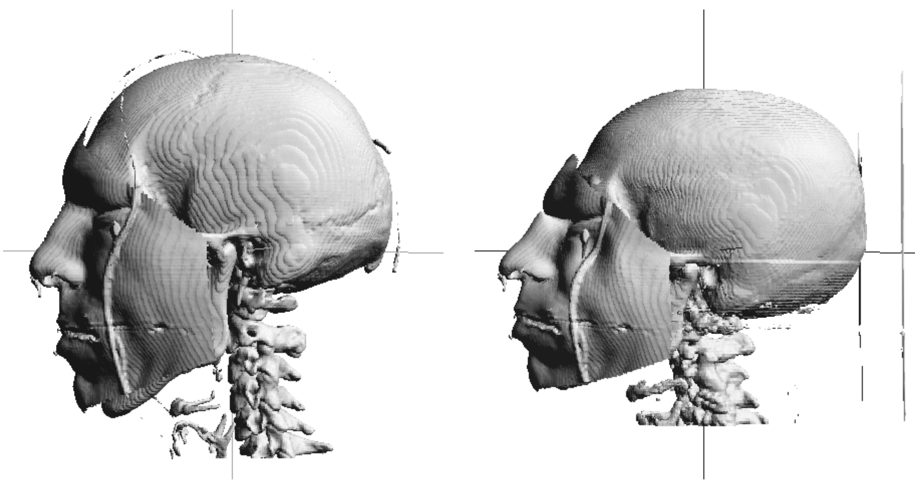


Fig. 6. The skull with the model face (left) and the result of deformation

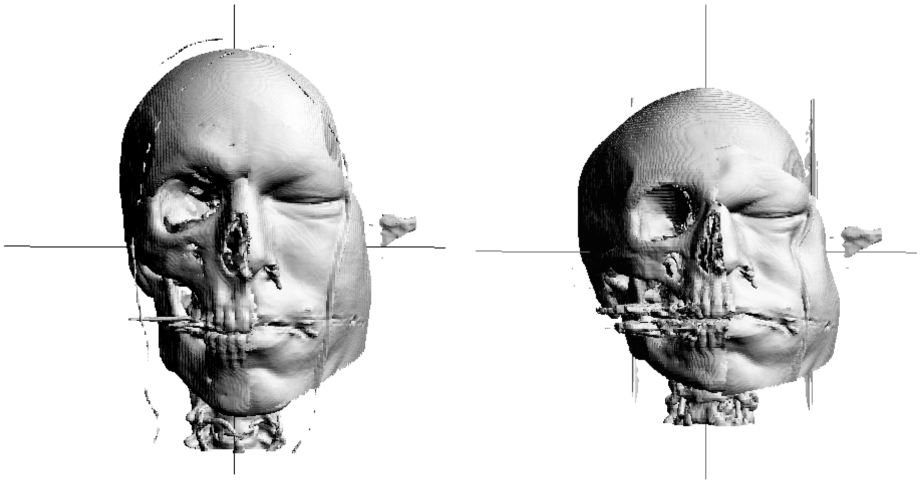


Fig. 7. The skull with the model face (left) and the result of deformation

Both presented in this article algorithms are very fast. In tests on Athlon XP 2100+ with 512 Mb and under Linux OS were used triangle meshes with over million and seventy thousand triangles. The time of selection of vertices takes under 1 second and the calculation of deformation takes about 3 seconds. The current work is focused on using bigger sets of landmarks of all the skull, not only the face, and other types of interpolations.

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All CT data are from Visible Human Project, National Library of Medicine, National Institutes of Health, USA as a model skull and skin and from Computer Graphics Laboratory, Stanford University (North Carolina Memorial Hospital), USA as unknown skull.