*archelogy, forensic sciences,*
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# METHOD OF THE CRANIOFACIAL ARCHAEOLOGICAL RECONSTRUCTION BY DEFORMATION OF THE MODEL FACE

Article presents fast method of the face reconstruction for forensic and archeology science developed by authors which is based on a deformation of the known skin aligned to skull. As a guide to deformation a position of the well known anatomical landmarks is used. Calculation of the new position of the vertices of a triangle mesh of the model presented is a result of the inverse distance weighted interpolation. To improve precision usage of the skin thickness values from anthropological tables is used. As a example of the available results reconstruction for archaeological investigation is presented.

## 1. INTRODUCTION

Many different and important factors are incorporated in process of the identification of human remains. This is the cause of hard to eliminate problems with a possibility of unequivocal identification, more often result could be obfuscate additionally by part or all body putrefaction or shatter. There is also pressure in the society to find out personality of all victims of the crime even with tolerance of uncertainty at the same time.

In forensic science division among few levels of the quality of identification from "probably" in case of correspondence of a tattoo, scars or dental cards, through "positive" in case of DNA or fingerprints examination exists [1,2]. Human face reconstruction in all cases is very biased by subjectivity. Anthropologist or Artist, or sometimes both along, makes reconstruction based on his anatomical knowledge as their own intuition, aesthetics and feelings. It is not only but one of the main reasons to not fulfil Daubert standard. Forensic face reconstruction could be only evidence of the identity. We could put here the question is there any cause to reconstruct victims face if result is in a such a big part tentative and subjective. But in forensic investigation a lot of methods is only support for researchers and help in case when all other ways to solve the case failed.

For us more interesting in this case is reconstruction made for needs of archeology or, rarely, anthropopaleology. It is situation where human curiosity is proximate cause of activity. Reasons are much simpler and margin of acceptable mistake is bigger. We should consider that lesser significance has accuracy of real and recreated look than aesthetics and educational value.

## 2. RECONSTRUCTION PROCEDURE

There is possibility to point out two main groups of the methods of computer face reconstruction. One, and probably more popular, are all algorithms based, as one presented in this article, on the deformation of model face according to selected geometrical [4] or anatomical circumstances. Another, and because of level of complication rarely implemented, are those methods which in strict way try to incorporate implementations of traditional clay methodologies of the reconstruction.

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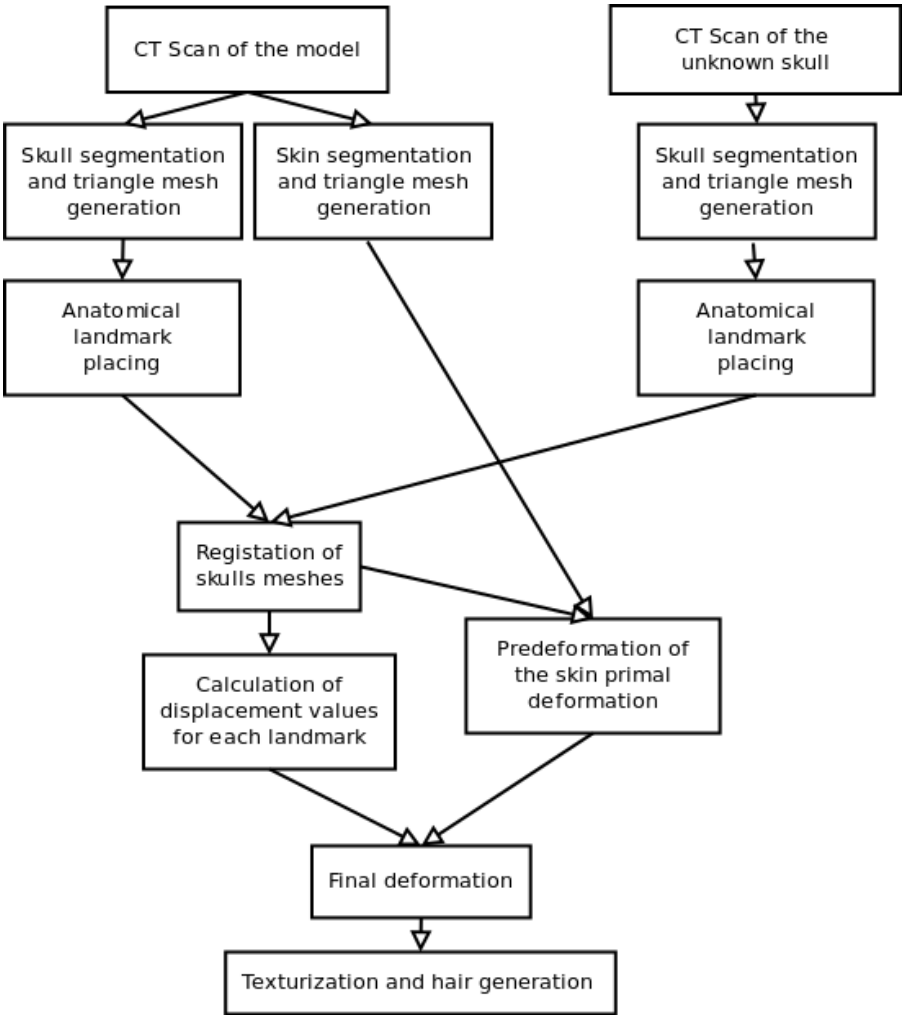


Fig. 1. General workflow of the reconstruction procedure.

As a start condition which should be met in the case of the traditional face reconstruction is ability to obtain clean skull without any remains skin or muscles. In some situation when not all soft tissues have away it is necessary to remove them with surgical tools, hot water or insect colony. We could use in situation like this for example *Dermestes Maculatus* bug which is able to clean all skull in about twelve hours [5]. Most skulls in archaeological investigations tissues are mummified and if we could and want to only way to soften them is water based bath. In any attempts very important is to be as careful as it possible with old skull because some, such as nasal, zygomatic arch and inferior orbital bones are delicate and easy could be broken. Many of tenth or hundreds years old bones became very degraded and fragile and it is one of the reason why in archaeological reconstruction very important seems to be leaving all remains intact for further investigations. Nowadays there are tendencies to use cast or, more often, based on CT scans, photolithographic copy of the skull. Additionally CT scans are also probably best point of the start to computer aided based craniofacial reconstruction. In the most cases first step of the all process is creation of the three dimensional volume from a data obtained with medical equipment acquisition. Then segmentation, even with using of the simplest methods, of the volume is done. This step is equivalent to cleaning skull in traditional, clay based methodology. At this stage creating of real 3D model is possible.

In next step it is necessary to find out equipotential planes and triangulate them by, for example, marching cube, marching tetrahedra or similar algorithm. As a result of this operation we obtain triangle mesh which is necessary to be reduced by decimation [16] or edge collapse and finally smoothed.

Method presented in this paper originally was based on 21 anatomical landmarks [8,9,10] which are in clay reconstruction used as a place where to put wooden dowels. All landmarks are well known and collected in many popular anthropological tables of soft tissue thickness [11,12,13]. This anthropological markers are bonded to the triangle mesh of skull on characteristic places. Deformation of the model skin

in presented method is done according to position of these landmarks which have to be placed as on model skull as well as skull on unknown victim. After registration process of skulls with Iterative Closest Point algorithm [14] value of the displacement $\Delta X_j$ is calculated. This is as a variance of the position for corresponding landmarks.

Because skin is correctly aligned to its skull for this moment for each vertex of the mesh of the model face it is necessary to find out value of displacement $\Delta X_j$. It could be obtained by interpolation of known values of $\Delta X_i$. Shepard's inverse distance weighted interpolation method was chosen for this purpose [15]:

$$F=\sum_{i=1}^{n} w_i f_i \tag{1}$$

where $n$ is a number of scatter points and in this case is equal to number of landmarks, and $f_i$ is value of each point and in this particular case it is $\Delta X_i$.

Now we could express equation for $\Delta X_j$ as a:

$$\Delta X_j=\sum_{i=1}^{n} w_i \Delta X_i \tag{2}$$

where:

$$w_i=\frac{h_i^{-p}}{\sum_{k=1}^{n} h_k^{-p}} \tag{3}$$

Because this method is geometrically dependent it is worth to emphasize that proper position of both skulls is very important. Any misalignment generates deformation because deformation is described only with translation not rotation.

Values $h_i$ and $h_k$ are just distances in Euclidean Metric between position of the scatter point which landmark is in this case and current vertex of the triangle in the mesh. Value $p$ is called power parameter and defines component of the individual scatter points in function of distance. We find out by experiment that in this case $p$ equal 2 is the best. Because procedure of finding proper parameters of displacement for vertices is formulated this way we could safely ignore any differences in size, shape or proportions of used skulls. Despite this fact oneness of race and gender could give us better results. Method give us also an ability to reconstruct all head not only face. This is possible thank to fact that proposed method extended list of used landmarks. To attain these possibility landmarks at new positions *vertex* and *opisthocranion* had been added. Procedure of the selection of the triangles of a face in the mesh of a model when we work with wide set of landmarks could be skipped [10].

Known in some cases problem of anomaly deformation visible near scatter points could be eliminated with new weights $w_i$ formula which incorporate information about distance to most distant scatter point had been implemented:

$$w_i=\frac{\left[\frac{R-h_i}{Rh_i}\right]^2}{\sum_{k=1}^{n}\left[\frac{R-h_k}{Rh_k}\right]^2} \tag{4}$$

Where:

$$R=max\{h_1, h_2 \square\} \tag{5}$$

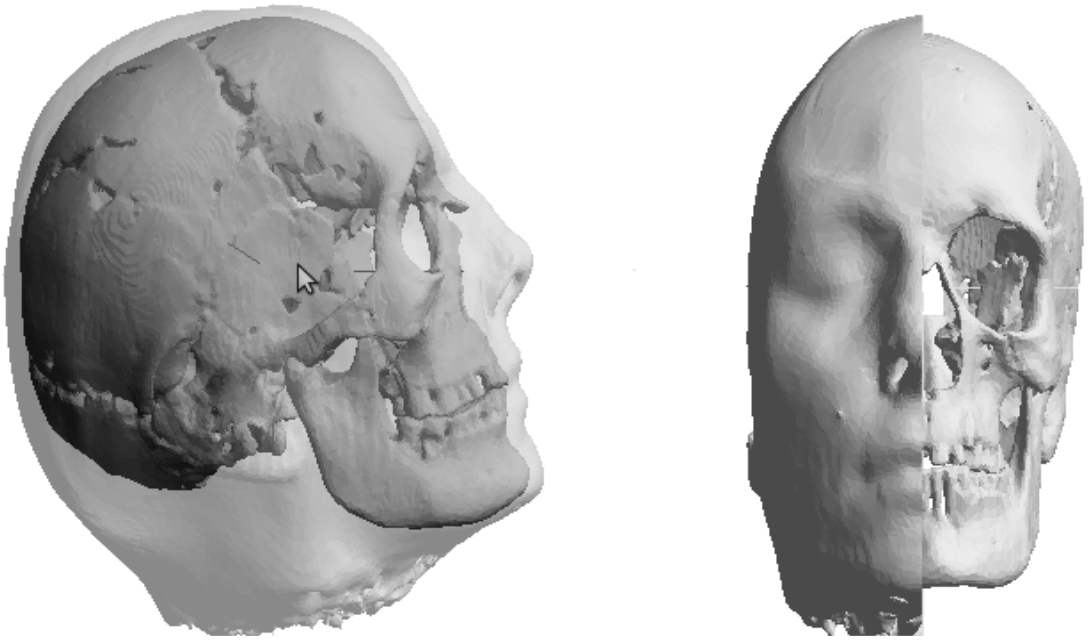

Fig. 2. The reconstructed face and unknown skull.

Presented method have improved quality of interpolation with additional scatter points generation, but concept of extending list of the anatomical landmarks is not good idea. It not only increases time required by anthropologist to put them on but also complicates methodology a lot. In our method availability all the time information about skin thickness from anatomical tables is used and virtual dowels are created similar to traditional, clay reconstruction. At this moment algorithm of interpolation uses twice as, 68, scatter points in which number 34 are landmarks and 34 are ends of the of virtual dowels. Preliminary simple deformation of the model skull and skin before main, inverted weighted deformation, increases quality of final reconstructed face. Parameters of rescaling along *0x*, *0y*, *0z* axis is find out according to most distant points in each of three planes: *vertex* and *menton*, *opisthocranion* and *rhinion*, left and right *zygomatic arch.*

In reconstruction last few steps are based on artist or anthropologist aesthetics. It is selection of texture, skin color pale, color and look of hair or shape, size and color of the eyes.

## 3. RESULTS

To the newest one and presented here reconstruction is the skull from a gravesite in Bavaria, Germany was used. Final visualization with proper texturing and hair generation could be seen on fig. 3.

In this case result of comparison of the generated face and the real one for unknown skull is not possible, but anatomical position of eyes, shape an position of nose and mouth is correct. Similar situation is for thickness of soft tissues which in most places is very close to expected values. Ear position to *auditory meatus* position is correct as seen on fig. 2. According to anatomical properties and results of earlier test we could set thesis that proposed method is accurate and trustful.

Fig. 3. Complete reconstruction textured and with generated hair.

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