*craniofacial forensic reconstruction,
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WORKFLOW FOR CREATION OF THE MODEL HUMAN HEAD FOR FORENSIC FACE RECONSTRUCTION

Article presents proposal of unified workflow for creation models of human head for usage in deformational method of forensic face reconstruction. Preparation of each model is made in two stages First one is creation of traditional dowel-clay reconstruction, second is in short triangle mesh preparation as a result of digitization. Article should be start point for discussion how obtain best results not only at computer science level but also anthropological. As a long time result we want to create database of standard reconstruction models with main races and genders at least.

1. INTRODUCTION

One of the key aspects of the deformational model face reconstruction method proposed by R. Stegierski [4, 9] besides proper placing of virtual dowels in anatomical landmarks [11] is usage of neutral and as anatomically as it possible accurate base model for deformation. To obtain such one method of searching and testing one by one examination of live humans is not only time and resources consuming, but also ethically doubtful. Best and not biased in any way, despite of artist and anthropologist sense of aesthetics, is creation of model from the scratch. This very average, reusable model is available when we decide to involve traditional methods in creation of reconstruction.

Clay model is only half way. Second part of preparation of the virtual head is repeatable list of steps in processing of data from raw space of vertexes obtained from computer tomography images to specially described and organized triangle mesh data of skull and skin.

2. STAGE ONE - TRADITIONAL RECONSTRUCTION

Anthropologists study relationship between flash thickness and age, gender, race and nourishment manners of people for over 150 years. Statistical databases are built on often tens, and sometimes even hundreds of cases around the World. Anthropological centres created its own methods and selected different anatomical points into sets because of lack of generally accepted norms. Number of points gathered in typical set is range from 9 to 35. Comparison of different datasets is additionally complicated by different nomenclature used for describing of the same point. Good example here is *sublabiale* which is the same as *labiomental* or *supramentale*.

Unquestionable pioneer of studies on skull skin and flesh thickness is Herman Welcker. He examined in 1883 thickness of thirteen dead people with lancet spiked in flesh at ten selected points. Wilhelm His twelve years later examined twenty eight people with needle and gum roller with extended set of points by six lateral ones [1]. Kollman and Buchly had used method similar to the His method with next three points added and presented results of examination of 25 people from 17 to 72 years old [3].

His method was a base for many anthropologists who created its own tables for different gender and races. We should mention J. Czekanowski in 1907, D. Berger in 1965, Leopold in 1968, P. R. N. Sutton in 1969 and J. S. Rhine in 1982 for Caucasians. F. Birkner in 1907, K. Suzuki in 1948 and J. S. Rhine in 1983 for Mongoloids, Von Eggeling in 1909 and J. S. Rhine and H. R. Campbell in 1980 for Negroids.

Right in 1935 V. Suk discussed precision of needle and similar methods of examination [5] but until nowadays when diagnostic equipment like ultrasonography, computer tomography or magnetic resonance imaging is used in this scope it was irreplaceable. Up to date new, in most of cases more accurate, anthropological tables have been created since fifties of twenty century. To the most popular datasets belong one created by I. M. Bankowski in 1958, W. Weining in 1958, D. Leopold in 1968, R. M. Georg in 1987 for Caucasians, D. Sahni in 2002 for Mongoloids, and W. A. Auslebrook in 1996 for Negroids. For first model we chose dataset of R. Helmer created in 1984 for Caucasians and based on very large database of cases which include not only criterion of gender but also age [13].

Clay reconstruction should be created with usage of Prag-Neave method which is probably the most accurate nowadays and in depth presented by C. Wilkinson [7] and based on standard anatomical model of skull assorted with gender and race. For reconstruction it is necessary to be as neutral as it possible without any marks of mood but wrinkles or other signs of aging are proper and should be included.

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3. STAGE TWO - BASE MODEL GENERATION

Creation of virtual human head model for reconstruction takes few main steps. As a result we get specially described, high quality, triangle meshes. All used in processing methods and parameters have to be the same for every model to preserve constant level of imprecision.

3.1. DATA ACQUISITION

First step is acquisition of data with computer tomography. It should be done with resolution about 1 millimetre per pixel and step 3 millimetres or less. Probably MRI as a source of images is also acceptable, but CT is not only easier accessible, but also preparation of set of data takes less time.

3.2. NOISE REDUCTION

In processing of live humans results of examinations any operations on medical images which remove or change characteristics of noise should be avoid. One of the ways to get smoother and better visually mesh as a result of preparation of the virtual head model for FFR[I] is reduction of unnecessary noise from acquisited images. From many available methods based on convolution and gradient filters most appropriate are median and Gaussian smoothing with standard deviation near 0.75 [6].

Table 1. Test results of noise reduction filters

Filter	*Average change of voxel value (HU)*	*Maximum change of voxel value i (HU)*	*Standard deviation (HU)*
Average	21,82	1446	60,14
Gaus σ = 0,5	9,13	564	24,64
Gaus σ = 0,75	17,86	1109	48,80
Gaus σ = 1,0	23,23	1357	63,46
Gaus σ = 1,5	29,06	1678	78,91
Median	14,30	1694	47,45
Contour preserve	0,295	427	4,71

3.3. SEGMENTATION

Next and very important step is segmentation of the data volume created from series of tomography images. It's quite easy in this case, because we have only three different materials in use. First is plastic of the anatomical model of skull, second wood dowels and third clay used in reconstruction of soft tissues. Simplest way is usage of standard binary thresholding, or even better version which conserves values over the threshold level and gives this way higher quality mesh after triangulation.

We also propose to use three directional threshold segmentation. This method is much better in case of single closed spaces like in this case. Its common part three of one dimensional min max segmentation described with formula:

$$M(x) = \begin{cases} 1 & for \quad x \in \langle x_{Imin}+1, x_{Imax}-1 \rangle \\ 0 & for \quad x \notin \langle x_{Imin}+1, x_{Imax}-1 \rangle \end{cases}$$

where

$$x_{Imin} = min(x) \qquad x_{Imax} = max(x) \qquad for\ D(x) > T_l \tag{1}$$

[I] abbreviation to Forensic Face Reconstruction

Where x is position in one dimensional space get as a result of decomposition of the volume, $D(x)$ is density at position and T_l is threshold level. For $min(x)$ and $max(x)$ we get smallest and greatest position over T_l.

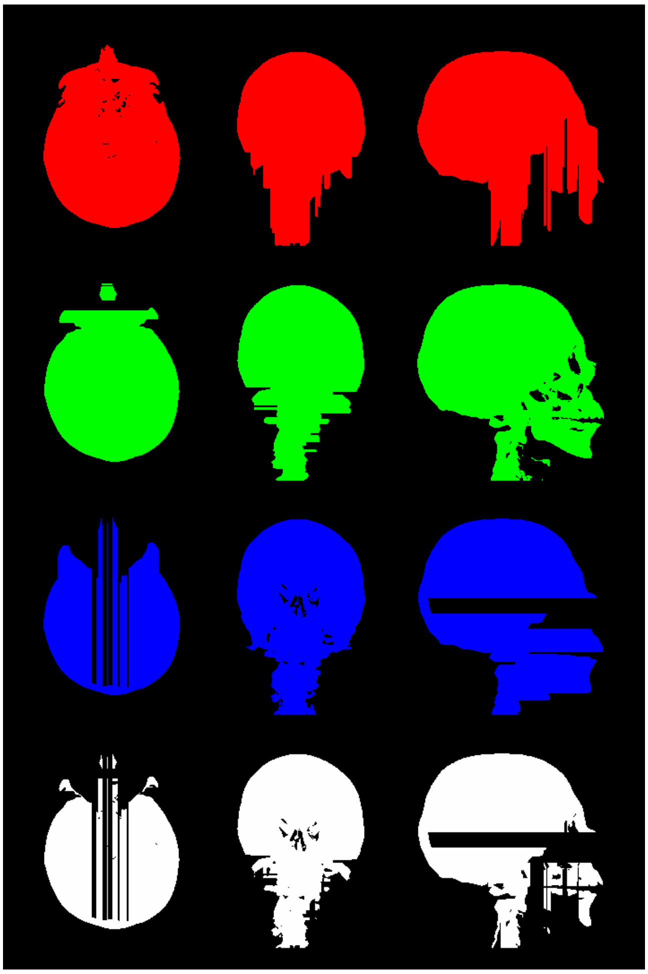

Fig. 1. Three directional segmentation, separate results for all directions and result of composition.

Final model after proposed segmentation and its triangularization contains up to 20% of triangles less.

3.4. GENERATION OF THE MESH

To obtain precise and accurate triangle mesh usage of the verified and foreseeable method should be used. We suggest extended by E. V. Chernyaev marching cubes version which removes topological errors of original method [10] or marching tetrahedron which is free of patent issues [8].

3.5. TRIANGLE MESH SMOOTHING AND REDUCTION

All triangularization method based on decomposition of volume into cubes gives non smooth connections between next triangles. To reduce this deficiency usage of smoothing algorithms is necessary. Simple relaxation is fast but doesn't preserve volume size of skull and soft tissues what is very important in face reconstruction. In these situation better results gives W. Pilgers mesh smoothing [14].

From volume with small distances between voxels as in this case we get very dense mesh which should be reduced to acceptable size with preserved level of details and. Klayman CAFFR System [6] is designed to work with models up to 1.5 million triangles per model so not very extensive reduction is necessary and any, even simple, method from decimation to edge collapse could be use.

3.6. LANDMARK PLACING

At this moment we have two registered models skull and soft tissues. Next step is placing of virtual dowels in anatomical landmarks. It should be done according to position from Helmers anthropological data of soft tissues thickness extended by two new points: *vertex* and *ophistocranion* to set proposed by R. Stegierski [6] and used as a base in Klayman CAFFR.

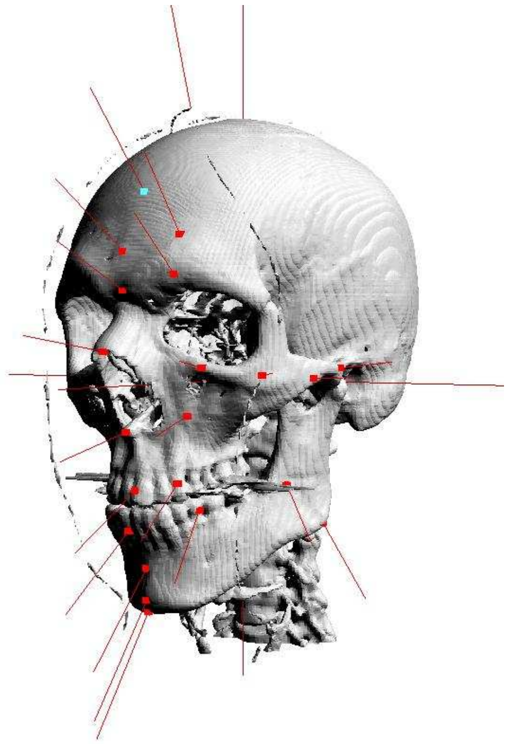

Fig. 2. Skull generated with proposed workflow with virtual dowel set on anatomical landmarks.

3.7. TEXTURIZATION

Full set of the textures for could be generated from set of photographs from traditional model if it was created with colorization and artificial glass eyes. Second way to obtain images for textures are photographs of the human in similar age, gender and race, but this time manual registration patches and model is necessary [2].

4. CONCLUSIONS

Presented workflow is result of few reconstruction models based on real human examinations. It was kind of pilot test for system and each proposed method. Finally we find out that repeatable way of the creation human head models for forensic reconstruction systems based on deformational methods is best way to build library of base models for different races, genders and ages. Computer aided forensic face reconstruction is relatively young branch of science and probably no other unified workflow has been presented so far. At this moment first one model of the 30 years old white male is under way and should help to verify proposed workflow on each level.

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