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APPLICATION OF COMPUTER MODELING FOR PLANNING PLASTIC SURGERIES

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Abstract
The paper presents the application results of reverse engineering technology for planning the plastic surgery. First step is digitalization of the patient body. It is realized by 3D structured light scanner. The scanning data are transferred into 3dsMax software and used for planning plastic surgery. The planning effect is shown using stereoscopy visualization method.

Keywords
reverse engineering, medicine, stereoscopy.

Introduction

The paper presents the application o reverse engineering technology for planning the plastic surgery. The reverse engineering gives tools for constructing the object basing on the material model – without traditional designing.

Nowadays, in many fields like engineering, medicine, science, cultural heritage, surface mapping of the three-dimensional object shape becomes essential. In the era of automation and pressure on product quality, industry sets high demands on the modern techniques of measuring the surface of objects. Many measurement techniques are strictly connected with a method of structured light.

The common feature of these methods is the use as a sources of illumination the object light digital projector or its equivalent, allowing the projection of detector matrix (CCD or CMOS cameras).

The scanning results are the base for the computer modeling of the object's geometry.

The paper presents the computer modeling of the face concerned with surgical planning and prediction of human facial shape after rhinoplasty, otoplasty, lip augmentation, chin and cheek augmentation using surgical implants. Facial plastic surgery corrects various facial flaws that undermine one's self-confidence. Cosmetic surgery, by correcting patients appearance, may change their feelings about themselves. Surgery simulation is a growing field of research comprising the efforts of various disciplines including computer graphics, computer vision, medicine, mechanics, robotics and even animation.

The last part of the paper describes the method of modeling results – the stereoscopy visualization, which can show the 3-dimensional (3D) virtual object in 3D space, instead the traditional projection of 3D object into flat surface of the computer monitor.

State of the art

The computer modeling in medicine is described in the literature.

Girod et al. [1] have been presented the computer-based system for simulation, visualization and manipulation of CT-data of craniofacial surgery. Surgical procedures in all areas of the bony skull have been performed interactively.

Liodaki et al. [2] have been shown the use of PET scan in plastic and reconstructive surgery.

Tepole et al. [3] have been described computational modeling of skin for prediction of tissue necrosis in reconstructive surgery.

Non-conventional application of computer modeling has been presented by Laurentini and Bottino [4] – computer analysis of face beauty.

Computer modeling for preoperative planning of oral and maxillofacial surgery has been shown by Thomas et al. [5].

Scanning system for reconstruction of scoliosis has been described by Rodriguez et al. [6].

Ozkul [7] has been worked out the computer simulation method for plastic surgery (rhinoplasty) planning.

Modeling of breast reconstruction has been presented by Szychta et al. [8] and Sun et al. [9]

Problem of accuracy in 3D face reconstruction has been worked out by Mestetskiy et al. [10].

3D facial reconstruction has been presented by Jo et all. [11] and Saracchini et al. [12], too.

Another application of computer modeling for craniofacial surgery has been described by Chowdhury et al. [13].

Similar problem – 3D simulation for nose surgery has been presented by Wang et al. [14].

The integrated computer environment for plastic surgery support has been shown by Porro et al. [15].

Scanning

The structured light 3D scanner with FlexScan3D software has been used for digitalizing of the patient face (Fig. 1).

For 3D scanning technologies, the distance and angles between imagers and the projected light source creates a base of the triangle. The angle of the projected light returning to the imager from the surface completes a triangle where a 3D coordinate can be calculated. By applying this principle of solving triangles repetitively, a 3D representation of an object is created.

A 3D scanner is a device for creating high resolution digital 3D models from real-world objects. The scanner is built around stereo-vision (normally two digital imagers) and structured light projection in order to generate 3D. The scanner is controlled by 3D scanning software that runs on a computer. A 3D scanner is also capable of capturing the color map of an object. By merging the color map onto the 3D model, a color 3D digital model is created.

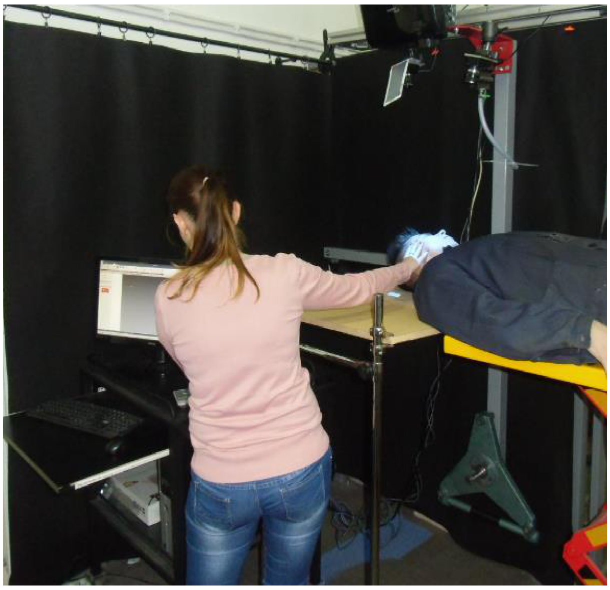

Fig. 1. Scanning apparatus [16].

The first step in conducting the scanning process was the preparation of a patient. Due to the method used in the measurement, it is necessary that the object does not give additional light reflections. Human skin is not inherently dull, especially on the face, therefore it was covered with matting powder. The next step was the preparation of the measuring table. Patient was lying that its longitudinal axis was perpendicular to the measuring arm in starting (vertical) position. After proper positioning of patient, face scans, using FlexScan3D software [17], have been made. During the measurement, patient had his eyes closed and laid motionless. To obtain complete three-dimensional model, it was necessary to scan patient's face under different angles. While the patient lays motionless on the table, the operator changes the position of the measuring equipment. Using the kinematic mechanism, scanner was set in nine scanner positions – accordingly for the left and right side of patient's face. When appropriate number of scans is done, the file should be saved as a one coherent image. For further analysis of acquired scans, the files were exported in .stl and .ply formats. These formats allow to perform data analysis in CATIA, 3ds MAX and other software, that has a possibility to import files in that extensions.

Modeling

Facial plastic surgery corrects various facial flaws that undermine one's self-confidence. Cosmetic surgery, by correcting patients appearance, may change their feelings about themselves. Surgery simulation is a growing field of research comprising the efforts of various disciplines including computer graphics, computer vision, medicine, mechanics, robotics and even animation.

File containing the point cloud was received using structured light 3D scanner and software FlexScan 3D. This was later processed to the solid object by successive operation in 3ds MAX system [18, 19] (Fig. 2).

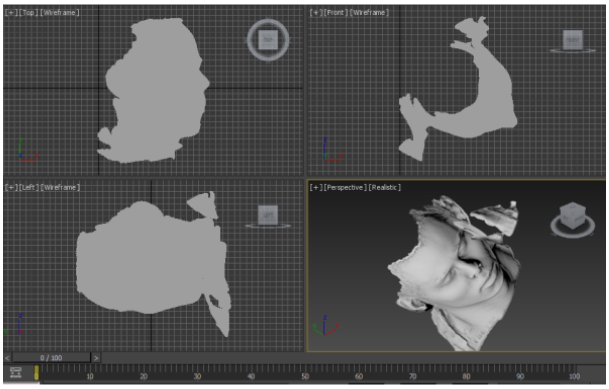

Fig. 2. Imported STL file in 3ds MAX [20].

Elements of face on 3D model were modified to show prediction of the treatment effects. Basic model was used to change proportion of the nose, ear, chin, cheek and lips. The goal was to predict the facial shape after standard procedures in selected plastic surgery treatment.

Rhinoplasty [21, 22] is a surgery which reshapes a nose. It can make the nose larger or smaller; change the angle of the nose in relation to the upper lip or correct bumps, indentations, or other defects in the nose. Nasal structures on 3D model were enlarged and reduced in different level (Figs. 3, 4).

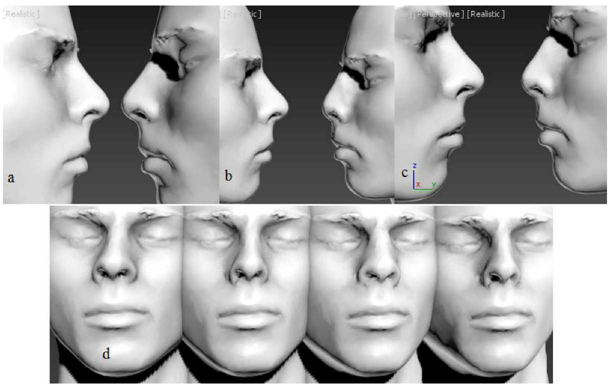

Fig. 3. Rhinoplasty – on the left side preoperative view: a) flattening and reducing the width – 10%, b) flattening 30%, c) flattening 20%, a reduction of the width 10%, d) front view of the base model and subsequent models after modifications [20].

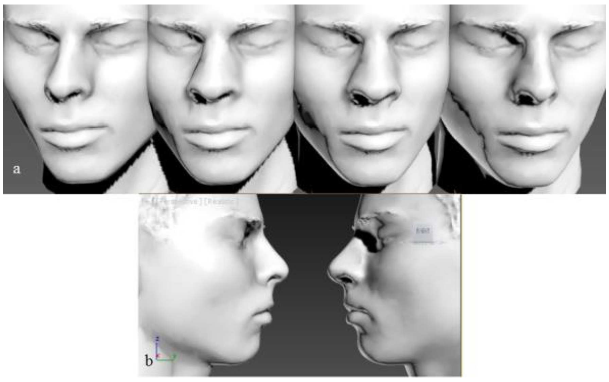

Fig. 4. Increase the size and inclination: a) frontal view – from the left side -base model and modifications: increase width 20%, increase width 20% and length 10%, inclination 2^0, b) increase width 20% and length 10% – profile view [20].

Otoplasty [23] – The goal of otoplasty is to correct protruding or deformed ears surgically. Ears on the model were reshaped in many different ways, mainly: ears pinning and reducing size of the ears (Figs. 5, 6).

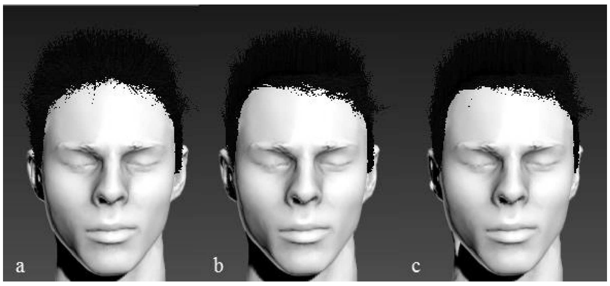

Fig. 5. Otoplasty – changing the angle of inclination: a) the base model, b) ear pinning 6°, c) ear pinning 8° [20].

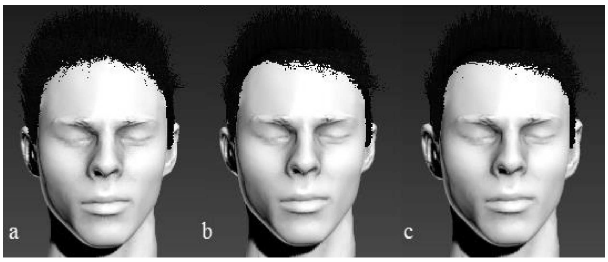

Fig. 6. Otoplasty – changing the size: a) the base model, b) reducing the size, c) increase the size [20].

Lip augmentation [23] is a procedure that aims to improve the appearance of the lips by increasing their fullness through enlargement. Volume of the model lips was increased (Fig. 7).

Facial implants [25] can be used to augment chin and cheek. They are available in a wide range of sizes and styles and restore contour and proportion of patient's face. Some 3D models were constructed to demonstrate effects of these treatments (Figs. 8, 9).

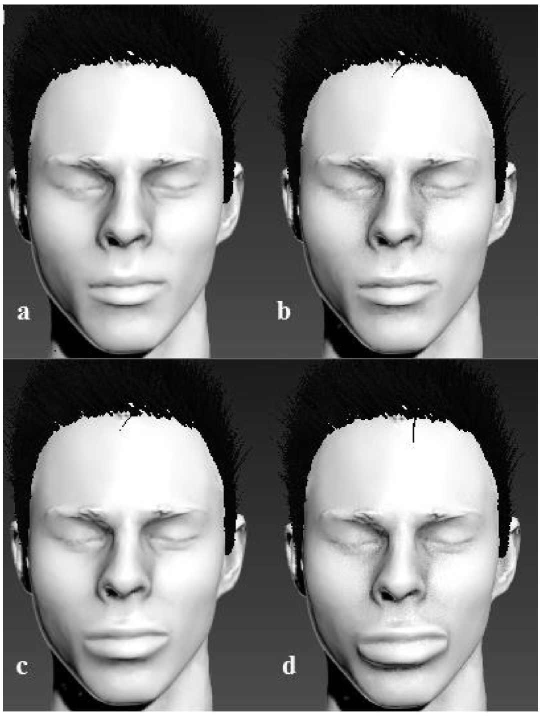

Fig. 7. Lip augmentation: a) the base model, b)increase lips volume – 5%, c) increase lips volume 10%, d) increase lips volume 20% [20].

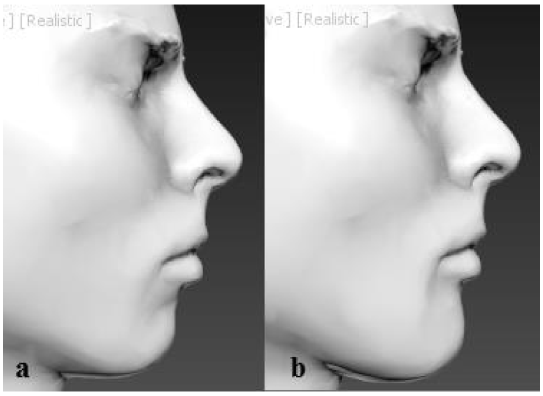

Fig. 8. Chin implant: a) the base model, b) computer – simulated result [20].

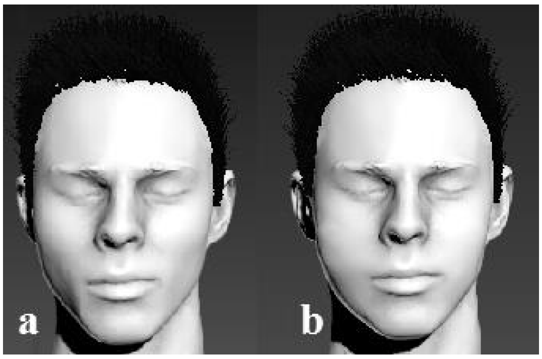

Fig. 9. Cheek implant: a) the base model, b) computer simulated result [20].

Visualization

The virtual face model for visualization should consist two elements: the object's geometry and the object's color texture.

The used scanner has two monochrome CCD cameras, that implicate the monochrome textures only. For increasing the visualization effects the color textures have been mapped on the scanned and modeled geometry and – on final – the virtual face model has been shown using the stereoscopy visualization.

At the first step the head textures (photo images) have been created and imported into Photoshop CS6 [24] (Fig. 10) – each texture has been located on the individual layer. The textures have been merged by managing the layer transparency (Fig. 11). The merged textures (bitmap) and object's geometry have been imported into 3ds Max software.

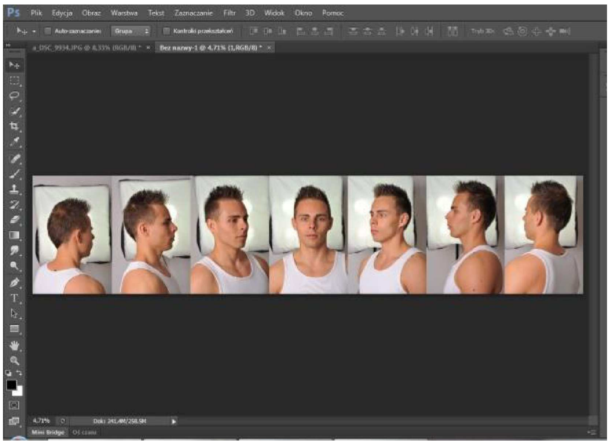

Fig. 10. Face textures in Photoshop CS6 [26].

Fig. 11. Merged textures [26].

The bitmap has been used as the texture in Material Editor (Fig. 12).

The bitmap has been mapped on geometry – this operation required some manual operation. It can be done by function *Modify-UVM Map*, which creates the tools named *Gizmo* (Fig. 13).

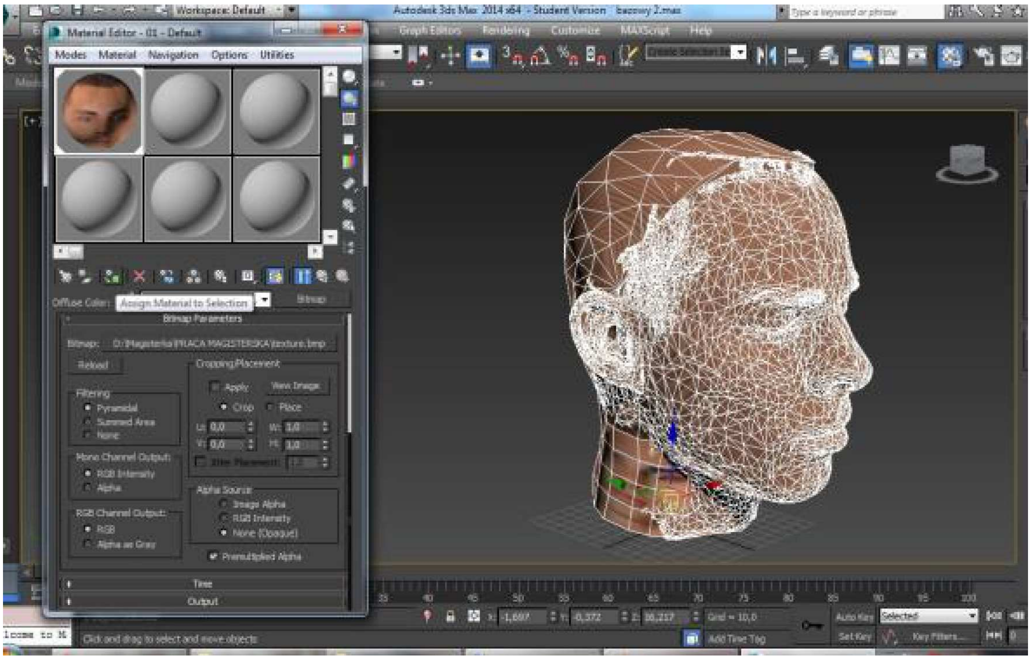

Fig. 12. Face bitmap as material texture [26].

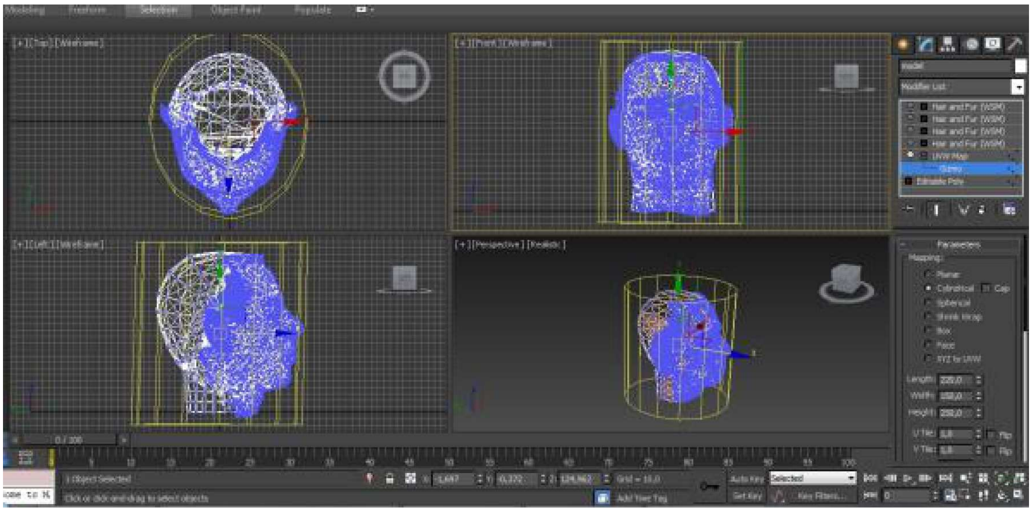

Fig. 13. *Gizmo* tool for texture fitting [26].

The result of final texture fitting is shown in Fig. 14.

The final step was the stereoscopy visualization using the anaglyph method.

The stereoscopy visualization [26, 27] requires the two virtual cameras, which can be defined in 3ds Max software (Figs. 15–17).

For stereoscopy visualization of the both images have to show as one image. It can be done using anaglyph technique [26, 28]. The green and blue colors are removed from left image. The red color is removed from the right image (Fig. 18).

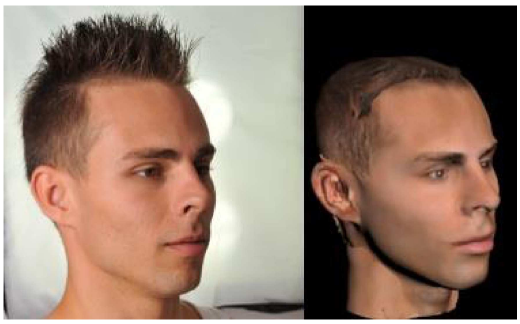

Fig. 14. Face photo and color texture mapped on 3D geometry of base model.

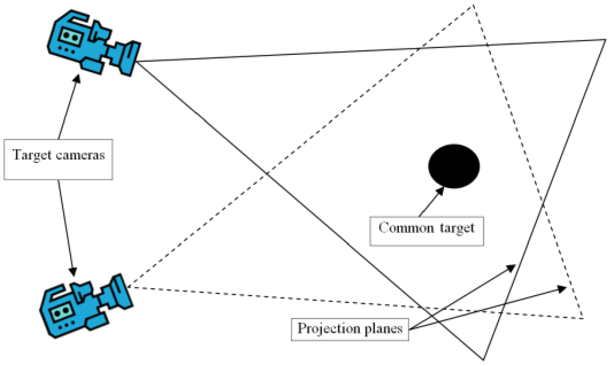

Fig. 15. Camera setup in stereoscopy. The both cameras create two images – each consist different object's view.

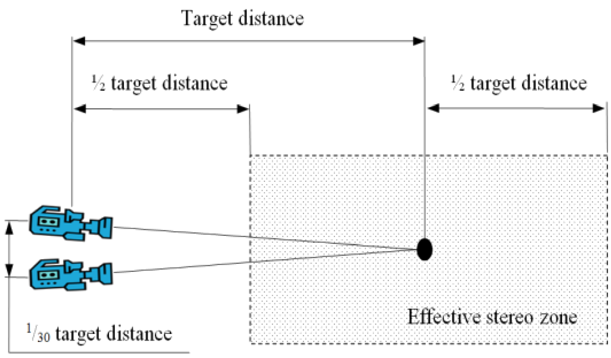

Fig. 16. Effective stereo zone and camera distance.

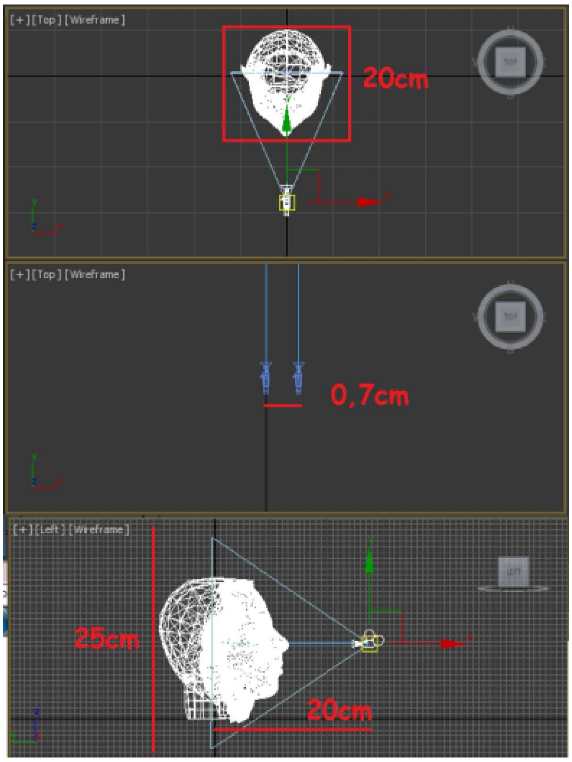

Fig. 17. Camera setup in 3ds MAX [26].

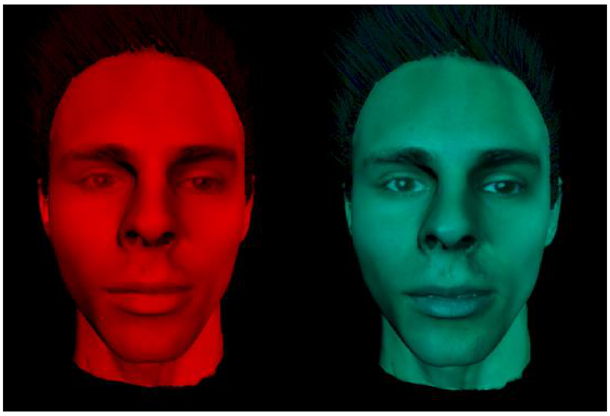

Fig. 18. Left and right images after removing colors [26].

Next, the images are merged by binary added of pixel values (Figs. 19, 20). The images can be viewed through the special glasses with red and cyan filters.

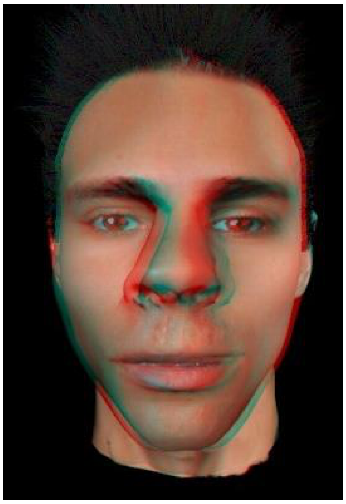

Fig. 19. Final anaglyph stereoscopy visualization of base model (special glasses with red and cyan filters are required for viewing the 3D effect) [26].

Fig. 20. Stereoscopy visualization of chin implant (refer to Fig. 8) [26].

Conclusions

The patient, which makes plans for plastic surgery, expects – first of all – aesthetical results. The method for planning surgery and showing results gives a chance for choice of the appearance accepted by patient. It is realized – first of all – by stereoscopy visualization of computer modeled patient body.

The described method affords possibilities for:

- scanning of patient's body – the virtual patient's model is the base for planning the plastic surgery;
- planning of the surgery – the method uses available computer modeling software 3ds MAX. The special expensive software is not required;
- the color texture mapping procedure has been added to the described method for better visualizations effects, because the used 3D scanner had not the color cameras. It is typical structured light scanner configuration – the color cameras are used seldom, due to lower scanning accuracy. Sometimes, the additional digital single lens reflex camera is used for the high resolution color texture capturing;
- the final anaglyph stereoscopy visualization can afford to view the plastic surgery results. The authors' experience points the better perception stereoscopy visualization than the 3D virtual model by the patients without technological skills.

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