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Event: Photonics Applications in Astronomy, Communications, Industry, and High Energy Physics Experiments 2022, 2022, Lublin, Poland

# 3-D modeling capabilities for planning rhinologic surgical interventions from CT-datasets

Oleg Avrunin*[a], Yana Nosova[a], Nataliia Shushliapina[b], Ibrahim Younouss Abdelhamid[a], Olesia Voitovych[c], Aliya Kalizhanova[d,e], Aida Uvaysova[f], Zbigniew Omiotek[f]
[a]Kharkiv National University of Radio Electronics, Kharkiv, Ukraine; [b]Kharkiv National Medical University, Kharkiv, Ukraine; [c]Vinnytsia National Technical University, Vinnytsia, Ukraine; [d]Institute of Information and Computational Technologies CS MES RK, Almaty, Kazakhstan; [e]Al-Farabi Kazakh National University, Almaty, Kazakhstan; [f]Lublin University of Technology, Lublin, Poland

## ABSTRACT

The essence of the development is to obtain data from imaging tools, as a rule, spiral computed tomography, which allows visualizing bone-cartilaginous and soft tissue structures of the nasal cavity with high spatial resolution and contrast, preparing a 3D model for prototyping using specialized programs - slicers dividing the reproduced object into sections, taking into account the hardware features of the prototyping device, the 3D printing stage for obtaining a mode and implementation of this model is given manipulation - training with the help of selected surgical instruments. After a virtual change in the spatial configuration of the nasal cavity and re-manufacturing of a real model, it is possible to conduct comparative tests of both full-scale models on an aerodynamic bench to determine and analyse indicators of nasal resistance – pressure drop and corresponding air flow.

**Keywords:** prototyping device, 3D model, virtual change, nasal cavity, air flow, aerodynamic, pressure drop

## 1. INTRODUCTION

Rapid prototyping technologies provide a fundamental qualitative leap in most medical applications, especially in implantology and in the planning of surgical interventions. The relatively short-term and fairly accurate process for the production of full-scale medical models allows modern rapid prototyping campaigns and, first of all, the methods of extrusion 3D printing, which has become most prevalent in the past few years[1-3].

Historically, technologies of high-precision planning of surgical interventions, for example, in stereotactic neurosurgery, have evolved through the use of phantoms — simplified models of the patient's head, which were used to work out operational techniques for precision guidance of a surgical instrument to the desired area inside the brain[4-5]. Modern means of introscopy and 3D printing allow you to personalize the phantom manufacturing process based on individual variability according to computed tomography[6-8]. This allows the specialist to visually assess the spatial location of the operated structures and select the minimum traumatic path of surgical access[9-12]. Such approaches are also relevant in modeling the closure of cranial defects for the manufacture of a full-scale prototype of a bone implant[13-15]. In the tasks of configuration planning of functional rhinosurgical operations, it is also advisable to perform full-scale visualization and modeling of dynamic changes in the geometric characteristics of the anatomical structures of the operating area[16-20]. In addition, full-scale models can be used to predict the functional result of the operation and pre-operative verification of decisions made using tests on special aerodynamic stands[21-24].

**Purpose of the work.** Based on this, the aim of the work is to develop an approach that allows the simulation of rhinological surgical interventions based on the creation and study of the geometric and functional characteristics of real personalised models of the internal structure of the upper respiratory tract using diagnostic data from computed tomography.

*oleh.avrunin@nure.ua

Photonics Applications in Astronomy, Communications, Industry, and High Energy Physics Experiments 2022,
edited by Ryszard S. Romaniuk, Andrzej Smolarz, Waldemar Wójcik, Proc. of SPIE Vol. 12476, 1247609
© 2022 SPIE · 0277-786X · doi: 10.1117/12.2659480

## 2. MATERIALS AND METHODS OF STUDYING

The essence of the development is to obtain data from imaging tools, as a rule, spiral computed tomography, which allows visualizing bone-cartilaginous and soft tissue structures of the nasal cavity with high spatial resolution and contrast, preparing a 3D model for prototyping using specialized programs - slicers, dividing the reproduced object into sections, taking into account the hardware features of the prototyping device, the 3D printing stage for obtaining natNeu model and implementation of this model is given manipulation - training with the help of selected surgical instruments. After a virtual change in the spatial configuration of the nasal cavity and re-manufacturing of a real model, it is possible to conduct comparative tests of both full-scale models on an aerodynamic bench to determine and analyse indicators of nasal resistance – pressure drop and corresponding air flow[25].

## 3. RESULTS AND DISCUSSION

The first stage was the construction of frontal multiplanar reconstructions of the upper respiratory tract, segmentation of the nasal passages (air ducts), and determining the geometric characteristics of their “living” sections, such as area, perimeter, equivalent diameter, taking into account the distance between sections[9]. An example of the preparation of spiral computed tomography data for segmentation of the structures of the nasal cavity is shown in Figure 1.

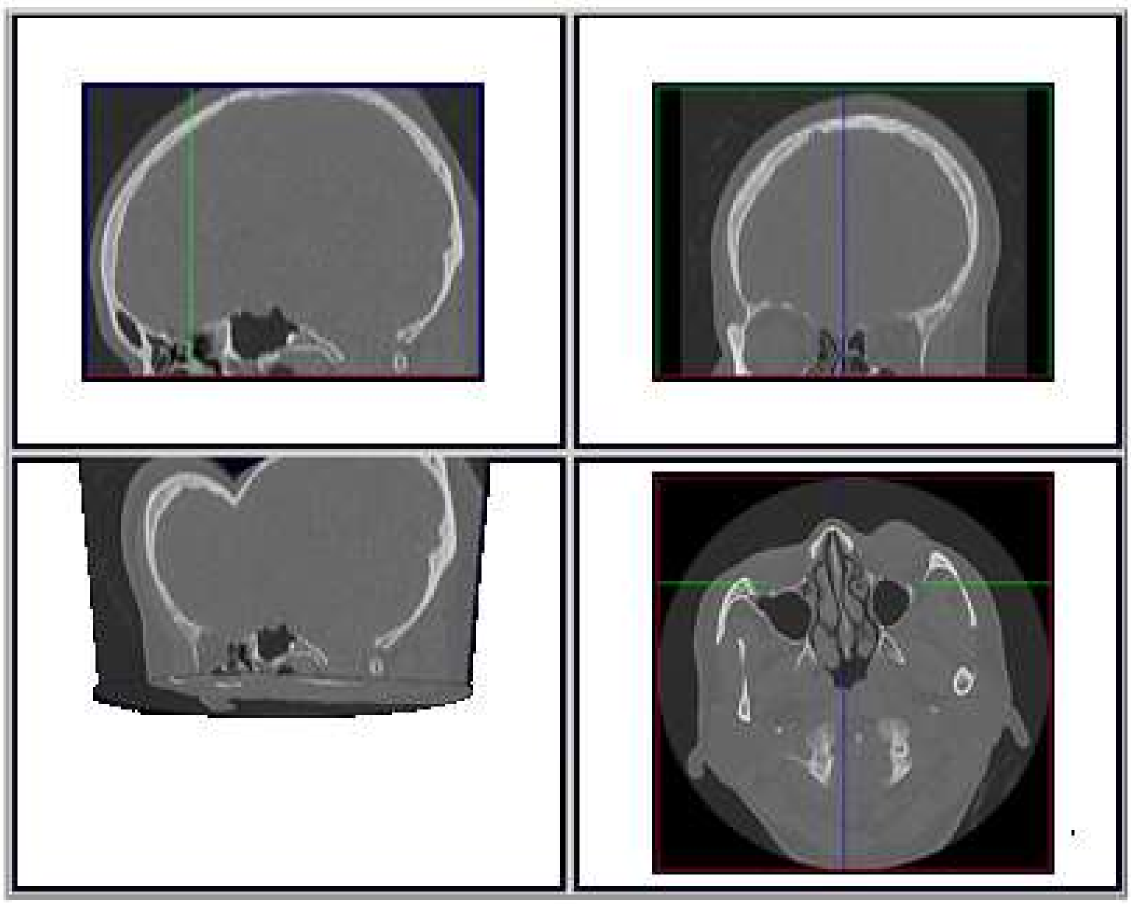


Figure 1. Illustration of preparing spiral computed tomography data for segmentation of nasal cavity structures.

The visualization of the segmented model of the nasal cavity is shown in Figure 2. The output of this stage is to obtain a geometric model in STL format. Further, the segmented model using special programs - slicers (see Figure 3a) is converted into a G-code, taking into account the characteristics of the 3D printer used and prototyping parameters for subsequent production. The appearance of the finished full-scale model of the upper respiratory tract is shown in Figure 3b.

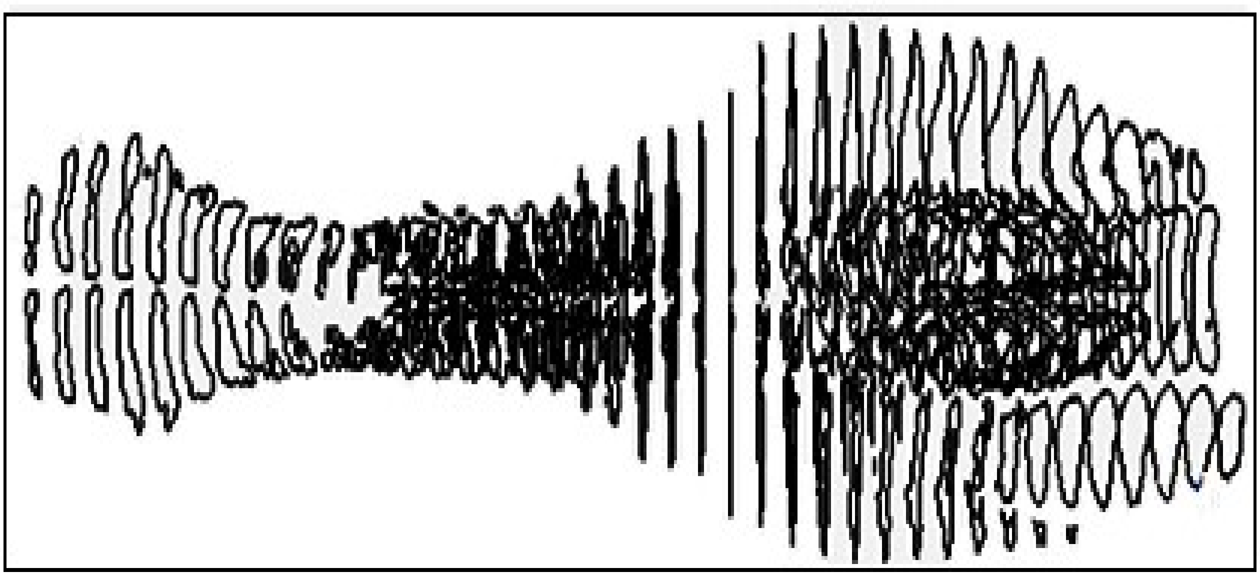
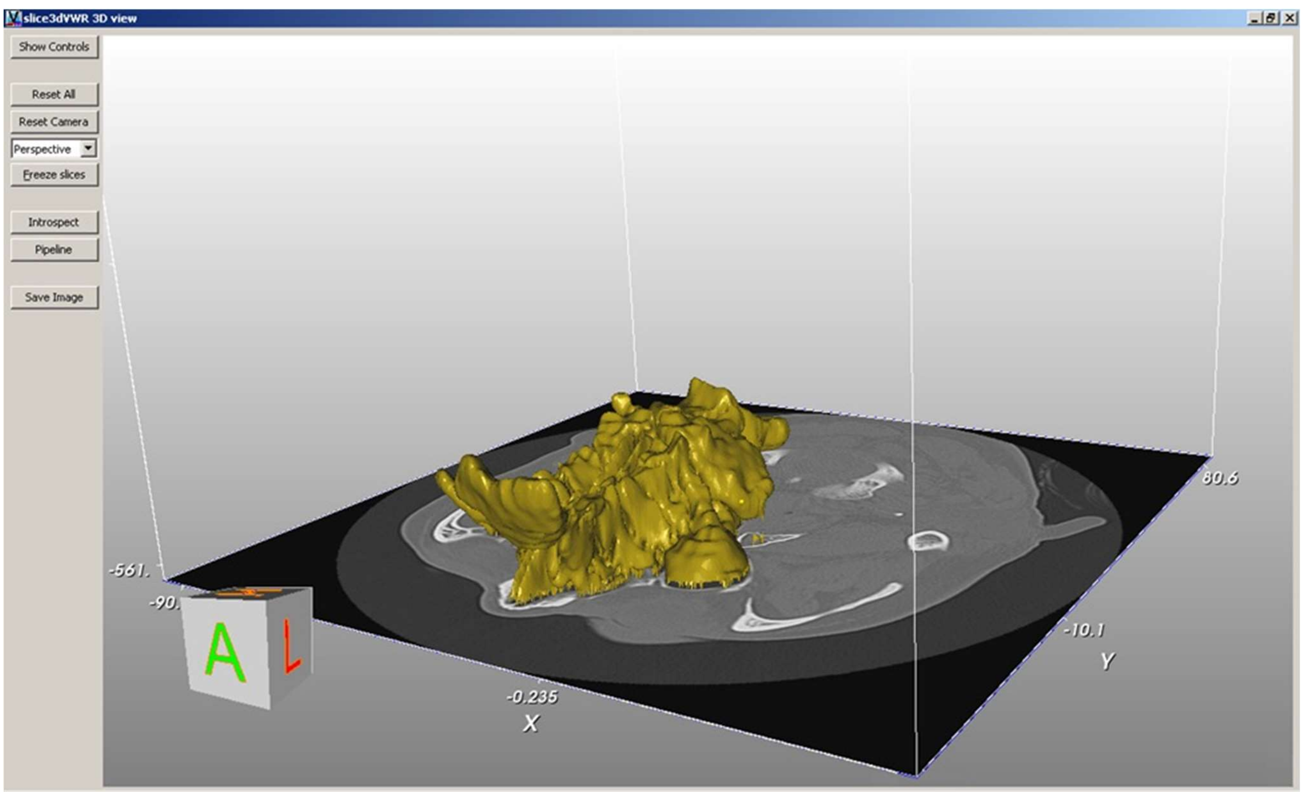


Figure 2. Segmented model of the nasal cavity.




a

b

Figure 3. Personalised model of the upper respiratory tract according to spiral computed tomography: a) virtual model; b) full-scale model.

Using the example of determining aerodynamic nasal resistance when performing configurational surgical planning for endonasalseptoplasty (elimination of the curvature of the nasal septum), we can further illustrate the steps of using full-scale models. On the initial frontal sections of the nasal cavity, virtual correction of the anatomical structures of the nasal cavity takes place by cutting two-dimensional warping taking into account the original (Fig. 4a) and the resulting (Fig. 4b) location of key deformation points. Moving the key points is set interactively by a specialist, and then the warping program calculates the new coordinates of the anatomical objects being changed (in this case, the nasal distension (SM) is eliminated to the right, as illustrated in Fig. 4c). After this, the above stages of manufacturing a full-scale model are repeated and comparative aerodynamic tests of the original and modified models are performed. At the same time, physiologically justified air flow is passed through manufactured natural models, and sensors of pressure drop and air flow are installed at the corresponding points.

Thus, double-virtual (based on mathematical modeling) and full-scale (based on full-scale modeling) prediction of functional results of a rhinological operation, taking into account the determination of aerodynamic resistance in each half of the nose according to the geometric parameters of living flow sections, is performed according to literature data for turbulent and laminar air flow regimes, respectively. Air consumption figures are taken either according to rhinomanometry, or taking into account the physiological age norm.

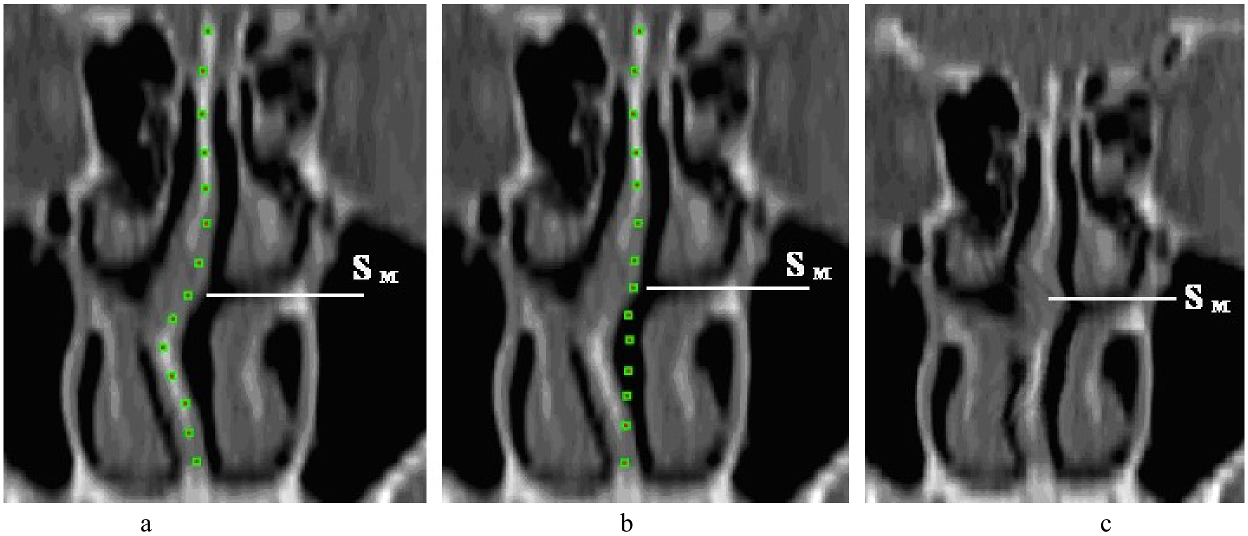



Figure 4. Illustration of performing two-dimensional warping at specified key points on a frontal tomographic slice: a) initial image; b) the resulting position of key points; c) the result of the warping (SM - designation of the positions of the nasal septum).

## 4. CONCLUSIONS

The introduction of rapid prototyping technologies into rhinology makes it possible to base on predicting the functional result of the operation not only according to mathematical modeling of the flow of air through the nasal cavity while breathing, but also taking into account the analysis of natural aerodynamic models of the area under study. The introduction of such simulation technologies takes the process of planning surgical operations to a qualitatively new level and allows to increase the reliability of the results of procedures related to the prediction of functional results of surgical interventions.

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