

# Reconstruction of human thorax from CT images

Nándor Fink

Budapest University of  
Technology and Economics,  
Faculty of mechanical  
engineering  
Department of Mechatronics,  
Optics and Information  
Engineering  
Budapest, Hungary  
[finknandor@mogi.bme.hu](mailto:finknandor@mogi.bme.hu)

Dávid Pammer

Budapest University of  
Technology and Economics,  
Faculty of Mechanical  
Engineering Department of  
Materials Science and  
Engineering.  
Budapest, Hungary  
[pammer@eik.bme.hu](mailto:pammer@eik.bme.hu)

Árpád Barsi

Budapest University of  
Technology and Economics,  
Faculty of Civil engineering  
Department of  
Photogrammetry and  
Geoinformatics  
Budapest, Hungary  
[barasi.arpad@epito.bme.hu](mailto:barasi.arpad@epito.bme.hu)

Rita M. Kiss

Budapest University of  
Technology and Economics,  
Faculty of mechanical  
engineering  
Department of Mechatronics,  
Optics and Information  
Engineering  
Budapest, Hungary  
[rita.kiss@mogi.bme.hu](mailto:rita.kiss@mogi.bme.hu)

**Abstract** - 3D printing, as a rapid prototyping method is become more common nowadays world widely, including medicine too. The purpose of this article is to reveal the potential of using 3D printing in medicine, especially with a specific example of making a human thorax model from the very beginning of imaging diagnose to the physical model. There will be shown in details how the model of bones, lungs and heart had been created. The circumstances of the 3D printing will be discussed too.

**Keywords** - human thorax model, 3D print, STL, segmentation, netfabb

## I. INTRODUCTION, LITERATURE RESEARCH

Rapid prototyping, especially 3D printing is being commonly used in industry nowadays, because it can make a prototype not only fast, but - in the case of few piece production - cheap too [1]. This process makes possible to realize complicated geometries too, for example a closed model with cavernous inside.

There are lots of possibilities of using 3D printing in medicine too. Prostheses are able to be created for small animals with ease, considering the individual sizes and needs. There is a special cranioplasty method developed by the University of Debrecen. In this process a 3D model was created from CT images (created with little slice distance) by the software called Mimics® (a special software, created for making a 3D model from the images of a human body). Then the 3D printed model was used as a casting mould for the surgeon replacing the skull bone [9]. Experiments are going on about the construction of a 3D printed, artificial human ear using living cells as base material of the printing [2]. 3D printing is quite a usable method for making individually designed dental implants, dental prostheses and retainers too [1,3,8].

The purpose of this article is to show the process of modelling the chosen parts of the human body (especially the heart, the lungs and the bones of the thorax) from the very beginning, the medical imaging process to the 3D printed end models in details. There are two options for using a 3D printed model of a human body part. The first option is using the model as an implant, and the second one is using it for

educational purposes. In education this kind of models are not only good for visual presentation, but for make it possible to practice before a non-routine surgery.

## II. MATERIALS

There were 118 piece of images were used for making the model with a resolution of 512 x 512 pixels, and a size of 514 kb each (1). The image series were given by the radiology department of a Hospital called Pest Megyei Flór Ferenc Kórház in DICOM format [4]. This format contains the meta data of the images as well (with the personal data of the patient), so they were anonymized before.



Figure 1 - CT images, as a starting point a) transversal section at the liver b) transversal section at the heart c) transversal section at the shoulders

The 3D printer used in this project had worked with the Fused Filament Fabrication (FFF) technology, and its extruder head had been on 221°C temperature. The size of its workspace had been 250 [mm] x 200 [mm] x 200 [mm], and the filament diameter had been 1.75 [mm].

The models made by PLA (Polylactic acid) with a 1 [mm] thick external shell and 15% triangle fills.

## III. METHODS

The first task was the segmentation, so a modified image series were created in binary, that contained information only about the target organ. The segmentation was made in MATLAB with own functions based on the basic theories of image processing. Working with own source code not only made possible wider parameterisation, but testing different kinds of windowing processes. These process are for making the model smoother, but there is a data loss as a consequence too. Because of the low resolution of the CT images (they

were ordinary CT images for medical diagnosis, not specially for this research) this methods didn't make the models better, so they were ignored hereinafter. After the segmentation an image manipulation software called ImageJ were used to build the STL typed surface model from the slices [5].

ImageJ is a free source software, with a surface building strategy of extending the outline of the object in normal direction with the length defined by the slice distance, then go on with the next slice. This model building strategy conspicuously shows the results of the low resolution starting images with a big slice distance, and the same time gives a good reference point to compare with a software upgraded model in the future.

Naturally, the images contained more or less noises too, that depended on the threshold value had been set in the segmentation step. The 2. figure shows that, the noises weren't disappear, even if the threshold value had been so strict that caused a large amount of data loss. That means more or less post procession is inevitable.

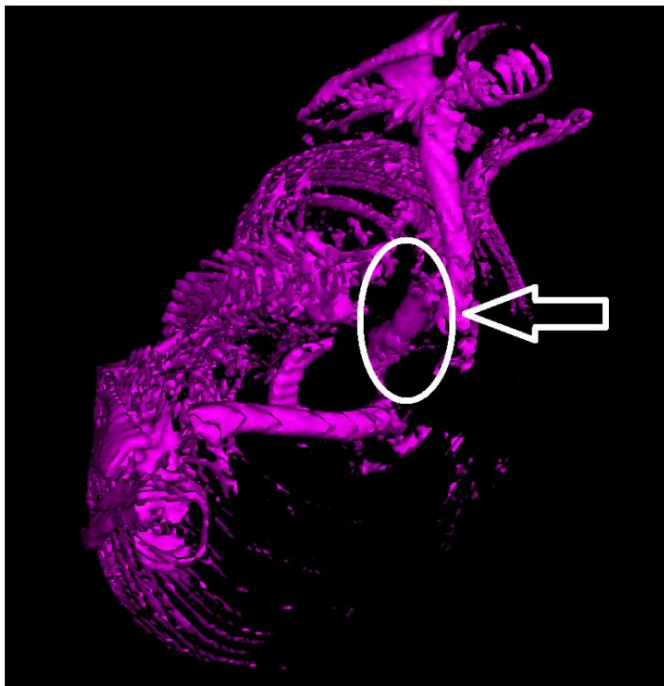


Figure 2 - Even with a strict threshold value there are noises

Counting with a wider range of the threshold value results increasing amount of post procession, but it makes the model finer and more continuous. The program used in the post process called netfabb [6]. In this software the elimination of the artifacts can be made by circumscribing (3).

It is practical to fix the one by one 3D printed models to each other in the position like the real ones in the human body. If the segmentation took to pieces one of the models, that had to be reconnected manually. Figure 4. shows the collarbone and scapula were made two individual models, so a special element had to be created to connect them.

The appearance of the blood vessels caused some problem with some of the organs. The solution was removing the blood

vessels of the heart (5), because the goal was to create dismountable models, not to show the vessels.

The heart is surrounded by the lung lobes, what makes impossible to insert the hearth model between the lungs model later. Also the lungs inhibit the movement of the heart horizontally. To make possible to insert the heart model later the lungs model was sliced into two parts by the main bronchus. The inhibition of the vertical movement can be guaranteed by creating a geometrical connection between the aortic and the bronchial bifurcation.

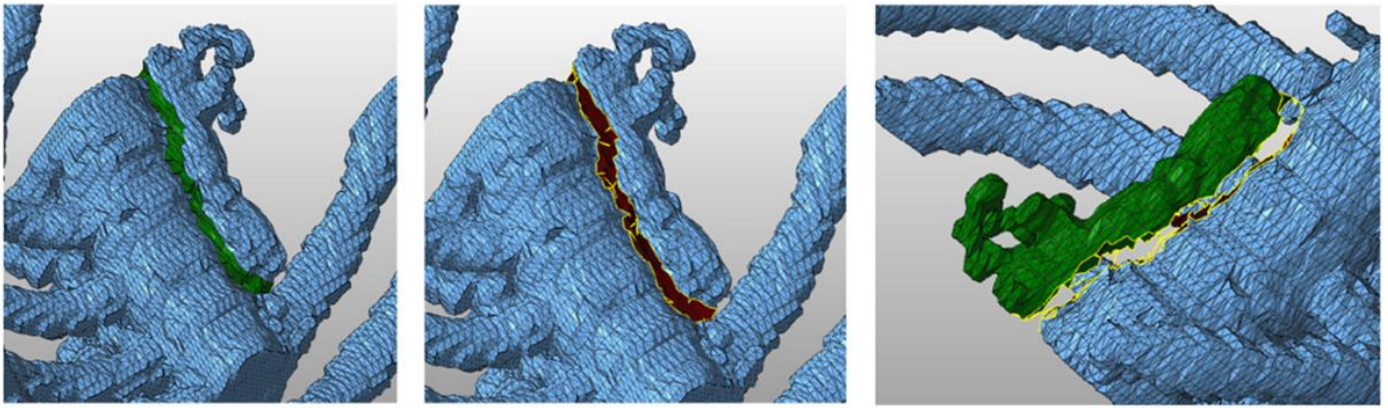


Figure 3 - Elimination of the artifacts a.) circumscribing triangle by triangle b.) removing the contour c.) removing the individual model

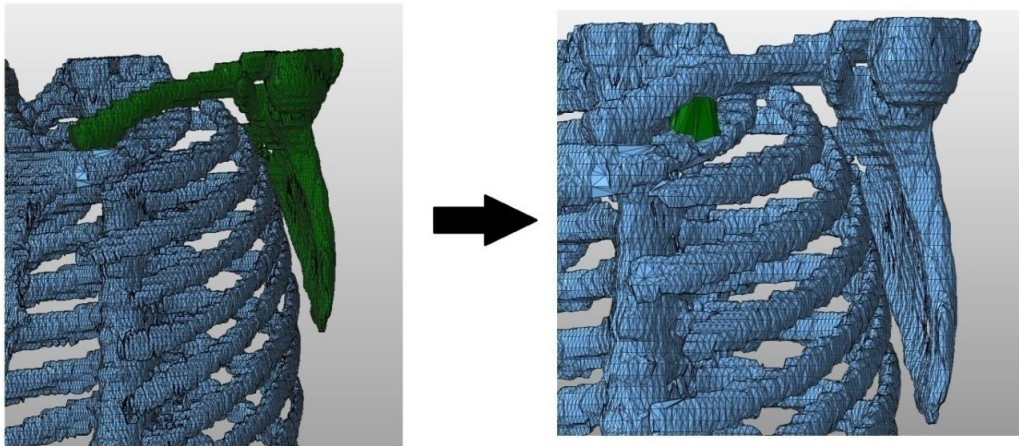


Figure 4 - Reunion of two separate part of one model

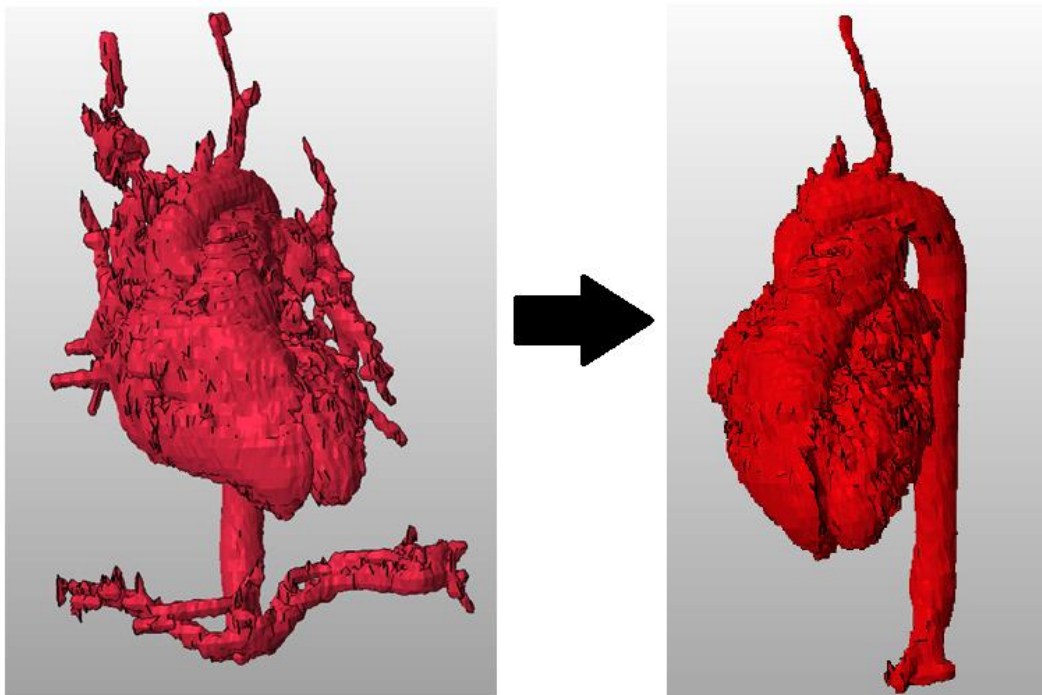


Figure 5 - Removing the blood vessels from the model of heart

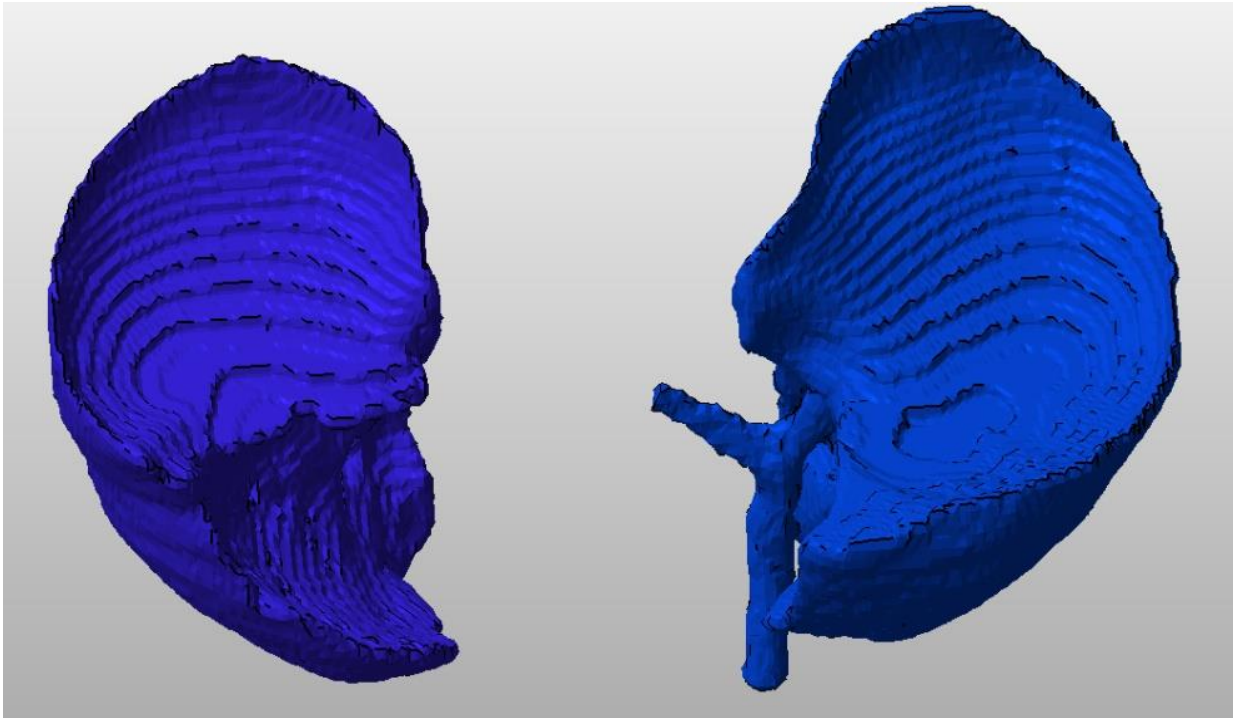


Figure 6 - The sliced lungs model (The gradual appearance on the bottom of the lobes makes noticeable the original slice distance of the CT)

#### IV. RESULTS

The bone model was with the most complex geometry, and it was the largest models too (containing: sternum, clavicle, ribs, spinal dorsal section, scapula). This model had a weight of 230.5 [g], and the 3D printing of it required 111 [m] PLA thread and 36 [hour]. For decreasing the time of printing, the amount of support material was below the required (7). That is the reason, why the model became hairy in some places (8).

About the straitening and connecting of the bone model with extra material could be said it is suitable to fulfil their duties, without being disturbing or conspicuous (9). After the modifications the model have become suitable to serve as a frame for the another models.

For the printing of the 59 [g] heart model 23.3 [m] of PLA was used, and the printing took for 10 hours (10). The big amount of post process made possible to fit the model for the others. The figure 11. shows the cutting place of the blood vessels, raising the awareness for the miss.

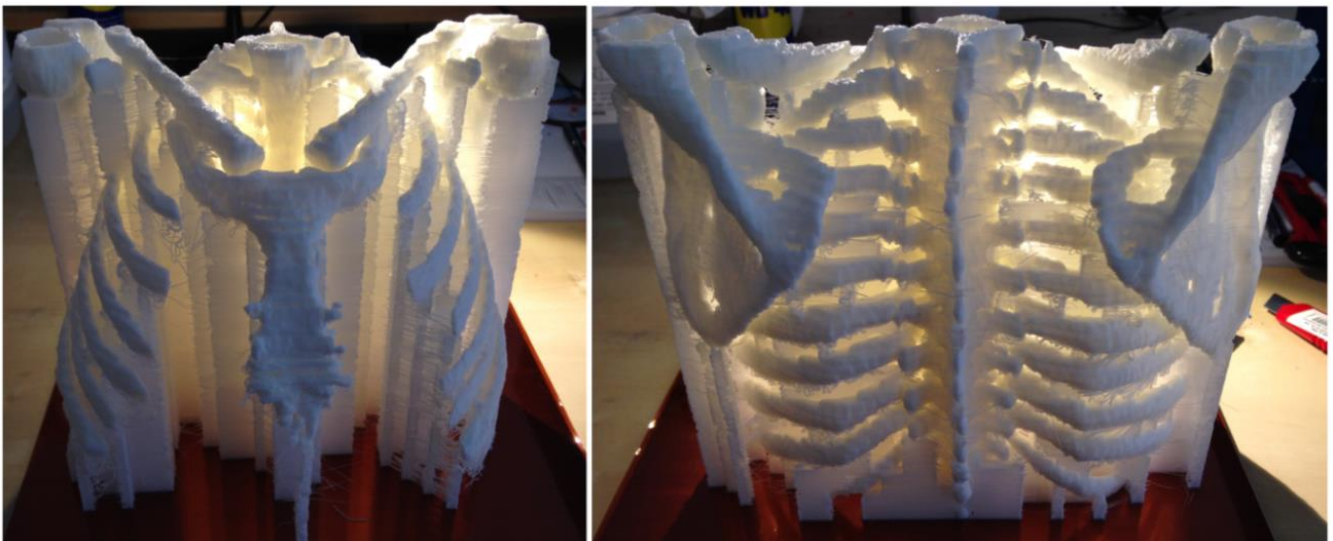


Figure 7 - Bone model before the removal of the support material



Figure 8 - The ends of the ribs became hairy, because of the inadequate amount of support material



Figure 9 - The modifications suits into the model



Figure 10 - Heart model



Figure 11 - The cutting place of blood vessels

The printing of the lungs model with a weight of 220 [g] was taken 80 [m] of PLA and an amount of 24 [hour]. After the separation of the lung lobes (6) the models fits well with the others (12).

After printing each part of the model, next step was to assembly them. The first step was to insert the heart model onto the lung lobe model with the bronchia, then close that

with the another lung lobe model. In the next step these three models could be push up into the ribcage. Finally they could be fixed with screw through the bone-, and the lungs models (13-15).

The overall dimension of the assembled model was 190 [mm] x 180 [mm] x 135 [mm] (16).

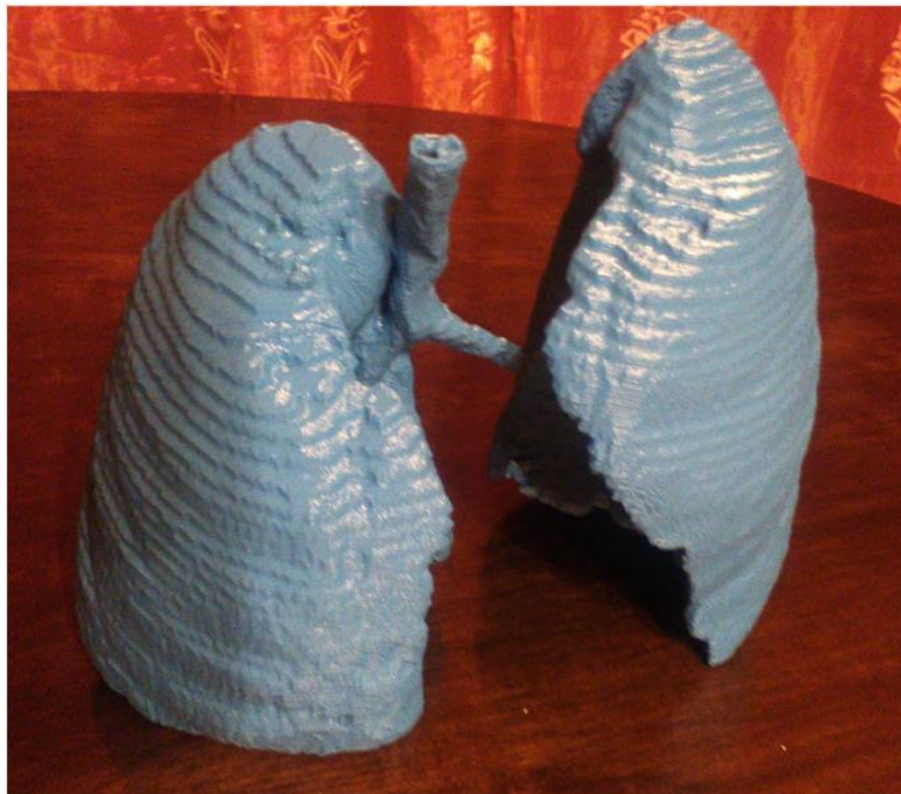


Figure 12 - The lungs model

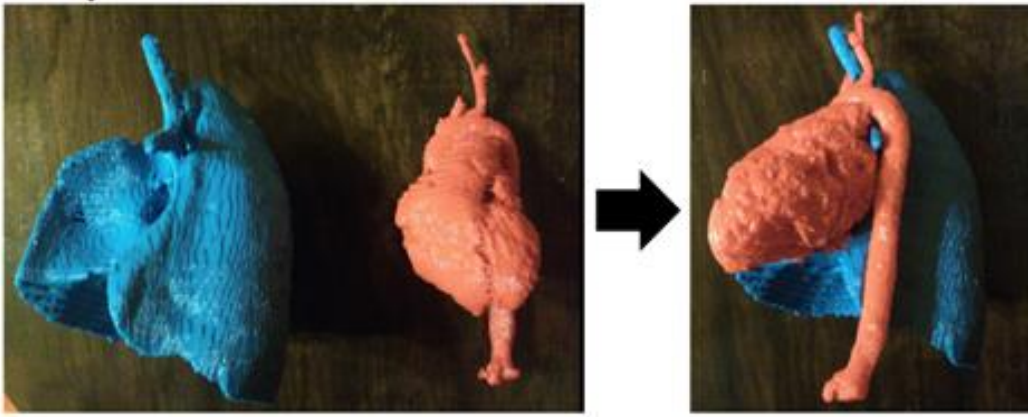


Figure 13 - 1. step: Inserting the heart model onto the lung lobe with the bronchia

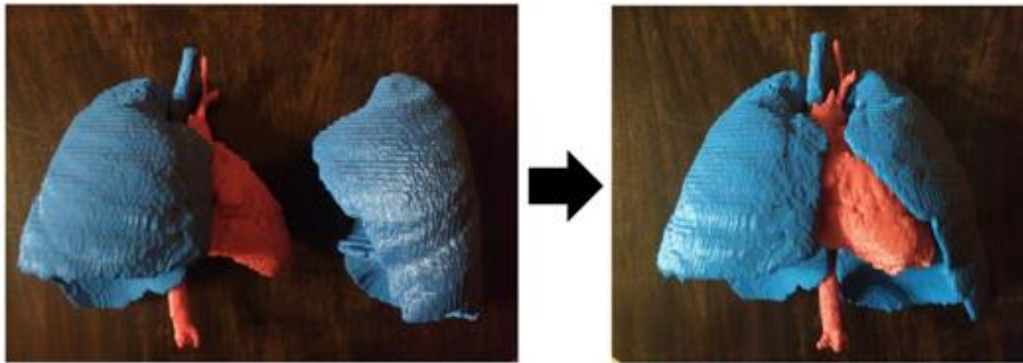


Figure 14 - 2. step: Closing the heart and lung lobe with the second one

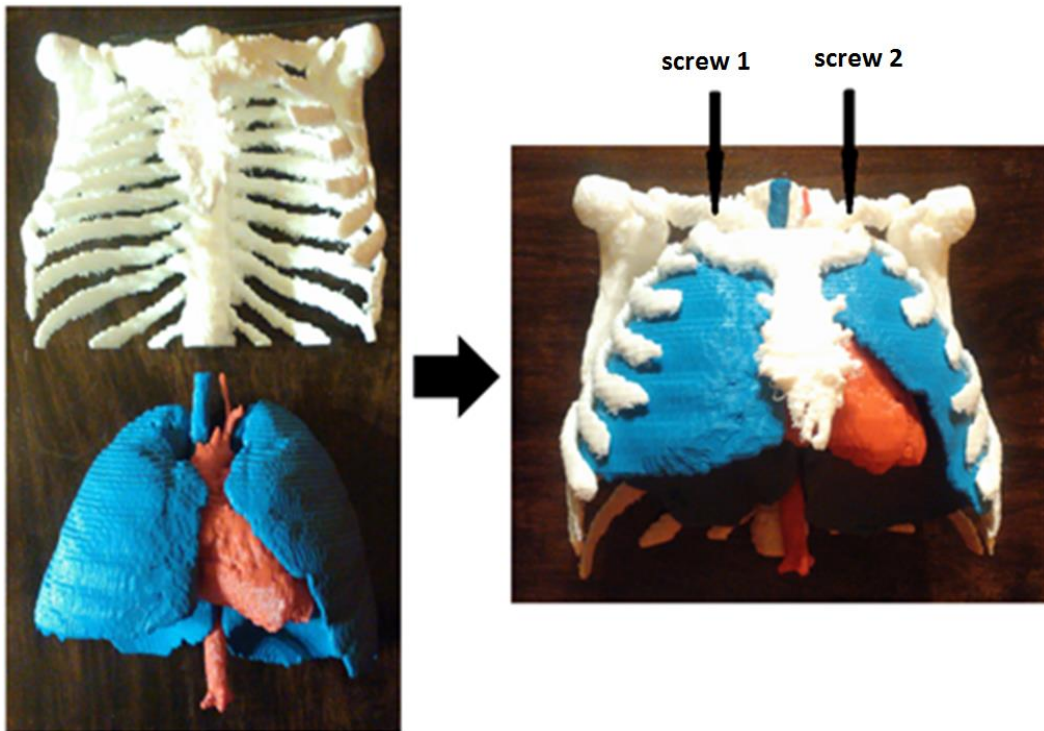


Figure 15 - 3. step: Push up the hear surrounded by the lung and fixing with screws

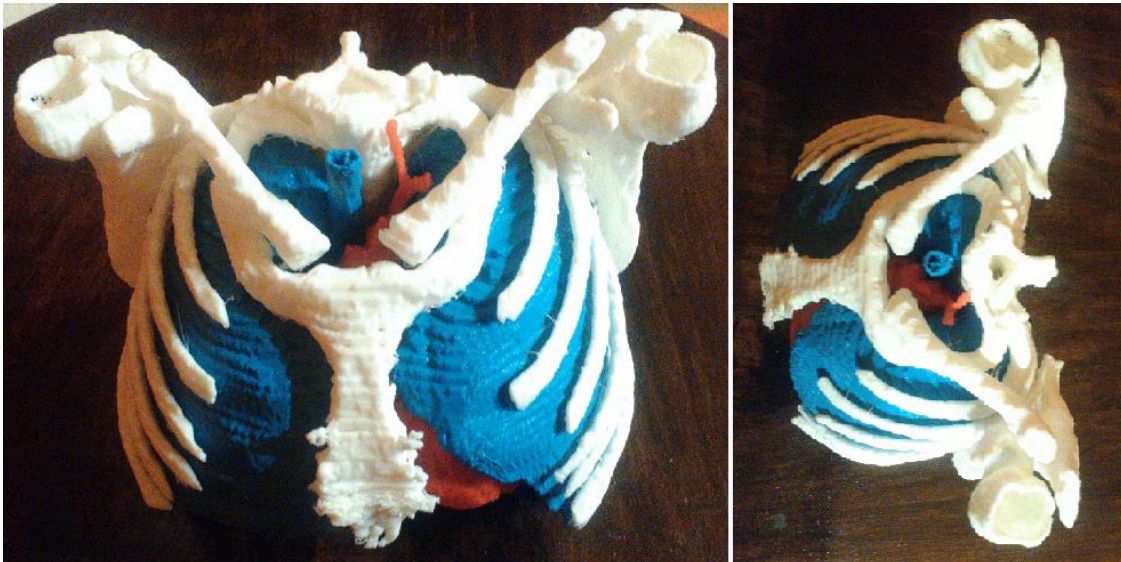


Figure 16 - Assembled model a) front view b) plan view

## V. DISCUSSION

The construction of the models were made by an ordinary CT image series, that was created for diagnostically purpose. The parameters of the CT set by the doctor not only determined the resolution of the images, but the resolution of the 3D model as well. The cutting places on the hearth model could be smoother with using the full version of the netfabb, because it contains the Boolean operations.

Making models with 3D printing have a good use for visually understanding the task of us, or the curriculum in medical education and for practicing surgery too. A well-trained surgeon also can use it, if there is a case of rare surgical techniques needed the 3D model provides the opportunity to develop the correct strategy, than testing it [1].

## VI. SUMMARY

The purpose of this article is to make a 3D thorax model (containing the heart and lungs too) from CT images made for diagnosis. Shows how the model was built, the circumstances and parameters of the 3D printing and the steps for the assembly. The last part of the article summarizes the advantages, disadvantages and limitation of 3D printing.

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