Creating Hi-Detailed Heart 3d Model Based on MRI and Contour Data and It's Representation in Augmented Reality

S V Strelkov, A S Klygach, V M Ivanov

Abstract.: ***This article describes a simple and effective approach for creation of highly detailed model of the heart. The approach of creating a three-dimensional model based on the use of data ventricular contours obtained by MRI study. This solution allows you to create a heart model with all internal structures, which simplifies the process of visualization and assessment of cardiac structures before and after surgery.***

Index Terms: Heart,MRI,Cardiac,Surgery

I. INTRODUCTION

Modern medical imaging methods allow you to see inside the human body without damaging it. This is especially true for athletes who are preparing for the competition and can not stop the training program. Available representation of three-dimensional image data of medical imaging is still not fully solved problem and current solutions has a low level of details. The technology described in this article, is an effective solution that will allow the doctor to explain more clearly to the patient his heart anatomy and pathology.

II. CREATION MASTER MODEL

The main principle used in the study is based on the creation of highly detailed master model of a healthy heart with all internal structures and textures based on the analysis of different sets of MRI data. This model will be used as a basis for further creation of detailed patients hearts models with a variety of defects. Depending on the type of defects later in the master model is ajusted specific to those or other pathologies.

The process of creating a master model is based on creationg a base model of the heart, and refinement its shape and anatomical structures with help of healthy hearts MRI data, then all data stores in final master model.

At the first stage we created an abstract model of the heart, which is based on the anatomical atlases. This model was made by digital artists together with doctors to obtain precise form with all the details of the surface and internal structures, such as valves and trabecular, which can not be fully reconstructed from MRI data. Next, artists created texture that was reconstructed using actual photographs of hearts.

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The result is a model of the heart, which will be used as a basis. At this stage, the base model is a form that has all the anatomical structure of the heart, but it can not yet be used as "a master model. It is necessary to verify the resulting model using MRI data of a healthy human heart.

The next step we load MRI data sets of few healthy patients. In addition to basic MRI layers data, the dataset usually presented with ventricles outer and inner surface contours. Contouring (manually delineating the anatomical structures of the heart) is carried out by a specialist. This approach is one of the main methods of segmentation and defining the contours of anatomical structures [2]. The contours are outlined in a certain stage of the cardiac cycle, in this case, in diastole (Fig.1).

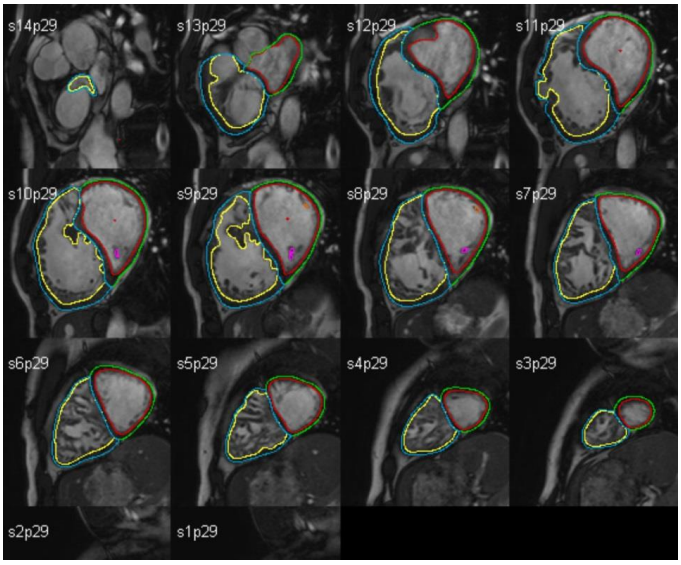

Figure 1. Contouring data overlay on MRI data.

By analyzing the specialized software contouring data we developed a programm which builds curves in three-dimension space, where the distribution of the vertical axis is the distance by MRI slices in the data set. These curves formed by the outer surface of the heart and the inner surface of the ventricles (Figure 2). After that programm builds surface upon these curves and as a recult we receive a 3d model heart fragment where ventricles is situated.

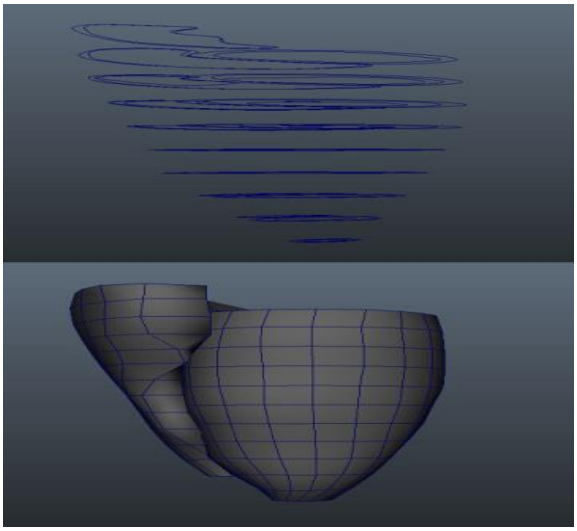

Figure 2. 3d curves(top) and surface(bottom) of ventricles.

MRI data often contain partial data, they are noisy and have low spatial resolution. To improve the image usually used various noise removal algorithms [1], but in most cases, this approach does not solve the problem. Thus, it is necessary to borrow the missing parts from another source, which is the base model of the heart, based on data from anatomical atlases. To implement this approach, it is necessary to relate the basic model with a model built on the basis of the contours. To solve this problem we load base model and 3d surfeces that was made from contours. Then we aligned these two elements in the horizontal and vertical planes on the basis of the extreme points of the ventricles. Next comes the construction of a grid-deformers on the perimeter of the base model with the number of subdivisions equal to the number of layers of MRI data and the distance between them. Then we corelate the grid-deformers points with contours ponts on each sections, while the points that do not belong to the grid (bottom and top part of the model) are scaled in proportion to the value of the average of the delta displacement of grid points (Figure 3).

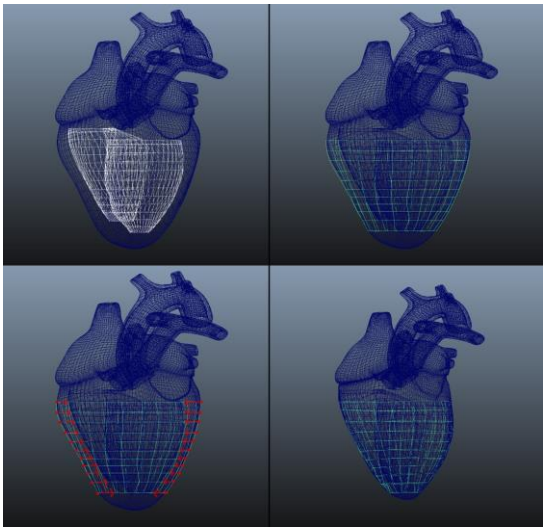

Figure 3. Stages of projection base model on surface from countours data

This approach represents the projection method and allows to fill the missing pieces that are not presented in the MRI data and at the same time preserve data of the outer and inner contours of the heart and the ventricles. Further, we repeated this process with datasets from three healthy patients, according to the algorithm described above(Fig. 4). The result of the averaging of these models was the master model is presented in Fig. 5. Now obtained master model can be interpreted as a main reference of healthy heart and will be used as starting point for creating different heart models.

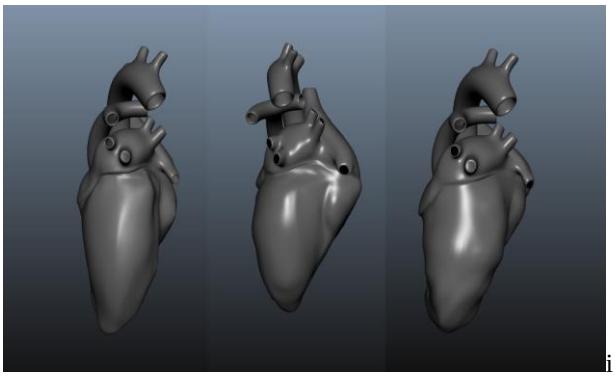

Figure 4. Three healthy hearts models volunteers

III. CREATING PATIENT'S HEART WITH PATHOLOGY

As a result, the model is personalize and gets a certain image of the patient's heart. For this purpose MRI data is taken from particular patient, and the patient's heart model is constructed using the algorithm described above. In this case, the basis is the average model of a healthy heart — master model, not an abstract built on the basis of anatomical atlases. Thus, a detailed model of the heart, which corresponds to the particular shape of patient's heart and has the necessary detail and texture quality (Fig. 6). Obviously, obtained result is not perfectly accurate three-dimensional representation of the patient's heart. However, within the framework of tasks, where the doctor is necessary to explain the state of the damaged organ, aided by his anatomy, this solution is optimal. In addition, this algorithm may be fully automated.

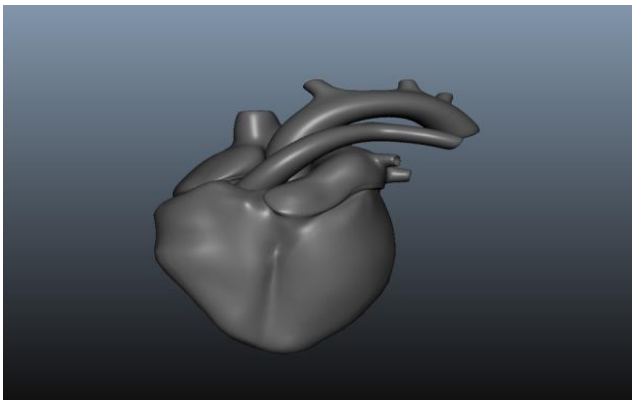

Figure 5. The average master model without textures

IV. INTEGRATION OF THE ALGORITHM IN CLOUD-BASED WEB SERVICE

An automated approach provides the opportunity to build a three-dimensional model remotely using cloud computing [3]. We developed web resource that will handle the MRI and output to give users a three-dimensional heart model. Web service is organized as follows: the first step the doctor upload the MRI data to the server; the server is compute data, and the doctor almost immediately (on request) gets final model, which can be viewed in a browser. It also features a number of manipulations, for example, to build a cross-section or compare to the previous state or with healthy hearts, rotate, zoom and explore a different angles.

The above solution allows an affordable and quick way to get a three-dimensional model, analyze it and 3d print it out and give to the patient if necessary. Furthermore the model can be represented with help of augmented reality technology (AR-technologies) [4], which provides the ability to store all the information about the three-dimensional model corresponding to QR-code. Using augmented reality technology is possible to make intuitive interface and is uses for communication between the specialist (doctor) and consumer services (the patient). The basic principle of this technology — a combination of virtual reality and information, as which, in our case, will be the three-dimensional heart patient. The idea lies in the fact that the QR-code is printed on the medical treatment record then patient reveal it to the webcam and on the screen he can see 3d model of his heart. By changing the position of the card and turning it, he can see the heart from different angles (Figure 7).

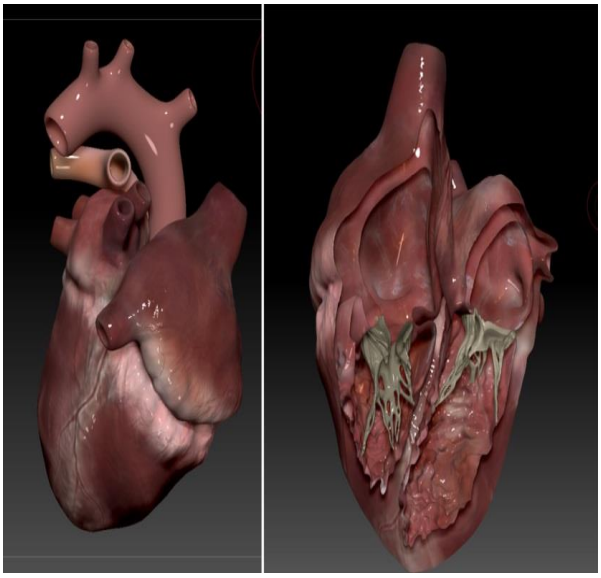

Figure 6. Generated patient model with the internal structure and texture

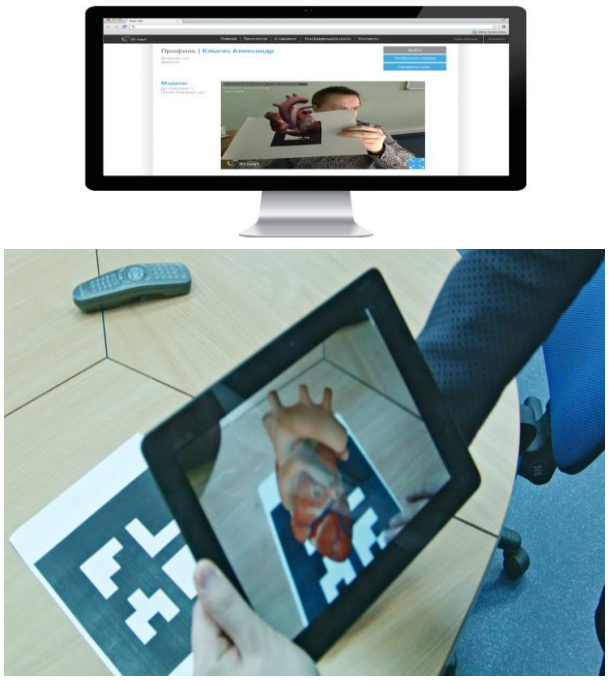

Figure 7. Representation of the heart model in augmented reality on computer (left) and on a mobile device (right).

V. CONCLUSION

In conclusion, it should be noted that the described approach has been used successfully in the creation and visualization of the three-dimensional model of the heart. Also this solution can be easily adapted for imaging other organs and bones. Using this solution, you can demonstrate the state of the patient's organs and thereby simplify the process of interaction between doctor and patient.

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