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3D RECONSTRUCTION OF CT SCANS FOR VISUALIZATION IN VIRTUAL REALITY

3D REKONSTRUKCE CT SNÍMKŮ PRO VIZUALIZACE VE VIRTUÁLNÍ REALITĚ

Abstract

Computed tomography allows analyzing the internal structure of an object, which is useful especially in medicine. The standard visualization displays scans in the 2D plane. 3D reconstruction of scans provides a complex image of the morphology of the scanned object. Matlab is a software commonly used for image processing and analysis. It includes Medical Image Processing Toolbox for displaying data from CT scan in DICOM format. However, it is not possible with this toolbox to export the dataset of the image as a 3D object. Therefore, the aim of the paper is the implementation of a toolbox for loading and displaying data as a 3D reconstruction. This toolbox allows the user to export the data in OBJ or STL format. That allows the user (i) to visualize the 3D models in virtual reality and (ii) to prepare the model for 3D printing. The OBJ model is imported to Blender and then exported out with a texture as an object file. In Unity, we created a 3D scene and imported model. The advantage of displaying the 3D model in virtual reality is a more realistic view of the shape and dimension of an object.

Abstrakt

Výpočetní tomografie umožňuje studovat vnitřní strukturu objektu, což je využíváno především v medicíně. Standardní zobrazovací techniky promítají snímky ve 2D rovině. 3D rekonstrukce snímků přináší komplexní pohled na morfologii snímané tkáně. Matlab je software běžně užívaný v oblasti zpracování a analýze obrazových dat. Zároveň obsahuje nástroj "Image Procesessing Toolbox", který umožňuje zobrazit CT snímky uchované ve formátu DICOM. Tento nástroj však neumožňuje vyexportovat zobrazený model jako 3D objekt. Cílem tohoto projektu bylo vytvoření nástroje pro načítání a zobrazení zrekonstruovaných 3D modelů. Tento nástroj umožňuje uživateli vyexportovat data v OBJ nebo STL formátu, který umožňuje (i) vizualizovat 3D model ve virtuální realitě a (ii) připravit model vhodný pro 3D tisk. V editor Unity byla vytvořena 3D scéna a do ní byl importován vygenerovaný model. Výhodou zobrazení 3D modelu ve virtuální realitě je přirozený pohled na prostorové uspořádání objektu.

Keywords

CT Scan, Matlab, Unity, HTC Vive, 3D model

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1 INTRODUCTION

Computed tomography (CT) is an imaging method base on x-ray scanning and image processing. This method provides information about the internal structures of the examined body, which is frequently used in medical imaging. CT scanning produces grayscale cross-sectional images. Distance between each slice depends on procedure settings and is in the millimeter range. The basic unit of CT scan is voxel containing gray scale level and information about its position. CT scans are usually analyzed slide by slide compared to each other. Advanced applications can reconstruct voxels as a 3D model and provide complex 3D structure visualization.

Currently, the most used software for 3D visualization of medical imaging data is open source 3D Slicer[1]. This software works self-automatic. It enables to load standard DICOM format, set threshold for selected tissue and display voxels in the different view plane. Then, selected tissue is extracted from data and plot as a rendered 3D model with shading and color that refers to anatomical standards (Figure 1). Model imperfections are manually editable in 3D Slicer GUI. This process requires editing skill and can take a lot of time. Even though, it is possible to plot a realistic 3D model from this application, is not permitted for diagnostics and treatment use.
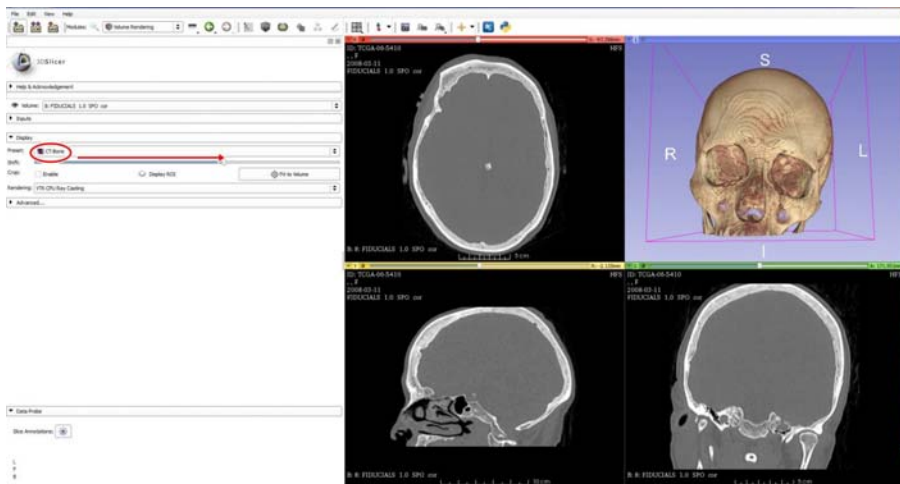

Fig. 1 3D Slicer GUI [8]

Standard visualization of 3D model is limited by a flat screen. It is possible to rotate with the model, but this method still requires spatial imagination and basic skills of orientation in the control system of the viewer[2]. This disadvantage could be eliminated via visualization in virtual reality (VR). Virtual reality is an immersive system that simulates scenes with a real feeling of space. Interactions in those systems are natural because it is tracking common action as walking and head rotation. Virtual reality imaging is useful not only in education but also in analyzing object morphology and in medicine for surgery planning and training.[5,6]

Virtual reality equipment usually consists of VR headset, controllers and base station system (according to tracking system). Minimum system requirements depend on used VR headset but do not differ significantly among the most common ones (HTC Vive, Oculus Rift). For HTC Vive the minimum system requirements for the used computer are 4 GB RAM, Intel i5-4590, Nvidia GTX 970 and inputs for HDMI 1.4, DisplayPort 1.2, USB 2.0.

Fig 1 Virtual reality set – controllers, base stations, headset [9]

2 METHODS

In this project, we focused on an automatic algorithm to reconstruct 3D models from CT scans. As a programming tool, we used Matlab, because of its wide use in the academical area and already implemented an application from Image Processing Toolbox. One of the applications for visualization of medical data is Volume Viewer. It allows the user to upload DICOM data, plot 3D model and set gray level threshold. There is a disadvantage of this application, that it is not possible to export the model to use it in a virtual reality scene. For this reason, we implemented our own toolbox with all common requirements, that will be described below.
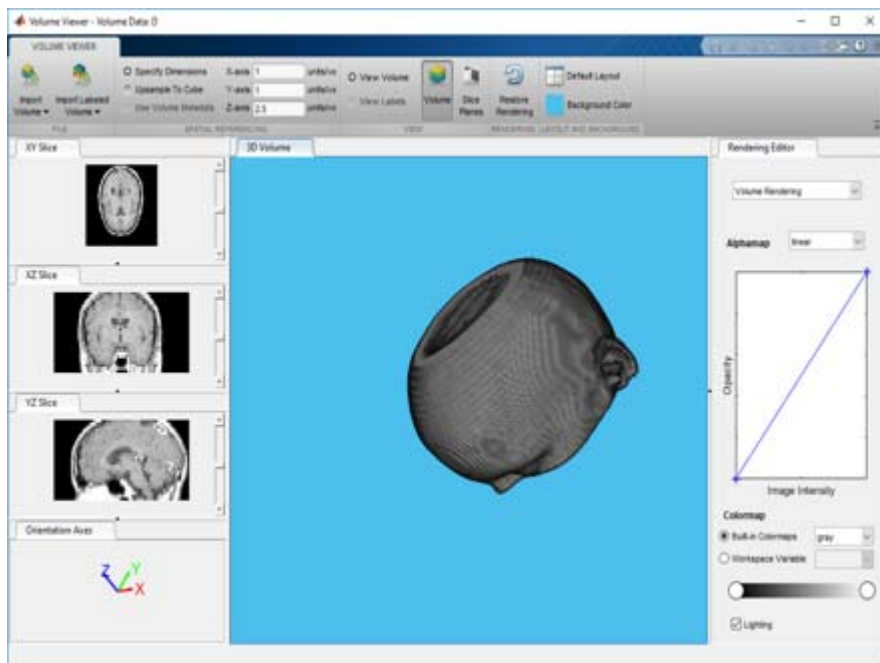

Fig 2 MATLAB – Volume Viewer [4]

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2.1 CT Scans Processing

The first part of our project was implementing functions for loading data and developing GUI to set parameters for model reconstruction. We processed data from CT scans saved in DICOM format with 5 mm and 1 mm resolution. In GUI the preview of the whole scanned body was displayed. In this part the grayscale threshold was set to a range of Hounsfield Unit HU corresponding to selected tissue, which can be calculated from the formula:

$$HU = 1\,000 \cdot \frac{\mu_{tissue} - \mu_{water}}{\mu_{water} - \mu_{air}},$$

(2.1)

where μ is a linear attenuation coefficient for tissue, water, and air. Next step was selecting an area of interest to make a less complex 3D model. There is displayed flow chart of CT scans processing in Figure 4. The selected area of the body was displayed as the final model. The last step of this content is exporting to STL or OBJ format according to the next application. 3D model of the scanned body was made using the marching cubes algorithm.
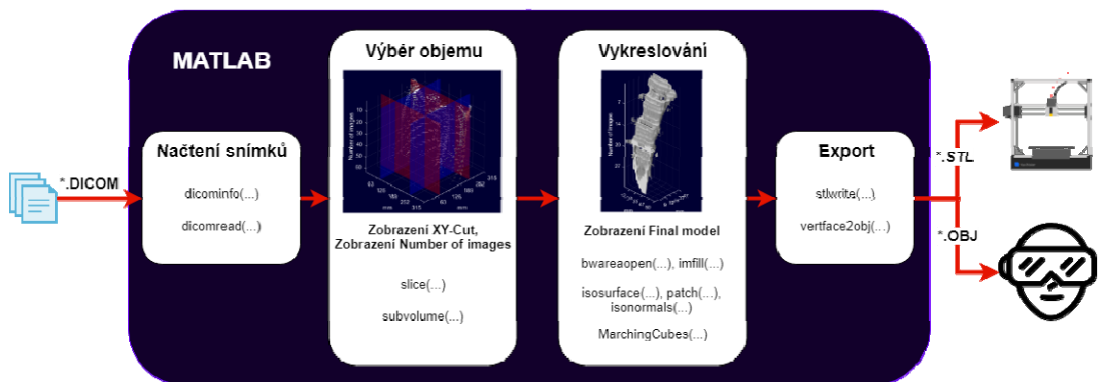

Fig 3 Flow chart of the implemented application

2.2 Virtual Reality

The second part of this project was displaying 3D medical models in virtual reality. For this reason, the virtual scene was created. As editor of the scene, the Unity was used and it was fit for the HTC Vive system. We used workstation equipped with 32 GB RAM, Intel Core i7 7700, Nvidia GTX 1070 Ti and running on Windows 10 64 bit. We implemented all prospective features for the VR scene. There were implemented examination room, where the user was able to move on the scene by walking and move to further distance by teleporting system. Our models were put to the scene and it was possible to grab them.

3 RESULTS

Example of the first implemented scene is in Figure 5, where are displayed models of lungs and whole thorax with 5 mm slice distance. Both models were displayed without smoothing adjustment to save as much information as possible from the original data. Also, textures were not used in reason to display the exact shape of the model.

Fig 4 Examination room visualization in VR.

On next Figure 6 is a detail of the model during grabbing interaction. When the area of the model is attached, the controller changes its color. While holding the trigger button the model was grab by the user, which made possible to discover the model from a different angle that was original position.
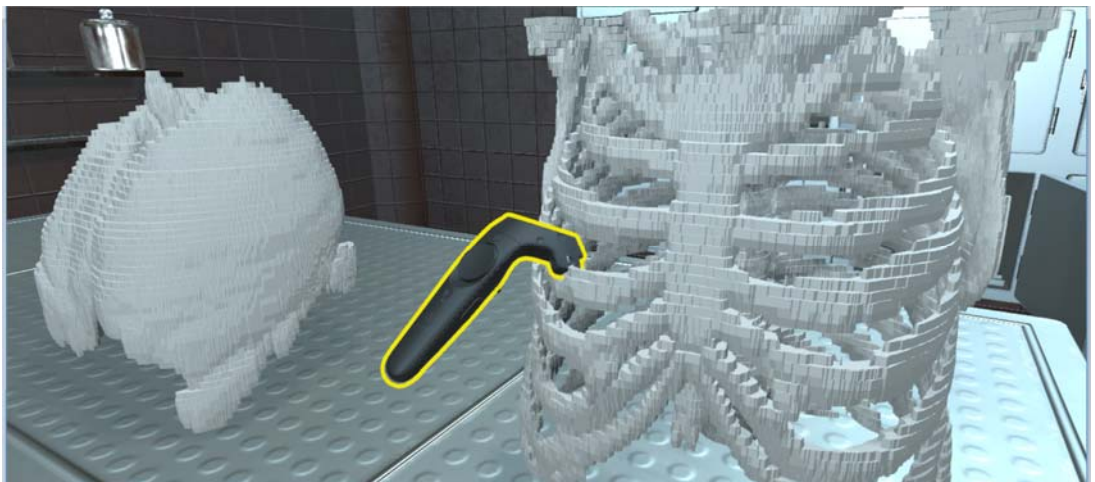

Fig 5 Detail of interaction with imported models

Our next scene is displayed in Figure 7 and Figure 8. The examination room is lighter and more spacious. Model is placed to a fixed position and view settings are editable via controls. It is possible to rotate mode in each plane by disk, which disappears after editing. Another editable parameter of the model is changing its size on the control panel demonstrated in Figure 7.
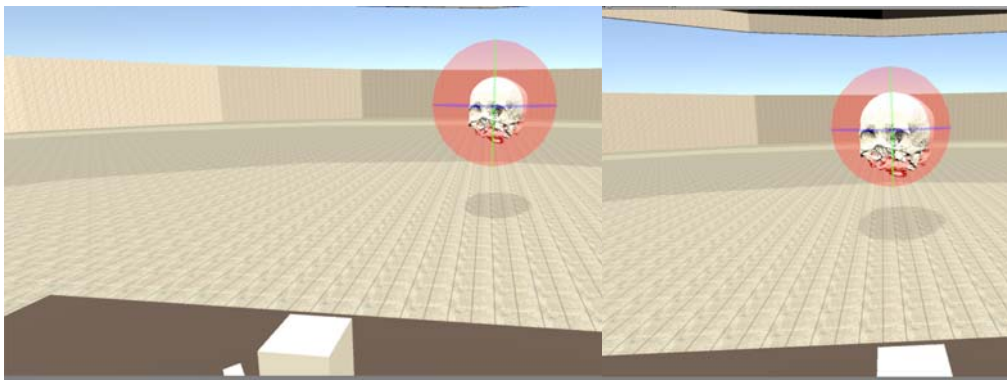

Fig 7 Control panel of model size.

The displayed model was generated from data with 1 mm resolution. This resolution makes the surface of the model much smoother, but the model is much more complex (whole thorax in 5 mm resolution 47 MB, skull in 1 mm resolution 59 MB).
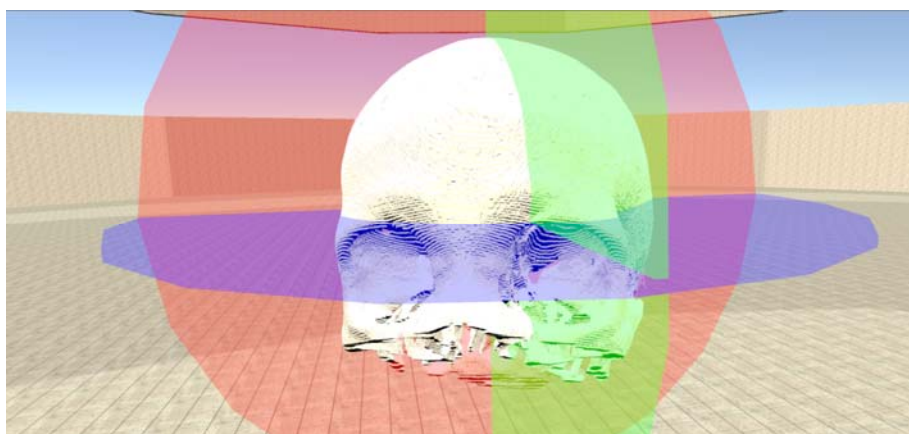

Fig 8 Detail of 1 mm resolution model

4 DISCUSSION

Virtual reality displays the 3D model in a realistic view. VR applications are most common in the gaming industry, but it is possible to use it also for education purpose or just for visualization which we are not able to do in another way. The biggest disadvantage of this technology is the purchase price and requirements for the computer. As better equipment is bought the better performance is provided. We can expect in the future this disadvantage will vanish with the development of this technology. Nowadays there is also a basic application for smartphones, that are used as part of the headset. [7]

Educational models are based on anatomical standards. If we want to use VR for medical examinations, it is necessary to modify the 3D model as low as possible. The basic property of voxel is its cube shape in 3D dimension because of discrete character. Standard adjustments eliminate outlier disconnected points and unnecessary areas of model (patient's coach)[3]. In data with a low resolution of 5 mm, the cube character is obvious. Model from data with 1 mm is smoother but this resolution increases its size and may cause longer processing time. Another aspect is texture. It helps to distinguish different tissue and it is assigned by some standard. Texture with professional shading cause, that model can look more precise than actual resolution is. To avoid misinterpretation, we did not use complex textures.

5 CONCLUSIONS

In this paper, we presented out the application of processing medical image data from the CT scanner for displaying in virtual reality. We used data from a CT scan with 5 mm and 1 mm slice distance resolution. Our application contains GUI for basic editing of the model – selecting an area of interest and tissue threshold. Generated model was exported in STL or OBJ format and imported to the virtual examination room. VR scene was made with a focus on basic interaction. It was possible to move on the scene and interact with objects.

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