PROPOSED MOBILE SYSTEM FOR BONE VISUALIZATION USING GPU RAYCASTING VOLUME RENDERING TECHNIQUE

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Abstract: *Despite the rapid development of mobile phones, the existence of medical visualization applications on stores is rare. This paper represents iOS mobile application that helps medical students and doctors to show bones processed over in an orthopedic surgery. The mobile application implements GPU ray casting algorithm. Experimental results obtained visually by comparing the result to the result obtained from ImageVis3D which use slice based volume rendering technique. ImageVis3D's development was initiated in 2007 by the NIH/NCRR Center for Integrative Biomedical Computing and additionally supported by the DOE Visualization and Analytics Center for Enabling Technologies at the SCI Institute. The result shows that proposed application based on GPU ray-casting technique present better visualized result than ImageVis3D. The dataset used in the experiment is CT images obtained from Osirix datasets for surgical repair of facial deformity.*

Keywords: *mHealth, volume visualization, mobile-based biomedical computing , CT images , GPU ray casting*

ACM Classification Keywords: *D.2: SOFTWARE ENGINEERING , I.3: COMPUTER GRAPHICS , J.3: LIFE AND MEDICAL SCIENCES*

Introduction

During common orthopedic surgery training, students must learn how to perform numerous surgical procedures like fixing fractures which requires training on artificial bones with the usage of surgical tools and implants. These artificial bones have a high cost that depends on the bone's type and quality. Thus the idea of using a computer based simulators for orthopedic surgery training appeared. Simulators will decrease the cost and help students to practice various procedures on a large number of available simulated surgeries in a safe and controlled environment. Also as they are designed dedicatedly for training with specific training goals and high quality visualization of bones, they will have much more to offer than artificial patterns. Visual representation of the bone is the key element in orthopedic surgery simulation. Nowadays and with the rapid development of mobile phones that can be similar to laptops, mobile devices became the trend toward information systems and ubiquitous graphical devices and native volume rendering due to their rapid development in the graphics hardware which can be similar to the PCs. GFXBench [GFXBench, 2016] is a high-end graphics benchmark that measures mobile and desktop performance with next-gen graphics features across all platforms. GFXBench used to compare the current apple laptops, iPhones and iPad to show the rapid development of mobile and tablets devices that in some cases can beat laptops performance. Figure 1 and 2 shows a comparison based on CPU speed between MacBook pros, MacBook, iPhone and iPad. As shown the speed of CPU in mobile phones and tablets begin to be as the same as laptop.

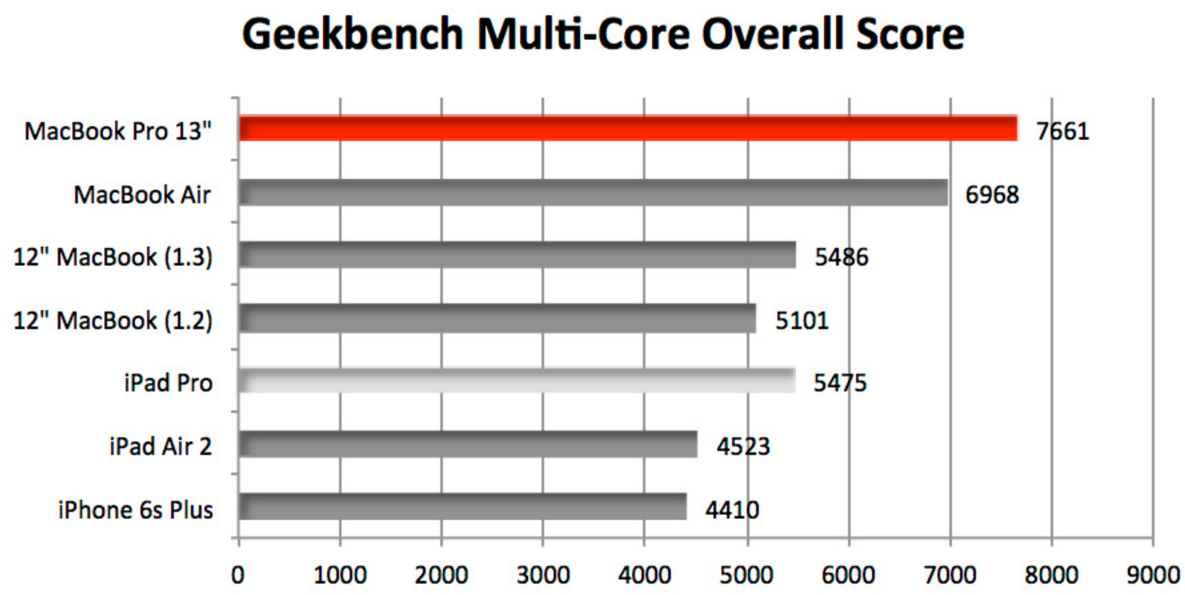


Fig 1 Geekbench single core overall score

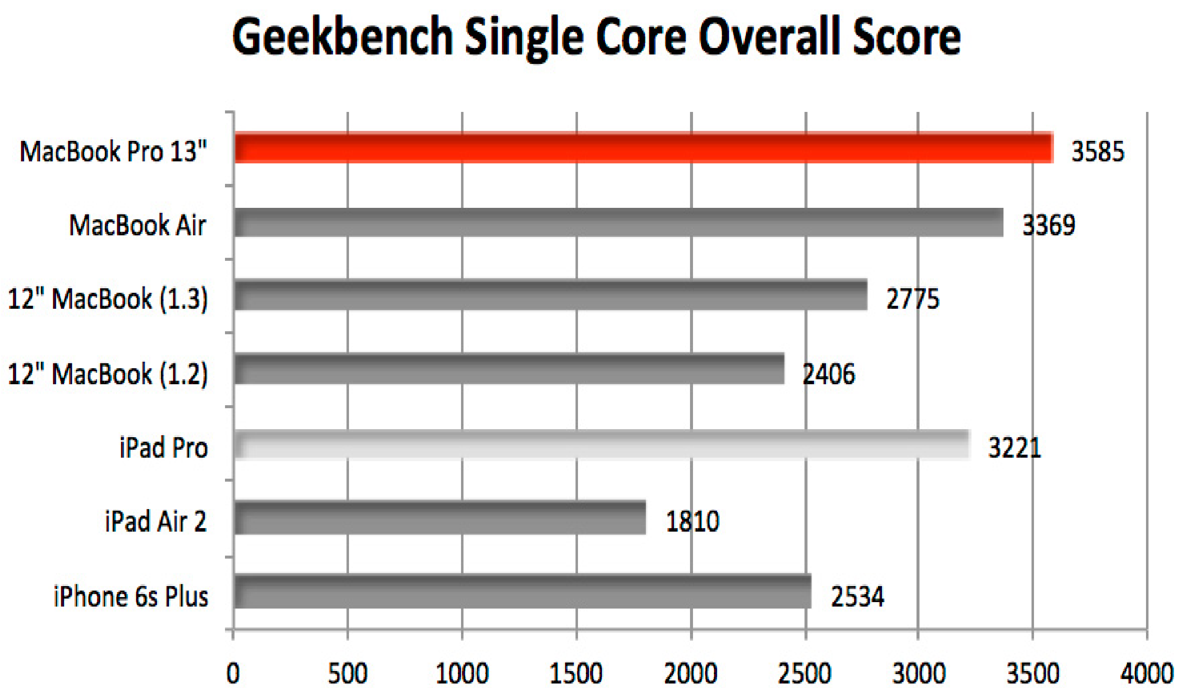


Fig 2 Geekbench Multi-core overall Score

Despite that rapid development, mobile stores has a rare free open source applications that implements the core of medical visualization. This paper presents an iOS mobile application for bone visualization that help medical students to visualize bones.

Paper organized as follows, firstly related work for volume visualization field listed. Secondly methodology used in this paper shown. Thirdly, experimental results shown. Finally conclusion and future work illustrated.

RELATEDWORK

There is two approach for visualization on mobile: first one is server-based rendering where datasets being render in server machine and the result image streamed to the mobile client, the second one is on-device rendering where datasets rendering in mobile directly.

The server-based approach appear due to the limitation on the mobile device and memory issues. [Lamberti and Sanna, 2007] present a powerful render server generates visualization images that are subsequently streamed to the mobile device for display. The advantage of this approach is that the rendering performance can be scaled by scaling the server capabilities and that very large datasets can be visualized.

Unfortunately, it suffers from a potentially substantial degradation of the interactive user experience, depending on the net-work quality [N. Tolia _et_al, 2006]; in particular, network latency on interactive responses can cause serious problems.

Therefore, on-device rendering on the mobile devices is preferable if fast interactive feedback is required and the net-work connection is not optimal. Fortunately, hardware development, along with basic texture mapping capabilities, is becoming increasingly available on mobile devices. [M.Moser and D.Weiskopf, 2006] propose a screen-adaptive hybrid low/high resolution rendering technique that achieves a good compromise between image quality and interactivity. [J.M.Noguera _et_al, 2012] develop a novel volume rendering algorithm perfectly suited to modern GPU-enabled mobile device. It addressed the limitations of mobile device, mainly the lack of 3D texture support. [Mobeen _et_al, 2012] represent two volume rendering algorithms using the WebGL platform for implementing medical image visualization on the mobile devices.

Mobile stores have a few open source application that present volume rendering techniques. Such as, [ImageVis3D, 2016], which will be concentrate on in this paper, is a lightweight open source, volume rendering application for interactive visualization on the iPhone and iPod Touch. It can display the built in visible human datasets as well as any dataset shared by the ImageVis3D application. ImageVis3D's development was initiated in 2007 by the NIH/NCRR Center for Integrative Biomedical Computing and additionally supported by the DOE Visualization and Analytics Center for Enabling Technologies at the SCI Institute. After an initial development phase of about one year the project was released under the MIT license and since then multiple institutions from America, Europe and Asia are contributing to the software. KiwiViewer [Kiwiviewer, 2016] application is a free, open-source visualization app for exploring scientific and medical datasets that runs on Android and iOS mobile devices with multi-touch interaction.

ToolKits available also in the mobile platform unfortunately, there is only one open source toolkit available called VES. VES [VES, 2016] is the VTK OpenGL ES Rendering Toolkit. It is a C ++ rendering library for mobile devices using OpenGL ES 2.0. VES integrates with the Visualization Toolkit (VTK) to deliver scientific and medical visualization capabilities to mobile application developers. Recently in 2015 VES become deprecated and combined with VTK.

PROPOSED METHOD

Ray casting, a standout amongst the most utilized volume rendering algorithm was initially presented by Levoy. In comparison to the other techniques, raycasting is widely accepted as the best quality volume rendering technique [Christian John Noon, 2012]. Additionally, it supports optimizations such as early ray termination and space leaping. It gives consequences of high quality, normally considered to give the best image quality. In this technique, a ray is produced for each desired picture pixel. Ray casting is a normal image order technique. Since there is no surfaces in direct volume rendering step through the volume must done carefully. The principle is as follows: a ray is shot out from a specific point in the screen, and the ray passes through the volume data, then equidistant sampling is obtained along the ray. The value at every sampling point is repeated accumulated according to its color value and opacity. This composited voxel can be presented the every sampling point in this ray. Eventually, the synthesis value of sampling in every ray show the map image. Figure 3 illustrates the pseudo code used for implement ray cast. Ray casting can produce high-quality 2D images from 3D volume data but the method is computationally demanding, especially when multiple volumes are involved, so a parallel GPU version has been implemented. Which is implemented in this paper.

The implementation is done using visualization toolKit. VTK has long evolved beyond just visualization. VTK consists of a C++ class library and several interpreted interface for visualization technique. Figure 4 shows the processes used to implement ray casting technique on iOS platform using VTK. The main class used from VTK to implement ray casting is vtkGPUVolumeRayCastMapper, which is a volume mapper that performs ray casting on the GPU. Ray casting is inherently an image-order rendering technique, with one or more rays cast through the volume per image pixel. VTK is inherently an object-order rendering system, where all graphical primitive (points, lines, triangles, etc.) represented by the vtkProps in the scene are rendered by the GPU in one or more passes.

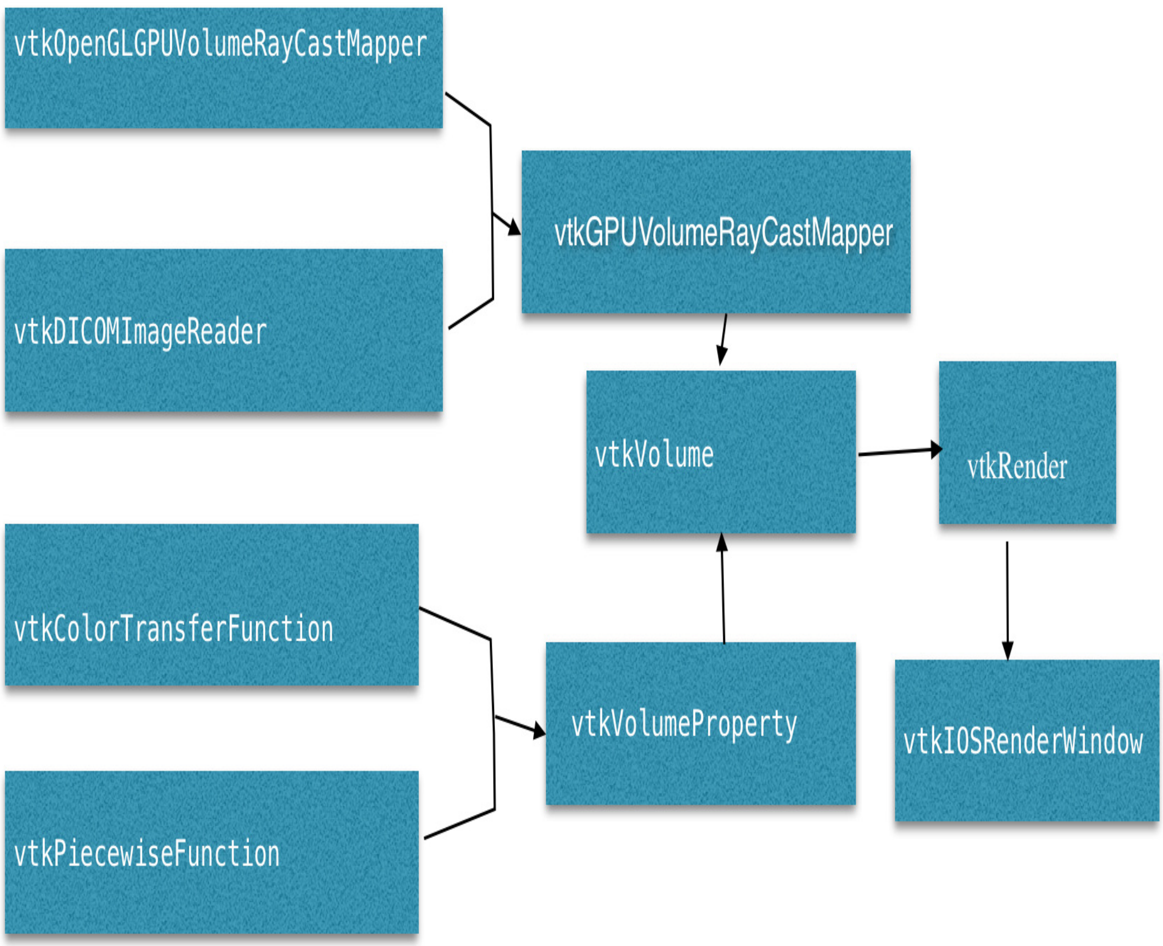


Figure 3: Volume rendering process using VTK

The proposed mobile based application architecture described in Figure 4. Here's the basic idea the user can load the DICOM image of the bone on the mobile, the application accepts images of CT data type. The application reads DICOM images and then apply RayCast volume visualization technique. The 3D object result of RayCast technique shows on mobile screen. The application is designed to be on-device rendering, as its read DICOM image, and implement the volume visualization technique on mobile without need any server side.

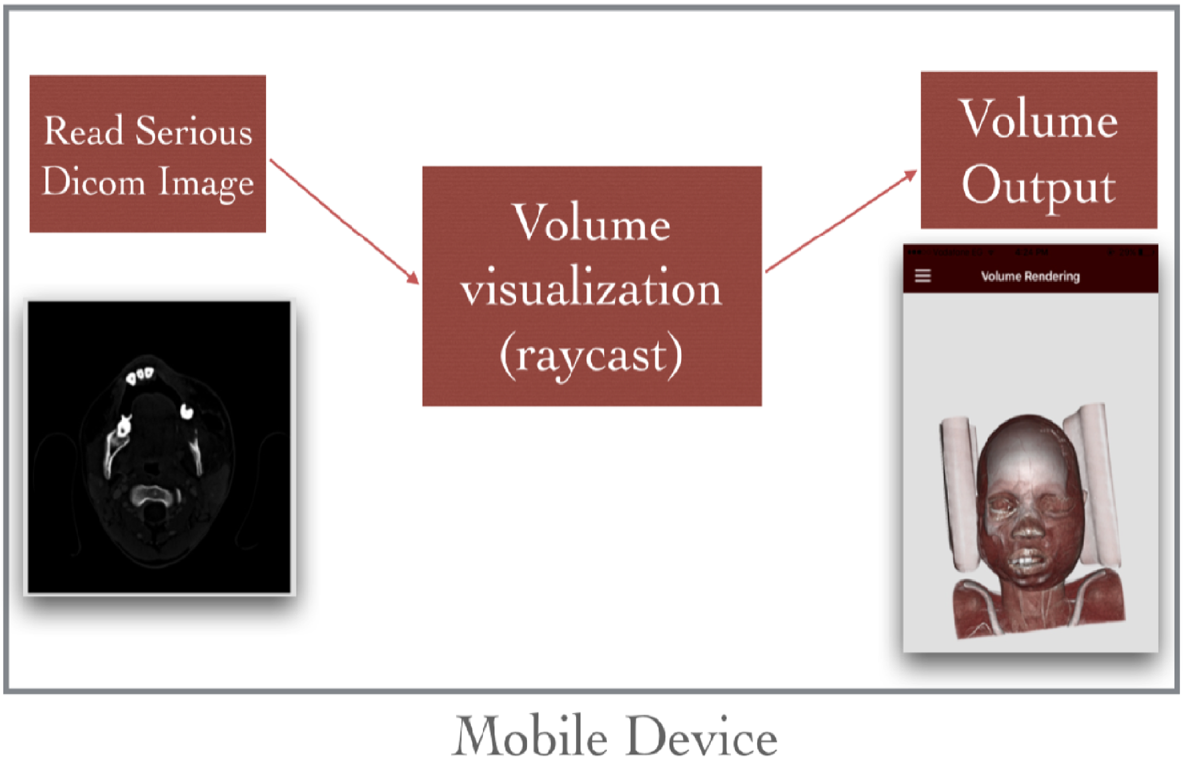


Figure 4: Proposed Mobile Based Application Architecture

EXPERIMENTAL RESULTS

A. Experimental Environment

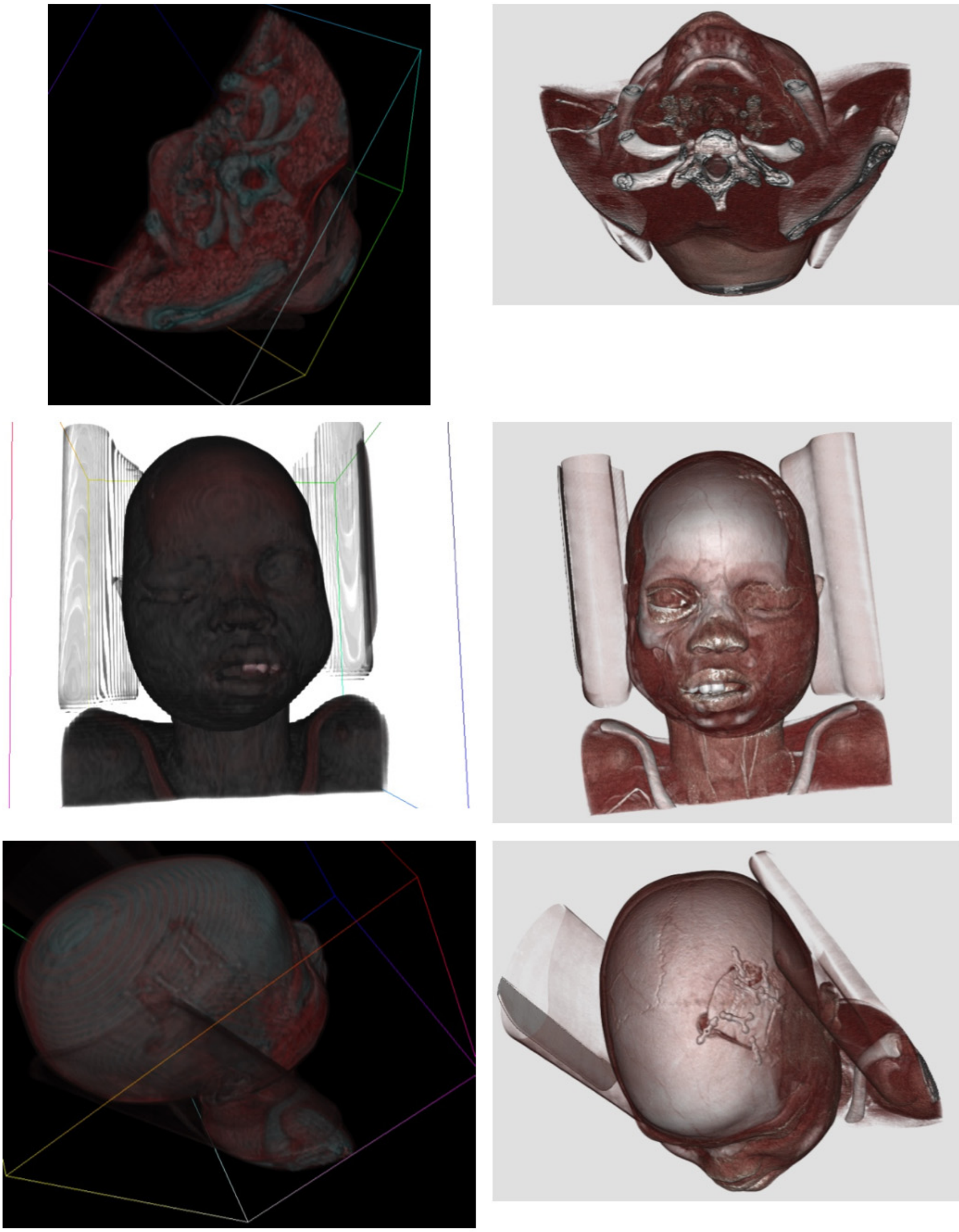
In our experiment we select iPhone 6s as a test platform that has PowerVR GT7600 GPU which render into 750 x 1334 frame buffers for display at so-called retina resolutions and Apple A9 Dual-core 1.84 GHz Processor. The device runs on iOS 9. The software was developed as a native iOS application.

B. DataSet

The data set used in this experimental is raw images obtained from Osirix [11] datasets . The raw images are CT images. File size is 120 MB compressed. Raw images are from surgical repair of facial deformity.

C. Results

Figure 5show the result obtained from the both application (a) represent the 3D object obtained from ImageVis3D and (b) represent proposed application. It is shown obviously the high visualized result gained by implementing GPU ray cast technique over sliced based volume rendering technique used in ImageVis3D. The surgical repair of facial deformity shown clearly in the implemented system over ImageVis3D.



(a) ImageVis3D **(b) Proposed system**

Figure 5: The results from ;(a) ImageVis3D application and (b) proposed application

D. Limitation

This system has been developed based on GPU ray casting technique. The system reads CT images from iPhone and apply the technique then the 3D object result rendering on the screen.

This system has the following recognition limitations :

- Runs only on iPhone and iPad devices
- Accepts only CT images
- Tests on small datasets “120Mb”
- Doesn't support large datasets Gigs

CONCLUSION AND FUTURE WORK

Now it's time for mobile, mobile phones gained high performance due to the rapid development in their hardware which live up to the laptop's hardware with the advantage of their mobility. This development made mobile phones be available for the heavy implementation of medical visualization techniques. Despite these developments, the stores of mobile suffer from the rare existence of medical volume visualization application. In this paper mobile application is represented to help in the orthopedic field. The implemented application shown high visualization result when compared to ImageVis3D.

For the future development there are several areas of focus. Mainly will focus on overcome the limitation of the mobile application for visualization medical image such as support large datasets ,GIGS, and support different datasets techniques like MRI.

The other focus will be virtual reality for 3d medical objects on mobile phones. As currently and with the development of virtual reality glasses for mobile phones and their cheap price, it become possible to develop mobile application that support virtual reality.

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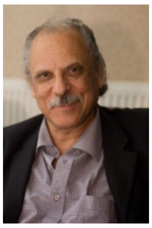

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