

Computer Aided Design for Osseo-Integration Applications

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Abstract: Prosthetic design has been an expensive proposition and incurs significant cost and delay for lack of affordable and user-friendly graphical computer aided design (CAD) tools. This paper presents such a tool developed to support 3d-modelling and printing of body parts based on advanced image processing of raw radiological medical images. The target body parts are electronically designed using real life medical images from sources such as MRI/CT by volumetric extraction and graphically interactive reconstruction and such parts can further be 3d-printed. This saves cost, time and complexity of design significantly over current manual methods. The CAD tool adopts DICOM standard for acquiring, processing and storing medical images and emits volumetric outputs of the designed parts in STL and OBJ standard formats to be compatible with 3d-printers. This paper presents the functionality and architecture of the tool along with specific results obtained from the same.

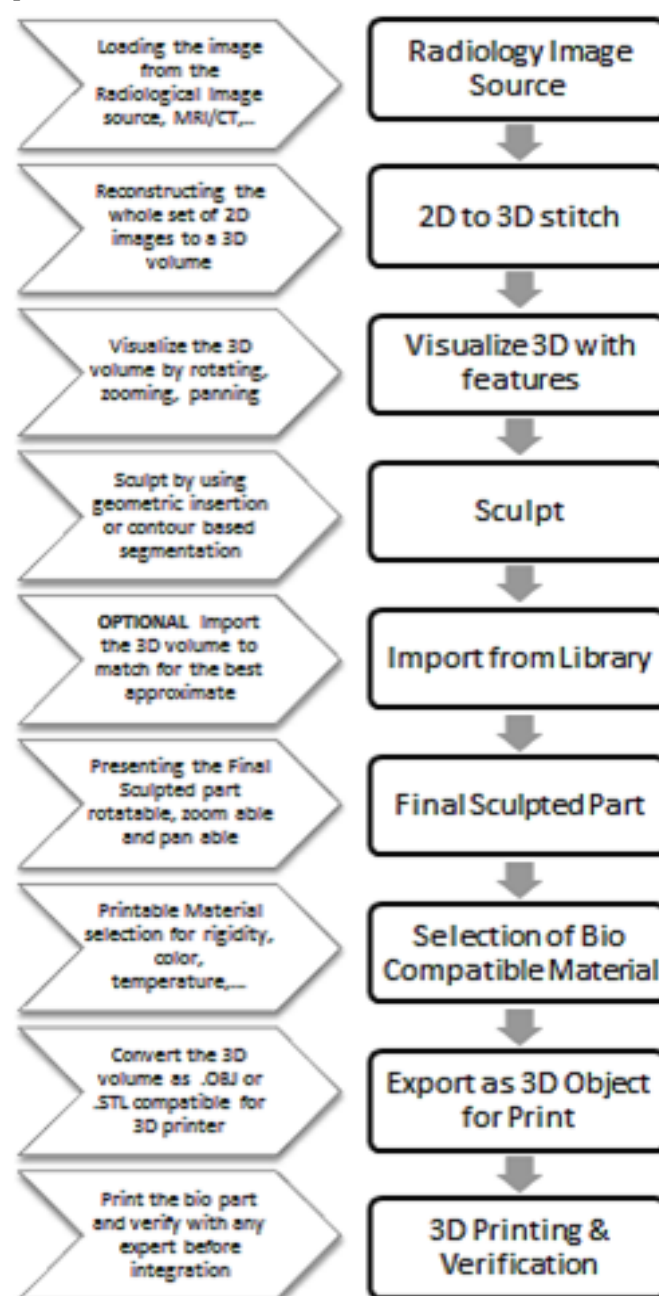
Keywords: Prosthetic, Dicom Viewer, Medical Imaging Software, View MRI Slices, View CT Slices, View PET-CT Slices, 2D To 3D Reconstruction.

I. BACKGROUND

Although radiological data can find profound relevance in computer aided prosthetic design, conventional usage of Radiological images have been used primarily for visual inspection for medical diagnosis and manual design of artificial bio-parts. Hence the associated tools such as DICOM Viewers only poses visualization features such as 3D and individual slice presentation with contrast adjustment, annotation, cropping and measurement utilities. But there is no facility to reconstruction segmentation, extraction and sculpting a volumetric 3d representation from 2D scanned medical image series. The conventional method employed largely is still a manual process involving casting of POP material in a manually formed die. Since every patient would need a personalized customized part, this process cannot lend itself to mass-manufacturing as in vehicles for example. For lack of such customization facility in rapid prototyping of body parts, current efforts for mass production utilize a standard set of sizes which causes incompatibility, inconvenience and injuries to the patient over long usage. Simply put, the shape, structure and size of a body part cannot be standardized as in a garment.

The tool described in this paper has been developed keeping in mind these factors so as to reduce design and production time for prosthetic replacement to a

couple of hours as compared to weeks for a manual production, while providing much higher customization, precision and structural compatibility to each patient with reusable infrastructure. Further, several value additions can be done as for example the prosthetic can be matched to the skin-tone of the patient with Bio-Compatible ink and smoothed to various degrees as needed. The tool has been successfully used in experimental design of parts such as nose and ear extracted from Radiological scan of patients.



II. DESIGN

The workflow for which the tool is designed is illustrated in figure (1.1). As seen in fig. 1.1, upon the load of the directory of DICOM images [1], a montage of all the images appear on the MONTAGE division of the UI. Upon the selection of the slice displayed in the MONTAGE section of the UI, the corresponding three views of the slice are displayed on the quadrant one, two and three as: Axial, Sagittal and Coronal views respectively.

The purpose of the project heading towards Osseo-Integration is one of the aids for amputees with prosthetic replacements. The present medical analysis of a human anatomy is done in two dimensions, majorly. The viewers of the medical imaging today, support most of the features this project has, but do not support the 3D rendering. So, this project helps in the printing of the three dimensional prosthetics [6][8].

The printing of the prosthetics can be for many different purposes which differ in structural and the physical properties. The printing can happen for a facial muscle replacement, bone replacement, tissue replacement, and limb replacement involving many materials with different densities and properties. One of the very important cosmetic value for the reconstruction of a Human Bio Part is the Facial Prosthetic Bio Replacements.

The scan can be of any modality, a CT, MRI or a PET-CT [5]. All the medical imaging is bound in the DICOM standard. The scanned 2D image is processed with an algorithm to reconstruct the stack of slices into the third dimension, forming a 3D volume [6], and fed to the 3D printer for printing the prosthetic.

III. IMAGING SCULPTING FEATURES

This Radiological User Interface is equipped with several functions for the image visualization and manipulation as follows.

A. Contrast Enhancement

The contrast adjustment is achieved by creating a window in the contrast adjustment histogram. Reducing the width of the window makes the contrast adjustment. Moving the window along the horizontal makes the brightness adjustment.

The contrast adjustment is achieved by creating a window in the contrast adjustment histogram. Resizing the width of the window makes the contrast adjustment. Sliding the window along the horizontal makes the brightness adjustment.

B. Measurement

This is a straight line, with the measurement capability. This indicates the length of the region to be measured in two dimensions in mm. The depth of the tumor can also be measured in two dimensions from the scalp of the head. Multiply the pixels **on** the annotation by a **1** and multiply the pixels **outside** the annotation by a **0**. Then calibrate the pixels of annotation in a straight line, in millimetres.



Figure 1: Ruler for measurement in the GUI

C. Generating a 3D Volume

The montage (icons) displayed to the bottom left corner of the window is all the images in the directory of images that are loaded. Those images are converted to form a 3D image [4].



Figure 2: Generating 3D in the GUI

The techniques used for the reconstruction of the 3D structure from the simple 2D medical Image scan can be visualized in the figure 2. The technique of Isolines, Isosurfaces and the Isonormalization are explained as follows.

Isolines are the basic contour mapping techniques which can be used to group the grey-scale medical image into different contour levels. Upon the classification of different contour levels in the two dimension medical image, the Isosurfacing can be implemented to these contour levels, making it a solid plane, or a patch of the surface. This is a single slice of the medical image. This is illustrated in the figure below, Fig. 3.

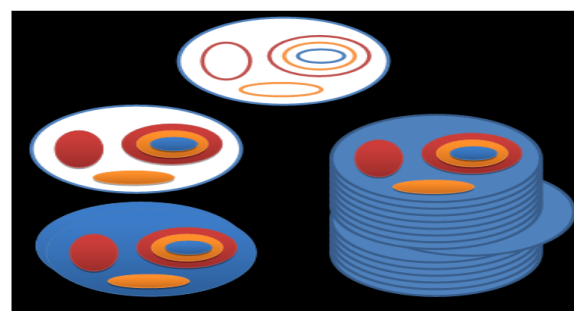


Figure 3: 3D Reconstruction Illustration

Many such slices converted into surfaces by patching, can be constructed on the third dimension as a 3D Volume. This involves Isonormalization. Here, the multiple slices of the medical image are grouped in the index using the triangulation. Drawing the triangle normals has its own cons when compared to drawing data normals as the precision in drawing the skin over the third dimension of the medical image is high. This can be visualized from the figure 4.

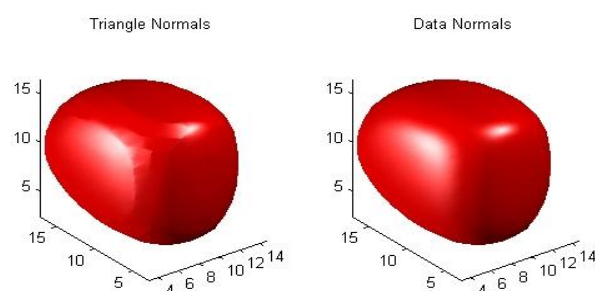


Figure 4: Isosurfacing using triangle and data normals

D. Sculpting

Sculpting of the 3D volumetric image is possible in two different ways.

1. Geometric Extraction
2. Library Extraction
3. Isometric Etching

In the figure below in Fig. 5, a cylindrical shape with an altered radius, length has been inserted in an inclined position along the forehead of the 3D volume, and the same portion is represented as sculpted part & the deficit over the forehead, as though there was an extraction. All the images are rotatable and zoom able.

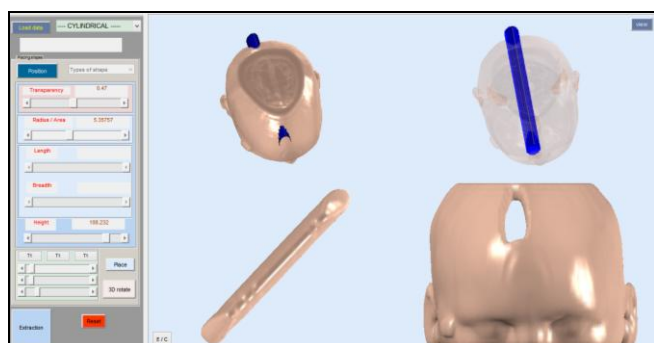


Figure 5: Geometric Extraction – Cylindrical

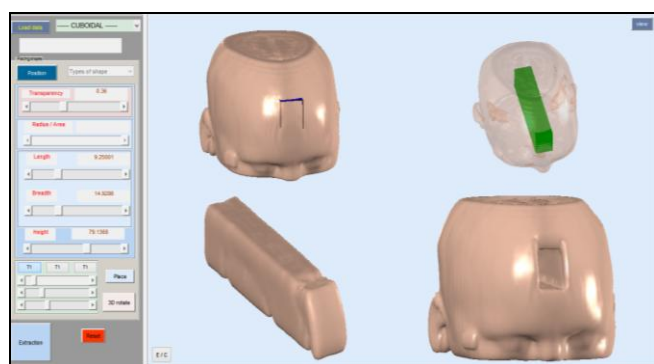


Figure 6: Geometric Extraction – Cuboidal

The purpose of building a library of bio parts is to get the ease and time efficiency of the whole process. Once the library aggregation is done with numerous shapes and sizes of the bio parts, it is just a matter of correlating the existing library part to the scanned volumetric deficit of the bio part. Fig. 6 shows the correlation and comparison of the library's best match for the current 3D volumetric scanned image.

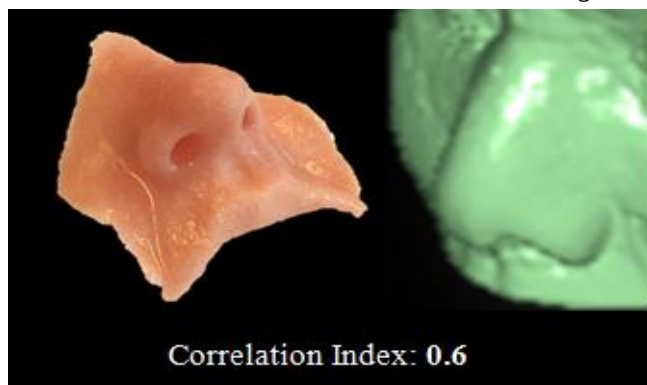


Image Source: www.3dprintingindustry.com

Figure 6: Library Extraction

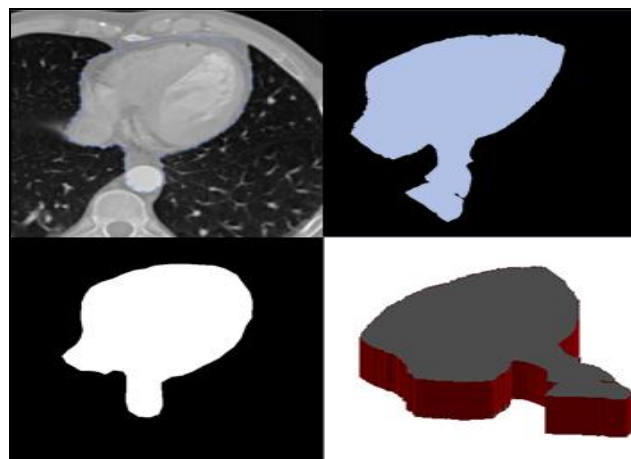


Figure 7: Isometric Etching

As seen in the above image, upon the loading of the 2D volume, the selection of any point of a region of interest would create an automatic contour around that region of interest, may it be an organ, tissue or any other part. This contour information is shared with all the other remaining slices in the Radiology file set, and may it be smaller or bigger, it would stitch it as a single set of 3D volume. This can be visualized as shown in the figures 7 and 8.

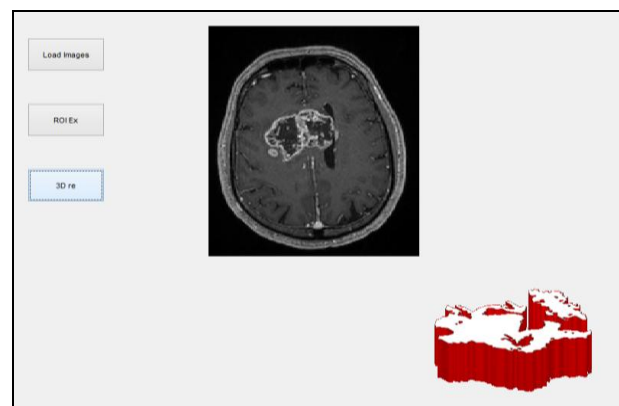


Figure 8: Isometric Etching

This method of sculpting can be referred to as geometric extraction of the region of interest. Here, the options of the geometric shapes given are cylindrical, spherical, prism and square. These shapes are customizable in all their geometries, before insertion for the extraction.

E. Converting the Volume into Printable Formats

The most common printable formats are .OBJ and the stereolithography .STL format. The output image after the 3D reconstruction, geometric extraction, Library comparison, and the Isometric Extraction; is converted as a 3D hollow/solid volumetric image accustomed to standards such as .Obj and .Stl and this can be seen as in the Fig. 9

F. Printing the Volumetric Image in 3D

The printing can be done in a 3D printer with the print button press. The scale of the model printed is defined in the printer software.

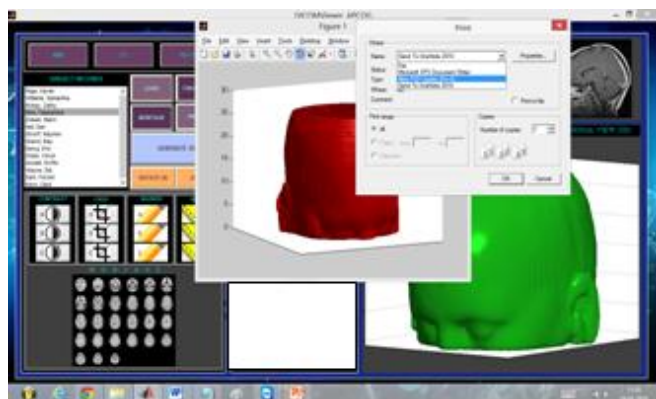


Figure 9: Printing the 3D Volume

IV. RESULTS

The present medical analysis about the MRI or other modalities is done normally with a 2D representation. It is just about the MRI image hand held or computer processed, which may not be very helpful for surgical methodologies. The advancement about the same is made by cropping in 3D.

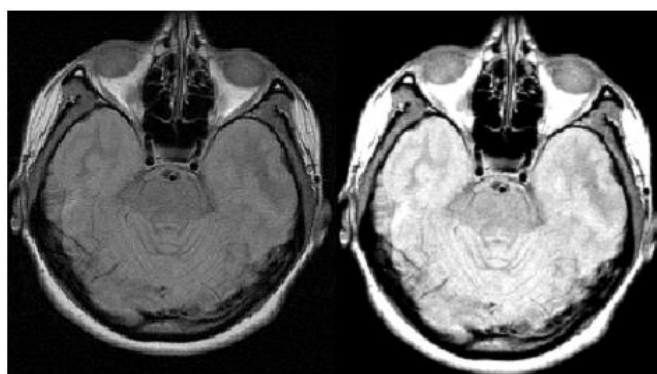


Figure 10: Contrast/Brightness Enhancement

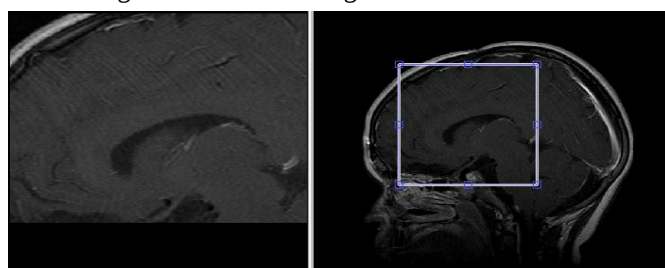


Figure 11: Zoom over a drawn Rectangle ROI

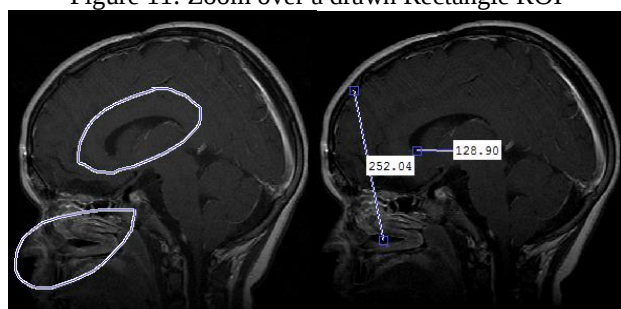


Figure 12: Annotate and Measure over the Image

The medical images irrespective of the modalities, the stitching happens and a 3D model of the same subject is produced with cropping and analysis over it. Here, the stacks of two dimensional images are converted from surface to volume. Now, we infer with the analysis of voxel (3D Pixels!) instead of pixels as in the earlier case.

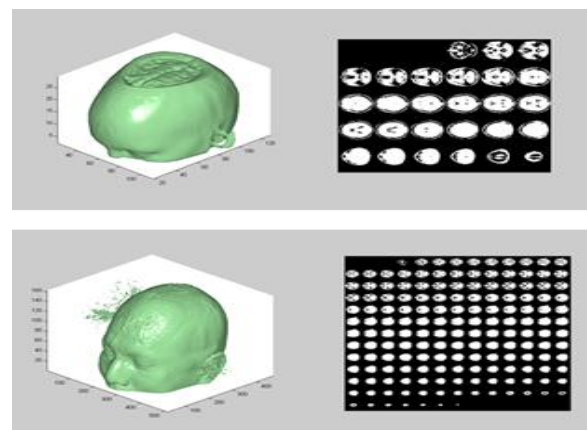


Figure 13: Reconstructed Volumetric Images from the side shown MRI 2D Montage Scans

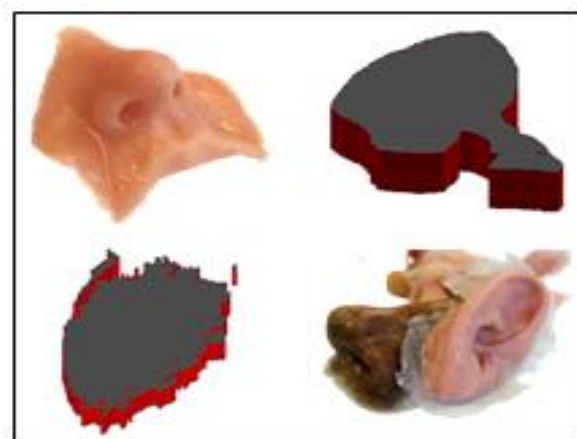


Figure 14: Similar Printed Bio Parts

The processing available in the Radiology Viewer are 2D-cropping, contrast adjustment, ruler and the marker application. The advancement of the three dimensional cropping is brought about in the later stages of the project.

As in above shown Fig.13 there are the two series of Radiological image set that are converted from the two dimensional stack into the third dimensional volumetric image structure. The first being the structure with 26 slices and the second being the structure built with 160 slices.

The volumetric reconstructed 3D object can be analyzed as seen in the figure 14, by cropping the volume [7]. The cropped Sub-volume can be of any defined organ, or a desired cross-section over the whole image.

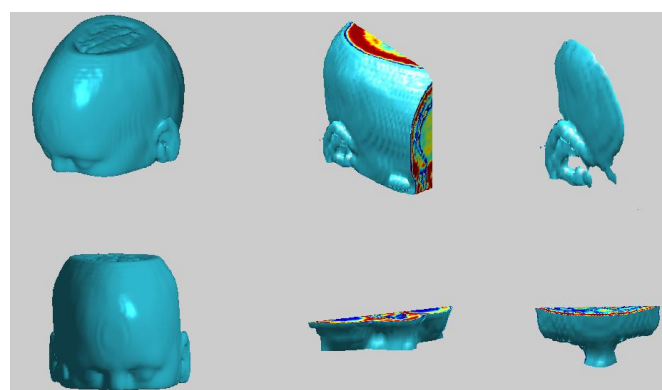


Figure 15: Ear and Nose Segmented

As the database library of pre-sculpted accumulate, the organs like ears, nose, limbs, and other defined organs can be borrowed more efficiently from the library and cropped by default and stored in a separate location in the database, and can be retrieved in a need to need basis as the nearest best approximate prosthetic to the amputee.

November 09, 2004

- [7] <http://Web.mit.edu/>
- [8] <http://dicom.nema.org/>
- [9] www.3dprintingindustry.com

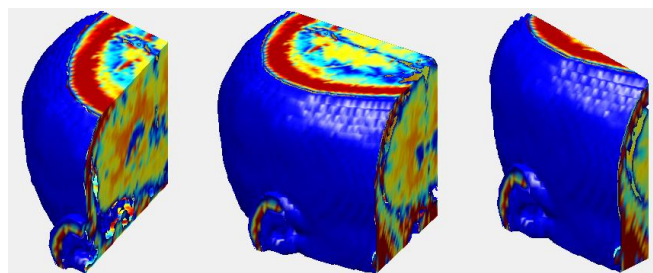


Figure 16: Cropping the Volume for Analysis

CONCLUSION

The medical Analysis and the visualization of the volumetric Images in the third Dimension is now possible with the ability of printing the 3D structure in a 3D printer, as an object file (.obj). The tool can be extended further in many features, as for example, the approximate color of the skin can be matched before printing the prosthetic for the amputee.

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