

Development of Computational Three Dimensional Solid Model from CT Scanned Data

Ashish Deoghare¹, Pramod Padole²

¹Professor, Mechanical Engineering Department,
GH Rasoni College of Engineering
Nagpur, India.

²Professor, Mechanical Engineering Department,
Visvesvaraya National Institute of Technology,
Nagpur, India

¹ashish_deoghare@yahoo.co.uk , ²pmpadole@rediffmail.com

Abstract. To provide better treatment and therapy to the patients, computational biomechanics is becoming an important part of orthopedic research and clinical studies. Prior to biomechanical computation, there is a need to develop the computer aided three dimensional model, showing all the anatomical features. In the present paper, a novel method has been proposed by developing a computer program code called 'Dicom Image Data Converter (DIDC)' which converts the complex data stored in the data elements of computed tomography (CT) images into the volumetric form. The developed three-dimensional model provides the necessary information to the physicians and surgeons to visually interact with the model, and if needed, plan the way of surgery in advance. The processed data of the model is versatile and compatible with the present commercially available rapid prototyping (RP) technique, computer aided design (CAD)/ computer aided manufacturing (CAM) and finite element analysis (FEA) soft-wares.

Keywords: Computed tomography, Threshold, Computer aided design, Rapid prototyping

1. Introduction

The primary function of human skeletal is enduring the mechanical loads generated by physiological activity. Bones and soft tissues undergoes several million loading cycles cumulatively within a year. These tissues are cyclically loaded in life (*in-vivo*) by routine physical activities. The excessive monotonic loading for prolonged duration spoils the functionality of organs. Once, the working mechanism of organs inadequately functions clinical intervention or the medical treatment became essential.

Present medical imaging modalities like X-ray, Computer tomography and Magnetic resonance imaging provide the radiograph in two-dimensional form. Medical practitioners require skill and experience to correlate images for the correct diagnosis. In many situations, the 2D image interpretations are insufficient for correct diagnosis of the causes. For this reason, the literature survey in the fields of medical image processing and orthopedic sciences are carried out which reveals that there is a scope for improvising the present medical practices. In-depth multiple viewpoints from multiple instigators and a series of published articles in related areas are carefully examined [1, 2, and 3]. Based on the information, it is felt that the present technique used in the areas of medical image processing and surgery can be made more accurate and patient specific.

2. Development of DIDC software

An insight to the visualization of CT data sets for understanding the current anatomical status of the patients is of paramount importance to the doctors, scientists and physicians. But exercising these techniques

has found some limitation such as, CT images acquired from scanner are platform dependent, the surface model obtained is a pseudo illusion.

The process of developing patient specific 3D models of the body organs begins with the acquisition of raw CT scan slices which is used for developing the three-dimensional geometry. To build in-house program for DIDC software a "stack of slices" approach has been employed, to construct 3D volume [4]. The program code uses image processing functions of MATLAB tool (Mathworks Inc., Natick,MA) and specially developed subroutines.

The region of interest from the CT images data set, at different threshold can be used to delineate the required anatomical structure. Volume segmentation by threshold process is employed which facilitates automatic extraction of the anatomical organ or region-of-interest [5]. Threshold value is used to create a binary partition of voxel intensities. All voxels with intensities greater than the threshold are grouped together into one class and those below the threshold are grouped together into another class. Use of a single threshold thus results in a binary segmented volume. The technique is very effective in getting segmentation done in volumes with a very good contrast between regions. The main drawback of this technique is that the results are too tightly coupled with the thresholds used [6]. Any change in the threshold values can give a different segmented region. However use of threshold approach is very sensitive to noise and partial volume effects. Interactive visual feedback provision is available for the user to select required threshold limits. Following functions are used to find the maximum and minimum range of threshold value from the 'dicomvector' data.

$$[mint]=\min(\min(\min(Dicomdata)));$$

$$[maxt]=\max(\max(\max(Dicomdata)));$$

The functions [mint], [maxt], are used to find smallest and largest intensity values from the vector data elements respectively. These maximum and minimum values are used to execute segmentation task. According to the threshold values given as input, the volume of the region of interest can be visualized. The 'show3D' variable highlight the 3D view of the image, it checks each pixel intensity value, if the pixel is in selected range of threshold value, its intensity values are retained otherwise they are changed to zero.

Apart from the own developed subroutines some inbuilt functions and mathematical morphological operators such as 'dicomread', 'dicomVolume', 'imshow', 'isosurface', 'isonormal', 'patch', 'camlight,' 'trimesh', 'trisurf,' 'imdilat', 'unsharp' filter and 'bwareaopen' are used to ensure desired quality of 3D representation.

Following major steps are carried out in-order to develop the computer tool.

1. Data acquisition from CT slices.
2. Convert the acquired data into a format that can be easily manipulated, filtered out noise, and highlighting the required body organs.
3. Display the converted data in 3D graphical form.
4. Saved this data in .stl ("StereoLithography") format so that it can be further exported to the commercial CAD/CAM/CAE packages.

3. Data processing for .stl file format

.stl ("StereoLithography") describes a raw unstructured triangulated surface by the unit normal and vertices, ordered by the right-hand rule of the triangles using a three-dimensional Cartesian coordinate system [7]. The surface is tessellated or broken down logically into a series of small triangles (facets). Each facet is described by a perpendicular direction and three points representing the vertices of the triangle. The ASCII file has the following format:

```
Solid name
facet normal n1 n2 n3
outer loop
vertex v11 v12 v13
vertex v21 v22 v23
vertex v31 v32 v33
endloop
endfacet
endsolid name
```

The words shown here in bold are keywords and the italics representing the data. Point cloud and connectivity matrix data written in this format can be imported into a variety of grid generation soft-wares

and RP manufacturing technique. The developed subroutine used to perform the task of generation of .stl file is as follows.

```

Vertices2Stl
function b = Vertices2Stl(Vertice, faces, strStlFileName);
P1 = Vertice(1:3:end,:); % P1(ii,:) will be the 1st vertex of the ii'th triangle
P2 = Vertice(2:3:end,:); % P2(ii,:) will be the 2nd vertex of the ii'th triangle
P3 = Vertice(3:3:end,:); % P3(ii,:) will be the 3rd vertex of the ii'th triangle
m=min ([size (P1, 1) size (P2,1) size(P3,1)]);
P1=P1(1:m,:);P2=P2(1:m,:);P3=P3(1:m,:);
U = P2 - P1; % a side of each triangle
V = P3 - P1; % the other side of each triangle
TriangleNormals = cross(U,V); % 1- sign ambiguity ... (can't be resolved) % 2- yet to be normalized
NoOfTriangles=size(TriangleNormals); % --start: write to file
fid = fopen(strStlFileName, 'w');
if(fid == -1)
    fprintf('Error: could not write to file');
    b = false; return; end
fprintf(fid, 'solid Object\n');
for ii = 1:NoOfTriangles
    NormalizedTriangleNormal = TriangleNormals(ii,:) / norm( TriangleNormals(ii,:));
    fprintf(fid, ' facet normal %f %f %f\n', NormalizedTriangleNormal);
    fprintf(fid, ' outer loop\n');
    fprintf(fid, ' vertex %f %f %f\n', P1(ii,:));
    fprintf(fid, ' vertex %f %f %f\n', P2(ii,:));
    fprintf(fid, ' vertex %f %f %f\n', P3(ii,:));
    fprintf(fid, ' endloop\n');
    fprintf(fid, ' endface\n');
end
fprintf(fid, 'endsolid\n');
fclose(fid);
% --end: write to file
b = true;
return

```

Executable competency of the .stl file developed by the DIDC software is verified by manufacturing the different medical models by exporting it to the rapid-prototyping manufacturing system and to commercial CAD/CAM/CAE software shown in Fig.1 (a) and (b). The software has unique feature to process the CT scan data of metallic parts. The feature is used for modeling intricate shapes, sculptures, automobile and die designing parts for which the drafting is impossible with present modeling software's.

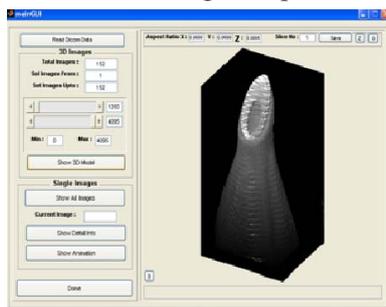


Fig. 1 (a) Metal funnel CT slices processed in DIDC software

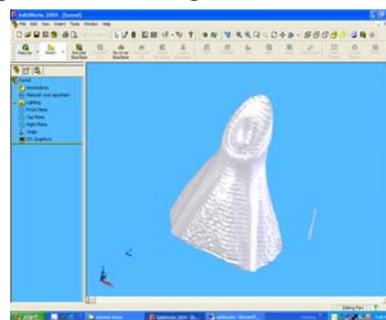


Fig. 1 (b) Metal funnel in Solidworks2004® software

4. Discussion

The software tool overcomes the platform dependability to visualize the DICOM (CT) image data. It is capable to animate the required views of CT scan (2D) images and able to detect the boundary and planes of CT images from all the sides. The software tool processes the CT slices data at the different threshold value to highlight the internal organ in 3D form. As an example shown in given below Fig.2 (a) and (b). The set 90 CT slices images are stacked to visualize 3D model with zero and 1200 threshold. The threshold value can be changed as per the visual feedback. Fig. 2 (a) indicates, 3D model of human body from chest to abdomen

with skin as threshold selected is zero. Whereas, Fig. 2 (b) shows the bone structures of the same model showing the complete vertebral column from thoracic region with chest ribs to the sacrum. It is observed that the range of 1200 to 1350 threshold shows bone structures.

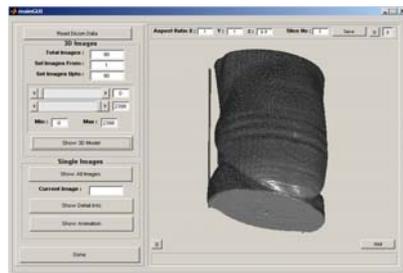


Fig. 2 (a) 3D model of human body organs covered with skin tissues

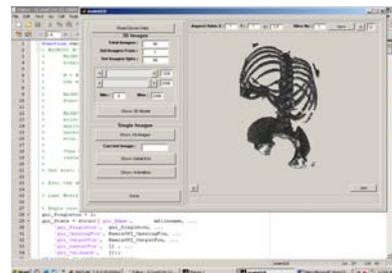


Fig. 2 (b) Vertebral Column from Thoracic to the Sacrum region

The software allows the user to visualize the anatomical structured at any orientation. The shades colors can be used to investigate minute details of the obtained anatomical structure.

5. Conclusions

The anatomical structure obtained from DICOM software allows doctors, scientists and physicians to virtually interact and able to get potential lifesaving information. The software facilitates, the generation of required 3D volumetric data on the diagnostic console of doctor. The process makes it possible to visualize images without the need of the proprietary third party software for image manipulation. The process data is compatible to analyze the bio-system at different loading conditions with and without implants.

6. References

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