

A MATLAB image processing approach for reconstruction of DICOM images for manufacturing of customized anatomical implants by using rapid prototyping

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Abstract

The paper deals with the DICOM images reconstruction which is initially very useful for production of customized anatomical implants by using rapid prototyping technology. The researchers are always focusing on biomedical 3D imaging reformation. The MATLAB image processing has been strongly developed and almost implemented in every modern tomographical modalities. The CT slices of interested region of customized implant in DICOM format are initially preprocessed using developed MATLAB code. In the next step the images are imported in Invesalius. It is an open source medical software used to reconstruct structures of the human body. Based on two-dimensional images, acquired using CT or MRI images. This software generates three-dimensional models corresponding to anatomical parts of the human body. After reconstructing three-dimensionally DICOM images, the software allows the generation of STL files. These files can be further used for Rapid Prototyping. This project in biomechanical area has been developed to provide the facility in very cheap expense with highest technological support comparatively with expensive imported facilities and software. This paper shows first step results of discussed project of implementing fundamental problems in DICOM medical image reconstruction for medical imaging and designing a preprocessing noise removing software for reconstructing DICOM image from a set of CT/MRI images using MATLAB image processing tool & RP.

Keywords

Matlab Image Processing, DICOM, Invesalius, Rapid Prototyping

1. Introduction

Medical image diagnostic equipments such as CT scanners, MRI, ultrasound etc. have been used worldwide. The outputs of these equipments are useful for production of customized anatomical implants. But this is possible only at some high quality hospitals and medical diagnostics centers. These equipments have been alternatively assisted by information technology, which need strong computers with dedicated softwares for maintaining patients specific data.[2,3] The initial data required for customized implant is taken from locally available low grade medical scanners(single or double

slices) & then by using developed MATLAB code these images are filtered for getting optimized results. Then the output files are imported in open source software for further 3D reconstruction of anatomical model. This paper introduces first step results of building 3D image reconstruction softwares, which are very necessary tools for medical image processing. [1, 4]

2. Fundamental Theory

An image may be considered to contain sub-images referred to as regions-of-interest. DICOM image reconstruction is a part

of a field called revelation. This concept reflects the fact that images frequently contain collections of objects each of which can be the basis for a region. In a sophisticated image processing system it should be possible to apply specific image processing operations to selected regions. Thus one part of an image (region) might be processed to suppress motion blur while another part might be processed to improve color rendition. It is the data presentation by pictures in order to help users to understand and manipulate data by a visually enhanced way [5]. Now a days, revelation especially with aids of computers has been applied in a lot of fields such as simulation, education, economy etc. This processing technique may be Image enhancement, Image restoration, and Image compression. [6, 7]

Image enhancement: It refers to sharpening, of image features such as edges, or contrast to make a graphic display more useful for display & analysis. This process does not increase the inherent information content in data. It includes gray level & contrast manipulation, noise reduction, edge crispening and sharpening, filtering, interpolation and magnification, pseudo coloring, and so on.

Image restoration: It is concerned with filtering the observed image to minimize the effect of degradations. Effectiveness of image restoration depends on the extent and accuracy of the knowledge of degradation process as well as on filter design. Image restoration differs from image enhancement in that the latter is concerned with more extraction of image features.

Image compression: It is concerned with minimizing the number of bits required to represent an image. Application of compression are in broadcast TV, remote sensing via satellite, military communication via aircraft, radar, teleconferencing, facsimile transmission, for educational & business documents, medical images that arise in computer tomography, magnetic resonance imaging and digital radiology, motion, pictures, satellite images etc.

2.1. DICOM Images and Reconstruction

All recent medical image reconstruction techniques create 3D images from sets of 2D slices, which can be recorded by various modalities such as CT, MRI, ultrasound etc. Each type of scanner has his own uniqueness due to substantial principles of image recording, e.g. images of CT scanner are

often parallel slices with high contrast, images of ultrasound scanner are either parallel or divergent slices with low contrast etc.[8,9] Thus there are different 3D reconstruction techniques for each type of data (fig. 1).

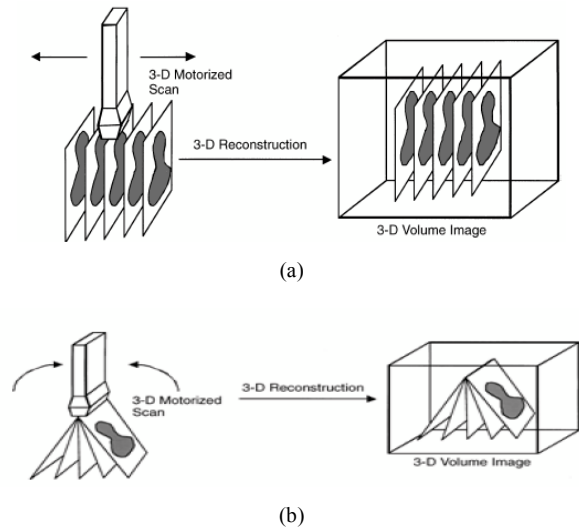


Fig. 1. (a)Parallel and (b)Divergent types of 2D slices

However, the general principle of 3D reconstruction is composed of following steps:

- Step 1: 2D data slices need to be read and set exactly with the real spatial positions, the result is a data volume. This data volume is saved in other memory of computer.
- Step 2: use rendering techniques to visualize data volume as 3D image. Usual rendering techniques for DICOM image are multiplanar rendering (MPR), surface rendering (SR) and volume rendering (VR).[9,10]

2.2. Rendering Techniques

2.2.1. MPR Technique

MPR does not require too many calculations, so it is suitable for low configuration computers. This technique can be used to reslice structure, i.e. with axial slices we can use MPR technique to reslice according to different directions such as coronal, sagittal or diverse fig1.1.

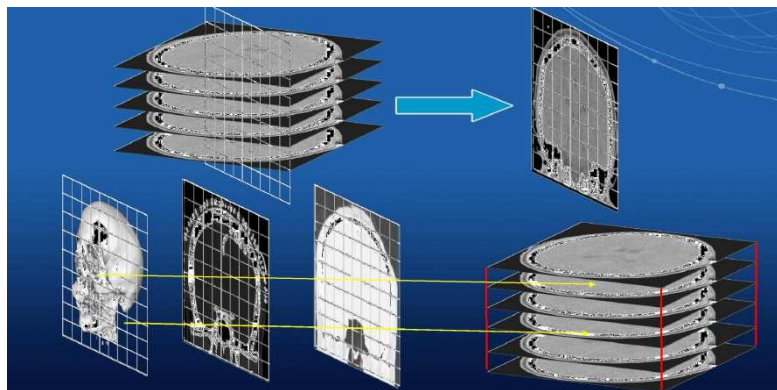


Fig. 1.1. MPR technique for reslicing.

2.2.2. SR Technique

SR technique visualizes a 3D object as a set of surfaces called iso-surfaces. Each surface contains points which have the same intensity (called iso-value) on all slices. This technique is used when we want to see the surfaces of a structure separately from near structure, e.g. skull from slices of head, blood vessel system from slices of body etc. SR technique is often used for high contrast data. Two main methods for reconstructing iso-surfaces can be well thought-out as follows:

- Contour based reconstruction: Iso-contours, which are extracted from each slice can be connected to create iso-surfaces.
- Voxel based reconstruction: Iso-surfaces are built directly from voxels having identical iso-value

2.2.3. VR Technique

VR method is used to visualize the total volume transparency of the object. Images will be performed by projecting rays through volume data. Along each ray, cloudiness and color need to be calculated at every voxel. Then information calculated along each ray will to be aggregated to a pixel on image plane. This technique helps us to see comprehensively an entire compact structure of the object. One of disadvantages of this technique is enormous amount of calculations, which requires strong configuration computers. This technique is appropriate for low contrast data.

Two main methods for rays projecting can be considered as follows:

- Object-order method: Projecting rays go through volume from back to front from volume to image plane.
- Image-order or ray-casting method: Projecting rays go through volume from front to back from image plane to volume. There exists some other methods to composite image, appropriate methods depending on the user's purposes. Some usual methods in medical image are MIP (maximum intensity projection), MinIP (minimum intensity projection), AC (alpha compositing) and NPVR (non-photorealistic volume rendering).

2.3. Reconstruction from a Set of Parallel Slices

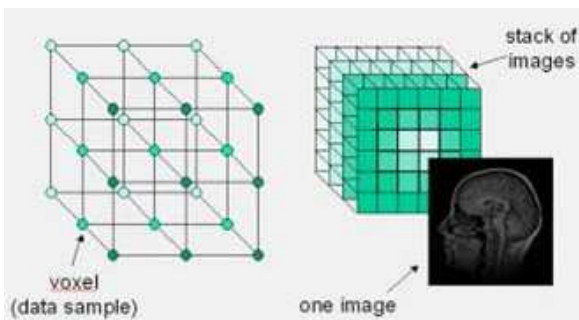


Fig. 2. Arrange slices to a volume data

Set of parallel slices can be recorded by CT scanners,

MRI scanners etc. In reality, the distance between 2 consecutive slices is about 0.5 to 2 mm. Reconstructing 3D image from CT data is easier than other types of data because of high contrast of CT images.[11]

Usual configuration can be considered is isometric volume data (fig. 2), in which the distance between two successive slices is equal to real distance. Value of each voxel is the value of the correlative pixel, which is often the gray level of pixel. After arranging of parallel slices, rendering techniques will be selectively use to perform the volume data.[12]

The following are the comparative data which can gain by spiral scanners of different brands shown in table1.

Table 1. Comparative of Measuring Parameters Of Different brands

Measuring Parameters	Toshiba	GE 750 HD	Philips ICT	Siemens Dual Source
Row Thickness	0.5	0.625	0.625	0.6
Detector Rows	320	64	128	64
Spatial Resolution	035	0.24mm	0.34	0.4mm
Detector coverage	160	44mm	80	38.4mm
Speed of Rotation	350	350 Ms	270 Ms	280Ms

3. Programming

Software for reconstructing DICOM image from a set of CT images was built by using matlab code & image processing tool. A DICOM image contains high frequency noises that cannot be removed easily by using any medical modelling software. Thus it is essential to filter/reconstruct image first though written matlab code & then further processed using Invesalious open source medical modelling software [13].

3.1. MATLAB Image Processing

An algorithm is an effective method for problem solving using a finite sequence of instructions. In computer science, algorithms process numbers using mathematical operations. In radiology too, algorithms process numbers representing tissue information and radiological density in the case of conventional MRI and CT and primarily generate images by mapping quantitative results as a gray-scale or color parameter. The creation of new and customized visual representations by applying mathematical algorithms using MATLAB to the original data is called a reconstruction technique. Many techniques have been developed to post-process CT volumetric data. The simplest techniques extract one single parameter of the volumetric data and produce two-dimensional (2D) reconstructions highlighting a desired structure. The most commonly used of these simple techniques are: the average projection, MIP, and Min IP . More advanced operations process volumetric data, creating an elaborate 3D model, which can be further manipulated for visualizing complex structures.[14,15]

3.2. Programming

3.2.1. Structure

CT slices of customized region in DICOM format are

initially pre processed using MATLAB programming. Fig. 3 illustrates the flowchart structure of the software for preparing 3D anatomical model.

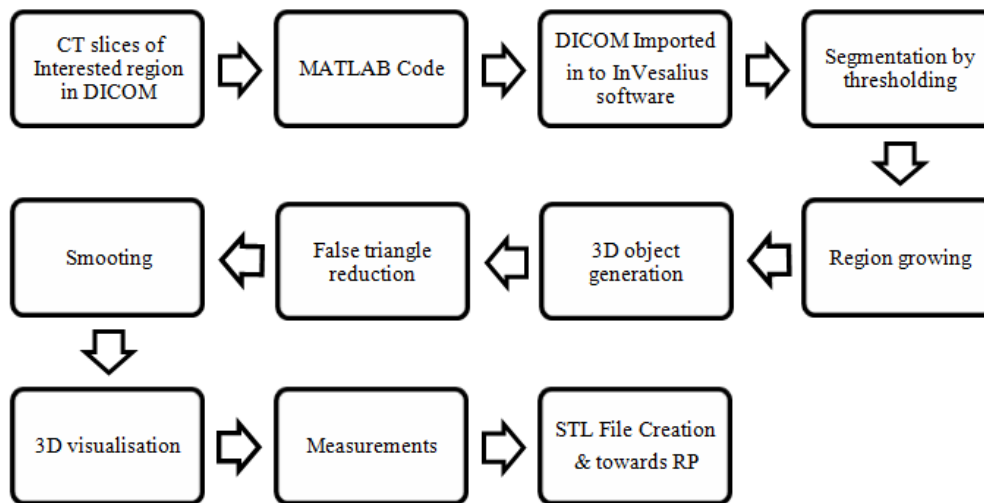


Fig. 3. Structure of software & Flow

3.2.2. Interface Design (fig. 4)

Invesalius generates 3D medical imaging reconstructions based on a series of 2D DICOM files acquired with CT or MRI equipments. The main user interface of the software is functionally similar to some professional medical image softwares. It contains a screen on the right to display

original and processing images. This screen can be displayed with different modes. General toolbars are placed on the top and control panel on the left. However, due to the main educational and training purpose of the software, it contains some more control components.[17]

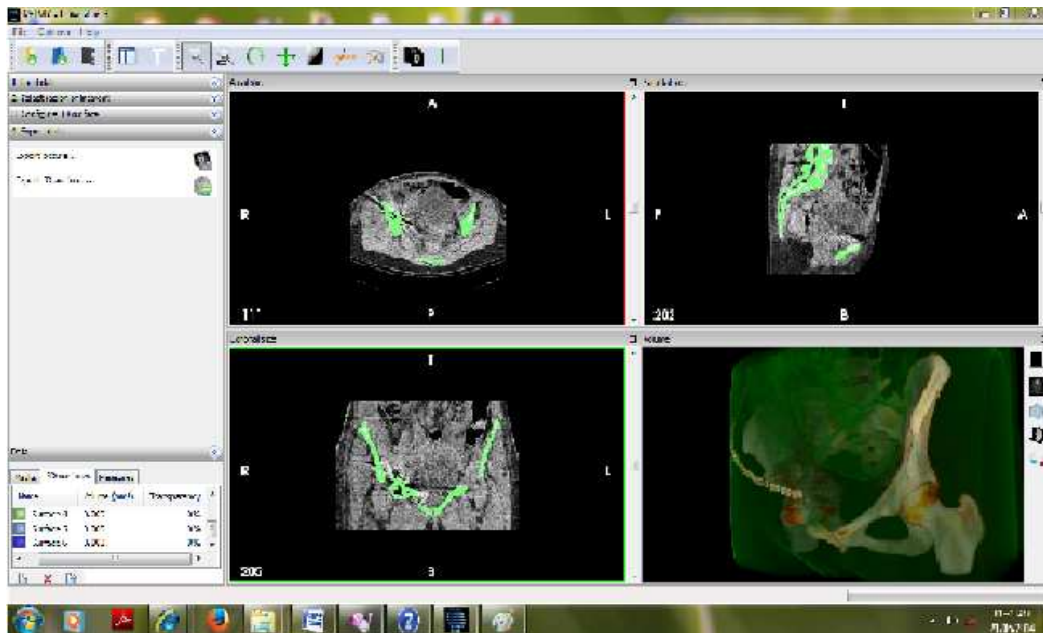


Fig. 4. Main screen of Invesalius V-3.0

3.2.3. Functions

Invesalius provides multi-platforms & performs main functions are as follows:

- Image manipulation facilities
- Segmentation based on 2D slices
- Pre-defined threshold ranges according to tissue of

interest

- Edition tools based on 2D slices
- 3D surface creation
- 3D surface connectivity tools
- 3D surface exportation
- High-quality volume rendering projection

- Pre-defined volume rendering presets
- Volume rendering crop plane
- Picture exportation

3.2.4. Problems

Program runs gradually with and there are not a lot of functions yet, e.g. no function for data pre-processing. Invesalius provides a semiautomatic image segmentation feature. This segmentation is done using the Hounsfield scale, a quantitative scale that describes radio density. The scale sets grayscale values according to the density of the region to be segmented, thus distinguishing air, fat, water, muscle, contrast and bone.[19,20] Many kinds of imperfections may be found on images before segmentation. Some cases are due to noise generated by metallic material (amalgam, titanium plates, shrapnel from firearm bullets etc.) found in the patient's body. In other cases, tomography equipment without proper calibration generates images in which hard tissue and soft tissue densities present approximately the same grayscale values, i.e., low contrast. This induces InVesalius semiautomatic segmentation to, for example; incorrectly segment some pieces of soft tissues when it should select only hard tissue (bone).[21,22]

4. Rapid Prototyping

Thus after completing all the reconstruction procedures the cad model of implant made ready & by converting it into stl file a solid model is manufactured. This model "in hand" is needed for easier collaboration between designer and surgeon. The implant model made by RP technology based on sectional medical images is helpful for researchers to know about configuration, position and anatomical structure of surgical location, to measure geometric parameters of bones[23]. RP operates on the principle of depositing material in layers or slices to build up a model, rather than forming a model from a solid block. The space between the layers is typically 0.05 to 0.10 mm. The smaller the space, the more accurate the product and more time for fabrication. Stereolithography apparatus (SLA), laminated object manufacturing (LOM) and fused deposition modeling (FDM) are typical RP systems [24]. This method greatly shortens the design cycle and the time span from sectional image files to a final exact-fit implant product to within a few days.

5. Conclusion

The project of designing medical modelling i.e. customized medical implants has been developed in order to provide master biomedical image processing technology and to develop compatible products to some extent taken place of standard imported products. This paper introduces first step results of partially mentioned project & implementing essential problems in 3D medical image reconstruction for medical imaging such as DICOM reconstruction, algorithms, rendering technique, etc. And designing a new code for reconstructing 3D image from a set of CT images. The high

frequency noises from series of DICOM images has been successfully removed & by using Invesalius software a customized medical model has been developed & made ready for manufacturing by rapid prototyping.

References

- [1] Pianykh O.S.: Digital Imaging and Communications in Medicine (DICOM). Springer-Verlag Berlin Heidelberg New York, 2012.
- [2] William J. Schroeder, Kenneth M. Martin, William E. Lorensen. (2002) The Design and implementation Of An Object-Oriented Toolkit For 3D Graphics And Visualization
- [3] Yoo T. S.: Insight Into Images: Principles and Practice for Segmentation, Registration, and Image Analysis. A K Peters, Wellesley, Massachusetts, 2004.
- [4] Cerini R, Faccioli N, Barillari M, De Iorio M, Carner M, Colletti V. Bionic ear imaging. *Radiol Med*. 2005;113:265–77.
- [5] Rao ND, Gulati MS, Paul SB, Pande GK, Sahni P, Chattopadhyay TK. Three-dimensional helical computed tomography cholangiography with minimum intensity projection in gallbladder carcinoma patients with obstructive jaundice: comparison with magnetic resonance cholangiography and percutaneous transhepatic cholangiography. *J Gastroenterol Hepatol*. 2005;20:304–8.
- [6] Peloschek P, Sailer J, Weber M, Herold CJ, Prokop M, Schaefer-Prokop C. Pulmonary nodules: sensitivity of maximum intensity projection versus that of volume rendering of 3D multidetector CT data. *Radiology*. 2007;243:561–9.
- [7] Salvolini L, Bichi Secchi E, Costarelli L, De Nicola M. Clinical applications of 2D and 3D CT imaging of the airways: a review. *Eur J Radiol*. 2000;34:9–25.
- [8] Fox LA, Vannier MW, West OC, Wilson AJ, Baran GA, Pilgram TK. Diagnostic performance of CT, MPR and 3DCT imaging in maxillofacial trauma. *Comput Med Imaging Graph*. 1995;19:385–95.
- [9] Nghiem HV, Dimas CT, McVicar JP, Perkins JD, Luna JA, Winter TC, 3rd, et al. Impact of double helical CT and three-dimensional CT arteriography on surgical planning for hepatic transplantation. *Abdom Imaging*. 1999;24:278–84.
- [10] Fotheringham T, Chabat F, Hansell DM, Wells AU, Desai SR, Gückel C, et al. A comparison of methods for enhancing the detection of areas of decreased attenuation on CT caused by airways disease. *J Comput Assist Tomogr*. 1999;23:385–9.
- [11] G.Scott Owen, HyperVis. ACM SIGGRAPH Education Committee, the National Science Foundation (DUE-9752398), and the Hypermedia and Visualization Laboratory, Georgia State University.
- [12] Jolesz FA, Lorensen WE, Shinmoto H, Atsumi H, Nakajima S, Kavanaugh P, et al. Interactive virtual endoscopy. *AJR Am J Roentgenol*. 1997;169:1229–35.
- [13] Sajjad Z, Oxtoby J, West D, Deakin M. Biliary imaging by spiral CT cholangiography: a retrospective analysis. *Br J Radiol*. 1999;72:149–52.
- [14] Sun Z. 3D multislice CT angiography in post-aortic stent grafting: a pictorial essay. *Korean J Radiol*. 2006;7:205–11.

- [15] Nino-Murcia M, Jeffrey RB, Jr, Beaulieu CF, Li KC, Rubin GD. Multidetector CT of the pancreas and bile duct system: value of curved planar reformations. *AJR Am J Roentgenol*. 2001;176:689–93.
- [16] Abildgaard A, Karlsen JS, Heiberg L, Bosse G, Hol PK. Improved visualization of artificial pulmonary nodules with a new subvolume rendering technique. *Acta Radiol*. 2008;49:761–8.
- [17] Diederich S, Lentschig MG, Overbeck TR, Wormanns D, Heindel W. Detection of pulmonary nodules at spiral CT: comparison of maximum intensity projection sliding slabs and single-image reporting. *Eur Radiol*. 2001;11:1345–50.
- [18] Lee DH, Ko YT. The role of three-dimensional and axial imaging in advanced gastric carcinoma by spiral CT. *Abdom Imaging*. 1999;24:111–6.
- [19] Pretorius ES, Fishman EK. Spiral CT and three-dimensional CT of musculoskeletal pathology. *Radiol Clin North Am*. 1999;37:953–74.
- [20] Calhoun PS, Kuszyk BS, Heath DG, Carley JC, Fishman EK. Three-dimensional volume rendering of spiral CT data: theory and method. *Radiographics*. 1999;19:745–64.
- [21] Li AE, Fishman EK. Cervical spine trauma: evaluation by multidetector CT and three-dimensional volume rendering. *Emerg Radiol*. 2003;10:34–9.
- [22] Kinami S, Yao T, Kurachi M, Ishizaki Y. Clinical evaluation of 3D-CT cholangiography for preoperative examination in laparoscopic cholecystectomy. *J Gastroenterol*. 1999;34:111–8.
- [23] Galantucci LM, Percoco G, Angelelli G, Lopez C, Introna F, Liuzzi C, De Donno A (2006) Reverse engineering techniques applied to a human skull, for CAD 3D reconstruction and physical replication by rapid prototyping. *J Med Eng Technol* 30(2):102–111.
- [24] Webb PA (2000) A review of rapid prototyping (RP) techniques in the medical and biomedical sector. *J Med Eng Technol* 24(4):149–153.