Threshold Determination in Multislice CT-Scan using Improved Marching Cube Algorithm (IMCA) for 3D Image Reconstruction Process (3D-IRP)

I L I Purnama¹², A E Tontowi¹, and Herianto¹

¹Mechanical and Industrial Engineering Department, Gadjah Mada University, Yogyakarta, Indonesia
²Industrial Engineering Faculty, Atma Jaya Yogyakarta University, Yogyakarta, Indonesia
luddy.indra@uajy.ac.id, alvaedytontowi@ugm.ac.id, herianto@ugm.ac.id

Abstract. Medical diagnostic information has been a change in clinical medicine development, including medical image and computer technology. The paper aims to determine the threshold for the 3D-IRP with a multislice Computerized Tomography Scan (CT-Scan). The 3D-IRP method is the IMCA technique. Skull and Sternum are the focus of the 3D medical image. It is in the multislice CT-Scan format of Digital Imaging and Communications in Medicine (DICOM). Surface volume and area, and visual shape are performance criteria of the 3D-IRP are matching with a software package (InVesalius ver. 3.1). The optimum threshold for the 3D bone representation of objects is 210. The difference in 3D image surface area and volume between the prototype's performance and the software package is smaller than 0.50%. Based on the three radiologists, the Skull and Sternum's visual shape is roughly 100% balanced.

1. Introduction
Medical diagnostic information has been a change in clinical medicine development, including medical image and computer technology. A doctor can quickly obtain the 3D model of their patient by the CT-Scan. However, the 3D image can only display certain layer information with the user interface in the stand-alone computer system [1,2]. The first step is to develop a 3D medical model with a 3D printer in a cloud system is to reconstruct a 3D medical image [3]. The input of the 3D-IRP is the 3D image with a DICOM format. The result is the object surface area.

The Bone 3D-IRP of an object is the first step in biomechanics for a model. The following stand-alone software (using user interface) and tools standard used in 3D-IRP are InVesalius, 3D Slicer, and Itk-SNAP. With InVesalius, the initial anatomical structural bone threshold value is always 226. Adjust the image manually using erasing tools [4].

This paper presents to determine the threshold in multislice CT-Scan using the Improved Marching Cube Algorithm (IMCA), aiming to find the best 3D-IRC with performance criteria such as surface volume and area, and visual shape that matches with a software package (InVesalius version 3.1) [5,6,7]. 3D-IRP can produce Stereolithography (STL) file. A 3D printer with an STL file can be used to renovate and replace customized medical equipment and implants as well as to create models for clinical and teaching education, medical training and visualization, clinical research, and pre-operative planning. [8,9]

2. Literature Review
Multislice CT-Scan using on A third-generation platform. The critical distinction between a single and multi-slice CT-Scan is the detector array size. The main detector element within Z-direction in the
multi-part CT-Scan is split into lesser detector elements. In one of the first modern multislice CT-Scan, a detector configuration consists of 16 rows of detector elements [10].

One technique in 3D-IRP is the IMCA. The IMCA is more efficient than other techniques and produces better results during reconstruction [7]. 3D-IRP can be using 3D Geometric Moment [11,12,13,14], Transformation [15,16,17], and Curve [18].

Hounsfield Units (HU) is a CT-Scan scale, describing the average radiodensity of the tissue in a three-dimensional pixel (voxel) quantitatively. A single HU value corresponds to the mean attenuation of several x-ray projections approaching the same point from different angles in a matrix. The HU scale reflects the linear transformation of the uniform average water- and air-distilled attenuation coefficient at the Standard Temperature and Pressure (STP). The water radiodensity value is 0 while at air -1000 HU. The bone HU scale is between +700 to +3000).

3. Methods
The 3D-IRP algorithm is the following steps:

- Step 1: Reading the DICOM file;
- Step 2: Translating the 3D image into the HU scale. We can classify the quality of the 3D medical image with the HU scale;
- Step 3: 3D-IRP uses the IMCA technique;
- Step 4: Plotting of the 3D model;
- Step 5: Presenting an interactive 3D model in the display;

This prototype software uses Phyton version 3 for language programming. The operating system of prototype software is Linux (Ubuntu 18.4). The specification of the computer must use Graphis Processing Unit (GPU) with memory 11-gigabyte. Observational samples are Skull and Sternum, both from the DICOM library website.

The IMCA technique proceeds through the following steps: [7]

- Step 1: Loading the memory of the slices;
- Step 2: Iterating among two primary slices, and producing a rational cube from the eight surrounding voxels;
- Step 3: Evaluate the scalar field gradient by the finite-difference technique on the eight voxels;
- Step 4: Evaluate of the binary index of a cube by evaluating the voxel output with the isovalue;
- Step 5: Get the form of triangulation from the lookup table;
- Step 6: Computing of the position of the triangle vertex by linear interpolation;
- Step 7: Computing the gradient of the scalar field of triangle vertexes by linear interpolation, and
- Step 8: Place the coordinates of the triangle pole and the gradient components.

4. Results
The observational samples can be seen in Table 1. The observational samples have a slice thickness of 1 mm.

| Table 1. The Observational Samples |
|-----------------------------------|
| Object   | Amount Slice | Dimension Size (mm) |
|---------|--------------|---------------------|
| Skull   | 161          | 512 x 512           |
| Sternum | 162          | 512 x 512           |

To validate the 3D-IRP output, we consult with three radiology doctors. The 3D-IRP performance is a visual process from the software package and the prototype software. Skull examination focuses on temporal, sphenoid, maxilla, zygoma, and mandible. Through an examination of the sternum focuses on clavicles, scapula, acromion, capsule, and humerus.

Figures 1 and 2 show the Skull and Sternum HU scale histogram, respectively. The histogram bins size is 50. The histogram suggests not bone only, but there is a lot of air, some lung, and soft tissue. On the Skull, there are HU Scale at -3000, and there must be some artifact at the Skull.
Table 2 displays the Skull and the Sternum 3D-IRP performance with the surface volume and area criteria. From table 3, The difference in 3D image surface area and volume between the prototype's performance and the software package is smaller than 0.50%.

| Criteria | Skull     | Sternum   |
|----------|-----------|-----------|
|          | Package   | Prototype | Package   | Prototype   |
| Volume (mm$^3$) | 794,828.604 | 794,823.615 | 624,322.228 | 624,315.275   |
| Area (mm$^2$)  | 372,742.669 | 372,724.975 | 399,676,323  | 399,657,233  |

Figures 3 and 4 show the Skull and Sternum 3D-IRP from the software package and the prototype. The level of visual form matching for Skull and Sternum is 100%. In 3D-IRP the threshold for all samples is 210.
5. Conclusion
The medical 3D-IRP threshold for the prototype is 210. The performance of the prototype program is running well. Input is a DICOM file from multislice CT-Scan. The difference in 3D image surface area and volume between the prototype's performance and the software package is smaller than 0.50%. The visual shape of the Skull and Sternum is roughly 100 percent balanced based on evidence from three radiology doctors.

Refer to industry 4.0 development, future work will focus on developing 3D printing from the DICOM file. The 3D printing process is based on the cloud-system.

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References
[1] Hui D, Ling X, Jin Z and AnDong C 2013 Medical Image Reconstruction Based on ITK and VTK International Conference on Computer Sciences and Applications (IEEE) 642–645
[2] Senthil T K and Anupa V 2012 3D Reconstruction of Face from 2D CT Scan Images Procedia Engineering 30(2011) 970–977
[3] Ignatus L I P, Alva E T, Bertha M S and Herianto 2018 Development of Medical Props Production Towards Industry 4.0 International Conference on Bioinformatics, Biototechnology, and Biomedical Engineering - Bioinformatics and Biomedical Engineering (IEEE) 1–5
[4] Katsiaryna M, Claudio B, Alberto L and Stefano D Quantitative Comparison of Freeware Software for Bone Mesh from DICOM Files Journal of Biomechancianics 84 247–251
[5] Jack S, Bartos C, Robert S, Zuzana K and Anna Z 2015 Conformance Criteria for Validation of Target Volume Surface Reconstructed from Delineation Applied Mathematics and Computation 267 456–464
[6] Maureen van E, Juha K, Kalle K, Tymour F and Jan W 2017 The Impact of Manual Threshold Selection in Medical Additive Manufacturing International Journal of Computer Assisted Radiology and Surgery 12(4) 607–615
[7] Giovanni L M, Bruno G and Oliva P 2013 An Improved Marching Cube Algorithm for 3D Data Segmentation Computer Physics Communications 184(3) 777–782
[8] Andrew S 2018 3D Printing and Medical Imaging Journal of Medical Radiation Science 65(3) 171–172
[9] Jordi M, Maureen van E, Wouter K, Faruk D, Adrienne M and Jonathan W 2018 CT Image Segmentation of Bone for Medical Additive Manufacturing Using a Convolutional Neural Network Computer in Biology and Medicine 103 130–139
[10] Lee W G 2008 Principles of CT: Multislice CT Journal of Nuclear Medicine Technology 36(2) 57–68
[11] Patrice K 2012 Fast Recursive Computation of 3D Geometric Moments from Surface Meshes IEEE Transactions on Pattern Analysis and Machine Intelligence 34(11) 2158–2163
[12] Prashant P, Pierre G, Antony J H and Rafeer A 2018 Fast and Automatic Bone Segmentation and Registration of 3D Ultrasound to CT for The Full Pelvic Anatomy: A Comparative Study International Journal of Computer Assisted Radiology and Surgery 13(10) 1515–1524
[13] Waseem G S and Andrew W 2018 Bone Fragment Segmentation from 3D CT Imagery Computerized Medical Imaging and Graphics 66 14–27
[14] Brent F, Anand A J, Marissa B, Yasser A, Robert D B and Abhijit J C 2018 WRIST: A WRist Image Segmentation Toolkit for Carpal Bone Delineation from MRI Computerized Medical Imaging and Graphics 63 31–40
[15] Chengwen C, Cheng C, Li L and Guoyan Z 2015 FACTS: Fully Automatic CT Segmentation of a Hip Joint Annals of Biomedical Engineering 43(5) 1247–1259
[16] Tadaki N, Hiromitsu D, Yasushi Y, Takashi I, Kazuyuki M, Tomoya O, Yoshiki O, Nobuhiro Y, Koichi S, Ryotaro T and Masahiro J 2017 Use of A Digital Phantom Developed by QIBA for Harmonizing SUVs Obtained from The State-of-The-Art SPECT/CT Systems: A Multicenter Study *EJNMMI Research* 7(1) 53-62

[17] Pat B, Mengqi H, Rahul K and Srinivasan K 2017 A Semi-automated Approach to Improve the Efficiency of Medical Imaging Segmentation for Haptic Rendering *Journal of Digital Imaging* 30(4) 519–527

[18] Abdul M, Abd R M P, Muhammad R, Johari Y A and Zainul A R 2017 NURBS Curves with The Application of Multiple Bones Fracture Reconstruction *Applied Mathematics and Computation* 315 70–84