3D Mass Visualization of Thyroid CT Images thru Marching Cubes Method

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Abstract: Thyroid cancer is the type of cancer caused by the cells of the thyroid gland. This is less common than other types of cancer. If the correct diagnosis is made and appropriate treatment is given, the disease can be completely removed.

Herein, we present an algorithm to 3D visualize thyroid cancer using 2D Dicom images. As is known, Dicom is the de-facto file standard in medical imaging, and these files contain useful metadata as well. We use some of these meta-attributes to calculate the Hounsfield Unit. In other words, the pixel values are calculated according to the average attenuation of the tissue corresponding to a scale of -1024 to + 3071 on the Hounsfield scale. Dicom images used in the study were obtained from patients under the supervision of specialist doctors. Thyroid cancer tumors were modelled in 3D using the pixel values thru Marching Cubes Algorithm.

Keywords: Computed Tomography (CT), Marching Cubes Algorithms, Hounsfield Unit (HU)

Marching Küpleri Yöntemi ile Tiroid CT Görüntülerinin 3D Kitle Görselleştirilmesi

Özet: Tiroid kanseri, tiroid bezinin hücrelerinin neden olduğu kanser türüdür. Bu diğer kanser türlerinden daha az görülür. Doğru tanı konulur ve uygun tedavi verilirse hastalık tamamen kaldırılabilir.

Bu çalışmada, 2D dicom görüntüleri kullanarak tiroid kanserini 3D'ye görselleştirmek için bir algoritma sunuyoruz. Bilindiği gibi, Dicom tıbbi görüntülemede kullanılan başlıca dosya standardıdır ve bu dosyalar da yararlı meta veriler içerir. Hounsfield Birimini hesaplamak için bu meta özelliklerin bazılarını kullanırız. Başka bir deyişle, piksel değerleri, Hounsfield ölçeğinde -1024 ila + 3071 arasındaki bir ölçeğe karşılık gelen dokunun ortalama zayıflamasına göre hesaplanır. Çalışmada kullanılan dicom görüntüleri uzman doktorların gözetiminde hastalardan elde edildi. Tiroid kanseri tümörleri, Marching Cubes Algoritması ile piksel değerlerini kullanarak 3D olarak modellenmiştir.

Anahtar Kelimeler: Computed Tomography (CT), Marching Cubes Algorithms, Hounsfield Unit (HU)

1.Introduction

Thyroid cancer is the type of cancer caused by the cells of the thyroid gland. Thyroid cancer is relatively uncommon compared to other type of cancers. It affects 35-40% of Turkish society and occurs especially in women. Thyroid cancer after breast cancer in women in Turkey into second place. If the correct diagnosis is made and appropriate treatment is given, the disease can be completely removed [1].

On the other hand, Computed Tomography (CT) is a special x-ray technique that displays the body in cross-sections with the aid of X-rays. As in the X-ray examination, calcified or bony structures (eg skeleton) appear white on CT images, soft tissues (eg heart) gray, and air tissues (eg, lung and intestine) appear black.. CT scanning is often the best method for detecting many different cancers since the images allow your doctor to confirm the presence of a tumor and determine its size and location [2].

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3D visualization has been implemented in many problem areas and has therefore become an important tool for exploring data and discovering information. Volumetric data can be defined as a collection of 3D points $P_i=(x_i,y_i,z_i)$ [3].

In this paper, we present an algorithm to 3D visualize thyroid cancer using 2D dicom images. We employed the Marching Cubes Method for generating 3D structures. We extensively use Hounsfield Units values throughout the algorithm to isolate all bone structures and water structures so that we create a 3D mesh of those structures thru the Marching Cubes.

The rest of the paper is organized as follows. In section II we recall Marching Cubes Method. Then, in section III, we describe Hounsfield Unit and give Hounsfield scale for the quantitative measure of radiodensity. Finally, we present experimental results in section IV.

2.Marching Cubes Method

The Marching Cubes (MC) Method by William Lorensen and Harvey Cline is commonly used algorithm for extraction of isosurface out of volumetric data. It uses a divide and conquer approach in which volume data is processed through voxels. The algorithm creates a triangular mesh by calculating isosurfaces from separate data. By drawing all these triangles, we can build a 3D visualization of the CT-Scans [4].

Multiple image slices for processing are arranged as a multidimensional array. And two adjacent slices are taken into account at a time as shown in Figure 1.
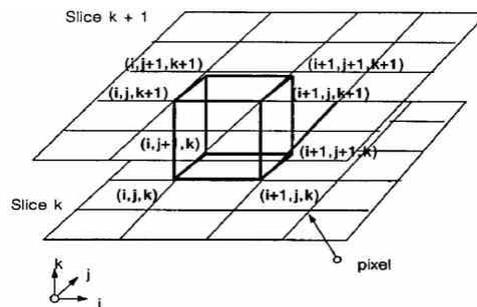

Figure 1: Cube formed on grid [5]

The Marching Cube Algorithm consist of two main sections. The first part is to find out how to define the surface sections that cut the individual cube. If we classify each corner above or below the equivalent value, the total corner classifications have a total of 256 possible configurations. In these 256 feasible configurations, two of them are unimportant. For the remainder of the configurations, we must decide whether the isosurface has passed along each edge of the cubes, and we must use these margins to create one or more triangular patches for isosurface. When the value of the vertex is greater than or equal to isovalue it is internal, and when it is less than isovalue it is external [4].We assigned 0 to vertex outside the surface and appoint 1 to vertex inside the surface in Figure 2.
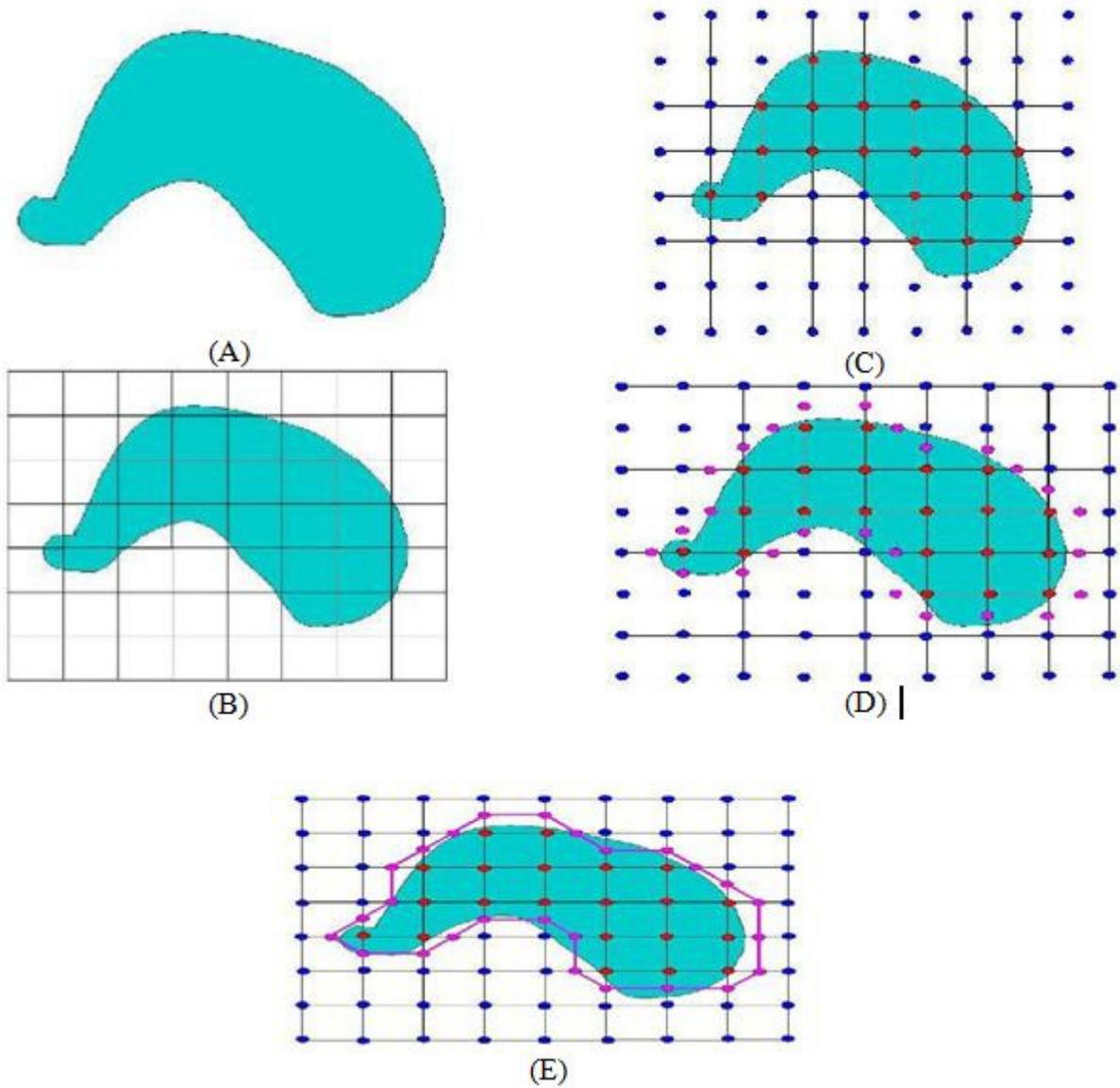
Figure. 2: Pre-Processing (A) Image (B) Segmented Image (C) Intersected Point (D) Offset Points (E) Join all Offset points [6].

When symmetries cases are considered in Figure 4, there are only 14 unique configurations in the remainder of the 254 configurations indeed in Figure 3.
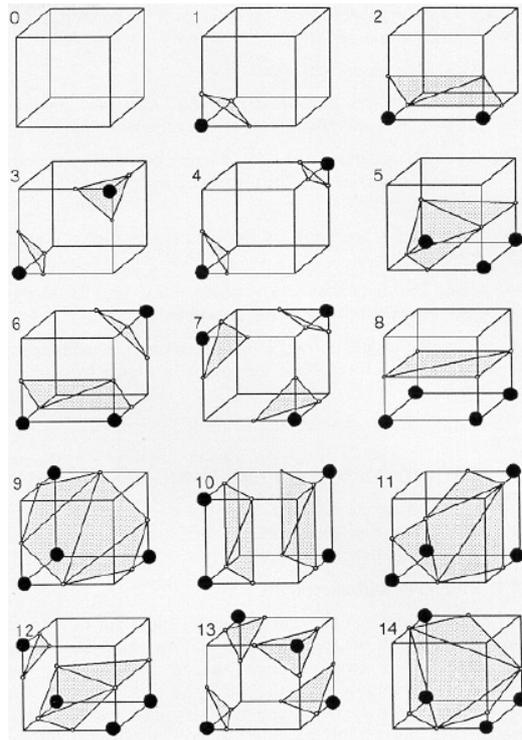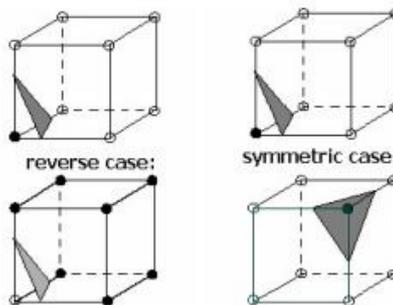
Figure 3: Unique configurations

Figure 4:Symmetry cases

If only one corner is less than the equivalent, it forms a single triangle that intersects the edges that meet in this corner. There are 8 equal configurations belongs to this situation in Figure5. [4].
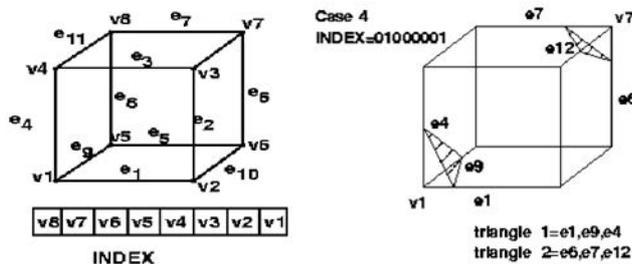

Figure 5: Triangulation

The second section in Marching Cubes Method is to calculate a unit normal for each triangle vertex. It is used to create Gouraud-shaded images in the rendering algorithms. [4].

To calculate surface normal, we need to determine gradient vector g. The gradient at cube vertex (a ,b, c), is estimated using central differences along the three coordinate axes by:

$$\text{Gradient}_x(a,b,c)=\text{Density}(a+1,b,c)-\text{Density}(a-1,b,c) / \Delta x \qquad (2.1)$$
$$\text{Gradient}_y(a,b,c)=\text{Density}(a,b+1,c)-\text{Density}(a,b-1,c) / \Delta y \qquad (2.2)$$
$$\text{Gradient}_z(a,b,c)=\text{Density}(a,b,c+1)-\text{Density}(a,b,c-1) / \Delta z \qquad (2.3)$$

In Equation (2.1), (2.2), (2.3), Density (a, b, c) is the density at pixel (a, b) in slice k. Δx, Δy, Δz are lengths of the cube edges [5]

3.Hounsfield Unit

The pixel value in a Computed Tomography image gives us a direct way to roughly identify the type of tissue to which each pixel belongs. Thus, we can simply flatten out the image from the image by matching the image with known intervals. So we calculated the Hounsfield Unit. [7].

The Hounsfield unit is a numerical measure of radiodensity. Pixels in an image acquired by Computed Tomography are indicated radiodensity. The value of pixel is showed on the Hounsfield scale based on the average attenuation of the corresponding tissue from -1024 to 3000. [7].

We converted raw pixel data to HU. Herewith, CT's DICOM images usually contain two most commonly called metadata. These are RescaleSlope and RescaleIntercept. The formula for calculating HU from the raw pixel value is given below [7]:

$$\text{HU} = \text{PixelValue} * \text{RescaleSlope} + \text{RescaleIntercept} \qquad (3.1)$$

The materials corresponding to the Hounsfeld value are shown in Table 1 [8].

Table 1: Hounsfiel Unit-Material [8]

Material	Hounsfield Unit
Air	-1000
Water	0
Blood	25
Muscle	25 to 40
Bone	200 to 1000

4.Experimental Results

Thyroid dicom images were taken from a local hospital. The properties of the images used in the study are given in Table 2. This means we have 3,27 mm slices, and each voxel represents 1,36 mm. A CT slice is typically reconstructed at 512 x 512 voxels, each slice represents approximately 700 mm of data in length and width.

We implement the algorithm in Python programming language and open source scientific libraries such that Pydicom, Matplotib, Scikit-Learn.

Table 2:Properties of images

Properties	Value
Slice Thickness (mm)	3,27
Pixel Spacing (row, col) (mm)	1.367188, 1.367188
Number of Slices	247
Dimensions	512x512

Using DICOM's metadata, we can find the size of each voxel as the slice thickness. That's why we have resampled each slice into 1x1x1 mm pixels and slices to view the CT in 3D isometric form and to compare different scans. After sampling, new dimensions are 808x700x700. CT images are shown in Figure 6 by skipping every 10 slices to get an overview of the work.
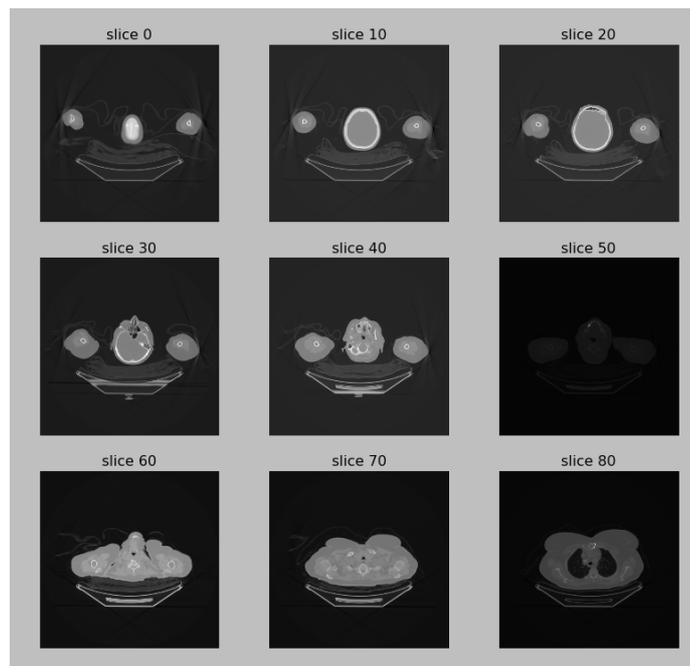

Figure 6:Slices

The histogram of all voxel data is shown in Figure 7. According to the histogram Mostly there is plenty of soft tissue a little fat
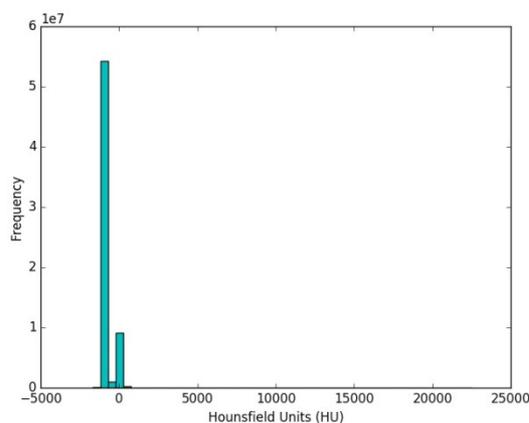

Figure 7: The histogram of all voxel data

Thyroid CT dicom images thresholded it to values over 350 HU In this way, all bone structures were isolated and then We created a 3D mesh of bone structures using Marching Cubes

Algorithm In Figure 8a, bone structures are shown. Dicom images thresholded it to values over 0 HU. All tumor structures were isolated and then We created a 3D mesh of tumor. In Figure 8b, tumor structures are shown.
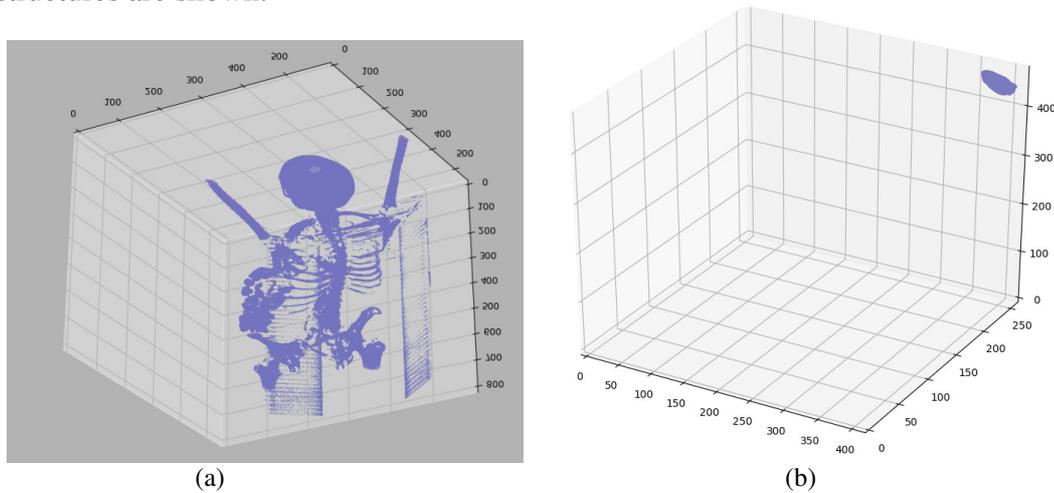

<div align="center">(a)   (b)</div>

<div align="center">Figure 8: Tumor (a) and Bone (b) Structures</div>

Calculated verts matrix is [[361. 252. 453.][362. 252. 452.][362. 251. 453.],[411. 254. 443.][411. 254. 444.][411. 254. 445.]] Calculated faces matrix is [[2   1   0][4   3   0][0   3   2],[4494 4508 4495][4495 4508 4509][4495 4509 4491]]

This application is also used practically in the evaluation of tumors. A tumor is benign if the HU value is less than 10 [9]. As a result, the tumor volume is calculated. According to the results obtained, the tumor is benign.

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