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AN ALGORITHM TO BIOLOGICAL TISSUES EVALUATION IN PEDIATRIC EXAMINATIONS

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ABSTRACT

A prerequisite for the construction of phantoms is the quantification of the average thickness of biological tissues and the equivalence of these simulators in simulator material thicknesses. This study aim to develop an algorithm to classify and quantify tissues, based on normal distribution of CT numbers of anatomical structures found in the mean free path of the X-rays beam, using the examination histogram to carry out this evaluation. We have considered an algorithm for the determination of the equivalent biological tissues thickness from histograms. This algorithm classifies different biological tissues from tomographic exams in DICOM format and calculates the average thickness of these tissues. The founded results had revealed coherent with literature, presenting discrepancies of up to 21,6%, relative to bone tissue, analyzed for anthropomorphic phantom (RANDO). These results allow using this methodology in livings tissues, for the construction of thorax homogeneous phantoms, of just born and suckling patients, who will be used later in the optimization process of pediatrics radiographic images.

Key Words: Biological tissues, Simulator materials, Pediatrics, Classification, Quantification

1. INTRODUCTION

For over sixty years, various simulations materials of biological tissues have been used for the construction of phantoms [1]. Phantoms are structures made of materials that have characteristics of absorption and scattering of radiation in a similar manner to biological tissues [2]. The phantoms have been used in radiotherapy and diagnostic radiology for investigation of the radiation dosimetric effects in irradiated tissues and surrounding tissues [3] as well as for radiographic image optimization of chest, skull in profile typical for adult patients and patients with different thicknesses [2, 4].

A prerequisite for the construction of phantoms is the quantification of the average thickness of biological tissues present in the mean free path of the X-rays beam and the equivalence of these

in simulator materials thicknesses. Literature presents works in which were used algorithms for automatic segmentation of biological tissues from CT images [5, 6]. These algorithms are called classifiers and working with tissues segmentation of pixels in the image through the texture of them. [6]. For the most of these algorithms, the aim is differentiate a CT image in some organs or tissues such as aorta, fat, kidney, liver, lung, muscle, spleen and trabecular bone [7].

Some studies show the differentiation of tissues from algorithms that can create masks through optical density in CT images. Still others worked with algorithms able to create gray-scale histograms for each type of tissue from different values of optical density as well as tridimensional information (3-D) of a given pixels neighborhood in the image [8]. The different types of organs or tissues classified by these algorithms are: lung, atria, blood, fat, hone, muscle, skin, kidney, air, liver, spleen, esophagus, soft tissue, left ventricle, right ventricle, cerebrospinal fluid, stomach, pancreas, gut, internal air, great vessels, connective tissue, papillary, intestinal fluid, and soft bone [8].

Work on quantifying the average thickness of biological tissues, has been made from CT images with the aid of grids containing of 1.0 cm^2 cells. In these systems, the tissues distinction is made from the optical densities of the different tissue types in each cell and the quantification as the average length of a cell line containing the same type of tissue one of the Cartesian axis (x, y) [4].

The literature has mostly methodologies for segmentation of tissues in adult patients, there is a gap for the segmentation and quantification of children biological tissues.

Thus, this study aim to develop an algorithm to classify and quantify tissue, based on normal distribution of CT numbers of anatomical structures found in the mean free path of the X-rays beam, using the examination histogram of CT scan examinations to carry out this evaluation, and convert the found thicknesses in thicknesses of simulator materials. This study is necessary as a preliminary measure for the construction of pediatric chest phantoms for newborns and infants, to be used in the Pediatric Imaging optimization process in future work.

2. MATERIAL AND METHODS

We developed a computational algorithm, able to read each axial CT image in DICOM format (Digital Imaging and Communication in Medicine) and make the distinction and quantification of biological tissues present in the mean free path of the beam of X-rays.

In this procedure we estimated the average thickness of biological tissue in a pediatric patient chest for the age group under study. Then, these thicknesses were converted into simulators materials for the construction of pediatric phantoms. The validation of the algorithm developed in this study was conducted in images of standard adult patient [9].

The tasks performed by this algorithm are presented on a flowchart in Figure 1.

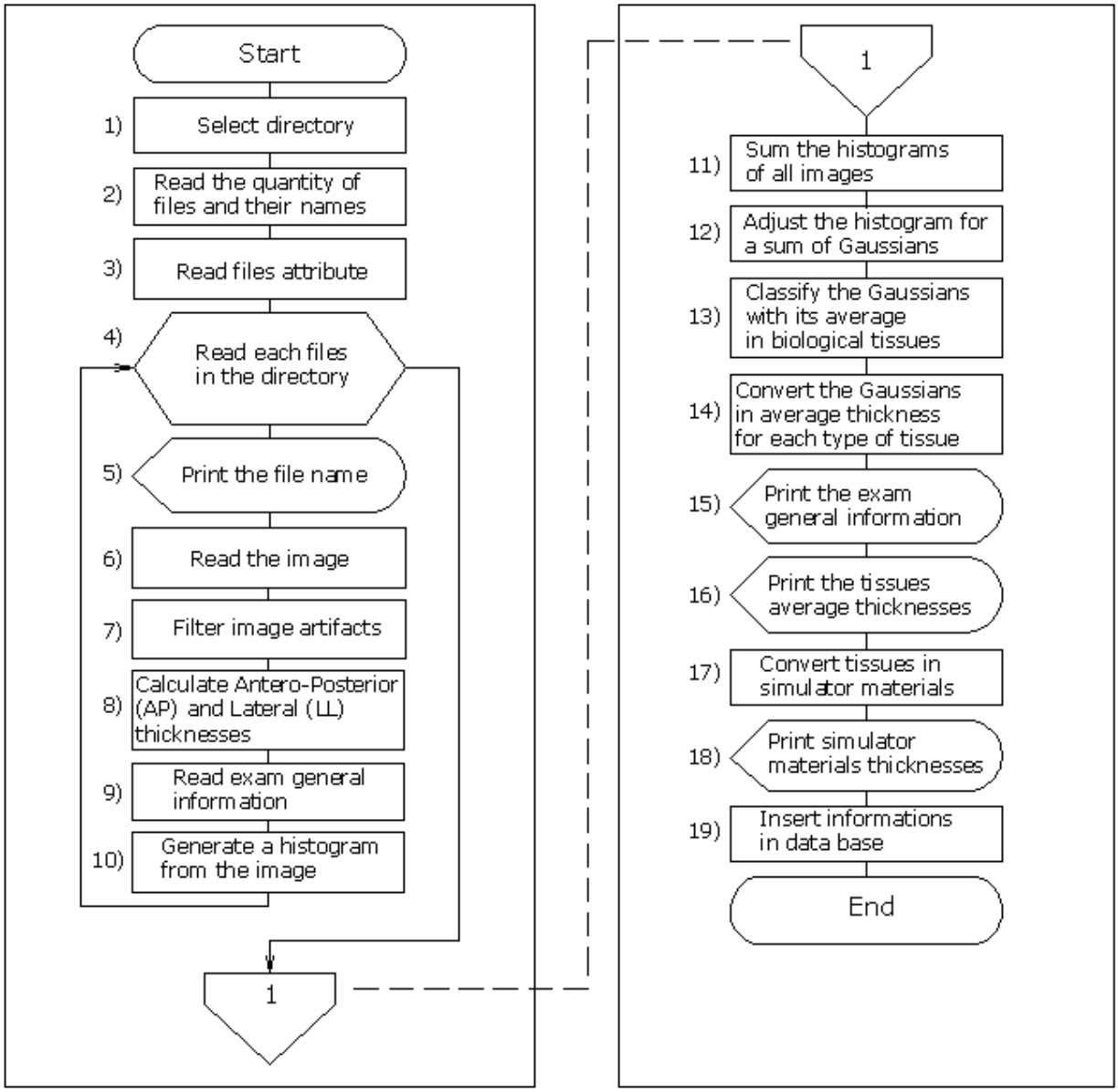

Figure 1: Flowchart of the algorithm that converts biological tissue thickness in simulator materials by histogram analysis

Biological tissues were classified using histograms, which show the number of pixels by the CT number (Computed Tomography - the tomographic image gray scale measured in HU - Hounsfield Unit), in: bone, soft tissue (muscular, nervous and connective tissue), adipose tissue and lung (air, bronchioles and alveoli).

These histograms were fitted based on Gaussian functions, which allow greater precision to the data obtained [10]. Adjustments were made, taking as parameters the number of CT as a reference for each tissue, which has the largest number of pixels in each curve, and from which we can obtain the values of standard deviation (σ) of Gaussian [10].

The algorithm developed in this study is able to read the name of all files within an operating system directory and store them. Next, for each image in this indicated directory (step 6), the algorithm filters artifacts (table of the CT scanner, non biological tissues wrapped in the patient, etc.), and quantifies the pixel size (in mm) and presents histograms (number of pixels with CT number range for each tissue). The area directly below the curves shown by the histograms represents the total number of pixels for each tissue evaluated, considering a reference CT number.

Considering this fact, the areas under each curve were converted to average thickness of their respective biological tissues.

To finish this process, biological tissues (bone, soft tissue and air) were then quantified in average thickness and converted into respectively simulator materials (aluminum, Lucite and air) for each CT slice evaluated. This study considered the effective energy of X-ray beam at 40keV, which is the effective energy for a beam of X-ray equipment [11].

The method validation was performed from CT scans of the chest of an anthropomorphic RANDO phantom (Radiation Analog Dosimetry system), which simulates a standard adult patient [9], [12], [13]. After validation, the whole methodology was applied to pediatric examinations.

3. RESULTS

Figures 2 and 3 illustrate, respectively, the histograms obtained for the RANDO anthropomorphic phantom (standard adult patient), and for chest CT scan of a pediatric patient with 1 month of life.

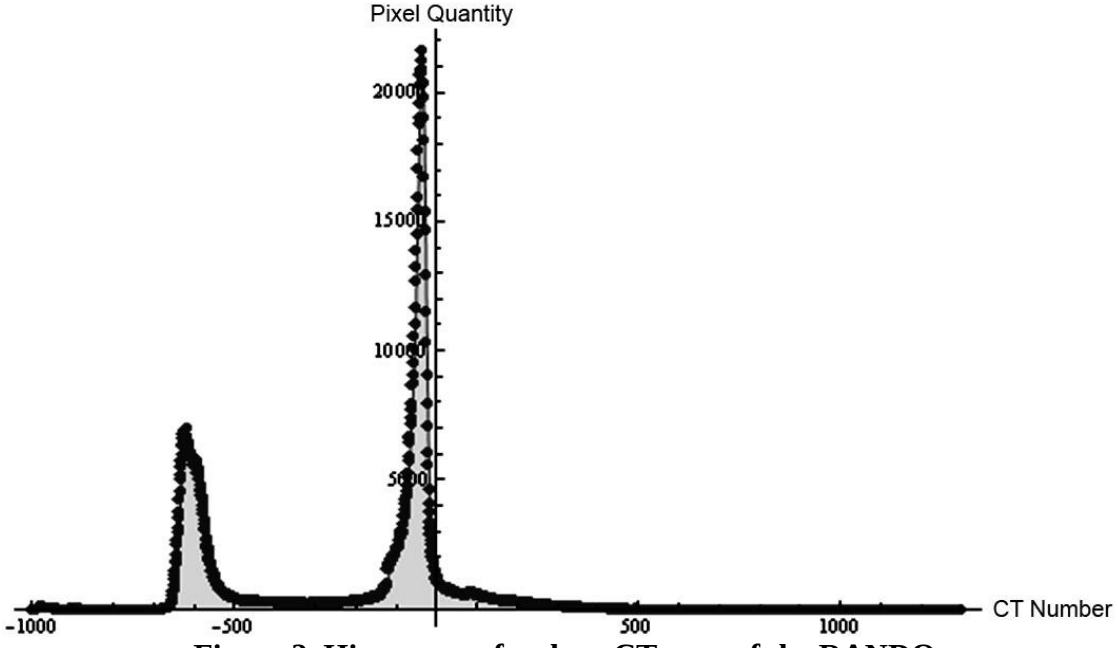

Figure 2. Histogram of a chest CT scan of the RANDO

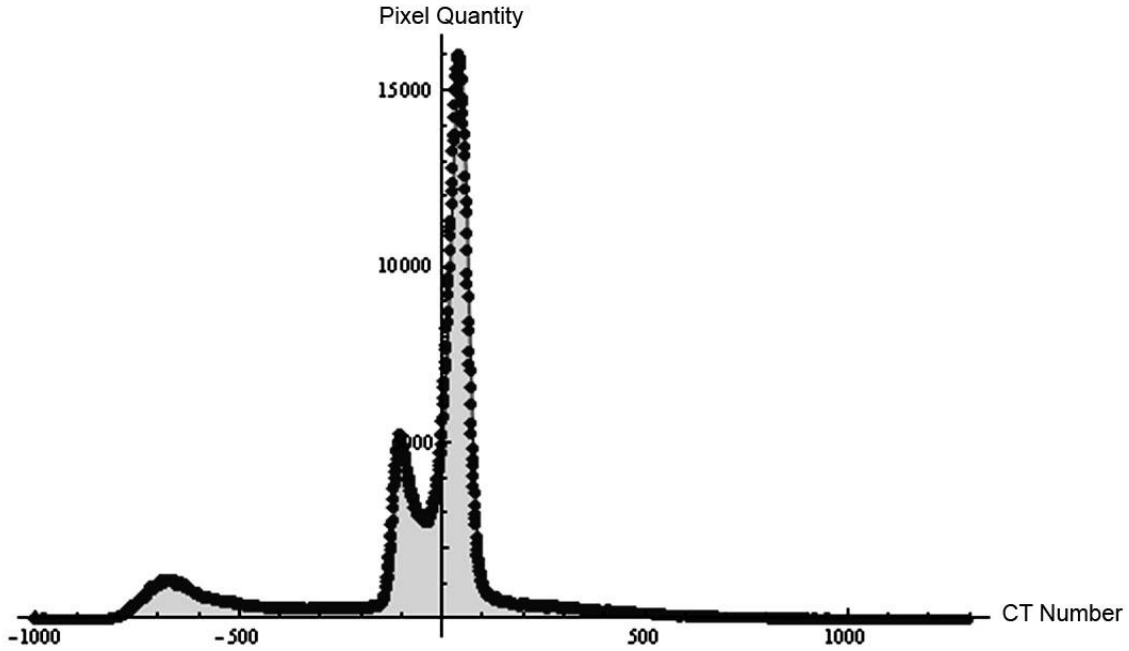

Figure 3: Histogram of a chest CT scan of a patient with 1 month of life.

Table I shows the result of the quantification of bone, soft and air to the anthropomorphic RANDO phantom. This lists the values obtained in this study with the values presented in the literature [4].

Table I: RANDO tissues thickness obtained by the algorithm and presented in the literature

Tissue	Tissue thickness (algorithm)	Tissue thickness (literature)
Pulmonary	51.7	50 mm
Soft	73.0	74 mm
Bone	13.3	17 mm

Table II presents the quantification results of the biological tissues average thickness, existing in the mean free path of X-ray beam, and Table III presents the conversion of the of Table II thicknesses in their simulator materials. Both tables show are separated by anterior posterior thickness ranges.

Table II: Anterior Posterior Diameter (APD), average air thicknesses (Air), total soft tissue (Tot soft), Bone (Bone) and its standard deviations, in percentage, (SD (%)) for the average thicknesses of biological tissues.

APD (mm)	Ar (mm)	SD (%)	Tot soft (mm)	SD (%)	Bone (mm)	SD (%)
90-95	15.2	3.89	52.8	11.2	6.31	0.97
95-100	15.8	4.95	54.5	8.24	7.13	1.50
100-105	19.7	7.43	52.6	7.25	7.23	1.24
105-110	18.8	8.23	56.4	7.84	6.49	1.50
110-115	21.5	6.77	58.5	8.02	6.83	1.24
115-120	22.2	5.25	58.3	5.73	7.25	1.22
120-125	18.6	8.01	58.9	8.36	6.62	0.99

Table III: Anterior Posterior Diameter (APD), average air (Air), Lucite (Luc.), Aluminum (Al) thicknesses and its standard deviation, in percentage, (SD (%)) for the average thickness of the materials simulators

APD (mm)	Air (mm)	SD (%)	Luc. (mm)	SD (%)	Al. (mm)	SD (%)
90-95	15.2	3.89	66.1	15.3	1.10	0.21
95-100	15.8	4.95	68.3	11.2	1.24	0.33
100-105	19.7	7.43	64.5	10.4	1.26	0.27
105-110	18.8	8.23	71.2	12.5	1.30	0.33
110-115	21.5	6.77	70.7	10.5	1.19	0.27
115-120	22.2	5.25	70.3	8.56	1.26	0.27
120-125	18.6	8.01	71.8	8.43	1.15	0.22

4. DISCUSSION AND CONCLUSIONS

The histograms illustrated in Figures 2 and 3 shows that are possible to distinguish bone, soft tissue and lung from CT scans of the chest. Based on the literature, it is possible to identify these tissues from the CT reference numbers, which represents the maximum amount of pixels in each distribution evaluated [10], [14].

A preliminary step to the quantification of living tissues was performed in an anthropomorphic RANDO phantom.

The histogram shown in Figure 2 shows the different simulator materials of biological tissues for RANDO. In this it is possible to distinguish bone, epoxy resin (representing the soft and fat tissues) and lung, with their respective CT numbers of reference. According to literature, the CT

reference number to air is around -1000; for the lung, between -700 and -200, for the epoxy resin, between -60 and -30 and for bone tissue, between 100 and 400 [10], [13], [14].

The quantification of the anthropomorphic phantom constituent materials made by the algorithm, shown in Table I, when confronted with the literature data show that the largest difference found was 21.6% for bone tissue. However, the literature shows that variations of up to 30% in bone thickness had no significant influence on the quality of radiographic images.

The analysis of Alderson RANDO phantom evaluates the overlap of Gaussians of air, epoxy, and bone tissue. The epoxy resin represents the soft and fat tissues as a single tissue, and thus presents a single peak in the region between the CT numbers between -100 and 0. Since this phantom is also used in conventional radiology, the radiographic density of the epoxy resin should be between the soft tissue and fat. In fact, we observe a similar behavior in computed tomography by Figure 2, where the Gaussian peak is located at -34 (between -140 and 100), that is, between the soft and fat tissues [10], [14].

Once we get carry out the quantification of tissue RANDO without significant changes that is the validation of the algorithm we can use this to evaluate examinations with living tissues. This validation assesses the ability of the algorithm to separate the Gaussian tissues evaluated (for RANDO, epoxy, air and bone tissues). The results in Table I allow this methodology is applied to living tissue.

According to literature, the CT reference number to air is around -1000; for the lung, between -700 and -200; for fat, between -140 and -20; for soft tissue, between 20 and 100 and for bone tissue, between 200 and 400 [10], [14]. The evaluation of the histogram of Figure 3 shows that the results are consistent with the literature, and thus may be used for the quantification of biological tissues.

The average thickness of biological tissue and its simulator materials are presented in Table 6. These results show that even a phantom can simulate patients with different ranges of APD, since variations in thickness up to 6mm acrylic and 0.3 mm aluminum not significantly influence the sensitometric response of screen-film system for the beam energy X-ray used in clinical routine [4].

Thus, the algorithm developed in this study can be considered appropriate for the distinction and quantification of biological tissues found in the mean free path of X-ray beam, in the chest of pediatric patients.

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