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XRAY MEDICAL IMAGE CHARACTERIZATION WITH SPARSE RADIATION BASED ON WAVELETS

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Abstract: In medical radiology there are large amounts of digital images in hospitals and health centers. Equipment that enables the acquisition of medical radiographs uses X-radiation sensor plates for image acquisition in medical diagnosis. Medical radiology equipment uses anti-scatter grids, which are physical devices, to avoid unwanted effects on imaging. In the present work, we analyse from a qualitative point of view the radiation scattering effect that is caused in images without the presence of the anti-scattering grid. In this research, the acquisition of radiological images was made by means of X-ray equipment with an anti-scattering grid, capturing images without scattering and others that only present radiation scattering as a point of comparison. The methodology uses the Wavelet transformation to image characterization in segment process that define the regions that affect the different types of dispersion presented in X radiation. The tool used for the analysis of the images is the multi-resolution Wavelet transform, specifically the Discrete Wavelet Transform (DWT). The methodology was applied to different 2D radiological images in shades of gray. In the images used, it showed a robustness in the differentiation of X radiation incidence zones. This work is the beginning of a distortion analysis for the reconstruction of this type of images.

Keywords: Image Processing, Characterization, Discrete Wavelet Transform, Scattered Image, Radiology, Wavelet.

I. INTRODUCTION

The images digitization has many advantages that could not be taken advantage of in the past, when using static recording media such as X-ray plates, for the record images. Using digital means for image registration opens a door to use digital image processing in its treatment. Digital image processing is the modification of certain eligible features of an image to selectively accentuate or dim them by means of digital equipment.

An image is defined as a two-dimensional function $f(x, y)$, where x and y are the spatial coordinates, and the amplitude of f at any pair of coordinates (x, y) is called the intensity of the image at that point, for 2D images in grayscale. When x and y define the positions of amplitude values of f and are finite discrete quantities, the image can be defined as digital. An image can be seen as a mesh of values that is mathematically represented by means of a matrix, where each minimum element of representation of the image is a pel or pixel. The term pixel is the most used when talking about the elements of a digital image [1].

There are different methods that modify an image it in the domain of space by directly modifying its basic properties, such as the intensity of each pixel. By transforming an image to a different domain from the spatial one, its characteristics are represented by elements of the new domain. To get the image back in its original domain, the spatial domain, the inverse transformation is performed, which recovers the image and allows the result of the processing to be evaluated. There are procedures that transform an image from its spatial domain to the frequency domain such as the Fast Fourier Transform (FFT), the Continuous and Discrete Transform of Waves or Wavelets (DWT or CWT) and the Discrete Cosine Transform (DCT) between several more [2].

The Wavelet Transform (WT) is a mathematical method for processing an image in multiple resolutions, it is also an efficient way to store important image information. This transformation stores time, space, and frequency information from the original image in coefficients that contain the transformed features.

In recent years the Wavelet Transform has been used with good results as a tool for the characterization of images in regions such as the identification and mass classification of images. One of the main reasons to use it over the Discrete Fourier Transform or the Discrete Cosine Transform, is the ability to facilitate classification, compression or restoration [3].

This research analyzes from a qualitative point of view the radiation scattering effect that is caused in radiological images without the presence of the anti-scattering grid. The objective is to characterize a radiological medical image that presents electromagnetic dispersion, acquired by means of the X-ray equipment without an anti-scattering grid. From this final image, the elements that define the regions that affect the different types of dispersion presented in the images are determined.

The methodology uses the Wavelet transformation to image characterization in segment process that define the regions that affect the different types of dispersion presented in X radiation. The tool used for the analysis of the images is the multi-resolution Wavelet transform, specifically the Discrete Wavelet Transform (DWT). The characterization of scattering regions identifies the effects of radiation scattering in the image and allows to analyze the results, by identifying specific areas.

This research does not intend to provide medical criteria or diagnoses, but only to show how images can be treated using processing tools based on Wavelets, and specialized radiologist can work and analyze them as a result.

This work is presented in five sections, the first being the one that introduces the topic. The second section presents background information on the subject and research. The third section presents the methodology used, and the fourth presents the results with characterization images. The fifth section presents the conclusions of the work.

A. *Theory*

An image in gray´s shades can be represented as a 2D function of type f(x, y) of intensities. This image can be processed in the spatial domain by means of techniques that modify the intensity of the pixels that form it in different ways. One tool for analyzing a signal or image in the frequency domain is the Fourier Transform (FT). In this transformation, the result is a ratio of frequency components in the signal. It is recommended to use when analyzing stationary signals and does not provide information on spatial characteristics [4].

B. *Discrete Wavelet Transform*

Discrete Wavelet Transform (DWT) is a mathematical method for processing an image in multiple resolutions. The process of transforming a signal using the Wavelet methodology uses mathematical convolution by applying a time-limited kernel to a target signal. The process consists of using a previously defined "small wave" and carrying out a mathematical integration process with an original signal. This little wave is known as "Wavelet". The fig. 1 shows the process used to transform a signal to a multi-resolution Wavelet scheme.

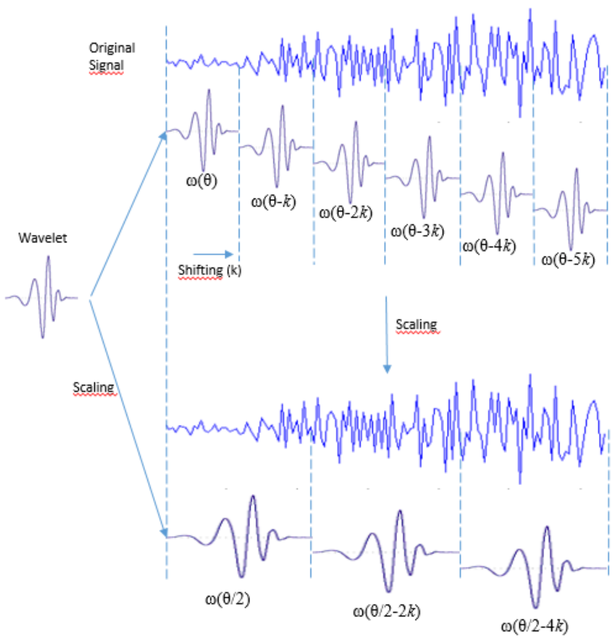

Figure 1. Process of transforming a signal using DWT. Own elaboration.

An image defined in its original spatial domain as $f(x,y)$ with dimensions $M\ x\ N$, the transformation function will be defined as $T(u,v,\ldots)$ expressed by (1).

$$T(u,v,\ldots) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)g(x,y,u,v,\ldots) \quad (1)$$

Where $x\ and\ y$ are variables defined for the spatial domain, $u,v,\ldots$ are variables resulting from the transformation to the Wavelet domain.

The inverse process can be done from $T(u,v,\ldots)$, with the inverse Discrete transform and obtain $f(x,y)$ as described by (2).

$$f(x,y) = \sum_{u=0}^{M-1}\sum_{v=0}^{N-1} T(u,v,\ldots)h(x,y,u,v,\ldots) \quad (2)$$

where $g(x,y,u,v,\ldots)$ and $h(x,y,u,v,\ldots)$ are called kernel transformation. This pair of functions are used for direct and inverse transformation.

One of the algorithms that is probably the most used in the area of Discrete Wavelet Transformation is the Mallat algorithm for multi-resolution analysis (MRA). This analysis has become a great application tool for image processing [1].

Wavelet technology-based MRA analysis takes an image and breaks it down into components of different frequencies, allowing each component to be studied at a different resolution, called Wavelet Frequency bands (WFBs). In WFB an image is broken down into frequency components, which can also be located in the physical space structures of the original image. This decomposition is composed of elements of different frequencies depending on the resolution being analyzed. the WFB's with lower resolutions, related to the transformation with low frequencies, and higher resolutions represent high frequencies [4]. The DWT MRA encodes frequency and space information of the image in its spatial domain. This transformation identifies in each image, frequency and time information, as well as horizontal, vertical and diagonal components that make up the image [5].

C. *Characterization*

The evaluation of the characteristics of an image by defining zones of similar behavior is called characterization. This method consists of the grouping of elements that share fundamental characteristics, and that are denoted by their similarity [6][7]. The elements identified by the characterization share characteristics that can denote similar textures, depths or effects caused by similar events.

D. *Medical radiology*

The medical radiology equipment that allows the acquisition of radiographs use an X-radiation emitting bulb and sensor plates in the formation of images for medical diagnosis, allowing their processing by digital means. To improve the acquired image –from a radiological point of view- anti-scatter grids are used, which are physical devices, to avoid unwanted effects on the radiation presented in the acquired images. The fig. 2 shows the general diagram of a radiology device and the way in which radiation impacts the detector, with radiation passing through the object of study. The same figure shows the anti-scattering grid used to prevent rays refracted by semi-opaque bodies from showing up in the image generated by the medical equipment.

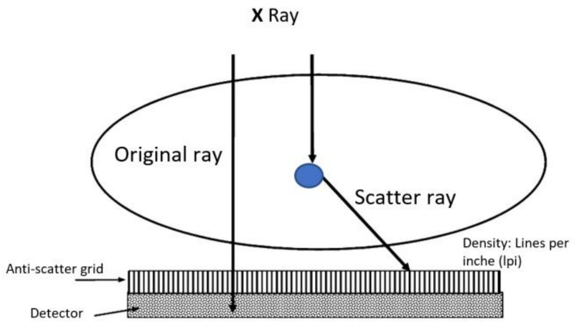

Figure 2. Schematic of the image capture device and anti-scatter grid. Own elaboration.

X-rays are a type of high-frequency, short-wavelength electromagnetic radiation, located in the lower part of the visible light spectrum. Its phenomenology is best studied by analyzing its properties as waves rather than particles. The propagation of this radiation is linear like that shown in visible light [8]. In the formation of the radiological image there are 4 effects of X radiation. The effect of reflected radiation, which does not pass through the body study and does not affect the sensor board. The radiation that hits the sensor board directly without passing through any semi-opaque body, which generates the highest intensities on the board. Refracted radiation, which is the one that changes in speed and direction when passing through media of different densities and that is presented on the sensor board as radiation scattering. And finally, the diffracted radiation is the one that is deflected when passing through objects of drastically different densities through their limits. This radiation is scattered in many directions but the intensity it presents is regionalized in regions very close to the origin of the distortion [9].

E. Related Research.

Research field related to this work is in Wavelets application and image characterization. In the search for content based on images (CBIR content-based image retrieval), the Wavelet transform was used to identify images from a medical database [10]. Image transformations were analyzed in identifying relevant signatures and distance measurements in images, for medical interpretation. The transformation of the image by means of Wavelets was carried out by adaptively introducing coefficients. The result of the characterization that is obtained are vectors with numerical content called signatures. In this way, image signatures were compared and similarity and classification could be established for medical analysis purposes.

A characterization method adapted to the Wavelet transform for specific problems, using the Wavelet multidimensional analysis is proposed by Quellec in [7] for image analysis. This method, considered a light scheme (lifting), proposes banks of coefficients for the Wavelet filter, which are designed in a simple and agile way, and are operated in the same way. This scheme shows that the application of simple Wavelets for the characterization of images gives good results for the analysis of images of patient mammograms. The retrieval of images with content with similar signatures in medical databases allows searches with approaches to medical diagnosis.

An investigation that proposes an algorithm to compute the characterization of images using different Wavelet kernels to search for each image in a bank of images, used in an image-based content retrieval system [11]. It is interesting how this characterization method allows the use of different Wavelets for the analysis of each image for the recovery of signatures, obtaining acceptable results. The research compares the application of various Wavelets and defines the best use of kernels. Its application is related to characterization studies of medical images, in medical investigations of ophthalmology, in the detection of faces and recognition of textures.

The researcher Quellec describes a method for the detection and diagnosis of breast cancer in women using mammographic images [12]. This method uses image characterization and a learning methodology to support the diagnostic process. The characterization is based on the segmentation by means of Wavelets for the determination of textures that allow the definition of signatures for the feeding of the learning system. The application of the methods allows the characterization of densities in the images, very useful in the identification of tissues.

The proposal for characterizing images using the Fast Wavelet Transform (FWT), for the development of a CBIR system is a method used in medical investigations [3]. The Wavelet Transformation allows obtaining signatures for each image in a single resolution. Each of the signatures can be compared in the image database to support the diagnosis of brain cancer. The characterization is using a Wavelet kernel in a single dimension and the method of comparing the signatures is based on the Euclidean distance between the coefficients of the signatures.

In industrial research such as the manufacture of Polystyrene, the characterization of the particle size distribution is important in determining the stress resistance of the material. The evaluation of the microstructural characteristics of the material is an important element to evaluate. The proposal of a characterization system for this type of materials is analyzed by means of image processing techniques, differentiated sizes and shapes of the particles [6].

II. METHOD

The purpose of the current work is to present an analysis that evaluates qualitative results. Images captured using X-ray medical radiology equipment are analyzed, acquiring images with scattered radiation, processed without the anti-scattering grid, which we will call "scattered images". Additionally, images that only present scattering are obtained. The images are obtained from a real medical radiology equipment using bodies called ghosts, used in the medical equipment manufacturing industry, for the calibration and testing of radiological devices. The two captures are made of the same object of study under the same conditions and position.

In this way, we have the scattered image and one that shows only dispersion, finally used for the comparative analysis. The scattered image will be the reason for the characterization and the image that only presents scattering will be analyzed against the characterized regions.

The images are obtained in Raw or original format, 2D in shades of gray, with a resolution of 1420 x 1420 pixels, with a definition per pixel of 16 bits representing 65536 shades of gray and occupying a space of 3.8 Mbytes. The methodology based on the Wavelet transform was designed on the RAW image.

RAW images are the result of the acquisition process in a medical radiology equipment, using ghosts' bodies, which emulate parts of human bodies, with characteristics similar to real human bodies. They emulate the transparency and opacity that the tissues of a human body present when penetrated by X radiation. There are ghosts from different parts of the human anatomy, and in this study those that represent the thorax will be used.

The scattered image shows the effects of direct incidence, refraction and diffraction. Each of these elements present in the images can be considered to have similar characteristics due to the distortion effect of the radiation they show. The characterization of the image with the developed methodology allows its differentiation and analysis.

The characterization of the images is done using the multi-resolution of the DWT, considering the higher frequency WFBs. Image processing is performed by analyzing the reconstruction of the 2 Wavelet high frequency resolutions, and using on them an analysis of textures and thresholds to determine areas of direct incidence and refraction of X radiation. A Wavelet with Symlet kernel is used for the use that is had in several of the cited articles.

Using zone filling methods (floodFill) and thresholds, zones with the presence of refraction and diffraction are determined. With the same processing, the weak refraction zones are determined by the presence of fairly uniform soft tissue. By processing the direct incidence image, it is possible to obtain the limits with elements of the image of greater density that cause the diffraction of the radiation.

The image processing is carried out with the Python 3.7 programming language using the Anaconda development platform, open source libraries for image management and developing image processing tools for 16-bit resolutions.

In the next phase, the graphic results present in the partially characterized images are integrated into an image that shows areas characterized with the different effects of X-radiation scattering, in different shades. The resulting image is the one that allows the differentiation of elements of the image characterized according to the effects of the radiation present in the acquired image. The methodology is shown in fig. 3.

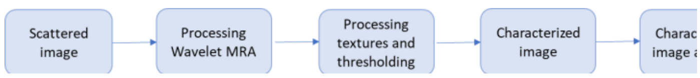

Figure 3. Methodology graphic representation. Own elaboration.

Finally, a qualitative analysis of the characterized regions is made, comparing it with the image that presents only the radiation scattering. the evaluation is a test prior to future research work for image reconstruction.

III. Results and Discussion

The methodology was applied on different radiological images of the thorax. Fig. 4 shows processing steps of 2 chest images. (a) and (e) are the original RAW images captured with the medical radiology equipment without dispersion. In the direct induction zone, there is a scattering caused by the radiological equipment, specifically it is an unwanted effect generated by the anti-scattering grid. This unwanted effect was eliminated by applying low intensity step thresholding on the scattered image.

In fig. 4 Scattered images are (a) (e) images of Wavelet transformation are (b) (f), texture analysis images (c) (g) and initial refractive area analysis (d) (h). Images (b) and (f) of fig. 4 are the application of multi-resolution DWT reconstructing the 2 highest resolutions using the combined coefficients of the WFB 9 and 10 of the transformation. On this transformation, a texture analysis is processed with Gabor filters with a kernel of dimension 9, in the vertical and horizontal components of the WFBs, obtaining as a result images (c) and (g). Images (d) and (h) are the result of processing with smoothing filters and binary thresholds, for the generation of uniform regions.

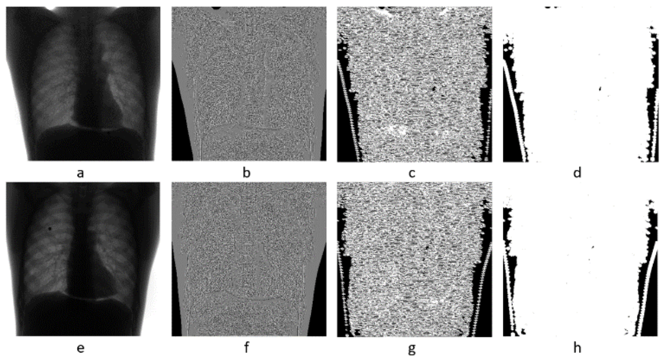

Figure 4. Image pre-processing for characterization(a) (e) scattered images, (b) (f) Wavelet transformation, (c) (g) texture analysis (d) (h), refractive region analysis. Own elaboration.

In the fig. 5 the effects of refraction and diffraction in a specific region are presented. Image (a) is a section of the image without scattering, and image (b) shows only the scattering. This effect becomes noticeable by observing a greater intensity in image (b) than that present in image (a), each point being affected by its close neighborhood. Image (c) is a section of the image without scattering and image (d) shows the diffraction effect in the right zone and direct incidence in the left zone. These two very different effects require a treatment each that allows the construction of the image from the scattering image.

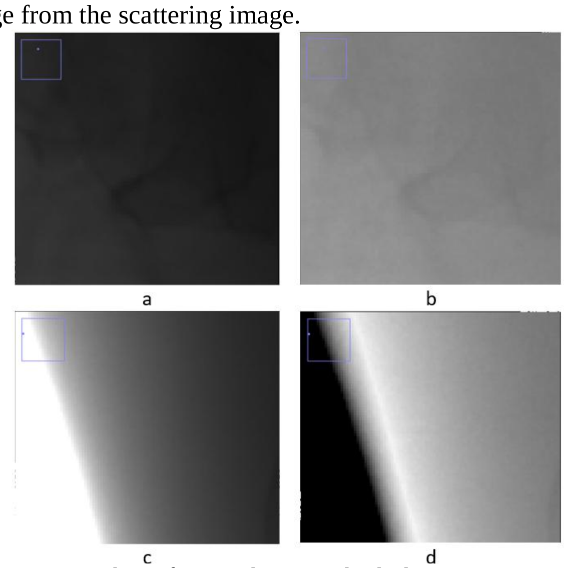

Figure 5. Analysis of scattered image and only dispersion image section. Own elaboration

The diffraction effect is analyzed in a close-up of one of the X-ray images captured by the medical radiology machine, in fig. 5. This effect is different from the dispersion effect that affects other regions of the image, this result suggests a treatment of the image by regions with different filters for reconstruction purposes.

The fig. 6 shows the continuation of the image processing, with the scattered images in (a) and (e). Images (b) and (f) of the same figure are the result of applying Gabor filters with a kernel of dimension 9 and applied to the diagonal components of the selected WFBs. Applying binary thresholds, we obtain dark areas that are the areas of direct incidence of X radiation, which directly affects the sensors without the presence of objects that cause interference.

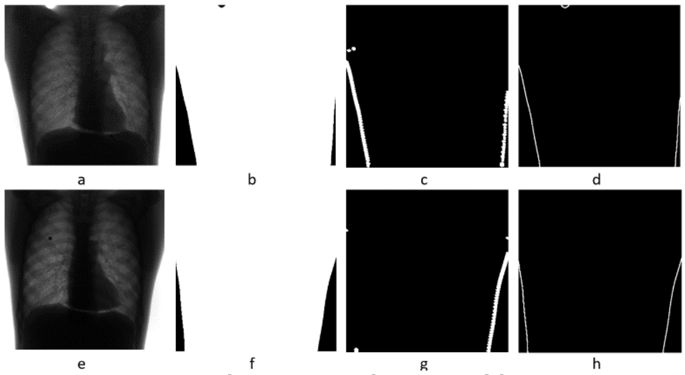

Figure 6. Characterization Phases. Own elaboration.

The images (c) and (g) of the fig. 6, are the result of applying a processing of filling larger sets (floodFill), filling areas and applying binary thresholds to the images (d) and (h) of the fig. 4, which represent the region where the refraction effect and a slight diffraction occur. Procesando las imágenes (b) y (f) se obtienen los límites de las figuras, que son las regiones de presencia de alto efecto de difracción de la radiación, mostrado en las imágenes (d) y (h) de la figura 6.

The fig. 7 shows the images (a) and (c) resulting from the integration of the two previous processes shown in the figs. 4 and 6, and the images that only present radiation scattering, which are images for qualitative comparison of the characterized regions (b) and (d).

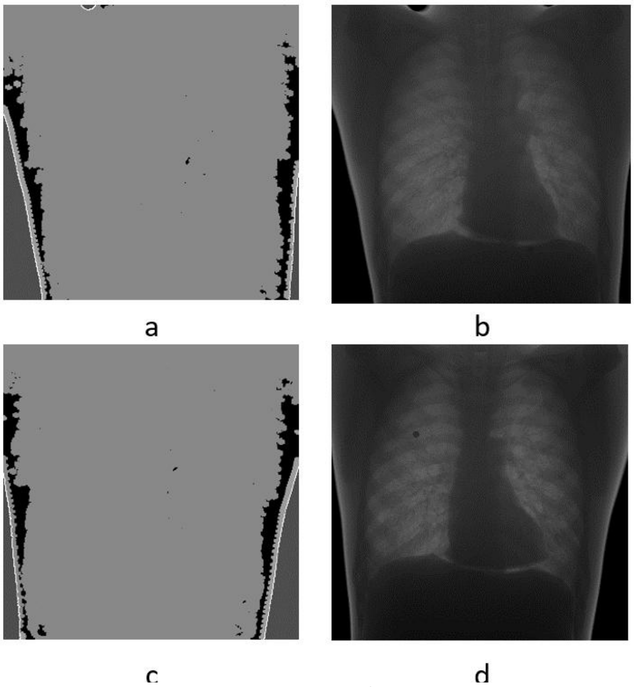

Figure 7. Qualitative comparison of images. Own elaboration.

Image (a) in fig. 8 shows the characterization of the original X-ray image of fig. 4 in image (a), where the characterized regions are observed with different shades of gray.

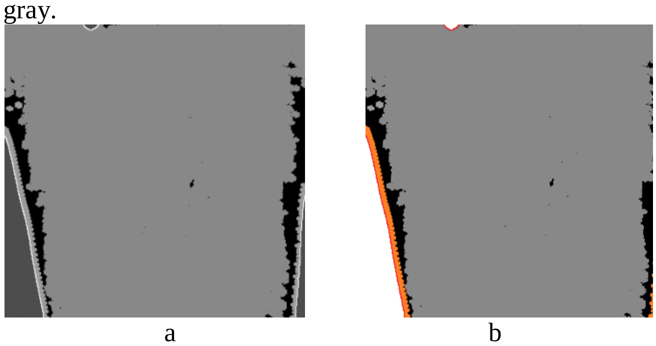

Fig. 8. Image characterized. Own elaboration.

The colors in image (b) of the fig. 8, shows the characterization by regions of the scattered image. The image shows the white area as the direct incidence area without interference. The area marked with orange color shows an area with strong diffraction previously analyzed in the fig. 5 image. The orange zone is a region with the presence of medium refraction and weak diffraction. The black region shows only slight refraction due to the presence of soft tissues. And the gray region exhibits radiation refraction mainly.

IV. Conclusions

The methodology was applied to different 2D radiological images in shades of gray. In the images used, it showed a robustness in the differentiation of areas of incidence of X radiation, this allows us to ensure that the development of a system using the methodology will provide reliable results.

The characterization of medical radiological images of the chest, by means of the Wavelet transformation allows an identification, which allows the clear differentiation of regions that present the main effects of radiation scattering. The zones clearly define the presence of refractive scattered radiation in most of the image that represents a person's torso. Identify the region of direct incidence and refraction of the radiation. Additionally, it is possible to identify areas that present a weak refraction due to the presence of soft tissues, and mixed areas of diffraction refraction.

Future characterization investigations will have a reconstructive purpose for images that present distortion generated by radiation scattering in the capture of radiological images without anti-scatter grid. Another research based on the current one will analyze different radiological images acquired from different sections of the human anatomy, characterizing them and analyzing their behavior.

The scope of this study is not intended to perform reconstruction but to provide criteria for the use of DWT and the characterization of radiological images.

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VI. REFERENCES

[1] C. Gonzalez, R. Woods, Digital image processing. Pearson Prentice Hall, 2014.

[2] C. Chui, Wavelet analysis and its applications, USA. Academic Press, 1992.

[3] S. Anwar, F. Arshad, M. Majid, “Fast wavelet based image characterization for content based medical image retrieval,” International Conference on Communication, Computing and Digital Systems (C-CODE), 2017.

[4] S. Mallat, “A wavelet tour of signal processing,” USA. Academic Press is an imprint of Elsevier, 2009.

[5] J. Acuna-Garcia, S Canchola-Magdaleno, F Jacques, “Comparative study: 2D image processing in gray scale using wavelets,” International Journal of Computer Science and Sof tware Engineering (IJCSSE), Volume 8, Issue 7, July 2019, pp: 151-160.

[6] F. Manriquez and I. Terol, “Caracterización de HIPS mediante técnicas de análisis de imágenes,” Revista mexicana de física 50 suplemento 1, 2003.

[7] G. Quellec, M. Lamard, G. Cazuguel, B. Cochener, C. Roux, “Fast wavelet-based image characterization for highly adaptive image retrieval,” IEEE Transactions on Image Processing, vol. 21, no. 4, pp. 1613–1623, 2012.

[8] C. Carlsson and G. Carlsson, “Basic physics of X-ray imaging,” ser. Report / Linkopings hogskola, Institutionen for radiologi. Department of Medicine and Care Radio Physics, 2014.

[9] G. Dougherty, “Medical image processing,” ser. Report / Linkopings hogskola, Institutionen for radiologi. Springer New York Dordrecht Heidelberg London, 2011.

[10] G. Quellec, M. Lamard, G. Cazuguel, B. Cochener, C. Roux, “Wavelet optimization for content-based image retrieval in medical databases,” Medical image analysis, vol. 14, no. 2, pp. 227–241, 2010.

[11] G. Quellec, M. Lamard, G. Cazuguel, B. Cochener, C. Roux, “Adaptive nonseparable wavelet transform via lifting and its application to content-based image retrieval,” IEEE transactions on image processing, vol. 19, no. 1, pp. 25–35, 2010.

[12] G. Quellec, M. Lamard, G. Cazuguel, M. Cozic, G. Coatrieux, “Multipleinstance learning for anomaly detection in digital mammography,” IEEE Transactions on Image Processing, vol. 35, no. 7, pp. 1604–1614, 2016.