

Detection of Osteoporosis using Medical Images

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Abstract— In this work a series of algorithms are presented, in order to select from automatically, in the neck of the femur, Ward's triangle. A method was also developed to detect if the patient has Osteoporosis, Osteopenia, or healthy by analyzing this. The main objective of this work is to achieve a technique capable of detecting and recognize using radiographic images of the femur, Ward's triangle located in the area of the neck of the femur. Using processing techniques images such as smoothing techniques (low pass filter), detection of edges (Frei-Chen filters, Prewitt, Sobel, Roberts), automatic tread (method of Otsu), skeletonization techniques (Hilditch algorithm), among others. Once detected said zone, an osteoporosis detection method based on the algorithm will be applied of representation vector.

Keywords— osteoporosis detection, osteopenia, radiographic images, smoothing techniques, skeletonization techniques.

I. INTRODUCTION

This section introduces a brief description of the disease Osteoporosis and the relationship of medicine with the processing of images. Osteoporosis [1] is a disease in which decreases the amount of minerals in the bone, losing the trabecular bone part and reducing the cortical area by a defect in the absorption of calcium, which makes them brittle and susceptible to fractures and microfractures, as well as anemia and blindness. The mineral density of the bones is established by bone densitometry. This disease is the main cause of bone fractures in women after the menopause and the elderly in general. Osteoporosis does not have a well-defined beginning and, until recently, the first visible sign used to be a fracture of the hip, of the vertebral bodies that caused pain or deformity.

During the last 15 years, a growing number of techniques concerning images digital have been introduced into medical practice. Many radiologists and staff Medical laboratories know and manipulate digital images such as those produced by Computer-assisted tomography, magnetic resonance imaging and medicine methods nuclear. Due to the development, capacities and great feasibility of execution of the computers, the images in medicine, which were traditionally recorded on films, now they can be manipulated in digital form. In this way the X-ray images [2] can be store directly in digital form by means of luminescence phosphor plates photostimulable. The development of digital image storage techniques in medicine has been accompanied by an increase in the use of tools to manipulate images. These tools are designed to help laboratory technicians and doctors to perform objective evaluations of the images, and thus provide a more accurate diagnosis precise that which can give the only visual interpretation.

II. THEORETICAL CONCEPTS

In this section, the most relevant concepts are presented of processing images that help to understand the steps that allowed the development of proposed application.

A. Stages of image processing

Below are the stages that make up the image processing.

- Capture: Design of the capture properties.
- Pre-processing: Reduce the environment that is not of interest to the problem.
- Segmentation: Recognize and extract each of the objects present in the image.
- Feature extraction: Select and extract "features" appropriate for the identification of the desired objects.
- Identification of objects: Use a decision-making model to decide on what category does each object belongs to.

B. Image

The term image refers to a two-dimensional function of light intensity $f(x, y)$, where x and y denote the spatial coordinates and the value of f at any point (x, y) is proportional to the brightness (or gray level) of the image at that point. A digital image is a function $f(x, y)$ that has been discretized in coordinates spatial and in brightness. A digital image can be considered as a matrix whose row and column indexes identify a point in the image and the corresponding value of the element of the matrix that identifies the level of light intensity at that point.

C. Histogram

A histogram is a statistical graph that allows representing the distribution of intensity of the pixels in an image, that is, the number of pixels that corresponds at each luminous intensity. By convention, the histogram represents the level of intensity with X coordinates ranging from the darkest (left) to the lightest (on the right). In this way, the histogram of an image with 256 levels of gray will be represented by a graph that has 256 values on the X axis and the number of pixels in the image on the Y axis.

D. Normalization

A Normalization becomes necessary, to have a certain independence of the properties of the image, such as brightness and contrast. The equation that we allow this is the following:

Let $I(x, y)$ be the input image,

$$N(x, y) = \frac{(N^{\circ} Niveles - 1)}{(max(I) - min(I))} \cdot (I(x, y) - min(I))$$

where: • $I(x, y)$, gray level of the image in the coordinate (x, y) . • $min(I)$, $max(I)$: minimum and maximum level of gray in the image respectively. • $N(x, y)$, gray level of the normalized image in the coordinate (x, y)

E. Convolution

It is the most used and known image treatment. Discrete convolutions are widely used in image processing, both for smoothing images, Edge detection, and other effects. Through this process, the value of a determined point according to yours and that of your neighbors, applying a simple mathematical operation based on which a resulting value for the point will be obtained in question. A sliding window, called a convolution window, focuses on each pixel of an input image and generate new output pixels. To apply the mask to that zone, multiply the values of the points that surround the pixel by its corresponding input or coefficient in the mask, and then add up (see Figure 1). The cost of said process focuses on the size of the image. But given its simplicity and effectiveness it is one of the most used.

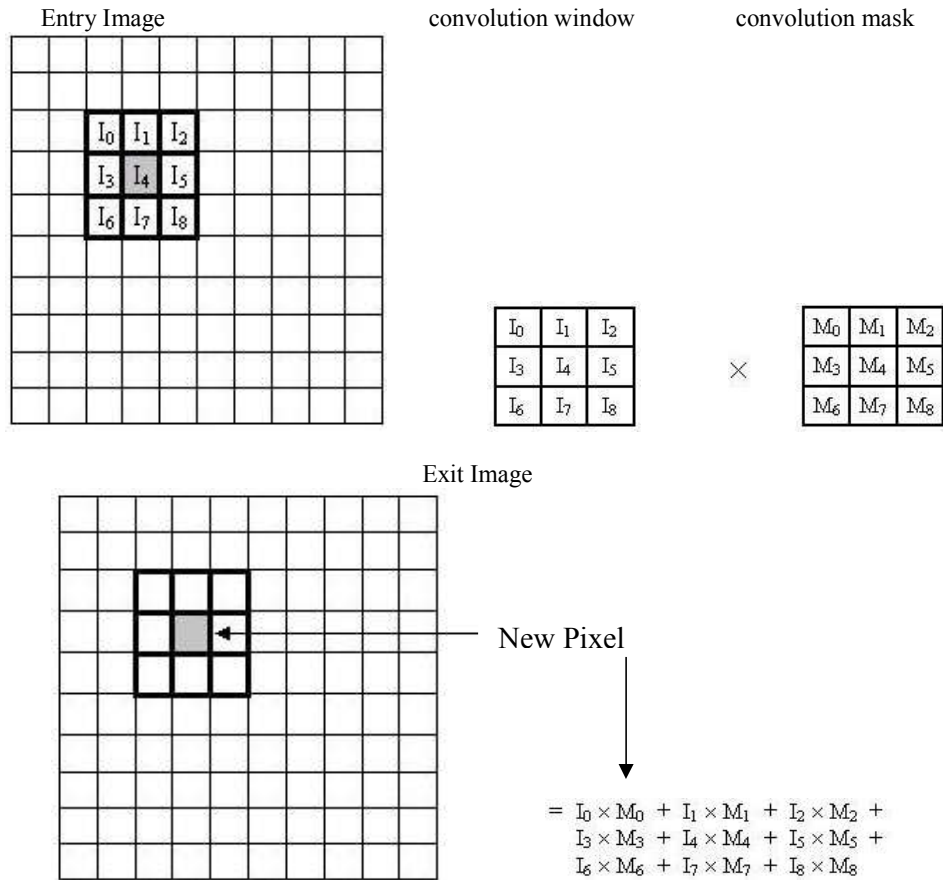


Figure 1: Convolution process

When the masks used have coefficients totaling 1, the image convolved will have the same average intensity as the original image. Other masks of convolution have positive and negative coefficients and add a total of 0, in this situation will generate negative pixel values. In case we get out of the imposed range for the image $f(x, y)$, we must normalize the result by applying the most appropriate function in each case. There is a problem in dealing with the edges of the image. When the convolution window focuses on the first pixel of an image in $(0,0)$, the sliding window protrudes from the image on the upper edge and on the left, as you can (see Figure 2). Here are several methods to solve this problem:

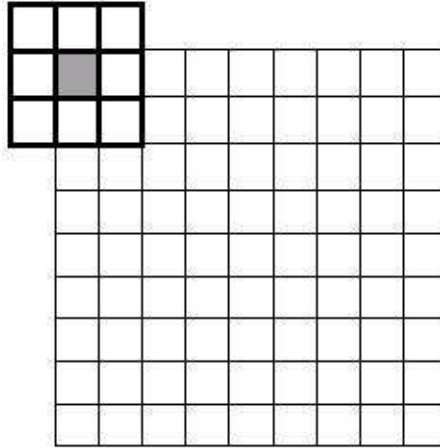


Figure 2: Problem of applying the window of convolution

- The first solution is to treat the empty cells in the convolution window as zeros. This is known as Zero-Padding. It's easy to do but it's not a good idea when the edges of the resulting image are as important as the rest of the image.
- The next solution is to start the convolution in the first position where the window does not protrude from the image. If the convolution mask is of size 3x3, it is would start convolving with the pixel in $(1,1)$ instead of the pixel in $(0,0)$. This method is simple to implement. In the output image, the convolved edges are copied to create an image with the same size as the input image.
- Other methods extend the image before convolving it. One way to do it is duplicate the edges. Using a 3x3 mask, the upper and lower rows would be copied, as well as the left and right columns.
- The other method is to "wrap" the image, that is, consider as a pixel contiguous to the from the left edge, the pixel from the right edge and vice versa, as well as from the edge upper and lower. (see Figure 3).

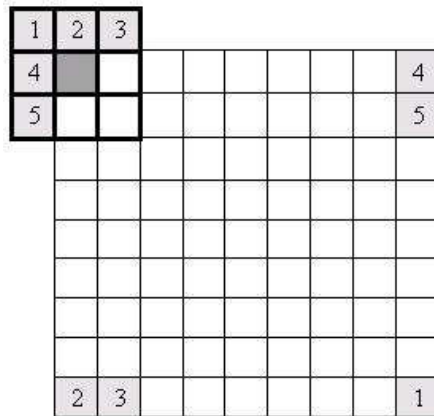


Figure 3: Solution using the method of "wrapping" the image

III.FILTERS

Filtering techniques [3] are pixel-to-pixel image transformations, which do not depend only on the level of gray of a certain one, but also on the value of the gray levels of the neighboring pixels in the original image. The filtering process is performs

using matrices called masks, which are applied to the image. The image resulting from the application of a filter is a new image. The filters are used to soften or enhance details of the image, or even minimize noise effects.

Noise is defined as any object in the images, data or intermediate results which are not interesting for the process that is intended to be carried out. The Smoothing filters, consist of eliminating the objects explained above. In this case, will proceed to explain the low pass filter, which is used in this work.

The low pass filter is a type of smoothing filter used to remove high noise. Spatial frequency in a digital image [4]. This noise is usually introduced in the image during the analog-to-digital conversion process as an effect secondary of the physical conversion of luminous energy patterns to a cancellation of the fastest variations between pixel and pixel. The noise appears randomly to way of points in the image, usually with values quite different from the neighbors closest. The visual effect of a low pass filter is the smoothing of the image and reduction of the number of gray levels in the image. The high frequencies, which correspond to the abrupt transitions, are attenuated. Smoothing tends to minimize noise and originates a less clear image, with gray levels more blurred. The cutoff frequency of the filter is determined by the size of the filter mask and of the coefficients. The mask for a low pass filter always makes sense for a number greater than 1. The sum is subsequently normalized, thus the coefficients represent a percentage of contribution of each pixel to the new pixel.

The main objective of Enhancement filters is to highlight those characteristics of the image which, because of the means of capture or by some error, have been poorly defined in the picture. This type of filters is widely used as a direct method to improve an image. Then proceed to explain the high pass filter, which is one of the most simple and most used

In general, the high pass filter operates in the same way as the low pass filter, by analyzing the values of each pixel and changing these according to the values of neighboring pixels. The effect on this filter is the opposite. Instead of getting a smoothing the image, the high pass filter enhances image details. Unfortunately, this also tends to emphasize noise on many occasions existing in the image. Therefore, the use of this filter should preferably be reserved to images with very little noise. It is used to amplify the details with high frequencies in an image, while all low frequencies of the image remain the same. The high pass filtering is the most used when the objects in an image are little identified. With this filtering, the parts of the image with high frequencies will be highlighted, while the image portions with low frequencies will be obscured. He contrast of the image is usually increased with the negative effect that the noise it is amplified.

The detection of corners and lines is based on the edge detection operators, by calculating first and second derivatives. Which allow determining points of major importance to be able to make the necessary measurements. In the analysis of objects in images it is essential to be able to distinguish between object of interest and the rest of the image. The techniques used to determine these Objects are known as segmentation techniques. One of the most common is the segmentation by edge detection.

When talking about edge detection, it is assumed that the algorithm used will give as result a contour of the object. However, the goal of this algorithm is to obtain images whose output shows pixels of greater intensity in the values they detect transitions nearby. The edges are found in areas where the level of intensity It varies significantly. The faster the change in intensity occurs, the edge it's stronger. In order to detect the edges of objects we must obtain those points that form it. Thus, an edge point can be seen as a point in a image where a discontinuity occurs in the gradient. A good process of Edge detection facilitates the elaboration of object boundaries, thereby making the process of object recognition is simplified. The edge detection algorithms [5] that were developed are the following:

Techniques based on the gradient:

- Roberts Operator
- Sobel Operator
- Prewitt Operator
- Isotropic operator (or operator of Frei-Chen)

The most accepted method in the detection of edges consists of applying filters of smoothing followed by gradient filters [6]. The latter are the ones used to detect the changes or transitions in the gray levels in an image. The operators based on the gradient assume that the edges of an image are pixels with a high gradient. A rapid rate of intensity change in some direction given by the angle of the gradient vector can be observed in the pixels of the edges. The magnitude of the gradient indicates how marked the edge is. If we calculate the gradient in uniform regions we will obtain a vector of value 0, which means that there are border pixels. Next, the operators used will be detailed:

One of the options that can be implemented to detect an edge is to study the gray levels of adjacent pixels and see if there are variations. The most intuitive way to check if there is variation is the difference. Therefore, Roberts operator method implements a mask that, applied to a pixel, calculates the difference between the gray level of this pixel and a neighboring pixel.

Sobel operator [7] is one of the classic filters for edge detection, which uses two masks or filters. One to detect the vertical edges and one for the horizontal ones. So, to get the full edges is done the sum of the images that we found with the vertical and horizontal edges. In addition you can also add masks with different directions to get better results. One of the advantages of this operator is that it not only detects edges, but also reduces the noise of the image resulting.

Prewitt operator [8] consists of 8 matrices that are applied pixel by pixel to the image. Then he add the images to get the edges well marked. The Prewitt filter brand very well the edges since their matrices attack these from eight different sides. In general, each matrix takes the name of a cardinal point: North, South, East, West, Northwest, Northeast, Southwest, Southeast.

The logic of Isotropic Operator (or operator of Frei-Chen) method is to weight the neighboring pixels according to the distance that it separates it from the pixel where we are evaluating. This means there are no directions privileged in the detection of the edges.

IV. THRESHOLDING

Thresholding [9] is a widely used segmentation technique. It is used when there is a clear difference between the objects to be extracted from the background of the image. The principles that govern are the similarity between the pixels belonging to an object and its differences with respect to the rest. Therefore, the image must be characterized by a uniform background and similar objects.

When applying a threshold, T , the grayscale image, $f(x, y)$, will be binarized; where the '1' correspond to the object and with '0' to the bottom or vice versa. Most thresholding techniques are based on statistics about the one-dimensional histogram of an image. The co-occurrence matrix is also used of an image. Parametric procedures can be used to locate the thresholds and non-parametric. In the parametric, the distribution of the gray levels of a class of object leads to find the thresholds. In non-parametric procedures, the thresholds are obtained optimally according to some criteria. In particular, the Otsu method chooses the optimal threshold by maximizing the variance between classes by an exhaustive search.

F. Otsu Method

The Otsu method [1, 10] uses statistical techniques to solve the problem. In concrete, the variance is used, which is a measure of the dispersion of values - in this case it is about the dispersion of gray levels. The Otsu method calculates the threshold value so that the dispersion within each segment is as small as possible, but at the same time the dispersion is the highest possible between different segments. For this, the quotient between both variances and a threshold value is sought for which this quotient is maximum.

As a starting point we take two segments of points ($K_0(t)$ and $K_1(t)$), which will be defined from the threshold value t . t is the variable we are looking for, and the two segments they are the desired result in segmentation. Let $p(g)$ be the probability of occurrence of the gray value $0 < g < G$ (G is the gray value maximum). Then the probability of occurrence of the pixels in the two segments is:

$$P_0(t) = \sum_{g=0}^t p(g) \quad P_1(t) = \sum_{g=t+1}^G p(g) = 1 - P_0(t)$$

If we take two segments (that is, a single threshold value) the sum of these two odds will obviously give 1. If \bar{g} is the arithmetic mean of the gray values in the whole image, and \bar{g}_0 and \bar{g}_1 mean values within each segment, then you can calculate the variances within each segment as:

$$\sigma_0^2(t) = \sum_{g=0}^t (g - \bar{g}_0)^2 p(g) \quad \sigma_1^2(t) = \sum_{g=t+1}^G (g - \bar{g}_1)^2 p(g)$$

The goal is to keep the variance within each segment as small as possible and make the variance between the two segments as large as possible. A) Yes we obtain:

$$Q(t) = \frac{\sigma_{zw}^2(t)}{\sigma_{in}^2(t)}$$

The variance between the segments is:

$$\sigma_{zw}^2(t) = P_0(t) \cdot (\bar{g}_0 - \bar{g})^2 + P_1(t) \cdot (\bar{g}_1 - \bar{g})^2$$

The variance within the segments is obtained from the sum of both:

$$\sigma_{in}^2(t) = P_0(t) \cdot \sigma_0^2(t) + P_1(t) \cdot \sigma_1^2(t)$$

The threshold value t is chosen so that the quotient $Q(t)$ is maximum. $Q(t)$ is at both the measure sought. In this way we choose a threshold value that optimizes the two segments in terms of variance

In a general way, morphology refers to the study of the shape and structure of a object. The image processing field provides a tool for the extraction of components, useful in the representation and description of the shape of a region. Mathematical morphology uses set theory to represent the forms of the objects in an image. In this way, morphological operations can be described simply by adding or removing pixels from the original binary image.

G. Erosion and Dilation

The erosion [11] operation consists in the elimination of the neighboring pixels of an object. In the same way dilation is understood as the incorporation of pixels to objects of a binary image. In both operations, the same criteria are followed for application. The simplest criterion for erosion is the search for pixels marginal with logical value V having a neighbor with logical value F ; the erosion produces when the marginal pixels change their logical value from V to F . Applying a similar criteria for dilation, look for the pixels neighboring the marginal line of the object having a logical value F and changing its value from F to V . illustrates the complementarity of erosion and expansion operations (see Figure 4). The Erosion operation produces the decrease of the image area and the dilation produces the increase of it. But, in addition, both operations produce

important changes in the thin regions of objects, changing their perimeter and shape, as well as the number of holes that the object contains; a dilation makes the object grow by its periphery, while filling the holes of small size. The operations of Erosion and dilatation can be combined in order to restore, as much as possible, the additions or decreases of the peripheral pixels after the corresponding counter operation. Without However, it is not always possible to reconstruct all the peripheral pixels with dilation after erosion.

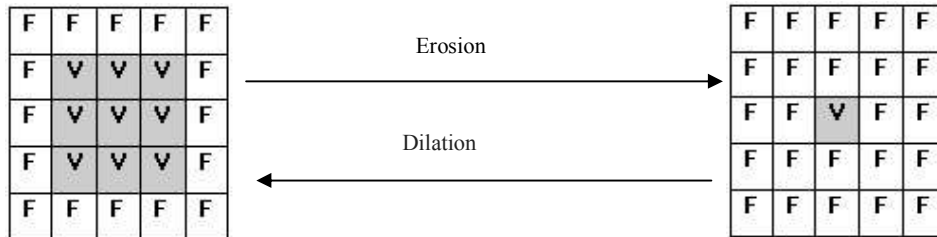


Figure 4: Erosion Vs. Dilation

H. Opening and Closing

The opening of an image is the realization of an erosion followed by a dilation using the same structural element (structure that defines the size and shape of the neighborhood in which the morphological operation will be applied) in both operations. East method is applied when you want to remove the small objects and keep the size in the big ones. The lock operation of an image is performed when the dilation is applied and subsequently the erosion (opposite to the opening). This process is characterized by filling holes and connects objects that are close to each other.

I. Skeletonization

The skeletonization [12] aims to obtain from an image, a continuous pattern that contains as little data as possible, but still contains a trace of the original object. For this there are algorithms (Hilditch) that operate in a general way eliminating pixels under pre-defined rules, and stopping when there are no more changes to make.

Hilditch's algorithm requires a certain mask and the passage of it through the entire image, so that the pixels covered by the mask are analyzed by certain basic conditions. Of these conditions it defines that the point is erased from the image or not. The technique used by this algorithm is that of the eight neighbors. For this it is considered a 3x3 mask, where the pixels are numbered in the following way (see Figure 5):

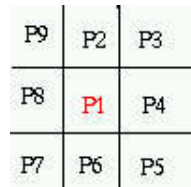


Figure 5: 3 x 3 mask

The conditions that were mentioned initially require the definition of two basic functions. We have the function A (p), which represents the number of times the pattern 0,1, repeated in the sequence of points of the matrix, taken from point p2 until p2 same, in a time mode. In other words, you have to count how many times the pattern 0.1 is repeated in p2, p3, p4, p5, p6, p7, p8, p9, p2. And there is also the function B (p), which is defined as the number of pixels 1 around the central pixel. Once, determined the mentioned functions, the mask must be passed through all the image, and the central pixel below the mask will be changed to the background color, if it is that meets the following conditions:

- 2 <= B(p1) <= 6
- A(p1)=1
- p2.p4.p8=0 or A(p2)!= 1
- p2.p4.p6=0 or A(p4)!= 1
- Obtaining excellent results.

V. DEVELOPMENT OF PROPOSED STRATEGY

This section will explain the selected methods, which were previously mentioned, for the different stages of image processing applied to our case study.

A. Capture

In this stage, the patient is exposed to an X-ray machine, which is ordered to perform the capture of the radiography for further analysis. X-rays are a form of electromagnetic radiation (like a light) that they produce a great energy and penetrate through the human body generating an image. In this step, the radiation changes and, therefore, when passing through dense

structures such as bone on the plate will appear a white tone, if it goes through structures with air a black tone. Between both densities different shades of gray may appear, depending on the density of the structure traversed by the beams of rays. It should be clarified that the taking of said radiography is external to the system, with which, the It depends on a person trained to perform this activity.

B. Pre-processing

Once the X-ray image of the femur is chosen, it can be seen that the same. It has information that is not important for the purpose of the work. Therefore, it allows the user, through a simple way through the application, to select the area of interest manually and apply the corresponding filters for the improvement of the picture. The steps to follow would be:

- Cut out the desired area.
- The image is softened, using a low pass filter.
- An edge detection filter is applied, more precisely, the Prewitt filter, since it was the one that produced the best results. It should be noted that in this step, Other filters can be applied depending on the objective.

C. Segmentation

During this stage we proceed with the objective of selecting objects in a way independent of the background of the image. For this the methods were developed corresponding binarization, skeletonization, among others. Here are the steps that are followed when making the segmentation:

- Once the pre-processed image has been obtained, the threshold for the binarization of the image. This threshold is chosen automatically using the Otsu method, or manually using an application tool.
- In cases where the binarized image does not have completely joined edges it is appropriate to use the closing algorithms, (with the option to choose a dilation, erosion or opening). In turn, if necessary, You can use the gap filling algorithm. Once the image is totally united, we proceed to use a skeletonization algorithm, which is developed using the Hilditch algorithm.
- If the previous image obtained presents noise, an algorithm is applied that eliminate.

As an illustrative summary, (see Figure 6) you can see the transformations that apply to a particular image, using the algorithms belonging to the stage of pre-processing and segmentation.

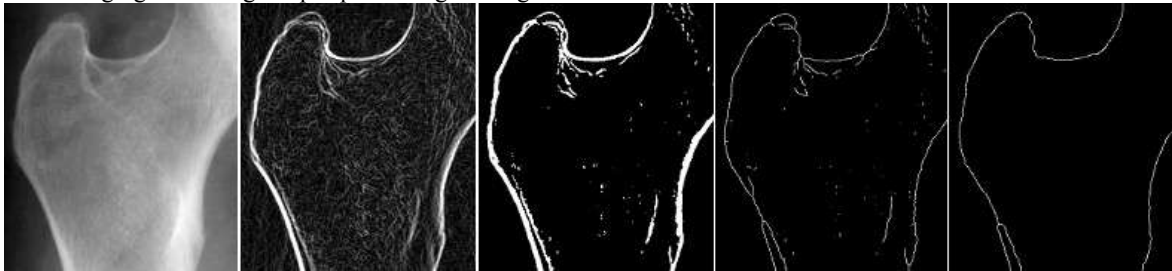


Figure 6: Low pass - Prewitt - Umbralado (Otsu) - Skeleton (Hilditch) - Skeleton without noise

D. Feature Extraction

In this stage, from the image of the bone skeleton of the femur, the Ward's triangle (see Figure 7). The method consists of a series of mathematical steps that are detailed below:

- Detect the minimum distance line of the neck of the femur (see Figure 7, red line smaller).
- Calculate the axis of symmetry for said line (based on the midpoint of the line of minimum distance and the slope of it) (see Figure 7, in blue line).
- Find the critical point (calculated with approximations of tangents with straight lines of 5 pts in length).
- Find the base line that is perpendicular to the axis and that passes through the critical point (see Figure 7, longer red line).
- Detect the triangle (see Figure 7, in blue):
 - Find the midpoint of the minimum distance line
 - Find the line (base of the triangle) whose points belong to the base line and at the intersection of the perpendicular lines that pass the two extreme points of the minimum distance line Form the triangle with the data obtained in A) and B)
- Find the center point of the triangle (see Figure 7, in sky blue) and define a square of $N \times N$ centered on said point which is called "Ward's Triangle" (see Figure 7, in green).

E. Identification of Objects

In this last stage, the osteoporosis index presented by the patient is calculated. For the calculation of the same, the method based on the Algorithm of Vector Representation, which consists of:

- Calculate the average of the values of the region of interest
- The image is binarized from the previously calculated value.
- Taking each row of the binary matrix and applying the formula the \cos_i value is obtained.

$$\cos(\alpha_i) = \frac{\sum_{j=0}^N I_{i,j}}{\sqrt{\sum_{j=0}^N I_{i,j}^2} \sqrt{N+1}}$$

Once said formula is applied to all the rows of the matrix (the \cos_i vector is built), proceeds to perform the same procedure but with the columns. After this procedure ends, the average of the horizontal vectors (H) is obtained and vertical (V) respectively. The procedure ends with the following calculation: $(H + V) / 2$. Which stipulates the Osteoporosis index presented by the patient.

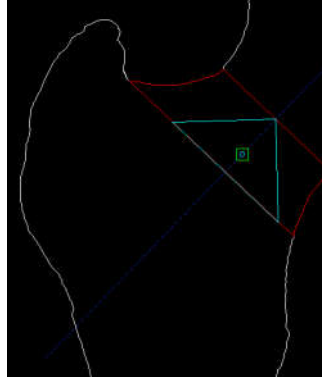


Figure 8: Ward's triangle

VI. CONCLUSIONS

In the present work, different techniques were proposed and developed processing of images to be used on medical images, more precisely on radiographs of the femur. To fulfill our objectives, the algorithms studied within the an easy-to-use tool, which includes the possibility of applying different techniques on the same image, to then be able to compare them. As well as the option to perform the osteoporosis screening study, on the images of the patients, automatically.

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