Proposals for highlighting broken bones in radiological images using image processing in LabVIEW

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Abstract. In this work, two proposals for highlighting broken bones in radiological images using different methodologies are presented. The first one, works using border detection while the second one, by extracting the cortical section of the bone. For border detection, first derivate operators (Sobel) were applied, to obtain the intensity changes in the image borders, applying the operators vertically and horizontally and adding them to get a general gradient image. Afterwards, the general gradient image is binarized and subtracted to the original image, leaving in black the zones that had borders. For cortical extraction, the image is binarized considering the healthy bone’s intensity value, next, the binarized image is subtracted from the original one eliminating the bones from the radiography, leaving the soft tissue and the bone’s interruptions, then, the image that contains the soft tissue was binarized an subtracted to the original one getting only the bone, eliminating the soft tissue and the bone’s interruptions, highlighting the broken bones.

1. Introduction

1.1 X-ray images and broken bones
X-ray images are the result of acquiring human body images from the controlled exposition to X-rays. The finality of this kind of images is to get a diagnosis from them. Since the discovery of X-rays by Wilhelm Conrad Röntgen and the posterior use of X-rays to medicine at lately XIX century image diagnosis has had several applications, from strange object identification to pulmonary disease diagnosis and others [1]. The obtained images have the property that, as higher is the density of the object exposed to the X-rays, the higher the intensity will be in the image [2] allowing the visualization of the skeleton. Inside a radiography, the cortical section is the thickest zone of a bone. A broken bone is present when the continuity of a bone is totally or partially interrupted. Broken bones can be classified in different ways according to their position, complexity, etc [3]. The main diagnosis technique for broken bone is obtaining an X-ray image [2]. According to the Social Security Mexican Institute (IMSS), at 2016 10.15% of the patients attended for job accidents suffer broken bones [4].
1.2 Digital Image Processing

Digital image processing is a group of techniques used to analyze and obtain information from digital images. This processing technique uses the numerical values the matrix that conforms and shapes a digital image, where each matrix position is a pixel and the numerical value is an intensity value (figure 1) [5].

![Fig. 1 Comparison between a digital image and its matrix.](image1)

1.3 Image borders

An image border is found when the intensity of a section of an image has an abrupt change (from dark gray to white for example) [5]. One of the most used techniques to obtain the border in an image are the first derivative operators, because, they can be used to get the changes in one specific direction (figure 2). The resulting image is called gradient image.

![Fig. 2 Graphical example of applying the first derivative to an image](image2)

One of the most common first derivative operators, is the Sobel operator, which allows to get the gradient image in horizontally and vertically [5].

1.4 LabVIEW

LabVIEW is a graphic programming environment, which finality is to develop virtual instruments. Because the programming is graphic, this platform is intuitive and easy to use, allowing the development of several applications. Also, LabVIEW counts with multiple tool boxes for different tasks [6]. LabVIEW has a specific toolbox for image processing (Vision and Motion).
2. Methodology
Each proposal will be described with the techniques used in them, the description will start with the border extraction proposal, and then, continue with the cortical extraction proposal.

2.1 Border Extraction
Border extraction proposal start by filtering the image with a gaussian smoothing filter. Image filtering is the result of iteratively applying the convolution of the original image with a kernel matrix (equation 1).

\[ f_o(x, y) = \sum_{m=1}^{k} \sum_{n=1}^{k} f \left( x - \frac{k+1}{2} + m, y - \frac{k+1}{2} + n \right) h(m, n) \]  

Where \( f_0 \) is the filtered image, \( f \) is the original image and \( h \) is a \( k \times k \) matrix denominated kernel, always that \( k \) is a impair number. According to the values of \( h \), the filter can be low pass or a high pass filter. After the image is filtered, the horizontal and the vertical gradient images are acquired using equation 1 and the Sobel operator Kernels.
Both gradient images were added to get a general gradient image that considered the border in the horizontal and vertical axes. This general gradient image was binarized using equation 2.

\[ g_b(x, y) = \begin{cases} \text{max intensity value} & g(x, y) \geq a \\ \text{min intensity value} & g(x, y) < a \end{cases} \]  

Where \( g_b \) is the binarized image, \( g \) the original image and \( a \) the binarizing threshold. Then, the binarized image obtained by setting \( a \) at 30 and then, is subtracted from the original one leaving as black zones the areas where borders were found.

2.2 Cortical Extraction
The cortical extraction proposal is a consecutive application of equation 2 and subtraction between the images obtained from the binarization.
The proposal starts by binarizing the original image setting \( a \) at the mean value of intensity at the cortical line, leaving all the soft tissue and the bone’s interruptions in the lowest intensity value. This image is subtracted from the original image eliminating the bone from the radiography. The resulting image is binarized again leaving in the highest intensity value the soft tissue and the bone’s interruptions. The soft tissue image is binarized, and then, subtracted from the initial radiography leaving only the bones and getting as dark zones the interruption.

3. Results
The results of both programs and the original radiography from a patient with a splint are displayed (figure 3).

Fig. 3 From left to right, original radiography, border detection results and cortical extraction results.
Also, the result of both programs and the original radiography from a patient with a broken bone are displayed (figure 4).

![Images of radiography and results](image)

Fig. 4 From left to right, original radiography, border detection results and cortical extraction results.

The images from both programs were presented to ER physicians from the IMSS to see which one was better for diagnosis. The physicians commented that the cortical extraction proposal is easier to use.

4. Conclusions
Two proposals for X-ray diagnosis were presented and compared, getting results from both. For the border extraction proposal, the algorithm can find thinner lines but is more sensitive to noise produced by textures, while the cortical extraction proposal is less affected by noise, it can eliminate useful information. Both techniques can be used as pre-processing algorithm for further image classification techniques.

5. References
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