

A New Approach to Automatic Segmentation of Bone in Medical Magnetic Resonance Imaging

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Abstract. This paper presents the modelling and segmentation with correction of inhomogeneity in magnetic resonance imaging of shoulder. For that purpose a new heuristic is proposed using a morphological method and a pyramidal Gaussian decomposition (Discrete Gabor Transform). After the application of these filters, an automatic segmentation of a bone is possible despite of other semiautomatic methods present in the literature.

1 Introduction and Background

Magnetic Resonance Imaging (MRI) is a technique used, primarily, as medical diagnosis tool, producing high quality images of organs and structures from human body. MRI provides additional information that cannot be obtained from an X-ray, ultrasound, or CT scan.

In MRI scanning, the area of the human body to study is positioned inside a strong magnetic field. The MRI can detect changes in the normal structure and characteristics of organs and tissues. It also can detect tissue damage or disease, such as a tumor or infection. Information from an MRI scan can be digitally saved and stored in a computer for further study.

The use of computer systems to help physicians has extremely increased in the last years in all medical fields. More important than saving and storing information, orthopaedic specialist will be helped by computers on diagnosis and planning processes that require detailed studies and analysis before exposing a patient to a possible high risk intervention treatment.

We are interested in the 3D MRI clinical modelling in order to shape and to analyze the shoulder. It is necessary to do distinguish the different elements that make up the surgical field of a shoulder as bone, cartilage, ligaments, muscle and skin. Therefore it is necessary to review and to have a thorough knowledge of the different pathologies by means of research, in order to help to prepare and to treat them [1], [2], [3].

Our interest focuses on the segmentation of different parts of shoulder and especially on the bone in real MR images. Most muscle-skeletal segmentations are still manually

performed by experts, requiring extensive and meticulous analysis, as well as many hours of intense human effort [4]. We investigate on the possibility of automating the segmentation technique and to support and accelerate manual segmentation (semiautomatic) where full automation is not possible.

One obstacle in automatic segmentation performing is the presence of inhomogeneities in the MR images which affect the measured gray level values of pixels in different regions of the image, reducing the accuracy of classification algorithms. Gray scale inhomogeneities in MR images may have different causes [5], [6], [7] and to characterize the field of inhomogeneity of MR machines is almost impossible since it changes with every sample under different study.

Removing inhomogeneity intensity of MRI is an essential requirement for the image qualitative analysis. It contributes to the strength of the image segmentation. There are many algorithms that allow later illumination correction by means of parametric and nonparametric approach. These methods have been extensively treated in the literature, making evident the importance to approach this problem. Some authors [5] present an exhaustive comparison of six algorithms for this purpose.

Most part of cases comes from of a segmentation of the image with illumination in an implicit or explicit way, though there are methods that not need segmentation [8], [9], [10], [11], [12], [13].

In this work we propose a procedure which considers independently both inhomogeneity correction and 2D image segmentation. The illumination artifact correction is based on a homomorphic algorithm with a low step filter. In order to segment the image, we use firstly multiresolution decomposition based on Gaussian Pyramid (Gabor Transform) [14], [15] and the segmentation itself is performed by applying a combination of edge detection algorithm as well as other mathematical morphological algorithms.

2 Materials and methods

In order to achieve our aim, we are interested on using a scheme of edge detection methods (Canny edge detector) [16] as well as other morphological methods. Our experience show that these methods perform poorly when they are applied on 2D muscle-skeleton MR image automatically, given the complexity of the image. In order to reduce this complexity, we prepare the image in advance, by correcting the illumination inhomogeneity using a homomorphic filter and by decomposing the image into low and high frequencies in the Gabor domain.

The following algorithm is employed:

- Correction of intensity inhomogeneity
- Multiscale Analysis in Gabor domain

- Segmentation
 - Edge detection
 - Remove end points of lines without removing small objects completely
 - Remove isolated pixels (1's surrounded by 0's)
 - Fill isolated interior pixels (0's surrounded by 1's).

All the different steps in the proposed algorithm were performed by using Matlab software (6.5.1 version).

2.1 Illumination correction.

Firstly, we remove illumination inhomogeneity and other potential problems that may make more difficult the process of automatic segmentation by using a homomorphic filter. The homomorphic filter has been designed to correct intensity inhomogeneities in the frequency domain. This filter compresses illumination conditions brightness and simultaneously, it enhances the contrast between reflection properties of objects. This filter is used when the interference is multiplicative; that is, when the original image is the result of the product of a free noise image by an illumination image. As the illumination component usually dominates the low frequencies and the reflection component dominates high frequencies, the resulting image can be effectively manipulated in the Fourier domain.

Whereas an increment in high frequency component in Fourier image improves the reflection image, the illumination image is attenuated [17], [18], [19]. This can be achieved by using the 2D Butterworth filter which approaches the constant magnitude in the stop band of an ideal filter.

2.2 Gabor Domain Multiresolution Analysis.

Once grayscale inhomogeneity has been removed and in order to break down our image of interest into low and high frequency components, we use the multiscale analysis presented by a previous work [14], where the authors focus on the spatial domain implementation, arguing two important advantages from the Fourier method: it is more plausible one for modelling vision and it permits local processing which is restricted to areas of interest and non rectangular shapes. Their algorithm proposed on [14] improves the original work [15] by (1) incorporating a High-Pass Residual (HPR) covering the high frequencies and (2) improving the quality of the reconstruction by assigning different fixed gains to the Gabor channels before adding them together; and (3) separating one dimensional filter masks with small size (11-tap), resulting in a spatial domain implementation faster than the implementation in the frequency domain via FFT, while maintaining a high fidelity in the filter design. The low frequency image is subjected to the segmentation procedure.

2.3 Segmentation

Segmentation is performed on the basis of edge detection by using canny algorithm [16], [19]. This algorithm concentrates an ideal step edge, represented as a sign function in one dimension, corrupted by an assumed Gaussian noise process. In practice this is not an accurate model but it represents an approximation to the effects of sensor noise, sampling and quantisation. The approach is based on convolution of the image function with Gaussian operators and their derivatives.

In order to improve this edge segmentation, we use a series of morphological operators for multidimensional binary images [19], [20], [21], [22], [23], [24], [25], such as removing spurious and isolated pixels and filling regions [26].

3 Results

We present the results obtained by applying the proposed method to a volume magnetic resonance image of shoulder. The image dimensions are 150 X 256 X 92 scans. The image is courtesy of the Ruber International Hospital in Madrid. In order to present results of the different steps proposed we select one of the slides of the image. Figure 1 shows the original image; note the illumination artifact cause by the patient position respect of the acquisition coil.

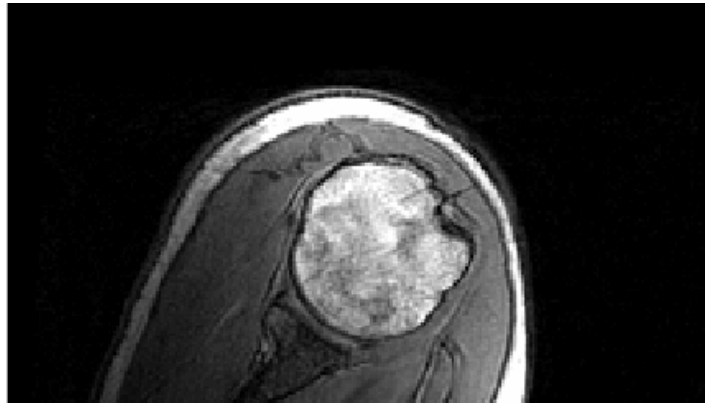


Figure 1: Original Image

Figure 2a shows the corrected image after applying the homomorphic filter described in 3.1. The image presents now a much more homogeneous appearance of gray levels.

According to the proposed algorithm we next separate our image into low and high frequency images in the Gabor domain. We are interested in obtaining the low frequency image with lower resolution that allows us to segment the object of interest, in

this case bone, by applying the Canny method. Figure 2b presents the low frequency component of our image after Gaussian Filter by mean Gabor transform.

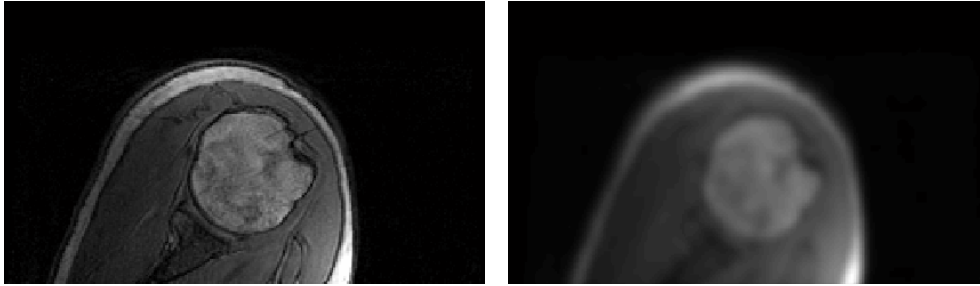


Figure 2: a) Image corrected y b) Gabor image low frequency

Then, we submit this image to the of edge detection procedure based on the Canny method. Some computational background is necessary in order to determine the threshold to use in this method. For instance, in Figure 3a, a 0.03 threshold has shown to perform satisfactorily.

Once edges haven been detected in the image, we apply morphological algorithms for binary images in order to remove spurious and isolated pixels. Figures 3b and 3c show the resulting image after removing spurious and isolated pixels, respectively. Finally figure 3d shows the slices bone, perfectly segmented after applying a morphological operator to fill in regions of interest.

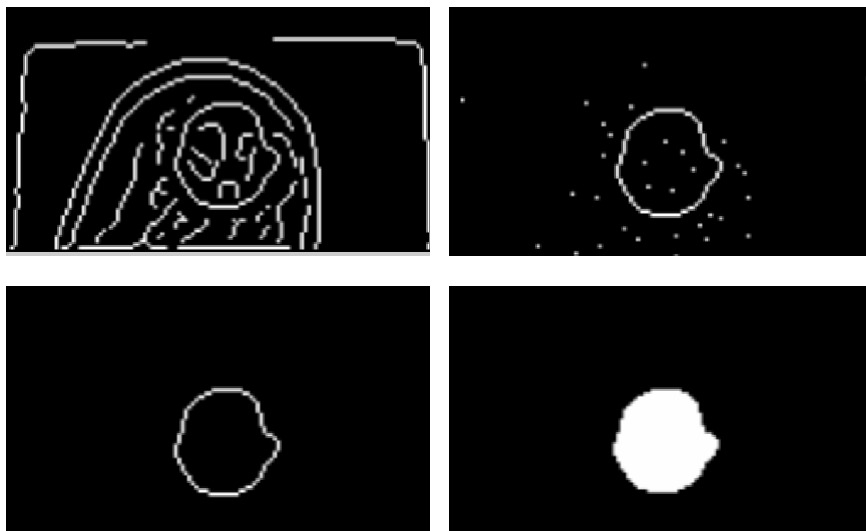


Figure 3: a) Edges image, b) region of interest with spurious pixels after morphological filter, c) isolated pixels removed d) Segmented bone.

4 Discussion & Further Studies

The algorithm proposed allows automating segmentation of the bone in high quality MR images. The algorithm is not capable to deal with other kind of tissues.

We have detected some problems for the automatic segmentation in images with poor signal to noise ratio or in extreme images (far from the acquisition center).

Now, our interest is focus on improving the heuristic to segment soft tissues. Furthermore we are trying to obtain an automatic bone 3D rendering using our automatic segmentation as a previous step.

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