Abstract:

This paper talks about a segmentation of metacarpal in the hand radiograph. The Shannon local entropy concept is used to segment the bone and tissue from the radiograph correctly. The Shannon entropy, mean and standard deviation were calculated with the small sliding window size. Then, thresholding & different morphological operations are used to segment the metacarpals with carpals and phalanges. In this primary study, the middle 3 metacarpals are focused and segmented. But changing the morphological parameters can also segment other metacarpals.

Keywords: Image segmentation, Local entropy, Morphological operations

1. Introduction

Through Image Processing, Images of Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) can be enhanced. The aim behind enhancing the image is to vary according to different applications like bone segmentation, fracture detection, etc. In radiograph images, a closer examination is required to detect and classify the abnormalities. Traditionally the radiograph image is examined by the human experts. It is very easy to detect the abnormalities by eyes inside the hand radiograph like bone fracture or overlapped bones. Sometimes coding is tedious to do these tasks which are easily detectable by eyes. But when radiologist wants to measure the region properties of bones like types of bones, fracture area or diversity in shapes of bones, coding works efficiently as compare to human observation.

This paper talks about the hand radiograph to segment the bones mainly metacarpals. It is a hybrid approach for segmenting the metacarpals. Which consist of following steps: (1) Contrast enhancement; (2) Statistical & Entropy-based metacarpals segmentation with surrounding tissue; (3) thresholding & morphological operations. The proposed algorithm is suitable for segmenting the metacarpals with minimal user inputs.

2. Methodology

In this image processing task, the first step is to enhance the contrast of the radiograph since some part of the image is not visible due to less contrast. In figure 1, the less contrast region is highlighted with a red circle. So direct Matlab function – adapthisteq is used to split the images into small areas and enhance the contrast according to the local histogram equalization. Figure 2 shows the raw images after enhancing contrast. Here in Matlab function adapthisteq, I am using 2 parameters . (1) 'NumTiles': used to divide the image into [4 4]; (2) 'ClipLimit': is used for contrast enhancement limit between [0 1]. Here 0.1 is used. By using this parameter, it will increase the contrast so we can see the bones clearly. Here in all the figures, left image is data file 9, middle image is data file 10 & right image is data file 11.Contrast enhancement is mandatory because, in the next step, the user has to crop interested metacarpals for segmentation. So the next step is to select the region of interest (ROI) from the hand radiograph. After cropping the image, the location of the crop region is saved to crop again the original raw image (which is not enhanced). And then adapthistiq Matlab function is used on selected ROI of the original raw image. Before this task, we enhanced the whole image, but enhancing the cropped image gives contrast according to the ROI and we can see that figure 3 has higher contrast between bone and tissue. Figure 3 shows a contrast-enhanced image of ROI. Here I am selecting the middle 3 metacarpals (as required). After this step, image padding is necessary because while applying a sliding window (in the next step) with the padded image has less distortion on the edges of the images.

Figure 1: Raw image (data file 9, 10, 11 respectively).

Figure 2: Contrast Enhanced raw image (data file 9, 10, 11 respectively)

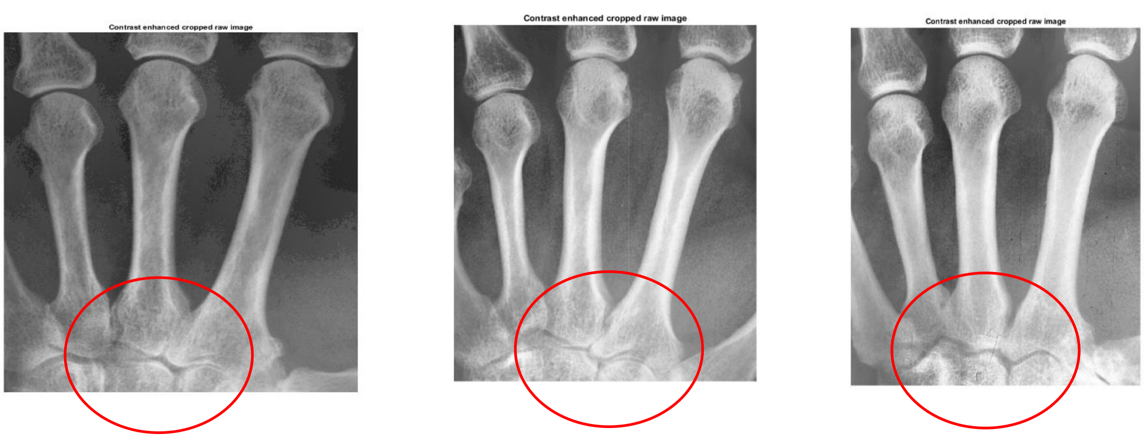

Figure 3: enhanced raw image (enhance the image before the cropping- data file 9, 10, 11 respectively).

Figure 4: enhance the contrast only on cropped image (data file 9, 10, 11 respectively)

The following step is to define a small kernel size/window size (having n x n dimension). From this sliding kernel, we are going to find the local Shannon entropy, mean and standard deviation, based on neighborhood. And change the central pixel value of the kernel according to the formulation. Shannon entropy equation is:

$$H(X) = \sum_{i=1}^{n} P(x_i)I(x_i) = -\sum_{i=1}^{n} P(x_i)log_b P(x_i).$$

Figure 5: Shannon entropy

Where P(X) is the distribution of pixel intensities inside the kernel, b is the logarithmic base. Form the experiments, kernel size was chosen as 9. [1]. after finding the Shannon entropy in each kernel, most of the boundary region of the bone is enhanced. Because when the bone is detected with the surrounding tissue, the entropy is high due to pixel intensity diversity [1] and where the alone bone or surrounded tissue is detected, the entropy is low. We proposed here to multiply standard deviations and divide mean(speckle contrast equation) of the kernel with the entropy to emphasize the low and high entropy difference clearly. In the hand radiograph, the standard deviation is high, where the kernel has bone and tissue together. And the standard deviation is less, where the kernel has alone bone or surrounding tissue. In figure 6, the proposed algorithm image is shown. But after seeing figure 6, the surrounding tissue is still detected (shown in green circle). At this point, if we are trying to apply the thresholding, it will include so much background tissue. And the goal is to segment bone only. So for eliminating these surroundings, the proposed algorithm complement the entropy image first (most of the surrounding tissue is brighter- figure 7) and then used un-sharp masking. To apply this first, the direct Matlab function imgaussfilt is used to smooth the image with standard deviation 20. And subtract that image from the entropy image (figure 6). After using the un-sharp mask, surrounded tissue was removed (figure 8 highlighted with green circle).

Figure 6: proposed algorithm image (entropy image - data file 9, 10, 11 respectively)

Figure 6: Complement of entropy image (data file 9, 10, 11 respectively)

Figure 7 :apply the unsharp mask to the complement of entropy image (data file 9, 10, 11 respectively)

In figure 8, we can see that the edge of the bone has higher intensity counts and the surrounding tissue has lower intensity counts. And somewhat inside the bone, there are some higher counts due to the image quality (which is very fine so inside bones algorithm detects small edges - shown with blue circles.). So In the next step, we need to threshold the image to segment bone edges with surroundings. For this operation, Matlab direct function graythresh is used. This function defines the threshold point according to otsu's thresholding method. And the Matlab function imbinarize is used to making BW (logical map) mask according to the threshold. Figure 9 shows us the threshold image.

Figure 8: Threshold image(data file 9, 10, 11 respectively)

For figure 9, we can say that, after the thresholding, still some of the surrounding edges in the background is thresholded. Some morphological operation has to be performed to remove false detected edges or sorroundings as much as the morphological operation can. In the next step series of morphological operation is performed. Follows by (1) Skeletanization; (2) remove the small flash object/edges. Figure 9 shows us a thick border on the edge (highlighted with yellow circle). And it is recommended to make it 1-pixel wide line. So Matlab function bwmorph(BW,'skel') is used to make it single pixel line. The results are shown in figure 10.

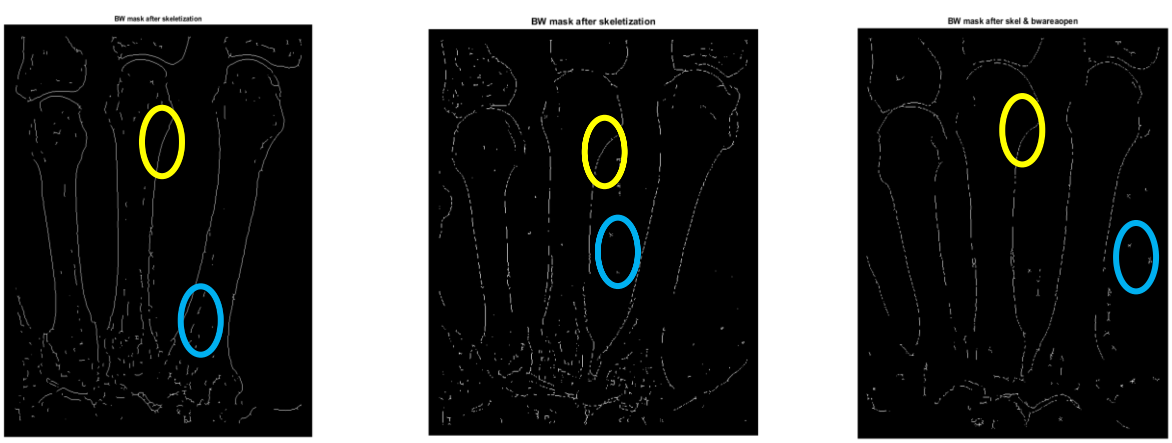

Figure 9: skeletelization on BW threshold mask. (data file 9, 10, 11 respectively)

If we compare figure 9 and 10, the detected edges are shrinking to the single pixel line (shown with yellow circle). But if we inspect the figure 10, there is some edge detection inside the bone and in the surroundings (shown in the blue circle.). So the following morphological operation is bwareaopen. That will remove the pixel up to the threshold. Here I am using 20 pixels as the threshold. So in figure 10, the bunch of pixels, which are 20 pixels or less than 20 pixels wide, will be removed. Figure 11 shows this operation results.

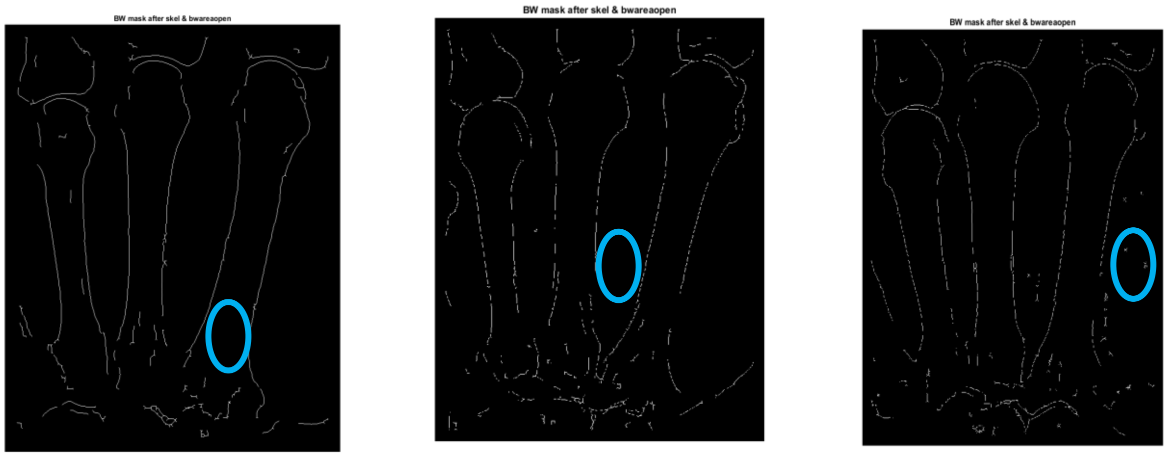

Figure 10: BW mask after skeletization & removing the false edges. (data file 9, 10, 11 respectively)

By figure 11, we can say that most of the false edges are removed (in figure 11 blue circle).but at some places it is not removing because of the threshold of 20 pixels.

This BW mask is overlaid on the original cropped image. Figure 12 shows the overlaid image. For overlaying, I am directly using the matlab function, iamoverlay. The whole process is summaries in figure 13.

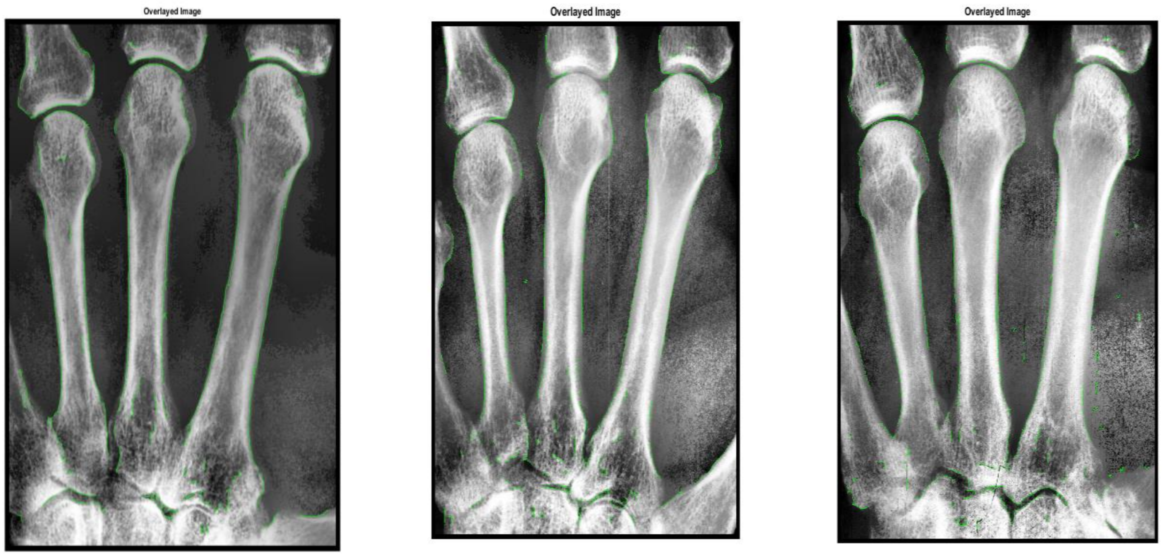

Figure 11: Final overlayed image with bone segmentation (data file 9, 10, 11 respectively)

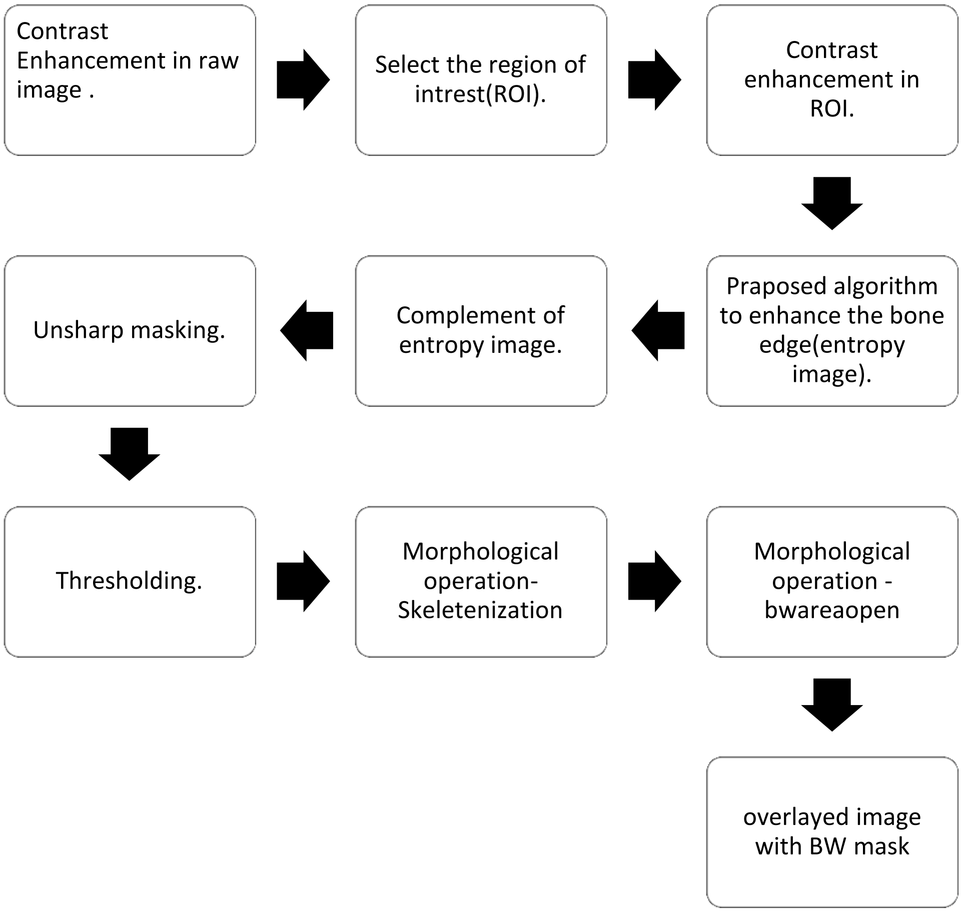

Figure 12: Image processing flow chart for segmenting metacarpals.

3. Discussion

To automatic segmentation of the bones in the hand radiograph efficiently is a time-consuming task. Here our task is to segment the metacarpals (mainly middle 3 metacarpals) with phalanges and carpals. When we see the contrast-enhanced image (figure 2) the first time, we can say that some of the metacarpals are overlapping to each other, it is very hard to see the borders of bones (where the intersection of the metacarpals and carpals) and they have less contrast image. So enhancing the contrast will give us the easily visual image. And it is very easy to set the ROI(figure 3). Here if we compare figure 3 and 4, figure 4 shows us a good contrast image after doing contrast stretching in ROI. By inspection, the thresholding is a suitable option to segment the metacarpals. But before this, we need to enhance the bone edge to segment it properly. So the proposed algorithm is used to enhance the bone edge. The proposed algorithm makes a sliding window according to kernel size, and finds Shannon entropy, mean and standard deviation. Here Shannon entropy is not appropriate to detect the bone edges because the place, where metacarpals and carpals are intersecting, has less contrast. So the algorithm needs to be enhanced. The division of standard deviation with mean is speckle contrast equation that find (enhance) the small speckles (same intensity pixels together) in the image. Using the multiplication of Shannon entropy with standard deviation and divide this multiplication with mean, figure 6 shows us good bone edge enhanced image. As explained in the methodology, due to many surrounding tissues the unsharp mask is used to reduce the effect of surroundings. After thresholding, most of the metacarpals are detecting (figure 9). The reason behind the used morphological operation is explained in the methodology section. But still some the edge is missing in the overlaid image. Because the contrast is different in all 3 raw images (the visibility of bone is decreasing from data file 11 to 9). here I have used a high clip limit parameter in adapthistiq. So we can see the data file 9 accurately. That might give adverse effect on data file 10 &11(It has higher contrast). So in figure 6, higher surrounding tissue is detected in figure 10 & 11. And threshold function is thresholding some of the surrounding tissue (figure 9 images 2 & 3). This is the thing when you are working on automatic code; you have to take care of so many parameters. This causes problem while doing morphological operation on data file 10 & 11. But it is still durable that the little chunks which are segmenting the metacarpals and carpals are partially segmented (figure 12).

4. Reference

1) https://www.mdpi.com/1099-4300/21/4/338.