Histogram Equalization on Medical Images: CLAHE implementation on CT images

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Abstract

In recent years, the development of both computer technology and advanced mathematics has brought the technology namely as image processing into light. Image processing is a versatile way of processing images by using algorithms on digital computers, with detail greater even than this of the human eye. Various diseases can be detected and treated timely, due to the advance of computer vision. In the medical field, a faster diagnosis equals to faster treatment process, therefore the development of image enhancing algorithms is of very important meaning, as medical images are developed in various conditions. The most common problem of medical images is low contrast. Therefore, Histogram Equalization is the most common technique used for image enhancement in the medical field. As every image is different, separate techniques should be used on each one. In this report we examine whether the use of CLAHE on Computer Tomography scans can be of benefit.

1. Introduction

In recent years, the development of both computer technology and advanced mathematics has brought the technology namely as image processing into light. Image processing is a versatile way of processing images by using algorithms on digital computers, with detail greater even than this of the human eye.
Nowadays, image processing comprises a fascinating research field, especially in medical field, due to the vast variety of processing the entirety of different medical image types that are in existence.

A plethora of perilous and widespread diseases, such as brain tumors, Cancer and Diabetes to name a few, can be diagnosed easily and accurately with the help of image processing.

The Magnetic Resonance Imaging (MRI) is a common technique for detecting tumors, as it is useful for extracting detailed, crucial information out of the medical image. Digital image processing techniques and machine learning in general can contribute in the early detection of tumors, as the tumor area itself is often clearly depicted in MRI, but there is the need for physicians to be able to quantify and extract more information out of the tumor area for a more accurate diagnosis and the subsequent treatment. [2]

The general processes that are followed in Computer Vision and Image Processing, are categorized into three levels: Low-Level, Mid-Level and High-Level.

- Low-Level processes: In such processes belong some basic functions, such as pre-processing, image sharpening and contrast enhancement.

- Mid-Level processes: segmentation and classification are characterized as Mid-Level processes.

- High-Level processes: Finally, High-Level processes include processes that attempt to represent human vision operations, such as object detection etc.

During the segmentation process, the medical image must go through several algorithms in order to detect the suspicious parts of the tumor and isolate them from the rest of the image. Vital information, such as the tumor location and size, need to be specified in order to be driven to a diagnosis and the subsequent treatment.

Two types of segmentation techniques exist, namely as automatic and manual. Manual extraction is proved to be more straining according to Vaishnavee et al [1], due to the reason that it requires more effort and more specialized knowledge from the human, thus the computational efficiency drops over time. Furthermore, according to Mohan et al., the automatic segmentation however is more efficient, as it is based on histogram analysis. The efficiency of this technique is significantly reduced though, when the image contains high levels of noise.

Medical Images are possible to be captured under various circumstances, and contain a variety of factors that make the image processing (especially the segmentation and all the subsequent processes) more difficult. In order for the whole medical image processing to be easier and the diagnosis to be more accurate and timelier, image enhancement is a vital process in the field of medical computer vision.

The term Image Enhancement describes the procedure of algorithm development, that serve to the clarification of the images in question. These procedures may involve speckle noise removal techniques, contrast increasement algorithms etc. There are several Image enhancement algorithms, such as gamma correction, homomorphic filter and etc., and each one exceeds in a different field, as image processing is used in various fields, such as medicine, space exploration, automated industry inspection, authentication etc.

There are specific criteria to determine which method should be preferred in each field. These criteria stem from the problem that is faced due to the "imperfections" of the image in question, as well as from the requirements in the detail of the data which is needed for each field.

For example, in the medical field, a low contrast image cannot offer much data, as there is the need for sharpness in the images of objects and clarity of boundaries, in order for the chosen features to be easily detected. Thus, a good and accurate way of medical image enhancement is the enforcement of Histogram Equalization Techniques as these techniques offer a satisfactory enhancement in terms of the contrast of an image. [3]

On section 2, two histogram equalization techniques applied in medicine are reviewed, section 3 presents the use of Contrast Limited Adaptive Histogram Equalization (CLAHE) in CT images, section 4 consists of the results, and section 5 concludes this report.

2. Histogram Equalization Techniques in Medicine

Histogram Equalization is the most common used technique when it comes to contrast enhancement in an image, due to its simplicity, compared to other, more traditional methods. Histogram Equalization functions based on the histogram of the input image. The output image consists of almost uniformly intense pixels, and a much-flattened histogram [5]. Histogram Equalization can have very good results in enhancing the contrast on a low-contrast image, but as mentioned above, every type of medical image has different needs. This is the reason why additional variable techniques of Histogram Equalization are used in Medicine.

2.1. Adaptive Histogram Equalization (AHE)

Histogram Equalization can only have one histogram as output, however Adaptive Histogram Equalization (AHE) is able to produce multiple histograms, corresponding to a different segment of the input image every time. AHE is usually used on medical images with dense backgrounds, such as mammograms, according to Singh H. et al. [6].

Fazli et al. [8], proposed an adaptive HE technique for segmentation of blood vessels in color retinal images. In this technique, two individual methods of retinal vessel segmentation are examined, specifically retinal vessel segmentation including first derivative of Gaussian matched filter and Gaussian matched filter. The results indicated that AHE is actually a suitable method for the Image Enhancement of medical images with low contrast, as the implementation of the two methods showed an accuracy of 0.9353, which was a raise of about 2 percent, compared to existing methods.

2.2. Multi-scale Adaptive Histogram Equalization (MAHE)

While AHE is a suitable HE technique for the enhancement of low-contrast medical pictures, there is a flaw that is caused because of the simultaneous processing to the picture that AHE performs, due to working over a certain size of a local window to determine each enhanced density value. Multi-scale Adaptive Histogram Equalization (MAHE) though, as Jin et al. [7] state, has the ability to separate the input signal into several separate spatial-frequency components. Thus, a different, suitable for each frequency filter can be applied, reducing the noise in the output as much as possible, and selected features can be extracted from the picture more easily.

The results of Yin et al. [7] implementation of MAHE indicate that it is a very promising method in the field of CT- image analysis, as it combines the simplicity of AHE with advantages of other modern methods, such as the selectivity of spatial-frequency components from wavelet analysis.

3. Use of Contrast Limited Adaptive Histogram Equalization (CLAHE) in CT images

Although the rest of the Histogram Equalization methods have the ability to enhance an image's contrast by working on the histogram of an input picture, there is a significant disadvantage when it comes to pictures with high intensity on several areas. As mentioned above, medical images can be developed in various conditions. For example, Magnetic Resonance Images often are low contrast. However, in medical pictures like Computer Tomography scans in areas with high density (for example a chest or a brain CT) if simple Histogram Equalization is applied, some parts may get too intense, and lots of valuable data deriving from details may be lost. In this case, Contrast Limited Adaptive Histogram Equalization (CLAHE) could be applied.

3.1. Methodology

CLAHE works by maximizing the contrast of pixels in an image after applying histogram equalization in properly segmented, contextual areas of the image. The use of the clipping limit is to lessen the noise amplification in the produced histogram, as any value above the clipping limit is cut. The cut part doesn't get discarded, but it gets evenly redistributed in the produced histogram, resulting in an enhanced, more balanced image, with greater detail and a more flattened histogram.

The algorithm which was used in order to enhance the image with CLAHE has the following steps:

Step 1: The image is loaded.

Step 2: Contextual areas are set. The size of the contextual area can be regulated by altering the limit.

Step 3: Equal pixels, meaning pixels with the same value in each contextual area, are counted.

Step 4: A clipping limit is set. This limit threshold will determine which values will pass on the histogram after the equalization. It must have value between 0 to 1. The clipping limit should be different, regarding the density of the picture

Step 5: Each pixel's value is compared with the clip limit value. The part of the histogram that was over the clip limit wasn't discarded. Instead, it will be redistributed.

The redistribution happens as follows. If a pixel with value greater than the clip limit is detected, then the following operation happens

increment=clip limit/value of pixel examined

Thus, the increment is incremented with the value of the clip limit divided by the intensity of the pixel. Otherwise, if the value of the pixel is less than the clip limit, then the increment is 1

Step 7: A partial rank is calculated with the function

partial rank=partial rank + increment;

Step 8: The redistribution happens. New distributed pixel values can be found from the redistribution value and will be incremented by partial rank.

redistribution = (total clipped value/(limit of window *limit of window)).*data(x,y)
output(x,y)=partial rank + redistribution value

4. Results

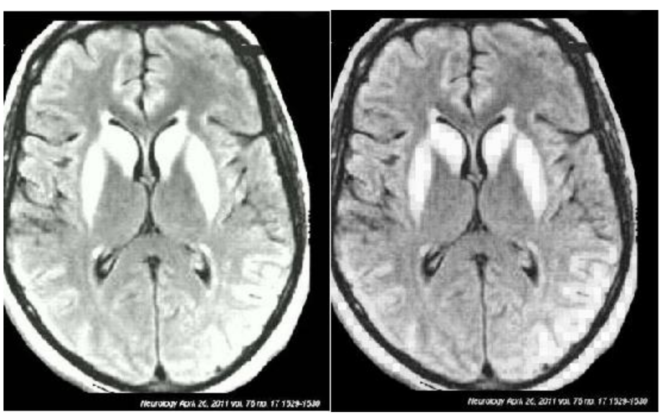

Figure 1: CT scan of brain before and after CLAHE

As it can be seen on Figure 1, the image after CLAHE implementation was a bit enhanced. Some more detail can be seen on otherwise intense areas.

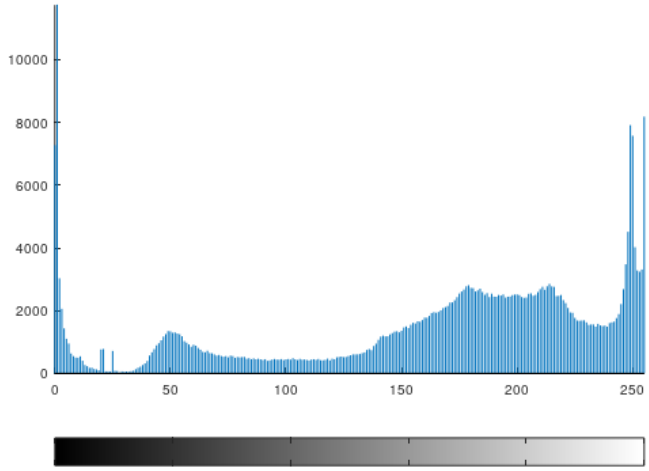

Figure 2: Histogram of image before CLAHE

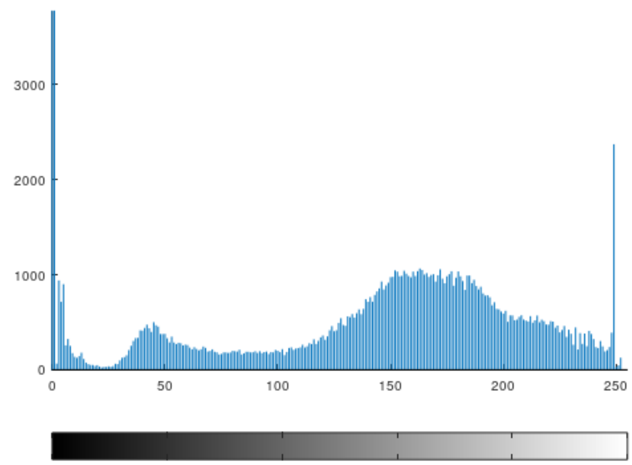

Figure 3: Histogram of the image after CLAHE

It can also be seen that the histogram of the image after CLAHE is a bit flatter than the histogram of the image before CLAHE. The values are a bit more evenly and uniformly distributed.

Although the results are good, there is still much detail that cannot be seen. Perhaps the combination of CLAHE with another method would have given some more detail.

5. Conclusion

This report was focused on the use of Histogram Equalization in the field of Medicine. Two types of Histogram Equalization (namely as Adaptive Histogram Equalization (AHE) and Multi-scale Adaptive Histogram Equalization (MAHE)) along with the original Histogram Equalization were presented. It was concluded that , even though Histogram Equalization is a decent Image Contrast Enhancing technique, it isn't adequate for use on its own in Medical images, therefore an alternative should be used, depending on the kind of the image. In addition, the use of Contrast Limited Adaptive Histogram Equalization (CLAHE) in Computer Tomography images with large intensity was examined. An algorithm for the application of CLAHE on a CT image was also examined. It was concluded that although the results were good and a bit more detail was visible, the technique still needs to be combined with another technique in order to have better results.

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