Medical Images Enhancement with Pseudo-HDR Method

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***Abstract*—Medical images are an important part of the diagnostic process. In many cases the accuracy of diagnosis depends on the quality of the image. Therefore, the image quality improvement is an essential part of medical imaging techniques. Now the quality enhancement process is divided into two parts: pre-processing, whose task is to optimize the image quality in the process of its creation by digital devices and apparata, and post-processing, whose task is increasing the readability and intelligibility of images on the physician's computer display. The proposed paper offers a new post-processing method for X-ray image quality enhancement using the theory of High Dynamic Range images (HDR-images). Since one could not get real images with different exposures, four techniques to simulate various levels of image exposures for HDR-image creation are proposed and analysed in the presented paper.**

Keywords - medical imaging; X-rays; HDR-images; quality enhancement.

I. INTRODUCTION

The investigation and development of new medical image processing methods and systems has received great attention over the last two decades. This is due to its wide range of applications in computer-assisted methods and computer-aided methods. Among the many types of image processing, image enhancement is one of the vital processes – it is one of the preparatory steps and it is applied before starting the image analyses. Image enhancement refers to any technique that improves or modifies digital images, so the resulting image is better suited than the original for a particular application. Essential image enhancement includes but is not limited to intensity and contrast manipulation, noise reduction, background removal, sharpening and filtering edges. In this context, 'image enhancement' means any method or technique which change digital images, so the resulting image is better suited than the original to a particular application. Due to this the basic types of image enhancement include manipulation of intensity, changing the local or global contrast, noise reduction, filtering and sharpening edges. During the image enhancement process one or more attributes of the image are modified. The choice of attributes and the way they are modified is specific to a given task. Moreover observer-specific factors such as the human visual system and the observer's experience will introduce a great deal of subjectivity into the choice of image enhancement methods [1].

X-ray images are grayscale images with 12-14 bits depth and their visual perception depends on the three most common image characteristics: brightness, contrast (local and global) and sharpness. Apart from these saturation and image dynamic range have a significant influence on the human perception of the images but they are not directly relevant to X-ray images, because images are grayscale (no saturation), and the dynamic range of the visualization systems (computer displays) is less than human vision dynamic range. Therefore, all quality enhancement methods change the intensity of pixels so as to provide optimal brightness, contrast and sharpness values. While brightness, contrast and sharpness may appear to be the simplest of image controls on the surface and may appear to be mutually exclusive controls, they are related and intertwined in such a way that changing any one of them can create quite complex effects in post-processed images. This specifies a wide variety of methods that have been proposed and are being created now – each of these methods seeks to solve the task of determining the image characteristics optimal values. A sample classification of medical image enhancement methods is shown in the Figure 1. [5][6][7][8]

This paper presents a new image enhancement method for X-ray images. The method uses HDR-image creation as a technique to increase the image dynamic range. This allows after mapping HDR-image to LDR-image (low dynamic range image) to get a better distribution of the intensity over all pixels in the image. The result is enhancing brightness, contrast and/or sharpness of images without the appearance of visible medical artefacts.

This present paper is structured as follows:

- Section II looks into the set of methods for HRD imaging
- Section III presents the proposed new enhancement method
- Section IV presents the implementation and analyses of the presented method
- Section IV presents the conclusion.

II. HDR IMAGING

A set of methods in photography/imaging, supposed to capture/create greater dynamic range between the darkest and lightest image areas than current standard digital imaging methods, is named High Dynamic Range Imaging [2][3]. The human eye covers the dynamic range of about 10^5:1 at one time and this is bigger than the top dynamic range of most real-world scenes. For comparison, computer

 ISBN: 978-1-61208-327-8

displays have dynamic range of 10^3:1 and digital cameras have dynamic range of 10^4:1. In the last two years HDR cameras with dynamic range just over normal human vision dynamic range and displays with near to human vision dynamic range began to appear on the market.

The human vision can be accommodated to a dynamic range of 10^{14}:1 but the iris is simply not as flexible and the human perception of intensity changes is logarithmic (the Weber law). This is much more than the capabilities of modern devices for image creation and visualization. Therefore, a non-HDR image device takes pictures at one exposure level with a limited contrast range. This leads to the loss of details in dark or bright image areas, depending on the camera exposure setting. HDR methods compensate detail loss by taking multiple pictures at different exposure levels and stitching them together to create an image which presents the greatest number of details in both dark and bright areas. Data stored in HDR-images typically corresponds to the physical values of luminance/radiance that can be observed in the real world and this presents a great difference from classical digital images: classical digital images represent intensities and colours that should appear on an output device (display, printer, plotter, etc.). Therefore, HDR image formats are called scene-referred while classical digital images are called device-referred.

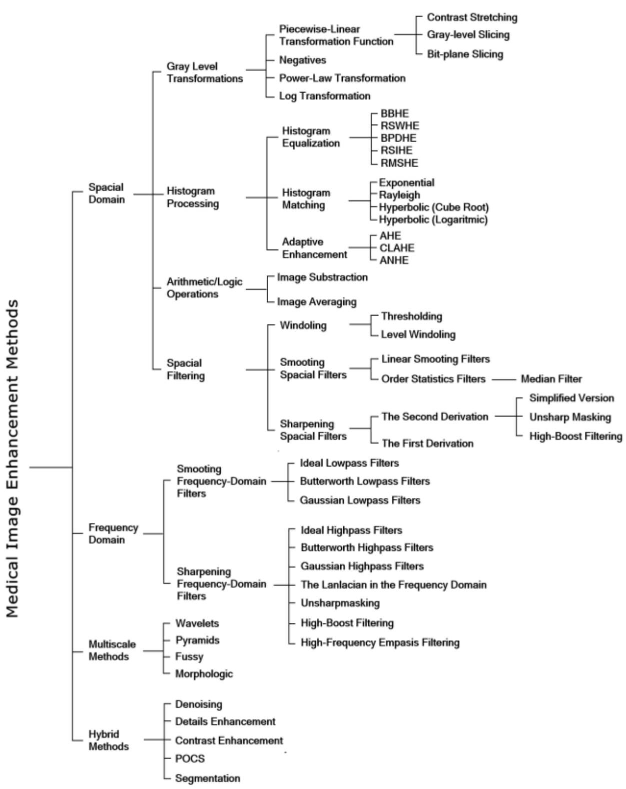


Figure 1. Medical image enhancement methods classification.

In photography dynamic range is measured in EV (Exposure Values) differences between the darkest and brightest parts of the image that show detail: an increase of 1 EV is a doubling of the amount of light. Using EVs not very strict categories of images are [4]:

- High Dynamic Range (HDR) images: These have a dynamic range of about 14EV and these images (they use 32-bit float values without limitation for channels bits depth) are usually produced by merging multiple 12-14 bit images of different exposures (most often these are raw data files).
- Medium Dynamic Range (MDR) images: These have a dynamic range of [9 EV, 12 EV] and can originate from a file with 16-bit depth, or by merging 3 or more 8-bit images with different exposures.
- Low Dynamic Range (LDR) images: These have a dynamic range of lover than 8 EV. This means one 8-bit image.

III. OUR QUALITY ENHANCEMENT METHOD

X-ray images are 12-14 bit grayscale images and their visual perception depends on the three most common image characteristics: brightness, contrast (local and global) and sharpness. Thus, when the image has no sufficient quality, this is the result of some incorrect values. As stored information in the grayscale images is the values for intensity of the image pixels, then all methods for quality enhancement are aimed at changing the pixel intensity as a way to change the basics characteristics of the image. This limits the opportunities for selection of optimal values, because a limited amount of information about the luminosity/radiance power stored as pixel intensity is used.

The method proposed below uses a different approach to solve the issue of the optimal intensity distribution over image pixels. Following this approach a model of the luminosity distribution is created instead, which has led to the current image. This is achieved by creating a HDR-image because it represents the description of the luminosity/radiance in the nature scene. After a HDR-image is created the method allows to determine the optimal mapping from a HDR-image to a LDR-image.

To achieve the correct results, it is necessary to establish a correct luminosity model of the simulated scene. For the HDR-image this is achieved by correctly selected additional images with different exposure. In photography this is achieved through capturing a new image with a selected exposure. Here this is not applicable and the main problem is to obtain an image that is accurate enough to simulate changes in the original image after changing the exposure.

From the image processing point of view increasing or decreasing the exposure changes the values of brightness, contrast and sharpness. Therefore, if the change of image pixels intensity resulting from the exposure change can be imitated, it can be used to simulate the image exposure change when a HDR-image is created. Our tests and analyses of results showed that for simulation a change in intensity a few different techniques can be used: using the brightness and the contrast control; using the gamma-correction; using the brightness and the contrast control followed by a gamma-correction; using the gamma-correction followed by a brightness and contrast correction.

 ISBN: 978-1-61208-327-8

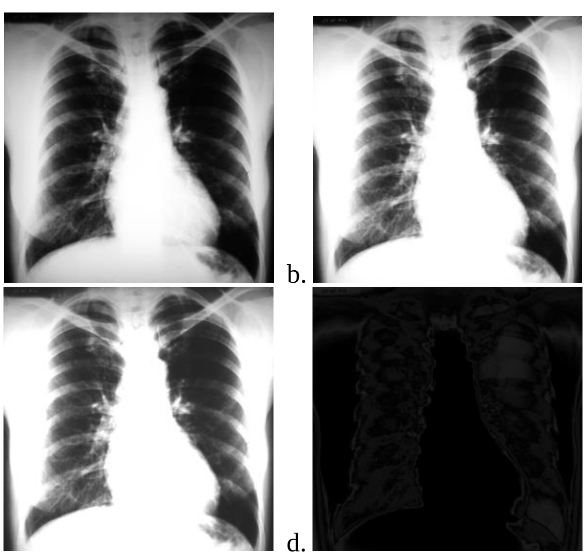
A. Using the brightness and the contrast control

One approach to solve the problem is based on the understanding that exposure change by 1 EV means doubling the amount of light. As the visual result is increasing of the pixels intensity for the entire image, the imitation of intensity shift requires calculation of brightness shift. Unfairness of this approach is that doubling the amount of light does not lead to doubling pixels intensity, because graphic devices and the characteristics of the created images reflect the human vision characteristics (logarithmic law for change of the intensity sensibility). Therefore, besides brightness there is also a considerable change in contrast.

Tests to determine brightness and contrast values were conducted: X-rays are captured with different exposures (from -3 EV to +3 EV by a 0.5 EV step) and the difference between the real image and the simulated image is evaluated to select values for brightness and contrast – Table 1 shows the results obtained for brightness and contrast (values of brightness and contrast are between -100 and +100). An example of -1.5 EV exposure simulations is shown in Figure 2.

TABLE I. EXPOSURE SIMULATION: GAMMA-CORRECTION VALUES

	Exposure (EV steps)					
		-2.5	***-2***	***-0.5***	***-1***	***-0.5***
Brightness		-81	-70	-55	-38	-21
Contrast		-35	-27	-20	-11	-5
	Exposure (EV steps)					
	0.5	***1***	***1.5***	***2***	***2.5***	
Brightness	22	40	56	71	83	
Contrast	6	16	26	34	46	



a. b. c. d.

Figure 2. Using brightness and contrast control: a) the original image; b) the image with +1.5 EV; c) the simulated image with -1.5 EV; d) the difference between images (b) and (c) - the histogram is stretched twice in order to see the difference.

Our experiments show that simulation of exposures above 2.5 EV and below -2.5 EV is unrealistic and cannot be used for HDR-like image generation – when mapping to a LDR-image the result always contains medical artefacts. However, for bone X-rays, this approach gives very good simulations.

B. Using the gamma-correction control

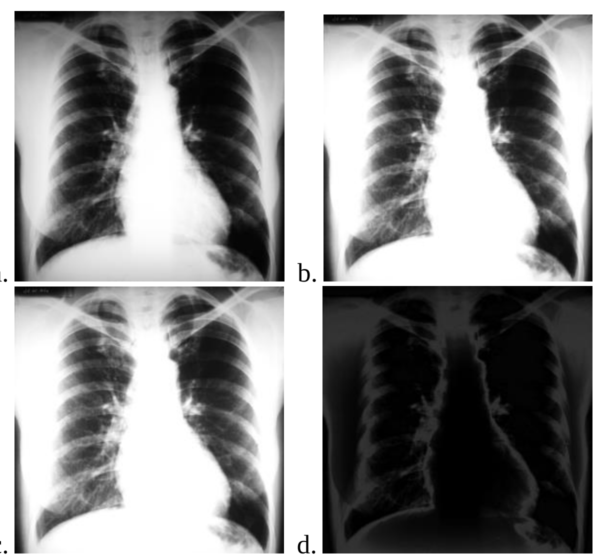
Another way to simulate changing the intensity of pixels is by changing the gamma-correction.

The difference between brightness and gamma-correction control is that increasing the value of gamma-correction can make the image to look brighter, but it is a non-linear change and it only increases brightness of the shadows and mid-tones in the image without affecting the highlights. Our experiments showed that this is particularly useful for simulating the overexposed images or the lung X-rays.

Another significant difference is the ability to simulate exposure values in the range [-5 EV, +5 EV]. Figure 3 shows an example from Figure 2, and Table 2 shows calculated values for gamma-correction.

TABLE II. EXPOSURE SIMULATION: GAMMA-CORRECTION VALUES

	Exposure (EV steps)					
	-3	***-2.5***	***-2***	***-0.5***	***-1***	***-0.5***
gamma-correction	6.0	4.9	3.7	2.8	1.9	1.3
	Exposure (EV steps)					
	0.5	***1***	***1.5***	***2***	***2.5***	***3***
gamma-correction	0.81	0.71	0.6	0.52	0.45	0.4



a. b. c. d.

Figure 3. Using gamma-correction control: a) the original image; b) the image with +1.5 EV; c) the simulated image with -1.5 EV; d) the difference between images (b) and (c) - the histogram is stretched twice.

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C. *Using the brightness and the contrast control followed by gamma-correction*

The main disadvantage of using brightness and contrast control is the incorrect change of local contrast between lung structures and ribs. That is why we tested additional image correction – the gamma correction. The result is a significant improvement of the simulation - Figure 4 shows the example from Figure 2, but now with the new way of correction. Table 3 shows calculated values for simulation of an exposure change.

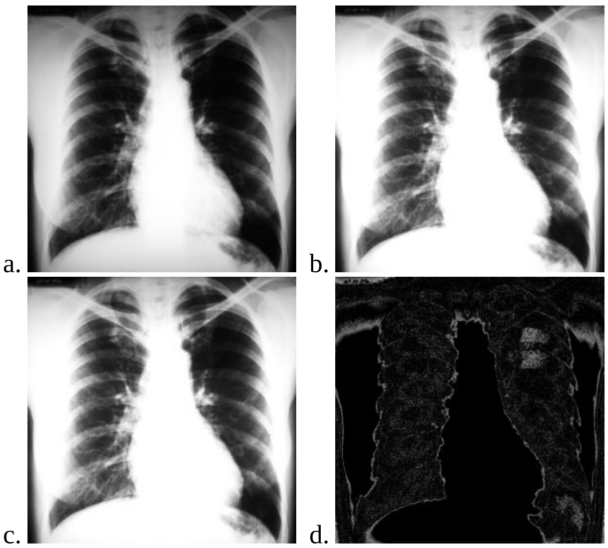

Figure 4. Using brightness and contrast control: a) the original image; b) the image with +1.5 EV; c) the simulated image with -1.5 EV; d) the difference between images (b) and (c) - the histogram is stretched 32 times.

TABLE III. EXPOSURE SIMULATION: BRIGHTNESS AND CONTRAST FOLLOWED BY GAMMA-CORRECTION

	Exposure (EV steps)					
		-2.5	***-2***	***-0.5***	***-1***	***-0.5***
brightness		-81	-70	-55	-38	-21
contrast		-35	-27	-20	-11	-5
gamma-correction		1.55	1.34	1.21	1.12	1.05
	Exposure (EV steps)					
	0.5	***1***	***1.5***	***2***	***2.5***	
brightness	22	40	56	71	83	
contrast	6	16	26	34	46	
gamma-correction	0.95	0.87	0.78	0.66	0.53	

D. *Using the gamma-correction control followed by brightness and the contrast correction*

The last approach to create an exposure simulation is gamma-correction control followed by brightness and contrast correction. This approach differs from the previous one, because the operations are not commutative. When comparing the result with the second approach, it appears that in this case the lighter areas are correctly changed. The result is the best simulation of exposure change of an image - Figure 4 shows the example from Figure 2. Table 4 shows calculated values for simulation of an exposure change.

Another advantage of the third approach is the possibility to simulate a much larger range of exposure values.

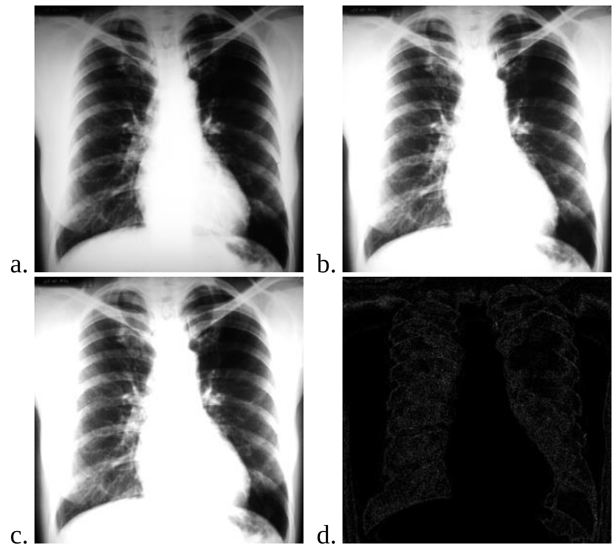

Figure 5. Using brightness and contrast control: a) an original image; b) an image with +1.5 EV; c) a simulated image with -1.5 EV; d) the difference between images (b) and (c) - the histogram is stretched 32 times.

TABLE IV. EXPOSURE SIMULATION: GAMMA-CORRECTION CONTROL FOLLOWED BY BRIGHTNESS AND CONTRAST CORRECTION

	Exposure (EV steps)					
	-3	***-2.5***	***-2***	***-0.5***	***-1***	***-0.5***
brightness	-52	-41	-26	-13	-4	-2
contrast	-55	-48	-34	-23	-17	-9
gamma-correction	6.0	4.9	3.7	2.8	1.9	1.3
	Exposure (EV steps)					
	0.5	***1***	***1.5***	***2***	***2.5***	***3***
brightness	6	14	18	22	25	27
contrast	7	17	24	32	38	42
gamma-correction	0.81	0.71	0.6	0.52	0.45	0.4

IV. METHOD IMPLEMENTATION AND ANALYSIS OF RESULTS

Using this method to enhance the X-ray quality gives a significant change even in the exposure values [0 EV, -0.5 EV, +0.5 EV] but in general this is not the best combination of values.

There are several different options for the number of LDR-images and their exposures from which the HDR-image will be generated – most common are 3 LDR-images

 ISBN: 978-1-61208-327-8

with exposures [0 EV, -2 EV, +2 EV]. Our tests have shown that this set of exposures often leads to increased noise levels. So, as a standard set of exposure values, we used [0 EV, -1.5 EV, +1.5 EV]. This list of exposure values can be used in most cases, but for some specific purposes there are other parameters:

- In case of overexposed images, the best results are achieved with a set of 5 images with exposure values [0 EV, -1.5 EV, +1.5 EV, -2 EV, +2 EV].
- In case of underexposed images, the best results are obtained when using the set of exposure values [0 EV, -1 EV, - 2.5 EV].
- In case of X-rays of bones, good results are obtained with asymmetric values for the minimum and maximum exposure – for example [0 EV, -2 EV, +1 EV]. This set increases details in lighter areas (like bone structures).
- In case of lung or soft tissues X-rays, good results are obtained with opposite asymmetric values for the minimum and maximum exposure – for example [0 EV, -1 EV, +2 EV]. This set increases details in darker areas.
- In case of an image with a small dynamic range, a set of 5 images has to be used. This increases the details for all structures with different radiographic densities.

Another major advantage of the proposed method is the ability to manage the transformation from a HDR-image to the final LDR-image. This allows an optimal image quality to be obtained without the occurrence of medical artefacts.

The comparison of the results of the proposed method with other techniques showed that this method can help to obtain a major improvement in quality without the occurrence of medical artefacts. Especially important is the opportunity to use the same characteristics in all cases and always to get good quality – for example 5 images with exposure values [0 EV, -1.5 EV, +1.5 EV, -2 EV, +2 EV].

A few examples of the method implementation and comparison with Laplacian pyramids filter and CLAHE are shown in Figure 6.

V. CONCLUSION

Image quality enhancement is very important because it increases readability and understandability of the analysed images, their details and structure. When the exploited for image generation model is known this increases possibilities to correct the image without generation of medical artefacts. The presented method for pseudo HRD enhancements of medical images enables increasing quality of understanding and information gathering.

The next steps of this research are oriented to X-ray images of other body parts like bones, abdominal cavity, other soft tissues as well analyses of images from CT and other medical image sources.

ACKNOWLEDGMENT

This work is funded partially by the Bulgarian NSF under DO02/113 and DRNF02/3 projects.

REFERENCES

[1] K. Arulmozhi, S.A. Perumal, K. Kannan, and S. Bharathi, “Contrast Improvement of Radiographic Images in Spatial Domain by Edge Preserving Filters,” IJCSNS International Journal of Computer Science and Network Security, Vol.10 No.2, February 2010, pp. 233-240.

[2] E. Reinhard, W. Heidrich, P. Debevec, and S. Pattanaik, High Dynamic Range Imaging: Acquisition, Display, and Image-Based Lighting, 2nd Edition, Morgan Kaufmann, ISBN 978-0123749147, 2010.

[3] F. Banterle, A. Artusi, K. Debattista, and A. Chalmers, Advanced High Dynamic Range Imaging: Theory and Practice , A K Peters/CRC Press, ISBN 978-1568817194, 2011

[4] D. Nightingale, Practical HDR: A complete guide to creating High Dynamic Range images, 2nd edition, ISBN 978-0240821221, 2011

[5] R. Maini and H. Aggarwal, A Comprehensive Review of Image Enhancement Techniques, Journal of Computing, Vol. 2, issue 3, March 2010, pp.8-13.

[6] A. M. Trifas, Medical Image Enhancement, PhD Thesis, Louisiana State University and Agricultural and Mechanical College, Dec. 2005.

[7] Y. Abu Sadah, N. Al-Najdawi, and S. Tedmori, Exploiting Hybrid Methods for Enhancing Digital X-Ray Images, The International Arab Journal of Information Technology, Vol. 10, No. 1, January 2013,28-32.

[8] S.S. Bedi and R. Khandelwal, Various Image Enhancement Techniques - A Critical Review, International Journal of Advanced Research in Computer and Communication Engineering, Vol. 2, Issue 3, March 2013, pp.1605-1609.

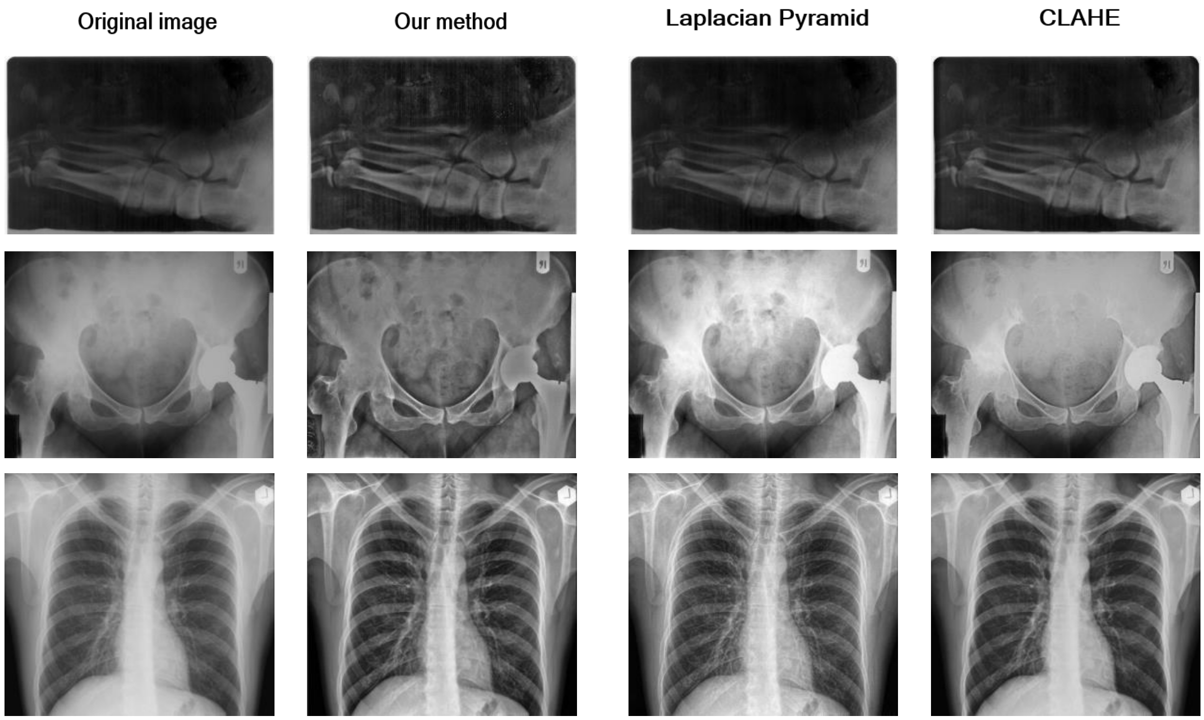

Figure 6. Comparison between our method, Laplacian pyramids and CLAHE: the proposed method improves contrast and details.