

Enhancement of Computed Tomography Image using Laplacian Filtering Technique

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ABSTRACT

Computed tomography image enhancement is the processing of medical images to improve their appearance to human viewers, in terms of better contrast and visibility of features of interest, or to enhance their performance in subsequent computer-aided analysis and diagnosis. In this paper, laplacian filtering techniques are applied on the computed tomographic image for improve their performance. These techniques are mathematical techniques that are aimed at realizing improvement in the quality of a given image. The result is another image that demonstrates certain features in a manner that is better in some sense as compared to their appearance in the original image. Basic aim of paper is to improve the image quality of the CT image. Various image quality measures have been applied to find the performance of the image enhancement.

Keywords: Medical imaging, Laplacian filtering, image enhancement, RMSE, PSNR.

1. INTRODUCTION

Medical imaging [6, 7] deals with the interaction of all forms of radiation with tissue and the design of technical systems to extract clinically relevant information, which is then represented in image format. Medical images range from the simplest such as a chest X-ray to sophisticated images displaying temporal phenomena such as the functional magnetic resonance imaging (fMRI) [6].

Medical imaging systems detect different physical signals arising from a patient and produce images. An imaging modality is an imaging system which uses a particular technique. Some of these modalities use ionizing radiation, radiation with sufficient energy to ionize atoms and molecules within the body, and others use non-ionizing radiation. Ionizing radiation in medical imaging comprises x-rays and γ -rays, both of which need to be used prudently to avoid causing serious damage to the body and to its genetic material. Non-ionizing radiation, on the other hand, does not have the potential to damage the body directly and the risks associated with its use are considered to be very low. Examples of such radiation are ultrasound, i.e. high-frequency sound, and radio frequency waves.

Medical imaging involves a good understanding of imaging medium and object, physics of imaging, instrumentation, and often computerized reconstruction and visual display methods. Though there are a number of medical imaging modalities available today involving ionized radiation, nuclear medicine, magnetic resonance, ultrasound, and optical methods, each modality offers a characteristic response to structural or metabolic parameters of tissues and organs of human body.

Medical imaging is a process of collecting information about a specific physiological structure (an organ or tissue) using a predefined characteristic property that is displayed in the form of an image. For example, in X-ray radiography, mammography and computed tomography (CT), tissue density is the characteristic property that is displayed in images to show anatomical structures. The information about tissue density of anatomical structures is obtained by measuring attenuation to X-ray energy when it is transmitted through the body. On the other hand, a nuclear medicine positron emission tomography (PET) [6, 7] image may show glucose metabolism information in the tissue or organ. A PET image is obtained by measuring gamma-ray emission from the body when a radioactive pharmaceutical material, such as flurodeoxyglucose (FDG) [6] is injected in the body. FDG metabolizes with the tissue through blood circulation eventually making it a source of emission of gamma-ray photons. Thus, medical images may provide anatomical, metabolic or functional information related to an organ or tissue.

The basic process of image formation requires an energy source to obtain information about the object that is displayed in the form of an image. Some form of radiation such as optical light, X-ray, gamma-ray, RF or acoustic waves, interacts with the object tissue or organ to provide information about its characteristic property. The energy source can be external (X-ray radiography, mammography, CT, ultrasound), internal [nuclear medicine: single photon emission computed tomography (SPECT); positron emission tomography (PET)], or a combination of both internal and external

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such as in magnetic resonance imaging where proton nuclei that are available in the tissue in the body provides electromagnetic RF energy based signals in the presence of an external magnetic field and a resonating RF energy source. As described above, image formation requires an energy source, a mechanism of interaction of energy with the object, an instrumentation to collect the data with the measurement of energy after the interaction, and a method of reconstructing images of information about the characteristic property of the object from the collected data. The following imaging modalities are commonly used for medical applications today.

Tomographic imaging, of which x-ray computed tomography (CT) is an example, is a technique that was developed for producing transverse images, by scanning a slice of tissue from multiple directions using a narrow fan-shaped beam. The data from each direction comprise a one-dimensional projection of the object, and a transverse image can be retrospectively reconstructed from multiple projections.

2. LAPLACIAN FILTERS

The directional sensitivity of the laplacian filters means it is necessary to apply rotated variants of the kernels several times and combine the outputs to get a direction insensitive output. Often it is more convenient to use a more isotropic single kernel. The simplest and commonest of these is the Laplacian, the 3 X 3 kernel of which is shown in Fig. 3.31 together with its corresponding Fourier spectrum. The Laplacian is formally a *second derivative* filter [1, 5] – it measures, effectively, the gradient of the gradient. The advantage of a second derivative filter for edge detection is that it will usually define edges more precisely than a first derivative filter.

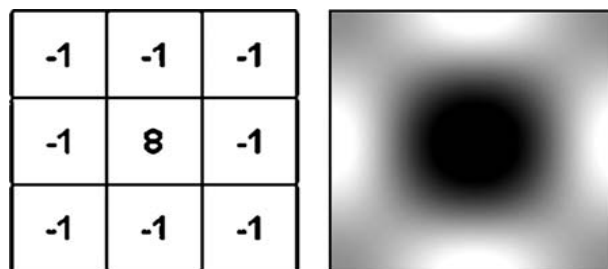


Fig.1: Laplacian kernel calculates the second derivative of the image intensity. The 3 X 3 Laplacian kernel and its Fourier spectrum are shown here. Note that the sum of the kernel elements is zero, so the output is not scaled. The Fourier spectrum confirms that convolution with this kernel acts as a high pass filter

How can we tell that the Laplacian calculates the second derivative of pixel intensities? This is not immediately obvious looking at the kernel, but it makes sense if we think about what is happening in any single line through the center of the kernel: The sequence of kernel elements is -1,8,-1. In other words, the kernel is the sum of four 3 X 1 kernels (one vertical, one horizontal, and two diagonal) whose elements are [-1 2 -1]. Any one of these 3 X 1 kernels is the sum of two 2 X 1 difference kernels with elements [-1 1] and [1 -1], or the *difference* between two identical difference kernels with elements [-1 1] where the second kernel is displaced one pixel from the first. The 2 X 1 kernels calculate the intensity differences between one particular pixel and those on either side of it. Subtracting one offset kernel from the other gives the 3 X 1 kernel [-1 2 -1] that calculates the difference between the differences – in other words, the second derivative! In contrast to the Roberts Cross filter [5] we now have a single central kernel element so there is no confusion about where to put the output. The sum of the elements of the Laplacian is zero. If it is applied to a neighborhood in which all the gray scale intensities are identical the output will be zero. Thus any region of constant intensity will become black in the filtered image. When the intensity of the central pixel differs substantially from its neighbors, as may be the case for noise, the output of the Laplacian is very high because it sums *all* differences between a pixel and its eight neighbors. Although the Laplacian filter [1, 5] is good for edge detection it has a tendency to exaggerate lines and noise even more than edges. For this reason it is sometimes used as a point defect detector. This effect is demonstrated in Fig. 2 where we see a test pattern comprised of mid-gray features: a rectangle, a narrow line, and a series of very small (almost invisible) points comprised of single pixels. When a 3 X 3 Laplacian kernel is applied to this image the edges of the rectangle are isolated as expected. However, the line feature is enhanced more than the edges of the rectangle, and the previously very faint points become quite distinct.

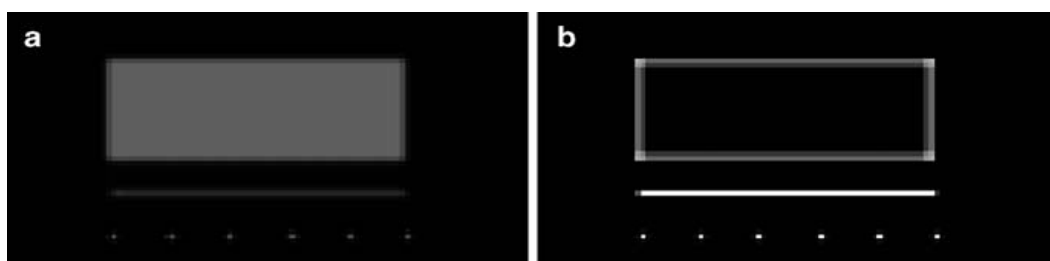


Fig. 2: Demonstration of edge selection and point and line exaggeration of Laplacian kernel. (a) Test image. (b) Effect of convolution with 3X 3 Laplacian. Note that the originally inconspicuous point features (single pixels of same intensity as large rectangle) are strongly enhanced, the line feature less so, and the edge of the gray rectangle less again. This is a notable characteristic of Laplacian filters

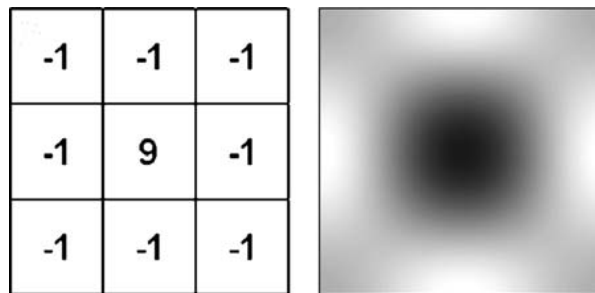


Fig. 3: a 3x3 ‘High Boost’ kernel and its corresponding Fourier spectrum. Note that the sum of the kernel elements is one so the image intensity in homogeneous regions will be unchanged. The gray center of the Fourier spectrum indicates that low frequencies are only partially attenuated so tonal detail is retained

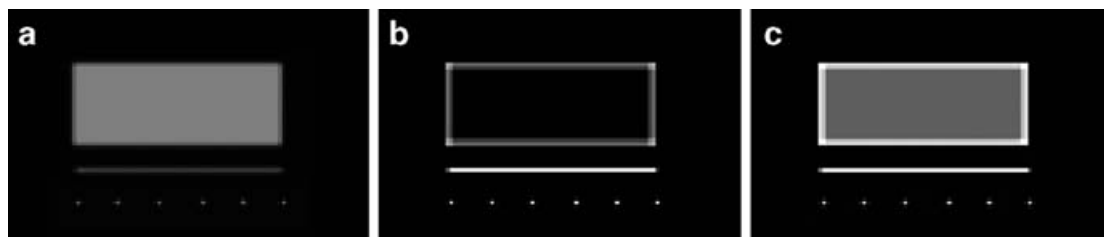
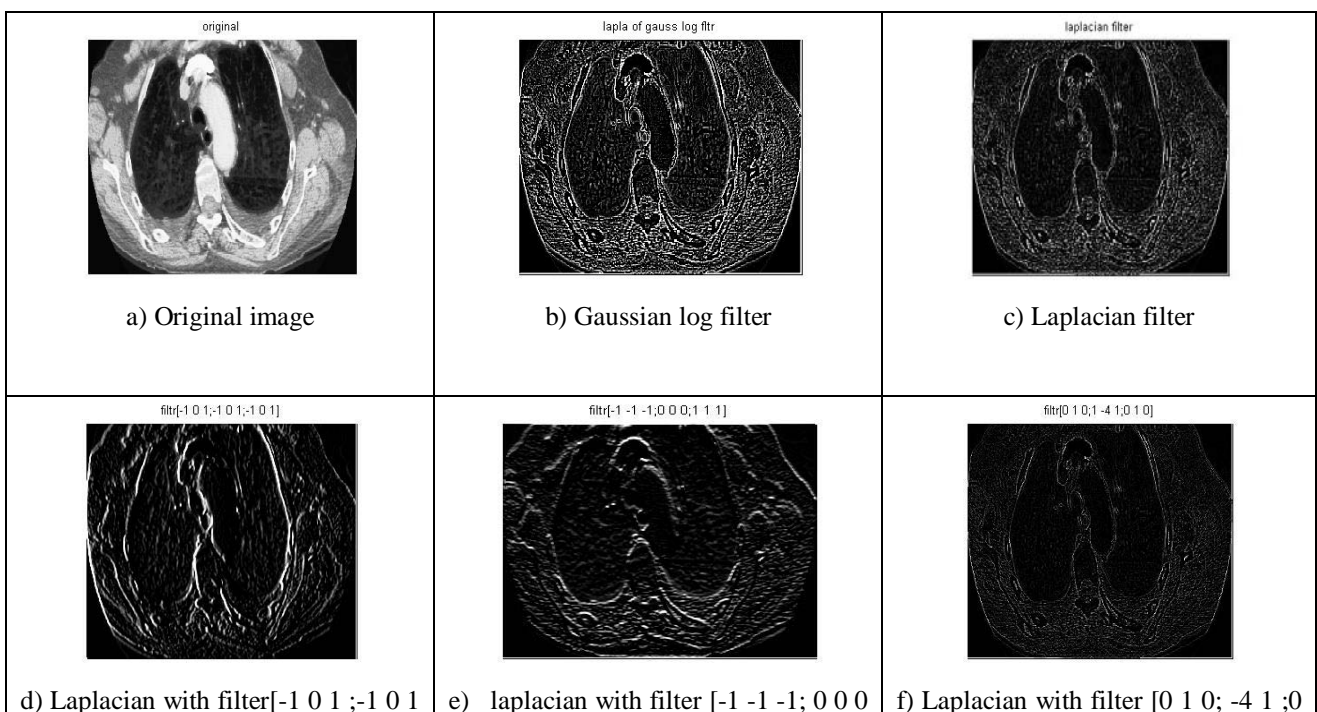


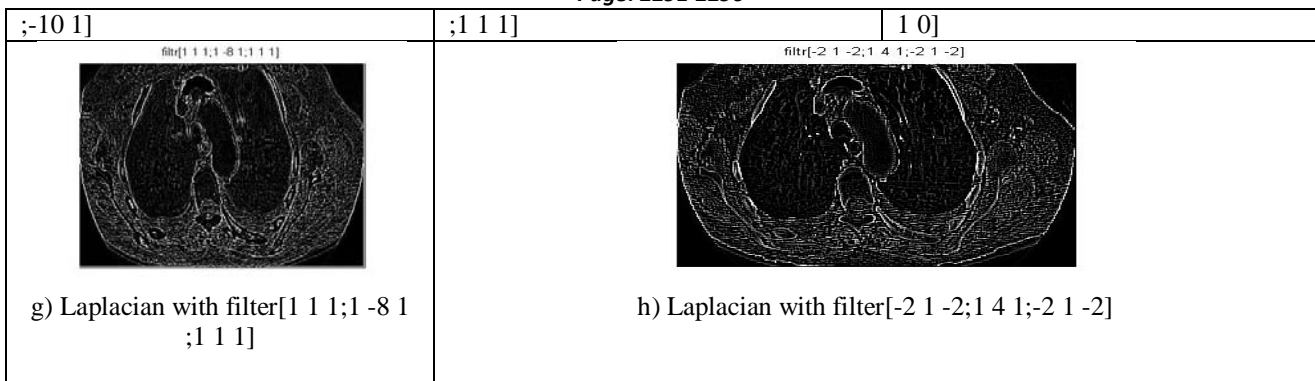
Fig. 4: High Boost filter demonstration. (a) Original image. (b) Laplacian only. (c) High boost.

Often the aim is not to isolate the edges in an image but to *enhance* them. This can be achieved by adding the output of a Laplacian high pass filter to the original image. This is equivalent to adding a one to the central element of the Laplacian convolution kernel (Fig. 3). The resulting filter is referred to as a *High Boost* filter because its effect is to increase the relative intensity of high spatial frequencies (Fig. 4).

3. EXPERIMENTAL RESULT

Table 1 reports the performance of the filters upon the computed tomography image. Figure 5(a) shows the original image. The other images in figure 5(b-h) shows the results for the laplacian filter,





For the filtering method as mentioned in the Sr.no 1 to 7 which are the laplacian methods with the various mask as mentioned in the fig. These filters are popularly used for detecting and enhancing the edges of the medical images. From the Table 1 it is clearly observed that mean square error(MSE) of the proposed laplacian 4 with mask[-1-1-1;0 0 0;1 1 1] performs better result as compared to the other laplacian filters. However, from the figure 5 the corresponding figure for the said mask detects the edges efficiently compared to the other laplacian filters. Hence, it is conclude that the performance of the proposed laplacian filter 4 is highly enhanced as compared to the other laplacian filters.

Sr. No	Filtering method	MSE	RMSE	PSNR	AVG DIFF	MEAN	STD
1	ct_laplacian_log	9658	98.27	8.28	39.86	122.52	115.50
2	ct_laplacian	9318	96.53	8.43	49.43	112.92	116.11
3	ct_laplace5	9130	95.55	8.52	53.23	109.15	117.70
4	ct_laplace4	9051	95.14	8.56	55.45	106.93	117.36
5	ct_laplace3	9855	99.27	8.19	59.02	103.36	118.01
6	ct_laplace2	9357	96.73	8.41	48.45	113.93	115.93
7	ct_laplace1	7391	85.97	9.44	50.43	111.95	116.48

Table 1: Performance of the laplacian filters upon the CT image

Fig 5: Output images of the filtering methods for the CT image.

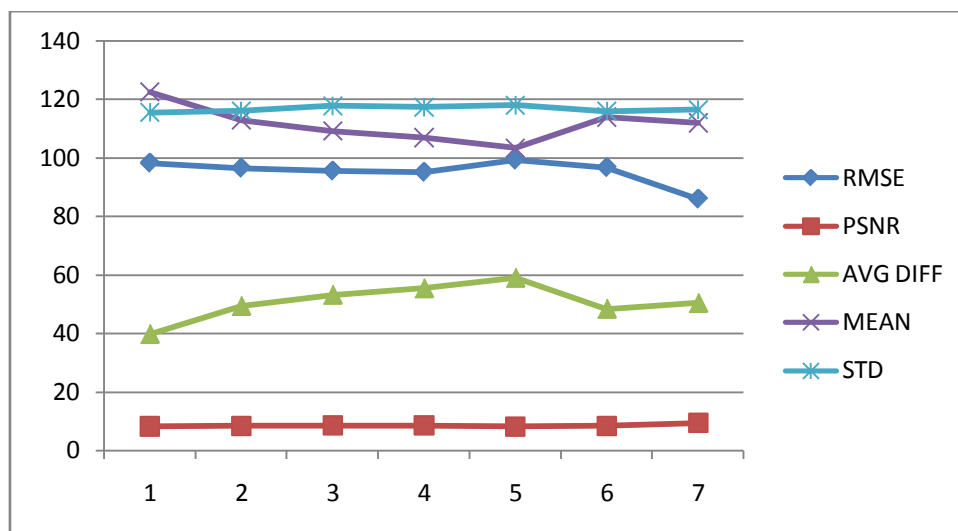


Fig 6: Graphical Analysis

4. CONCLUSION

This research has been devoted to the image enhancement techniques based upon the laplacian filter that can be applied to enhance noisy CT medical image. The trade-off between noise elimination and detail preservation was analyzed using the MSE, RMSE, PSNR, AD, MEAN and STD and visual criteria. Thus a comparison between the qualities and performance of various laplacian filtering techniques were deduced using these criteria. Effectiveness of each laplacian filter with various kernel size and values is dependent on the type of image, the error criterion used, the nature and amount of contaminating noise. It was seen that the laplacian filtering techniques with mask[-1-1-1;0 0 0;1 1 1] performs better result as compared to the other laplacian filters value; this can be clearly seen with its considerable improvement in PSNR and producing visually more pleasing images.

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