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Research paper

Comparative analysis of image enhancement techniques applied to CT liver image

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Abstract

Computed Tomography (CT) is very much useful for doctors to analyze biological changes of internal organs. CT images of liver and lungs will have low contrast. So doctors cannot identify all types of diseases from CT images. Hence image processing techniques are used to enhance the CT images to help doctors for diagnosis has considerable interests now a day. In this paper, different methods of image enhancement for low contract liver CT images are studied.

Keywords: *CT Scan; Image Enhancement; Image Negative and Image Sharpening*

1. Introduction

Computed tomography uses both X–ray and computer technology to produce 3D images that is horizontal, or axial images of any body part, including internal organs, fat, muscles and bones. CT scan of any body part gives more detailed image than X-rays.
CT scan may be done to identify various types of cancers, abnormal tumors, growths or lumps. They also used to identify the location of tumors and stages of cancer for diagnosis. Jaundice is of obstructive or nonobstructive, this can be identified in CT scan of liver.
CT scans of abdomen give more information about the liver, gallbladder and other structures of abdomen than X-rays.
The liver functions include protein production, blood clotting factor, manufacturing cholesterol, glucose (sugar), and iron metabolism. A variety of illnesses can affect the liver, for example, hepatitis, cirrhosis, non-alcoholic fatty liver disease, alcohol abuse, Epstein Barr virus (infectious mononucleosis), iron overload (hemochromatosis), etc. liver disease cannot be identified in the CT scan image. Hence image enhancement techniques are used to enhance the CT Liver image so that doctors can identify the disease more clearly.

2. Related work

a) Image Enhancement Techniques

Image enhancement techniques are used to improve the features of image such as edges and changing the contrast of image to make it more useful for analysis and diagnosis purpose in case of medical images.
Commonly used image enhancement techniques are point operation, spatial operations, transform operations and pseudocolouring [1].
Point operations: These operations map the gray level of input image to gray level of other values depending upon transformation. The following are gray level transformation techniques.

Contrast stretching: Usually Low contrast images occur due to improper lighting situations or due to low dynamic range of sensor. Fig. 1 shows contrast stretching enhancement method, which is explained in equation (1).

$$v = \begin{cases} \alpha u & 0 \le u \le a \\ \beta(u-a) + v_a & a \le u \le b \\ \gamma(u-b) + v_b & b \le u \le L \end{cases} \quad (1)$$

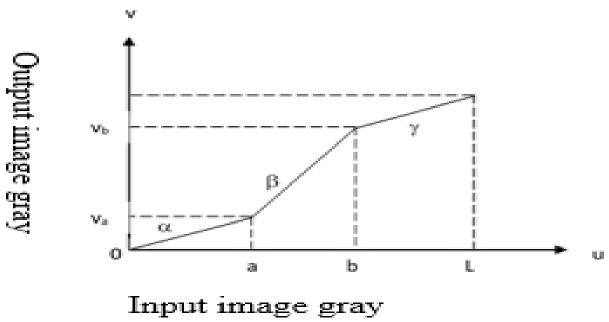

Fig.1: Contrast Stretching.

b) Clipping and thresholding: In contrast stretching, if α=γ=0, then it is called clipping. Clipping is mainly used for noise removal. A special case of clipping is thresholding where a=b≜t and in thresholding output image is binary image.

c) Digital Negative: Digital negative of an image is obtained by subtracting input image gray levels from highest grey value present in the input image according to the formula $v = L - u$ where u indicates input image, v indicates output image, L is highest value of gray level present in input image.

d) Range Compression or Log transformation: This transformations can be expressed by the formula

$$v = c\log(u+1) \quad (2)$$

Where c is a constant value, u and v are the grey values of the input and the output image. Since log(0) is infinity. If there are any grey level value of input image is zero, value 1 is added to all grey level values of input image. So that log(0) will not occur.
In log transformation, the pixels with low inteensity values in input image are expanded as compare to the pixel values with high intensity values. The pixel values eith high intensity are compressed in log transformation.

e) Power-Law transformation: This transformation can be given by the following equation:

$$v = cu^{\gamma} \quad (3)$$

The symbol γ is called gamma, because of that the transformation is called as gamma transformation. By changing the value of γ, the quality of the images also changes.

f) Image slicing without background: in this, if v is less than A and greater than B, u=0, else if v is greater than A and less than B, then u=255

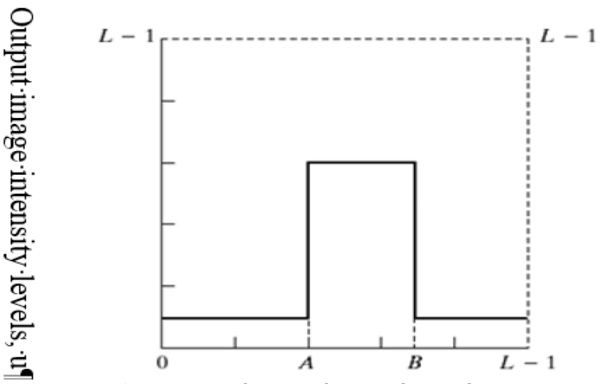

Fig. 2: Image Slicing without Background.

g) Image slicing with background:
In this, if v is less than A and greater than B, u=v, else if v is greater than A and less than B, then u=255

1) Histogram Modelling: The histogram of an image gives how frequently different gray levels occur in the image. Histogram modeling methods are used to change an image so that its histogram has a required form. To get enhanced image from low contrast image whose histogram is concentrated at low intensity levels and it has narrow histogram also. This is one of the useful method for enhancing the quality of image.
2) Spatial Operations: Spatial operations are performed on local neighborhoods of input pixels. Spatialoperations are used in many image enhancement techniques. In this method, the input image is convolved with impulse response of filter (called spatial mask) to get output image.
3) Transform Operations: In this method, first transform techniques are used, then finally output image will be obtained by inverse transformation techniques.

3. Image enhancement operations on CT scan of liver

Various image enhancement operations are applied on CT image of liver with cancer as shown in fig.4. Fig.5. is output image obtained by performing contrast stretching with values the following values: α=1.5, β=1.3 and γ=0.3. In fig.2, most of liver area has become smooth. The cancer parts of liver can be identified. Fig.6. is output image obtained by applying digital negative to input image as shown in Fig.4. In Fig.6. also cancer part of liver can be identified.
The output image, after applying Power law transformation with gamma=1.1 is show in fig.7. The output image with gamma transformation with gamma=1.1 gives better output compare to contrast stretching and digital negative image output. The output image using Log transformation is shown in Fig.8 and the output image using Power law transformation with gamma=0.9 shown in Fig 9 does not give better results compare to other methods. The output image using range compression is shown in Fig. 10.
Other output are obtained using MATLAB commands and masks as explained below Spatial high pass filtering: the following two masks are used to enhance the high frequency component of image [0, -1, 0; -1, -1, -1; 0, -1, 1] and [0, -1, 0; -1, 5, -1; 0, -1, 0]
The output image using above mask is shown in fig.14.

1) Average filtering: Here fspecial and imfilter operations are used to perform average filtering operation. The Matlab code for these operations are

```
h = fspecial ('average', 3)

F=imfilter (I,h)
```

The ouput image obtained using above code is shown in Fig.16.

2) Spatial Averaging/Low-Pass Filtering: the following masks are used to perform spatial averaging and low pass filtering of image respectively.

[1/9, 1/9, 1/9; 1/9, 1/9, 1/9; 1/9, 1/9, 1/9] and
[1/8, 1/8, 1/8; 1/8, 1/2, 1/8; 1/8, 1/8, 1/8]
The output image using above mask is shown in fig.15.

3) Image sharpening using mask: the following mask is used to sharpening the images

F2= [1 1 1 1 -8 1; 1 1 1]

The output image using above mask is shown in fig.17.

4) Image sharpening using imsharpen:" imsharpen" is matlab command for sharpen image using unsharp masking. B = imsharpen(A) gused to enhance the image features such as edges. Using this command edges are sharpened using unsharp masking method.

The output image using matlab command imsharpen is shown in Fig.18.

5) Output image using imadjust: imadjust is matlab comman used in obtaining the results.

```
U = imadjust (V, [L_IN; H_IN], [L_OUT; H_OUT])
```

imadjust maps the intensity values in input image V to pixel values in output image U such that values between L_IN and H_IN in input image are mapped to values between L_OUT and H_OUT in output image, where are values less than L_IN intensity values and intensity values above H_IN are clipped;
In the results, we have used the code

```
K = imadjust (I, [0.3 0.7], []);
```

The output image using above command is shown in Fig.20. In the above command, the intensity values of image between 0.3 and 0.7 are mapped to all the intensity values of output image.

6) Median filtering: The input image pixel is substituted by the median of the pixels confined in a window or mask around that particular pixel. In the results, we have used the matlab command medfilt2. B = medfilt2 (A) performs median filtering of input image represented by matrix A using the 3-by-3 neighborhood windows.

The output enhanced image using medfilt2 is shown in Fig.11.

7) Edges of input image: Edges of input image is obtained multiplying input image with the 3-by-3 neighborhood mask [0, 1, 0; 1, -4, 1; 0, 1, 0]

The output image using above mask is shown in fig.21.

Fig. 4: Original Input CT Scan Image of Liver.

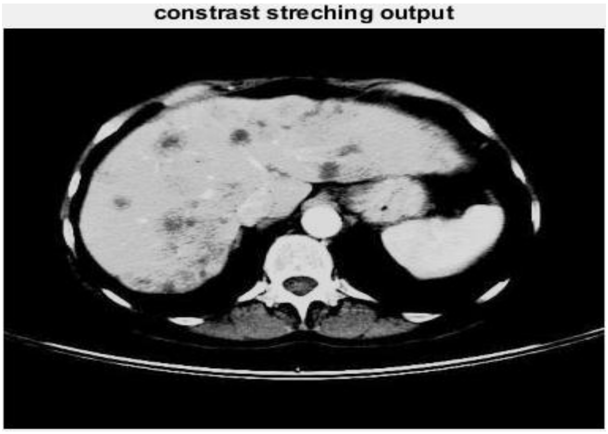

Fig. 5: Output Image Using Contrast Stretching.

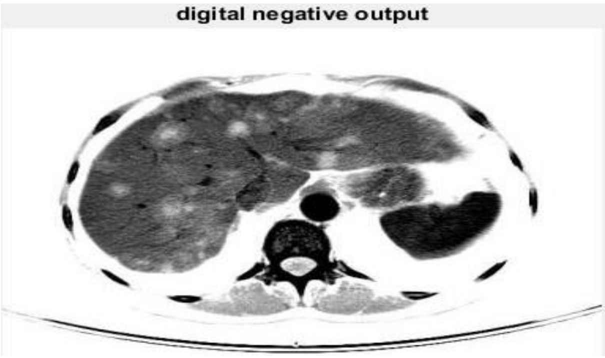

Fig. 6: Digital negative of Fig.4

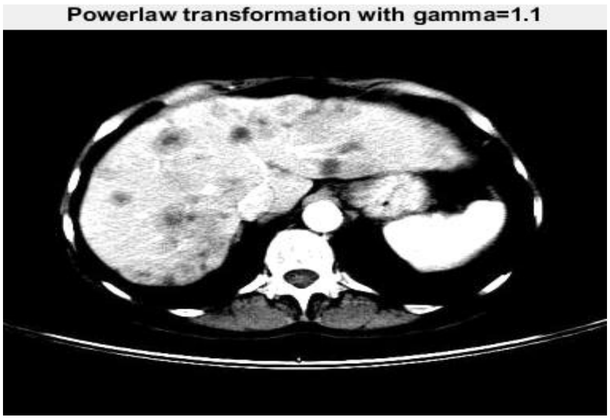

Fig. 7: Power Law Transformation with Gamma=1.1.

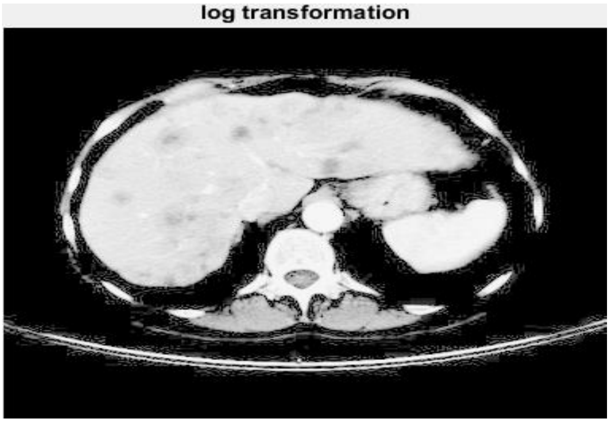

Fig. 8: Log Transformation.

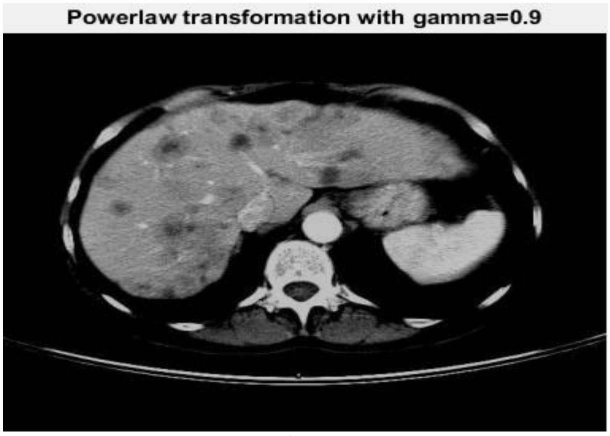

Fig. 9: Powerlaw Transformation with Gamma=0.9.

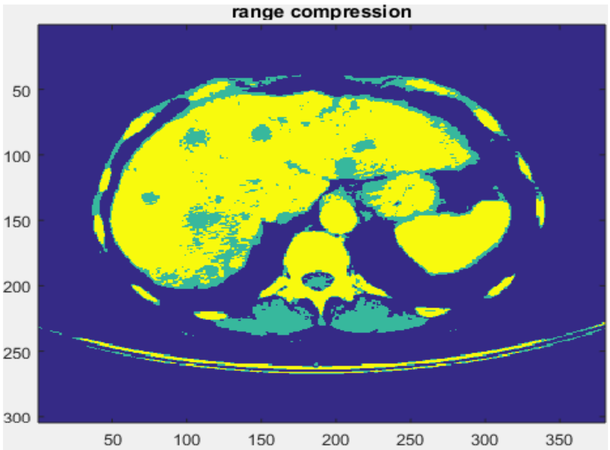

Fig. 10: Output Using Range Compression.

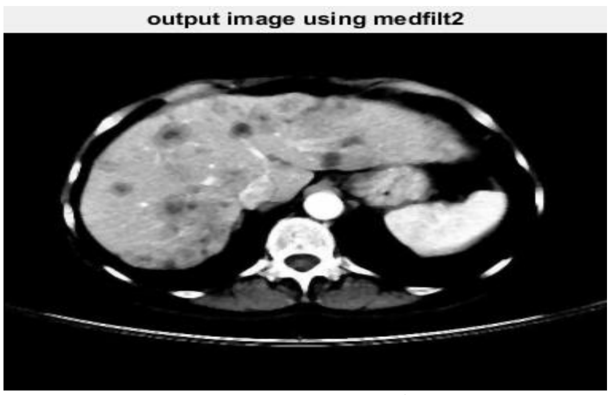

Fig. 11: Image Using Medfilt2.

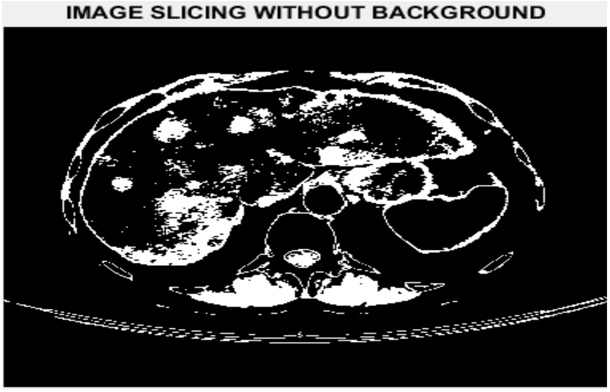

Fig. 12: Image Slicing Without Background.

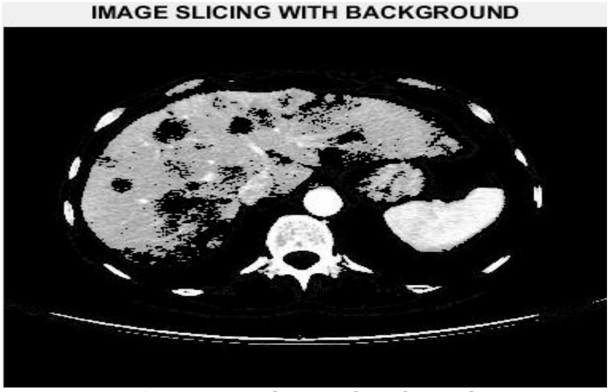

Fig. 13: Image Slicing with Background.

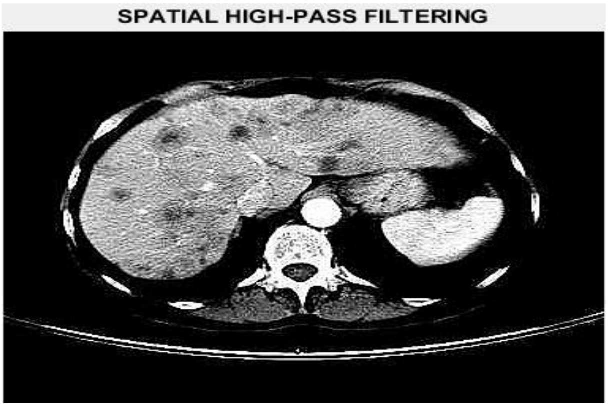

Fig. 14: Spatial High Pass Filtering Image.

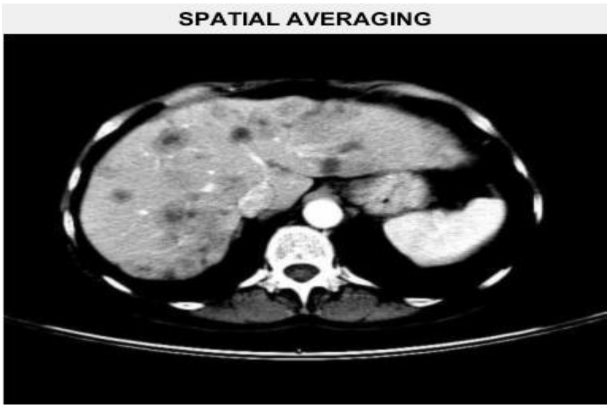

Fig. 15: Spatial Averaging Image.

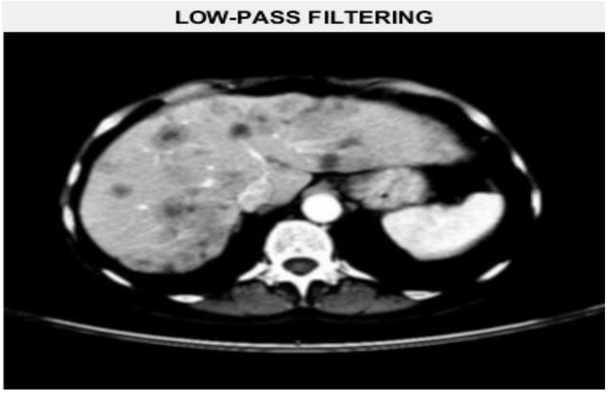

Fig. 16: Average Filter Output.

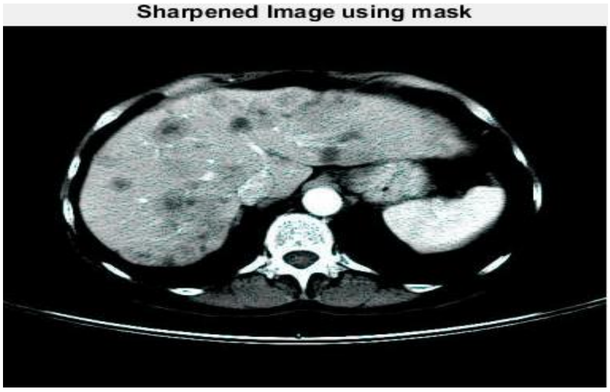

Fig. 17: Sharpened Image Using Mask.

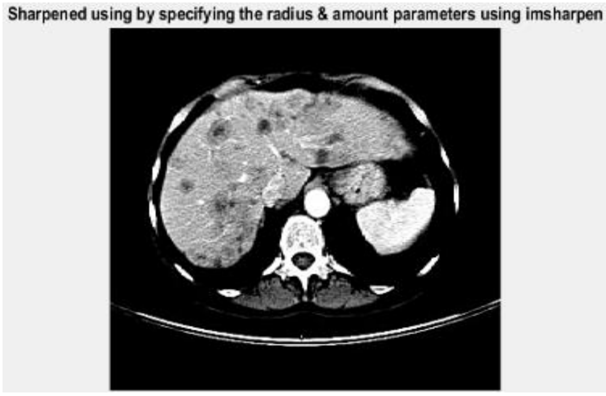

Fig. 18: Image Sharpening Using Imsharpen.

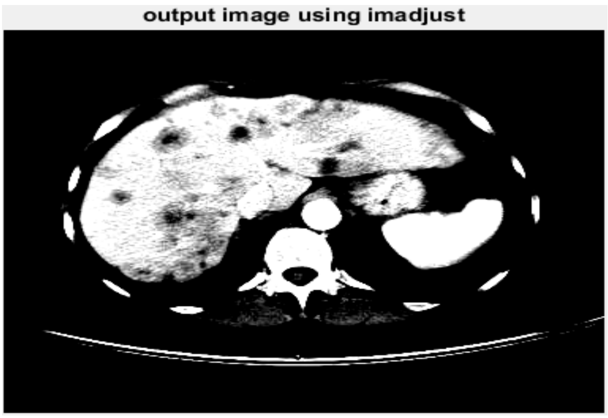

Fig. 19: Output Image Using Madjust.

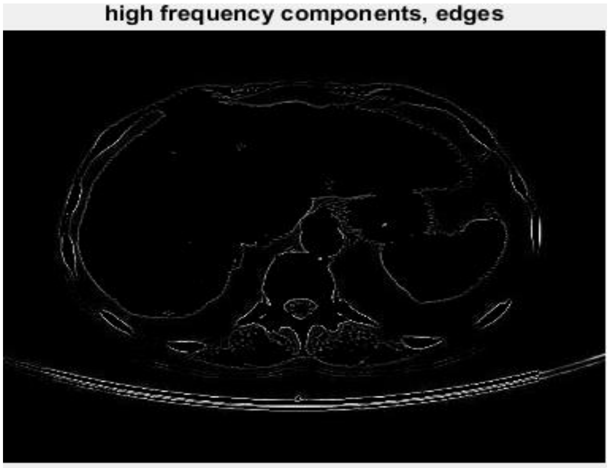

Fig. 20: Edges of Original Image.

4. Image quality measures

In this paper, different image quality parameters are used to measure output enhanced image with reference to an original input image. The list of Image Quality parameters used to measure are implemented in this paper include, Structural Content (SC), MSE:Mean Square Error, Maximum Difference (MD), NCC:Normalized Cross-Correlation, AD: Average Difference, PSNR: Peak Signal to Noise Ratio in dB.

With reference to Table I and Table II, we have concluded that Range compression is giving high NCC and low SC values, Spatial averaging give low MSE, high PSNR, low AD, low MD and low NAE. Since noise is not added to original signal, NCC and SC is used to measure the quality of image in this case.

Table 1: MSE, PSNR, NCC Measurements for Different Image Enhancement Techniques

S. No	Image Enhancement	MSE	PSNR	NCC
1	Contrast Stretching	178.96	25.603	1.0445
2	Image negative	$4.91X10^{4}$	1.2132	0.4449
3	Power law Transformation	506.51	21.08	1.2109
4	Range compression	0.3893	52.228	2.6084
5	Medfilt2	0.0011	77.58	0.9853
6	Slicing without background	$1.07X10^{4}$	7.8367	0.3195
7	Slicing with background	$3.029X10^{3}$	13.318	1.181
8	Spatial High Pass Filtering	0.0222	64.674	1.0851
9	Spatial Averaging	$3.4633X10^{-4}$	82.7356	0.9894
10	Average filtering using fspecial	127.5448	27.0742	0.9734

Table 2: AD, SC, MD, NAE Measurements for Different Image Enhancement Techniques

S. No	Image Enhancement	AD	SC	MD	NAE
1	Contrast Stretching	-4.3732	0.9016	37	0.1416
2	Image negative	-154.08	0.1848	255	4.1329
3	Power law Transformation	-11.425	0.6763	0	0.2264
4	Range compression	-0.3284	0.1417	0.15	1.6994
5	Medfilt2	0.0023	1.0216	0.75	0.0539
6	Slicing without background	21.1031	1.1896	255	1.1395
7	Slicing with background	-18.198	0.5875	0	0.3607
8	Spatial High Pass Filtering	$-4.7X10^{-19}$	0.7507	1.31	0.3092
9	Spatial Averaging	$-2.3X10^{-20}$	1.0191	0.24	0.0386
10	Average filtering using fspecial	0.0033	1.0405	1.47	0.0894

5. Proposed work

From above results it can be observed that image enhancement techniques such as image negative and image sharpening techniques can improve visible quality of medical image.Image enhancement and image quality can be further improved by applying integrated approach which includes both transformed operations and spatial operations. In Integrated approach, first CT Liver image is converted to transformed domain using DWT or Curvelet transform, next spatial operations can be performed on transformed image, next inverse transformed will be applied on the output, then finally thresholding operation is performed on the image.

Fig. 21 shown below shows the integrated approach for image enhancement

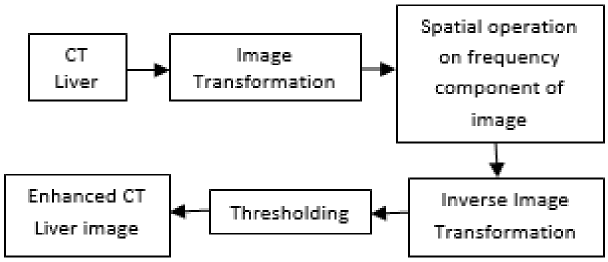

Fig. 21: Integrated approach for Image Enhancement.

6. Conclusion

CT Liver Images can be enhanced by different techniques. The Quality of medical images can be increased by integrated approach for image enhancement.

Further research includes study and application of integrated approach on medical images.

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