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# Denoising and Enhancement of Medical Images Using Wavelets in LabVIEW

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***Abstract***—In this paper, we have proposed a novel image enhancement technique based on M band wavelets. The conventional image enhancement algorithms opt for contrast enhancement using equalization techniques. Contrast enhancement is one of the most important issues in image enhancement techniques. High difference in luminance reflected from two adjacent surfaces results in a good contrast image which makes the object more distinguishable from other objects in the background. Many a times owing to over contrast, minute details of the images are lost; which cannot be tolerated for biomedical images. Moreover, they don't account for the noise embedded in the images. Also denoising using conventional filters result in blurring of images. The proposed algorithm not only denoises the image by retaining the high frequency edges, but also increases the contrast and generates a high resolution image. Various parameters like MSE and PSNR are been taken into account for comparison of enhanced images generated from the proposed algorithm with that of the conventional techniques.

***Index Terms***—Contrast enhancement, Image Denoising, General histogram equalization, Resolution enhancement, SVD Theorem, Wavelets.

## I. INTRODUCTION

Medical imaging techniques that are found in hospitals are X rays, MRI, CT, ultrasound, OCT etc. A lot of scientific research is been carried out with the aim to improve the quality of the images after data acquisition. The issues that physicians encounter while analyzing these images are poor quality, noisy image, low resolution and low contrast. All these issues must be tackled simultaneously so that the system generates a good resolution denoised better contrast images.

Literature survey [1-4] shows that enhancement of resolution of images is a topic which is widely applied specially in the field of satellite imaging. Such algorithms tend to increase the resolution of the images by eight times or even more. Raw images are processed to get supper resolution images. Ref. [7] discusses the method to improve the resolution of satellite images by $\alpha^2$ times where $\alpha$=4. However medical images don't require super resolution. Generally interpolation techniques are used to increase the resolution. Some of the standard techniques include Linear, Nearest Neighbor and Bicubic interpolation. Traditional methods work in time domain. However to maintain regularity these techniques can be implemented by using wavelet transforms.

Bicubic interpolation produces smoother edges than bilinear interpolation. Interpolation methods increase the intensity of low frequency components resulting in less number of sharp intensity transactions per pixel. A new method using DWT and SWT for resolution enhancement which preserves high frequency contents of the image is been proposed. The resolution of the final image will be four times greater than that of the original image and regularity in the image will also be maintained.

General Histogram Equalization is the most common technique for improving the contrast of the images. However GHE algorithm may not always produce desired results. GHE usually introduces two types of artifacts into the equalized image namely over enhancement of the image regions with more frequent gray levels, and the loss of contrast for the image regions with less frequent gray levels.

Also one of the disadvantages of GHE is that the probability distribution function (PDF) of the image is lost. Preserving the PDF is necessary as it has been used in PDF based pattern recognition techniques and many other techniques where we can't afford to lose the PDF information. For this reason, wavelets can be used for improving the contrast of the images.

The paper has been divided into three parts. Firstly wavelets and SVD theorem has been discussed in general. Then proposed algorithm using wavelets has been discussed in the later section and finally results and analysis has been done.

## II. DWT AND SVD THEOREM

### A. Discrete Wavelet Transform

The discrete wavelet transform is developed from continuous wavelet transform with discrete input, but it is simplified mathematical derivation. The relation between input and output can be represented as [6]

$$X_{a,L}[n] = \sum x_{a-1,L}[2n-k]\, g[k] \quad (1)$$

$$X_{a,H}[n] = \sum x_{a-1,H}[2n-k]\, h[k] \quad (2)$$

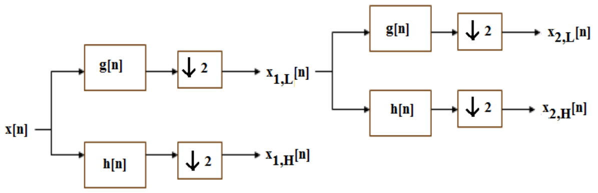



Fig. 1. Analysis of 1D signal

Where k varies from 0 to K-1. g[n] is a low pass filter just like scaling function, h[n] is a high pass filter just like mother wavelet function. Thus discrete wavelet transform resolves the signal into a low frequency components and high frequency components. The whole system is as shown below [6].

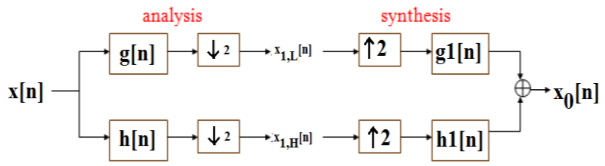



Fig. 2. DWT and IDWT of a 1D signal

When the signal is a 2D image, DWT decomposes input image into four sub bands LL, HL, LH and HH where H denotes the high frequency and L denotes the low frequency. We have used 'Haar' wavelets throughout the analysis. These four sub bands formed have size equal to half of that of the original image.

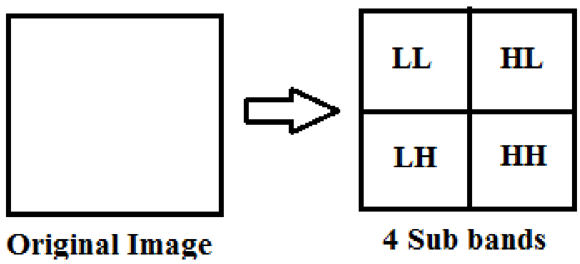



Fig. 3. DWT and IDWT of a 2D signal

*B. SVD Theorem*

Singular value decomposition (SVD) is a general linear algebra technique related to diagonalization of matrices and is used in variety of signal and image processing applications. Modifying the singular value decomposition of the image is one important technique in contrast enhancement applications. Singular value decomposition takes a rectangular image matrix A of size [n, p] and decomposes it into 3 vectors $U_{nxn}$, $S_{nxp}$ and $V_{pxp}$.

$$A_{n,p} = U_{n,n} \times S_{n,p} \times V^{T}_{p,p} \quad (3)$$

The S matrix has dimension same as that of the original image matrix. U and V are orthogonal matrices. Calculating the SVD consists of finding the eigen values and eigen vectors of $AA^T$ and $A^TA$. The eigen vectors of $AT^A$ make up the columns of *V*, the eigenvectors of $AA^T$ make up the columns of *U*. Also, the singular values in S are square roots of eigen values from $AA^T$ or $A^TA$. The singular values are the diagonal entries of the *S* matrix and are arranged in descending order.

## III. Proposed Algorithm

Proposed algorithm consists of 3 stages. First stage comprises of resolution enhancement. The second stage consists of denoising of image and finally stage three consists of contrast enhancement.

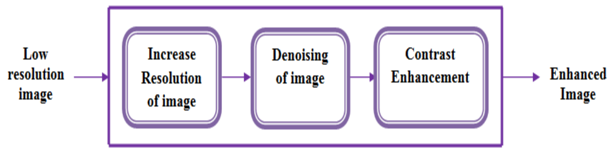



Fig. 4. Image Enhancement

*A. Resolution Enhancement*

The low resolution image is given to DWT (discrete wavelet transform) and SWT (stationary wavelet transform). As shown in the fig.5, DWT generates 4 sub bands $LL_w$, $LH_w$, $HL_w$, and $HH_w$. Similarly, SWT generates 4 sub bands $LL_S$, $LH_S$, $HL_S$ and $HH_S$. The 4 sub bands formed from SWT has same size as that of original image however the sub bands of DWT has size half of that of original image. The 4 individual sub bands of DWT are given to bicubic interpolation to get new HH, HL and LH bands. These new sub bands are added with the SWT sub bands $LH_S$, $HL_S$ and $HH_S$ to get the final high frequency bands. Instead of taking $LL_w$ or $LL_{S,}$ the original image is take as the low frequency sub band (LL). Finally the high resolution image is form by taking the inverse DWT of these 4 sub bands.

*B. Denoising and Contrast Enhancement*

The high resolution image is given to GHE and DWT simultaneously. Here we have used two stage decomposition. DWT generates 4 sub bands LL2, HL2, LH2 and HH2. Using LL2 second stage decomposition sub bands LL21, HL21, LH21 and HH21 are formed. To remove the noise, wiener filter is applied to GHE matrix simultaneously. The filtered matrix is given to DWT and the two stage decomposition sub bands LL11, HL11, LH11 and HH11 are formed. SVD theorem is applied to LL11 and LL21 to get S1 and S2 matrix. The maximum diagonal element of S1 and S2 is found out to get the correlation coefficient. Using this correlation coefficient new S matrix is formed. Finally, new LL sub band is formed using U2, $S_{new}$ and V2. Final enhanced image is obtained by taking the inverse DWT of these sub bands.

*C. HTML Report Generation using Lab VIEW*

Automatic report generation facility is added to the GUI so as to get automatic report for future analysis. By clicking the “Generate report” button, and automatic HTML report file gets generated in default web browser like Google chrome/IE.

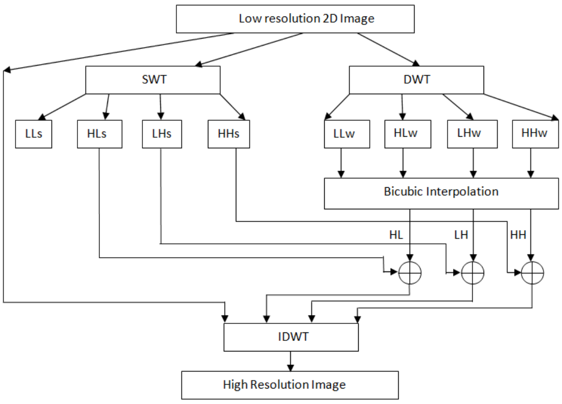



Fig. 5. Proposed algorithm for resolution enhancement

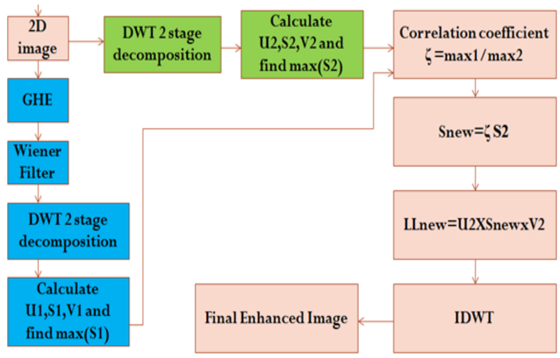
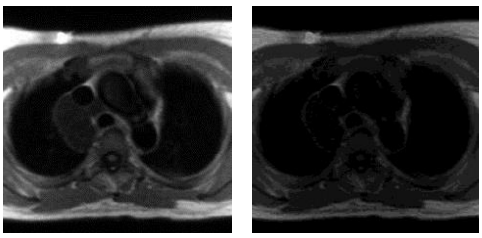



Fig. 6. Denoising and contrast enhancement

## IV. Experiment Simulation and Result Analysis

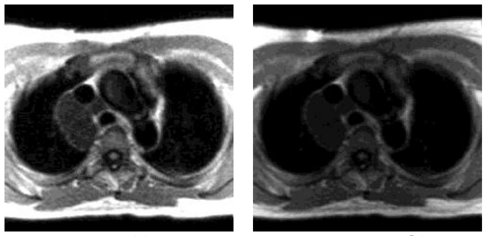
The proposed algorithm was tested on various images including X ray images, MRI images, CT scan and OCT images. Some of these images are shown along with their analysis.

Fig.7(a), 9(a), 11(a), 13(a) and 15(a) shows the original raw images. These images are first processed to get high resolution images as shown in Fig.7(b), 9(b), 11(b), 13(b) and 15(b).



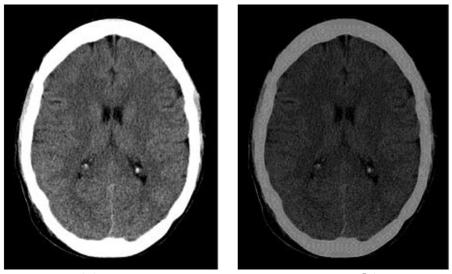
(a) (b)

Fig. 7. (a) CT scan image with resolution 232x234 (b) High resolution image 464x468



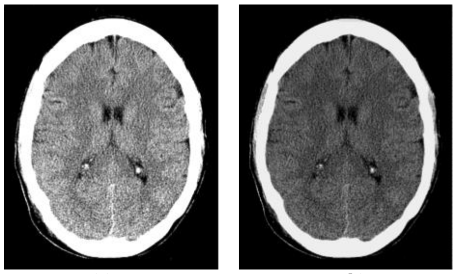
(a) (b)

Fig. 8. (a) Enhanced image using 1 stage decomposition (b) Enhanced image using 2 stage decomposition



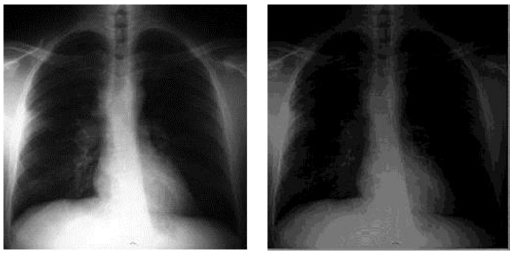
(a) (b)

Fig. 9. (a) CT scan image with resolution 600x482 (b) High resolution image 1200x964



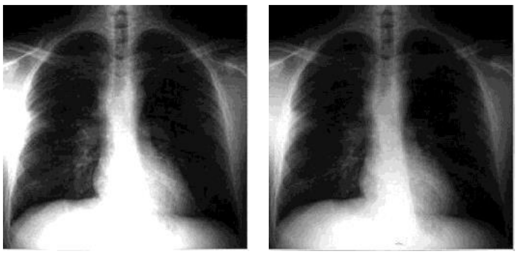
(a) (b)

Fig. 10. (a) Enhanced image using 1 stage decomposition (b) Enhanced image using 2 stage decomposition



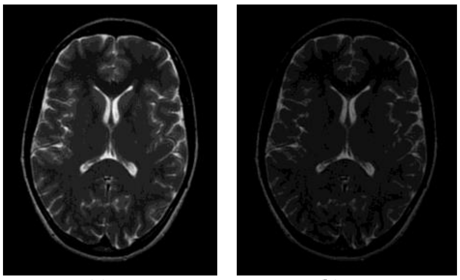
(a) (b)

Fig. 11. (a) X ray scan image with resolution 238x238 (b) High resolution image 476x476



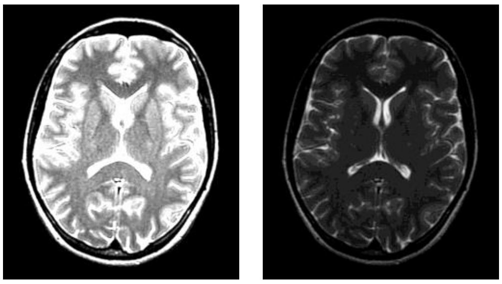
(a) (b)

Fig.12. (a) Enhanced image using 1 stage decomposition (b) Enhanced image using 2 stage decomposition



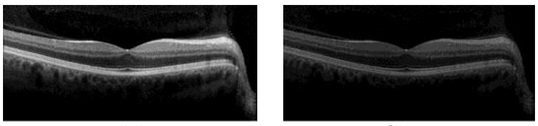
(a) (b)

Fig. 13. (a) MRI image with resolution 752x640 (b) High resolution image 1504x1280



(a) (b)

Fig. 14. (a) Enhanced image using 1 stage decomposition (b) Enhanced image using 2 stage decomposition



(a) (b)

Fig. 15. (a) OCT image with resolution 254x600 (b) High resolution image 508x1200

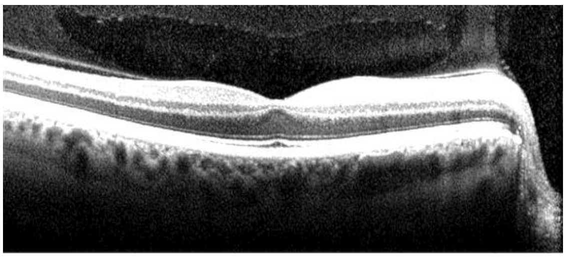


Fig. 16. (a) Enhanced image using 1 stage decomposition

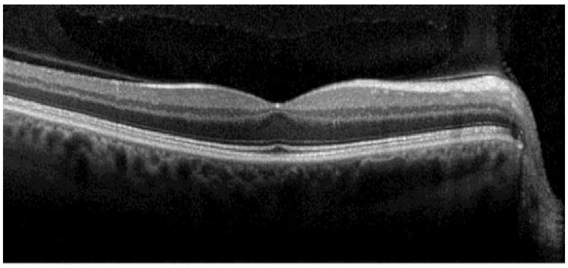


Fig. 16. (b) Enhanced image using 2 stage decomposition

Then these high resolution images are given DWT and GHE & Wiener filter as shown in fig.6. We have considered 2 cases. First we have processed the high resolution images using one stage decomposition and then we have repeated the algorithm for 2 stage decomposition. Thus Fig.8(a), 10(a), 12(a), 14(a) and 16(a) are the final images generated using single stage decomposition. Whereas Fig.8(b), 10(b), 12(b), 14(b) and 16(b) are the final images generated using two stage decomposition. It can be seen that the resolution of all the images has increased by four times. Also unlike GHE algorithm, the “over contrast” problem has not occurred in any of the enhanced images, thus retaining the PDF. Also no blurring effect has been seen even after noise removal and high frequency edges have been retained to get a better enhanced image. Table 1 shows the comparison of all the images based on MSE. For calculation of MSE the size of both the images must be same. So the MSE calculations have been done by taking the high resolution images generated at stage I as input.

Table 1. Comparison of various techniques based on MSE

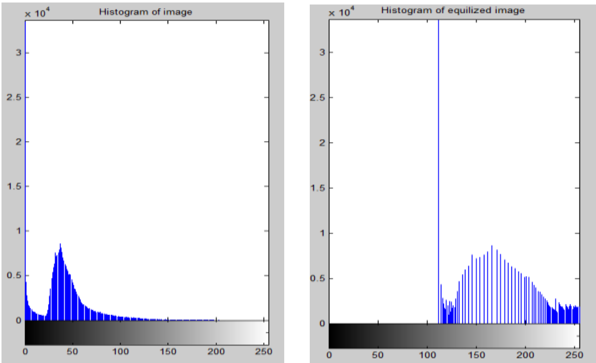
| Sr. No. | Figure No. | GHE | Proposed Algorithm with 1 stage decomposition | Proposed Algorithm with 2 stage decomposition |
|---|---|---|---|---|
| 1. | 7(b) | 12965.5 | 8478.4 | 1288.27 |
| 2. | 9(b) | 10636.5 | 7136.76 | 2388.81 |
| 3. | 11(b) | 9087.31 | 6201.27 | 2970.57 |
| 4. | 13(b) | 20353.5 | 14472.1 | 510.819 |
| 5. | 15(b) | 13586.7 | 8399.68 | 1296.5 |

Table 2. Comparison of various techniques based on PSNR in dB

| Sr. No. | Figure No. | GHE | Proposed Algorithm with 1 stage decomposition | Proposed Algorithm with 2 stage decomposition |
|---|---|---|---|---|
| 1. | 7(b) | 7.0029 | 8.84767 | 17.0308 |
| 2. | 9(b) | 7.8628 | 9.59519 | 14.349 |
| 3. | 11(b) | 8.54645 | 10.206 | 13.4024 |
| 4. | 13(b) | 5.04442 | 6.52547 | 21.0481 |
| 5. | 15(b) | 6.19966 | 8.88818 | 17.0033 |

MSE generated by all three methods: GHE, proposed method using single stage decomposition and proposed method by two stage decomposition has been compared. Table 1 shows that MSE decreases drastically when we use proposed method using two stage decomposition. Note that the MSE generated by the conventional GHE algorithm is very high because of histogram stretching. Owing to this, as discussed in the beginning, probability distribution function (PDF) of the image is lost. However the proposed algorithm retains the PDF of the image. Fig.17(a) shows the histogram of original MRI original image ( fig.13.(a)). The histogram of the original image is compared with that of histograms generated by GHE algorithm and proposed algorithm. The PDF of the GHE enhanced algorithm doesn’t resemble to that of the original image. However, the histogram of enhanced image by proposed algorithm matches with that of histogram of original image. Table 2 shows the comparison of the 3 methods based on PSNR values. It can be seen that the PSNR of the enhanced images has increased to a great extent.




(a) (b)

Fig. 17. (a) Histogram of original image (b) Histogram of enhanced image using GHE

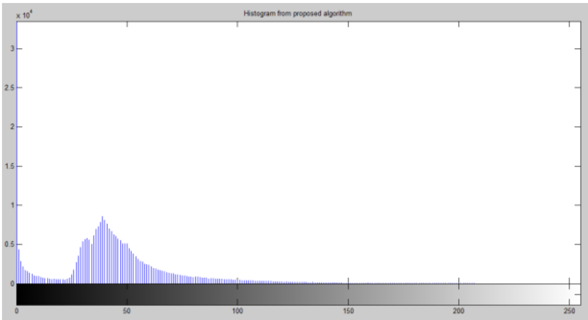


Fig. 18. Histogram of enhanced image using proposed algorithm (2 stage decomposition)

The algorithm was developed in LabVIEW using Matlab scripts. Fig.19 shows the block diagram of the implemented algorithm. The sub VI takes the image as input from the browsed link and plots the original image.

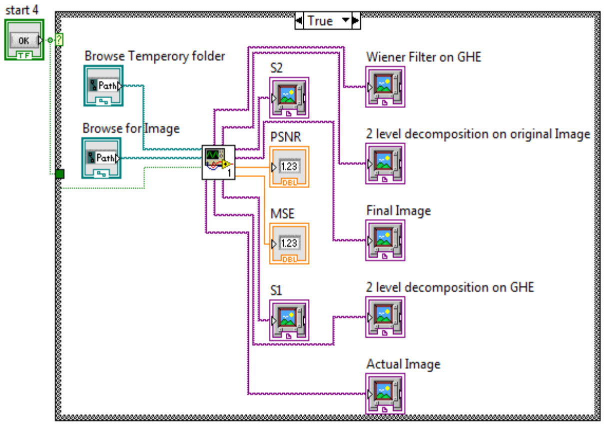



Fig. 19. Block diagram implemented in labVIEW

The intermediate S1 and S2 matrices of SVD theorem are plotted. The final enhanced image is plotted along with the PSNR and MSE values. Here the sub VI uses math scripts to perform the wavelet and other processing. Fig.20 shows the GUI designed in Lab VIEW. The actual image is been acquired and all the intermediate steps have also been shown which comprises of S matrices and two stage decomposition images. The final enhanced image is been plotted along with the MSE and PSNR values. Also other utilities like automatic report generation and temporary log folder creation have been added for future analysis.

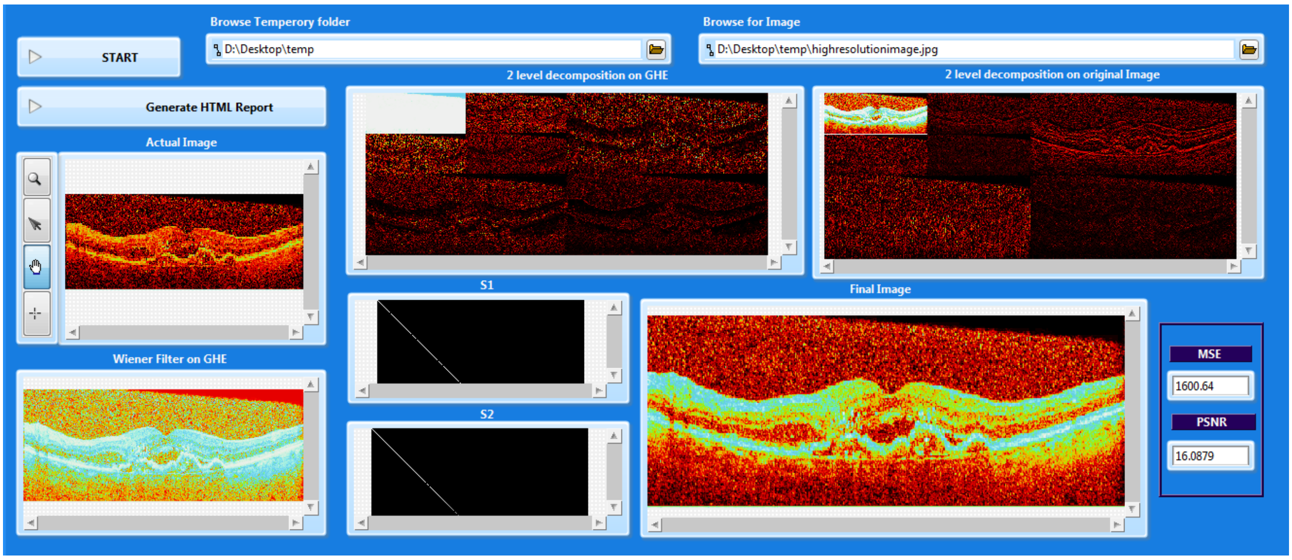



Fig. 20. GUI for image enhancement

## V. Conclusion

This main objective of the research work is to generate medical image enhancement algorithm which would take into account all the short comings of the existing algorithms and thereby come up with some techniques that will help to generate high resolution denoised good contrast images. The proposed algorithm uses wavelets for this purpose and generates high resolution images having better PSNR and less MSE as compared to conventional algorithms. The proposed algorithm was tested on various medical images like X rays, MRI, CT and OCT. Finally, UI was designed to browse the raw images and to plot the enhanced images along with other utilities like automatic HTML report generation, saving log files for future analysis.

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