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Acoustic image enhancement using Gaussian and laplacian pyramid – a multiresolution based technique

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Abstract Acoustic images captured by side scan sonar are normally affected by speckle noise for which the enhancement is required in different domain. The underwater acoustic images obtained using sound as a source, basically contain seafloor, sediments, living and non-living resources. The Multiresolution based image enhancement techniques nowadays play a vital role in improving the quality of the low resolution image with repeated patterns. Image pyramid is the representation of an image at various scales. In this work, a three level Gaussian and Laplacian pyramids are constructed to represent the image in different resolution. The multiscale representation requires different filters at different scales. The contrast of each image in Gaussian and Laplacian pyramids are improved by applying both histogram equalization and unsharp masking method. The sharpened images are used to reconstruct the enhanced image. The performance measure, peak signal to noise ratio proves that the unsharp masking method applied to difference images of Laplacian pyramid outperforms the other image enhancement methods.

Keywords Acoustic image · Enhancement · Gaussian · Histogram equalization · Laplacian · Pyramid · Unsharp masking

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1 Introduction

Underwater acoustic images are generally dominated by speckle noise which is caused due to the side scan sonar instruments [7]. Imaging the seafloor with sonar is done by towing a tow fish over the survey area. The tow fish consists of set of transducers that emit and receive acoustic pulses in a specific range. The pixel values in the acoustic images are due to the variations in the targets such as seafloor, sediments, objects and rocks. As sea surface is a good reflector of sound they may produce noise [7]. The literature proves that there are many works carried out for generation and processing of acoustic images [14]. The nonlinear estimator based on the sparse model and orthogonal matching pursuit is used for improving the quality of the image [23]. The acoustic image contains temporal information that can be easily handled by wavelet transforms. The acoustic image is decomposed to Low-Low (LL), Low-High (LH), High-Low (HL) and High-High (HH) sub-bands using discrete wavelet transform and the low frequency component is enhanced using Karhunen Loeve (KL) transform [16, 21]. Related works have been carried out for generic image where the low frequency components are enhanced using Singular Value Decomposition (SVD) [6]. The enhanced low frequency components and the high frequency components are given to inverse discrete wavelet transform and high resolution enhanced image is obtained. Along with Discrete Wavelet Transform (DWT), Stationary Wavelet Transform (SWT) is also used for image super resolution [2, 26, 28]. The contrast of the image was improved by Singular Value Equalization (SVA) by converting the image to the SVD domain [5].

The contourlet transform is also used as image enhancement technique which can be processed in two steps namely pyramidal decomposition and directional sub band decomposition [3]. Many filtering methods such as Gabor filter combined with Fast Fourier Transform (FFT) [27], complex Finite Impulse Response (FIR) filters [11] and aperture filters [13] are used for image enhancement and for sharpening. The steerable pyramid transform for color image enhancement is also proposed [4] where the RGB color image is converted into luminance and chrominance factors. The transform is applied only on the luminance components and the final image is reconstructed using the enhanced components. Fuzzy statistics was also used along with histogram equalization for brightness preserving image enhancement [22]. The images are decomposed into band pass images and histogram equalization technique is used for brightness and contrast improvement [10, 17, 24]. It has also been proved that multilevel Laplacian pyramid is used to decompose the image [8] and multiscale contrast measure is used to modify the coefficients iteratively to get an enhanced image [12, 19]. There are many filtering techniques used for both image smoothing and sharpening. Among these techniques, unsharp masking is one of the method that has proved itself as a good sharpening technique [15, 25]. The related works [18, 20] shows that image preprocessing techniques such as image enhancement and restoration are the essential steps for the intermediate processing such as segmentation and feature extraction and also post processing techniques such as object recognition and modelling.

A Multiscale representation of an image can be achieved by techniques such as wavelet transformation [16], Gaussian pyramid, Laplacian pyramid etc. These methods can extract different features such as smooth areas and edges in each levels. However, the multiscale representation can be used for image compression and image enhancement.

The basic idea of an image pyramid is to develop a multiscale representation to extract features such as edges or interest point, and to suppress the noise. The image pyramid is used for redundancy reduction and modelling for image enhancement or restoration. A Gaussian image pyramid is formed by continuously downsampling a single image till a stopping point is reached. The images in the Gaussian pyramid are constructed by convolving the Gaussian kernel to the image and downsampling the image by factor of two continuously. An Laplacian image pyramid is in turn formed by finding the difference image of the smoothed version of Gaussian pyramid between each levels. The image at the last level of the Laplacian pyramid is not a difference image but it is the image obtained from last level of Gaussian pyramid.

The objective of the discrete wavelet transform is to capture transitions of various frequency bands at different levels and different locations on the same level. The successive low pass, high pass filtering and downsampling are done to decompose the image into set of approximations and details [26]. During analysis phase, the image is decomposed into different levels of hierarchy and the original image is reconstructed in the synthesis phase.

The proposed system uses the multiscale representation technique. The features of the acoustic image can be viewed in different scales and enhancement is done in various levels to improve the quality of the image using image pyramid. This method uses the enhancement techniques such as histogram equalization and unsharp masking methods for images at multiresolution of both the Gaussian and Laplacian pyramid. These techniques are normally used directly on the image. But, when applied to acoustic images the quality of the image does not tend to improve. The insufficient illumination in the images that are captured by side scan sonar generally have dark shadows and low contrast. The acoustic images contain textural information where the underlying objects can be easily differentiated from the sediments and seafloor only with a high contrast image. The proposed method improves the quality of the image such that the object, sediments and the seafloor are easily differentiable.

The rest of the paper is organized as follows. In Section 2, multiresolution representation methods such as Gaussian and Laplacian pyramids are discussed. The Sections 3 and 4 discuss the acoustic image enhancement techniques and the proposed multiresolution based enhancement methods respectively. In Section 5, the experimental results of the existing and proposed methods are demonstrated. Finally, the conclusion of this paper is described in Section 6.

2 Multiresolution representation

Image pyramid is the representation of an image in hierarchical manner. The images in various levels of hierarchy have different features [1]. The high resolution image in the top level of the hierarchy consists of both low and high frequency components. The low resolution image in the bottom level of hierarchy consists of only the low frequency components. Image pyramid is of two types namely low pass (Gaussian) and band pass (Laplacian) pyramid. The pyramid construction is a two step process consisting of repeated smoothing and down sampling. Smoothing is the process of convolving the filter or mask with the original image [9].

2.1 Gaussian pyramid

The low pass pyramid can be constructed using filters such as Gaussian, average and median filters [9]. The pyramid constructed using Gaussian kernel to smooth the image is called as Gaussian pyramid [1]. The smoothed image is downsampled by the factor of two and the process is repeated to achieve a low resolution image of size 2×2. Each iteration results in a smaller image with increased smoothing and reduced size. The images in various levels of the pyramid are called multiresolution representation. Gaussian kernel is generated from the third row of pascal's triangle whose values are [1 2 1]. The sum of the elements in the row of the triangle is 4. Gaussian kernel is generated as:

$$\frac{1}{4}\begin{bmatrix}1\\2\\1\end{bmatrix}\times\frac{1}{4}[1\ \ 2\ \ 1]=\frac{1}{16}\begin{bmatrix}1&2&1\\2&4&2\\1&2&1\end{bmatrix} \tag{1}$$

The Gaussian function is given by:

$$G(x,y)=\frac{1}{2\Pi\sigma^2}e^{\frac{-x^2+y^2}{2\sigma^2}} \tag{2}$$

where x is the distance from the origin in the horizontal axis, y is the distance from the origin in the vertical axis, and σ is the standard deviation of the Gaussian distribution. Gaussian functions are rotationally symmetric in two dimensions. The amount of smoothing performed by the filter is same in all directions. It does not give importance to edge features in any specific direction. In acoustic images, the object may be present in any inclination as the side scan sonar sweeps the floor in any direction. Smoothing using the Gaussian kernel will be right choice for acoustic images. The degree of smoothing is dependent on the value of the variance. A large variance value will lead to greater smoothing and the small objects along with the sediments and seafloor may also be removed. The two dimensional Gaussian functions are separable, hence it can be applied separately for x and y dimensions.

2.2 Laplacian pyramid

The band pass pyramid is obtained by differencing the image at level *n* with the interpolated image at the level *n-1* of the Gaussian pyramid. The image in the lowest level alone is not the difference image and it is the same image in the lowest level of the Gaussian pyramid. Laplacian filters are normally used for noise reduction. Figure 1 shows the Gaussian and Laplacian pyramid construction used for image enhancement. Acoustic images of side scan sonar captured by sound as a source are texture images with repeated patterns. The pyramid where Gaussian blur is used for smoothing the images can be used to improve the quality of the texture images. The details of the image such as edge features can be extracted which in turn helps in identifying the objects in the sea floor.

3 Acoustic image enhancement techniques

Image transformation can be done using intensity transformation, spatial domain transformation and frequency domain transformation. The intensity level transformation techniques can change the pixel values in an image to improve the visual quality. The spatial and frequency domain transformation techniques can be used for smoothing or blurring the image to reduce the noise and also can be used for sharpening the details in an image. Among the techniques, histogram equalization and log transformation can be used for improving the contrast of acoustic images. The log transformation maps a narrow range of low gray level input image into a wider range of output levels. It expands the values of dark pixels in an image which leads to more black surfaces in turn makes the objects indifferentiable with sediments and seafloor. The pixel intensity of an image can be improved by histogram equalization technique based on the gray level distribution in the neighbourhood of every pixel. This method

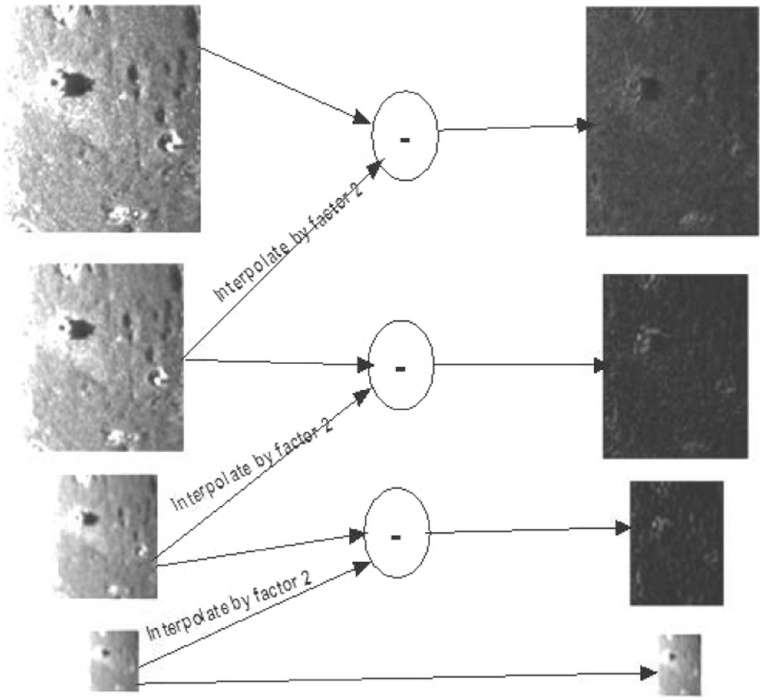

Fig. 1 Gaussian and Laplacian pyramid construction

improves the global contrast of the images when intensity values are closer. The cumulative mass function of the intensity values are calculated by the probability mass function and spreads out the most frequent intensity values. As histogram equalization is implemented using probability distribution function, the low contrast areas in an image can be improved to have better contrast. It tries to uniformly distribute the contrast in the image.

Unsharp masking is one of the image sharpening method that can be used for enhancing the edge features, in turn improving the quality of the image. This method uses a mask which is created by the difference of the original image *F(x,y),* and the smoothed version of the original image *F'(x,y),* to enhance the image as illustrated in the Fig. 2. The unsharp mask is added with the original image to obtain the enhanced image *G(x,y)*. The unsharp masking method is used to increase the high frequency components such as edges in an image.

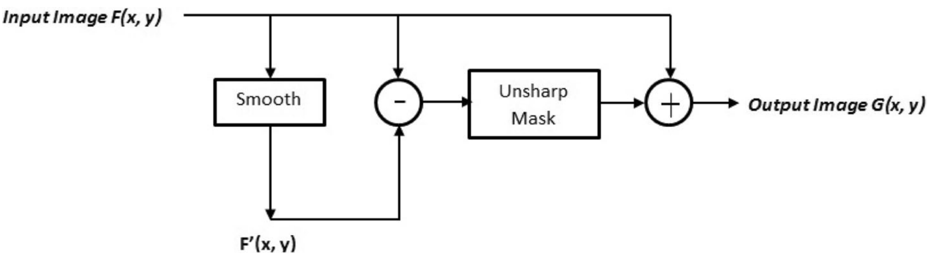

Fig. 2 Unsharp masking method

4 Proposed system

The proposed system takes the low contrast acoustic images as input and the images are decomposed into multiscale representation in Gaussian and Laplacian pyramid. In Section 4.1 and 4.2, filtering using Gaussian and Laplacian pyramid are discussed respectively. Section 4.3 elaborates the reconstruction of images at various levels of the pyramid to obtain the enhanced image.

4.1 Filtering using Gaussian pyramid

The image $GP_i(x, y)$ at level *0* of the Gaussian pyramid is the original acoustic image *I* given by:

$$\sum_{x=1}^{m}\sum_{y=1}^{n} GP_i(x,y) = I \tag{3}$$

The image can be decomposed to *n* levels where size of the image at n^{th} level is equal to the size (1×1). The image at level $i + 1$ is obtained by:

$$\sum_{x=1}^{m/2}\sum_{y=1}^{n/2} GP_{i+1}(x,y) = reduce\left(\sum_{x=1}^{m}\sum_{y=1}^{n} GP_i(x,y)\right) \tag{4}$$

The *reduce* function performs two major task such as Gaussian smoothing and down sampling by the factor of two using bicubic interpolation. This process is repeated to obtain the images in multiscale representation. For improving the contrast of the images in various levels, histogram equalization technique is applied separately to all the images in the pyramid by:

$$\sum_{x=1}^{m}\sum_{y=1}^{n} H_{i+1}(x,y) = histeq\left(\sum_{x=1}^{m}\sum_{y=1}^{n} GP_{i+1}(x,y)\right) \tag{5}$$

where $H_{i+1}(x,y)$ denotes the histogram equalized image at level $i + 1$ of the Gaussian pyramid.

The sharpening method such as unsharp masking is applied to the images in different resolution and the filtered images shows greater improvement in their contrast and it is represented by:

$$\sum_{x=1}^{m}\sum_{y=1}^{n} UM_{i+1}(x,y) = unsharpmask\left(\sum_{x=1}^{m}\sum_{y=1}^{n} GP_{i+1}(x,y)\right) \tag{6}$$

Where $UM_{i+1}(x,y)$ denotes the image at level $i + 1$ after applying unsharp masking.

The following procedure shows the construction of Gaussian pyramid and filtering of the images using histogram equalization and unsharp masking methods:

Step 1: The original acoustic image *I* is considered as the image at level *0* of the Gaussian pyramid.

Step 2: The image at level $n + 1$ is obtained by smoothing and downsampling the image at level *n* by factor of two. In the proposed method, this process is repeated only three times to yield levels *1,2* and *3*.

Step 3: The histogram equalization technique is applied to images in various levels of the pyramid, to improve the contrast.

Step 4: Finally, in the Gaussian pyramid, unsharp masking filtering method is applied to sharpen the images.

The image enhancement methods such as histogram equalization and unsharp masking can be applied to the images directly to improve the quality. Due to the textural properties of the acoustic images, these methods when applied, do not show major improvement. In the proposed method, the acoustic images are smoothed by Gaussian filter and downsampled to form three level Gaussian pyramid. On applying histogram equalization and unsharp masking at different resolution of the Gaussian pyramid improves the quality of the images in various levels of pyramid.

4.2 Filtering using laplacian pyramid

The images in the Laplacian pyramid are obtained by differencing the images of the Gaussian pyramid. The image in level *n* of the Laplacian pyramid is obtained by subtracting the level *n* image with the interpolated level *n-1* image of the Gaussian pyramid.

$$\sum_{x=1}^{m}\sum_{y=1}^{n} LP_i(x,y) = \sum_{x=1}^{m}\sum_{y=1}^{n} GP_i(x,y) - \exp\ and\left(\sum_{x=1}^{m/2}\sum_{y=1}^{n/2} GP_{i+1}(x,y)\right) \tag{7}$$

Where $LP_i(x,y)$ is the image at level i of the Laplacian pyramid.

The *expand* function is used for interpolating the image using bicubic interpolation which is used to enlarge the images. The image in the lowest level of the Laplacian pyramid is same as the image in the lowest level of the Gaussian pyramid and it is given by:

$$\sum_{x=1}^{m}\sum_{y=1}^{n} LP_n(x,y) = \sum_{x=1}^{m}\sum_{y=1}^{n} GP_n(x,y) \tag{8}$$

Next, the histogram equalization technique is applied to all the images in the Laplacian pyramid to improve the contrast of the difference images.

$$\sum_{x=1}^{m}\sum_{y=1}^{n} LH_i(x,y) = histeq\left(\sum_{x=1}^{m}\sum_{y=1}^{n} LP_i(x,y)\right) \tag{9}$$

Where $LH_i(x,y)$ is the histogram equalized image at level $i + 1$ of the Laplacian pyramid.

The unsharp masking method is then used to filter the images in the Laplacian pyramid using:

$$\sum_{x=1}^{m}\sum_{y=1}^{n} UML_i(x,y) = unsharpmask\left(\sum_{x=1}^{m}\sum_{y=1}^{n} LP_i(x,y)\right) \tag{10}$$

Where $UML_i(x,y)$ denotes the filtered image at level i obtained by unsharp masking .

The following procedure shows the construction of Laplacian pyramid and filtering of the images using histogram equalization and unsharp masking methods:

Step 1: The image at level *n* of the Laplacian pyramid is constructed by differencing the image at level *n-1* and interpolated image at level *n* of the Gaussian pyramid.

Step 2: The image in the lowest level of the Laplacian pyramid will be equal to the image in the lowest level of the Gaussian pyramid.

Step 3: Histogram equalization technique is applied to all the images in the Laplacian pyramid to improve the contrast of the images.

Step 4: Then, apply the unsharp masking method to all the images in the Laplacian pyramid to sharpen the images by preserving the edge features.

The filtering methods tend to normally improve the quality of the images. Among them the Laplacian filters are used for sharpening the images. In the proposed method the images in the various levels of the Laplacian pyramid are obtained by differencing the image at level *n-1* and the interpolated image at level *n* of the Gaussian pyramid. On applying the histogram equalization and unsharp masking, all the three levels of the Laplacian pyramid tend to increase the contrast of the image.

4.3 Reconstruction of enhanced images

The enhanced image is reconstructed by interpolating all the images to the size of the original image and adding the images. The images *I1* and *I2* shows the enhanced image obtained by adding the original image with the histogram equalized images of both Gaussian and Laplacian pyramid. The filtered images which are in different size and resolution are interpolated using different upscaling factor.

$$I_1 = I + \sum_{i=1}^{3} \exp and \left(upscale, \sum_{x=1}^{m} \sum_{y=1}^{n} H_i(x,y) \right) \tag{11}$$

$$I_2 = I + \sum_{i=1}^{3} \exp and \left(upscale, \sum_{x=1}^{m} \sum_{y=1}^{n} LH_i(x,y) \right) \tag{12}$$

The images *I3* and *I4* are the enhanced image obtained by adding the original acoustic image with the filtered images produced by applying the unsharp masking method.

$$I_3 = I + \sum_{i=1}^{3} \exp and \left(upscale, \sum_{x=1}^{m} \sum_{y=1}^{n} UM_i(x,y) \right) \tag{13}$$

$$I_4 = I + \sum_{i=1}^{3} \exp and \left(upscale, \sum_{x=1}^{m} \sum_{y=1}^{n} UML_i(x,y) \right) \tag{14}$$

Where *upscale value* = *2,4,6..*for *i* = *1,2,3...* respectively.

The reconstruction of enhanced image using Gaussian and Laplacian pyramid is shown in the following procedure:

Step 1: The filtered images obtained after histogram equalization in Gaussian and Laplacian pyramid are used for reconstruction of the enhanced image.

Step 2: The images in different levels of hierarchy will be in different size. In order to perform addition, the images are interpolated accordingly.

Step 3: The original image *I* is added with the filtered images to obtain the enhanced image *I1* and *I2*.

Step 4: The filtered images obtained after applying unsharp masking in Gaussian and Laplacian pyramid are added with the original image *I* to get the enhanced image *I3* and *I4*.

The input image is decomposed to various levels to form the Gaussian and Laplacian pyramid. The sharpening methods are applied to each image in the levels of the pyramid which enhances the images in various levels. The enhanced image is reconstructed by adding the images in the different levels of the pyramid. The proposed method has led to an improved result after reconstruction of the acoustic image using unsharp masking in Laplacian pyramid.

5 Results and discussion

The proposed method is compared with the existing image enhancement techniques. In Section 5.1, the details about the dataset taken for the experiment are discussed. In Section 5.2, experimental results are demonstrated and Section 5.3 discusses the performance measures in terms of peak signal to noise ratio.

5.1 Dataset

The acoustic images are obtained using the Edgetech 4125, ultra high resolution, light weight side scan sonar. The 4125 series dual-frequency side scan sonar system is composed of a 4125-P portable topside processor, a 4125 tow vehicle (commonly called a Tow fish), and a tow cable with 400–600 KHZ in frequency. The side scan sonar was immersed in a depth of 20 m in Bay of Bengal. The scene of the sea floor are imaged using discover imaging software.

5.2 Experimental results

Figures 3, 4, and 5 shows the improvement of the low resolution acoustic image in its contrast using Gaussian and Laplacian pyramid. The figure (a) is the input low contrast and low resolution acoustic image of side scan sonar. Figures (b) to (h) shows the results of the existing methods adaptive histogram equalization, DWT and KL transform [16], DWT and SVD methods [6], Singular Value Equalization [5], improved unsharp masking method [25], Brightness Preserving Dynamic Fuzzy Histogram Equalization (BPDFHE) [22] and auto enhancement method [9] respectively.

Figures (i) and (j) shows the reconstructed image of Gaussian pyramid after applying histogram equalization technique and unsharp masking method respectively. Figures (k) and (l) shows the reconstructed image of Laplacian pyramid after applying histogram equalization technique and unsharp masking method respectively. The idea of Gaussian pyramid is to view the smooth areas of an image in different scale. The main goal of Laplacian pyramid is to get the details such as edges in various scales. On applying the histogram equalization technique on the images in the Gaussian pyramid and Laplacian pyramid and then by reconstructing the image, the contrast seems to be improved. As

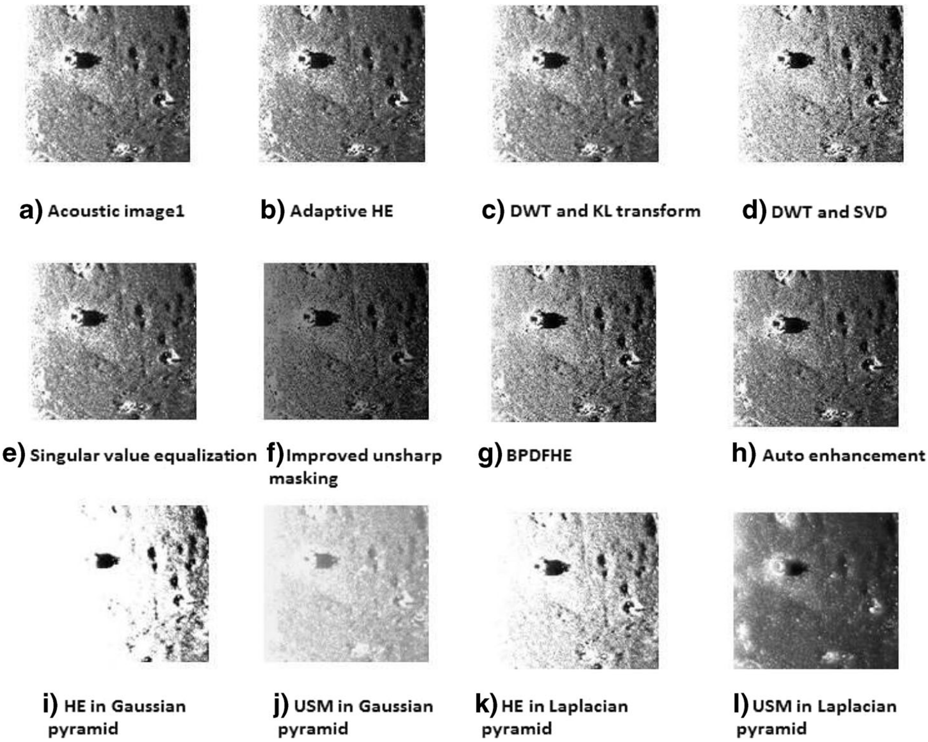

Fig. 3 Results of various methods for acoustic image 1 with Latitude 13:07.7935 N and Longitude 80:18.1166E

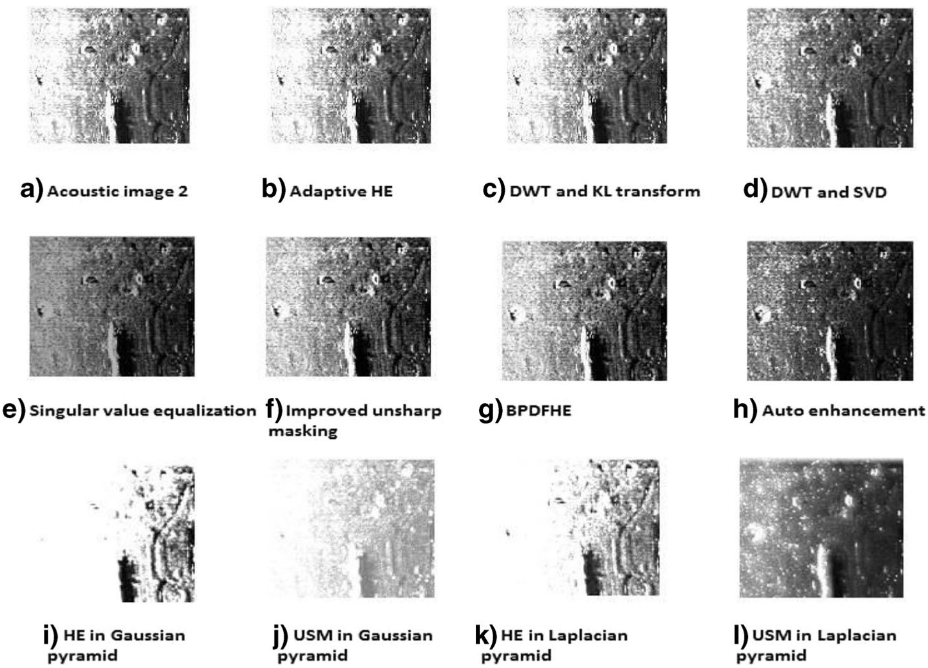

Fig. 4 Results of various methods for acoustic image 2 with Latitude 13:07.7250 N and Longitude 80:18.1793E

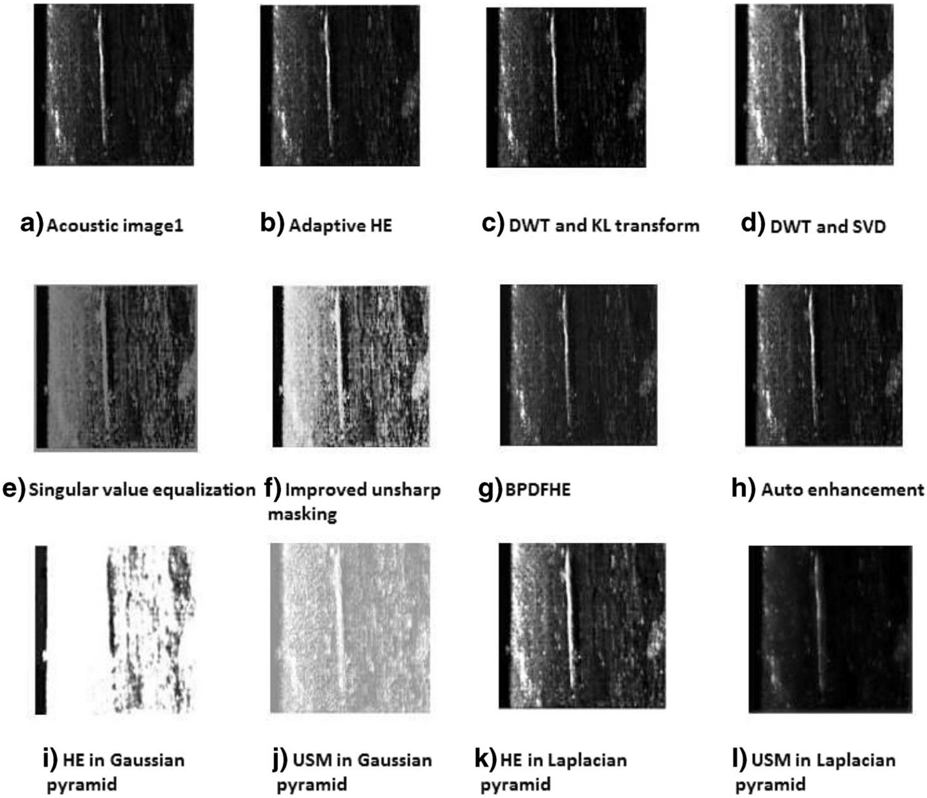

Fig. 5 Results of various methods for acoustic image 3 with Latitude 13:07.8007 N and Longitude 80:18.1383E

the real gray level values on the acoustic images at various levels of the pyramid are distributed equally, more lighter pixels have been produced that has led to poor visual quality. The objects in the acoustic image could not be differentiated from the seafloor and the sediments.

The unsharp masking method is used as sharpening technique over the images of the Gaussian pyramid and Laplacian pyramid. This method tends to increase the sharpness of only the edge pixels and not on the original image as a whole. While reconstructing the enhanced image, the sharpened images are added with the input low contrast image. The images reconstructed after applying the unsharp masking method in the Laplacian pyramid seem to have improved in its contrast and quality were the object and the seafloor are easily differentiated. The images in the Laplacian pyramid have edge features and high frequency components. On applying the unsharp masking method for sharpening, the quality of the images are improved and while reconstruction this method, shows real enhancement.

5.3 Performance measures

For quantitatively evaluating the image quality, a measure based on the Mean Squared Error (MSE) and the Peak Signal-to-Noise Ratio (PSNR) is used [20]. The MSE issued to measure the amount of data loss through the pixel value comparison. As the PSNR is derived from MSE, it is used to measure the image quality. The equation for calculating the PSNR value is as follows:

$$PSNR = 10\log_{10}\frac{\sum_{x=1}^{m}\sum_{y=1}^{n}255^2}{\sum_{x=1}^{m}\sum_{y=1}^{n}\left[I(x,y)-I_4(x,y)\right]^2} \qquad (15)$$

where $I(x,y)$ is the input image and $I_4(x,y)$ is the enhanced image obtained by the proposed method.

The Table 1 shows the PSNR for three images obtained from Gaussian and Laplacian pyramid measured in decibels (dB) using Mean squared error. In Gaussian pyramid, the enhancement techniques such as histogram equalization and unsharp masking method is applied only on the low frequency components. The PSNR value of the proposed method, that is unsharp masking in Laplacian pyramid is greater compared to other existing methods because the enhancement is done on the fine details such as edges rather than the low frequency components.

6 Conclusion

The acoustic images acquired using side scan sonar are low resolution images where textural information are present along with the speckle noise. On applying the multiresolution based techniques, the image in various resolution can be viewed with different features. The images in the Gaussian pyramid are obtained iteratively by performing the Gaussian smoothing and down sampling. Filtering techniques such as histogram equalization and unsharp masking methods are applied individually on the images and the enhanced image is reconstructed using the filtered images. The Laplacian pyramid is constructed using the images of the Gaussian pyramid by differencing the level *n* image with the interpolated level *n-1* image. The images in

Table 1 PSNR values for the various techniques

Techniques for image enhancement	Acoustic image1 (dB)	Acoustic image 2 (dB)	Acoustic image 3 (dB)
Adaptive histogram equalization – CLAHE	12.29	13.16	14.05
DWT and KL transform [16]	15.34	16.32	23.76
DWT and SVD [6]	15.04	15.98	22.07
Image equalization with SVE [5]	14.72	15.26	21.68
Improved unsharp masking method [25]	13.38	14.68	20.24
Brightness preserving dynamic fuzzy histogram equalization [22]	15.56	16.06	24.64
Auto enhancement method [9]	15.34	16.36	23.24
Histogram equalization in Gaussian pyramid	6.62	9.74	7.78
Unsharp masking in Gaussian pyramid	7.62	11.09	11.92
Histogram equalization in Laplacian pyramid	7.26	10.50	9.55
Unsharp masking in laplacian pyramid	16.44	17.15	26.10

the various levels of Laplacian pyramid are subjected to histogram equalization and unsharp masking methods.

The histogram equalization method tend to equally distribute the intensity values on the image globally. When applied to images of Gaussian pyramid and Laplacian pyramid has led to over contrast image where the underwater objects could not be clearly seen. The unsharp masking method applied on the images of the Laplacian pyramid increases the sharpness of the edges and when enhanced image is reconstructed, the objects in the images are easily identified by the real improved contrast. The experimental results show that the reconstructed image after applying unsharp masking in Laplacian pyramid outperforms the other methods.

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References

1. Adelson EH, Anderson CH, Bergen JR, Burt PJ, Ogden JM (1984) Pyramid methods in image processing. RCA engineer 29(6):33–41
2. Anbarjafari G, Izadpanahi S, Demirel H (2015) Video resolution enhancement by using discrete and stationary wavelet transforms with illumination compensation. SIViP 9(1):87–92
3. Asmare MH, Asirvadam VS, Hani AFM (2015) Image enhancement based on contourlet transform. SIViP 9(7):1679–1690
4. Cherifi D, Beghdadi A, Belbachir AH (2010) Color contrast enhancement method using steerable pyramid transform. SIViP 4(2):247–262
5. Demirel H, Anbarjafari G, Jahromi MNS (2008) Image equalization based on singular value decomposition. In: IEEE 23rd International Symposium on Computer and Information Sciences, 2008. ISCIS'08, (pp 1–5)
6. Demirel H, Ozcinar C, Anbarjafari G (2010) Satellite image contrast enhancement using discrete wavelet transform and singular value decomposition. IEEE Geosci Remote Sens Lett 7(2):333–337
7. Dura E (2011) Image processing techniques for the detection and classification of man made objects in side-scan sonar images, sonar systems. In: Nikolai K (ed) INTECH. Available from: http://www.intechopen.com/books/sonar-systems/image-processing-techniques-for-the-detection-and-classification-of-man-made-objects-in-side-scan-so
8. Fronthaler H, Kollreider K, Bigun J (2007) Pyramid-based image enhancement of fingerprints. In: IEEE 2007 I.E. Workshop on Automatic Identification Advanced Technologies, (pp 45–50)
9. Gonzalez RC, Woods RE (2007) Image processing. In: Digital image processing, Prentice Hall, New Jersey, (pp. 104–168)
10. Hasikin K, Isa NAM (2014) Adaptive fuzzy contrast factor enhancement technique for low contrast and nonuniform illumination images. SIViP 8(8):1591–1603
11. Kara F, Vural C (2016) Blind restoration and resolution enhancement of images based on complex filtering. SIViP 10(6):1159–1167
12. Liu X, Tang J, Xiong S, Feng Z, Wang Z (2009) A multiscale contrast enhancement algorithm for breast cancer detection using Laplacian Pyramid. In: IEEE International Conference on Information and Automation, 2009. ICIA'09, (pp 1167–1171)
13. Mahmoud TA, Marshall S (2009) Document image sharpening using a new extension of the aperture filter. SIViP 3(4):403
14. Murino V, Trucco A (2000) Three-dimensional image generation and processing in underwater acoustic vision. Proc IEEE 88(12):1903–1948
15. Peng KS, Lin FC, Teng KT (2015) Efficient image resolution enhancement using edge-directed unsharp masking sharpening for real-time ASIC applications. Journal of Computer Science & Systems Biology 8(3):174
16. Priyadharsini R, SreeSharmila T, Rajendran V (2015) Underwater image enhancement using discrete wavelet and KL transform. In: IEEE International Conference on applied and theoretical computing and communication technology, (pp 563–567).
17. Santhi K, Banu RW (2015) Contrast enhancement by modified octagon histogram equalization. SIViP 9(1):73–87

18. Sharmila S, Raja S (2013) Comparative analysis of satellite image pre-processing techniques. J Comput Sci 9(2):176–182
19. Sharmila TS, Ramar K (2014) Efficient analysis of hybrid directional lifting technique for satellite image denoising. SIViP 8(7):1399–1404
20. Sharmila TS, Ramar K, Raja TSR (2014) Impact of applying pre-processing techniques for improving classification accuracy. SIViP 8(1):149–157
21. Sharumathi K, Priyadharsini R (2016) A survey on various image enhancement techniques for underwater acoustic images. In: IEEE International conference on Electrical, Electronics and Optimization techniques, (pp 2930–2933)
22. Sheet D, Garud H, Suveer A, Mahadevappa M, Chatterjee J (2010) Brightness preserving dynamic fuzzy histogram equalization. IEEE Trans Consum Electron 56(4):2475–2480
23. Stefanakis N, Marchal J, Emiya V, Bertin N, Gribonval R, Cervenka P (2012) Sparse underwater acoustic imaging: a case study. In: IEEE 2012 I.E. International Conference on Acoustics, Speech and Signal Processing (ICASSP), (pp 2509–2512)
24. Thangaswamy SS, Kadarkarai R, Thangaswamy SRR (2013) Developing an efficient technique for satellite image denoising and resolution enhancement for improving classification accuracy. J Electron Imaging 22(1):1–7
25. Wu Z, Yuan J, Lv B, Zheng X (2010) Digital mammography image enhancement using improved unsharp masking approach. In IEEE 2010 3rd International Congress on Image and Signal Processing (CISP), vol 2. pp 668–672
26. Yang G, Zhang Y, Yang J, Ji G, Dong Z, Wang S et al (2016) Automated classification of brain images using wavelet-energy and biogeography-based optimization. Multimedia Tools and Applications 75(23):15601–15617
27. Zahedi M, Ghadi OR (2015) Combining Gabor filter and FFT for fingerprint enhancement based on a regional adaption method and automatic segmentation. SIViP 9(2):267–275
28. Zhang Y, Dong Z, Liu A, Wang S, Ji G, Zhang Z, Yang J (2015) Magnetic resonance brain image classification via stationary wavelet transform and generalized eigenvalue proximal support vector machine. Journal of Medical Imaging and Health Informatics 5(7):1395–1403

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