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Research Article

A Hybrid Approach for Underwater Image Enhancement using Wavelet based Fusion

Priyanka Holambe and Dr. Gayatri Bhandari

JSPMs Bhivarabai Sawant Institute of Technology and Research, Wagholi Pune

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Abstract

When an image is captured under water, it becomes hazy because of many undersea medium effects. The effects are influenced from suspended sediments which lead to light absorption and dispersion while image formation activity.Under water environment is not suitable for processing image data. It leads to reduced contrast and colour disappear issues.Hence,in image based exploration process, it becomes necessary to improve imaging data for future processing.Here, we present a waveletbased fusion technique for underwater image improvement. Wavelet filters are designed as Euler Frobenius polynomial (EFP). In the method, we use Euler Frobenius polynomial (EFP) to primarily flatten Euler Frobenius halfband polynomial (EFHP).It is achieved through imposing vanishing moments (VMs) and perfect reconstruction (PR) constraints on EFP. This leads to EFHP, that is used in four steps lifting model to analyse high and low pass filters. It is assured that filters proposed have linear phase and PR property. Thus,it has been ensured that openly available unclear undersea images are analysed and enhanced qualitatively using state of art techniques.This quantitative research of image quality exhibits favourable outcomes.

Keywords: *Euler Frobenius polynomial etc*

Introduction

Currently, the automated inspection and research operations are executed in profound Oceans. The submerged imaging is an important parameter of these automated based events. The light is extenuated in submerged habitat because of absorption effects of water particles, suspended elements and other contaminated particles. When light travels deep into the water attenuation increases . In such submerged environment during image formation process, less radiance extends to camera from an object in the site which changes original colors of an object.Perforation of visible spectrum colours depends on their wavelength and depth of the water. Wavelengths that are long are absorbed first while wavelengths that are short stay at longer distance in water (see Fig. 1). For example, underwater red colour disappears first at depth of 3 meters.While yellow and orange fade at 10 meters and 5 meters respectively [1]. In more depths, undersea images are mainly influenced by green or blue colours because of the shorter wavelengths.In light transmission within water, photons strike into water molecules and other fragments. The collisions result in direction changes of photons, such kind of arbitrary change in photons direction influences light dispersion phenomenon [2]. In many images,forward dispersion is accountable for contrast issues.Low contrast restricts visibility in underwater habitat and image development activity, these images will be dark.Low contrast issues affect feature extraction process in image processing methods. For example, in a research on undersea 3D reconstruction of volcanic rocks using structure from motion (SFM) in a topographical study, authors face low contrast issues [2].Less information about cloud points and depth, makes it hard to rebuild 3D model from the actual situation for a computer probe [1]–[5].

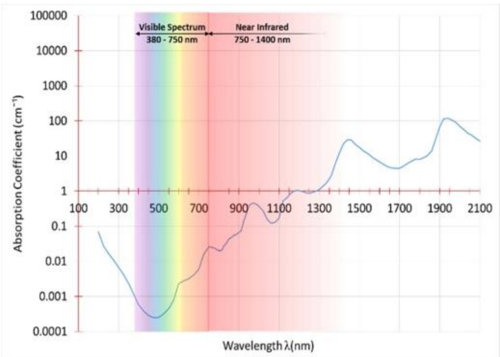


Fig. 1. Absorption coefficient of visible light in water.

Wavelet filterbanks(FBs) have received substantial acceptance in image and signal processing applications,for example,denoising, compression, pattern recognition, watermarking etc.Filter-banks are

categorised as bi-orthogonal or orthogonal.Bi-orthogonal (BO) Filter banks are chosen for image processing applications for linear phase criteria.It is advisable wavelet filters hold characteristics like flatness, regularity, high frequency selectivity etc.Obtaining good regularity measure for wavelet filters is important in design and is achieved by enforcing zeros at $\omega = \pi$ or $z = -1$
(aliasing frequency) on low pass filters. These zeros termed as vanishing moments (VMs). In hypothesis, highest vanishing moments give smooth scaling function that exhibits complex signals precisely. Hence, it is a advisable criterion to consider designing a filterbank [6]–[8].

Numerous filterbanks design methods succeeded to date in literature appear in [9]–[14]. It is found that,often used technique for designing various wavelet FBs is done using factorization of half band polynomials [10]. The popular biorthogonal FBs, example, CDF-9/7, spline wavelet [15]–[17] are designed using factorization methods. The Lagrange hal fband polynomial (LHBP) are factorized to design filter.The polynomial includes highest number of zeros at $z = -1$, that gives highest consistency measure.But,wavelet filters developed from this technique do not include free parameters that hold control of frequency response by filters.Hence, to hold certain control over frequency response by wavelet filters patil et al [10] has used few independent variables to develop generic halfband polynomial(GHBP).Factorization technique is used to achieve bi-orthogonal wavelet filter from GHBP [10].

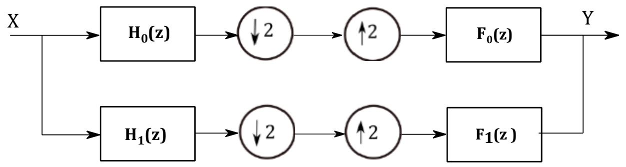


Fig. 2. Two channel PR filter banks structure.

But,it is found that factorization is mathematically complex for higher order HBPs. The lifting scheme technique is common and attracts schemes for designing FBs to provide PR functionally.Phoong et al. [18] observed a new halfband filterbank model that uses lifting scheme of two kernels. Though, disadvantage of the model is that,frequency response values of filters at $\omega = \pi/2$ has limited to values 0.5 and 1.0 only. To control the issue [19], triplet halfband structure (THFB) is proposed by Ansari et al. [19] with three lifting kernels. The tunable factor implemented in the study leads to more flexibility to shape frequency response of filters. In this work, we present a wavelet-based fusion method to enhance the hazy underwater images. The wavelet filters are designed *Euler Frobenius polynomial (EFP)*.In this method, we applied *Euler Frobenius polynomial (EFP)* to develop a maximal flat Euler Frobenius halfband polynomial (*EFHP*). This is achieved using vanishing moments (VMs) and perfect reconstruction (PR) limits on *EFP*. This results in *EFHP*, that used four steps to lift structure to obtain analysis of high pass and low pass filters. It is confirmed proposed filters include PR phase and linear phase property [9], [20]. It is assured that public available unclear undersea images are analysed and enhanced qualitatively using few state of art techniques. The quantitative work of image quality exhibits encouraging conclusions. The paper is structured as below.Section II has preliminaries of formulation of four step lifting scheme and two channel filterbanks . Section III shows proposed technique using choice of lifting parameters and demonstrates few design examples. Conclusions are presented in Section V.

Fbs design with eulerfrobenius polynomials(efp) and four step lifting

In the section, a new method to design biorthogonal two channel PR filterbank is suggested that includes four step lifting construction and Euler Frobenius Polynomials.

A. Framework of Two Channel Filter bank

Fig. 2 shows model of two-channel biorthogonal filter banks. The four filters form two channel filter bank that analyses high pass ($H_0(z)$), analyses low pass ($H_1(z)$), Synthesis high pass ($F_0(z)$) and Synthesis low pass ($F_1(z)$). The two channel FBs are known as perfect reconstruction(PR) FBs if they meet below equations:

$$H_0(z)F_0(z) + H_0(-z)F_0(-z) = cz^l \quad (1)$$

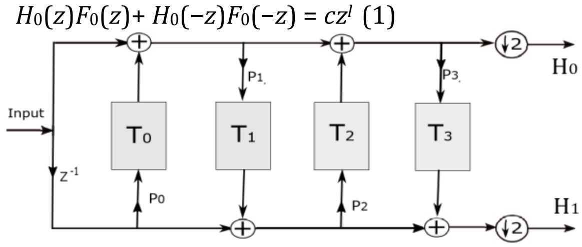


Fig. 3. Four-step lifting structure.

where, l is the value of delay. The PR condition can be reached if alias cancellation is obtained. This can be obtained using below analysis and synthesis of high-pass filters as

$$H_1(z) = z^{-1}F_0(-z) \;\&\; F_1(z) = zH_0(-z) \quad (2)$$

The product filter is defined as $P(z) = H_0(z)F_0(z)$. The product filter is associated with special class half band filters. The wavelet and scaling functions of analysis filters are shown by

$$\phi(t) = \frac{2}{H_0(\omega)|_{\omega=0}} \sum_n h_0(n)\phi(2t-n)$$

$$\psi(t) = \frac{2}{G_0(\omega)|_{\omega=0}} \sum_n h_1(n)\phi(2t-n)$$

where, $h_1(n)$ and $h_0(n)$ are the analysis high-pass and lowpass filters coefficient respectively.

B. Four Step lifting Construction

The mentioned filters are developed using four step lifting structure. Fig 3 represents lifting model for analysis filters. This method is proposed by Tay et.al. in

[21] that reserves PR property. It is parametrized using four half band filters. Analysis filters are reconstructed via four lifting steps and are shown by

$H_0(z) = C_0\{1+(p_1+p_3)\check{T}(z)+p_2p_3\check{T}^2(z) + p_1p_2p_3\check{T}^3(z)\}$ (5)

$F_0(z) = z^{-1}C_1\{1+(p_2 + p_4)\check{T}(z) + p_1p_2p_3p_4\check{T}^4(z) + (p_1p_2+p_1p_4+p_3p_4)\check{T}^2(z)) + p_2p_3p_4\check{T}^3(z)\}$ (6)

where, the kernels $\check{T}(z)$ are designed from κ^{th} order halfband polynomials. The halfband filter $P(z) = 1 + \check{T}(z)$.The objective is to design lifting kernels $\check{T}(z)$ using good frequency regularity and selectivity. The high-pass filters are achieved using equation (2). The lifting parameter p is the degree of freedom that provides flexibility to choose magnitude at $\omega = \pi/2$.

C. Design of EulerFrobenius Half band polynomial

The*Euler-Frobenius Polynomials (EFP)* is popular and used in model of spline wavelets [22]. The *EFP* has characteristics that its coefficients are integers and polynomial is equal.

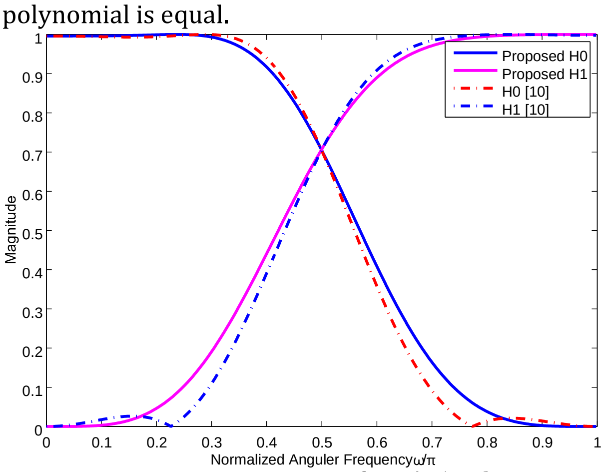


Fig. 4. Frequency Response of 19/25 Filters: Dotted line: Filters given in [21], Solid Line: Proposed filter pair.

This coefficients are determined recurrently. The generic *Euler Frobenius Polynomials* (*EFP*) are termed as

$$E_f(z) = \sum_{i=0}^{m} \hat{e}(i+1)z^{?i} \quad (7)$$

where m illustrates order of *EFP* and coefficients are acquired by:

$$\hat{e}(i+1) = \sum_{\ell=0}^{i}(-1)^{\ell}\binom{m+2}{\ell}(i+1-\ell)^{m+1} \quad (8)$$

In the study, we used *EFP* to form required halfband polynomial. The odd length *EFP* are added with VMs (zeros at z = -1) and initiate few independent variables β_i in order to change them into half band polynomials. The new polynomials are known as*Euler Frobenius halfband polynomials (EFHBP)* and is represented as:

$$P(z) = (1+z^{-1})^{\eta}E_f(z)\sum_{i=0}^{L}\beta_i z^{-i} \quad (9)$$

where, η exhibits number of VMs. The m^{th} order *EFP* is shown by $E_f(z)$. The product filter $P(z)$ has order $K = \eta + m + L$. Order of free polynomial is $L = K/2-1$. Free variables β_i are structured such as PR state shown in equation (1) is met. Required K^{th} order kernel of lifting scheme is shown by

$$\check{T}(z) = z^{K/2}P(z) - 1 \quad (10)$$

We contemplate above equation for lifting kernels design.

D. Design Examples

The section shows some examples to demonstrate proposed filterbank model. We consider the DC gain $G_{DC} = 1$. *Example 1:*

The $K = 6$ *EFHBP* has been used to form halfband kernel $T(z)$. Filters H_0 and F_0 resulted into lengths 19 and 25 respectively. We choose $M = 3$ to achieve highest regularity

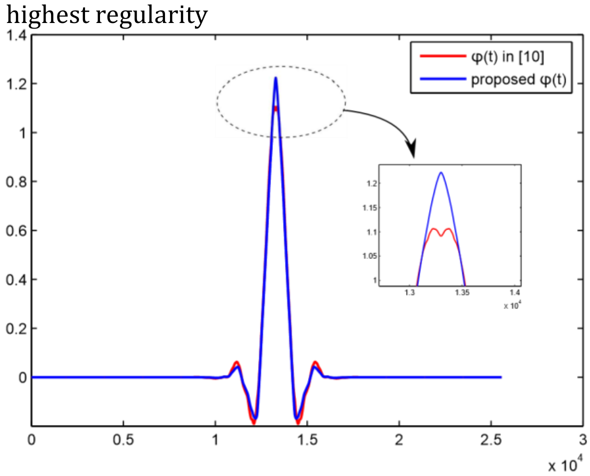


Fig. 5. Plot of analysis scaling functions

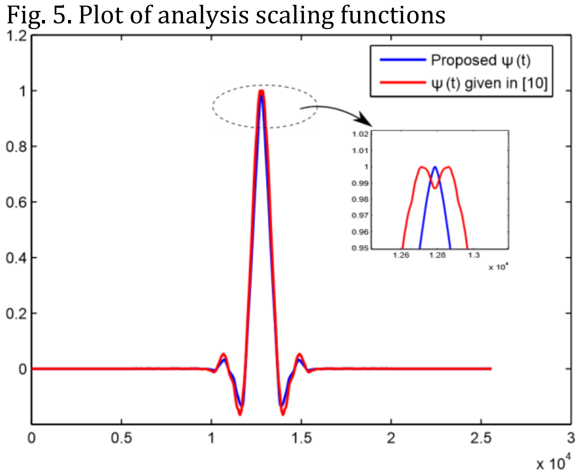


Fig. 6. Plot of analysis wavelet functions

Table I Property Measures Of Length 19/25 Filters

Property Measures	Existing FBs [21]	Proposed FBs
Symmetry	2.0006	2
Sobelov Regularity	1.096	1.3687
Frame Bound	1.0433	1.0022
Frequency Selectivity	257	256.97

$4t$	0.54775	0.42958
4ω	0.90067	0.93648
$4t.\ 4\ \omega$	0.49334	0.4023

and L = 2 to impose the PR limits. This results into three linear equations-

$$4\beta_0 + 4\beta_1 = 0 \quad (11)$$

$$4\beta_0 + 24\beta_1 + 4\beta_2 = 1 \quad (12)$$

$$4\beta_1 + 4\beta_2 = 0 \quad (13)$$

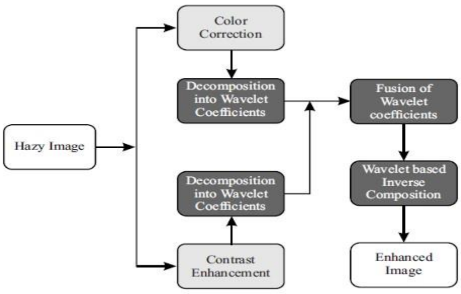


Fig. 7. Wavelet based fusion approach for underwater image enhancement

Solution of simultaneous linear equations,gives $\beta_0 = -1/16$, $\beta_1 = 1/16$, $\beta_2 = -1/16$. By replacing these values in an equation (9), we get result as halfband product filter. The resultant $P(z)$ is used in equation (10) for design of kernel $T(z)$. We have examined same kernels. These kernels are substituted in (5) and (6),in order to obtain synthesis and analysis of low pass filters. Frequency response of suggested 19/25 length wavelet filters are shown in Fig 4. Ripples are observed in stop band areas of frequency response for filters stated in [21] as shown in Fig. 4.

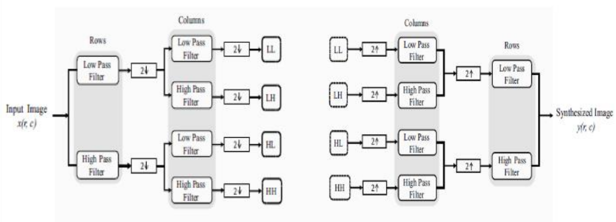
Image compression application when used ripples form in stop band region of filter response results information to spill into high-pass sub bands. This lessens efficiency of compression.Ripples also reduce uniformity of filters as corresponding wavelet and scaling functions are relatively inconsistent. This consequence is exhibited in Fig. 5 and 6.Though, proposed filters do not include such ripples and therefore are beneficial in such uses. It is proved that suggested filters have high degree of smoothness. Wavelets with high smoothness result into allowable reconstruction quality for various image processing applications. We have computed properties, example,timefrequency localization, symmetry, frame bound ratio and frequency selectivity. The properties measures is depicted in Table I. The frequency and time localization measures are shown in Table I. It is observed that the filter hold great time frequency localization.

The Wavelet Based Fusion

In image and signal processing fusion is implemented to resolve various issues. This technique relies on image fusions with discrete wavelet transforms for improvement of undersea figures [4], [23]. In the suggested technique color attenuation and low contrast of unclear images is considered.Hence, we employ histogram and CLAHE stretch methods for color correction and contrast enhancement. The whole process for wavelet based fusion method is exhibited in Fig. 7. Originally, the unclear submerged images are cloned in two version. The versions processed in parallel to improve color profiles and image contrast .Then inverse composition, wavelet-based decomposition and fusion are performed to achieve contrast and color enhancement on image.For color rectification, image is transformed from RGB(Red-Green-Blue) to HSV (HueSaturation-Value) color range stretched on complete interval. This procedure enhances brightness of existing colors in an image. Then Saturation and Hue are combined with corrected value parameters and therefore image is transformed back into RGB color range. Inside RGB color range,histogram is again stretched on the complete interval (0 to 255) to obtain colour rectification across all three channel.To improve contrast of undersea images, we consider contrast restricted adaptive histogram equalization(CLAHE). The CLAHE is a form of adaptive histogram equalization (AHE) [3], [24]. In AHE noise overamplification inclination is more while contrast improvement. Hence, to reduce issue, contrast limit is proposed for CLAHE to reduce unwanted interval from histogram. The restricted limit is determined with normalization of histogram and so size of neighborhood interval in pixel range. it is confirmed that the (blue shaded) bins over clip regions are reallocated.Redistribution pushes few bins over defined clip limit this effect is reduced by redo of process repetitively until extra area is minor. The CLAHE is implemented on all three color sections in RGB color space independently to improve contrast of all existing colors in a picture. The results are shown in Fig. 10 and 11.

Conclusion

This study represents new method of designing biorthogonal halfband filterbank using perfect reconstruction. The Euler Frobenius polynomial is implemented to design maximal flat Euler Frobenius halfband Polynomial (*EEHP*) by using *VM* constraints and *PR*. The suggested *EEHP* is used in four steps lifting restructure for designing the new class of sharp biorthogonal filters.



Proposed technique results into degree of freedom to control frequency response of filter with free variables. The design example exhibits proposed filters are comparable with existing techniques. Additionally , these filters result in more regularity, unit frame bound ratio as compare to existing filter banks, better frequency selectivity and less timefrequency localization. Thus, the proposed filter obtains perfect reconstruction criterion.

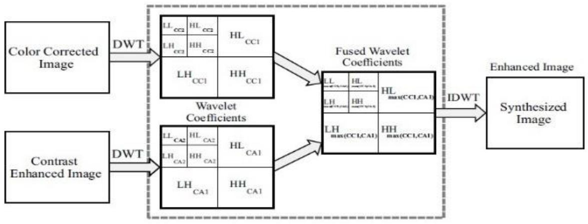


Fig. 9. Two-level-2D decomposition, fusion of coefficients and image synthesizing

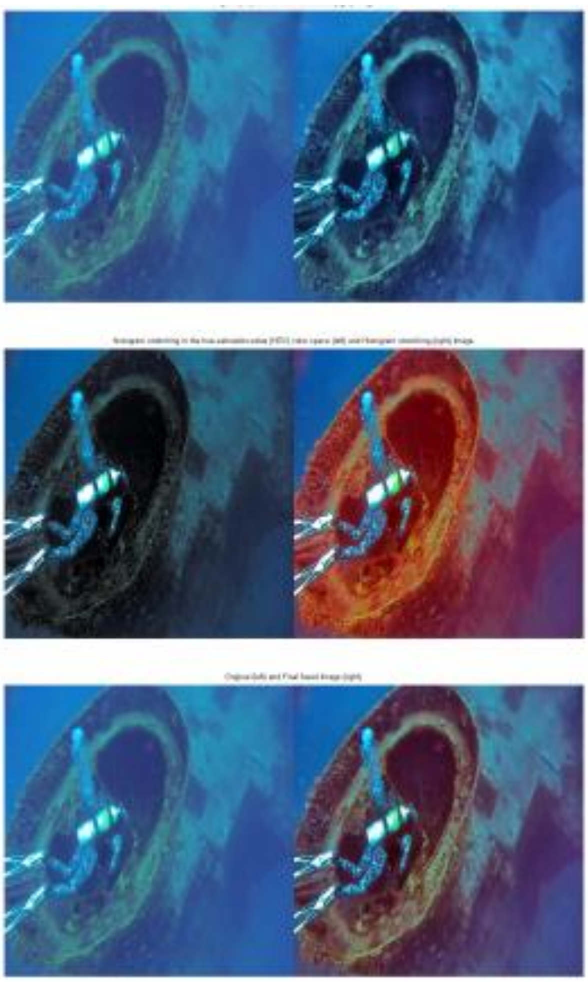


Fig. 10. First row: histogram stretching in the hue-saturation-value (HSV) color space (left) and Histogram stretching (right) Image; Second Row: Original (left) and Contrast Enhanced (right) Image; Third row: Original (left) and Final fused Image (right)

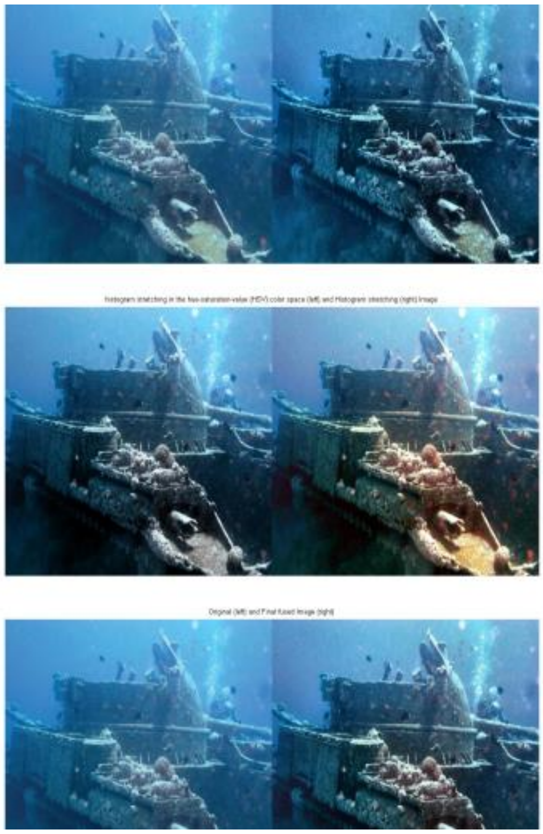


Fig. 11. First row: histogram stretching in the hue-saturation-value (HSV) color space (left) and Histogram stretching (right) Image; Second Row: Original (left) and Contrast Enhanced (right) Image; Third row: Original (left) and Final fused Image (right)

References

[1] A. Khan, S. S. A. Ali, A. S. Malik, A. Anwer, and F. Meriaudeau,"Underwater image enhancement by wavelet based fusion," in *2016 IEEE International Conference on Underwater System Technology: Theory and Applications (USYS)*, pp. 83–88, 2016.

[2] C. Ancuti, C. O. Ancuti, T. Haber, and P. Bekaert, "Enhancing underwater images and videos by fusion," in *2012 IEEE Conference on Computer Vision and Pattern Recognition*, pp. 81–88, 2012.

[3] R. Hummel, "Image enhancement by histogram transformation," *Computer Graphics and Image Processing*, vol. 6, no. 2, pp. 184 – 195, 1977.

[4] S. Emberton, L. Chittka, and A. Cavallaro, "Hierarchical rank-based veiling light estimation for underwater dehazing," pp. 125.1–125.12, 01 2015.

[5] C. Ancuti, A. Codruta, T. Haber, and P. Bekaert, "Enhancing Underwater images and videos by fusion," pp. 81–88, 06 2012.

[6] P. P. Vaidyanathan, *Multirate Systems and Filter banks*. NJ: Englewood Cliffs Prentice-Hall, 1993.

[7] M. B. Nagare, B. D. Patil, and R. S. Holambe, "On the design of biorthogonal halfband filterbanks with almost tight rational coefficients," *IEEE Transactions on Circuits and Systems II: Express Briefs*, pp. 1–1, 2019.

[8] V. P. Khalane and U. S. Bhadade, "A parameterized

halfband filterbank design for image encryption," in *2018 IEEE 13th International Conference on Industrial and Information Systems (ICIIS)*, pp. 32–35, 2018.
[9] M. B. Nagare, B. D. Patil, and R. S. Holambe, "Design of two channel biorthogonal filterbanks using euler frobenius polynomial," *Journal of Signal Processing Systems*, Jan 2020.
[10] B. Patil, P. Patwardhan, and V. Gadre, "On the design of FIR wavelet filter banks using factorization of a halfband polynomial," *IEEE Signal Processing Letters*, vol. 15, pp. 485–488, 2008.
[11] B. Patil, P. Patwardhan, and V. Gadre, "Eigenfilter approach to the design of one-dimensional and multidimensional two-channel linear phase FIR perfect reconstruction filter banks," *IEEE Transactions on Circuit and Systems Vol-I,*, 2008.
[12] D. B. H. Tay, "Rationalizing the coefficients of popular biorthogonal wavelet filters," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 10, pp. 998–1005, Sep 2000.
[13] D. B. H. Tay and Z. Lin, "Almost tight rational coefficients biorthogonal wavelet filters," *IEEE Signal Processing Letters*, vol. 25, pp. 748–752, June 2018.
[14] J. P. Gawande, A. D. Rahulkar, and R. S. Holambe, "A new approach to design triplet halfband filter banks based on balanced-uncertainty optimization," *Digital Signal Processing*, vol. 56, pp. 123 – 131, 2016.
[15] I. Daubechies, *Ten Lectures on Wavelets*. Philadelphia: SIAM, 1992.
[16] I. Daubechies and J. Feauveau, "Biorthogonal bases of compactly supported wavelets," *Communication Pure Appllied Mathematics*, no. 45, pp. 485–560, 1992