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DESIGN OF DYADIC-INTEGER-COEFFICIENTS BASED BI-ORTHOGONAL WAVELET FILTERS FOR IMAGE SUPER-RESOLUTION USING SUB-PIXEL IMAGE REGISTRATION

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Abstract

This paper presents image super-resolution scheme based on sub-pixel image registration by the design of a specific class of dyadic-integer-coefficient based wavelet filters derived from the construction of a half-band polynomial. First, the integer-coefficient based half-band polynomial is designed by the splitting approach. Next, this designed half-band polynomial is factorized and assigned specific number of vanishing moments and roots to obtain the dyadic-integer coefficients low-pass analysis and synthesis filters. The possibility of these dyadic-integer coefficients based wavelet filters is explored in the field of image super-resolution using sub-pixel image registration. The two-resolution frames are registered at a specific shift from one another to restore the resolution lost by CCD array of camera. The discrete wavelet transform (DWT) obtained from the designed coefficients is applied on these two low-resolution images to obtain the high resolution image. The developed approach is validated by comparing the quality metrics with existing filter banks.

Keywords:

Super-Resolution, Sub-Pixel Image Registration, Integer Wavelet, Discrete Wavelet Transform, Half-Band Polynomial

1. INTRODUCTION

Image super-resolution is the process by which one or more low-resolution (LR) images are processed together to create an image with a high spatial resolution. The well-known existing scheme for the super-resolution is based on the standard interpolation techniques (pixel replication, bilinear, bicubic, linear interpolation) that increases the pixel count without adding the details [1][2][3]. However, interpolation based super-resolution techniques introduced the blur effect in edges. Generally, super-resolution technique can be divided into three types: Frequency domain reconstruction, Iterative, and Bayesian methods. Tsai and Haung [3] first introduced the frequency domain reconstruction super-resolution scheme where images are transformed into frequency domain by the use of Fourier transform (FT). Next, these transformed coefficients converted into spatial domain to obtain a higher resolution than the original frame. However, this method relies on the motion being composed of only horizontal and vertical displacements. Irani and Peleg [4] proposed the iterative algorithm that uses the current initial guess for super-resolved (SR) image to create LR images and then compare the simulated LR image with original LR image. These difference images are used to improve the initial guess by back projecting each value in the difference image on-to the SR image. Gajjar and Joshi [1] presented a learning-based approach for super-resolving an image using single observation by the use of learning of high frequency sub-bands derived from discrete wavelet transform (DWT). In their work, orthogonal wavelet filter bank (db4) is used to extract the high frequency contents from the LR image. However, this method suffers from boundary distortions of image due to orthogonal wavelet filter bank. Ji and Fermullar [5] proposed super-resolution reconstruction system by addressing the problem of frame alignment and image restoration based on standard bi-orthogonal wavelet filter bank (cdf-9/7). However, the hardware complexity in terms of number of shifts and adders increased (requires infinite precision) due the irrational coefficients of cdf-9/7. Jiji et al. [2] presented singe frame image super-resolution using wavelet coefficients than pixel values in different frequency sub-bands to determine high frequency components. This method allows more localized frequency analysis than global filtering using FT. This method requires regularity characteristics in the wavelet domain to keep output visually smooth and free from wavelet artifacts. Nguyen and Milanfar [6] proposed wavelet-based interpolation-restoration method for super-resolution. Anbarjafari and Demirel [7] presented a new super-resolution scheme based on the interpolation of high-frequency sub-bands derived from DWT (cdf-9/7 FB) and the input image. The same authors improved this super-resolution scheme by combining the interpolation of high frequency sub-bands derived from DWT, stationary wavelet transform (SWT) from the same FB and the input image [8]. Chappali and Bose [9-10] investigated the effect of threshold level on reconstructed image quality in lifting scheme based wavelet super-resolution. The objective of this scheme was to remove as much of the corrupting noise as possible without affecting the reconstructed image quality due to blur introduced in the super-resolution process. The majority of the super-resolution algorithms depend upon relative motion at the sub-pixel level, between the low-resolution images. Hence, the super-resolution algorithms require the registration scheme that determines the relative sub-pixel motion between the image frames [12]. Ward [12] mentioned that the adjacent frames in a video sequence overlap most of the same information. Thus, it is necessary to use image registration algorithm to determine the multiple frames of the overlapped area that requires for the image super-resolution. Based on this work, Patil and Singhai [13] proposed the super-resolution algorithm by the use of fast discrete curvelet transform (FDCT). However, this algorithm suffers from high computational complexity. It is because of the following inconveniences in the implementation of FDCT: 1) FDCT requires large support area and thus computational complexity is high 2) curvelet coefficients organized into sub-band with different size 3) redundancy ratio is not fixed but varies within range and thus creates problem for memory allocation.

It is observed that all of these super-resolution schemes used off-the-shelf wavelet basis i.e. orthogonal wavelet bases (Daubechies family), bi-orthogonal wavelet bases (9/7), and Haar basis. However, many issues are still open in the field of image super-resolution related to the choice of filter bank (FB). It is also well known that the performance of wavelet based systems is highly dependent upon the choice of wavelet. Also, the class of wavelet filter banks (FBs) with integer and rational coefficients are very important in the field of image super-resolution because of fast hardware-friendly finite-precision implementation and low power consumption. Hence, this paper proposes super-resolution scheme by the design of a specific class of dyadic-integer-coefficients based wavelet filter bank.

2. REVIEW OF THE RELATED FILTER BANKS

Multirate filter banks and wavelets are widely used in the analysis, processing, and representation of digital signals [14][15]. The specific class of FBs with integer and rational coefficients is a better solution because of fast hardware-friendly finite-precision implementation and low power consumption. Generally, the design of wavelet FBs revolves around the orthogonal and bi-orthogonal wavelets. Both have their respective advantages. However, orthogonal wavelet are not symmetric that leads to non-linear phase. The linear phase plays an important role in order to handle boundary distortions of images [14-15]. These both the characteristics (orthogonality and linear phase) exist in Haar wavelet. But, the Haar wavelet provides the discontinuous phase. Hence, the bi-orthogonal wavelet is preferred over orthogonal wavelets for image processing due to its linear phase characteristics. Most of the popular bi-orthogonal FBs (e.g. Cohen-Daubechies-Feauveau (CDF) 9/7 and spline family of wavelet FBs) [14] are designed by the factorization of Lagrange half-band polynomial (LHBP), which has the maximum number of zeros at $z=-1$ so as to achieve better regularity. However, LHBP filters do not have any degree of freedom and thus there is no direct control over frequency response of the filters. In order to have some independent parameters (which can be optimized to obtain some control over frequency response of the filter), Patil et al. [16] used general half-band filter factorization (not LHBP) to design two-channel bi-orthogonal wavelet FIR FBs (BWFB). However, factorization (decision of factorization of remainder polynomial and reassignment of zeros) improves the frequency response of one of the filters (analysis/synthesis) at the cost of the other filter (synthesis/analysis). The improvement in the frequency response of both the filters totally depends on the factorization of a halfband polynomial. This is somewhat tedious task for higher order polynomials. In order to solve these issues, Rahulkar and Holambe [17] proposed a new class of triplet half-band filter bank (THFB). However, the combined length of this FB is 32 which may not be suitable for hardware implementation. Also, the coefficients obtained from these above designed filter banks [16, 17] are irrational numbers that requires floating point arithmetic implementation. With this, the computational complexity increased due to which hardware implementation becomes difficult. Hence, it is necessary to design the filters which give hardware friendly dyadic coefficients. Naik and Holambe [18] have been achieved this objective by designing the family of low-complexity wavelet filters. Most of the researchers have been used the quantization criteria on the frequency response of the designed filters. However, the quantization affects on the performance of the designed filters [18] by the shift of the location of zero at $z = -1$. In this paper, a new specific class of dyadic-integer-coefficient based 9/7 wavelet filter is designed by imposing the sufficient number of vanishing moments and suggested the use of this designed filters in the field of super-resolution so as to reduce the computational complexity.

2.1. GENERAL BACKGROUND

The two-channel bi-orthogonal filter bank is shown in Fig.1 where the analysis and synthesis high-pass filters (HPF) are obtained by quadrature mirroring the low-pass filters (LPF) so that aliasing cancellation is achieved as:

$$H_1(z) = z^{-1}G_0(-z),\ G_1(z) = zH_0(-z).$$

The analysis scaling and wavelet functions are given by the following equations:

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

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

where, $h_0[n]$ and $h_1[n]$ are LP and HP filter coefficients.

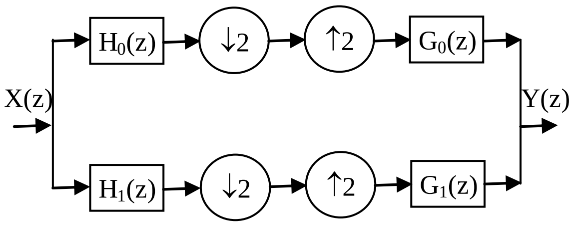

Fig.1. Two-channel filter bank

2.2 DESIGN OF THE PROPOSED DYADIC-INTEGER-COEFFICIENTS BASED WAVELET FILTERS (DICWF)

This section presents the design of the proposed class of wavelet filter banks. First, the integer coefficients based half-band polynomial of an order 14 is designed by the use of splitting approach based on the number of vanishing moments. Next, this designed half-band polynomial is used to obtain the dyadic-integer coefficient based low pass analysis and synthesis filters. It is well known that the standard CDF-9/7 FBs is designed by the use of a Lagrange half-band polynomial (LHBP). This FB gives the irrational coefficients because of LHBP that leads to increase the computational complexity. Hence, in order to obtain the rational (dyadic-integer) coefficients, the integer coefficient based half-band polynomial is designed. The construction of the proposed DICWF is discussed as follows.

It is known that the low-pass analysis and synthesis filters obtained by the spectral factorization of the product polynomial (half-band polynomial) $P(z)$ [15]. Thus, this product filter can be written as $P(z) = H_0(z)G_0(z)$ and the perfect reconstruction condition can be written as $P(z)+P(-z) = 2z^{-m}$. The regularity is imposed in the design of $P(z)$ by forcing $P(z)$ to have zeros at

z = –1. In order to have the more regularity in the filters (maximally flat frequency response at $\omega = \pi$), maximum number of zeros at z = –1 has to be imposed. With this, the half-band product polynomial can be written as the product of maximum number of vanishing moment (maximum number of zeros at z = –1) and the remaining roots as $P(z) = (1+z^{-1})^M R(z)$, where $R(z)$ is the remainder polynomial. This remainder polynomial is factorized to obtain the two remainder polynomials $R_1(z)$ and $R_2(z)$. Next, the low-pass analysis and synthesis filters $H_0(z)$ and $G_0(z)$ can be obtained by the reassignment of number of zeros at z = –1 to $R_1(z)$ and $R_2(z)$. The maximum number of zeros at z = –1 for N^{th} order product polynomial can be imposed is $M = (N/2) + 1$. The well-known CDF-9/7 FB is obtained from 14th order half-band polynomial and the eight maximum number of zeros at z = –1 can be imposed to get maximally flat frequency response at the cost of irrational coefficients.

In this paper, the product half-band polynomial of order 14 is expressed using splitting approach as,

$$P(z) = (1+z^{-1})^{N1} R_1(z) R_2(z) \tag{1}$$

where, N_1 is the number of zeros at z = –1, $R_1(z)$ and $R_2(z)$ are the unknown polynomials. Based on the extensive observations, we have assumed the value of N_1 = 4 and obtained one of the half-band polynomials of order 6. This is expressed in order to obtain integer coefficients as:

$$R_3(z) = (1+z^{-1})^4 R_1(z) \tag{2}$$

Thus, $R_3(z)$ of order 6 can be written given by Eq.(3) as by imposing four zeros at z = –1:

$$R_3(z) = (1+4z^{-1}+6z^{-2}+4z^{-3}+1z^{-4})(1+a_1z^{-1}+a_2z^{-2}) \tag{3}$$

This $R_3(z)$ can be written as:

$$\begin{aligned} R_3(z) = 1 + (4+a_1)z^{-1} + (6+4a_1+a_2)z^{-2} + \\ (4+6a_1+4a_2)z^{-3} + (1+4a_1+6a_2)z^{-4} \\ +(a_1+4a_2)z^{-5} + a_2 z^6 \end{aligned} \tag{4}$$

We need $R_3(z)$ as a half-band polynomial, so the coefficients of odd power of z except at center of symmetry will be zero. This can be written as:

$$4+a_1 = 0$$
$$a_1+4a_2 = 0$$

The solution of these equations gives the value of a_1 = –4 and a_2 = 1. Hence, one of the half-band polynomials is obtained by substituting these values in Eq.(4) as:

$$R_3(z) = 1\text{-}9z^{-2}\text{-}16z^{-3}\text{-}9z^{-4}+z^{-6} \tag{5}$$

With this, the product half-band polynomial can be expressed as:

$$P(z) = (-1+9z^{-2}+16z^{-3}+9z^{-4}-z^{-6}).R_2(z) \tag{6}$$

where, $R_2(z)$ is 8th order unknown polynomial and expressed as:

$$R_2(z) = 1+b_1z^{-1}+b_2z^{-2}+b_3z^{-3}+b_4z^{-4}+b_5z^{-5}+b_6z^{-6}+b_7z^{-7}+b_8z^{-8} \tag{7}$$

Thus, the resultant product half-band polynomial $P(z)$ can be written as:

$$\begin{aligned} P(z) = &–1–b_1z^{-1} + (9–b_2)z^{-2} + (16+9b_1–b_3)z^{-3}+(9+16b_1+9b_2–b_4)z^{-4} \\ &+ (9b_1+16b_2+9b_3–b_5)z^{-5} + (9b_2–1+16b_3+9b_4–b_6)z^{-6} \\ &+ (–b_1+9b_3+16b_4+9b_5-b_7)z^{-7} + (–b_8+9b_6+16b_5+9b_4–b_2)z^{-8} \\ &+ (9b_7+16b_6+9b_5–b_3)z^{-9} + (9b_8+16b_7+9b_6–b_4)z^{-10} \\ &+ (16b_8+9b_7-b_5)z^{-11} + (9b_8-b_6)z^{-12}-b_7z^{-13}-b_8z^{-14}, \end{aligned}$$

The constraints from this above equation for the half-band polynomials are as follows:

$$–b_1 = 0;\ –b_7 = 0$$
$$16+9b_1–b_3 = 0;$$
$$9b_1+16b_2+9b_3–b_5 = 0;$$
$$–b_1+9b_3+16b_4+9b_5–b_7 = 0;$$
$$9b_7+16b_6+9b_5–b_3 = 0;$$
$$16b_8+9b_7–b_5 = 0;$$

The solutions of these equations for the symmetric and dyadic-integer coefficients polynomials are:

$$b_8 = 1;\ b_1 = b_7 = 0;\ b_2 = b_6 = –8;\ b_3 = b_5 = 16;\ \text{and } b_4 = 46$$

With this, the resultant designed integer coefficient based half-band polynomials is expressed by Eq.(8) as:

$$\begin{aligned} P(z) = -1 + 17z^{-2} - 109z^{-4} + 605z^{-6} + 1024z^{-7} \\ + 605z^{-8} - 109z^{-10} + 17^{-12} - 1z^{-14} \end{aligned} \tag{8}$$

Now factorized this $P(z)$ to obtain low-pass analysis $H_0(z)$ and synthesis $G_0(z)$ filters. The problem with such factorization is the distribution of roots. If $P(z)$ is factorized into two equal roots, then symmetry will be lost. This non-symmetric wavelet basis degrades the performance due to its non-linear phase. In order to achieve the symmetry, Chebyshev polynomial is used to factorize this $P(z)$. Thus, the $P(z)$ is factorized and assigned the four specific roots and two zeros at z = –1 to low-pass analysis filter $H_0(z)$. Next, selected the two specific roots and four zeros at z = -1 to obtain low-pass synthesis filter $G_0(z)$. The reason behind these selections is to obtain the dyadic-integer coefficient wavelet filters. Thus, the resultant designed filters are expressed as;

$$H_0(z) = 1/32(1–8z^{-2}+16z^{-3}+46z^{-4}+16z^{-5}–8z^{-6}+1z^{-8}) \tag{9}$$

$$G_0(z) = 1/32(–1+9z^{-2}+16z^{-3}+9z^{-4}+z^{-6}) \tag{10}$$

The length of H_0 and G_0 are 9 and 7 respectively and hence called as dyadic-integer-coefficient based 9/7 wavelet filters (9/7 DICWF).

The frequency responses of the LPF and HPF are compared with the existing well-known FBs as shown in Fig.2. It is observed that proposed DICWF gives comparable frequency response with the popular CDF-9/7 FBs. The proposed scaling and wavelet functions are shown in Fig.3(a) and Fig.3(b) respectively.

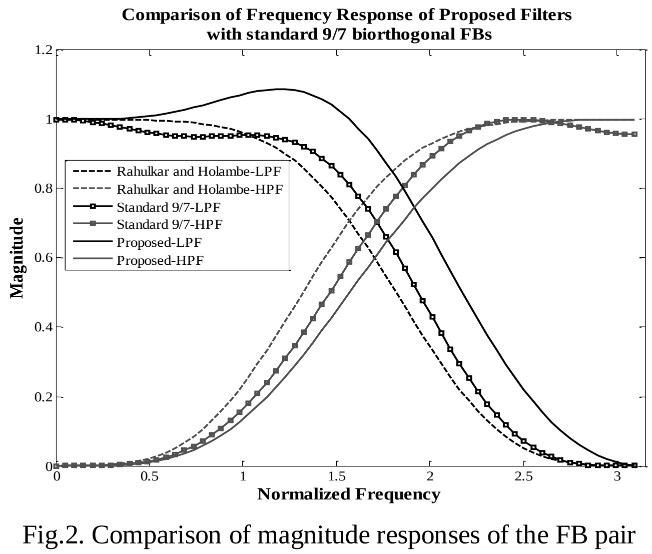

Fig.2. Comparison of magnitude responses of the FB pair

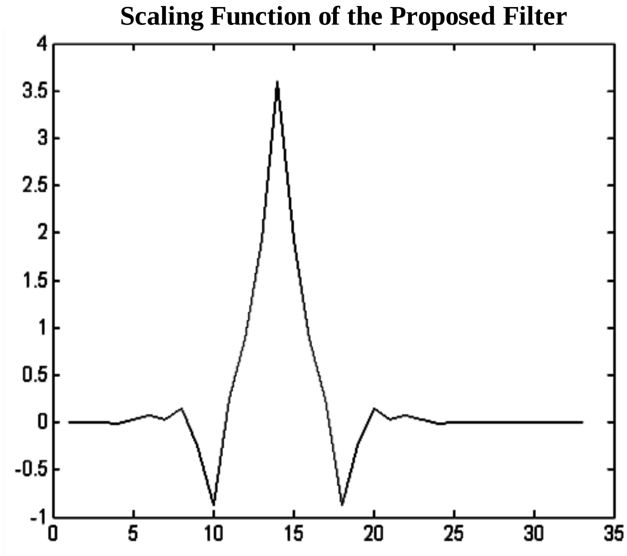

Fig.3(a). Scaling Function

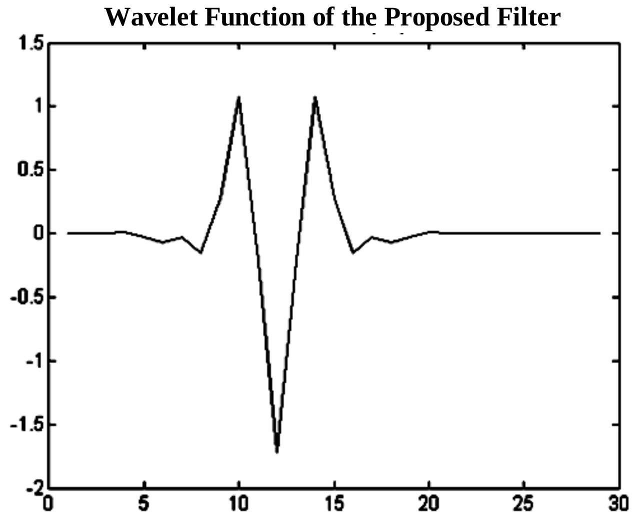

Fig.3(b). Wavelet Function

In order to apply the DICWFs to images, 2-D extension of wavelets are required. An obvious way to construct separable 2-D wavelet filters is to use tensor product of their 1-D counterparts. A 2-D approximation and three detail functions are obtained from Eq.(11) as:

$$
\begin{aligned}
L(z) &= H_0^{1d}(z_1)\times H_0^{1d}(z_2), \qquad H(z) = H_0^{1d}(z_1)\times H_1^{1d}(z_2),\\
V(z) &= H_1^{1d}(z_1)\times H_0^{1d}(z_2), \qquad D(z) = H_1^{1d}(z_1)\times H_1^{1d}(z_2).
\end{aligned} \tag{11}
$$

where, $H_0^{1d}(z_1)$ and $H_1^{1d}(z_1)$ are 1-D LPF and HPF respectively of DICWFs. The one-level decomposition results in *Vertical (V), Horizontal (H),* and *Diagonal (D)* sub-bands and one *approximation sub-band (L),* which corresponds to LH, HL, HH, and LL sub-bands respectively.

3. SUPER-RESOLUTION SCHEME BASED ON THE PROPOSED CLASS OF DICWFS

The existing super-resolution schemes used the interpolation techniques. However, the resulting image using this method contained blurred effect in the edges. Hence, multi-resolution analysis (MRA) based technique can be very useful in order to preserve the edges. It is well known that discrete wavelet transform (DWT) is a very powerful tool in MRA. The power of DWT is to give good time resolution for high frequencies and good frequency resolution for low frequencies. However, the presence of down-sampling by factor-2 in DWT causes the information loss in the respective sub-bands. Hence, in order to mitigate this effect, the three detail sub-bands without down-sampling factor (called as stationary wavelet transform) has been introduced in the interpolated detail sub-bands to obtain super-resolved image [8]. However, such type of wavelet based super-resolution algorithm introduced the spatial domain noise. This type of noise can be reduced with the help of wavelet-coefficient based thresholding technique. Thus, Chappalli and Bose [9] investigated the effect of soft-thresholding level on the reconstructed image quality by the use of existing wavelet based on the two-step lifting step. However, these algorithms required the irrational coefficients based wavelet filters that lead to increase the hardware computational complexity. In order to reduce this issue, a wavelet filter based on dyadic-integer coefficient is proposed to reduce the hardware complexity in the field of image super-resolution.

First, the two low-resolution images I_1 and I_2 are obtained from the original image based on the half-pixel shift in both the directions (row and column-wise). Both of these frames are then rotated by an angle of 45º using quincunx sampling so as to determine the measure of similarity of the pixel values between two frames. These rotated images are interpolated to denote the missing pixels in the super-resolution image. The proposed specific class of DICWFs is applied on these two rotated high-resolution images and the interpolation is performed at one scale. Next, the proposed class of reconstruction DICWFs are applied to these interpolated rotated images and combined into a single image. This single image is the post-rotated back to its original orientation so as to obtain the super-resolved image. The super-resolution algorithm based on the proposed class DICWFs are as follows:

First, the original image is used to obtain the two low-resolution images (frames) I_1 and I_2 by quincunx sampling (sampling at half-pixel in horizontal and vertical directions of the original image) [12]. The image I_1 contains only the odd indices pixel values and the image I_2 contains even indices pixels. This shift in two images represents the diagonal motion of a camera over an area, assuming CCD array of the camera samples the area in this half-pixel manner. The Fig.4 illustrates quincunx sampling by splitting the pixel image of 6 × 6 into two 3 × 3 pixel images at desired half-pixel shift. The zeros indicate odd indices pixels and the cross indicates the even indices pixels.

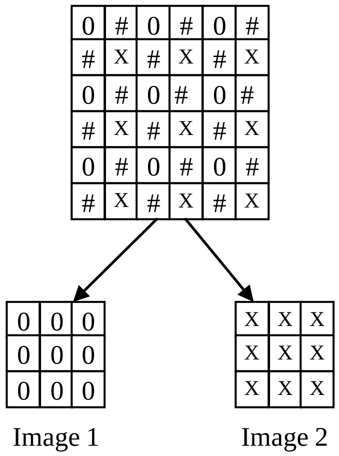

Fig.4. Procedure to obtain the two-resolution images

These two low-resolution frames are then combined on a quincunx sampling grid. The placing of these two low-resolution frames into a high resolution frame correspond to half-pixel shift in *x* and *y*-directions. This high-resolution grid is obtained by doing some transformation on these two-resolution frames and can be written as:

$$H(x_H,y_H)=T(I_1(x_1,y_1),I_2(x_2,y_2)) \tag{12}$$

where, $H(x_H,y_H)$ is a quincunx sample of the desired high-resolution image, I_1 and I_2 are the two-resolution images (frames), and T is transformation to obtain quincunx sampling grid. The relationship between the co-ordinates of the two-resolution images and high-resolution is given as [12]:

$$x_1 = 2x_H–1,\ y_1 = 2y_H–1,\ x_2 = 2x_H,\ y_2 = 2y_H.$$

This is illustrated in Fig.5 which is a combined image of two low-resolution images.

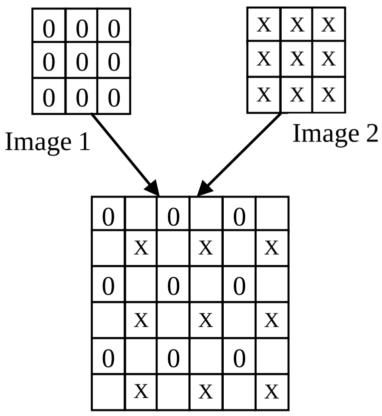

Fig.5. Combined high-resolution image from two resolution images

Next, the complete high-resolution image has been created by interpolating the missing pixels in the wavelet domain using proposed class of separable DICWFs. In order to obtain the wavelet coefficients, the resultant sampling grid need to be rotated by angle of 45º so as to exploit the relationship between these two low-resolution images. This is achieved by using Eq.(13) as:

$$H_{\mathrm{rot}}(x_{\mathrm{rot}}, y_{\mathrm{rot}}) = \mathrm{Rot}[H(x_H, y_H)] \tag{13}$$

This rotated image is up-sampled by 2 in order to create the space for obtaining the missing pixel values. This resultant image is decomposed at the first level by the use of proposed class of DICWFs. With this, three detail sub-bands (LH, HL, and HH) and one approximation sub-band have been obtained. The missing pixel coefficients have been calculated using linear interpolation. The reconstructed DICWFs are applied on this interpolated image to construct the high-resolution image by the use of post-wavelet domain processing. The detail algorithm is given in [12-13]. The algorithm is summarized as follows:

- Original image is sampled to obtain the two low-resolution images.
- Two resolution frames are then mapped on to the quincunx sampling grid.
- Rotate the resultant image by an angle of 45º.
- Decomposed the rotated image by the use of proposed class of DICWFs.
- Obtained the missing coefficients using interpolation technique.
- Reconstruction DICWFs are applied on this interpolated at one level.
- Performed post-wavelet domain processing to obtain high-resolved image.

4. EXPERIMENTAL RESULTS

The proposed method is validated by comparing the peak signal to noise ratio (PSNR) values of the proposed scheme with the PSNR values obtained from existing FBs. The performance of the proposed super-resolution scheme has been tested over three standard images. The two low-resolved images have been obtained by half-pixel shift in *x* and *y*–directions from the original image. The performance measure in terms of PSNR is measured in order to obtain an insightful analysis. The PSNR values are known to be mathematically convenient, so generally used for judging image quality.

The proposed method is validated by comparing the PSNR values with a standard wavelets includes orthogonal FBs (db6, db9) [14], standard CDF–9/7 FB [14][15], and a class of THFB [17]. The performance comparison of DICWF with existing well-known FBs is shown in Table.1. It is observed that the proposed DICWFs yields superior performance than the well-known orthogonal FBs. This is due to the linear-phase and more number of zeros at $z = –1$ present in the proposed design of the wavelets. It is also observed that the proposed method using rational wavelet coefficients gives comparable performance with the well-known CDF-9/7, and a class of THFB [17]. Thus, the proposed method reduces the hardware computational complexity which leads to use in real time applications. This is because the number of adders and shifter required for computing the integer coefficients will be very less as compared to irrational coefficients. The visual effect of the image super-resolution using CDF-9/7, THFB [17], and DICWFs is shown in Fig.6.

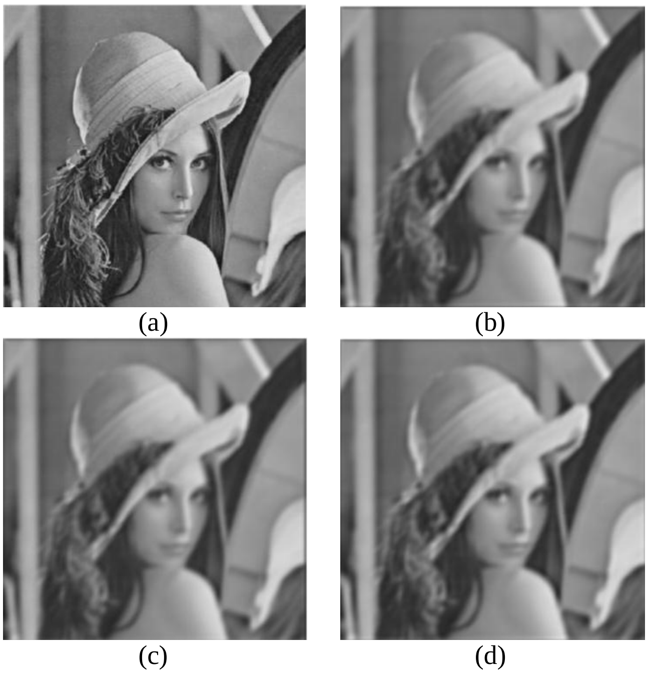

Fig.6.(a). Original Image, (b). Super-resolved using CDF-9/7 wavelets, (c). Super-resolved using RH wavelets [17], (d).Super-resolved using proposed class of DICWFs

Table.1. PSNR values for proposed DICWFs with well-known existing FBs

	PSNR in dB					
	Lena	**Baboon**	**Peppers**	**Cameraman**	**Barbara**	**Elaine**
Proposed DICWFs	29.7295	30.3266	23.8236	26.62	24.33	28.85
CDF-9/7 wavelets	29.8146	30.3839	23.944	26.65	24.37	28.91
RH wavelets [17]	29.88	30.4334	24.05	26.045	24.15	28.67
Orthogonal wavelets (db4)	28.73	29.036	23.02	26.012	24.02	27.37
Orthogonal wavelets (db6)	29.02	29.89	22.93	26.53	24.23	27.39

5. CONCLUSION

This paper proposed an efficient super-resolution scheme based on sub-pixel image registration by the design of a new class of a dyadic integer coefficient based wavelet filters. In this paper, a specific class of DICWFs bi-orthogonal wavelet basis has been introduced based on half-band polynomial and investigated its use in the field of image super-resolution in order to reduce the computational complexity. The super-resolved image has been reconstructed by registering the image frames at sub-pixel shift and interpolated the missing pixel locations in discrete wavelet domain. The two-resolution frames have been registered at a specific shift from one another to restore the resolution lost by CCD array of camera. The discrete wavelet transform (DWT) obtained from the designed coefficients is applied on these two low-resolution images to obtain the high resolution image. The proposed class of DICWFs gives acceptable PSNR values and is less complex as compared to the existing wavelets.

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