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Image Representation using combined 2-D quincunx and 1-D Directional Filter Banks

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Abstract: **In this paper, an effective image representation using directional filter banks by using new combined 2-D and 1-D directional FB combinations named the TODFBs, its simple to implementation and low computation costs as compared to method like separable WT and 9/7WT.it is very efficient. Furthermore, the calculation of the curves in images is no longer needed in contrast to the adaptive directional WTs. In spite of the simplified structure, the proposed MIRs preserve the diagonal frequency information as well as the horizontal, vertical and low-frequency information. The proposed method yields simple implementation and low calculation costs compared to the other 1D and 2D FB combinations or adaptive directional WTs. In applications on nonlinear approximation and image coding, the proposed filter bank shows visual quality improvements and has higher PSNR.**

***Index Terms*— wavelet transforms, directional filter banks, image coding, nonlinear approximation.**

I.NTRODUCTION

The traditional wavelet transform (WT) is categorized as a separable transform, which is used in various applications. However, it has poor diagonal orientation selectivity since frequencies which represent different orientation are gathered into one sub band in each resolution. For example, in image coding, these diagonal high-frequency coefficients are often truncated (not transmitted to the decoder side) and thus, the reconstructed image has blurred regions for diagonal orientations. To reduce the artifact, some combinations of 1D separable and 2D nonseparable filter banks (FBs) have been proposed.

Some directional WTs support sub-pel and quarter-pel accuracy for each direction which contributes to better representation of curves along with a significantly higher computation cost than that of the separable WTs. Furthermore, they need to transmit the side information of the curves to decoder. Although this barely affects the entire bit budget to be encoded, it usually requires a careful manipulation to store or transmit since it should be lossless data. To overcome the previously mentioned problems, we propose new combinations of 2-D and 1-D directional (TOD) FBs based on 2-D nonseparable FBs and the directional WT. In this paper, one TODFB is provided to use the effective existing framework of the separable WT. Their frameworks are shown in Fig.1. These TODFBs uses a combined FB before decomposing by the separable WT. The first stage in the TODFB extracts the curves in the sub bands by the 2-D FBs, and the second stage reduces the redundancy in these curves by the directional WTs.1-D filters are rotated to fit lines in images, we denote this type of WTs as "directional WT" The proposed combinations are simple, but preserve both low- and high-frequency information even after The quantization/truncation of many transformed coefficients.

II. BRIEF REVIEW

Directional Filter Bank

The directional FB was first proposed by Bamberger and Smith [3], [4] the key idea is to divide the frequency plane into several parts which correspond to the specific frequency directions. The frequency plane partition of a directional FB with eight sub bands is represented in Fig. 2.1 They are realized by using quincunx FBs and parallelogram ones, where quincunx means the down sampling matrix Q for 2-D FBs and is defined as $Q = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$.Their resulting downsampling matrix D for the subband i is

$$D = \begin{cases} \mathrm{diag}\left(2^{(n-1)}, 2\right) & 0 \le i \le \left(2^{(n-1)} - 1\right) \\ \mathrm{diag}\left(2, 2^{(n-1)}\right) & 2^{n-1} \le i \le \left(2^{n} - 1\right) \end{cases}$$

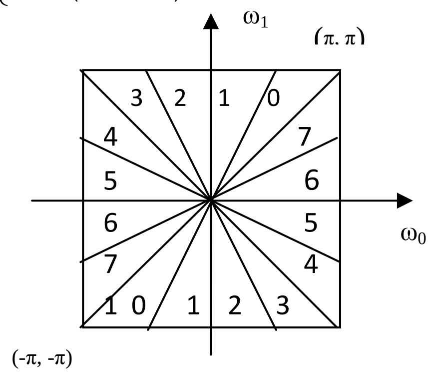

Fig2.1.Frequency partition for direction FB with eight subband

Directional Wavelet Transforms

Directional WTs are based on the combination of 1-D downsampling and transforming by 1-D WT filters along

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the 2-D directions. Lines in the images called curves in this paper, often flow toward diagonal orientations. Some of the directional WTs [5],[6],[7] are based on the lifting implementation of the separable WTs . We use this scheme for our proposed combination. The directional lifting steps are illustrated in Fig.4 Let x(m,n) denote the pixel value at (m,n). A prediction step for a direction θ with the vertical downsampling is represented as

$$H(m,2n+1)=x(m,2n+1)–P(m,2n) \quad \text{……….. (2)}$$

Where h(m,2n+1) represents a highpass branch of the directional lifting step and

$$P(m,2n) = pi\ (x\ (m – \tan\theta,\ 2(n-l)) + x\ (m + \tan\theta,\ 2(n + l + 1\ )) \quad \text{…..(3)}$$

In which p_i is a coefficient for this prediction step and l is a nonnegative integer. An updating step is given by

$$l(m,2n)=x(m,2n)+U(m,2n+1) \quad \text{…….(4)}$$

Where l(m,2n) represents a lowpass branch and

$$U(m,2n+1) = u_i\ (h\ (m – \tan\theta,\ 2(n-l)\ -1) + h(m + \tan\theta,\ 2(n-l)\ +1)) \quad \text{……(5)}$$

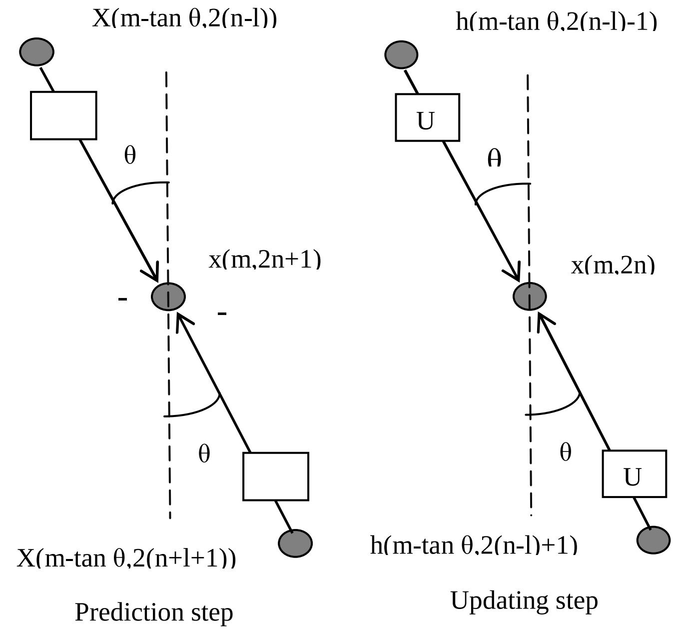

Fig2.2.Directional Lifting steps for the directional WT

In which u_i is an updating coefficient Clearly, these lifting steps are perfect reconstruction and can be cascaded with other lifting steps similar to the separable WTs. In this paper, we use the lifting coefficients of the 9/7 WT .

$p_0 = -1.586134342$, $u_o = 0.05298011854$
$p_1 = 0.8829110762$, $u_1 = 0.4435068522$
$s_0 = 1.149604398$, $s_1 = 1/s_0$

Where so and s1 are scaling coefficients of lowpass and highpass branches, respectively.We define the notations of the transform direction by the directional WT as the relative pixel position from the pixel to be transformed. Some typical directions are illustrated in Fig 2.2. Where the direction for the separable WT is defined as (0, 1). In this paper, we consider only the directions for the vertical down sampling Mv = diag(1,2) since the horizontal downsampling version can be easily obtained as the transposition of the vertical downsampling one. Note that the even (odd) row to be transformed requires neighbor odd (even) rows in each lifting step for perfect reconstruction. Therefore, the directions (1,2), (-1, 2) etc., cannot be transformed without interpolating pixels.

III.TODFB WITH QUINCUNX FBs

This section introduces the TODFB using quincunx FBs as its 2-D stage. The image is primarily decomposed by the quincunx FBs, and then it high-frequency subbands are transformed by the directional WTs for specific directions. The entire decomposition is shown in Fig 3.1. In this figure,

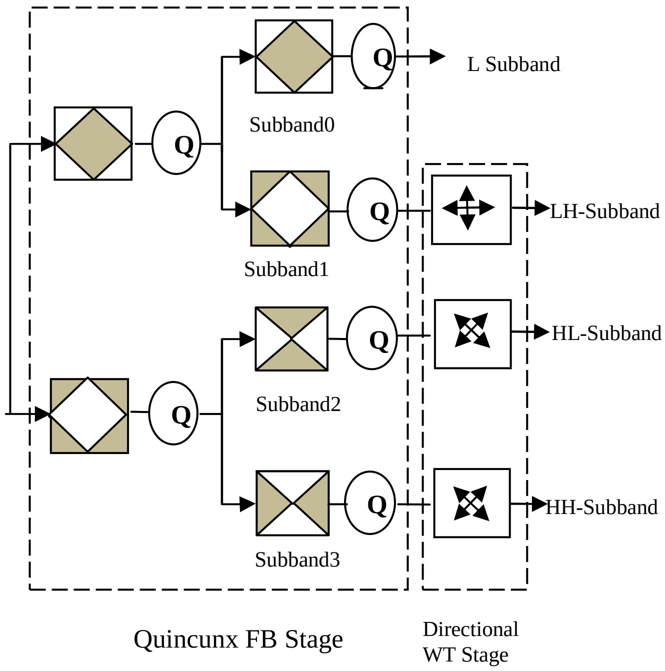

Fig3.1. Q-TODFB Decomposition.

The arrowheads in “Directional WT stage” represent the transform directions. For subbands 1,2, and 3, and 9/7 directional lifting WT is applied in the direction (0, 1), (-1,1) and (1,1) first, and then in the direction (1,0), (1,1) and (-1,1), respectively. The down sampling matrix for the low-frequency resolution (sub band 0) is always Q^2 = diag (2,2), which is the same as that of the separable WT. Consequently, the low-resolution image is transformed recursively by the TODFB or the separable WT. Hereafter, this kind of TODFBs is called Q-TODFB where “Q” stands on the initial letter of quincunx FB. To fit the obtained MIR for the TODFBs to the traditional quad-tree MIR, we consider one important condition. That is the enter downsampling matrix should be diag (2^k, 2^k) where k is a positive integer since the resulting subbands should keep the aspect ratio of the original image.

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A. 2-D Stage in Q-TODFB

In the Q-TODFB, the original image is first decomposed by two 2-D quincunx FBs, one consisting of a diamond filter and its complementary filter, and the other a fan filter pair. The fan FB is fundamentally realized to modulate horizontally (or vertically) the diamond FB by $e^{j\Pi}$; thus, we now consider required properties for a diamond FB.

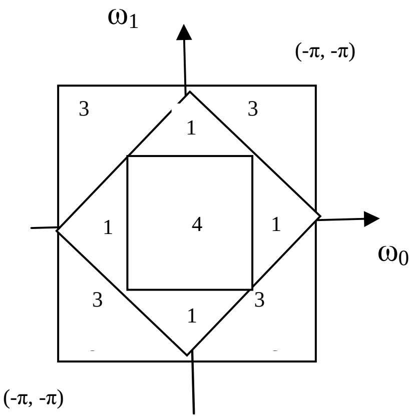

Fig 3.2. Frequency plane partition of 2-D stage in the Q-TODFB where number represent sub band indices

The most important property in the Q-TODFB or other image processing using FBs is regularity of filters since avoiding DC leakage in highpass filters is strongly desirable. In this paper, we employ the diamond FB proposed in which is based on the direct optimization of its filter coefficients. Both lowpass and highpass filter sizes are 11x11. There are many methods to design 2-D diamond or fan FBs, however the FB used here has a short highpass filter length. The regions conaining high-frequency, e.g. edges and curves, usually exist locally. The short highpass filter will capture that high-frequency information well. The fan FB is determined as a modulated version of the diamond FB. Fig 3.2 shows the frequency plane partition using quincunx FBs, it captures the high-frequency coefficients which are distributed on the specific direction along (-1, 1) Consequently, the 2-D stage in the Q-TODFB framework provides a new MIR with the downsampling matrix diag (2.2); low pass highpass with the horizontal vertical curves, highpass with the curves along (-1, 1), and highpass with the curves along (1, 1).

B. Directional 1-D Stage in Q-TODFB

The previous subsection shows that the 2-D quincunx FBs decompose directional high-frequency energy in the original image well.In this paper, the 9/7WT is used for subband 1 to 3. It is realized by the lifting factorization of their filter coefficients which consists of two prediction and update steps, and one scaling.

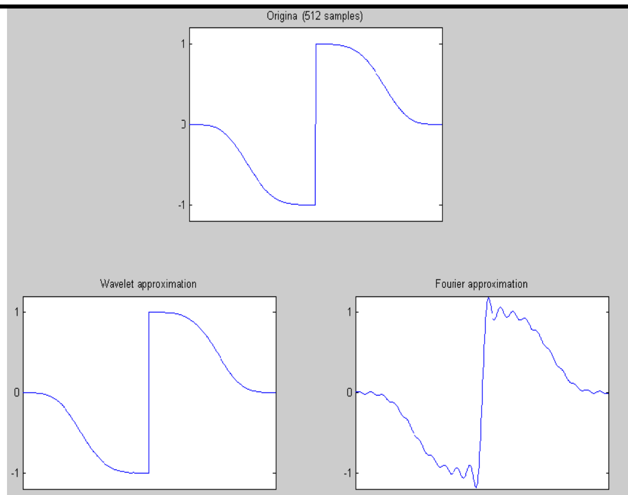

Fig 3.3Comparison of Wavelet and Fourier approximation using 9/7WT

For subband 2 and 3, the 9/7 directional lifting WT is applied in the direction $\pi/4$and - $\pi/4$ first, then in the direction -$\pi/4$, and $\pi/4$ respectively. The directional lifting WT for the direction $\pi/4$ with the vertical down sampling is shown in fig3.33. In this fig. “p” and “u” denote coefficients for prediction and update steps, respectively. Additionally, white and gray circles indicate the even and odd rows, respectively. In this stage, the subband1 is further decomposed by the separable WT. It corresponds to transforming along the vertical and horizontal curves since the subband1 can be classified into a subband with high-frequency components including these curves. Furthermore, the down sampling matrix for the subband 0 is diag(2, 2); thus, its size is one fourth of the original image.
Decomposition of image (barabara) using 9/7 WT

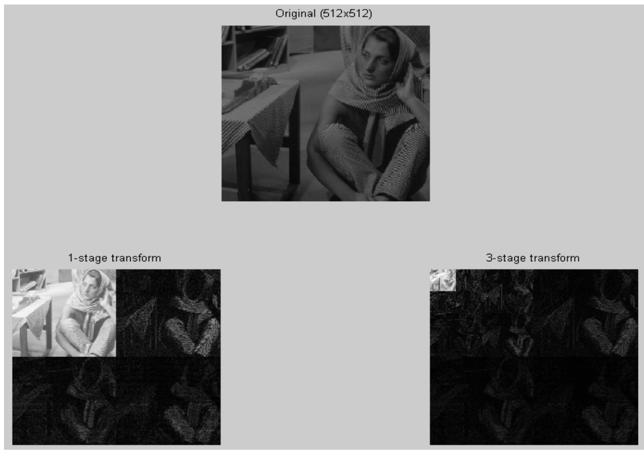

Fig 3.4The Q-TODFB can be applied to the subband 0 recursively if needed

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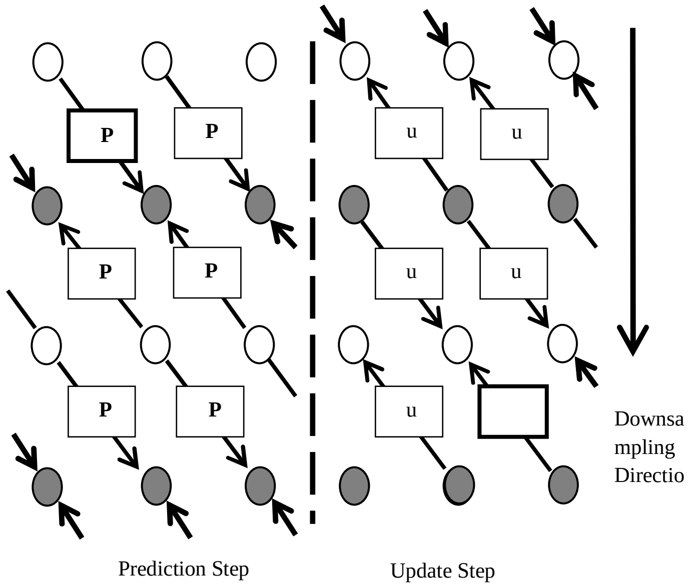
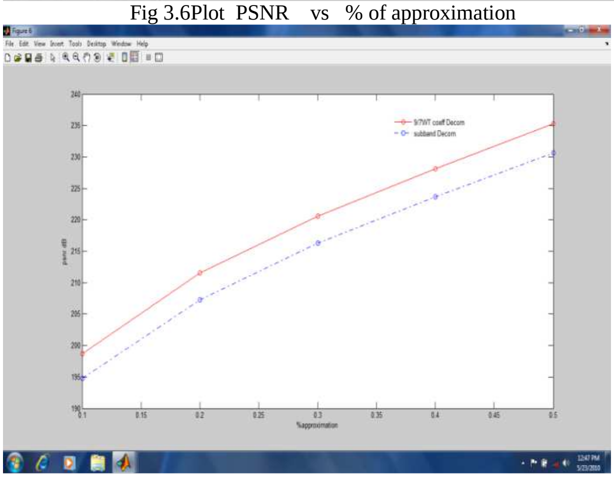


Fig3.5. Directional lifting WT along the direction

Reconstruction (10,20,30,40,50) of barabara image of using

Fig 3.6Plot PSNR vs % of approximation



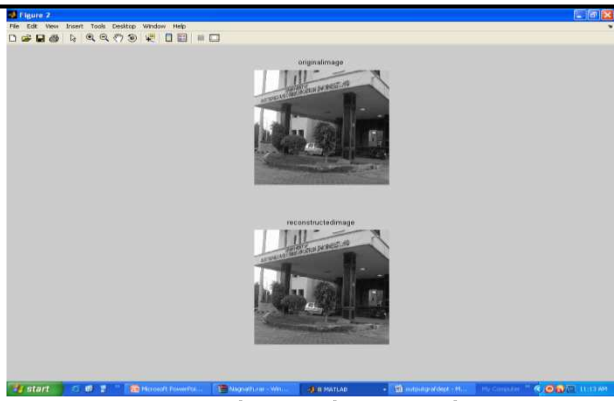


Fig.3.7. Original image and reconstructed image

Fig. 3.8. NLA reconstructed image comparison of Dept image. From left to right: Q-TODFB, D-TODFB

• Q-TODFB with a 1-level decomposition for the quincunx FB/directional WT pair and a 4-level one for the separable WT, labeled Q-TODFB (1, 4).
• Q-TODFB with a 2-level decomposition for the quincunx FB/directional WT pair and a 3-level one for the separable WT, labeled Q-TODFB (2, 3).
• D-TODFB whose highest frequency resolution is decomposed by the diagonally quadrant FB/directional WT pair, labeled D-TODFB (1, 4).
• D-TODFB whose two highest frequency resolutions are decomposed by the diagonally quadrant FB/directional WT pair, labeled D-TODFB (2, 3).

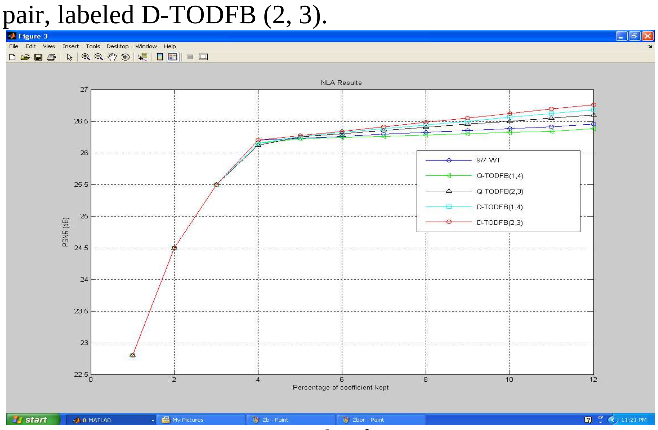


Fig.3.9. NLA results of Dept image

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Table.3.1. Comparison Results for NLA Results For Image Dept

% of Co-Efficient	3	4	8	10
9/7 WT	**25.5**	**26.0**	**26.10**	**26.10**
Q-TODFB(1,4)	**25.6**	**26.15**	**26.40**	**26.60**
Q-TODFB(2,3)	**25.65**	**26.20**	**26.50**	**26.30**
D-TODFB(1,4)	**25.6**	**26.15**	**26.45**	**26.65**
D-TODFB(2,3)	**25.65**	**26.25**	**26.55**	**26.80**

Nonlinear Approximation

Nonlinear Approximation (NLA) is a good measure to estimate the potential of transforms for MIR. All 2-level decomposed dept image is set to have the same number of the highest coefficients and the remaining coefficients are set to zeros as shown in fig.3.8. It clearly, the TODFB always has higher PSNR then 9/7 WT for image dept. of the reconstructed image as shown in Fig.3.8 it clear that TODFB preserve high frequency region such as lines in the image.

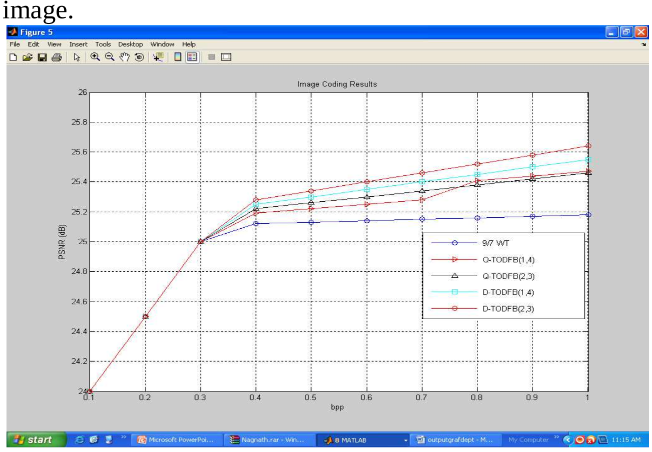

Fig.3.10 Image Coding Result

Table.3.2 Comparison Results for Image Coding For Image Dept

Bpp	0.3	0.4	0.6	0.8
9/7 WT	**25.00**	**25.10**	**25.10**	**25.10**
Q-TODFB(1,4)	**25.10**	**25.20**	**25.20**	**25.40**
Q-TODFB(2,3)	**25.15**	**25.18**	**25.25**	**25.40**
D-TODFB(1,4)	**25.15**	**25.18**	**25.30**	**25.45**
D-TODFB(2,3)	**25.20**	**25.25**	**25.40**	**25.45**

Image coding is one of the key applications using MIR. Based on the NLA results, the TODFBs are expected to have good image coding performance. Here we compare the proposed TODFB with the 9/7 WT and the main purpose of TODFB is to reduce energy in high-frequency subbands. The results for various bit-rates are shown in Fig. 3.10. The TODFBs outperform the 9/7 WT in low bit rates for rich textured images from above graph it
shown that for various bit rates the TODFB gives higher PSNR value then 9/7WT, at lower bit for rich texture image It's shown the usual quality in a reconstructed image is more and diagonals lines are clearly visible in the reconstructed image.
As camper to above results of image dept and nag image , the TODFB gives higher PSNR value as compare to result of nag image because at lower bit rate for rich textured image gives higer PSNR and it shows the better visual quality in reconstructed image.

APPLICATIONS

In this section, we discuss applications using the TODFBs. For fair comparison, three benchmark results are presented. Those are the separable 9/7 WT, the contourlet and the HWD [7]. The 5-level decomposition is used for all of the transforms including the TODFBs.

CONCLUSION

In this paper, we propose new 2-D and 1-D dictional FB combinations named the TODFBs. They yield better results than those of the 9/7WT, the contourlet or theHWDin the applications of NLA, image coding and denoising. Moreover, the proposed systems are very efficient Furthermore, the calculation of the curves in images is no longer needed in contrast to the adaptive directional WTs. In spite of the simplified structure, the proposed MIRs preserve the diagonal frequency information as well as the horizontal, vertical and low-frequency information.

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