Abstract—JPEG2000, the international standard for still image compression, uses wavelet transform. The filters used by JPEG2000 for transformation are the 9/7 Daubechies filters and the 5/3 Le Gall filter. At present, to achieve image mirroring or rotation for images, we have to convert them back to spatial domain and proceed. This paper presents methods by which we can implement the same in the wavelet domain, without extra computational complexity. To do so, we manipulate the transform domain coefficients so that the condition of perfect reconstruction still holds true.

Index Terms—Mirroring, Rotation, JPEG2000 filters, Wavelets

I. INTRODUCTION

JPEG2000 [1], the still image compression standard which resulted from the joint efforts of International Telecommunications Union (ITU) and International Organization for Standardization (ISO), uses wavelet transform. The image undergoes forward transform, quantization and entropy encoding on its way to the compressed format. To reconstruct the original image, we have to apply entropy decoding, inverse quantization and inverse transform.

Suppose we have image information in transform domain. At present, if we need a mirrored or rotated image, we have to apply inverse transform first and then proceed with our operations in the time domain. This paper discusses a method to obtain transform domain coefficients of the mirrored/rotated image from those of the original image, thereby doing away with the necessity of having to retrieve the original image first. The methods described here do not add further computational complexity.

II. PROPERTY OF PERFECT RECONSTRUCTION

Let us consider a two channel filterbank. At the analysis side, let \( H_0 \) and \( H_1 \) be the low pass and high pass filters respectively. On the synthesis side, let \( F_0 \) and \( F_1 \) be the low pass and the high pass filters, respectively. To be able to reconstruct the image from wavelet coefficients, we require that the filters satisfy the property of perfect reconstruction [5], according to which the product filter should form a half band filter. That is, the product filter \( P(\omega) \) should:

\[
P(\omega) + P(\omega + \pi) = 2
\] (1)

Here, the product filter \( P(\omega) \) should satisfy the condition that:

\[
P(\omega) = H_m(\omega)F_m(\omega)
\] (2)

where \( m = 0,1 \).

A. The Idea:

If our image information in frequency domain is represented by \( X(\omega) \), then after filtering and downsampling in the analysis side, we obtain:

\[
1/2 \ast [H_m(\omega/2)X(\omega/2) + H_m(\omega/2 + \pi)X(\omega/2 + \pi)]
\] (3)

where \( m = 0,1 \).

If we were to flip our results in time domain, we would get the expression:

\[
1/2 \ast [H_m(-\omega/2)X(-\omega/2) + H_m(-\omega/2 + \pi)X(-\omega/2 + \pi)]
\] (4)

Equation (4) can be looked upon as filtering of reverse sequence by reverse analysis filters. In order to maintain conditions of perfect reconstruction, and obtain the reverse sequence as our final output, we can reverse our synthesis filters as well and proceed with the synthesis. This is equivalent to saying that reversing input and the filter would produce the output in reverse.

Now, consider the case where our analysis and synthesis filters are symmetric, as is the case in JPEG2000 9/7 and 5/3
For symmetric filters, coefficients in forward and reverse order are the same, i.e.,

\[ H_m(\omega) = H_m(-\omega) \]  

for \( m = 0,1 \).

In this case, replacing \( H_m(-\omega) \) with \( H_m(\omega) \) we can view (4) as filtering of reversed input by the analysis filter bank. Hence, we can continue with our synthesis without having to reverse the synthesis filters as well.

### III. Mirroring and Rotation

Let LL, LH, HL and HH be the four components obtained by passing the image information through the two channel filter bank, each component denoting the output of a particular branch in the filterbank. Now, in the synthesis bank, let LL’, LH’, HL’ and HH’ denote the branches which accept the four components, LL, LH, HL and HH respectively. Let

\[
J = \begin{bmatrix}
......1 \\
......10 \\
......100 \\
......1000 \\
1......
\end{bmatrix}
\]

be a reverse identity matrix of the same dimension as LL, LH, HL and HH components. Then, we can form the mirrored and rotated images as is discussed next.

In each of the figures, the synthesis filter bank is denoted by SFB. In the case of horizontal mirroring, we simply, reverse each of the components and apply it to the synthesis filterbank - ie., we post multiply each component matrix by J and then give it to the filterbank. For vertical mirroring, we premultiply each component by J instead of postmultiplying.

For image rotation by 90 degrees, we post multiply by J, take the transpose, and then apply to SFB. One point to be noted is that, here, the \((LH \ast J)^T\) is given to HL’ and \((HL \ast J)^T\) is given to LH’. For 270 degrees, we adopt a similar step - the only difference is that here we premultiply by J instead of post multiply.

For 180 degrees on the other hand, we simply have to pre multiply and post multiply by J, each of the four components, and apply them to the filterbank.

### IV. Results

The resulting figures are as shown in Figs. 7 and 8. In the Fig. 7, we used the 9/7 Daubechies filters for transformation. Fig. 8 used the Le Gall 5/3 filters for transformation.

### V. Conclusions

We discussed methods for achieving image mirroring and rotation for JPEG2000 without having to convert the image to time domain in the first place. This gives us the option of processing the transform coefficients directly without having to do the inverse transformation.

1The asterisk * denotes multiplication operation

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**REFERENCES**


Fig. 1. A simple two channel filter bank

Fig. 2. Horizontal Mirroring

Fig. 3. Vertical Mirroring

Fig. 4. Rotation by 90 degrees

Fig. 5. Rotation by 180 degrees

Fig. 6. Rotation by 270 degrees

Fig. 7. Lena image with 9/7 Daubechies filter coefficients. Top left - horizontal mirroring, Top center - rotation by 180, Top right - rotation by 270. Bottom left - vertical mirroring, Bottom right - rotation by 90.
Fig. 8. Girl image with 5/3 Le Gall filter coefficients. Top left - horizontal mirroring. Top center - rotation by 180, Top right - rotation by 270. Bottom left - vertical mirroring. Bottom right - rotation by 90.