New Method To Implement Low Cost and High Speed 2D QMF

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Abstract

There are two methods of H/W (hardware) implement of the 2D (two dimension) QMF (quadrate mirror filter), first method is a very low cost and a low speed, that use one pair of FIR (finite impulse response) filters LPF (low pass filter) and HPF (high pass filter). This method uses the pair of FIR filters to decompose the image to L and H bands in the first step that will called row decomposition, this method is a low speed but it required low cost.

Second method is a high speed and high cost that use three pairs of FIR filters LPF and HPF, this method is a high speed but it required to a high cost.

The proposed method in this paper is using the time sharing in column decomposition part to reduce the cost of the second method of the 2D QMF. The dissipation time of column decomposition equal to half time of the row decomposition, therefore some one can use one pair of FIR filters to column decomposition that is meaning that this method use two pairs of filters.

The required time to this method equal to the same time of the second method, and about to two third of the cost of the second method, therefore this method is a high speed but it required to a low cost.

Keywords

Wavelet Quadrature Mirror filter, Field Programmable Gate Array, Two Dimension Filter, Low Pass Filter, High Pass Filter, Rational Gain Value, High Band, High High Band, High Low Band, Hardware, Constant Coefficient Multiplier, Low Band, Low High Band, Low Low Band and Finite Impulse Response.

الخلاصة

هناك طريقتين أساسية لبناء المرشح الرباعي الانعكاسي ذو البعدين (QMF)، الأولى تستخدم زوج واحد من المرشحات و تكون هذه الطريقة ذات كلفة قليلة و سرعة واطئة. أما الطريقة الثانية فتستخدم ثلاث أزواج من المرشحات و تكون هذه الطريقة ذات كلفة عالية و سرعة عالية أيضا.

إن الطريقة المقترحة هي عبارة عن تحوير للطريقة الثانية حيث سيتم استخدام زوجين من المرشحات فقط، الزوج الأول يستخدم لإنجاز الخطوة الأولى، بينما يستخدم الزوج الثاني لإنجاز الخطوة الثانية والثالثة والتي تستغرق نصف الوقت اللازم لإنجاز الخطوة الأولى مستخدما مبدأ التقاسم الزمني (time sharing) في المرشح الثاني. إن هذه الطريقة لها نفس سرعة الطريقة الثانية وتتطلب ثلثا الكلفة فقط.

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1- Introduction

Quadrature mirror filter (QMF) banks are among the most widely used filter banks, and many methods have been developed for their design [1,2]. Usually QMF banks are designed with symmetrical impulse responses in order to achieved linear phase response. As a result, the reconstruction delay is equal to N-1, where N is the length of the filter used. The system delay can be too large for some applications.

Recently several approaches have been proposed for the design of flow-delay filter banks. These include a time-domain [3] and an optimization method [4].

The input-output relation of two-channel filter bank shown in fig.(1) is given by:

$$\hat{X}(z)=\frac{1}{2}\{H_0(z)G_0(z)+H_1(z)G_1(z)\}X(z)+\frac{1}{2}\{H_0(-z)G_0(z)+H_1(-z)G_1(z)\}X(-z) \quad (1)$$

By assuming that H1(z) = H0(-z), G1(z) = - H0(-z) and G0 (z) = H0(z), the aliasing term on the right-hand side of (1) is cancelled and hence:

$$\hat{X}(z)=\frac{1}{2}\{H_0^2(z)-H_0^2(-z)\}X(z) \quad (2)$$

In conventional QMF banks, filter H0 has symmetrical impulse response which guarantees a linear-impulse response, and perfect reconstruction requires that

$$H_0^2(z)-H_0^2(-z)=z^{-(N-1)} \quad (3)$$

where N is the length of H0 and is assumed to be even. Hence the system delay, often referred to as the reconstruction delay, is N-1.

If N is a large or if the filter bank is to be used in a tree structure system, the reconstruction delay will be quite large, which is highly undesirable in real-time applications. In [4] a method for the design of two-channel QMF banks with low reconstruction delays has been proposed, in which the analysis and synthesis filters have the same mirror- image relationship as in conventional QMF banks and the perfect reconstruction condition becomes:

$$H_0^2(z)-H_0^2(-z)=z^{-K_d} \quad (4)$$

where Kd < N-1 is the system delay.

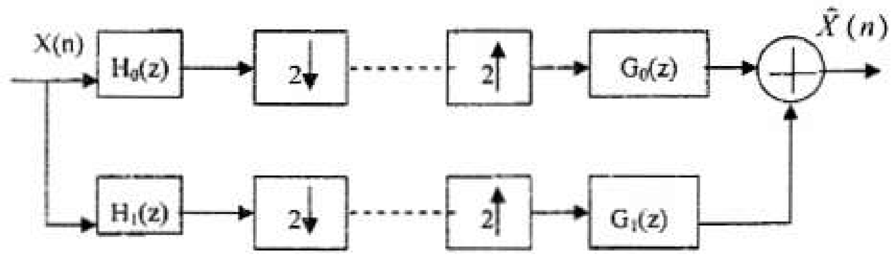

Fig (1): Two channel FIR filter bank

2-The Discrete Wavelet Transform

We have shown how to decompose a sequence x(n) into two subsequences at half rate, or half resolution, and this by means of "orthogonal" filters (orthogonal with respect to even shifts). Obviously, this process can be iterated on either or both subsequences. In particular, to achieve finer frequency resolution at lower frequencies.

We iterate the scheme on the lower band only. If g(n) is a good half band low pass filter, h(n) is a good half band high pass filter. Then, one iteration of the scheme on the first low band creates a new low band that corresponds to the lower quarter of the frequency spectrum. Each further iteration halves the width of the low band (increases its frequency resolution by two), but due to the sub_sampling by two, its time resolution is halved as well. At each iteration, the current high band portion corresponds to the difference between the previous low band portion and the current one, that is, a pass band, schematically, this is equivalent to fig.(2).

An important feature of this discrete algorithm is its relatively low complexity. Actually, the following somewhat surprising result holds: independent of the depth of the tree in fig (2), the complexity is linear in the number of input samples, with a constant factor that depends on the length of the filter. The proof is straightforward. Assume the computation of the first filter bank requires C0 operations per input sample (C0 is typically of the order of L). Then, the second stage requires also C0 operations per sample of its input, but, because of the sub_sampling by two, this amounts to C0/2 operations per sample of the input signal. Therefore, the total complexity is bounded by equation (5) as follows.

$$Ctotal = C0 + C0/2 + C0/4 + \dots + \dots < 2C0$$

Which demonstrate the efficiency of the discrete wavelet transform algorithm and shows that it is independent of the number of octaves that one computes. [5, 6]

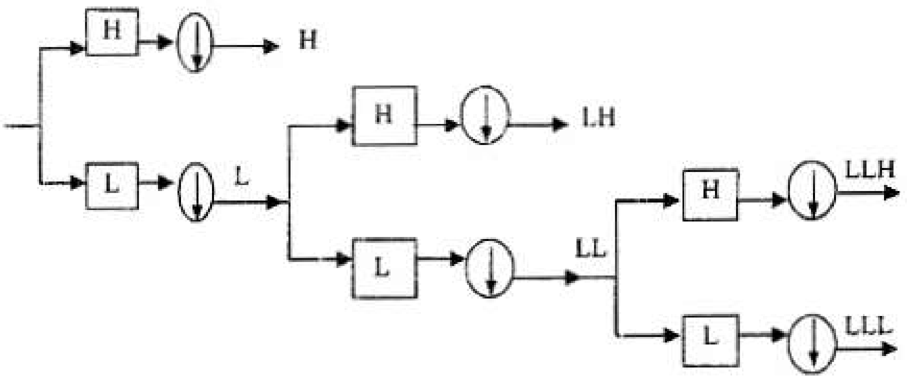

Fig (2): Circuit of a simple 1D QMF.

3- H/W Implementation of 2D QMF

There are two methods to H/W implement of the QMF, first method is a very low cost and a low speed, that use one pair of FIR filters LPF and HPF as shown in fig (3). This method uses the pair of FIR filters to decompose the image to L and H bands in the first step that will called row decomposition as shown in fig (2).

The second step is using the same pair of FIR filters to decompose the L band to LL and LH bands, then decompose the H band to HL and HH bands that will called column decomposition.
The required time in this method to process the row/column equal to two times of the first step as shown in fig (4), therefore this method is a low speed but it required to low cost.
Second method is a high speed and high cost that use three pairs of FIR filters LPF and HPF as shown in fig (5). This method use the first pair of FIR filters to decompose the image to L and H bands in the first step (row decomposition) as shown in fig (2).[7, 8]

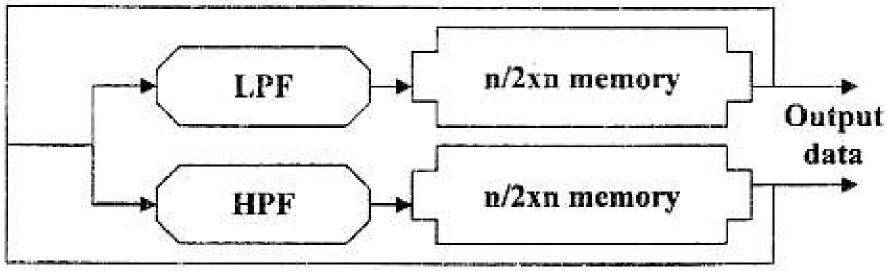

Fig (3): H/W implement of the very low cost and low speed QMF.

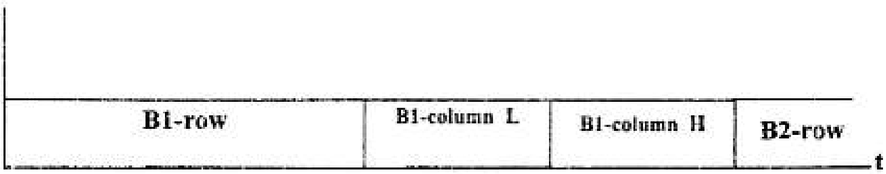

Fig (4): Timing cycles of the very low cost and low speed QMF.

At the same time it will use the second pair of FIR filters to decompose the L band to LL and LH bands, and uses the third pair to decompose the H band to HL and HH bands (column decomposition).
The required time to this process equal to the same time of the first step as shown in fig (6), therefore this The dissipation time of column decomposition in fig (6) equal to half time of the row decomposition, method is a high speed but it required to a high cost. [9, 10]

4 - Proposed Method
The idea of this method is using the time sharing in column decomposition part to reduce the cost of the second method of H/W implementation of the 2D QMF.
therefore some one can use one pair of FIR filters to column decomposition.

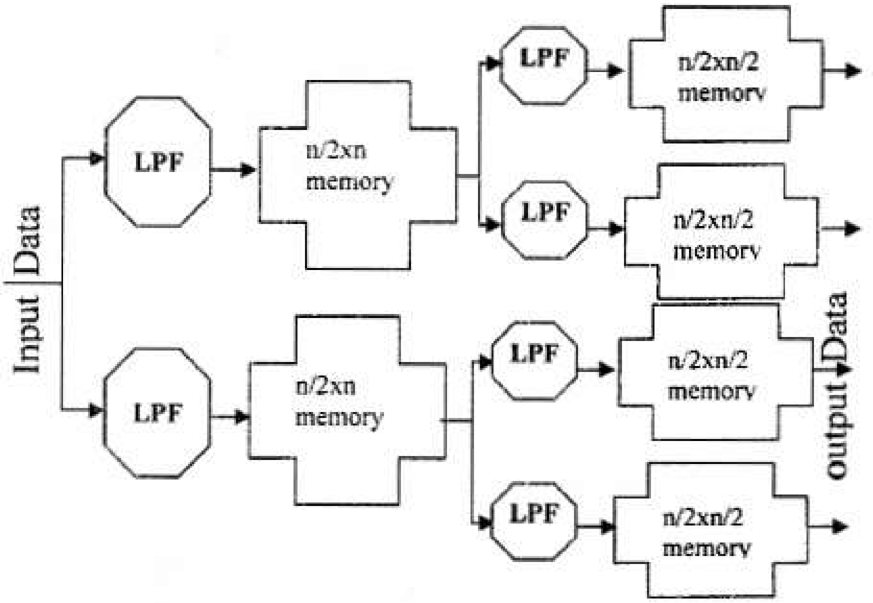

Fig (5): H/W implement of the high speed and high cost QMF.

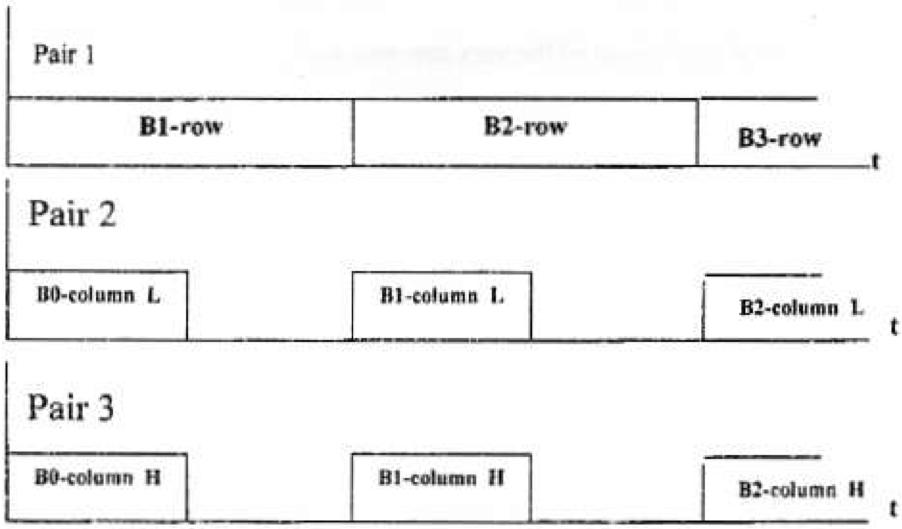

Fig (6): Timing cycles of the high speed and high cost QMF.

This pair of FIR filters uses to decompose the L band to LL and LH bands in the first half of the row decomposition, and uses the same pair to decompose the H band to HL and HH bands in the second half of the row decomposition as shown in fig (7).The required time to this process equal to the same time of the first step as shown in fig (8), therefore this method is a high speed but it required to a low cost.

5- Example Design

This part will compare between the three methods from implement of a Daubechies-6 12-bit 2D QMF using Xilinx FPGA (field programmable gate array), each FIR filter required to 6 multiplier units, 5 adder/subtractor units and 6 delay units as shown in fig. (9).

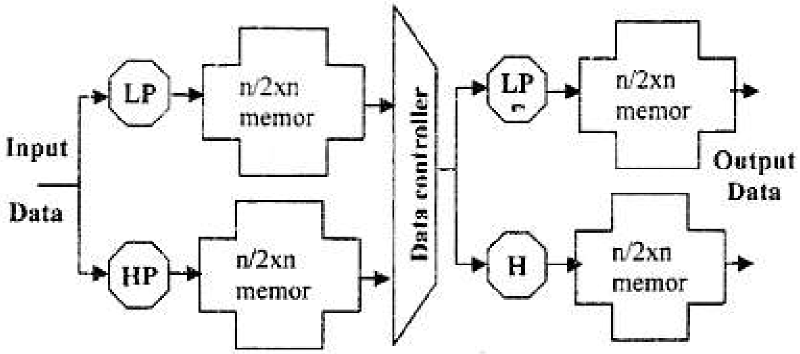

Fig (7): H/W implement of the proposed method of the

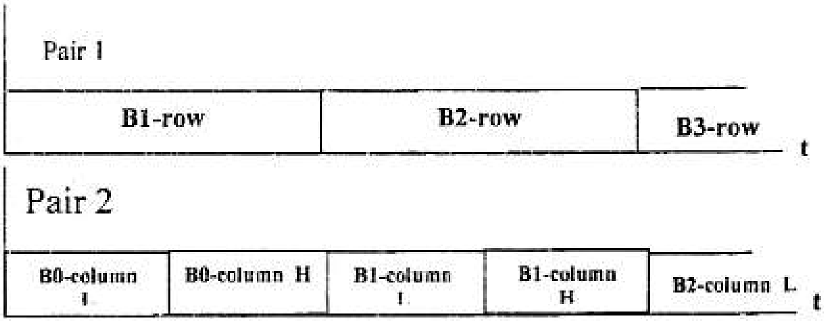

Fig (8): Timing cycles the proposed method of the QMF.

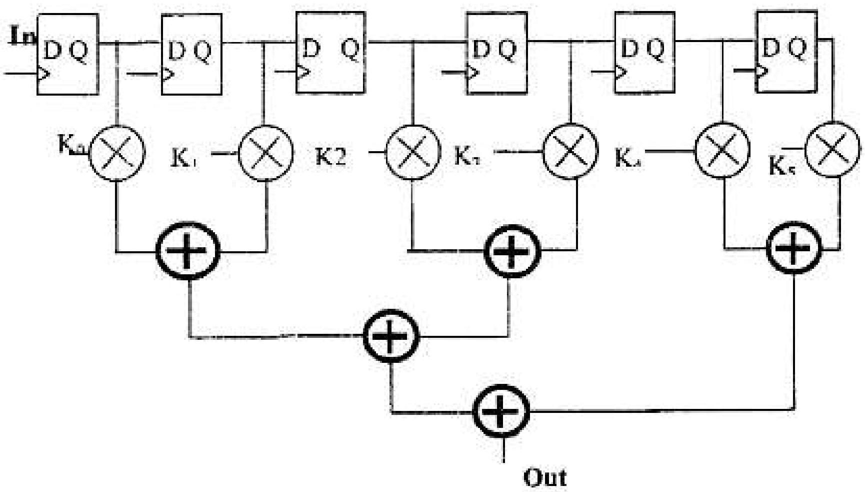

Fig (9): FIR Filter Structure Employing Tree of Pipelined Adders

The implementation of the multiplier unit required to 210 cells, while the implementation of the adder/subtractor unit required to 35 cells and the implementation of the delay unit required to 8 cells when applied in design Vertix FPGA series. [11, 7]

Then, implementation of one FIR (LPF or HPF) unit using KCM approach required to 1,100 cells, however the implementation of the 12-bit 6x6 memory unit required to 400 cells and the implementation of the controller unit in fig (7) required to 13 cells. The requirement to implementation of a **Daubechies-6 /12-bit 2D QMF** uses vertix Xilinx FPGA (xcv 400-bg432-6) shown in table (1).

Where RGV is the rational gain value that represents the optimization factor will calculate from equation (6):

$$RGV=\frac{\text{cost2}}{\text{cost1}}*\frac{\text{speed1}}{\text{speed2}}=\frac{6660}{\text{cost1}}*\frac{\text{speed1}}{58867506} \quad (6)$$

Table (1): The cost, speed and RGV for the three methods.

Method	Total cost /cell	Speed pixel/sec	RGV
Very low cost	2,258	31,974,215	1.6
High speed	6,660	58,867,506	1
Proposed	4,468	83,533,116	2.11

6- Conclusions

The using of the time sharing in the high speed and high cost method reduced the total cost from 6,660 cells to be 4,468 cells (by ratio of 70% from the total cost). The routing approach in the Xilinx FPGA will increment the speed in the proposed method from (58,867,506) to (83,533,116) (about rational speed of 140% from the total speed). The total effect of the proposed method will enhanced system performance of RGV to (2.11),

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List of Symbols

2D QME: Two dimensional QMF.
FIR: Finit impulse response.
FPGA: Field programmable gate array
H: Hugh band
HH: High high band
HL: High low band.
HPF: High pass filter
H/W: Hardware
KCM: Constant coefficient multiplier
L: Low band
LH: Low high band
LL: Low low band
LPF: Low pass filter
QME: Quadrate mirror filter
RGV: Rational gain value