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FIR Filter Design Using Vedic Mathematics

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***Abstract* – Digital Signal Processing operation using Vedic mathematics which performs the signal processing operations like Convolution, Circular Convolution, Cross Correlation, auto-correlation and filter design. Digital Signal Processing (DSP) operations are very important part of engineering as well as medical discipline. Designing of DSP operations have many approaches. This design process provides the analysis of signals for improving the accuracy of the mathematical calculations. It facilitates the time sharing for all signals to compute mathematical operations simultaneously. Vedic mathematics is the ancient mathematics which has a unique technique of mental calculation with the help of simple rules and principles based on 16 sutras. The use of multiplier with higher speed is of utmost importance to any DSP. Convolution is the basic concept of designing Finite Impulse Response (FIR) filter. FIR filter is also called convolution filter. Our effort has proved the efficiency of Urdhava-Tiryagbhyam method for multiplication which delivers a difference in the actual process of multiplication itself. In this paper, we design FIR filter using Urdhava-Tiryagbhyam sutra. This algorithm is implemented in MATLAB and performed in GUI. FIR filter based on Urdhava-Tiryagbhyam reduces the processing time as compared to inbuilt function of MATLAB. The results show that Urdhava-Tiryagbhyam has greater impact on improving the speed of FIR filter.**

***Keywords* – FIR Filter, DSP, Urdhava-Tiryagbhyam, Vedic Mathematics, Linear Convolution.**

I. Introduction

Process of filtering is a very important for Digital Signal Processing (DSP). DSP operations [1] such as convolution, correlation plays vital role in linear filtering method. In DSP, filtering is a common term that is applied to various applications. Digital signals are used for two general purposes: (1) separation of signals that have been combining, and (2) restoration of signals that have been distorted in some way. A signal or data stored in memory contains lots of information both desirable and non-desirable. Desirable information may be specific information at a specific frequency and non-desirable information may be the noise present in the signal. Digital video require digital filters to reduce noise due to coding and transmission through a noisy channel [2]. Digital filter performs mathematical operations on a sampled, discrete-time signal to reduce or enhance certain aspects of the signal. One of the most important used operations in DSP is finite impulse response (FIR) filtering. Many DSP applications need convolution operations for filtering of signals. Linear convolution is the basic concept for designing the FIR filter. FIR filter is also called convolution filter because convolution of two sequences in time domain is equivalent to multiplication of two sequences in frequency domain. The convolution formula is used to compute the response of FIR filter to any arbitrary Input signal x (n) [3]. In this paper, a method of computing discrete linear convolution using Vedic multiplication technique is presented.

II. Vedic Mathematics

Vedic mathematics consists of four Vedas known as books of wisdom. It is section of Sthapatya- Veda that contain book on civil engineering and architecture, which is an upa-veda (separate section) of Atharva Veda. It deals with many modern mathematical terms including arithmetic, trigonometry, geometry (plane, co-ordinate), quadratic equations, factorization and even calculus.

His Holiness Jagadguru Shankaracharya Bharati Krishna Teerthaji Maharaja (1884-1960) comprised all this work together and gave its mathematical explanation while discussing it for various applications. Swami-ji constructed 16 sutras (formulae) and 16 Upa sutras (sub formulae) after extensive research in Atharva Veda. These formulae are not to be found in present book of Atharva Veda because these formulae were constructed by Swami-ji himself. Vedic mathematics is not only a mathematical wonder but also it is logical. That’s why Vedic Mathematics has such a degree of eminence which cannot be disapproved. Due to these phenomenal characteristic, Vedic Mathematics has already crossed the boundaries of India and has become a leading research topic in abroad. Vedic Mathematics deals with several simple as well as complex mathematical operations. Especially, methods of basic arithmetic are extremely simple and powerful [4, 5].

The word ‘Vedic’ is a Sanskrit word derived from the word ‘Veda’ which means the collection of all knowledge. Veda is a gift from ancient sages of India to this world. From the ancient times Vedas were passed from previous generation to next generation orally rather than written. Vedic mathematics is mainly based on 16 Sutras (or aphorisms) dealing with various branches of mathematics like arithmetic, algebra, geometry etc. These Sutra’s meanings with few words are enlisted below alphabetically:

1. (Anurupye) Shunyamanyat – If one is in ratio, the other is zero.
2. Chalana-Kalanabyham – Differences and Similarities.
3. Ekadhikina Purvena – By one more than the previous one.
4. Ekanyunena Purvena – By one less than the previous one.

5. Gunakasamuchyah – The factors of the sum is equal to the sum of the factors.
6. Gunitasamuchyah – The product of the sum is equal to the sum of the product.
7. Nikhilam Navatashcaramam Dashatah – All from 9 and last from 10.
8. Parvarya yojayet – Transpose and adjust.
9. Puranapuranabhyam – By the completion or no completion.
10. Sankalana- vyavakalanabhyam – By addition and by subtraction.
11. Shesanyankena Charamena – The remainders by the last digit.
12. Shunyam Saamyasamuccaye – When the sum is the same that sum is zero
13. Sopaantyadvayamantyam – The ultimate and twice the penultimate.
14. Urdhava-Tiryagbhyam – Vertically and crosswise.
15. Vyashtisamanstih – Part and Whole.
16. Yaavadunam – Whatever the extent of its deficiency.

The beauty of Vedic mathematics lies in the fact that it reduces the complex looking calculations in conventional mathematics to a very simple one. This is so because the Vedic formulae are claimed to be based on the natural principles and sutra on which the human mind works. This is a very interesting field and presents some effective algorithms which can be applied to various branches of engineering such as computing and digital signal processing [5,6].

III. Urdhava - Tiryagbhyam

The multiplier is based on an algorithm Urdhava Tiryagbhyam (Vertical & Crosswise) [7] of ancient Indian Vedic Mathematics. Urdhava - Tiryagbhyam Sutra is a general multiplication formula applicable to all cases of multiplication. It means "Vertically and crosswise" which is also known as array multiplication technique. It is based on a novel concept through which the generation of all partial products can be done with the concurrent addition of these partial products.

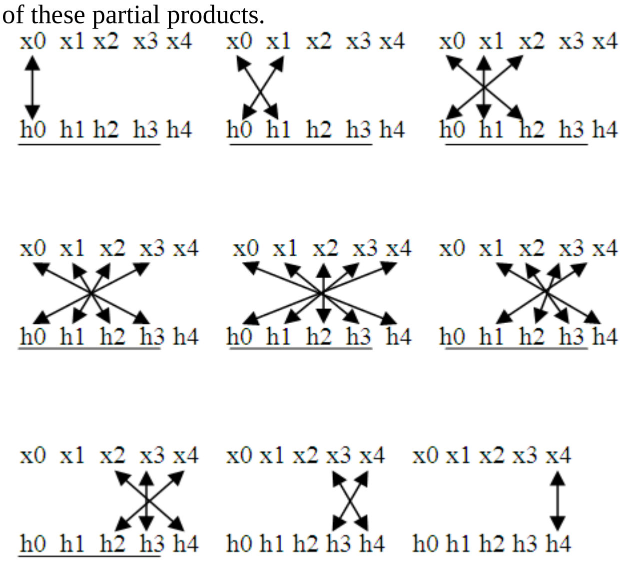

Fig.1. Urdhava-Tiryagbhyam Method

The parallelism in generation of partial products and their summation is obtained using Urdhava - Triyagbhyam. Multiplication technique plays important role in designing of FIR filter [8]. Urdhava - Tiryagbhyam multiplier is time, space and power efficient. This sutra can be generalized for any N x N bit multiplication. The Urdhava - Tiryagbhyam is always function for even number of sequence and gives odd number of sequences. Figure 1 illustrates the line diagram of 4x4 multiplier using Urdhava - Tiryagbhyam method.

IV. Linear Filtering Method

Linear filtering is same as linear convolution. Consider FIR filter having impulse response h (n) as represented in Figure 2.

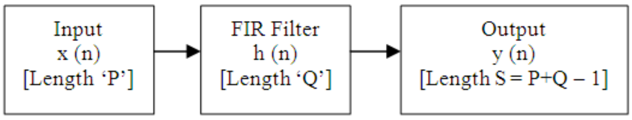

Fig.2. FIR Filter

Let x (n) = Input sequence having length 'P'.
x (n) = {0, 1, 2, … , P – 1}
h (n) = impulse response of filter having length 'Q'.
h (n) = {0, 1, 2, … , Q – 1}
The linear convolution of x (n) and h (n) produces the output sequence y (n) and the length of y (n) is

$$S = P + Q - 1 \qquad (\;)$$

The length of x (n) and h (n) can be made equal to 'S' by adding required number of zeros in x (n) and h (n). This is known as zero padding. It means we have to increase the length of x (n) by P points and length of h (n) by Q points to make the total length 'S = P + Q – 1'.

In FIR filter, both the sequences x (n) and h (n) are finite, so linear convolution [9] will be finite. The convolution having input x of length P with filter h of length Q will give the output sequence y (n).

$$y(n) = \sum_{k=0}^{Q-1} h(k)x(n-k) \qquad (2)$$

The direct form structure of FIR filter can be obtained using linear convolution. Figure 3 represents direct form structure of FIR filter. By expanding equation (2) we can draw the direct form structure of FIR filter.

$$y(n) = h(0)x(n) + h(1)x(n-1) + h(2)x(n-2) + h(3)x(n-3) + \ldots + h(Q-1)x(n-Q+1) \ldots\ldots\ldots (3)$$

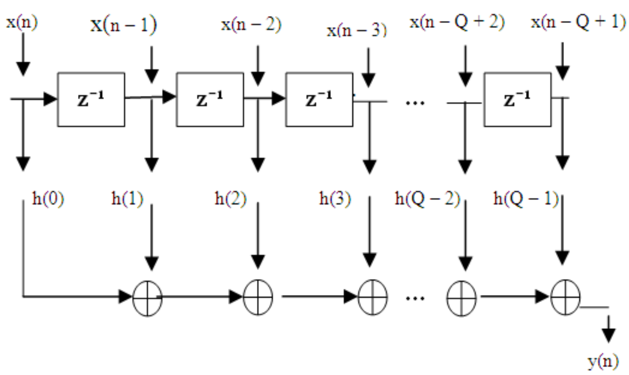

Fig.3. Direct form structure of FIR system

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The direct form realization structure is also called canonic structure since the number of delay elements in the block diagram is equal to the order of difference equation of a digital filter. The above figure contain ‘Q – 1’ delay blocks. This structure has ‘Q – 1’ additions and ‘Q’ multiplications.

V. Proposed Technique

The line diagram in figure 1 illustrates the algorithm for multiplying two 4x4 binary numbers multiplication using Urdhava - Tiryagbhyam. The following example will show the technique of linear filtering using Urdhava - Tiryagbhyam. Consider FIR filter has 2 - point input sequence x(n) = {1 , 5} and filter coefficient h(n) = { 2 , 7}. Here x(0) = 1, x(1) = 5 and h(0) = 2, h(1) = 7. The length of input sequence (P) and the length of filter coefficient (Q) is 2. Thus output sequence y(n) is obtained in 3 steps since length of output sequence is P + Q – 1 i.e. 3. In step 1 we multiply the left hand most digit of x(n) i.e. x(0) vertically by the left hand most digit of h(n) i.e. h(0), get their product y(0) as the first output sequence.

$$y(0) = x(0)*h(0) \qquad (\ )$$

In step 2 we multiply x(0) and h(1), and x(1) and h(0) cross-wise, then add the two, get y(1) as the second output sequence.

$$y(1) = x(0)*h(1) + x(1)*h(0) \qquad (\ )$$

In step 3 we multiply right hand most digit of x(n) i.e. x(1) vertically by the right hand most digit of h(n) i.e. h(1), get their product y(2) as the last output sequence.

$$y(2) = x(1)*h(1) \qquad (\ )$$

Thus output sequence of linear filter y (n) = {2, 17, 35}. This algorithm is applied for any value of N – point sequence.

VI. Result Analysis

A graphical user interface (GUI) window is design to show the results of Vedic method with respect to the conventional (inbuilt) method. GUI [10] has greater influence in the area of software application programming which provide human-computer interaction. Its aim is to increase the efficiency and ease of use for the logical design of a stored program. The combination of technologies and devices uses GUI to provide a platform for the user to interact with the software for the tasks of collecting and producing information.

Figure 4 illustrate GUI window for designing FIR filter in which Low pass response, Bartlett window, and order-64, unit step signal as input is selected and accordingly average processing time is shown for proposed and conventional method. GUI also shows bar graph in which red bar represents Vedic method (proposed) average time while blue represents conventional method (Inbuilt) average time.

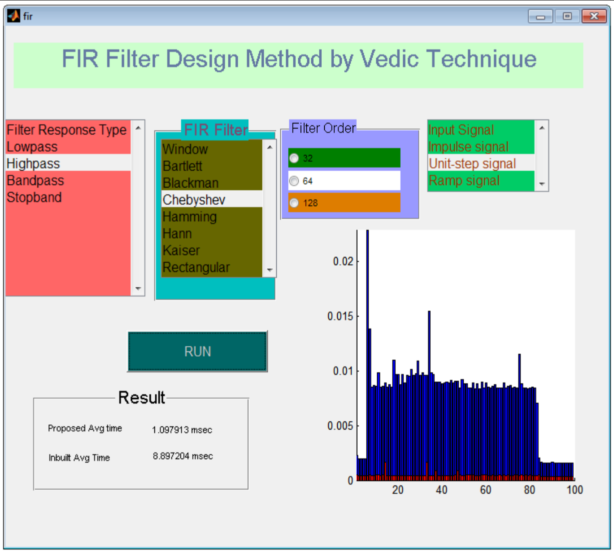

Fig.4. Graphical User Interface window

Table I – IV represents average time comparison between vedic method and conventional method for different order, FIR window, response type and input signal. For Low pass and High pass FIR filter, 100 kHz sampling frequency and 30 kHz cutoff frequency is taken while for Band pass and Stop band, 25 kHz lower cutoff frequency and 35 kHz higher cutoff frequency is taken.

A. For 64 order FIR filter with input as unit step signal

Table I. Conventional Versus Vedic Time in HPF

S.No.	FIR Window	Vedic Method (Proposed Average Time)	Conventional Method (Inbuilt Average Time)
1.	Bartlett	2.48 ms	14.31 ms
2.	Blackman	0.34 ms	8.04 ms
3.	Chebyshev	0.67 ms	10.47 ms
4.	Hamming	0.31 ms	1.72 ms
5.	Hann	1.03 ms	11.52 ms
6.	Kaiser	0.34 ms	7.49 ms
7.	Rectangular	0.32 ms	2.38 ms

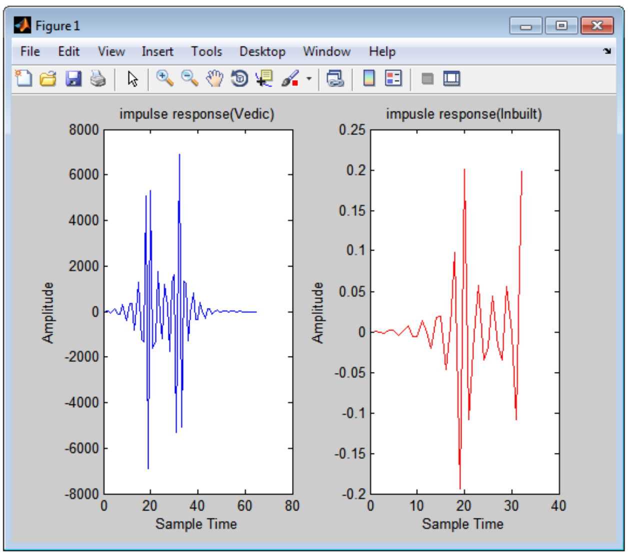

Fig.5. Output Response of FIR filter-64 order high pass Chebyshev window

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Table I represents Vedic versus conventional average time comparison for various window of 64 order high pass FIR filter with input as unit step signal. Figure 5 gives output response of FIR filter-64 order high pass Chebyshev window which shows that shape of output response in Vedic method is same as conventional method.

Table II. Conventional Versus Vedic Time in BPF

S.No.	FIR Window	Vedic Method (Proposed Average Time)	Conventional Method (Inbuilt Average Time)
1.	Bartlett	0.36 ms	2.34 ms
2.	Blackman	0.65 ms	11.88 ms
3.	Chebyshev	0.37 ms	11.18 ms
4.	Hamming	0.38 ms	11.59 ms
5.	Hann	0.64 ms	10.74 ms
6.	Kaiser	0.38 ms	7.81 ms
7.	Rectangular	1.03 ms	7.68 ms

Table II represents Vedic versus conventional average time comparison for various window of 64 order Band pass FIR filter with input as unit step signal. Figure 6 gives output response of FIR filter-64 order Band pass Hamming window which shows that shape of output response in Vedic method is same as conventional method.

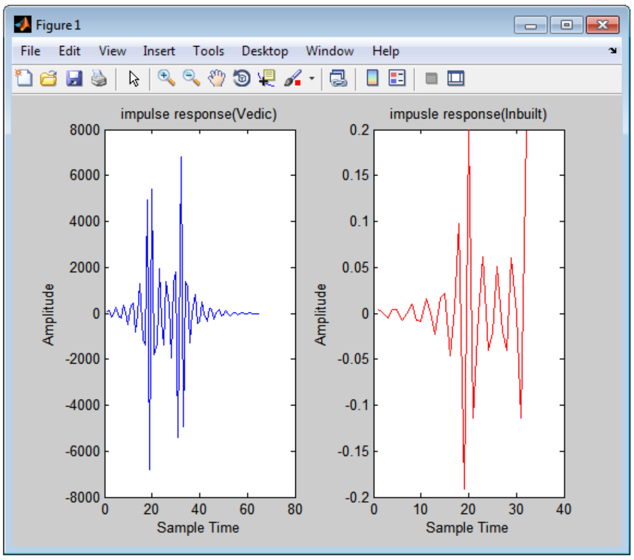

Fig.6. Output Response of FIR filter-64 order Band pass Hamming window

B. For 32 order FIR filter with input as ramp signal

Table III: Conventional Versus Vedic Time in Bandpas

S.No.	FIR Window	Vedic Method (Proposed Average Time)	Conventional Method (Inbuilt Average Time)
1.	Bartlett	1.23 ms	4.32 ms
2.	Blackman	0.15 ms	2.93 ms
3.	Chebyshev	0.17 ms	3.08 ms
4.	Hamming	0.67 ms	3.96 ms
5.	Hann	0.19 ms	6.99 ms
6.	Kaiser	0.13 ms	1.48 ms
7.	Rectangular	0.22 ms	7.78 ms

Table III represents Vedic versus conventional average time comparison for various window of 32 order Low pass FIR filter with input as unit ramp signal. Figure 7 gives output response of FIR filter-32 order Low pass Hann window which shows that shape of output response in Vedic method is same as conventional method.

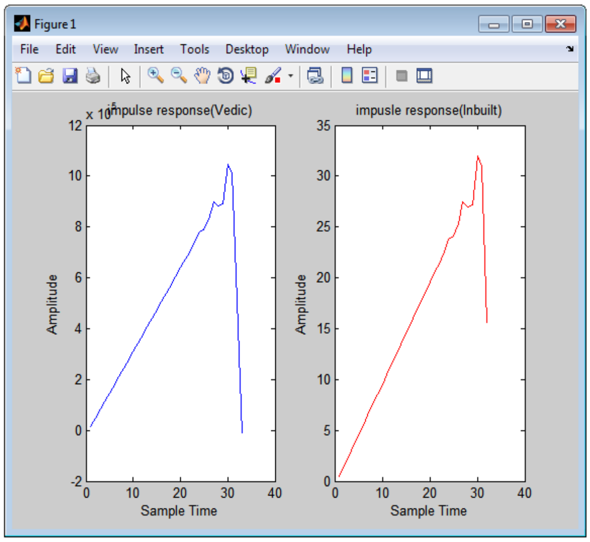

Fig.7. Output Response of FIR filter-32 order Low pass Hann window

C. For 128 order FIR filter with input as unit impulse signal

Table IV: Conventional Versus Vedic Time in Stop Band

S.No.	FIR Window	Vedic Method (Proposed Average Time)	Conventional Method (Inbuilt Average Time)
1.	Bartlett	1.23 ms	4.32 ms
2.	Blackman	0.15 ms	2.93 ms
3.	Chebyshev	0.17 ms	3.08 ms
4.	Hamming	0.67 ms	3.96 ms
5.	Hann	0.19 ms	6.99 ms
6.	Kaiser	0.13 ms	1.48 ms
7.	Rectangular	0.22 ms	7.78 ms

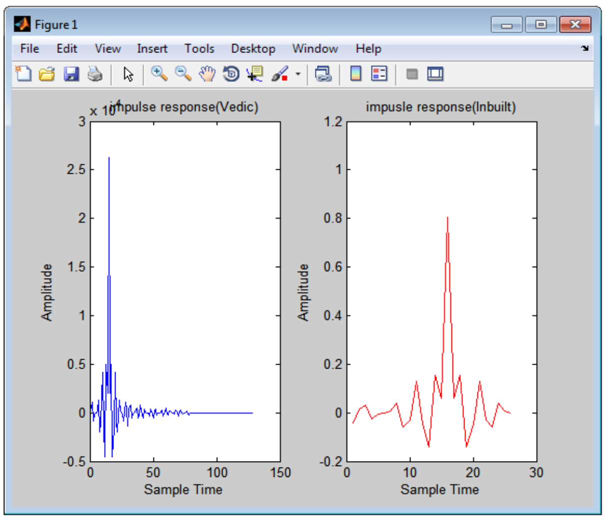

Fig.8. Output Response of FIR filter-128 order Stop Band Kaiser window

Table IV represents Vedic versus conventional average time comparison for various window of 128 order Stop band FIR filter with input as unit impulse signal. Figure 8 gives output response of FIR filter-128 order Stop band Kaiser Window which shows that shape of output response in Vedic method is same as conventional method.

VII. Conclusion

An FIR filter design is implemented using vedic multiplication technique in Graphical User Interface window. This paper proposed a design of FIR filter using Urdhava Tiryagbhyam method of vedic mathematics. The algorithms of vedic mathematics are much more efficient than conventional mathematics. It is shown that the Urdhava Tiryagbhyam method is faster than the conventional method of MATLAB. Thus FIR filter based on vedic method consuming less average processing time as compared to inbuilt function of MATLAB. Amplitude will depend on total processing time. In Vedic method we increase the amplitude to decrease total processing time. Vedic mathematics is long known but has not been used in DSP processor. Future works using Urdhava Tiryagbhyam method can be used to improve the filtering technique used in image processing applications and calculating the various transforms like Fast Fourier Transform (FFTs) and Inverse Fast Fourier Transform (IFFTs). By using these ancient Vedas sutra world can achieve higher performance and quality for the new technology devices.

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