

16-Order IIR Filter Design using Vedic Mathematic Technique

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Abstract – Digital Signal Processing (DSP) plays vital roles in various engineering applications. 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. Multiplication play important role in filter designing, convolution, correlation etc. Convolution is the basic concept of designing Infinite Impulse Response (IIR) filter. IIR 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 IIR filter using Urdhava-Tiryagbhyam sutra. This algorithm is implemented in MATLAB and performed in GUI. IIR 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 IIR filter.

Keywords – IIR Filter, DSP, Urdhava-Tiryagbhyam, Vedic Mathematics.

I. INTRODUCTION

Process of filtering is a very important class of 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. In general, any operation performed to extract desired information from a digital signal is termed as filtering. 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 Infinite impulse response (IIR) filtering. Many DSP applications need convolution operations for filtering of signals. Linear convolution is the basic concept for designing the IIR filter. IIR 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 IIR 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. Puranapurabhyam – 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. The parallelism in generation of partial products and their summation is obtained using Urdhava - Tiryagbhyam. Multiplication technique plays important role in designing of IIR filter [8]. Urdhava - Tiryagbhyam multiplier is time, space and power efficient. This sutra can be generalized for any $N \times N$ 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 4×4 multiplier using Urdhava - Tiryagbhyam method.

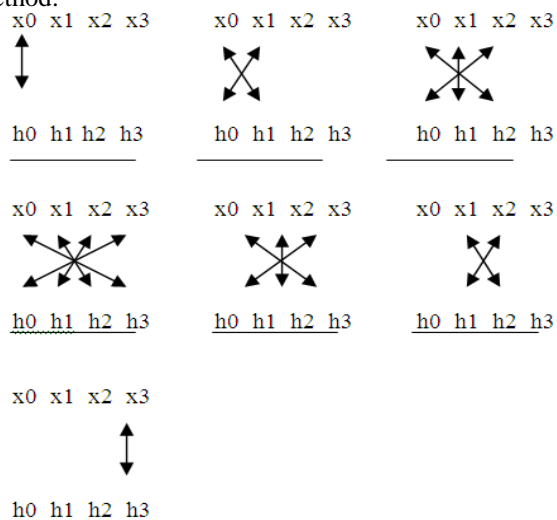


Fig.1. Urdhava-Tiryagbhyam Method

IV. INFINITE IMPULSE RESPONSE FILTER

Linear IIR filters are digital filters with infinite impulse response. Unlike FIR filters, they have the feedback (a recursive part of a filter) and are known as recursive digital filters therefore.

FIR Filter

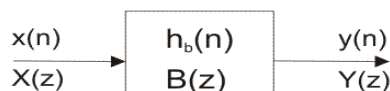


Fig.2. FIR Filter

IIR Filter

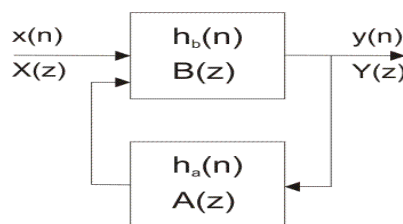


Fig.3. IIR Filter

For this reason IIR filters have much better frequency response than FIR filters of the same order. Unlike FIR filters, their phase characteristic is not linear which can cause a problem to the systems which need phase linearity. For this reason, it is not preferable to use IIR filters in digital signal processing when the phase is of the essence. Otherwise, when the linear phase characteristic is not important, the use of IIR filters is an excellent solution. There is one problem known as a potential instability that is typical of IIR filters only. FIR filters do not have such a problem as they do not have the feedback. For this reason, it is always necessary to check after the design process whether the resulting IIR filter is stable or not. IIR filters can be designed using different methods. One of the most commonly used is via the reference analog prototype filter. This method is the best for designing all standard types of filters such as low-pass, high-pass, band-pass and band-stop filters.

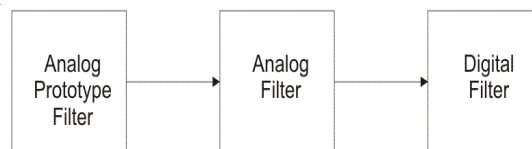


Fig.4. Derivation of digital filter from analog filter

The above diagram shows the derivation of digital filter from analog filter. Basically digital filters are of two types depending on the number of sample points used to determine the unit sample i.e. Impulse response of a LTI discrete time system .also if infinite number of sample points are used to determine the unit sample response then these digital filters are known as infinite impulse response (IIR) digital filter .it may be noted that infinite duration impulse response digital filter design procedures are those originally developed for analog filters.

As a matter of fact the basic function of a digital filter is to eliminate the noise and to extract the signal of interest from other signal. A digital filter is the basic device used in digital signal processing (DSP). The digital filters described by the differential equation can be implemented using software like C or assembly language. Since we can easily change the algorithm so we can easily change the filter characteristic

V. PROPOSED TECHNIQUE

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.

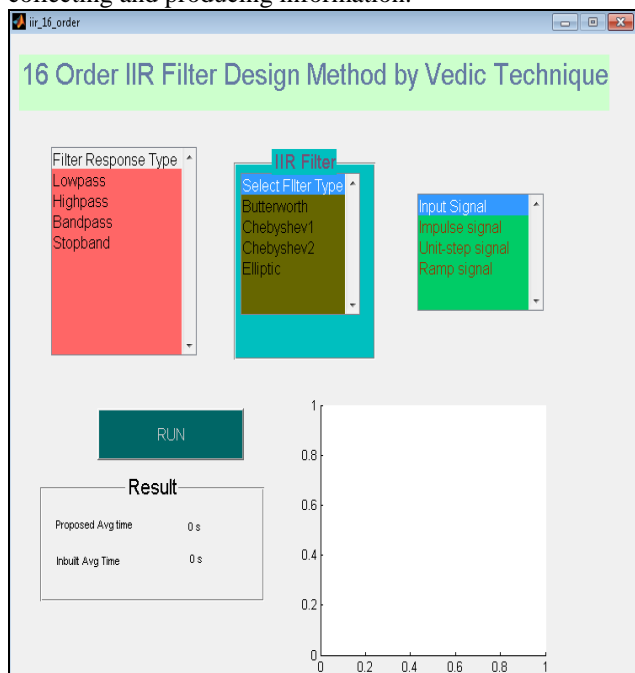


Fig.5. Graphical User Interface window

Figure 5 illustrate GUI window for designing IIR filter in which Low pass response, Bartlett window, and order-16, 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.

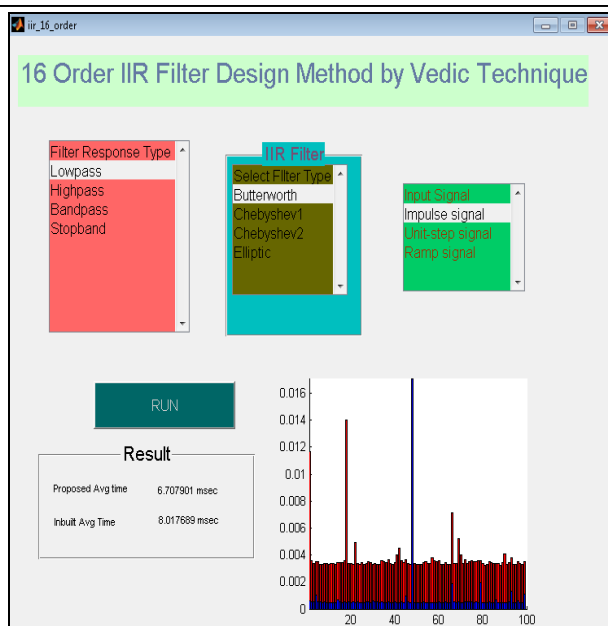


Fig.6. Output Response of IIR filter-16 order low pass Butterworth window

Figure 6 gives output response of IIR filter-16 order Low pass Butterworth window which shows that shape of output response in Vedic method is same as conventional method.

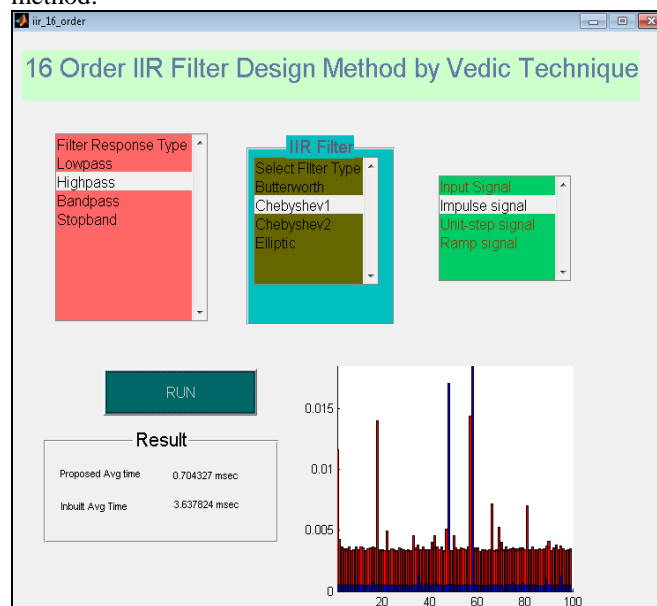


Fig.7. Output Response of IIR filter-16 order high pass Chebyshev1 window

Figure 7 gives output response of IIR filter-16 order High pass Chebyshev1 window which shows that shape of output response in Vedic method is same as conventional method.

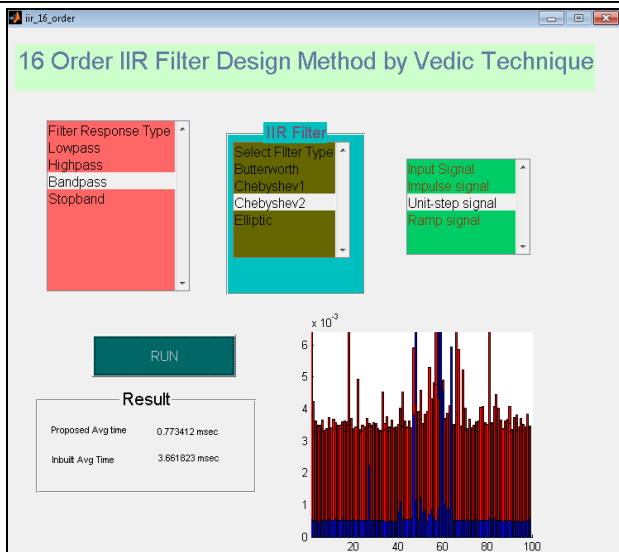


Fig.8. Output Response of IIR filter-16 order band pass Chebyshev2 window

Figure 8 gives output response of IIR filter-16 order High pass Chebyshev2 window which shows that shape of output response in Vedic method is same as conventional method.

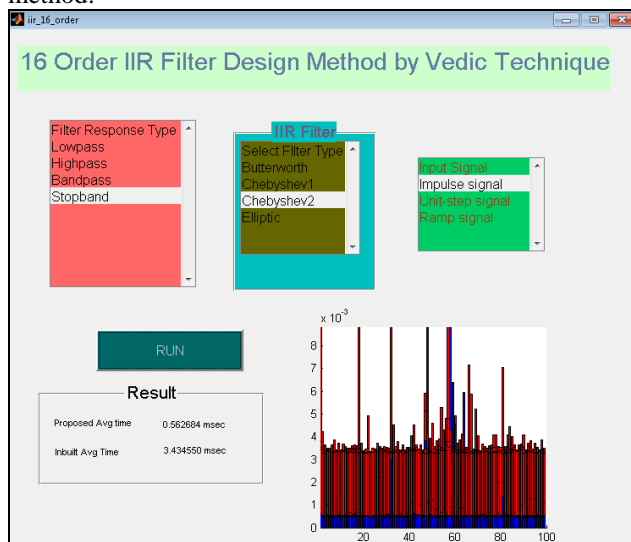


Fig.9. Output Response of IIR filter-16 order stop band Chebyshev2 window

Figure 9 gives output response of IIR filter-16 order Stop band Chebyshev2 window which shows that shape of output response in Vedic method is same as conventional method.

| S.No. | IIR Window | Vedic Method (Proposed Average Time) | Conventional Method (Inbuilt) |
|-------|-------------|--------------------------------------|-------------------------------|
| 1. | Butterworth | 0.53 ms | 4.03 ms |
| 2. | Chebyshev 1 | 0.60 ms | 3.43 ms |
| 3. | Chebyshev 2 | 0.67 ms | 3.61 ms |
| 4. | Elliptic | 0.65 ms | 3.55 ms |

Above Table represents Vedic versus conventional average time comparison for various window of 16 order Low pass IIR filter with input as impulse signal.

VI. CONCLUSION

An IIR filter design is implemented using Vedic multiplication technique in Graphical User Interface window. This paper proposed a design of IIR 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, IIR filter based on Vedic method consuming less average processing time as compared to inbuilt function of MATLAB 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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