# Design a DSP Operations using Vedic Mathematics

Akhalesh K. Itawadiya, Rajesh Mahle, Vivek Patel, Dadan Kumar

***Abstract*— Digital Signal Processing (DSP) operations are very important part of engineering as well as medical discipline. Designing of DSP operations have many approaches. For the designing of DSP operations, multiplication is play important role to perform signal processing operations such as Convolution and Correlation. The new approach of this implementation is mentally and easy to calculate of DSP operations for small length of sequences. In this paper a fast method for DSP operations based on ancient Vedic mathematics is contemplated. The implementation of high speed DSP operations of two finite length sequences using Vedic Urdhava-Triyagbhayam Multiplication Sutra (approach/method) is done. Urdhava-Triyagbhayam Sutra is very efficient multiplication formula applicable for all types of multiplication. This algorithm is implemented in MATLAB and all the operation is performed in single Graphical User Interface (GUI) window. Vedic mathematics based DSP operations reduce the processing time as compare to inbuilt function of MATLAB. It reduces the 40-60% time from inbuilt function and this algorithm operates in concept of Vedic multiplier.**

***Index Terms*— DSP, Vedic mathematics, Vedic Multiplier, Vedic Convolution, Vedic Correlation, GUI**

## I. Introduction

DSP operation is the heart of the mobile communication and satellite communication system. The convolution plays a preciously role in Digital Signal Processing and Image Processing. It is used for designing of digital filter and correlation application. The linear convolution effectively designs by using simple Vedic multiplier. Convolution is basic concept to designing the finite impulse response filter, Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT) [1]. Linear Convolution of two finite length sequence normally computed by using the application of Discrete Fourier Transform [2,3]. Design of all DSP operations with the help of high speed Vedic multiplier which increase the efficiency of system and reduces the processing time. This DSP implementation is design on Matlab with GUI, which is user friendly and easy to use. In this method compute the 2N-1 point convolution sequence from N point discrete time sequence and N-point circular convolution of using 2N-1 point Convolution of discrete time sequence. To reduce the processing time of DSP such as Right–angle circular convolution is operation proposed alternative method [4].

## II. Vedic Mathematics

Vedic mathematics is an ancient fast calculation mathematics technique which is taken from historical ancient book of wisdom. Vedic mathematics is an ancient Vedic mathematics which provides the unique technique of mental calculation with the help of simple rules and principles. Veda rediscovered by the holiness Jagad Guru Shree Bharti Krishna Tirtha Ji Maharaj (1884-1960) in between 1911-1918. According to Swami-Ji all Vedic mathematics is based on 16-Sutra (Algorithm) and 16- up-sutra (Sub-algorithm) after broadly research in Atharva Veda [5]. It computes all the basic as well as complex mathematical operation easily and quickly also provides a power full mantel technique. It is more consistent than modern mathematics and provides an expeditious solution. The term Vedic mathematics is evolving from the word "Veda" which means warehouse of all knowledge. It is based on sixteen sutras which transact different branches of mathematics i.e. algebra, geometry, arithmetic [6]. Former Shankrachrya Shree Bharti Krishna Tirtha of India was developed in to the ancient Vedic text and established the new method of this system in his pioneering work in Vedic mathematics (1965). Which was the starting point of the new work in Vedic math's era? A batter deal of research is also being transport how to develop more powerful and easy application of the Vedic sutras geometry, calculus, trigonometric, computing application (property). Modern mathematics is an integral part of the technical education most of the engineering system design is based on the various mathematical approaches. The necessity for expeditious processing speed used following Vedic mathematics algorithm.

1. Ekadhikena Purvena – By one more than the previous one.

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2. Nikhilam Navatascaramap Dasatah – All from 9 and last from 10.
3. Urdhva-Tiryagbhyam – Vertically and crosswise.
4. Paravartya Yojayet – Transpose and adjust.
5. Shunyam Samyasamuccaye – When the sum is the same that sum is zero.
6. (Anurupye) Shunyamanyat – If one is in ratio, the other is zero.
7. Sankalana-Vyavakalanabhyam – By addition and by subtraction.
8. Puranapuranabyham – By the completion or no completion.
9. Calana-Kalanabyham – Differences and Similarities.
10. Yaavadunam – Whatever the extent of its deficiency.
11. Vyastisamanstih – Part and Whole.
12. Sesanyankena Caramena – The remainders by the last digit.
13. Sopantyadvayamantyam – The ultimate and twice the penultimate.
14. Ekanyunena Purvena – By one less than the previous one.
15. Gunitasamuccayah – The product of the sum is equal to the sum of the product.
16. Gunakasamuccayah – The factors of the sum is equal to the sum of the factors.

## III. URDHAVA - TIRYAGBHYAM

Urdhva-Tiryagbhyam sutras are the basic sutras which is applicable for all case of multiplication. This itself is very short and compendious consisting of only one combine word and means "vertically and crosswise" i.e. the first bit of multiplicand and the first bit of multiplier are multiplied with vertically and crosswise method. Vertically and crosswise multiplication procedure is also known as array multiplication technique [7]. Fig-1 represents the 6×6 multiplier using vertically and crosswise method.

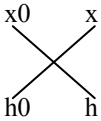
Multiplicand : x0 x1 x2 x3 x4 x5
Multiplier : h0 h1 h2 h3 h4 h5

Step-1



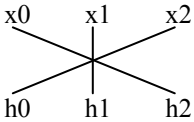
x0 x1 x2 x3 x4 x5
h0 h1 h2 h3 h4 h5
y0=x0*h0;

Step-2



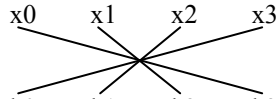
x0 x1 x2 x3 x4 x5
h0 h1 h2 h3 h4 h5
y1=x0*h1+x1*h0;

Step-3



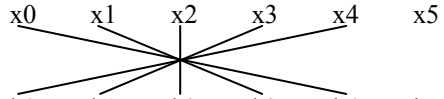
x0 x1 x2 x3 x4 x5
h0 h1 h2 h3 h4 h5
y2=x0*h2+x1*h1+x2*h0;

Step-4



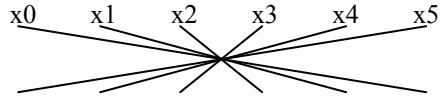
x0 x1 x2 x3 x4 x5
h0 h1 h2 h3 h4 h5
y3=x0*h3+x1*h2+x2*h1+x3*h0;

Step-5



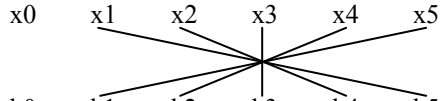
x0 x1 x2 x3 x4 x5
h0 h1 h2 h3 h4 h5
y4=x0*h4+x1*h3+x2*h2+x3*h1+x4*h0;

Step-6



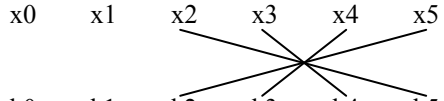
x0 x1 x2 x3 x4 x5
h0 h1 h2 h3 h4 h5
y5=x0*h5+x1*h4+x2*h3+x3*h2+x4*h1+x5*h0;

Step-7



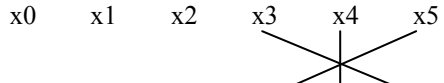
x0 x1 x2 x3 x4 x5
h0 h1 h2 h3 h4 h5
y6=x1*h5+x2*h4+x3*h3+x4*h2+x5*h1;

Step-8



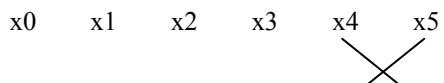
x0 x1 x2 x3 x4 x5
h0 h1 h2 h3 h4 h5
y7=x2*h5+x3*h4+x4*h3+x5*h2;

Step-9



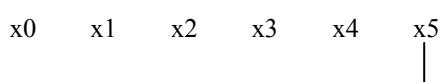
x0 x1 x2 x3 x4 x5
h0 h1 h2 h3 h4 h5
y8=x3*h5+x4*h4+x5*h3;

Step-10



x0 x1 x2 x3 x4 x5
h0 h1 h2 h3 h4 h5
y9=x4*h5+x5*h4;

Step-11



x0 x1 x2 x3 x4 x5
h0 h1 h2 h3 h4 h5
y10=x5*h5;

Fig. 1.Urdhava-Triyagbhyam Method

## IV. DSP OPERATIONS

### A. Linear Convolution

Let us consider two input sequence

$x(n)=[x(0), x(1), ....., x(L-1)]$ ...(u)

and

$h(n)=[h(0),h(1), ..... , h(M+1)]$ ...(v)

The convolution [8] of the length-L input X with the order-M filter h will output the sequence *Y(n)*.

$$y(n) = \sum_{m}^{M} h(m)x(n-m) \quad \text{... (1)}$$

$$0 \le m \le M \qquad \textit{For h(m)} \qquad \text{…(2)}$$

$$0 \le n-m \le L-1 \qquad \textit{For x(n-m)} \qquad \text{…(3)}$$

$$m \le n \le L-1+m \quad \text{or}$$

$$0 \le n \le L-1+M \qquad \textit{For n} \qquad \text{... (4)}$$

Then output sequence y(n) is y = [y(0), y(1),.....,y(L-1+M)];

$L_y = L_x + L_h - 1$

h = | M+1 |

x = | L |

y = x*h = | L | M |

From Equation (3)

$$-(L-1) \le m-n \le 0$$

Adding both side n

$$n-(L-1) \le m \le n$$

*m* must satisfy simultaneously the inequalities

$$0 \le m \le M$$

$$n-(L-1) \le m \le n$$

From above relation *m* must be greater than the maximum of the two left- hand sides and less than the minimum of the two right- hand sides.

$$Max\left(0, n-L+1\right) \le m \le Min(n, M)$$

Then the Direct form of Convolution

$$y(n) = \sum_{m=\max(0,n-L+1)}^{\min(n,M)} h(m)x(n-m);$$

n = 0,1,2, .....,L+M-1 …(5)

Equation (5) represent the linear convolution of input sequence x and *h* for n = 0, 1... L+M-1.

### *B. Circular Convolution*

Technically linear convolution gives an opportunity to calculate a L-point circular convolution of the two input sequence. The circular convolution of the L+M-1 point linear convolution calculate from given condition.

$$y_C(n) = y_0(n) + y_0(L+n) \quad \text{… (6)}$$

n = 0, 1... L-2

Equations (6) represent the Circular Convolution.

### *C. Correlation*

Design of correlation is similarly as linear convolution only that we deal with a reflected version of one signal. First input signal is simple but second input signal is reflected. After applying convolution process (Equation (u) is same and reflected the value of equation of (v)) [9]. Let us consider two input sequence are- x(n) = [x(0), x(1),....., x(L-2), x(L-1)] and h(n) = [h(M+1), h(M), .... , h(1), h(0)]. Convolution operation with both the input sequences, calculate the correlation operation y (n).

## V. PROPOSED ALGORITHM

### *A. For Linear Convolution*

The design of linear convolution has been show in fig. (1). For two 6-point input sequence x(n)= [x(0), x(1),x(2),x(3), x(4), x(5)] and h(n)= [ h(0), h(1), h(2), h(3), h(4), h(5)]. This algorithm is design for any large value of N.

| | | | | | | |
|---|---|---|---|---|---|---|
| x(n) = | x(0) | x(1) | x(2) | x(3) | x(4) | x(5) |
| h(n) = | h(0) | h(1) | h(2) | h(3) | h(4) | h(5) |

Length of input sequence x(n) is = L = 6
Length of input sequence h(n) is = M+1 = 6
Length of output sequence y(n) is = L+M+1-1=11
From Urdhava- Triyagbhyam method in fig.(1)
The Convolution is

| y = | y0 | y1 | y2 | y3 | y4 | y5 | y6 | y7 | y8 | y9 | y10 |
|---|---|---|---|---|---|---|---|---|---|---|---|

Show the technique of linear convolution using the Urdhava - Triyagbhyam sutras of Vedic mathematics. The convolved outputs sequences are given by the equation show below.

$$y(0) = x(0)h(0) \quad \text{…(7)}$$

$$y(1) = x(0)h(1)+x(1)h(0) \quad \text{…(8)}$$

$$y(2) = x(0)h(2)+x(1)h(1)+x(2)h(0) \quad \text{…(9)}$$

$$y(3) = x(0)h(3)+x(1)h(2)+x(2)h(1)+x(3)h(0) \quad \text{…(10)}$$

$$y(4) = x(0)h(4)+x(1)h(3)+x(2)h(2)+x(3)h(1)+x(4)h(0) \quad \text{…(11)}$$

$$y(5) = x(0)h(5)+x(1)h(4)+x(2)h(3)+x(3)h(2)+x(4)h(1) +x(5)h(0) \quad \text{…(12)}$$

$$y(6) = x(1)h(5)+x(2)h(4)+x(3)h(3)+x(4)h(2)+x(5)h(1) \quad \text{…(13)}$$

$$y(7) = x(2)h(5)+x(3)h(4)+x(4)h(3)+x(5)h(2) \quad \text{…(14)}$$

$$y(8) = x(3)h(5)+x(4)h(4)+x(5)h(3) \quad \text{…(15)}$$

$$y(9) = x(4)h(5)+x(5)h(4) \quad \text{…(16)}$$

$$y(10) = x(5)h(5) \quad \text{…(17)}$$

Equation (7-17) represents the output value of the convolution.

### *B. Circular Convolution*

The Urdhava –Triyagbhyam is always performed for even number of sequence and gives odd number of sequences. Circular Convolution perform the following steps are done.

- The middle term of the output of convolution is first marked according to figure-2. The output term y(5) is circled.
- Before the middle term output sequence y(0), y(1), y(2), y(3), y(4) consist array which is left side of array and after the middle term output sequence y(6), y(7), y(8), y(9), y(10) consist array which is right side of array.

- Put up the circled middle term is fixed, and MSB bit of left side array and right side of array will be added. Similarly all the bit position in the right side array will be added with successively left side bit array position show in fig-2.
- This step will go on until all the bit position in the left side and right side array of the middle bit according to above step. After addition we get output of the circular convolution. Final output calculates by following equation.

$$v(0) = y(0) + y(6) \quad \ldots(18)$$
$$v(1) = y(1) + y(7) \quad \ldots(19)$$
$$v(2) = y(2) + y(8) \quad \ldots(20)$$
$$v(3) = y(3) + y(9) \quad \ldots(22)$$
$$v(4) = y(4) + y(10) \quad \ldots(23)$$
$$v(5) = y(5) \quad \ldots(24)$$

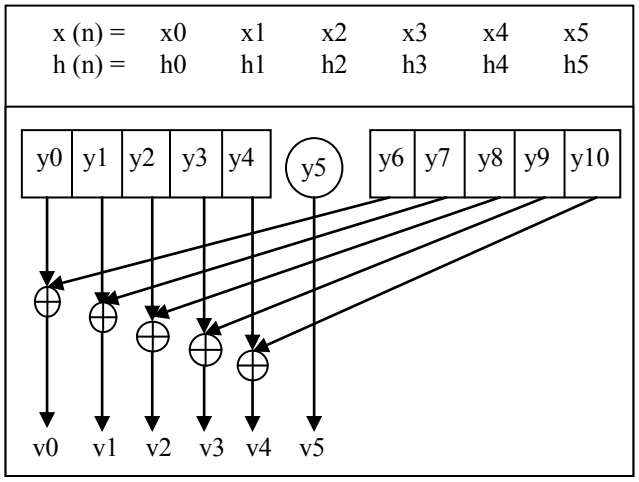



Fig. 2. Proposed Circular Convolution technique

### C. *Correlation*

The design of correlation is based on the linear convolution has been show in figure (1). For two 6-point input sequence x(n) = [x(0), x(1), x(2), x(3), x(4), x(5)] and h(n) = [h(5), h(4), h(3), h(2), h(1), h(0)]. This algorithm is design for any large value of N.

| | | | | | | |
|---|---|---|---|---|---|---|
| x(n) = | x(0) | x(1) | x(2) | x(3) | x(4) | x(5) |
| h(n) = | h(0) | h(1) | h(2) | h(3) | h(4) | h(5) |

Length of input sequence x(n) is = L = 6
Length of input sequence h(n) is = M+1 = 6
Length of output sequence y(n) is = L+M+1-1=11
From Urdhava- Triyagbhyam method in fig.(1)
The Cross - Correlation is

| y = | y0 | y1 | y2 | y3 | y4 | y5 | y6 | y7 | y8 | y9 | y10 |
|---|---|---|---|---|---|---|---|---|---|---|---|

$$y(0) = x(0)h(5) \quad \ldots(25)$$
$$y(1) = x(0)h(4)+x(1)h(5) \quad \ldots(26)$$
$$y(2) = x(0)h(3)+x(1)h(4)+x(2)h(5) \quad \ldots(27)$$
$$y(3) = x(0)h(2)+x(1)h(3)+x(2)h(4)+x(3)h(5) \quad \ldots(28)$$
$$y(4) = x(0)h(1)+x(1)h(2)+x(2)h(3)+x(3)h(4)+x(4)h(5) \quad \ldots(29)$$
$$y(5) = x(0)h(0)+x(1)h(1)+x(2)h(2)+x(3)h(3)+x(4)h(4 +x(5)h(5) \quad \ldots(30)$$
$$y(6) = x(1)h(0)+x(2)h(1)+x(3)h(2)+x(4)h(3)+x(5)h(4) \quad \ldots(31)$$
$$y(7) = x(2)h(0)+x(3)h(1)+x(4)h(2)+x(5)h(3) \quad \ldots(32)$$
$$y(8) = x(3)h(0)+x(4)h(1)+x(5)h(2) \quad \ldots(33)$$
$$y(9) = x(4)h(0)+x(5)h(1) \quad \ldots(34)$$
$$y(10) = x(5)h(0) \quad \ldots(35)$$

Equation (25-35) represents the output of the cross-correlation. For Auto-Correlation both the input sequence are similar use in above method.

## VI. Implementation And Result

Vedic operation is implemented on Graphical User Interface window. Basically GUI is a program which provides the benefits of computer's graphics capabilities to make program easy to use. Graphical user Interface provides user an spacious way to interact with software. The most renowned and essential part of the software that is being used today is Graphical User Interface, GUI [10].

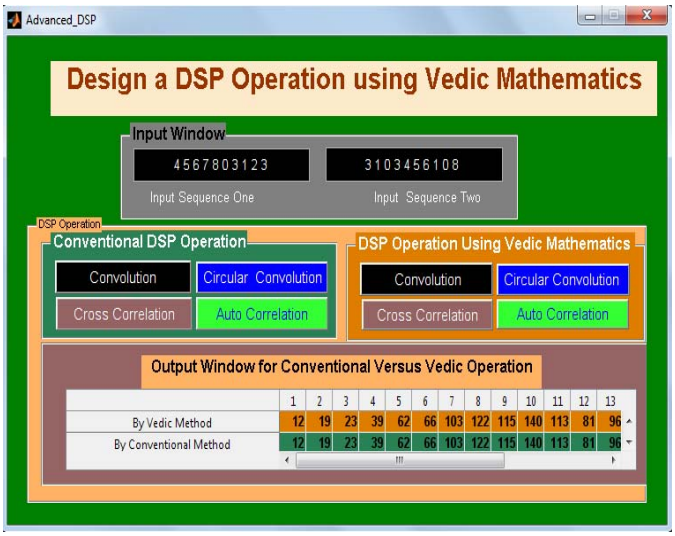



Fig. 3. Proposed DSP operations window

### 1. *For Convolution*

TABLE-1

| Comparison of time for Vedic Convolution versus Conventional Convolution | | | |
|---|---|---|---|
| No. of operation | 1 | 2 | 3 |
| Urdhava-Triyag-bhyam Method | $2.231\times10^{-6}$ | $7.585\times10^{-6}$ | $8.023\times10^{-6}$ |
| Conventional Method (Inbuilt) | $9.639\times10^{-5}$ | $8.121\times10^{-5}$ | $1.602\times10^{-4}$ |

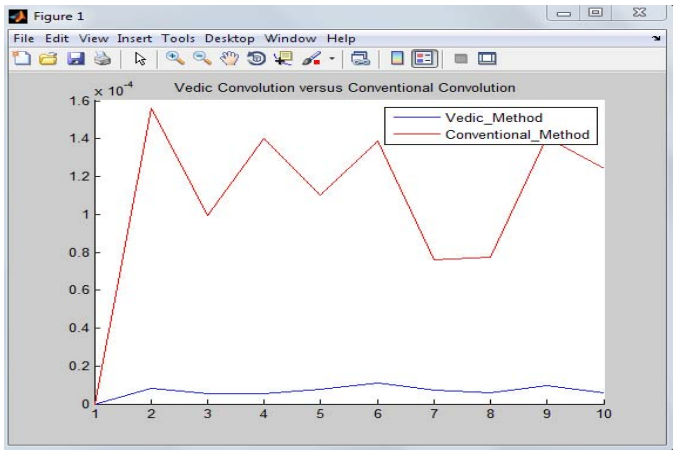



Fig. 4. Proposed convolution operation

*2. For Circular Convolution*

TABLE-2

| Comparison of time for Vedic Circular Convolution versus Conventional Circular Convolution | | | |
|---|---|---|---|
| No. of operation | 1 | 2 | 3 |
| Urdhava-Triyag-bhyam Method | $5.800\times10^{-6}$ | $5.354\times10^{-6}$ | $7.585\times10^{-6}$ |
| Conventional Method(Inbuilt) | $4.422\times10^{-4}$ | $7.090\times10^{-4}$ | $6.247\times10^{-5}$ |

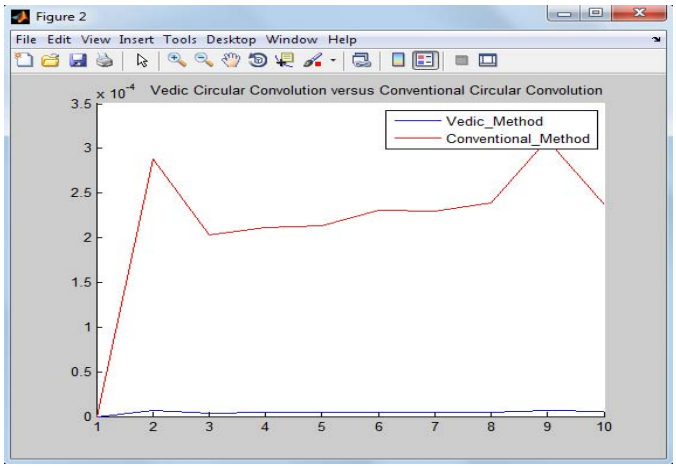



Fig. 5. Proposed circular convolution operation

*3. For Cross Correlation*

TABLE-3

| Comparison of time for Vedic Cross Correlation versus Conventional Cross Correlation | | | |
|---|---|---|---|
| No. of operation | 1 | 2 | 3 |
| Urdhava-Triyag-bhyam Method | $8.478\times10^{-6}$ | $4.016\times10^{-6}$ | $3.569\times10^{-6}$ |
| Conventional Method(Inbuilt) | $1.713\times10^{-3}$ | $1.315\times10^{-3}$ | $1.249\times10^{-5}$ |

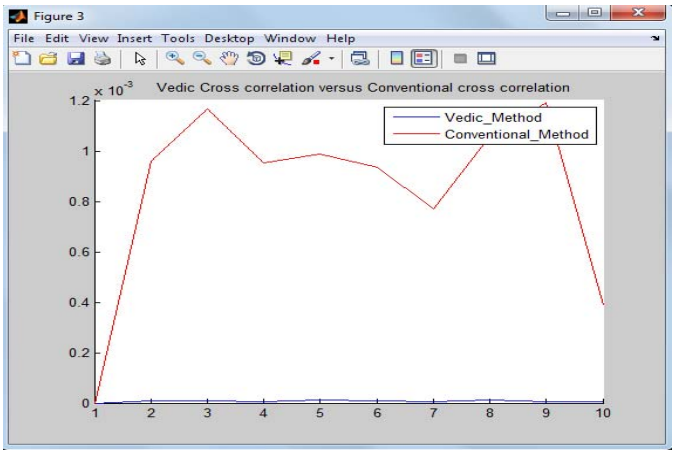



Fig. 6. Proposed cross correlation operation

4. *For Auto Correlation*

TABLE-4

| Comparison of time for Vedic Auto Correlation versus Conventional Auto Correlation | | | |
|---|---|---|---|
| No. of operation | 1 | 2 | 3 |
| Urdhava-Triyag-bhyam Method | $4.908\times10^{-6}$ | $4.462\times10^{-6}$ | $5.800\times10^{-6}$ |
| Conventional Method(Inbuilt) | $4.232\times10^{-4}$ | $1.111\times10^{-3}$ | $4.667\times10^{-4}$ |

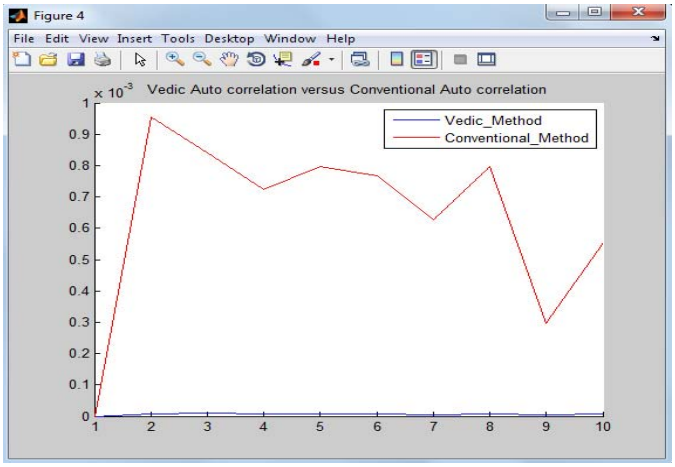



Fig. 7. Proposed auto correlation operation

Fig. (3) represent the main window for DSPs operation and performing the convolution operation for sequence one x(n)=[4,5,6,7,8,0,3,1,2,3], h(n)=[3,1,0,3,4,5,6,1,0,8].Display the convolution result y(n)=[12,19,23,39,62,66,103,122,115, 140,133,81,96,95,28,44,11,16,24]. Fig. 4-7 represents the graph between the time consumed by Vedic operation and conventional operation. In above figure the red graph show the time value for conventional operation and blue graph represent the value for Vedic operation. Table 1-4 show the time comparison between conventional versus Vedic operation for different input sequences and operations.

## VII. CONCLUSION

A fast computation of DSP operations of two finite length sequence implemented with the help of single GUI window. DSP operations are based on Urdhava-Triyagbhyam method of Vedic mathematics, which reduces the processing time as compare to inbuilt function of Matlab. Proposed algorithm provide average processing time in micro second and conventional operation provide average time in mili second. Mathematics operation time give in Graphical User Interface window is easy to use and user friendly. In future, the Fast Fourier Transform and Filter operation is design with the help of Vedic Urdhava- Triyagbhyam method.

## REFERENCES


[1] A.Kumar, A. Raman, Dr. Sarin, "Small area reconfigurable FFT design by Vedic math" *in Proc. 2nd IEEE Int. Conf. Computer and Automatic Engineering*, India vol. 5, 2010, pp.836-838.

[2] L. R. Rabiner and B. Gold, "*Theory and Application of Digital Signal Processing".* Englewood Cliffs, NJ: Prentice-Hall, 1975.

[3] J.G. Proakis and D.G. Monolakis, *"Digital Signal Processing".* Prentice- Hall International, Inc., 1996.

[4] W.Li, "The Modified fermat number transform and its application" *in Proc. IEEE Int. Symposium on Circuit and System,* Bethlehem, 1990, vol.3, pp. 2365-2368.

[5] Jagadguru Swami Sri Bharath, Krishna Tirathji, *"Vedic Mathematics or Sixteen Simple Sutras from The Vedas"*, Motilal Banarsidas, Varanasi (India), 1992.

[6] Jeganathan Sriskandarajah, *"Secrets of Ancient Maths: Vedic Mathematics"*, Journal of Indic Studies Foundation, California, 2003 pp. 15-16.

[7] Parth Mehta, Dhanashri Gawali, "Conventional versus Vedic mathematical method for Hardware implementation of a multiplier" ; *in Proc. IEEE Int. Conf. Advances in Computing, Control, and Telecommunication Technologies*, India, Dec. 2009, pp. 640-642.

[8] Sophocles J. Orfanidis *"Introduction to Signal Processing"* Prentice Hall, Inc.,1996–2009

[9] Sumantra Dutta Roy, Poonam Suryanarayan, "The Relation between discrete convolution / correlation and string matching, and exploring the possibility of a deterministic linear-time algorithm for discrete convolution/correlation" *in Proc. IETE Journal of education,* vol.51, April 2010.

[10] Isabella1and Emi Retna, "Study paper on test case generation for GUI based testing" *in proc. Int. Journal Software Engineering & Applications,* Vol.3, Jan 2012, pp. 3-8.