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Design and Implementation of Convolution and Deconvolution by using Sutras

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Abstract

In Digital Signal Processing, the convolution and deconvolution with a very long sequence is ubiquitous in many application areas. The basic blocks inconvolution and Deconvolution implementation are multiplier anddivider. A direct method of computing the discretelinear convolution, circular convolution and deconvolution. The proposed method is the development of a multiplier and divider architectur ebased on Ancient Indian Vedic Mathematics sutras Urdhvatriyagbhyam and Nikhilam algorithm. The results show that the implementation of linear convolution and circular convolution using Vedic mathematics. The coding is donein VHDL. Simulation and Synthesis are performed using XilinxI SE design suit 13.2.

Keywords: Linear Convolution, Circular Convolution, Deconvolution, Vedic Mathematics, UrdhvaTriyagbhyam, Nikhilam, VHDL.

1. Introduction

With the latest advancement of VLSI technology, digital signal processing plays a pivotal role in many areas of electrical engineering. Discrete convolution is central to many applications of Digital Signal Processing and Image Processing. It isused for designing of digital filter and correlation application. However, beginners of tenstruggle with convolution because the concept and computation requires a number of steps that are tedious and slow to perform. The most commonly taught approach is a graphical method because of the visualin sight in to the convolution mechanism. Graphical convolution is very systematic to compute but is alsovery tedious and time consuming [1].The principal components required for implementation of convolution calculation are adder and multiplier for partial multiplication. Therefore the partia lmultiplication and addition are bottle neck indeciding the overall lspeed of the convolution implementation technique. Complexity and excess time consumption are always the major concern of engineers which motivates them to focus on more advance and simpler techniques. Pierre and John[2] have implemented a fast method for computing linear convolution, circular convolution and deconvolution. This method is similar to the multiplication of two decimal numbers and this similarity makes this method easy to learn and quick to compute. Also to compute deconvolution of two finite length sequences, a novel method is used. This method is similar to computing long-hand division and polynomial division.As a need of proposed method, all required possible adders are studied. All these adders are synthesized using Xilinx Design Suit 14.2. Their delays and areas are compared. Adders which have the highest speed and occupy a comparatively less area are selected for implementing convolution. Since the execution time in most DSP algorithms mainly depends upon the time required for multiplication, so there is a need of high speed multiplier. Now a days, time required in multiplication process is still the dominant factor in determining the instruction cycle time of a DSP chip [3]. Traditionally shift and add algorithm is being used for designing. However this is not suitable for VLSI implementation and also from delay point of view. Some of the important algorithms proposed in literature for VLSI implementable fast multiplication are Booth multiplier, array multiplier and Wallace tree multiplier [4]. Although these multiplication

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techniques have been effective over conventional “shift and add” technique but their disadvantageof time consumption has not been completely removed. Vedic Mathematics provides unique solution for this problem. The Urdhva Triyagbhyam Sutra or vertically and Crosswise Algorithm for multiplication is discussed and then used to develop digital multiplier architecture. For division, different division algorithms are studied, by comparing drawbacks and advantages of each algorithm; Nikhilam Algorithm based on Vedic mathematics is modified according to need and then used.

II. PROPOSED ALGORITHM USING VEDIC MATHS

Vedicmathematics is an ancient Vedic mathematics whichprovides the unique technique of mental calculation with the help of simple rules and principles. It is based on sixteen sutras which transact different branches of mathematics i.e. algebra, geometry, arithmetic etc. In this paper the algorithms of Vedic mathematics are used to design multiplier and divider. With the help of these algorithms convolution, circular convolution and deconvolution are implemented.

A. Convolution

In this section novel multiplier architecture [5] based on Urdhva Triyagbhyam Sutra of Ancient Indian Vedic Mathematics is embedded into proposed method of convolution to improve its efficiency in terms of speed and area. This method for discrete convolution using vedic multiplication algorithm is best introduced by a basic example. For this example, let f(n) equal the finite length sequence (4 2 3) and g(n) equal the finite length sequence (4 5 3 4). The linear convolution of f(n) and g(n) is given by [1]:y (n) = f (n) ∗ g(n) (1)

$$y(n) = \sum_{k=-\infty}^{\infty} f(k)g(n-k) \quad (2)$$

This can be solved by several methods, resulting in the sequence y(n) = (16 28 34 37 17 12). This new approach for calculating the convolution sum is set up like multiplication where the convolution of f(n) and g(n) is performed as follows:

g(n):			4	5	3	4
f(n):			*	4	2	3
			12	15	9	12
		08	10	6	8	
	16	20	12	16		
y(n):	16	28	34	37	17	12

Fig: -1 Convolution by proposed method

As seen in the Fig. 2 computation of the convolution sum, the approach is similar to multiplication calculation, except carries are not performed out of a column. This first example shows the simplicity of this method and how easily the calculation can be performed. As shown below, this method can be used to check intermediate values in graphical convolution, as well as the final answer. In Fig. 1, the convolution sum is computed using graphical convolution. Fig. 1(a) shows the sequences f(n) and g(n). For each value of n, the convolution sum consists of a folding, translation, multiplication, and summation. For a given value of n, the summation is a product of the sequence f (k) and the folded and translated sequence g (n-k). The left-hand column of Fig.1 (b) shows both sequences f (k) and g (n-k) for each value of n, and the right-hand column shows the product of the two sequences Vn (k) which is given by

$$V_n = f(k)\, g(n-k) \quad (3)$$

$$f(n)*g(n) = \sum_{k} v_n(k) \quad (4)$$

The final answer for the graphical convolution method is shown in Fig. 1(c). This answer was verified above using the new method. The sequence vn (k), which is an intermediate an- swer in computing the convolution sum, may also be checked as shown below using the method presented in this paper.

g(n):			4	1	2	
f(n):		*	2	3	4	k
v(1):			16	04	08	1
v(0):		12	03	06		0
v(-1):	08	02	04			-1
y(n):	08	14	23	10	08	
n:	-1	0	1	2	3	

Fig.3: Verification of intermediateetermsusing proposed method

Above example illustrates the ease in computing the convolution sum for finite sequences using this new method.

1) Vedic Mutiplier:Urdhva Triyagbhyam: Among all avail- able multipliers, this paper proposes a systematic design methodology for fast and area efficient digit multiplier based on Vedic Mathematics. In the proposed convolution method the multiplier architecture is based on an algorithm Urdhva Triyagbhyam (Vertical and Crosswise) of Ancient Indian Vedic Mathematics [5].

The use of Vedic Mathematics lies in the fact that it reduces the typical calculations in conventional mathematics to very simple ones. Urdhva Tiryagbhyam Sutra is a general multiplication formula applicable to all cases of multiplication [6]. Because of parallelism in generation of partial products and their summation obtained, speed is improved. In this algorithm the small block can be wisely utilized for designing bigger NxN multiplier. For higher no. of bits in input, little modification is required. Divide the no. of bit in the inputs equally in two parts. Let's analyze 4x4 multiplications, say A3 A2 A1 A0 and B3 B2 B1 B0. Following are the output line for the multiplication result,S7 S6 S5 S4 S3 S2 S1 S0 . Let's divide A and B into two parts, say A3 A2 &A1 A0 for A and B3 B2 &B1 B0 for B. Using the fundamental of Vedic multiplication, taking two bit at a time and using 2 bit multiplier block, we can have the following structure for multiplication.

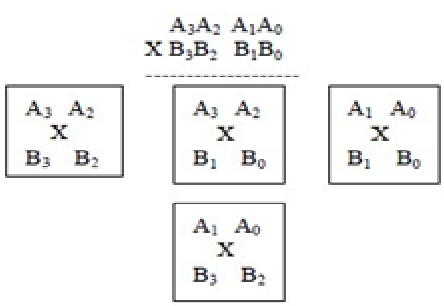

Fig. 4. Block diagram presentation for 4x4 multiplications

Each block as shown above is 2x2 multiplier. First 2x2 multiplier inputs are A1 A0 and B1 B0. The last block is 2x2 multiplier with inputs A3 A2 and B3 B. The middle one shows two, 2x2 multiplier with inputs A3 A2 and B1 B0 and A1 A0 and B3 B2. So the final result of multiplication, which is of 8 bit, S7 S6 S5 S4 S3 S2 S1 S0, can be interpreted. Assuming the output of each multiplication is as given above. For the final result, add the middle product term along with the term shown below.

B. Circular Convolution

Circular convolution has many applications and is usually introduced to electrical engineering students in a digital signal processing. The novel method for computing linear convolution using vedic mathematics from above subsection is easily modified for circularconvolution [2]. This method of computing circular convolution is best illustrated by example. Let f(n) = (2 3 1 0) and g(n) = (4 5 2 1). The circular convolution of f(n) and g(n) is given by

$y(n) = f(n) * g(n)$ (5)

y(n)= (13 13 23 23) where N is the length of the sequences. This circular convolution calculation may be performed similar to the method for linear convolution from above subsection. The multiplier architecture is implemented using vedic algorithm.

The location of the triangle of bold faced numbers is repositioned for circular convolution compared with linear convolution. The location of these numbers is due to the circular translation in circular convolution. The far left value in the circular convolution solution corresponds to y(N - 1) where N is the length of the sequence.

	2	3	1	0
⊗	4	5	2	1
	2	3	1	0
	6	2	0	4
	5	0	10	15
	0	8	12	4
	13	13	23	23
	y(3)	y(2)	y(1)	y(0)

Fig. 5. Circular Convolution by proposed method

C. Deconvolution

A direct method is also presented for the deconvolution of two finite length discrete-time sequences. This deconvolution method is similar to computing long-hand division and polynomial division, just as the direct convolution method is similar to multiplication [7]. Many other deconvolution methods are available. In this section, a basic recursive deconvolution method for finite length sequences is computed. This recursion can be carried out in a manner similar to long division.

```
          4  2  3  => f(n)
4 5 3 4 | 16 28 34 37 17 12
        | 16 20 12 16
        |-------------------
        |    8  22 21 17 12
        |    8  10  6  8
        |       12 15  9 12
        |       12 15  9 12
        |        0  0  0  0
```

Fig. 6. Deconvolution by proposed method

Division operation is implemented by using Nikhilam algorithm based on Vedic mathematics while to obtain partial products vedic multiplier is used. For instance, the first example in subsection A may be reworked, solving for f(n) given g(n) and y(n). The sequences are set up in a fashion similar to long division, as shown in Fig. 6, but where no carries are performed out of a column.

1) Vedic Divider: Nikhilam Algorithm: The Nikhilam sutra goes as follows: Nikhilam Navatascaramam Dasatah, literally meaning all from 9 and the last from 10. To illustrate the method further, we will take an example. Let us work out123/8.

8 2

1 2 | 3

0 2 | 8

————

1 4 | 11

1 5 | 3

The first line consists of the denominator followed by its10's complement (2 is 8's 10's complement). The numerator has been divided by a "|" such that there are as many digits to the right of the "|" as there are digitsin the denominator. Wethen put a zero under the first digit of the numerator. Now addup the digits in that column of the numerator to get a sum of 1 (1 + 0 = 1). Multiply it by the 10's complementto get 2 (1 x 2= 2). Put that under the second digit of the numerator. The sum of the digits under the second column is 4.Multiplying this by the 10's complement gives us 8. Put the 8 under the thirddigit of the numerator, right of the "|". Now we add up thenumbers under the columns. Note that there is no carry over from the right of the "|" to the left of it. Following the ruleson how to deal with a remainder greater than the denominator, we divide the remainder by the denominator and add the new quotient to the original quotient and retain the new remainder as the final remainder.

The same method is extended for other numbers. Nikhilam division algorithms just involves the addition of numbers which is very much different from the traditional division technique including multiplication of big numbers by the trial digit of the quotient at each step and subtract that result from dividend at each step [8].

III. SIMULATIONS AND RESULTS

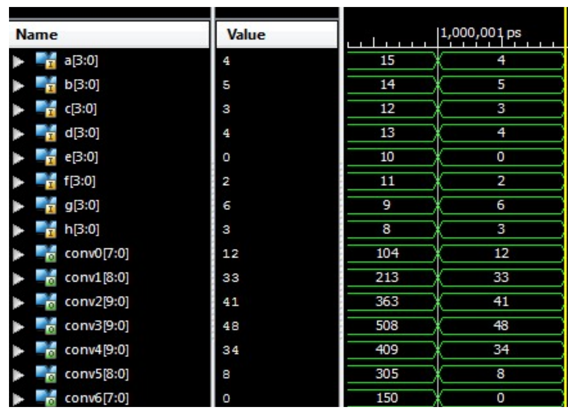

Fig. 7. Convolution using Vedic mathematics

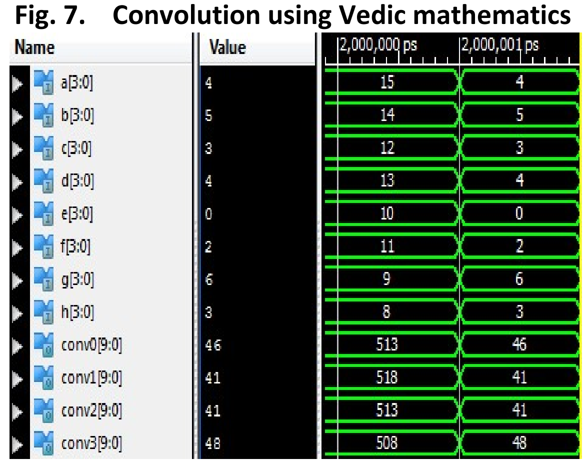

Fig.8. Circular Convolution using Vedic Mathematics

IV. CONCLUSION

The linear convolution, circular convolution and deconvolution with the help of Vedic algorithms that is easy to learn and perform. An extension of the proposed linear convolution approach to circular convolution using Vedic multiplier is also introduced which has less delay than the conventional method. The deconvolutionis performing a straightforward approach. The linear, circular convolution and deconvolution simulated and synthesized by using Xilinx 13.2 tool.

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