E-ISSN: 2583-9667
Indexed Journal
Peer Reviewed Journal
https://multiresearchjournal.theviews.in

Received: 21-07-2023
Accepted: 29-08-2023

INTERNATIONAL JOURNAL OF ADVANCE RESEARCH IN MULTIDISCIPLINARY

Volume 1; Issue 1; 2023; Page No. 517-521

Integrating Vedic mathematics with derivatives

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DOI: https://doi.org/10.5281/zenodo.13188792

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Abstract

Intuitive revelation allowed SWĀMĪ ŚRĪ BHĀRATĪ KR A TĪRTHAJĪ MAHĀRĀJA Śankarācārya of Govardhan ṢṆ Matha, Puri (1884-1960) to find the mathematics found in the Vedas, an old body of Indian text from 1911 to 1918. Incredible as it may seem, the ancient discipline of Vedic mathematics is slowly but surely making a triumphant return to the forefront of contemporary curricula throughout the globe. An attempt has been made in this paper to shed light on the research topic "The Contribution of Vedic Mathematics in Advance Calculus" by providing meaningful explanations of each Sūtra and their applications in solving various types of equations, including ordinary and partial, linear and non-linear differential equations, in addition to equations that are linear, quadratic, cubic, or quartic.

Keywords: Vedic math, mathematical calculations, classic approach, vedic sutra

Introduction

There is a deep connection between mathematics and astronomy in Indian culture. Many of the architectural and astronomical derivations found in the Vedas would not have been conceivable without the advanced mathematical understanding of the time. The Vedas, which are written in a mysterious script, are ancient scriptures. An essential component of the Vedas, Vedang Jyotish, delves into astrology and astronomy, requiring a thorough understanding of mathematics, while the Sthapatya Veda is replete with architectural wisdom. It was a challenging task to decode Sūtras from the Vedas, yet we can claim that the Vedas were the exclusive source of Vedic mathematics. Locating the current form of the Vedic mathematics Sūtras was a laborious task.

From 1911 to 1918, SWĀMĪ ŢRĪ BHĀRATĪ KRA TĪRTHAJĪ MĀHĀRĀJA, via intuitive revelation, rediscovered Vedic mathematics in ancient Indian texts. The construction of Vedic mathematics is based on sixteen aphorisms or Vedic Sūtras and thirteen sub-Sūtras from the Atharva Veda. These were rebuilt by spontaneous revelation and include word formulae that reveal regular procedures to solve any kind of mathematical complexity. The sixteen Sūtras are brief and memorable expressions of innovative ideas. The concepts of reasoning lie underlying Sūtras and Sub-Sūtras, even if TĪRTHAJĎ is supposed to have come easily to them.

The founder of Vedic Mathematics

In 1884, SWĀMĪ ŚRĪ BHĀRATĪ KRA TĪRTHAJĪ MĀHĀRĀJA came into this world. He is the one who founded Vedic Mathematics. In his early years, TĪRTHāJĪ was known as Venkatram and was a very educated scholar. When Madras University administered its matriculation test in January 1899, he came out on top. An accomplished scholar of Sanskrit, Jagadguruji also had extensive understanding of mathematics, history, and philosophy. He earned his Master of Arts from the American College of Sciences in New York after finishing first in his Bachelor of Arts class. He took his test in 1903 and 1904 at the Bombay Centre. At the tender age of twenty-one, he had already finished his post-graduate studies in seven topics, all of which he had excelled in. Truly, this set a new standard for intellectual genius on a global scale.

In 1965, the concepts of Vedic mathematics were published in a groundbreaking book by BHĀRATĪ KRA TĪRTHAJĪ, the previous Śankarāchārya, a significant spiritual leader of Puri in India. His work was based on study into the ancient manuscripts of the Vedas. Vedic mathematics rests on it. Vedic Mathematics, a new alternative to traditional mathematics, gained instant notoriety when a printed copy of the book appeared in London in the late 1960s. Jeremy

Pickles, Andrew Nicholas, and Kenneth Williams were among the prominent British mathematicians who were interested in this innovative method at the time. They spoke on Vedic mathematics in London and revised the rough draft of Tirthaji's book. These lectures were compiled into a book in 1981 called Introductory lectures in Vedic Mathematics. There was a renaissance of interest in Vedic mathematics among Indian scholars and teachers during Andrew Nicholas's two trips to the country (1981 and 1987). Vedic mathematics became more of a priority for them.

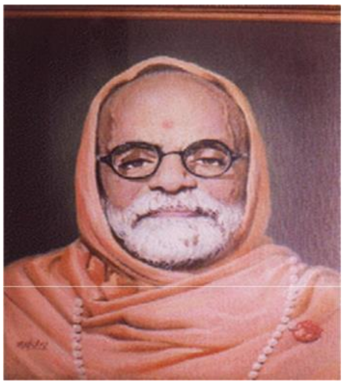


Fig 1: Swāmī Śrī Bhāratī Kra Tīrthajī Māhārāja

Review of Literature

The study "Hardware Implementation of 16 × 16-bit multiplier & apply Vedic math’s to a square" proposes a VHDL-described design for a 16 × 16-bit multiplier and square. This design addresses the drawbacks of array, carry save adder, modified booth, Wallace tree, and other multiplication algorithms. The authors propose a novel 16-bit multiplier and square design rooted in Vedic mathematics, using the ṛrdhva-Tiryagbhyām Sūtra and the Duplex Property.

Babaji D.K. (2022) [7], The research paper "Solving systems of linear use the Parāvartya rule to solve math" demonstrates the use of the Parāvartya Yojayet Sūtra to solve two linear equations. It also provides examples for resolving systems of n linear equations, whether they consist of three, four, or eight equations. The author argues that the Parāvartya Yojayet Sūtra is superior to Gauss elimination and LU Decomposition for solving systems of three linear equations and comparable to the Cramer Rule for solving two linear equations. The paper encourages further exploration of the Parāvartya rule for solving systems of three or four linear equations.

Syed Azman bin Ismail conducted a research study on the Vedic Method (VM) to understand why some children struggle with solving simple math problems. The study aimed to find a technique that is easy to understand and useful for solving product calculations, particularly those involving larger numbers. The authors administered a questionnaire to five fourth-graders, randomly selected from a class of thirty. The pre-test results were compared with post-test results after explaining the Sūtras of Vedic mathematics. One of the VM Sūtras proved beneficial for multiplying in a vertical and crosswise pattern. The students' affirmative responses confirmed the efficacy of the Vedic method in academic coursework. This outcome was confirmed through meticulous observational recording and comparisons.

The study explores the performance evaluation and synthesis of multipliers used in FFT operation using conventional and Vedic Algorithms. The Vedic approach is suggested for running multipliers in FFT, as it simplifies complex expressions using fundamental mathematical procedures. The study describes several effective algorithms for digital signal processing and fast Fourier transforms. The shortcuts recommended by VM help minimize efforts and increase productivity. Some Sūtras, such as Ūrdhva-Tiryagbhyām, Nikhilaṁ Sūtra, Ānurūpyena, and Vinculam, are beneficial for their speed and precision. The study recommends the binary system for exemplifying the Ūrdhva-Tiryagbhyām method, suitable for digital hardware. A typical 4-bit multiplier for 4-bit VM is required for performance evaluations independently. The study compared the two multiplier varieties based on criteria such as logic slice LUT count, IO count, overall memory consumption, LUT FF pair count, and BEL density. The Vedic multiplier method showed higher benefits when tested against the standard multiplier.

Acharya Eke Ratna (2015) [2], The goal of the article "Mathematics Hundred "Years Before and Now" is to look at mathematical history as a means to preserve manuscripts. This essay aims to bridge the gap between classical and current approaches in an effort to alter the mathematical archetype by analysing the signs of mathematical progress. This article has discussed the relation between first-order derivatives and factors of quadratic, cubic, and bi-quadratic expressions, as well as how to utilize derivatives to solve quadratic equations. The writer has also shown how to solve using the Vertical and Crosswise Sūtra via the use of instances difficulties involving integration by parts, consecutive differentiating algebraic and exponential product functions, among related problems. From this, the author draws the conclusion that although the subject matter has remained mostly same over the last century, the approach to problem-solving and algorithms have evolved.

Vedic mathematics in derivatives and integration, Differential Equations and Partial Differential Equations

Introduction to Differential Calculus: The most important achievement in the mathematics is the development of both the Differential Calculus and the Integral Calculus. There are lots of real-life applications which require us to find the rate of change of one parameter with respect to another for which Differential Calculus plays an important role.

Identifying the derivative of any function at a given point geometrically, draw a tangent at that point and evaluate the value of the slope. If $y = f(x)$ given then

$$\frac{dy}{dx} = f'(x)$$

With the help of Dhvaja Ghata, the power: The process for determining the first differential of every quadratic expression. $ax2 + bx + c$, is by lowering it by one and then multiplying its Dhvaja Ghata (power) by its Anka (coefficient).

Example: 1

Determine the slope of a quadratic equation $x2 - 9x + 14.$

Let $E = x2 - 9x + 14.$

Presently, when one takes the derivative of $y\ w.r.t.\ x$

$$\therefore \frac{dy}{dx} = f'^{(x)} = \frac{d}{dx} = (x^2) - 9\frac{d}{dx}(x) + \frac{d}{dx}(14)$$
$$= 2x - 9(1) + 0$$
$$\therefore \frac{dy}{dx} = 2x - 9$$

With the help of Dhvaja Ghata**,**

Locating the initial differential of each quadratic expression term $x2 - 9x + 14$,

$x2\ gives\ 2x;\ -9x\ gives\ -9\ and\ 14$ gives zero.

Therefore

$D_1 = fx = d/dx\ (x2 - 9x + 14) = 2x - 9$.

The Calana-Kalanābhyām Sūtra

Meaning: Differential Calculus

A connection between the first differential and the square root of the discriminant of a quadratic is shown in this Sūtra. This Sūtra was referred to by ŚRĪ BHĀRATĪ KRA as a formula for obtaining the two roots of a given quadratic equation in calculus. First differential, he says, is square root of discriminant of original quadratic equation.

$$i.e. D_1 = \pm\sqrt{Discriminant} = \pm\sqrt{b^2 - 4ac}$$

For this reason, we may solve two basic equations to get the roots of the supplied quadratic equations

Procedure for finding Differentials

The conventional form of the above polynomial is to write it with the constant term 1 before xn. Dividing the polynomial into its linear components is the next step.

As stated in the Guakasamuccaya Sūtra, the first differential D1 of a given polynomial may be found by adding the components that make it a product of those factors. Following is an explanation, with examples, of how to compute the derivative of a quadratic expression, a cubic expression, a quadratic equation, and a polynomial raised to the fifth power.

$$D5 = 5!\ [Sum\ of\ factor - products\ taken\ (n-5)\ at\ a\ time]$$

Differentials of quadratic expression

If the quadratic equation can be factorized into two linear components, as stated in the Gu_akasamuccaya_ Sūtra, $a_1 = x + m and\ a_2 = x + n$ Afterwards, we get the first differential D1 by combining those two linear elements. First Differential D_1 = 1! [Sum of factor product taken (2 - 1) = 1 at a time]

$$i.e. D_1 = \sum_{i=1}^{2} a_i = a_1 + a_2 = (x+m) + (x+n)$$

The second difference D_2 = 2!

Differentials of bi-quadratic expression

They may be factorized into four linear components for bi-quadratic expression.

$$a_1 = (x+m), a_2 = (x+n)\ a_3 = (x+p) and\ a_4 = (x+q)$$

Consequently, the first derivative of D is 1. [One step at a time, the sum of the factor products (4-1) equals 3]

$$D_1 = \sum_{i,j=1}^{4} a_i\ a_j\ a_k; i < j, i \neq j \neq k$$
$$= a_1a_2a_3 + a_1a_2a_4 + a_2a_3a_4 + a_1a_3a_4$$
$$= (x+m)(x+n)(x+p) + (x+m)(x+n)(x+q)$$
$$= (x+n)(x+p)(x+q) + (x+m)(x+p)(x+q)$$

Dual of the Second Kind, D= 2! The total factor product, when taken in increments of 2 (from 4-2)]

$$i.e.\ D_2 = 2!\sum_{i,j=1}^{4} a_i\ a_j\ a_k; i < j, i \neq j$$
$$= 2!\,[a_1a_2 + a_1a_3 + a_1a_4 + a_2a_3 + a_2a_4 + a_3a_4]$$
$$= 2!\,(x+m)(x+n) + (x+m)(x+p) + (x+m)(x+q)$$
$$= (x+n)(x+p) + (x+n)(x+q) + (x+p)(x+q)$$

D_3, the third differential, equals 3! The total factor product, when taken one step at a time, is (4-3).]

$$i.e.\ D_3 = 3!\sum_{i=1}^{4} a_i$$
$$= 3!\,[a_1 + a_2 + a_3 + a_4]$$
$$= 3!\,[(x+m) + (x+n) + (x+p)(x+q)]$$

Differential Type IV D_4 = 4!

Example: 6

Determine the potential differences of bi-quadratic expression $x^4 - 8x^3 + 8x^2 + 32x - 48$

We must first determine the components of the bi-quadratic expression that has been provided

Allow the components of E = $x^4 - 8x^3 + 8x^2 + 32x - 48$ be (x - 2), (x - 2), (x + 2) & (x - 6)

Initial difference

$$D_1 = \sum_{i,j,k=1}^{4} a_i\ a_j\ a_k; i < j < k, i \neq j \neq k$$

$$D_1 = [(x+2)(x-2)(x-2) + (x-2)(x-2)(x-6) + (x+2)(x-2)(x-6) + (x+2)(x-2)(x-6)]$$

$= [x^3 - 2x^2 - 4x + 8 + x^3 - 10x^2 + 28x - 24 + x^3 - 6x^2 - 4x + 24 + x^3 - 6x^2 - 4x + 24]$

$\therefore\ D_1 = 4x^3 - 24x^2 + 16x + 32$

The second difference

$D_2 = 2! \sum_{i,j=1}^{4} a_i\, a_j ; i < j, i \neq j$

$\therefore D_2 = 2!\, [x^2 - 4 + x^2 - 4 + x^2 - 4x - 12 + x^2 - 4x + 4 + x^2 - 8x + 12 + x^2 - 8x + 12]$

$= 2[6x^2 - 24x + 8]$

$\therefore\ D_2 = 12x^2 - 48x + 16$

Differential three $D_3 = 3! \sum_{i=1}^{4} a_i$

$= 3!\, [(x + 2) + (x - 2) + (x - 2) + (x - 6)]$

$\therefore D_3 = 6(4x - 8) = 24x - 48$

Binary Multiplication by using Vedic Sūtra

By using Vertically & Crosswise Sūtra based Vedic Multiplier: In DSP Vedic Mathematics algorithm is applied to digital multiplier. Ūrdhva-Tiryagbhyām algorithm used with the binary number system is also used with the decimal system. Two is the base in the binary system. Since there are only two bits involved, we can replace the vertically and method for combinatorial multiplication in which each AND is rather general. To generate cross-product these bits are added together.

Algorithm: Single bit vertical product is carried out between bits of minimum significance (LSBs) of multiplicand and multiplier.

Further calculation is done with 2-bits crosswise product and by incrementally adding by 1 bit until all bits are exhausted.

Moreover, decreasing bits from LSB for cross-multiplication and continuing this until MSB (only) is useful for vertical multiplication.

Concatenate all the result by carry over extra bit which is the final answer.

Architecture of Vedic multiplier by Vertically & Crosswise Sūtra: Vertically & Crosswise Sūtra based Vedic multiplier is applicable for multiplication and it reveals the efficiency of reducing the N × N bit multiplier to 2 × 2-bit structure.

The N × N bit multiplier structure is executed by N × N gates and N half adders and (N-2) * N Full adder i.e. total (N-1) * N adders.

The 2 × 2 multiplier is executed by 4 input AND gates and 2 half adders.

The 4 × 4 multiplier is executed by 16 input AND gates 4 half adders and 8 full adders.

Three 16 × 16-bit adders and four 4 × 4-bit multipliers carry out an 8 × 8-bit multiplier.

With the help of the basic 2 × 2-bit multiplier, multiplier with 4 by 4 bit developed, with the help of a series of blocks of 4 by 4 bits, followed by 8 by 8 bits, 16 by a 16-bit multiplier, and 32 by a 32-bit block multiplier based on Vedic Sūtra has been designed and thus ALU design with Vedic overlay algorithm is efficient related to rapidity, area and power consumption.

Binary Multiplication of 2 x 2 bit

(By using Vertically & Crosswise Sūtra based Vedic Multiplier)

Let A = $A_1\, A_0$ and B = $B_1\, B_0$ are given two-bit nos.

For finding A × B

$\boldsymbol{A_1} \qquad \boldsymbol{A_0}$

$\times \qquad \boldsymbol{B_1} \qquad \boldsymbol{B_0}$

$\boldsymbol{A_1 B_1 |\ A_0 B_1 + A_1 B_0 | A_0 B_0}$

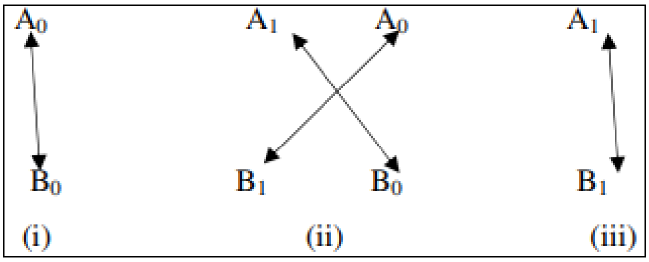
$\boldsymbol{C_1}$

$\boldsymbol{C_2 S_2 | \quad C_1 S_1 \quad | S_0}$

$\boldsymbol{C_2 \quad S_2 \quad S_1 \quad S_0}$

Thus, $A_1 A_0 \times B_1 B_0 = C_2 S_2 S_1\, S_0$

It can be explained by figure using Vertically & Crosswise Sūtra:



Algorithm: First, start with 1 x 1 bit vertically multiplication of the multiplicand (A_0) with the least significant Bit of multiplier (B_0). i.e. A × B_0 = S_0 which is the LSB of the answer.

Evaluate another product in the same way by exchanging numbers in the opposite format, and then find the crosswise multiplication of the 2 × 2 bit of the LSB of the multiplier with the next higher bit of the multiplicand. Then add both the product and the obtained result gives the second bit of the final answer.

For 2 × 2-bit maximum cross product width is 2. i.e. A0B1 + A1B0 = C1S1 where the S1 is the second bit of the final answer and carry C_1 add to the next step.

Now 1 × 1 bit vertically product of the most significant bit (MSB) of multiplicand (A_1) with MSB of multiplier (B_1) and then add the carry C_1 to that product.

i.e. $A_1 \times B_1 + C_1 = C_2 S_2$. Here, carry C2 and sum S2 make up the third component of the final result becomes the most significant bit of the final answer.

Thus, the final answer is $A_1 A_0 \times B_1 B_0 = C_2 S_2 S_1 S_0$.

Conclusion

Swāmī Śrī Bhāratī Krṣṇ A Tīrthajī Mahārāja, has given 16 Sūtras and 13 Sub-Sūtras which are written in a form of word formulae derived from Vedas. The researcher has tried to explain the meaning of Vedic Sūtras and Sub-Sūtras and applications by giving examples of each. Each formula deals with a different branch of Mathematics. Sūtras are very general and this is why they are so powerful and have such a wide range of applications. More research work in right direction needs to be done on each of these Sūtras summoning scholars from different fields to do research and decipher these. The world would surely find the right direction for exploring into advanced field. Vedic

Mathematics Sūtras can be effectively used in basic as well as in higher mathematics.

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