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Ancient Roots of Binary Number System

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Abstract:

The computing technology uses binary system of numbers. It is said that this system of number writing originated in Europe. However, serious research into the history of mathematics brings out that this system was designed in India many centuries ago. Acharya Pingla, an Indian poet developed this system to describe the poetic meters. This article describes the ancient roots of binary system of numbers.

1. Developments in Computing Techniques:

During the second World War Alan Turing made a computing machine that could analyze data received from different sources. Since then, computers have undergone tremendous changes. The machine that was a luxury at one time has become an instrument of daily use. We cannot imagine writing of an article, analysis of data or fast communication without this gadget. Interestingly this gadget uses binary system of numbers. Computers use binary system of numbers. It is a numbering system with a base 2 and uses only two numbers 0 and 1 to represent all data. Similar to base 10 decimal system binary system is also positional, with each digit representing powers of 2 (e. g. 20, 21, 22, 23, etc.).

2. The Origin of Binary System of Numbers:

The google search shows that this system was developed by Gottfried Wilhelm Leibniz, a German mathematician in 17th century. However, during my Visit to the University of Southwestern Louisiana, Lafayette (LA), USA I learned that binary system of numbers originated many centuries ago. At the University of Western Louisiana, I had an opportunity to interact with the faculty at the Centre for Advanced Computer Studies. The discussion was an eye opener for me. For the first time I learnt that the root of binary system lies in ancient Indian Mathematics. It was suggested by Acharya Pingala.



3. Pingala Acharya:

Pingala Acharya was an ancient Indian scholar, mathematician and poet from around the 3rd–2nd century BCE. Pingala authored the Chandaḥśāstra (Pingala Sutras), a foundational text on Sanskrit prosody that systematized poetic meters using short (laghu) and long (guru) syllables. Pingala pioneered binary-like patterns to enumerate meter combinations, predating modern binary code by over two millennia—using light/short and heavy/long, syllables. Let us understand Pingala’s work through examples.

- A single syllable could either be laghu (L) or guru (G). It will give two combinations – L, G.
- With two syllables, the combinations doubles: LL, LG, GL, GG. Result: Four combinations.
- With three syllables, combinations grow again: LLL, LLG, LGL, LGG, GLL, GLG, GGL, GGG.

Result: Eight combinations.

This doubling pattern matched what we now call powers of 2.

Table-1: Combination of 4 syllables in letters

For 4 syllables we have 16 combinations as shown below.

1.	G	G	G	G
2.	L	G	G	G
3.	G	L	G	G
4.	L	L	G	G
5.	G	G	L	G
6.	L	G	L	G
7.	G	L	L	G
8.	L	L	L	G
9.	G	G	G	L
10.	L	G	G	L
11.	G	L	G	L
12.	L	L	G	L
13.	G	G	L	L
14.	L	L	G	L
15.	G	L	L	L
16.	L	L	L	L

Table-2: Combinations of 4 syllables using numbers

If we replace the values as G = 0 and L = 1, we will get the following table.

1.	0	0	0	0
2.	1	0	0	0
3.	0	1	0	0



4.	1	1	0	0
5.	0	0	1	0
6.	1	0	1	0
7.	0	1	1	0
8.	1	1	1	0
9.	0	0	0	1
10.	1	0	0	1
11.	0	1	0	1
12.	1	1	0	1
13.	0	0	1	1
14.	1	1	0	1
15.	0	1	1	1
16.	1	1	1	1

4. Analysis of a Verse:

A verse in classical Sanskrit literature has a pada. The meter of a verse or pada is determined by the arrangement of the long and short swaras. The last syllable of a foot of a meter is taken to be a dheergha or Guru swara. So, let us refer to the dheergha swara as Guru and rharsha swara as Laghu. Here we have the second stanza of Bhavani Ashtakam composed by Adi Shankaracharya.

- Na Taato Na Maataa Na Bandhur-Na Daataa, Na Putro Na Putrii Na Bhrtyo Na Bhartaa |
- Na Jaayaa Na Vidyaa Na Vrttir-Mama-Iva, Gatis-Tvam Gatis-Tvam Tvam-Ekaa Bhavaani
||1||
- It is clear that this quarter has 12 letters. The arrangement of these letters is in the pattern: Laghu+ Guru+ Guru or LGG. The pattern is LGG+ LGG+ LGG+ LGG....This meter is called Bhujangaprayatam (like a snake advancing).

This stanza with 12 letters can be arranged in many ways. With just Laghu and Guru swar, and 12 letters we can calculate the number of arrangements as $2^{12} = 4096$. This means you can arrange the letters in 4096 ways to create a stanza.

5. Binary Numbers in Action:

Pingala's method didn't stop at creating patterns. He also devised a way to calculate any specific combination without listing all of them. For instance, if someone asked for the 19th combination in a sequence of five syllables, Pingala's algorithm could determine it directly. This innovative thinking mirrors modern programming, where algorithms solve complex problems efficiently. Pingala even explained how these combinations could be used to represent numbers, similar to the place value system in decimal numbers. For example:



- In decimal: 72 is written as $7 \times 10 + 2$
- In binary: 72 is written as $1 \times 2^6 + 0 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 0 \times 2^0$

This binary expansion reveals how modern computers store and process data. Each binary digit, or "bit," represents a power of 2, starting from the rightmost bit as $2^0 = 1$. For example, the binary number 101 equals $1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 = 4 + 0 + 1 = 5$ in decimal. Computers rely on this system because electronic circuits easily distinguish on/off states as 1s and 0s.

6. Conversions:

To convert decimal to binary, repeatedly divide by 2 and record remainders. Pingala started by dividing the number by 2. If it was divisible then he would write 1, otherwise 0.

- If the first division answered 1 as a remainder, then he added 1 and divided it again by 2. if it was divisible then he wrote 1, otherwise he wrote 0 to the right side of the first 1.
- If the first division answered 0 as remainder which meant it was fully divisible then he added 1 to the remaining and then divided it by 2. if it was divisible then he wrote 1 otherwise he wrote 0.

The process would continue until 0 remains as final remainder.

Let us convert 13 into Binary Number. $13 \div 2 = 6$ remainder 1; $6 \div 2 = 3$ remainder 0; $3 \div 2 = 1$ remainder 1; $1 \div 2 = 0$ remainder 1—yielding 1101.

Binary to decimal sums the place values of 1s, as in $1101 = 8 + 4 + 0 + 1 = 13$.

7. More to Pingala's Credit:

While exploring the number of possibilities of various combinations of the laghu and the guru, Pingala hit upon a series: 0, 1, 1, 2, 5, 8, 13, 21, 34, 55, ..., ... This was later called Fibonacci series. This sequence is seen abundantly in nature like branching in trees, the arrangement of leaves on a stem, etc. The Fibonacci number was initially called mātrāmeru (or Meruprasta) by Pingala. Now it is also known as the Gopala–Hemachandra number. Pingala is also credited with the binomial theorem for the index 2, i.e. for $(a+b)^2$.

8. Legacy of Pingala:

Pingala's contributions go beyond binary numbers. His work influenced many fields as enlisted below:

- **Mathematics:** Concepts like Pascal's Triangle and combinatorics.
- **Computing:** The binary system forms the foundation of digital technology.
- **Cultural Heritage:** Pingala's achievements highlight India's intellectual and scientific legacy.



Even today, his ideas inspire scholars and technologists, reminding us that innovation often begins with curiosity and observation.

Acharya Pingala's story is one of brilliance and timeless relevance. His exploration of poetry led to a discovery that powers the digital age. By understanding patterns in syllables, he unlocked a mathematical treasure that continues to shape our world. Next time you pick up a smartphone or log onto your computer, take a moment to appreciate the wisdom of Acharya Pingala—the sage who merged art, science, and mathematics to change the course of history.

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