Research & Innovation

Computational & Mathematical Concepts in Arts and Sciences

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RD Burman's *mere nainaa saavan bhaadon*, sung by Kishore Kumar and a 1982 song *there mere beech main kaisa hai ey Bhandon from the movie Ek Dhuje keliyey* were both hits of their times and perhaps of all times. Then again, we have the song *jaane kahaa.n gae vo din*, 1970 Raj Kapoor's *mera naam joker*. Besides being great hits do they have anything else in common? Well they are all similar in tune or melody, as they have a similar form in some mathematical ways or they all derive from the same Hindustani Raga Shivaranjani. When we tune our ears to these songs don't we recognize a pattern or a mathematical form of melody and rhythm? This happens to be the topic of my recent lecture at IIT Madras.

Humidity was still at its peak as the thermometer was touching nineties in the month of august when I was asked to deliver IIT, Madras extramural lecture. I was cautioned that the lecture must be on a topic of sufficient general interest to everyone at the undergraduate level from all disciplines and yet it should be technical enough to boggle the minds of the top cream of the crop of India. Added to that, I was told that last year's extramural lecture at IIT Madras was delivered by a Nobel Laureate and my distinguished Berkeley friend Prof. Yuan T. Lee. So you can all imagine what was going on in my mind! The extramural lectures at IIT are fully arranged by the student body, I get introduced with a welcome bouquet by a student who spends 10 minutes embarrassing me all about my honors and accomplishments, like they have thoroughly studied my background from science to my poetic accomplishments.

One of the central themes of my IIT lecture was such mathematical and also computational concepts in arts and sciences as the first part of my talk. Quantifying similarity as in patterns of nature is part of non-numerical branches of computational science such as artificial intelligence. The field is not only of aesthetic interest such as machine or cognitive perception of music but also of pragmatic value such as in the field of computer aided drug discovery and molecular similarity.

Who said aesthetics is only for artists and not scientists or engineers? Is it not amazing that there could be some latent mathematical form in aesthetics? Is it possible that science and arts can really come together? Well a part of my talk at IIT dealt exactly with that- the role of mathematical concepts originating from symmetry, asymmetry and duality with examples of ancient temples of Chola and Pallava of Tamil Nadu to Orissa temples. Consider one of the slides that I used in my presentation shown as Fig 1. This is from Kailasa Nadha temple located in Kancheepuram, a temple town about a 2 hour hop from Chennai.

The temple stands out as a monumental piece of sculptural aesthetics of the Pallava Empire. A recurring mathematical pattern that emerges from many of these temple sculptures is the union of concepts of symmetry, asymmetry and duality. For example there is overall symmetry of the flanking dancers and yet the niches have some asymmetry and duality built into them as if there needs to be a global balance beyond the usual symmetry. By duality I mean on one side you have an image of a young person and the other side an old. Some times you find the image of a demon and the other side an angel.

In a more general sense I explored the role of symmetry, asymmetry and duality in India's versatile and rich culture, religion and philosophy. While we understand symmetry in math as invariance under point group operations such as rotation, reflection, inversion, and improper rotation, concept of duality will be developed as a juxtaposition of contrasting images, as a flanking or union of images of "demon" and "devil" or "fire" and "water" or "shiva" and "shakthi" so as to bring equilibrium or global symmetry.

Mathematical and computational ideas were introduced in music Theory using mathematical And computer generation of ragas. A raga as we all know is the Backbone of melody and it is the most fundamental part of Indian music. So how many Ragas are really there? And are there new yet to be discovered Ragas. The answers for these intriguing questions are in combinatorics of raga formation and enumeration. This can be done systematically using polynomial generating functions called raga inventory by considering various kinds of arohan (ascent) and avarohan (decent) The coefficients of various terms in the raga inventory polynomial enumerate the various types and numbers of ragas. Then a computer code was developed to construct various ragas.

Finally it was shown that there are 262,144 non-vakra or non-kinky ragas. This means the ascent and descent have uniformly increasing and decreasing frequencies. We have created a list of such non-kinky ragas. Good news is ragas like shivaranjani, Bhoopali, Malkauns, charukesi, and so on are covered by the enumeration. But still ragas such as darbari kanada and Sri would not be included as they are vakra ragas.

My lecture then explored quantifying similarity in the context of molecular architecture and drug design. How does one quantify such a qualitative or aesthetic fetaure? One way is to develop a set of rules under which two species can be related or even 2 ragas may become related. Once the rules are in place one can define Euclidian types of distances between species or molecules and then use statistical methods such as clustering and principal component analysis.

The lecture showed that interesting amalgamation of concepts from computer science, mathematics, quantum mechanics, and biology could lead to some very unique perspectives. For example, how a complex proteome of a living organism such as rat's liver cell can be characterized using complex algebra and how we can develop algorithms for characterizing such complex 2d-gel patterns of complex array of thousands of proteins in a cell.

My second and final part of the lecture considered Einstein's theory of relativity and the nature of chemical bond in very heavy elements and newly discovered superheavy elements. Significant portion of my research deals with applications of relativity to the chemical bonding of molecules containing very heavy atoms. Well, we all heard that all that glitters if not gold, did you ever wonder that gold glitters because of relativity! Yes, you heard it right, but for Prof Einstein the beauty of gold would have been buried into a blackish or silverfish look. The yellow glitter of gold is attributed to relativity due to increased speeds of electrons of the gold atom. As you admire all that glittering golden jewelry, pay a tribute to Einstein for his landmark papers on relativity. As we keep discovering new elements, many of them yet to be named such as 114 and 115 discovered at Lawerence Livermore National Lab, relativity becomes more and more important as the speeds of electrons of these elements increase resulting in a parabolic relativistic effect as the atomic number increases. I showed some exciting new properties of such very heavy species as a result of relativity.

Look at the breadth of topics that I was able to speak on, aesthetics, sculptures, music, duality, similarity, relativity, quantum mechanics, bioinformatics, and of course quantum chemistry. How in the world did I manage to talk about the theory of Hindustani and carnatic music to pallava architecture to relativity to drug design-all in one lecture? As I deeply ponder over this question, I transcend back in time to India, to Pilani and vividly recollect the beautiful saraswathy mandir and the BITS clock tower. That is the beauty and versatility of the education that we have received as students of BITS. The greatest boon that one can get to face the modern world filled with such plethora of interdisciplinary topics is truly a multidisciplinary and broad education that Pilani offered to us and continues to offer. I ended my talk with a poem that I published in the Journal of Mathematical chemistry that summarizes a unique interdisciplinary culture that BITS cultivates.

Number Theory

All numbers are created equal
Yet some are more prime.
But then why some are real
And others are truly imaginary?

All numbers are created equal
Yet all numbers are complex.
But then why some numbers
Are more rational than others?

All numbers are created equal
And many numbers are integral
But then why some are positive
And others are negative?

All numbers are created equal
And many numbers have values
But then why there is a number
That's zero like an empty tumbler?

Are there equal numbers?
Or is it only in my slumber
That I see transcendental numbers
And the eternal infinity?