4 Computational & Mathematical Concepts in Arts and Science

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RD Burman's *'mere nainaa saavan bhaadon',* sung by Kishore Kumar and a 1982 song *'tere mere beech mein kaisa hai ye bandhan'* from the movie *Ek Dhuje keliyey* were both hits in their times and perhaps of all times. Then again, we have the song *'jaane kahaan gaye vo din',* in 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 and they all derive from the same Hindustani *Raga 'Shivaranjani'.* But do we recognize a pattern or a mathematical form of melody and rhythm? One of the central themes of this article is the mathematical and Computational Concepts in Arts and Science. 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 art can really come together? This article essentially deals with - the role of mathematical concepts originating from symmetry, asymmetry and duality with examples of ancient temples of Chola and Pallava of Tamil Nadu to the Orissa temples.

Consider Fig 1. This is from *Kailasa Nadha* temple located in Kancheepuram, a temple town about a 2 hour hop from Chennai.

Figure 1 - *Kailasa Nadha* temple in Kancheepuram

The temple stands out as a monumental piece of sculptural aesthetics of the Pallava Empire. A recurring mathematical pattern that emerges from many of such 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 that of an old. Sometimes 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.

How does one quantify such a qualitative or aesthetic feature? 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.

Moving on to music, 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 to 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*.

Moving on to quantifying similarity in the context of molecular architecture and drug design - how does one quantify such a qualitative or aesthetic feature? 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.

This would show an interesting amalgamation of concepts from computer science, Mathematics, quantum mechanics, and biology that 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.

Let us now consider Einstein's theory of relativity and the nature of chemical bond in very heavy elements and newly discovered super heavy elements. Significant portion of my research deals with the applications of relativity to the chemical bonding of molecules containing very heavy atoms. Well, we have all heard that all that glitters is 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 orsilverfish look. The yellow glitter of gold is attributed to relativity due to increased speed of electron in 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.

Look at the breadth of topics we have discussed - aesthetics, sculptures, music, duality, similarity, relativity, quantum mechanics, bioinformatics, and of course quantum chemistry. How in the world did I manage to write about the theory of Hindustani and Carnatic music to Pallava architecture to relativity to drug design-all in one article? As I deeply ponder over this question, I transcend back in time in India, to Pilani and vividly recollect thebeautiful 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 a plethora of interdisciplinary topics is multidisciplinary and broad education that Pilani offered to us and continues to offer.

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