SURC 2024

Azim Premji University

3rd Annual Science Undergraduate Research Conference

6–7 December 2024

Overview and selected abstracts

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3rd Annual Science Undergraduate Research Conference

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Table of contents

Foreword	06
Introduction	07
Selected Abstracts	10

Foreword

The year was 2018. Having graduated our first batch of BSc students, the science faculty at Azim Premji University, Bengaluru, reflected on what we had done well and what more we could do for our students . There were, of course, more questions ahead of us than answers; however, one sentiment was shared by most of us: our students needed more interactions with peers to communicate their work. They needed an avenue to come out of the bubble of their own institution, and mingle with other undergraduate students across the country.

In our undergraduate programmes, we are always trying to leverage opportunities for creativity. We do this largely by creating spaces for UG students to participate in processes involving observation, experimentation and documentation. In other words, we view research as a strong pedagogical tool. That said, we did not expect the breadth of work that would spring from this approach. We presumed that UG science students at other institutions could have similar experiences and wondered if we could address this by building a platform for students and faculty across the country to share their approaches, experiments, failures, and successes in science. This is how the Science Undergraduate Research Conference (SURC) was born.

SURC provides undergraduate students a rare platform to communicate their work to an audience from varied backgrounds. They also gain exposure to (1) a wide range of ingenious Do-It-Yourself solutions people have adopted (which are perhaps more common at this level of training, given the limitation in resources) for experiments, (2) the significance of and access to local issues such as lake pollution, traffic, urbanisation etc., and (3) how scientific conferences run. We are happy to see that since the first successful SURC, other institutions too initiated similar platforms.

We have produced this booklet to serve as an example of the possibilities for undergraduate research. We hope it will encourage undergraduate teachers and future undergraduate students to actively participate in research that helps deepen disciplinary knowledge, cultivate scientific thinking, and most importantly address local problems. A wonderful side effect of such efforts, is of course, the fun and excitement of discovery.

Sravanti Uppaluri
Associate Director, School of Arts & Sciences
Azim Premji University, Bengaluru

Introduction

As the third annual Science Undergraduate Research Conference (SURC) came to a successful conclusion on 7 December 2024, the organising committee and the student volunteers breathed a collective sigh and celebrated with an impromptu feast of cupcakes.

After nearly a year of planning, around 130 participants from institutions across India had convened at Azim Premji University, for a unique event aimed at energising undergraduate research in the sciences.

Over the course of two days, undergraduate researchers in environmental science, mathematics, biology, chemistry, and physics shared their work, received feedback from experts, explored avenues for collaboration, and formed new friendships.

And thanks to the extraordinary team of student volunteers, the events went off without a hitch! During the hands-on science workshops, students explored gene expression in fruit flies, DIY sun-dials, and the geometry of perspective drawing. There were wonderful plenary talks by Prof. Kusala Rajendran of Indian Institute of Science, Bengaluru and Prof. C Aiswarya of the Chennai Mathematical Institute. The morning birdwatching trip rewarded the keen observers with sightings of the coveted blue-faced malkoha, and the nighttime stargazing session presented clear views of Jupiter's moons.

The highlight of the conference was the student poster session, along with the student research talks. These covered a diverse range of topics, such as the highly specialised gut microbes of insects, the crucial ecological functions of the wetlands surrounding Kolkata, the detection of binary star systems, and closed formulas for the continued fraction expansions of quadratic irrational numbers. These sessions brought participants' research to life, and brought home the message that research is not a lonely, isolated activity, but a deeply human collaboration that thrives on active communication.

What follows is a selection of student abstracts that capture the vibrant spirit of this gathering. Please note that the presenter's name is underlined and the Principal Investigator's name is followed by an asterisk (*).

Vijay Ravikumar
Assistant Professor of Mathematics
Azim Premji University, Bengaluru

Selected Abstracts

Kolkata's kidneys

Title:
Exploring the east Kolkata wetlands

Team:
Adrita Majumdar, Niyati Reddy, Gayathri GS, Kajal Kumari, Dr. Santonu Goswami*

Institution:
Azim Premji University, Bengaluru

Abstract

The city of Kolkata is an ecologically subsidised city and the East Kolkata Wetlands (EKW) forms a lush bionetwork that maintains the health of the city. The EKW treats a huge volume of the sewage water which is generated by the city of Kolkata, and it does so in the most economical, efficient and natural way possible. They are considered as the "Kidneys of Kolkata" because of this natural sewage treatment potential. Just as the kidneys flush out toxic material from the body, EKW does the same for the city of Kolkata. The wetlands also act as a carbon sink, sequestering atmospheric carbon dioxide and cleaning up the city's air. This maintains the micro-climate of the region, making it habitable for the city's residents. The EKW is home to a variety of endemic flora and fauna and it prevents entry of invasive species into the wetlands. During the monsoon months, excessive flood water enters the city sewage system ultimately draining into the wetlands. In this way, EKW also acts as a natural flood control system for the city.

Rather than being treated as potential sites for reclamation for the wider societal and economic benefits, people are encroaching into the wetlands and using them for their own personal economic profit. Rapid urbanisation, changing land usage, eutrophication, and mismanagement of government policies, EKW is under threat. The size of the wetlands has been rapidly shrinking over the years.

We analyse EKW as a systems thinking ecosystem. We use various charts, mind maps, graphs, and models to look at this problem through a systems lens. Detailed literature reviews were performed to understand the main drivers of the size reduction of EKW. We created a quantitative and qualitative data table to compile the information that we got from the papers.

Tuning the symphony

Title:
tRNA-derived small non-coding RNAs are dynamically regulated during human monocyte-to-macrophage maturation

Team:
Anahita Chakravarthi Jayaram, Dr. Kamlesh Pawar*

Institution:
Shiv Nadar Institute of Eminence, Greater Noida

Abstract

The tRNA molecule is primarily known for its canonical role in facilitating translation. However, as a source of non-coding RNA, it also participates in various cellular processes. Previous research has shown that a protein called angiogenin (ANG) cleaves tRNAs at their anticodon loops to form 5'-tRNA halves and 3'-tRNA halves. The 5'-tRNA half acquires a characteristic cyclic-phosphate group at its 3'-end, a feature that has made tRNA-derived sncRNAs difficult to study using standard small RNA-seq platforms. These fragments of tRNAs have been found to play a crucial role in regulating cell proliferation, infection-induced immunological responses, stress granule formation, and have been linked to carcinogenesis and neurodegenerative disorders.

This study investigates the dynamic regulation of tRNA-derived sncRNAs during human monocyte-to-macrophage differentiation, and their potential impact on the functional characteristics of macrophages. These two cell types vary greatly in certain crucial biochemical processes and resulting phenotypic traits. We exposed THP-1, a human leukaemia monocytic cell line, to a potent differentiating compound PMA, to induce differentiation of monocytes. RNA samples were then examined from three different time points during this process: 0-, 6-, and 24-hours following PMA incubation. Resolving the total RNA by urea PAGE showed a decrease in overall small RNA abundance with increasing differentiation. TaqMan qPCR-based analysis of specific 5'-tRNA half levels indicated a significant reduction in 5'-tRNAHisGUG and 5'-tRNALysCUU levels. Recognising a promising angle, cDNA libraries were prepared from the RNA samples and small RNAs between 20-50 nucleotides in size were sequenced. Bioinformatic analysis of the sequencing data revealed a variation in contributions of different tRNA sources to the pool of tRNA-derived fragments (tRFs).

A noteworthy observation was the high abundance of 5'-tRNAHisGUG in 0-hour samples compared to all other tRFs, with a drastic reduction in 6-hour and 24-hour samples. This result was consistent with the data generated by TaqMan qPCR. Finally, the dynamics of ANG expression during differentiation were explored using SYBRgreen mRNA qPCR. ANG expression was found to reduce significantly with increased PMA treatment, which correlated with the decrease in 5'-tRNA half abundance. This strongly suggests that significant variations in 5'-tRNA half abundance might indicate their potential role in facilitating important cellular processes during differentiation.

What primitive cell membranes looked like

Title:
Modulating membrane lipid composition to enhance viability in mesoplasma fluorum-based minimal cells

Team:
Ayush Panda, Dr. James Saenz* (Technische Universität Dresden, Germany)

Institution:
NISER Bhubaneshwar, Khorda

Abstract

Non-bilayer forming lipids likely played crucial roles in primitive and archaeal cell membranes, contributing to essential membrane properties and functions. These lipids, such as the cone-shaped diacylglycerol (DAG), phosphatidylethanolamine (PE) and cardiolipin (CL), introduce curvature stress and enhance membrane fluidity and permeability. In primitive cells, their presence could have facilitated important processes like membrane fusion, vesicle formation, and cell division without the need for complex protein machinery. For archaeal cells, cardiolipin analogues with unique structures have been identified, suggesting a continued importance of non-bilayer lipids in these organisms.

In this study, we engineered minimal cells (derived from Mesoplasma fluorum) with the capability to modulate their membrane lipid composition through the incorporation of specific exogenous lipids into their growth media. The foundational lipid diet for these minimal cells consisted of cholesterol and sphingomyelin. We employed alpha-cyclodextrin as a delivery vehicle to introduce various conical lipids into the bacterial membrane, enabling a controlled alteration of membrane lipid composition.

We see that the incorporation of the conical lipids DAG, cardiolipin and 1,2-dioleoyl-sn-glycero-3-phosphoethanolamine (DOPE) significantly enhanced the growth and viability of the minimal cells. In contrast, the addition of the cylindrical lipid 1,2-dipalmitoyl-sn-glycero-3-phosphoethanolamine (DPPE) did not yield comparable improvements. Subsequent osmotic sensitivity and permeability assays revealed that conical lipids increased membrane permeability and fluidity, suggesting a potential mechanism for the observed enhancement in cellular viability.

Byte-ing back

Title:
Insights into cobra venom toxicity from structural bioinformatics studies

Team:
Bipasa Show, Dr. R. N. V. Krishna Deepak*

Institution:
Azim Premji University, Bengaluru

Abstract

During the decade spanning from 2000 to 2019, an estimated one million Indians succumbed to snake bites. In the same period, an estimated three million Indians were maimed due to snake bites. The only treatment for this neglected tropical disease in India is the administration of polyvalent antivenom (PAV), a life-saving cocktail of antibodies produced using archaic methods.

However, the PAV suffers from serious shortcomings. Primarily, it works only against only the “Big Four”, comprising Russell’s viper, Common krait, Indian cobra and the Indian saw-scaled viper. Several recent studies have shown that the PAV in use currently is also ineffective against the “Big Four’’ from different regions of the country owing to biogeographical variation in the venom profiles of these snakes. It is of vital importance to devise better therapeutic strategies.

Snake venom is a complex cocktail made up of different hemotoxins, cardiotoxins, cytotoxins and other non-enzymatic proteins. One of the major components of venom in elapid snakes is the three-finger toxins (3FTx) which are a small protein domain of about 60-80 amino acids long. These toxins have multiple physiological functions like disrupting cell membranes and binding to cell surface receptors.

Our computational studies aim to understand the structural basis of three-finger toxin toxicity from four species of cobras in India namely, *Naja naja, N. kaouthia, N. oxiana* and *N. sagittifera*. We employ structural bioinformatics and phylogenetic approaches to delineate the critical differences and similarities in the structures of these toxins and explain how they contribute to three-finger toxin toxicity. Our larger goal is to create a sequence-structure-function matrix for three-finger toxins which can aid in epitope prediction and rational design of anti-venom.

Microplastic microcosm

Title:
Microplastics alter soil microbiome and affect enzyme activity

Team:
Charu Hari, Dr. Beena D.B.*

Institution:
Azim Premji University, Bengaluru

Abstract

Microplastic pollution is a growing global concern. In soils, microplastics are of particular concern due to their widespread nature, potential to leach chemicals into ecosystems, their uptake of heavy metals and other toxins, and their unpredictable interactions with biotic and abiotic factors.

The effects of microplastics on soil-plant ecosystems is a relatively new area of focus; few long-term studies exist. This matters because certain parameters, such as soil aggregation, are long-term processes. Similarly, there is a lack of data on how microplastic presence may affect seed yield and nutritive quality. Additionally, no experiments look at variation in effects of different concentrations of microplastics.

I am tackling these questions through a microcosm experiment. My study focuses on the effects of microplastics in soil-plant ecosystems. I am investigating the effects of polymer type and concentration on soil physical properties, soil microbiome characteristics and plant growth. The polymers I am investigating are acrylic, polyamide and low density polyethylene. The concentrations I have chosen simulate urban microplastic concentrations and future projections. Monitoring parameters such as soil pH, enzyme activity, nitrogen content, microbial diversity, shoot height, biomass, flowering, seeding and seed nutritive quality, I found marked differences in pots that have been exposed to microplastics. Data collection for this experiment is expected to be completed by November 2024.

Zooming into integrins

Title:
The role of integrins in cancer: A structural perspective

Team:
Diya Narang, Dr. Shubhasis Haldar*

Institution:
Ashoka University, Sonepat, Haryana

Abstract

Recent advances in next generation sequencing and mass spectroscopy are revealing the hierarchical and dynamic architecture of a genome. Effective data visualisation is enabling rapid comprehension and hypothesis generation in cancer genomics. We investigate the mechanical impact of integrin molecules across various cancer types by analysing their expression and mutations using data from The Cancer Genome Atlas (TCGA), which encompasses over 10,000 patient samples. Integrin expression has distinct clusters, with certain integrins significantly upregulated across multiple cancer types.

Our analysis revealed that high and low mRNA expression of integrins is common in cancer patients, and these differences influence survival outcomes. Notably, high expression of integrins like β2, β5, and αE negatively impacts patients, as does low expression of integrins like αD. In addition to expression level changes, point mutations in integrin genes are also quite common across cancer types. Frequent single nucleotide changes were observed in integrin genes, with transitions (G-A and C-T) being more common than transversions. Further, amino acid substitutions due to cancer-specific mutations generally destabilise integrin protein structures, impacting their mechanosensitive functions. Interestingly, amino acid substitutions, particularly in the β propeller domain of α subunits and the βI domain of β subunits, are predominantly destabilising, potentially impairing integrin mechanical functionality. Additionally, it was also observed that expression of β2 integrin dimers correlated the maximum compared to any other physiologically expressed or unexpressed dimers. The study underscores the importance of integrins' mechanosensitivity and expression in cancer, suggesting that mutations possess the ability to impair integrin stability and function. There is a need for further research on integrin mechanosensation and its role in cancer.

Bugs and their gut microbes

Title:
Understanding host specificity in *oecanthus henryi*: Role of gut microbes

Team:
Faheema Nazar, Dr. Rittik Deb*

Institution:
NISER Bhubaneshwar, Khorda

Abstract

Biotic interactions are the cornerstone of any ecosystem. These interactions lead to adaptations and specialised strategies that help organisms survive better in their environment. In the case of plant-feeding insects, adopting strategies to tackle the chemical and physical defences of plants is pivotal for their evolutionary success. Recent studies suggest that forming associations with gut microbes to circumvent plant defences can be one such strategy.

The gut microbiota of herbivorous insects has been increasingly recognised for its diverse metabolic capabilities. Studies also suggest that gut microbiota can influence various aspects of insect physiology, including upgrading nutrient-deficit diets, development, and providing immune barriers. This allows these insects to expand their niche to otherwise inhospitable habitats.

Our study system consists of a phytophagous insect species (tree cricket *Oecanthus henryi*), which is only found in an invasive plant from the mint family, *Hyptis suaveolens. H. suaveolens* is known for its strong phytochemical profile (for example, phenolics, steroids, flavonoids and essential oils), which are plant secondary metabolites usually employed as chemical defences. Interestingly, apart from O. henryi, it is rare to find other insects living and feeding on these plants. To elucidate this unique host plant and phytophagous insect association, we are examining the relationship between *O.henryi* and its gut microbiome. Using traditional microbiological tools (culturing) and next generation sequencing, and by looking into the life history traits, we investigate if the microbiota of *O.henryi* aids the insect in adapting to the phytochemicals of *H. suaveolens.* This study will not only elucidate niche expansion via host-microbiome interaction but can also decipher the spread of this invasive plant across the Indian subcontinent. Understanding these relationships could provide valuable insights into how symbiotic relationships contribute to the evolutionary success of herbivorous insects in challenging ecological niches.

An exploration of continued fractions

Title:
Periods in infinite continued fractions of quadratic surds

Team:
Ganesh Chakali

Institution:
Azim Premji University, Bengaluru

Abstract

Continued fractions are valuable tools for representing quadratic irrational numbers because of their periodic structures. It was mathematician Joseph Louis Lagrange who first explored continued fractions of quadratic irrational numbers, proving that every quadratic irrational can be represented as a periodic continued fraction. Later, Euler established the converse. Inspired by this, I investigated patterns in the periodic structures of continued fractions of quadratic surds, aiming to uncover a closed formula for partial quotients. Through this exploration, I identified several recurring patterns based on specific numerical conditions, which led to closed formulas for the continued fraction representation in these special cases.

For example,

i. For all $k,n \in \mathbb{N}$ where $k > 1$,

$$\sqrt{(kn)^2 + k} = [kn; \overline{2n, 2kn}]$$

ii. For all $k, n \in \mathbb{N}$ where $k, n > 1$,

$$\sqrt{(kn)^2 - k} = [(kn - 1); \overline{1, 2(n - 1), 1, 2(kn - 1)}]$$

iii. For all $k,n \in \mathbb{N}$ where $k > 1$ and $n > 2$,

$$\sqrt{(kn)^2 - 2k} = [(kn - 1); \overline{1, (n - 2), 1, 2(kn - 1)}]$$

iv. For all $k, n \in \mathbb{N}$,

$$\sqrt{(kn)^2 + 2k} = [kn; \overline{n, 2kn}]$$

These patterns suggest underlying mathematical relationships that could lead to a closed formula for predicting periodic terms in continued fractions of general quadratic irrationals.

Hydra in microgravity

Title:
Simulating microgravity and hypergravity for hydra regeneration studies

Team:
Keerthana B, Dr. Sravanti Uppaluri*

Institution:
Azim Premji University, Bengaluru

Abstract

Life on Earth has evolved under the constant influence of gravity, yet its precise role in shaping fundamental biological processes remains a puzzle. This study explores how gravity affects regeneration, reproduction and cellular organisation in *Hydra viridissima,* a remarkable organism known for its regenerative abilities and asexual budding.

The actin cytoskeleton, a network of filaments that helps maintain cellular shape and structure, is known to be essential for regenerative and reproductive processes in Hydra. We hypothesise that gravity variations impact these processes by altering F-actin cytoskeleton organisation within Hydra's cells.

Using a custom-designed clinostat to simulate microgravity and a centrifuge to simulate hypergravity, we expose Hydra specimens to varying gravity levels (microgravity, Earth gravity, hypergravity) simulating spaceflight durations. We then compare the rate and extent of regeneration and budding to control groups. Additionally, fluorescence microscopy with phalloidin staining visualises changes in F-actin. This reveals if observed changes in regeneration and reproduction stem from altered F-actin polymerisation. By investigating the interplay between gravity and the cellular cytoskeleton, we aim to shed light on Hydra's adaptive mechanisms in response to gravity variations.

Home invasion!

Title:
Impact and concern of animal species imported into India

Team:
Khushi Thakur, Dr. Alok Bang*

Institution:
Azim Premji University, Bhopal

Abstract

Exotic animals are species that are introduced into a new environment from their native lands. If they are left unmonitored, they can become problematic for the native species of the ecosystem. This was seen in the case of the Burmese Python (*Python molurus bivittatus*) that was released into the wild by a civilian in Florida, USA, who was unable to take care of it. The python had no natural predators due to its large size and it preyed on the native smaller native species, disrupting the wildlife of Florida. There is a distinct possibility of something like this affecting India's delicate ecosystems.

There has been a recent growth in illegal wildlife trafficking, by which multiple exotic animals enter the country unmonitored and unaccounted for. In 2023, India imported live animals worth US$14.69 million, according to the United Nations COMTRADE database on international trade. This includes domestic pets, livestock, as well as wild animals such as cheetah, elephants, kangaroos, pythons, marmosets, lemurs, bushbabies, antelopes, lizards, alligators and more.

My work is centered around finding the real issue or the potential problems caused by the substantial input of exotic wildlife into India through monitored trade and wildlife trafficking. The introduction of exotic animals can cause issues on multiple levels; here we discuss the invasion and the conservation points of view.

The lack of solid legal frameworks allows for animal trafficking to occur unreprimanded. There should be further deliberation on the amount and species imported into India and its impact on the ecosystem. Another important point of discussion is whether India should be using its limited resources towards the conservation of exotic species that are not adequately suited to the subcontinent. Doesn't this come at the expense of native Indian fauna, which also needs to be conserved?

The sequence-quantum link

Title:
Tiny atoms, endless patterns and timeless constants

Team:
Madhan A

Institution:
Visveswaraya Technological University, Bengaluru

Abstract

The Fibonacci sequence, the golden ratio and other mathematical sequences have profound implications in the realm of quantum mechanics. The Fibonacci sequence, characterised by each number being the sum of the two preceding ones, is not just a numerical curiosity but a fundamental component in various quantum systems. This sequence is found in nature and manifests in the study of quasicrystals, atomic structures, and the behavior of certain particles under specific conditions. Its significance in quantum mechanics extends to the arrangement and stability of particles, contributing to the understanding of complex quantum systems.

The golden ratio, intrinsically linked to the Fibonacci sequence, appears frequently in quantum mechanics. This irrational number, approximately equal to 1.618, is often encountered in the energy levels and wave functions of quantum systems. The golden ratio influences the symmetry and stability of these systems, playing a crucial role in determining their behavior and properties. For instance, in the study of atomic and molecular structures, the golden ratio can describe the spatial configuration of electrons and other subatomic particles, leading to a deeper comprehension of their interactions and stability.

Beyond the Fibonacci sequence and the golden ratio, other mathematical sequences such as the Lucas numbers and the Padovan sequence also find relevance in quantum mechanics. The intersection of these mathematical sequences with quantum mechanics underscores their importance in both theoretical and practical advancements. The study of these sequences in quantum mechanics has led to the development of new mathematical techniques and models. Researchers have employed these sequences to solve complex problems, model the behavior of quantum systems, and predict the outcomes of quantum experiments. These contributions have broadened the scope of quantum mechanics, enabling scientists to explore new frontiers and address previously unsolvable problems.

How to get rich with maths

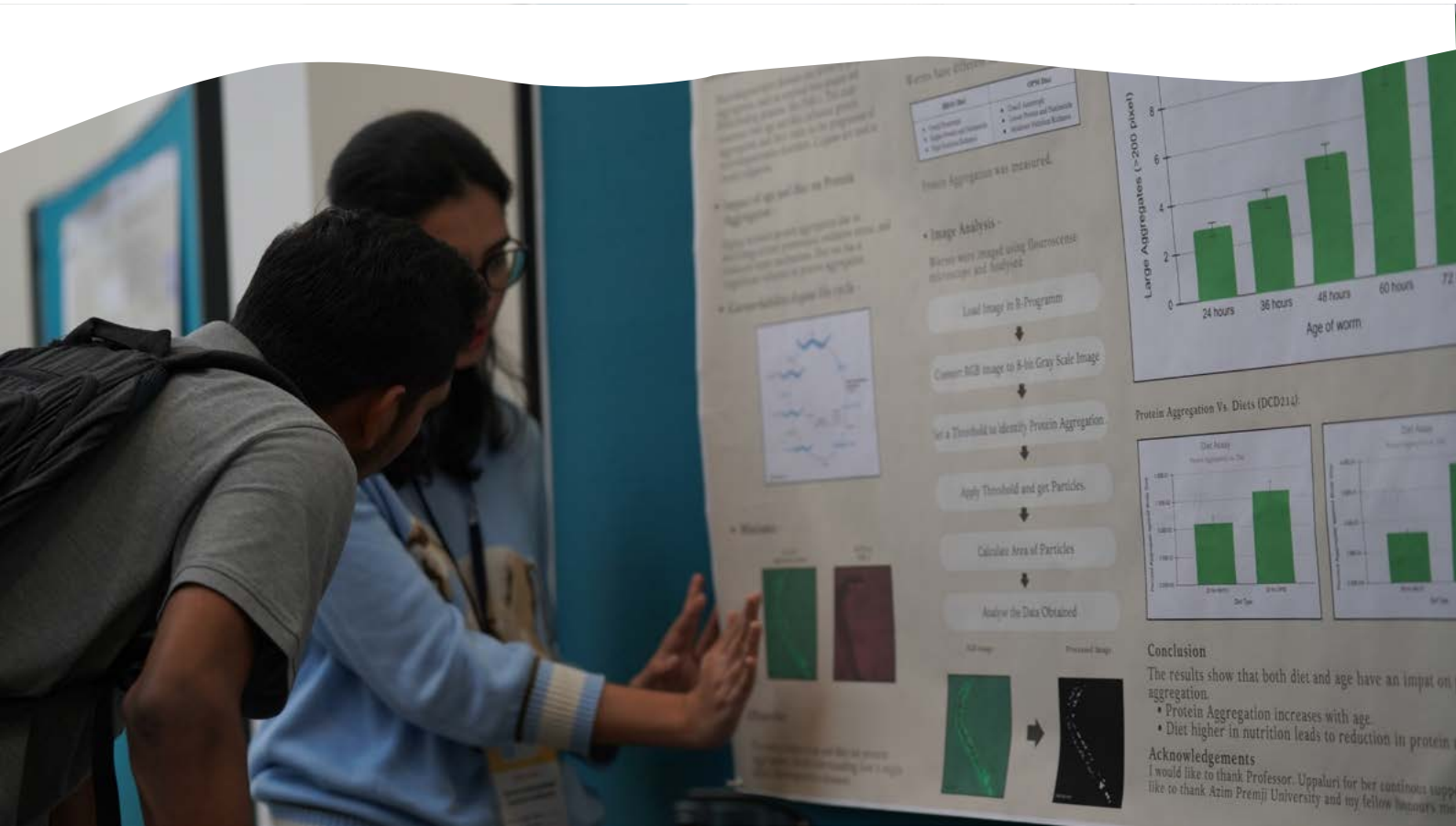
Title:
The lottery problem

Team:
Nishant Vakeel, Dr. Tulsi Srinivasan*

Institution:
Azim Premji University, Bengaluru

Abstract

This project is based on the lottery problem, which is an open problem in graph theory and combinatorics. A lottery involves selecting L numbers out of a set of N numbers, and winning such a lottery involves selecting and matching exactly K numbers out of these L numbers. But matching K - 1 or K - 2 numbers grants second and third place respectively. The question arises: what is the minimum number of tickets one must buy in order to guarantee winning some prize in a lottery. This project explores this question and provides an overview of some of the progress made on this open problem. In further work, a simulation will be run in Python for estimation.



Investigating ageing in plant 'mothers'

Title:
The effect of senescence on maternal control over seed size

Team:
Pooja Pullarkat, Dr. K G Srikanta Dani*

Institution:
Azim Premji University, Bengaluru

Abstract

Trade-offs between offspring (seed) size and fertility can be seen in almost all sexually reproducing higher organisms. In plants, a high number of seeds may compensate for the low survival probability of small seeds. Fewer and bigger seeds may ensure high quality fitness. The choice of strategy depends on the life history and environment of the organism.

Reproduction is a resource-intensive process. So, though many plants can grow and reproduce continuously throughout their lifespan, they show a gradual decline in fertility as they get older. Younger parents bear more offspring than older parents. Senescence involves mobilisation of ever depleting bodily resources from vegetative parts to growing reproductive parts. We are testing the hypothesis that diminishing resources in the maternal plant body may also weaken maternal genetic control over seed size to cause low fertility and high quality (large) seeds in older plants.

We will be using Brassica (common mustard) and its model relative Arabidopsis for experimental investigations. Through literature review, we have identified genes that regulate seed size. Primers for polymerase chain reaction (PCR) led amplification of those select transcripts, have been designed. Immature seeds produced at different stages of plant reproduction/senescence will be collected to separate embryonic from maternal tissues. Total RNA extraction, cDNA synthesis and PCR will be performed to quantify the abundance of these select transcripts (relative to those of housekeeping genes). Evidence would show if there is progressive weakening of maternal genetic control over resource allocation to her offsprings, as the plant goes through senescence, reaching the end of its life cycle.

The attempt may provide tangible evidence for parent-offspring conflict during senescence and may help discuss genetic imprinting in developing seeds, developmental responses to bodily resource limitations, and in the long run, help improve seed quality in edible crops (through genetic manipulation of senescence).

Big lake, big problems

Title:
Looking at Bellandur lake through a systems lens

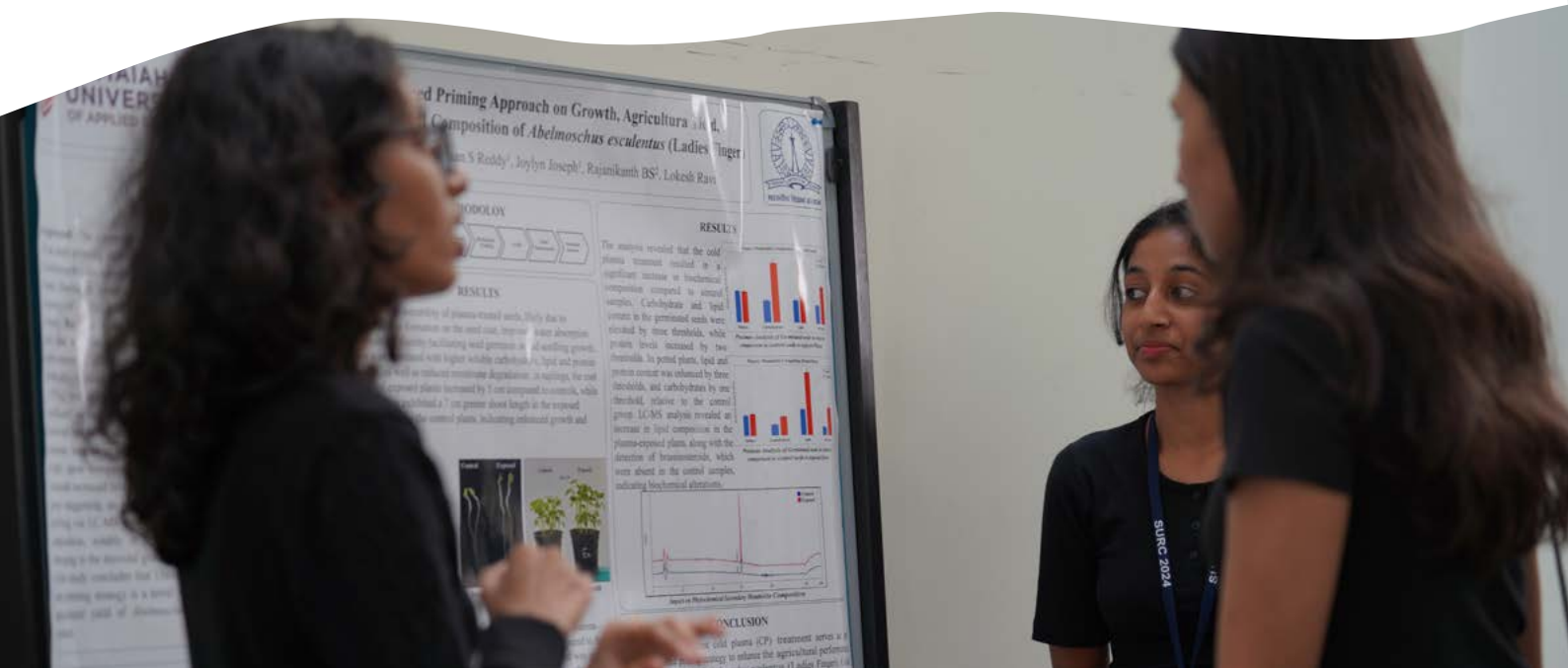
Team:
Prakrithi Padiyar, Spandanaa Gosu, Sivapriya S, Shreeya Sivakumar, Dr. Santonu Goswami*

Institution:
Azim Premji University, Bengaluru

Abstract

Urban lakes provide numerous benefits to the environment. As they are depleting at an alarming rate, it is important to take immediate action. Our paper specifically looks at Bellandur Lake, the largest lake in Bengaluru. In order to effectively address the challenges faced by the lake, it is crucial to consider all the factors that are affecting it, including encroachment of land, increase in effluent discharge, dumping of domestic sewage waste, and their respective effects through a comprehensive systems model.

Government efforts to rejuvenate the lake involved desilting the lake by clearing out the water and removing the layer of silt on the lakebed. However, the process has been delayed for four years, resulting in a failure to rejuvenate the lake. We analyse Bellandur Lake from a systems perspective, including the use of satellite imagery and remote sensing to assess changes in the lake's surface area over the past 20 years (from the 1980s to the present). We also examine the transformations in the lake system from periods of foam and fire to its current barren state. We evaluate government efforts and initiatives aimed at restoring Bellandur Lake, while proposing solutions for improving the condition of this lake and other lakes in Bengaluru.



Seizing the day

Title:
Analysis of CRISPR generated epileptic drosophila fly lines

Team:
Snigdha Kodali, Raghavi Visweswaran, Anannya Jayaprakash, Dr. Antara Das*

Institution:
Azim Premji University, Bengaluru

Abstract

Epilepsy is a widespread neurological disorder characterised by repeated seizures affecting all age groups. Nearly 80% of these patients are from low and middle-income countries, according to the World Health Organization. Seizures can be caused by numerous factors including brain tumours, gene mutations, traumatic brain injuries or stroke. Clinical and phenotypic variability in seizure phenotype implies that patients with identical mutations in the same gene do not respond to the same drug treatment. Hence it has been difficult to develop a universal anti-epileptic therapy.

Over 1,500 mutations have been mapped to a gene called Scn1a that encodes a voltage-gated sodium ion channel gene. CRISPR/Cas9 gene editing was used to introduce human epilepsy-causing mutations into the Drosophila Scn1a gene. These Drosophila models also phenocopy seizure phenotypes of human patients. This allows researchers to study the seizure behavior of fruit-flies in response to various pharmaceutical drugs, neurotransmitters and/or dietary modifications.

In this study, we are screening the anti-seizure properties of the neurotransmitter serotonin, and various plant-based compounds that can confer anti-epileptic properties. Furthermore, we are examining effects of different restrictive diets on reducing seizures in these epilepsy mutants. Our research has the potential to screen for anti-epileptic therapies.

Movers ‘n shakers

Title:
Cost effective tool to Induce sleep deprivation in drosophila

Team:
Sakshi Dunakhe[1a], Anshi Pillai[2a], Mrudula G.[2], Juhi Durgkar[2], Dr. Antara Das[2]*

a - co first authors

Institution:
1. IISER Bhopal and 2. Azim Premji University, Bengaluru

Abstract

Sleep is crucial for an organism’s normal physiology and metabolism. However, sleep remains a less understood phenomenon. Our research aims to decipher the long term effects of sleep disturbances on organism’s behaviour. However, the commercially available sleep deprivation set up is expensive, so we had to devise cost-effective equipment. In this abstract, we describe the standardisation of sleep deprivation protocol using a vortexer and a custom-built Arduino circuit.

In order to effectively induce sleep deprivation in a well studied wild-type strain of *Drosophila melanogaster,* total sleep time and duration was estimated from locomotor data collected using an automated locomotor monitoring system - the Drosophila Activity Monitor (DAM). Sleep deprivation was induced by placing one of the DAM monitors loaded with 32 individual flies on the vortexer. The vortexer was switched on for 12 hours at night time at 1,000 rpm with intermittent stop times. The customised Arduino timer circuit was programmed to turn on and off the vortexer in short pulses x 3600 times to induce intermittent shaking throughout the 12 hours of night time.

Using this set up, we successfully induced sleep deprivation in flies with intermittent mechanical disturbance. Flies had significantly reduced night time sleep on day 2, compared to day 1 night sleep, and sleep rebound was seen in flies on day 3, further showing that flies made up for lost sleep by sleeping during the daytime period.

Our customised sleep deprivation setup costs Rs 22,000, significantly lesser than the Rs 22 lakhs that the commercial setup costs.

The Psycho-logicians

Title:
A foundation to assisted formalisation

Team:
Vivek Soorya Maadoori, Shiv Pillai, Aditya Swami, Dr. T.V.H Prathamesh*

Institution:
Krea University, Sri City

Abstract

Proof assistants are software tools designed to help verify the correctness of mathematical proofs and programmes. Formalisation of a mathematical proof refers to the process of mechanical verification of the proof in a proof assistant, after translation of the proof to a logical framework amenable to the proof assistant. Formalisation of mathematics is of interest both from the perspective of verification of controversial proofs, and building digital libraries of mathematics to enable further formalisation.

We present a formalised proof of Dilworth's Theorem using the Isabelle/HOL (Higher-Order Logic) proof assistant. Dilworth's Theorem states that in any finite partially ordered set, the size of the largest antichain will be equal to the size of the smallest chain cover. The formalisation involves encoding necessary concepts from order theory, including antichains, minimal sets and maximal sets. The formalisation relies on both sub-lemmas we've proved that were necessary to show correctness of every statement within the proof, as well as established lemmas within the Isabelle/HOL library. Our formalisation not only verifies the correctness of Dilworth's Theorem, but also demonstrates the power of Isabelle/HOL in handling complex combinatorial proofs using the Isar structured proof language. This enables us to build crucial libraries in combinatorics and provide the building blocks for further formalisations such as proofs of Erdos-Szekeres theorem.

The ups and downs of elevator operation

Title:
Stochastic modeling of lifts

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Abstract

Elevators are great examples of stochastic processes, encapsulating the intricacies of probability, statistics, and both electrical as well as mechanical calculations. This interdisciplinary project aims to evaluate and optimise various real-world queuing scenarios within elevator systems using simulations. The primary objective is to minimise wait and travel times for users, drawing on the principles of physics to derive general observations and conclusions. Additionally, the project seeks to enhance energy efficiency in elevator operations. The algorithm is built on Python using principles of probability and statistics. Successful outcomes of this project have the potential to significantly improve the efficiency and user experience of elevator systems.

Scratching the surface

Title:
Decadal change of sea surface temperature in the Bay of Bengal

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Abstract

Sea surface temperature (SST) is critical to understand Earth's climate system. Our study examines SST trends and variability in the Bay of Bengal (BoB) from 2000 to 2019 using Advanced Very High-Resolution Radiometers (AVHRR) data.

The Malacca Strait shows an annual trend of 0.0177°C/year increase, with the highest increase during September-October-November (SON) and negligible change in the June-July-August (JJA) period. Mali Kyun-Myanmar has the highest annual trend of 0.0381°C/year increase, especially during March-April-May (MAM), while the Palk Strait exhibits a lower trend with cooling in MAM. SST fluctuations south of Kuakata and the Sundarbans are driven by monsoonal patterns, whereas Teknaf has a stable thermal environment.

Regions like the Central BoB and east of Puducherry show increased activity during JJA, with higher frequency variability observed east of Visakhapatnam. Continuous Wavelet Transform (CWT) analysis identifies key frequency and temporal patterns: Mali Kyun-Myanmar exhibits high wavelet energy reflecting frequent short- term SST variability driven by meteorological and El Niño-Southern Oscillation (ENSO) influences, while the Palk Strait shows minimal wavelet energy. The Malacca Strait features dominant low-frequency oscillations around 1 mHz, indicative of long-period phenomena such as tidal influences, with short-term spikes due to localised atmospheric events. South of Kuakata and the Sundarbans display prominent low-frequency oscillations linked to seasonal cycles and large-scale currents.

Seasonal SST contributions vary across the BoB: North BoB peaks in JJA, East BoB in SON and JJA, South BoB across all seasons, and West BoB in MAM, June-July-August (JJA), and December-January-February (DJF). A 400-day low-pass filter highlights long-term warming trends attributed to global warming. These insights enhance understanding of SST dynamics in the BoB and inform regional climate models and forecasts. By monitoring SST trends, we can better understand and manage the complex interactions within our marine and atmospheric systems, leading to more effective environmental policies and practices.

An energy boost

Title:
Production of renewable liquid biofuels by aqueous phase reforming

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Abstract

With the growth of the human population, the need for sustainable sources of energy has increased. Enhancing biological hydrogen (H2) production (BHP) through the use of nanoparticle (NPs) supplements could be a way ahead. Pure or mixed cultures of some microorganisms can produce H2 in presence of NPs from pure sugars and biowaste as a feed. However, their H2 production efficiencies vary significantly with the type of NPs and their concentration.

Using a suitable bacteria like C. *butyricum* as inoculum and gold nanoparticles (AuNPs) has shown to be an efficient way to produce H2 from sucrose. Also, *Kappaphycus alvarezii* and sludge was processed for bio-hydrogen production.

Aqueous phase reforming (APR) produces hydrogen from biomass-derived oxygenated compounds such as glycerol, sugars, and sugar alcohols. APR is done in the liquid phase which makes it unique and process-friendly. The process generates bio-hydrogen from the biofuel with the sludge of macroalgae such as K. *alvarezii.* This saves water, energy and reduces emissions. Common APRs utilise activated carbon. It is observed that AuNPs have the catalytic performance for the degradation of pollutants at an industrial level. Therefore, AuNPs exhibit excellent catalytic degradation and decomposition of pollutants making the environment cleaner and sustainable.

The maximum bio-hydrogen yield was 36.1% for 2:1 (sludge: algae) at 360°C. However, reforming the aqueous phase with 7.5 wt% AuNPs and a mixture of anaerobic culture and synthetic wastewater containing sucrose as feed resulted in 62.3% higher yield than those to the control applying the minimum amount of AuNPs. The overall catalysis resulted in 61.25% bio-hydrogen with the remaining from the water of the sludge. It can be used at domestic sectors and small scale synthetic wastewater treatment and production of biofuels and bio-hydrogen since the procedure is more expensive than the established Steam Methane Reforming or Catalytic Reforming.

Through a topological lens

Title:
Characterising continuous functions

Team:
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Abstract

My mathematics honours thesis topic deals with topology, specifically understanding the connectedness of the graph and its relationship with the continuity of its function. For this, I learnt the basics of topology from *Essential Topology* by M. D. Crossley. Then I moved on to reading the PhD thesis of Michal Ryszrd Wojcik on the same topic. Although it has only been a few months since I began working on my thesis, I have enjoyed the open-endedness of reading and discussing mathematics with my mentor, sometimes for several hours a day.

We focused on the 'topologist's sine curve', the graph of the function defined by f(x) = sin(1/x) for x not equal to 0 and 0 at x = 0. It is hugely important both as an example and counterexample for relationships between different concepts in topology. It is most commonly used to prove that connectedness does not imply path-connectedness (the graph of this function is connected yet not path-connected). Exploring such relationships is a large focus of the thesis.

It's been incredibly interesting to see how topology is used to better understand various areas of maths such as what it means for a function to be continuous (merely using the simple idea of open sets), or the analytical definition of a closed set being equivalent to the topological definition of closed as the complement of an open set.

Doctors on a mission

Title:
Sustainable development through systems thinking: A case study of Sittilingi valley

Team:
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Abstract

In this paper, we focus on Sittilingi Valley, located in Tamil Nadu's Dharmapuri district. About 5000 families of the Malavasi tribe reside there and have been overlooked by the government since independence. The infant mortality rate was around 147 of 1000.

The inspiring story of doctors Lalitha and Regi began in 1993 when they made it their mission to address the area's dire health situation. Post the establishment of healthcare facilities they initiated further self-sufficiency mechanisms, such as the Sittilingi Organic Farming Collective (SOFA), to do away with migration and improve the quality of life. Such holistic solutions are vital for environmental sustainability and the fostering of their ecosystem. Sittilingi Valley therefore becomes a unique landscape that offers us an example of a well-managed society.

To understand how the community was able to thrive, we used a systems thinking lens. Even though this is a small-scale setup, systems thinking enables us to properly evaluate, recognise patterns and understand modifications required for the smooth functioning of a composite network. A self-sustaining system was created, one where community health is maintained by preserving local ecology, and vice-versa. Initiatives such as sustainable agriculture, access to clean water, waste management and access to healthcare reduce the prevalence of diseases and enhance overall well-being. For instance, sustainable agriculture practices not only ensure food security but also preserve soil fertility.

Health is an aspect that is often said to improve as economic productivity increases, but in the case of Sittilingi, we recognised that it was the opposite. Here, the concerns of the tribal community were identified first instead of exposing them to new urban methods of economic growth. This approach not only preserves cultural heritage and knowledge, but also empowers the community to adapt to a rapidly changing world.

A million dollar problem

Title:
The Riemann hypothesis

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Abstract

The Prime Number Theorem deals with the asymptotic distribution of prime numbers among positive integers. While the distribution of prime numbers does not follow a regular pattern, the German mathematician Bernard Riemann observed that the frequency of primes is closely related to the behaviour of the Riemann zeta function. This function sheds light on the atoms of arithmetic, the prime numbers.

The Riemann hypothesis, proposed in 1859, states that “all non-trivial zeroes of the zeta function are complex numbers with real part ½ ”. It is one of the seven millennium prize problems announced in the year 2000 by Clay Mathematics Institute. Understanding the hypothesis requires understanding the behaviour of the zeta function in the complex field. Riemann used analytic continuation to further extend the zeta function, which was initially defined for complex numbers whose real part is greater than 1, to all complex numbers not equal to 1. Every negative even integer is a zero of the zeta function and they are called its trivial zeroes. Riemann had observed that any other zero of the zeta function other than the trivial zeroes lie on the ‘critical line, which consists of complex numbers with real value equal to ½. This observation has been verified for the first 10,000,000,000,000 solutions, but for the past 140 years, nobody has been able to prove this observation of Riemann. We present the story of the Riemann hypothesis and a few recent developments in resolving it.

Experiments in number theory

Title:
p-Adic numbers

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Abstract

Our knowledge of numbers stems from natural numbers, i.e., counting numbers. From there we developed the notions of whole numbers, integers and rational numbers. After that, we understood that there were certain gaps in between rational numbers. To put it mathematically, the field of rational numbers is not complete. Completion of a field is understood through the notion of distance between elements of the field or the norm defined on the field. A norm is a function defined on a field to non-negative real numbers which follows a few properties.

According to Ostrowski's theorem, any norm defined on rational numbers is either equivalent to the Euclidean norm (the absolute value norm) or is the p-adic norm. We define an equivalence relation on the set of all Cauchy sequences in rational numbers with respect to the Euclidean norm, where any two Cauchy sequences are related if and only if the difference of the sequences is a null sequence, to obtain the field of real numbers.

Similarly, by defining the same equivalence relation on all Cauchy sequences in rationals with respect to the p-adic norm, for a prime p, we obtain the field of p-adic numbers. Any element of the p-adic field can be written as an infinite series, similar to that of a real number, which is known as its canonical representation. The difference in understanding of norms in both fields results in the difference in the topology of p-adic field and the topology of reals. The presentation will consist of the results learnt in the ongoing research on the comparison between the two fields, with understanding of the differences in their respective analysis with the help of the book *p-adic Analysis Compared with Real* by Svetlana Katok.

A handy tool for star gazers

Title:
Navigating low air quality index areas for stargazing using GIS & remote sensing

Team:
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Abstract

Locating environments with low Air Quality Index (AQI) is essential to guarantee unimpeded, unobstructed views of the night sky. Environmental pollutants such as particulate matter (PM2.5), carbon monoxide (CO), nitrogen dioxide (NO2), and sulphur dioxide (SO2) can severely deteriorate atmospheric visibility, resulting in poor views and an adverse experience during stargazing. By using satellite imagery for monitoring air quality over large geographic regions, remote sensing technology provides a novel means of pinpointing these low-AQI spots.

Various variables influence the atmospheric conditions for stargazing, the primary among them being air pollution from automobiles, burning biomass, and industrialisation. Urban spaces are more susceptible to high pollution levels. Remote sensing is a valuable resource for advancing the comprehension of how environmental conditions influence celestial observation, as well as ensuring that stargazing remains a pleasurable and accessible experience in the face of rising pollution.

We used remote sensing, data analysis, and Geographic Information Systems (GIS) technology to identify low-AQI stargazing locations. Satellite-based systems like Sentinel-5P, MODIS, and VIIRS give high-resolution data on pollution concentrations. These satellites assess the amounts of NO2, SO2, CO, and PM2.5, among other pollutants, throughout the Earth's surface, providing near-real-time data that can be obtained and analysed for stipulated geographical locations using Google Earth Engine.

Knowing when to strike

Title:
Hunting behaviour of jumping spider *stenaelurillus lesserti* (Salticidae) with different types of prey

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Abstract

Two broad hunting strategies are prevalent across predators - active predation and ambush predation. However, it is difficult to track and quantify hunting behaviour in these large animals. Enter Salticidae, or jumping spiders, a family of spiders consisting of more than 6,000 described species, well known for their hunting abilities. Of their four pairs of eyes, the principal eyes are capable of colour vision and excellent spatial acuity, while the three secondary eyes are used for motion sensing. Their hunting sequence can be divided into three phases: orientation, pursuit and capture.

One of them, *Stenaelurillus lesserti*, is a termite specialist, and is found in grassy fields of Bengaluru. Such habitats are also home to several types of insects which can potentially serve as prey for these spiders. Given this background, we hypothesise that jumping spiders will exhibit different hunting strategies for walking and flying prey. We specifically examine if *S. lesserti* employs a pursuit or interception strategy based on the nature of prey. For walking prey such as termites, we expect spiders to actively move behind and capture them. For flying prey like moths, we expect them to predict their location, intercept and then capture them.

Spiders were collected from the field and carefully introduced into a petri dish containing prey (a termite or moth). Hunting behavior was recorded using a high-speed camera fixed above the experimental setup, for 10 minutes or until the spider captures the prey. From tracking the position of the predator and prey in these videos, we recorded various metrics and generated their trajectories using DLTdv8 software. These measurements can help us indicate if they pursue or intercept their prey.

Studies tracking and quantifying hunting behaviour in jumping spiders are scarce, so our project can bridge this gap in the literature. Such data enables us to better understand predator-prey strategies.

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