Research Spectrum

A compendium of Graphical Abstracts
Illustrating Research at IIT Indore

Editors

Prof. Anirban Sengupta
Prof. Biswarup Pathak
Dr. M. Tanveer
Prof. Pankaj R. Sagdeo

Research Spectrum

(A compendium of Graphical Abstracts illustrating Research at IIT Indore)

Research & Development Office, Indian Institute of Technology Indore

Khandwa Road, Simrol,

Indore 453552

www.iiti.ac.in

Email id: rndoffice@iiti.ac.in

Proof correction and Editing:

Dr. Archana Chaudhary (Executive Officer)

Editors

Prof. Anirban Sengupta

Prof. Biswarup Pathak

Dr. M. Tanveer

Prof. Pankaj R. Sagdeo

Director's Message

It gives me immense pleasure to write a foreword to the second issue of first volume of *Research Spectrum*. This publication will showcase high-quality research work, done by the faculty members and students of IIT Indore, in a graphical form. As we say '*a picture is worth a thousand words*,' we want to present a pictorial abstract of our complex research in a most simplified way through this endeavour of *Research Spectrum*.

It may be noted that majority of the research works presented in the *Research Spectrum* have been bestowed with the Best Research and/or Best Technology awards of the Institute. It also includes some of the prominent research works that were considered for the award. Further, to recognise the professors who have won the awards in a year, they have been requested to be the editors of the periodic volumes of *Research Spectrum* coming out during the year.

We sincerely wish that the readers will find *Research Spectrum* containing graphical abstracts of the research work of IIT Indore faculty and students easy to understand and will further help disseminate the novel research ideas depicted therein amongst the avid researchers and lovers of technology.

With best wishes,

Prof. Suhas S Joshi
Director

INDEX

Deciphering the Morphological Origins of X-shaped Radio Galaxies: Numerical Modeling of Backflow versus Jet Reorientation

Gourab Giri[1], Bhargav Vaidya[1], Christian Fendt[2]

[1]Department of Astronomy, Astrophysics and Space Engineering, Indian Institute of Technology Indore, India.

[2] Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany
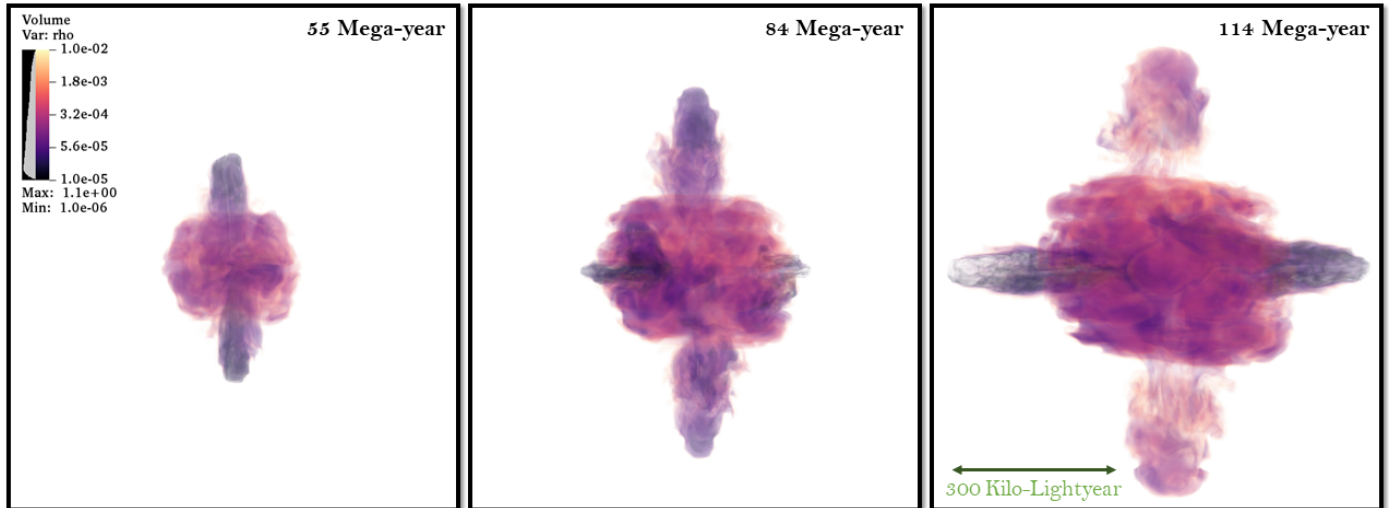
Fig.: Time evolution of density (denoted as rho) of the plasma matter ejected by a supermassive blackhole, residing at the center of a galaxy that has undergone a forced reorientation process of its jet ejection axis, producing an X-like morphology.

During an active phase, certain supermassive black holes expel bidirectional jets, yet some deviate, forming 'X'-shaped structures. This study investigates two causes: asymmetric surroundings or external black hole influence. Numerical simulations mimicking real X-shaped radio galaxies were performed, dismissing a universal model. Instead, the study explores diverse scenarios and suggested synthetic observerational signatures for insights into formation processes. This pioneering study challenges the notion of a one-size-fits-all model, encouraging a nuanced understanding of these enigmatic sources.

TIRAP-mediated activation of p38 MAPK in inflammatory signaling

Sajjan Rajpoot[1], Ashutosh Kumar[2], Kam Y J Zhang[2], Siew Hua Gan[3], Mirza S Baig[1]

[1]Department of Biosciences and Biomedical Engineering, Indian Institute of Technology Indore, India. [2]Laboratory for Structural Bioinformatics, RIKEN, Yokohama-230-0045, Japan. [3]School of Pharmacy, Monash University Bandar Sunway- 47500, Malaysia.
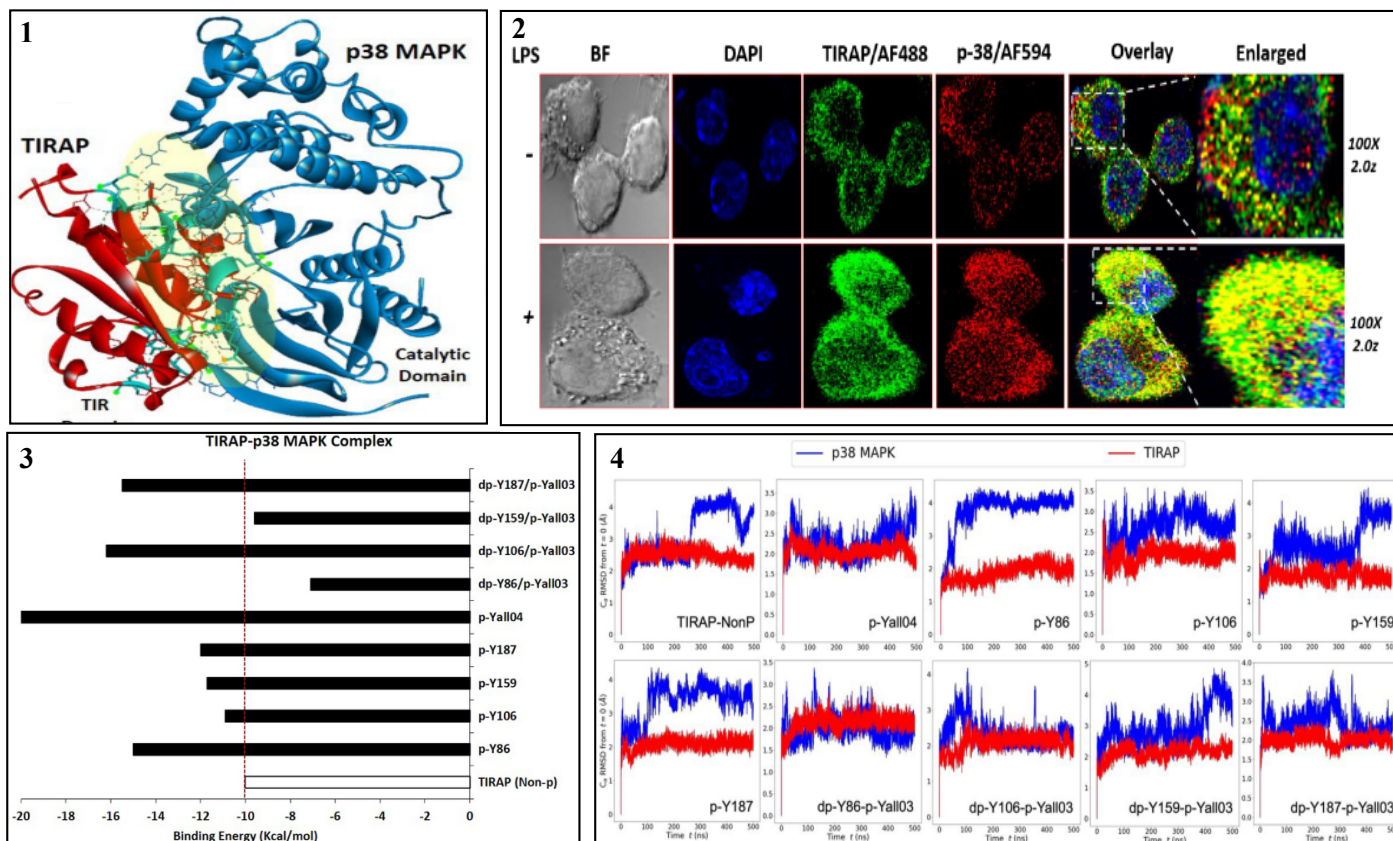
Fig.: Key outcome of the study. TIRAP TIR and p38 MAPK interaction through **(1)** Molecular docking, & **(2)** Immunofluorescence based co-localization **(3)** Effect of TIRAP TIR tyrosine phosphorylation (p) & dephosphorylation (dp) in p38 MAPK complex. **(4)** Molecular dynamic simulation of TIRAP and p38 MAPK docking complexes.

Macrophages play a crucial role in various inflammatory diseases as well as tumor progression. Toll-like receptors (TLRs) and TIR domain-containing adaptor proteins (TIRAP) are critical in macrophage inflammatory signaling. This study aimed to investigate the interaction between TIRAP and p38 MAPK and the significance of tyrosine phosphorylation in TIRAP's TIR domain for p38 MAPK activation. The findings highlight the importance of TIRAP's tyrosine phosphorylation, particularly at Y86 in facilitating its interaction with p38 MAPK, thereby regulating downstream inflammatory signaling.

The work has been published in the Scientific reports: Rajpoot et al., Sci. Rep., 12 (2022) 5601.
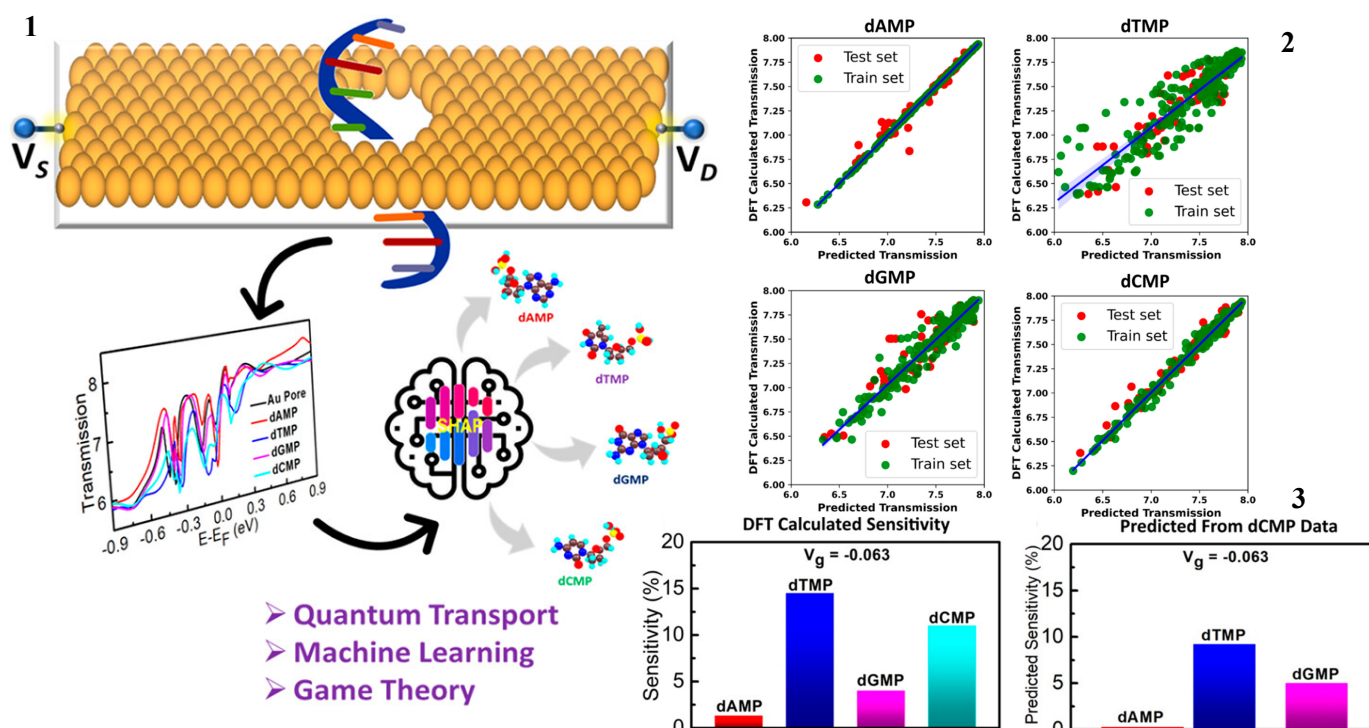
Machine Learning Aided Interpretable Approach for Single Nucleotide-Based DNA Sequencing using a Model Nanopore

Milan Kumar Jena[1], Diptendu Roy[1], Biswarup Pathak[1]

[1]Depratment of Chemistry, Indian Institute of Technology Indore, India.

Fig.: Schematic illustration of ML integrated quantum transport method with model solid-state gold nanopore for DNA nucleotide identification **(1)**. Parity plot for DFT calculated vs. ML predicted transmission datasets of nucleotide for the best ML model **(2)**. DFT calculated vs. ML predicted conductance sensitivity analysis **(3)**.

Mainstreaming DNA sequencing process into routine practice is vital for the development of genomic medicine and personalized treatments. This work reports that our ML integrated quantum transport strategy with the model solid-state gold nanopore can predict the transmission function of unlabeled nucleotides. The integration of ML techniques can alleviate experimental challenges of the quantum transport method by predicting the fingerprints of nucleotides and pave a new direction for the realization of cheap, accurate, and ultrafast DNA sequencing.
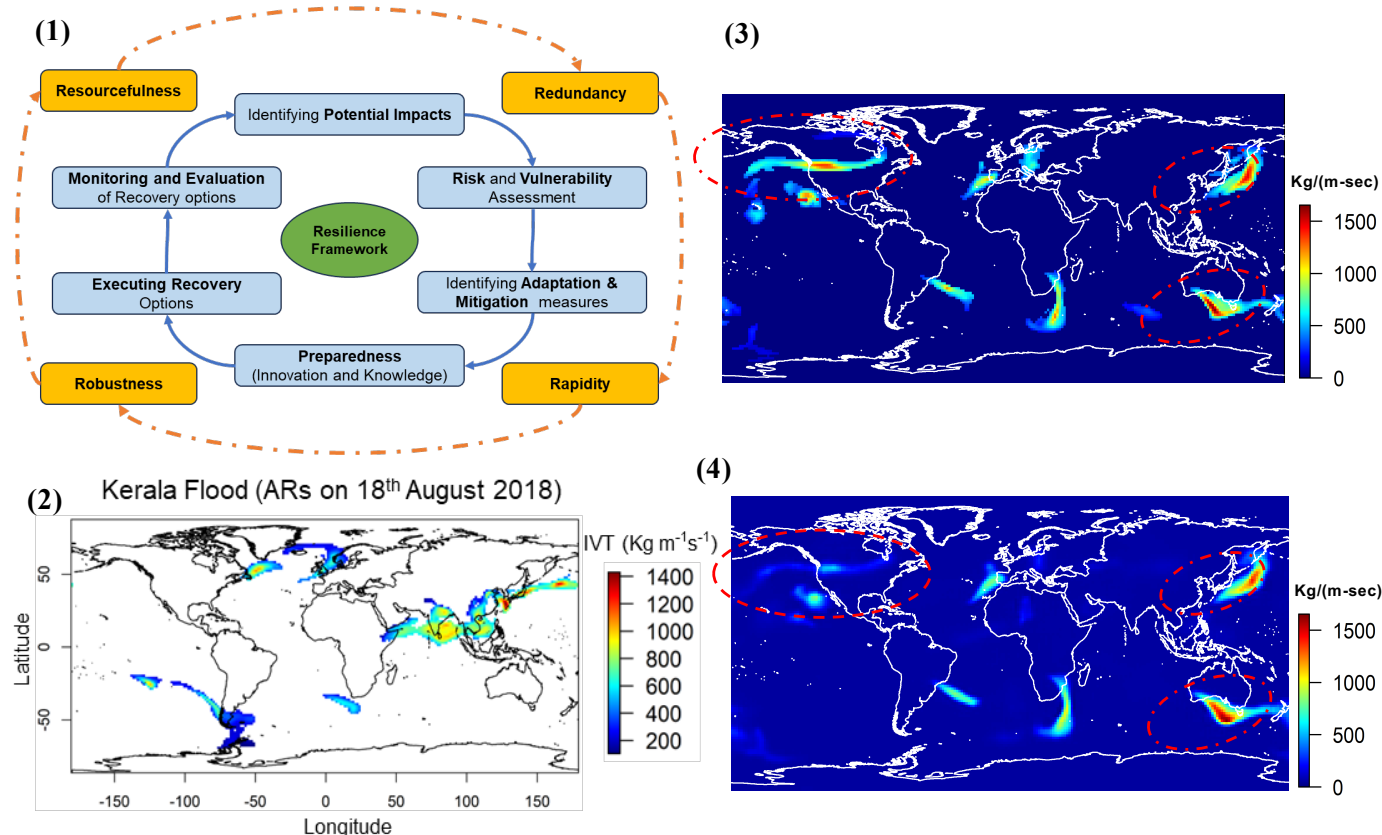
The work has been published in the Journal of Physical Chemistry Letters journal: Jena et al., J. Phys. Chem. Lett., 13 (2022) 11818–11830.

Enhancing climate resilience in businesses: The role of artificial intelligence

Shivam Singh[1], Manish Kumar Goyal[1]

[1]Department of Civil Engineering, Indian Institute of Technology Indore, India.

Fig.: Framework for building a climate-resilient business ecosystem **(1).** Intense ARs detected in India resulting in extreme precipitation during Kerala Flood in August 2018 **(2)** Prediction of ARs at next time frame, **(c)** ARs observed at a time derived from ERA5 reanalysis data of ECMWF **(3).** Predicted ARs in the same timeframe using convolutional Autoencoder **(4).**

The study presents a framework incorporating probable climate threats to business ecology with principles of robustness, resourcefulness, redundancy, and rapidity to adapt and mitigate associated risks for a climate-resilient business ecosystem. The integration of Artificial Intelligence with the business ecosystem in managing climate risk could be a promising tool for enhancing resilience towards climate change. Atmospheric Rivers (ARs), a weather extreme cause huge socioeconomic risk by triggering floods in various continents of mid-latitude regions. The results from the analysis advocate the application of deep learning algorithms to predict weather and climate extremes specifically ARs in decision support systems to enhance the climate resilience of a business ecosystem.

KisanQRS: A Deep Learning-based Automated Query-Response System for Agricultural Decision-Making

Mohammad Zia Ur Rehman[1], Devraj Raghuvanshi[2], and Nagendra Kumar[1]

[1]Indian Institute of Technology Indore, India [2]Shri Govindram Seksaria Institute of Technology and Science Indore, India
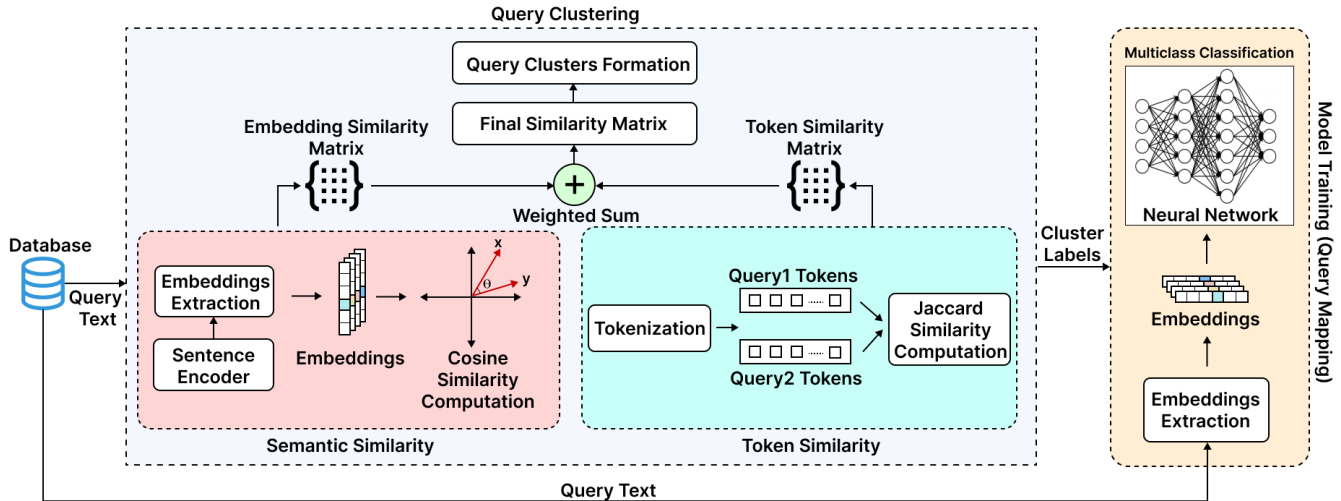
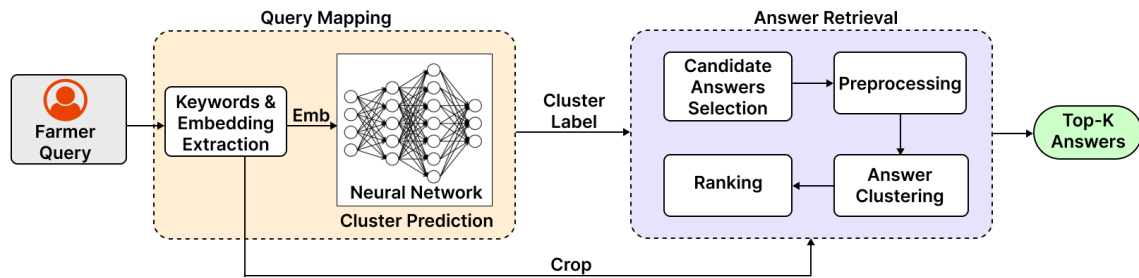**Fig. 1:** Query Clustering and Mapping System

Fig. 2: Proposed Answer Retrieval System

Delivering prompt information is critical in agricultural decision making. Farmers' helpline centers rely on the availability of call centre agents, leading to inconsistent quality and delayed responses. To this end, we propose Kisan Query Response System (KisanQRS) that integrates semantic and lexical similarities for clustering the queries and a neural network for query mapping as shown in Fig-1. A novel answer retrieval method is applied to retrieve and filter the most appropriate responses for farmers' queries. Fig-2 presents the proposed answer retrieval system. KisanQRS is useful in enabling farmers to make informed decisions by providing quick and pertinent responses.
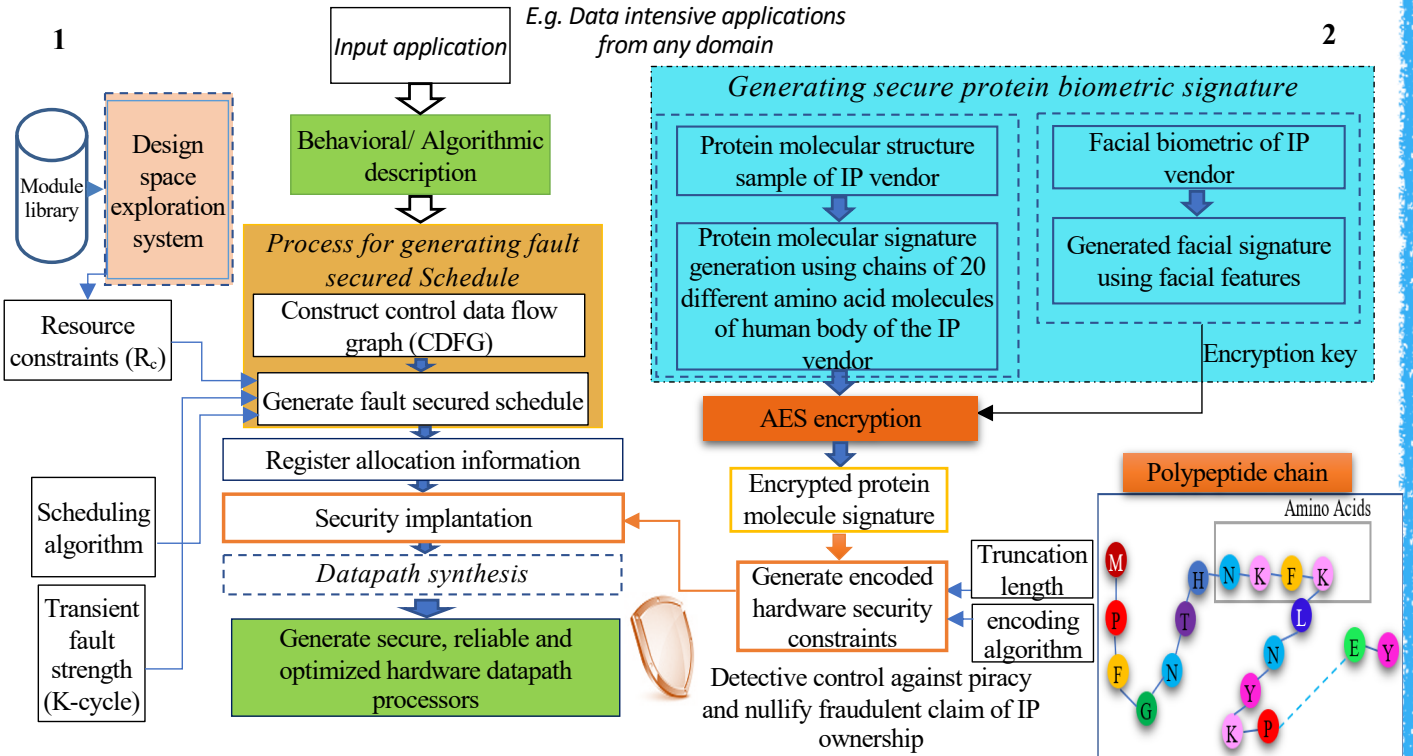
DESIGN SPACE EXPLORATION OF SECURE OPTIMAL K-CYCLE FAULT TOLERANT DATA PATH PROCESSORS WITH EMBEDDED ENCRYPTED PROTEIN MOLECULAR BIOMETRICS DURING HIGH-LEVEL SYNTHESIS

Anirban Sengupta[1], Rahul Chaurasia[1]

[1]Department of Computer Science and Engineering, Indian Institute of Technology Indore, India.

Fig.: HLS based approach for designing reliable and secure datapath coprocessors **(1)**. Polypeptide chain formed with twenty different amino acid molecules **(2)**.

Designing datapath processors for computationally intensive application frameworks is crucial for achieving higher efficacy. This invention enables to generate secure optimal fault tolerant datapath processors by embedding encrypted protein molecular biometric into fault tolerant design during high level synthesis for the first time. The methodology opens a new window for designing secure datapath processors (against the threats of IP piracy and ownership abuse) at minimal (zero) design cost overhead.
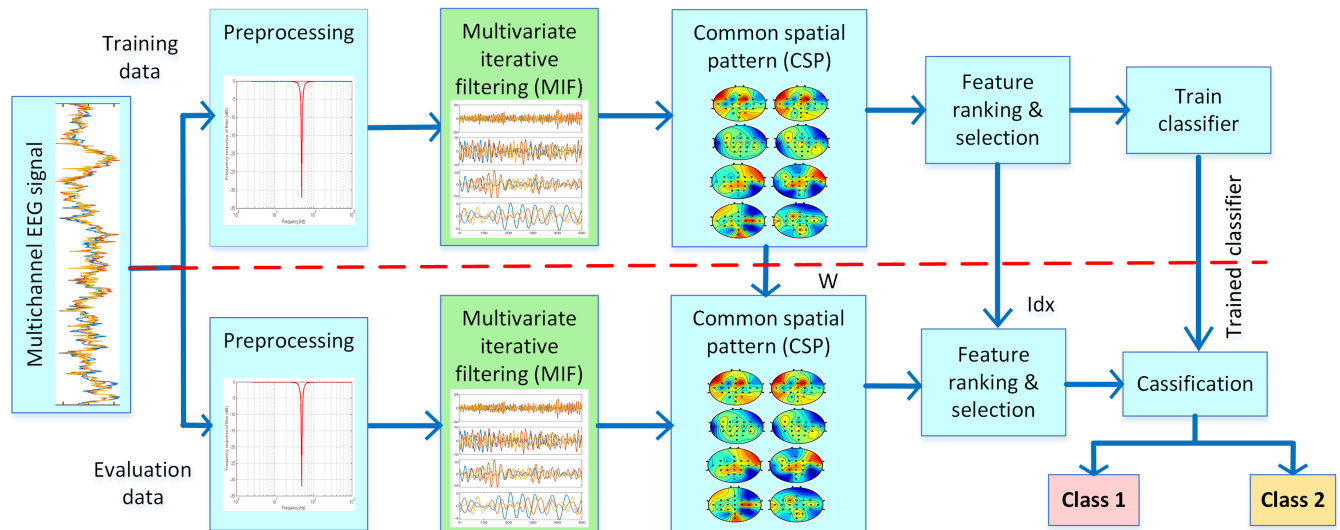
Electroencephalogram-Based Motor Imagery Brain- Computer Interface Using Multivariate Iterative Filtering and Spatial Filtering

Kritiprasanna Das[1], Ram Bilas Pachori[1]

[1]Department of Electrical Engineering, Indian Institute of Technology Indore, India.

Fig.: Block diagram of the proposed motor imagery brain-computer interface framework.

In motor imagery (MI)-based brain-computer interfaces (BCI), common spatial pattern (CSP) is famous for feature extraction. However, CSP's performance is influenced by manually selected or broadly set operational frequency bands.

We propose a framework based on multivariate iterative filtering (MIF) and CSP (MIFCSP) for MI-based BCI. MIFCSP automatically selects optimal frequency bands based on MIF. The MIF decomposes the electroencephalogram (EEG) signal into multivariate intrinsic mode functions, from which CSP extracts features. A linear discriminant analysis (LDA) classifier classifies different MI tasks.

Analyzing trend and forecasting of rainfall changes in India using non-parametrical and machine learning approaches

Bushra Praveen[1], Swapan Talukdar[8], Shahfahad[8], Susanta Mahato[4], Jayanta Mondal[4], Pritee Sharma[1], Abu Reza Md Towfiqul Islam[7], Atiqur Rahman[8]

[1]Department of Economics, Humanities and Social Sciences, Indian Institute of Technology Indore Indore, India. [2]Department of Geography, Faculty of Natural Sciences, Jamia Millia Islamia New Delhi, India. [3]Department of Geography, Faculty of Natural Sciences, Jamia Millia Islamia, New Delhi. [4]Department of Geography, University of Gour Banga, Malda, India. [5]Department of Geography, University of Gour Banga, Malda, India. [6]Department of Economics, Humanities and Social Sciences, Indian Institute of Technology Indore, India. [7]Department of Disaster management, Begum Rokeya University, Rangpur, 5400, Bangladesh. [8]Department of Geography, Faculty of Natural Sciences, Jamia Millia Islamia, New Delhi, India.
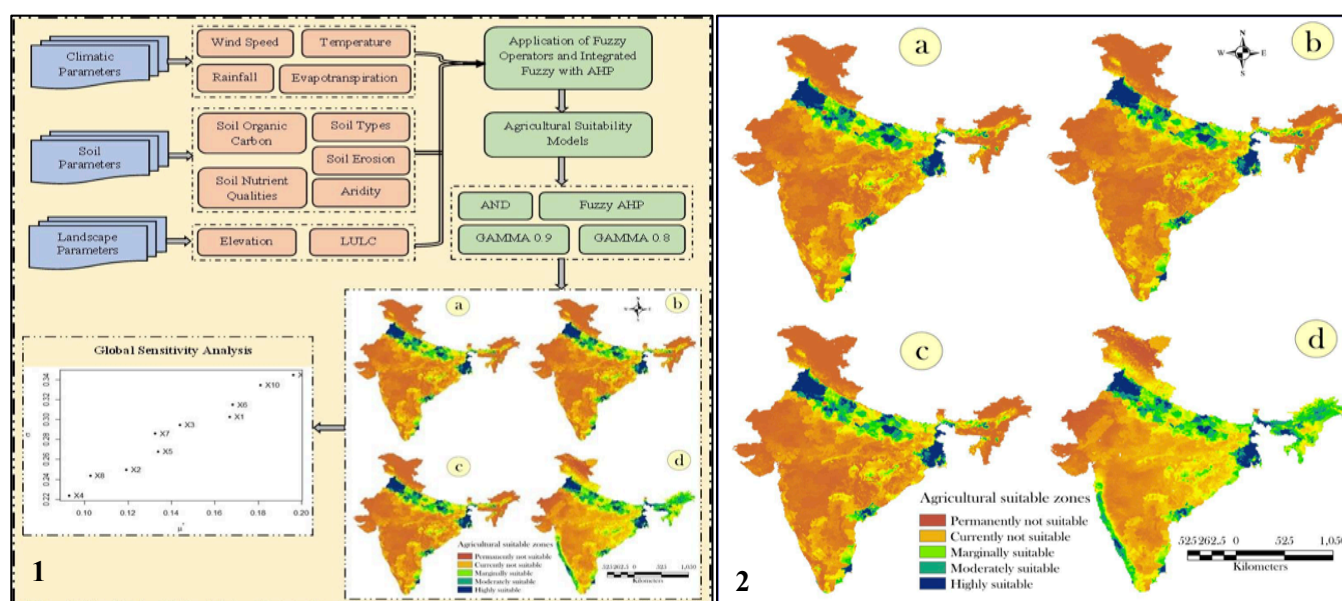
Fig.: An artistic illustration of Methodology of Agriculture land suitability (1). Agriculture suitability modeling Result using (a) fuzzy AND, (b) fuzzy gamma 0.9, (c) fuzzy gamma 0.8, (d) fuzzy AHP (2).

We compared four analytical methods of (i) AND), (ii) Fuzzy AHP, (iii) GAMMA 0.9, and (iv) GAMMA 0.8 to develop agricultural suitability models for India with respect to the past and current climatic conditions. The study shows the implications of climatic, soil and landscape parameters to generate the agricultural suitability maps for India. The findings of the analysis are directly utilizable for micro- and macro-level planning of cultivation plan and practices for private and public sector investments for improving agricultural productivity in the country.
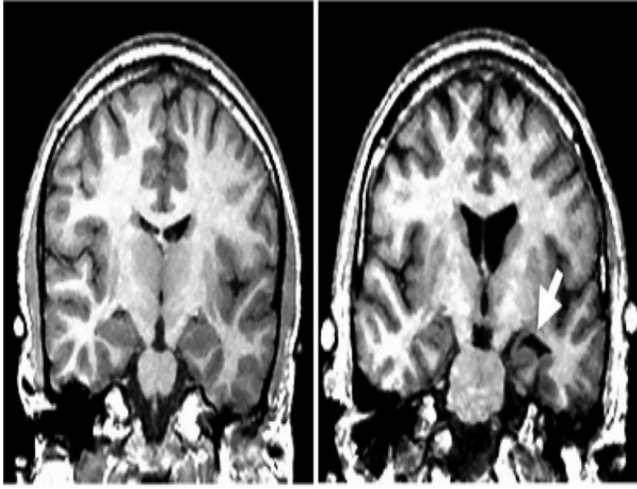
Intuitionistic fuzzy weighted least squares twin SVMs

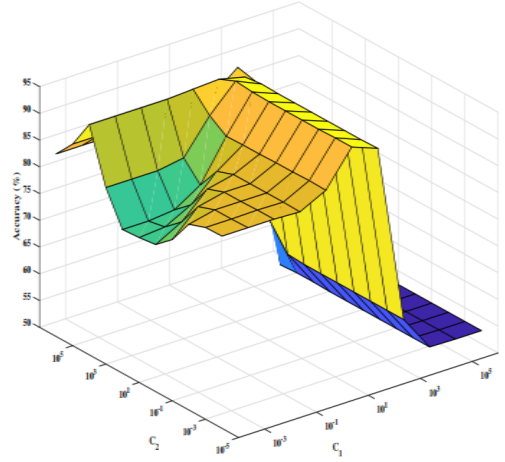**M. Tanveer[1], M.A. Ganaie[1], A. Bhattacharjee[1], C.T. Lin[2]**

[1]Department of Mathematics, Indian Institute of Technology Indore, India, [2]Center for Artificial Intelligence, Faculty of Engineering and Information Technology, University of Technology Sydney, Australia.

Fig.: MRI scan of normal subject **(1a).** MRI scan of Schizophrenia patient **(1b).** Performance of proposed IFW-LSTSVM model on Chess-krvkp data **(2)**.

Intuitionistic fuzzy twin support vector machine (IFTWSVM) combined the concept of intuitionistic fuzzy number with twin support vector machines to reduce the effect of outliers and distinguish support vectors from noise. Despite these benefits, twin support vector machines and intuitionistic fuzzy twin support vector machines still suffer from some drawbacks as i) the local neighborhood information is ignored among the data points ii) they solve quadratic programming problems, which is computationally inefficient. To overcome these issues, we propose a novel intuitionistic fuzzy weighted least squares twin support vector machines for classification problems (IFW-LSTSVM). The proposed approach uses local neighborhood information among the data points and also uses both membership and non-membership weights to reduce the effect of noise and outliers.
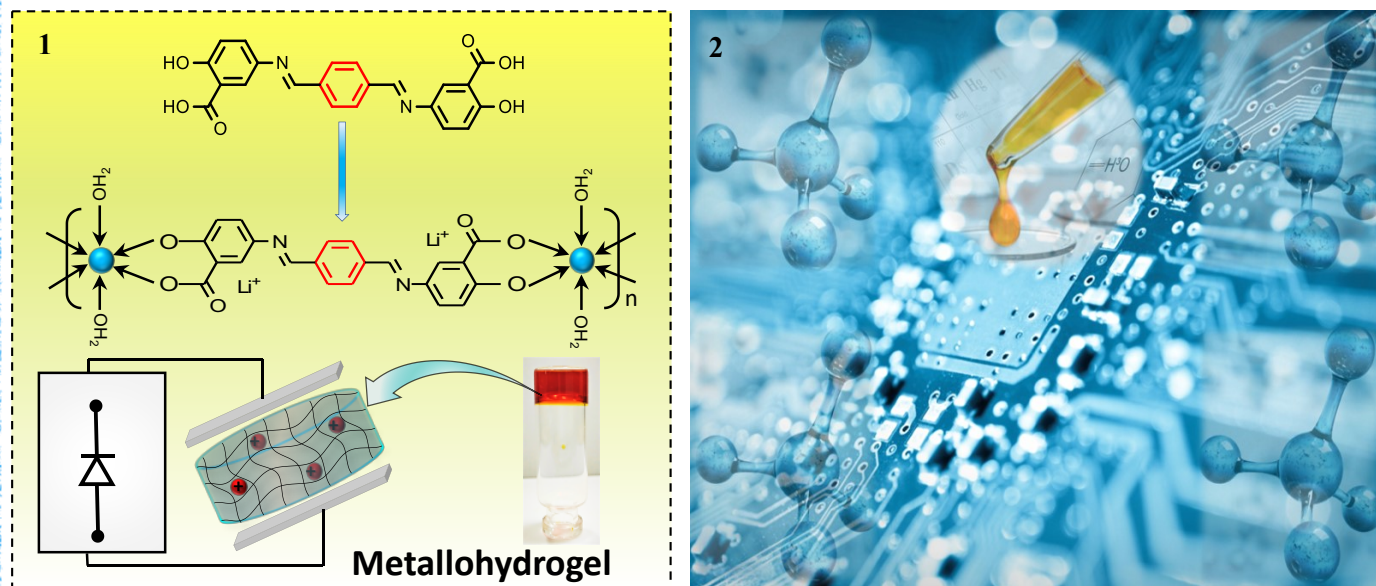
A Li+-integrated metallohydrogel-based mixed conductive electrochemical semiconductor

Yeeshu Kumar[1], Mrigendra Dubey[1]

[1]Soft Materials Research Laboratory, Department of Metallurgical Engineering and Materials Science, Indian Institute of Technology Indore, India.

Fig.: Schematic illustration for developing a metallohydrogel-based electrochemical semiconductor **(1)**. Prospective utilization of metallohydrogel as electronic material **(2)**.

Emergence of soft electronics has triggered a tremendous requirement of gel phase materials for development of electrochemical and electronic devices. Conventionally, doped agarose hydrogels and/or polyelectrolyte hydrogels are used to develop these devices. Hydrogels have low ionic conductivity, so external dopants are used to improve it, but this can lead to a loss of gel properties. We have synthesised a mixed-conductive metallohydrogel where metal ions not only enable gel formation, but also enhance ionic conductivity without sacrificing the gel's inherent properties.

Deep-CNN based damage classification of milled rice using a high-magnification image dataset

Bhupendra[1], Kriz Moses[1], Ankur Miglani[1], Pavan Kumar Kankar[2]

[1]Microfluidic and Droplet Dynamics Lab, Department of Mechanical Engineering, Indian Institute of Technology Indore, India, [2]System Dynamics Lab, Department of Mechanical Engineering, Indian Institute of Technology Indore, India
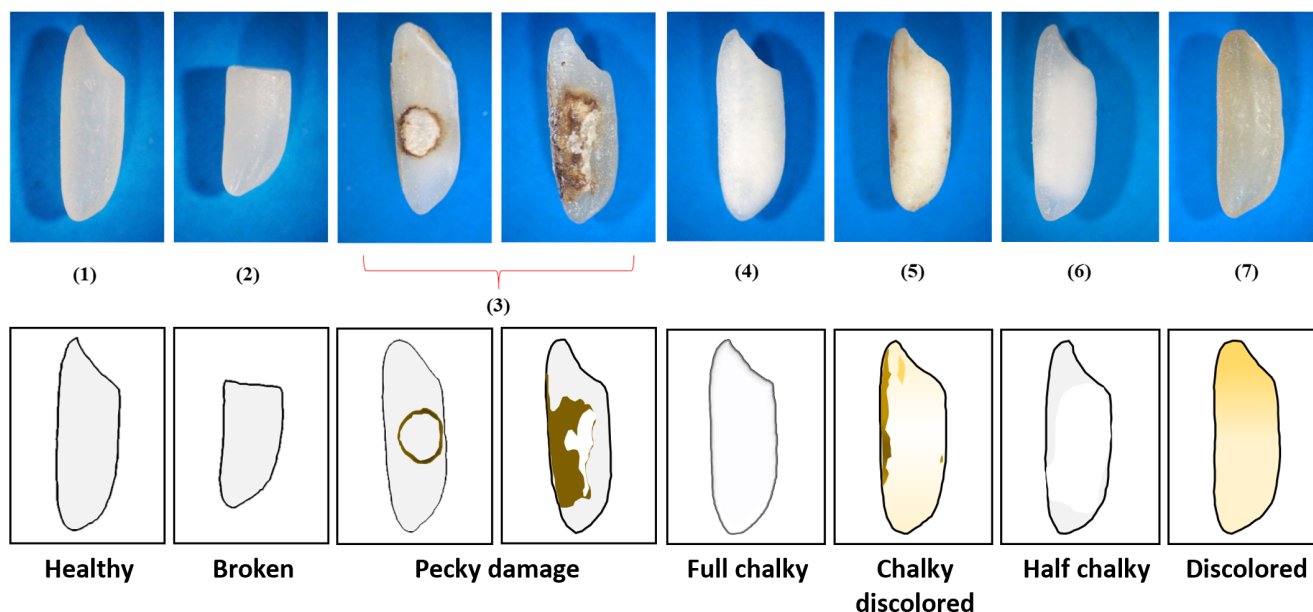
Fig.: The high magnification images of different types of damages in milled rice that are classified using CNN models such as Efficient Net and Mobile Net.

With a surge in food grain production for a growing population, an essential need arises for a cost-effective grain quality assessment tool that ensures fast, reliable, and objective decision-making. A significant effort has been directed for developing machine vision systems (MVs) with primarily focused on sorting the healthy grains from the damaged ones. In this context, the use and distribution of damaged rice grains remains unstructured due to lack of quality-assessment tools. To this end, this study demonstrates the application of Deep CNN models that are fine-tuned to enable classification of damage in rice grains with high accuracy.
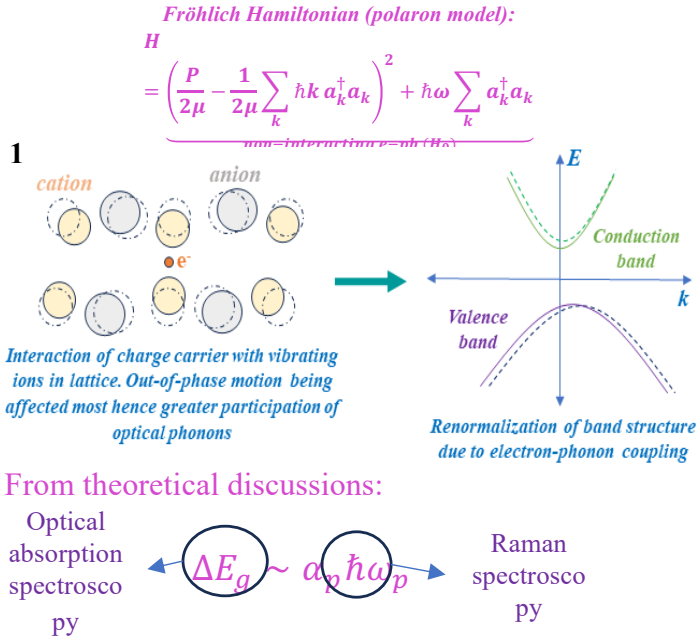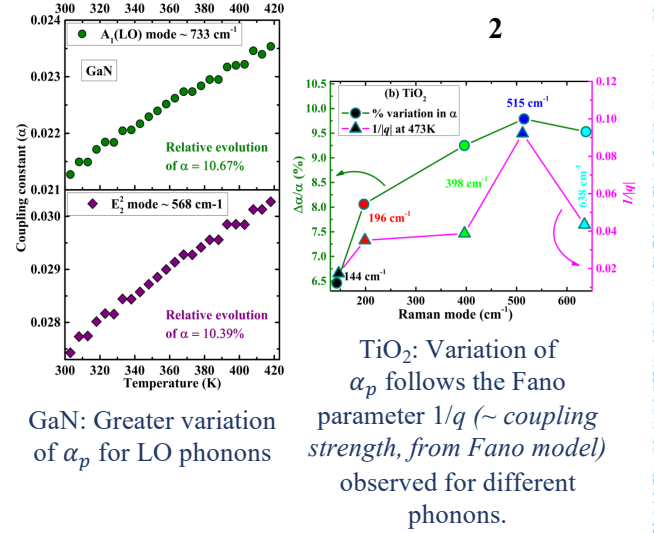
Phonon-mode-specific lattice dynamical coupling of carriers in semiconductors using Raman and optical spectroscopic techniques

Omkar V. Rambadey[1], Minal Gupta[1], Pankaj R. Sagdeo[1]

[1]Materials Research Laboratory, Department of Physics, Indian Institute of Technology Indore, India

Fig.: Depiction of electron-phonon interaction in an ionic lattice and its consequence as the bandgap renormalization which is discussed in terms of polaron model in present work **(1)**. The Experimental results on GaN and TiO$_2$ samples - *estimation of coupling constant α_p for different phonon modes and its comparison* **(2)**.

Different atomic/ionic vibrational modes can affect the charge-carriers distinctly and hence the materials' transport properties. Information of the (phonons) modes greatly participating in charge-lattice interaction can be crucial in optimizing transport properties, especially, in controlling the superconducting behaviour by selective excitation of strongly-coupled-phonons potentially responsible for superconductivity. This work attempts to resolve phonon-mode-specific coupling by exploiting widely accessible absorption– and Raman– spectroscopies on semiconductors by connecting 2nd-order correction in polaron energy with bandgap-renormalization due to electron-phonon coupling, seeking coupling constant α_p for p^{th} phonon-mode, investigated for GaN (preferential coupling of LO modes) and TiO$_2$ (change in α_p following Fano parameter).

12

Research Initiatives by IIT Indore

Translational Research Fellowship: A step towards Lab to Land Ecosystem

To inculcate a translational research ecosystem among the students, a Translational Research Fellowship scheme has been initiated by IIT Indore. The main objective of the Fellowship is to encourage students who have developed technologies and are aspiring for upgrading the technology for potential commercialization under the respective faculty member's mentorship. This fellowship is open for undergraduate, post graduate and Ph. D. students who are on the verge of completing their degree.

Five students have been awarded with Translational Research Fellowship till date.

(TRF)

TRL 1-3
(IIT Indore Ph.D scholar, B.Tech and PG students)

Handholding with IPR and Techno Commercial Expert

TRL 5 and above

List of Awardees of Translational Research Fellowship

S. No.	Name of the Student	Name of the Supervisor	Domain
1	Mr. Rahul Chaurasia	Dr. Anirban Sengupta	Hardware Security
2	Mr. Gyanesh Patnaik	Dr. Abhishek Rajput	Material for Defense
3	Mr. Chandrabhan Patel	Dr. Shaibal Mukherjee	Smart sensors & Environmental Sustainability
4	Mr. Anikeit Sethi	Dr. Aruna Tiwari	Smart City Infrastructure
5	Mr Sanchit Gupta	Dr. Sandeep Chaudhary	Infrastructure Development

Research Initiatives by IIT Indore

Young Faculty Research Seed Grant Scheme (YFRSG)

The Research Seed Grant Scheme for the Young faculty of IIT Indore (who are new to the institute) is a bridge funding provided by the institute before the first regular grant from the external funding agencies. This scheme is designed to inculcate a research ecosystem in the cutting-edge areas of national and international needs. The main objective of this scheme is to encourage newly joined faculty members towards innovative research and participate in technology development.

Twenty four faculties have received the financial support under YFRSG scheme till date.

Young faculty Research grant

Exposure to Project Execution
Upto Rs. 10, 00,000 against a project proposal with a duration of at least two years

Exposure to International Research Experience
Upto Rs 5, 00,000 to work in the dream laboratory during the vacation period

Exposure in Team building with Undergraduate students
Upto Rs 5,00,000 to closely work with Undergraduate students to develop product/process

Research Initiatives by IIT Indore

AWARD of 5G LAB to IIT Indore

Honourable Prime Minister, Shri Narendra Modi awarded 5G Lab to IIT Indore for students and start- up communities on 26th October 2023. It will help in building competencies and engagement in 5G and beyond technologies in students and the academic fraternity, encouraging academia-industry engagement to ideate and develop Indian specific 5G use cases for rural and remote areas, making Indian academia & startup ecosystem 6G ready.

Indian Institute of Technology Indore