INDIAN INSTITUTE OF TECHNOLOGY MADRAS
OFFICE OF ALUMNI AND CORPORATE RELATIONS

DART
AMERICAN EXPRESS LAB FOR DATA ANALYTICS, RISK & TECHNOLOGY

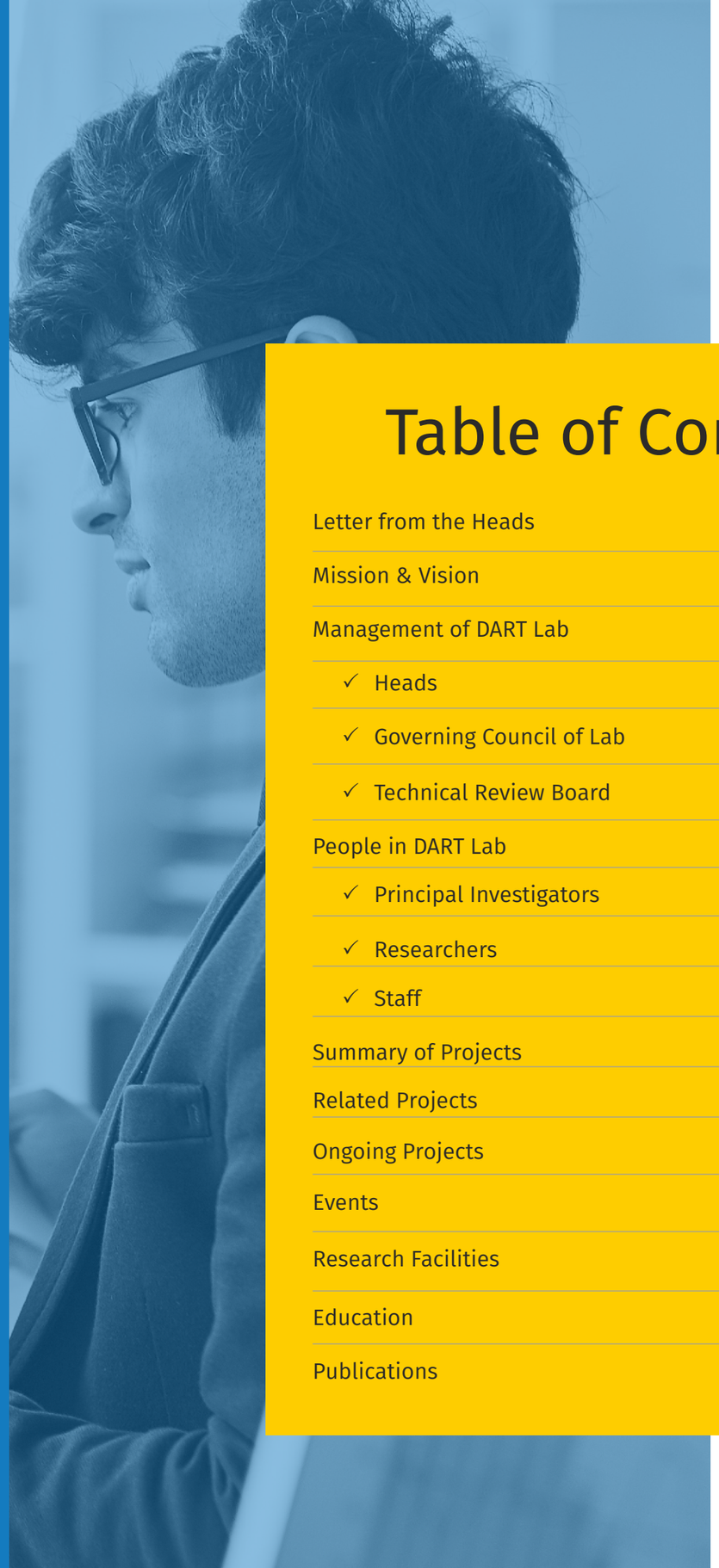
# AMERICAN EXPRESS LAB FOR DATA ANALYTICS, RISK & TECHNOLOGY (DART)

## Annual Report 2021-2022

# Annual Report 2021-22

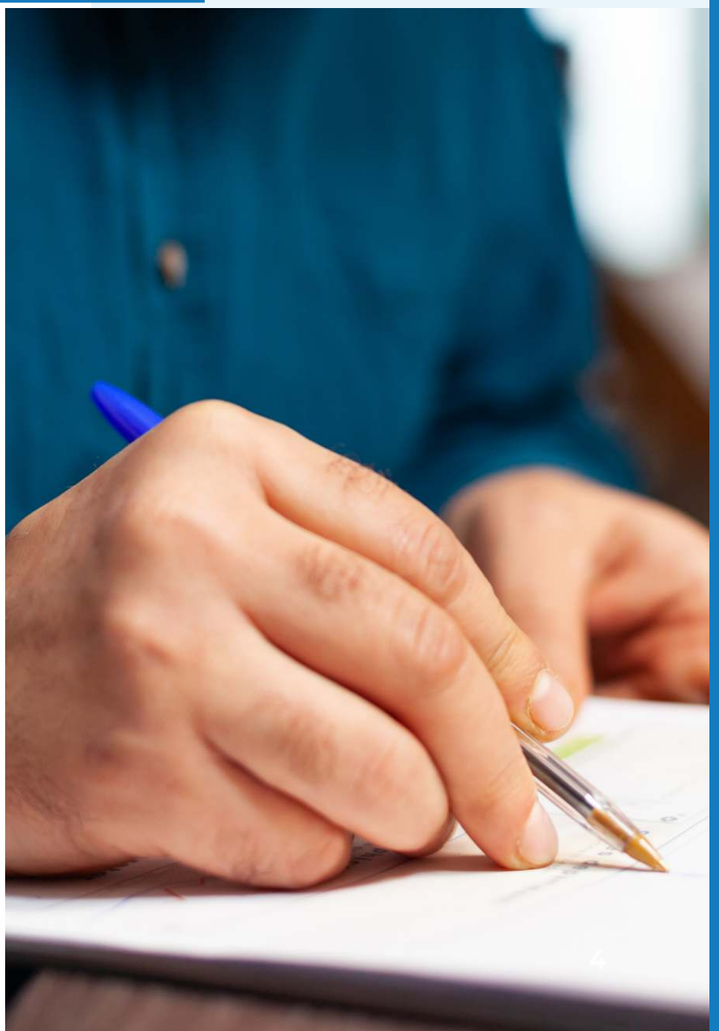
- ☞ **Risk Analytics**
- ☞ **Behavioral Sciences**
- ☞ **Technological Platforms**

Data Analytics, Risk, and Technology (DART) Lab is a cross-disciplinary research laboratory at IIT Madras with the objective to become a leader in the risk and behavioral sciences eco-system through research, societal impact, and teaching.



## Table of Contents

# Letter from the Heads







*In the second year of operation, DART Lab has continued to make significant strides in advancing research in the fields of data analytics and technologies which are instrumental to meet the sustainable development goals. Building on the foundation established in the first year, we have further expanded our global partnerships and collaborations.*

*Our experimental facility has also been expanded, with the addition of new state-of-the-art equipment for research in areas ranging from human allied AI, risk in operations and supply chain, cognitive science and healthcare. These facilities have enabled our researchers to work on cutting-edge technologies and have also helped to attract more researchers and students to our lab.*

*We are proud to announce that DART Lab has also grown in terms of faculty and researchers associated with it. As of now, we have 17 renowned faculty members and 30+ dedicated researchers who are actively working in different research areas and have contributed significantly in achieving our goals.*

*Overall, the DART Lab has made significant progress in its mission to bring a behavioral sciences and risk perspective to a wide variety of domains. We look forward to continued growth and impact in the coming years.*

**Prof. Rajagopalan Srinivasan &**
**Prof. Nandan Sudarsanam**
*Heads, DART Lab*
*IIT Madras*

# Mission & Vision

The DART lab aims to create a high impact in the risk and behavioural sciences eco-system in three ways:

I. **Research**

To become a world leader in research, where long-standing fundamental research problems are targeted and solved. This pure research would cross-cut various disciplines, while being application agnostic. Further, the fundamental and applied research that is pursued by the lab can potentially be leveraged in the promoted domains.

II. **Societal Impact**

a. Various tools, algorithms, and findings that come from the lab will be made publicly available.

b. Projects from the lab would also involve government collaboration across various pillars.

III. **Education**

To promote courses and workshops in the core areas with close collaboration with industry and government.






## Core Areas:

The Lab will promote research into core challenges and applied research in various areas, including, but not limited to:

I. **Risk Analytics:** Credit & Fraud Risk, Anomaly Detection, Systemic risk, network effects, rare event modeling, resilience, robustness and other ilities.

II. **Behavioral Sciences:** Behavioral risk, Human-in-the loop analytics, decision-making under uncertainty, behavioral operations research and human machine interfaces.

III. **Prescriptive Analytics and technological platforms:** Reinforcement learning and model predictive control, experimentation in online and offline environments.

The lab will explore a wide range of verticals with a key emphasis on Finance, Healthcare, Operations management (including manufacturing) and smart cities.

# Management of DART Lab

## Heads

**Prof. Rajagopalan Srinivasan**
Head, DART Lab
Professor
Department of Chemical Engineering
IIT Madras

**Prof. Nandan Sudarsanam**
Co-Head, DART Lab
Associate Professor
Department of Management Studies
IIT Madras





## Governing Council of Lab

**Prof. Ravindra Gettu**
Professor
Department of Civil Engineering
IIT Madras

**Mr. Sankara Narayanan**
VP & MD, Credit & Fraud Risk -
Centre of Excellence
American Express (India) Pvt Ltd

**Prof. Rajagopalan Srinivasan**
Head, DART Lab
IIT Madras

# Technical Review Board

**Prof. Balaraman Ravindran**
Professor
Department of Computer Science and Engineering
IIT Madras

**Mr. Tirthankar C Choudhuri**
Vice President, Digital Data Science
American Express (India) Pvt Ltd

**Prof. Rajagopalan Srinivasan**
Head, DART Lab
IIT Madras





# People in DART Lab

## Principal Investigators

**Prof. Amal Kanti Bera**
Department of Biotechnology

Prof. Amal Kanti Bera is a professor at IIT Madras in the Department of Biotechnology. He received his PhD in Biophysics from the University of Delhi and an MSc in Physiology from the University of Calcutta. He was a post-doc at Sackler School of Medicine, Tel Aviv University, Israel during 1998-99 and also a post-doc at UT Southwestern Medical Center in Dallas, Texas. He also worked as a research associate at the Albert Einstein College of Medicine. He specializes in Neurobiology and Neurophysiology.

**Prof. Arun K. Tangirala**
Department of Chemical Engineering

Prof. Arun K. Tangirala graduated with a Bachelors in Chemical Engineering from the Indian Institute of Technology Madras, India in 1996 and a PhD degree in process control and monitoring from the University of Alberta, Canada in 2001. He is currently a Professor with the Department of Chemical Engineering, IIT Madras. He is also a core faculty member of the Robert Bosch Centre for Data Science and AI, the Complex Systems Dynamics Group and the Network Systems and Learning Group.

Prof. Tangirala conducts cutting-edge research in process systems engineering, identification, soft sensing, network science and data analytics with applications to broad fields including seismology, climate, precision agriculture, transportation and healthcare. He is a recipient of different teaching and research awards, and is the author of a comprehensive classroom text titled "Principles of System Identification: Theory and Practice", published by CRC Press and co-author of a book titled “Active Buckling Control of Structures”, published by Ane Publishers in 2021. Prof. Tangirala currently serves as the Editor-in-Chief of the Institution of Engineers India: Series E journal, Associate Editor of the ASME Journal of Dynamics, Measurement and Control, and Associate Editor of the Control Engineering Practice journal.

**Prof. Arun Rajkumar**

Department of Computer Science

Prof. Arun currently serves as an Assistant Professor at the Computer Science and Engineering department of IIT Madras. Prior to joining IIT Madras, he was a research scientist at the Xerox Research Center (now Conduent Labs), Bangalore for three years. He earned his PhD from the Indian Institute of Science where he worked on 'Ranking from Pairwise Comparisons'.

**Prof. Babji Srinivasan**

Department of Applied Mechanics

Dr. Babji Srinivasan is currently an Associate Professor in the Department of Applied Mechanics at IIT Madras. He obtained his B. Tech in Instrumentation and Control from Madras Institute of Technology and went on to pursue his Masters chemical engineering from IIT Madras. Later, he pursued his PhD from Texas Tech University in Chemical Engineering after which he had a brief stint as Postdoctoral Scientist at Columbia University in New York. Before joining IIT Madras, he was as an Assistant Professor at IIT Gandhinagar and had a joint affiliation with both Electrical and Chemical Engineering departments. He was also a visiting Research Scientist at Columbia University in 2014.

The overarching goal of Dr. Babji's research is to develop a science-based understanding of human performance (cognitive and physical) in the Cyber-Physical Human Systems (CPHS). He is also a core member of Data Analytics Risk and Technologies (DART) lab at IIT Madras. He has received several grants worth over 80 million rupees from various funding agencies to carryout research in the field of CPHS. His research has resulted in more than 100 peer reviewed journals and international conference proceedings. He has co-authored an undergraduate text book titled: Process Control Fundamentals: Analysis, Design, Assessment and Diagnosis published by CRC press.





**Prof. Barun Sarkar**

Department of Mathematics

Dr. Barun Sarkar is a faculty at IIT Madras in the Department of Mathematics. He completed his PhD (from Germany) and postdoc (from Bengaluru). His Current research interests are - Stochastic partial differential equations, dynamical systems, and theoretical probability, and have a research group actively working in the field of Probability and Statistics.

**Prof. Krishna Malakar**

Department of Humanities and Social Sciences

Prof. Krishna Malakar currently serves as an Assistant Professor at the Department of humanities and social sciences, IIT Madras. She holds a PhD in the Interdisciplinary Programme in Climate Studies (Policy) from IIT Bombay and a graduate degree in Environmental Studies from the TERI School of Advanced Studies, New Delhi. Her research primarily focuses on understanding the human dimensions of environmental/climate change with the aim to inform policy and action. Some of her specific research themes include Vulnerability, risk, and adaptation to climate change, Resilience, response and recovery of communities from extreme weather events, Social barriers to technology adoption, and Livelihood and environmental sustainability.

**Prof. Lata Dyaram**

Department of Management Studies

Prof. Lata Dyaram Currently serves as faculty at IIT Madras in the Department of Management Studies. She holds a PhD from IIT Madras and undergraduate and graduate degrees from the University of Mumbai. Her Research Interests include Management & Organization studies, Organizational Behaviour and Human Resource Management.

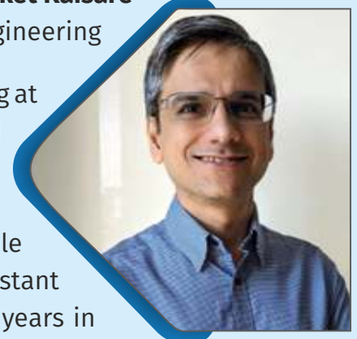
**Prof. Nandan Sudarsanam**

Department of Management Studies

Prof. Nandan Sudarsanam is a faculty member in the Department of Management Studies and a core member of the Robert Bosch Center for Data Science and Artificial Intelligence (RBCDSAI) at IIT Madras. He earned his PhD from the Engineering Systems Division at MIT, following which, he worked as a quantitative researcher for five years at a high-frequency algorithmic trading firm in New York. His research and work experience focuses on applications of experimentation, machine learning and the abstraction of data to models and algorithms. This spans data and problems across different domains, including but not limited to finance, urban mobility, digital platforms, civic services, and criminology. He publishes in machine learning conferences as well as peer-reviewed journals in engineering and applied statistics.

**Prof. Niket Kaisare**

Department of Chemical Engineering



Prof. Kaisare received his PhD in Chemical Engineering at Georgia Tech, working on "Modeling, Analysis and Control of Nonlinear Switching Systems." Thereafter, he did a post-doc at University of Delaware working on modeling of microchemical systems for portable power generation. He then spent four years as an Assistant Professor in IIT Madras, followed by three and half years in industrial R&D, working at General Motors and ABB Corporate Research. He current serves as a Professor in the department of Chemical Engineering at IIT Madras.

His major research thrust is in the area of Multi-scale Modeling, Analysis and Control of Reacting Systems for Energy Applications. The expertise of his group lies in both Reaction Engineering and Process Control. His group is engaged in integration of multiscale modelling, reactor design and optimal control in a coherent framework, combining simulation-based work with reactor-scale experiments.





**Prof. Nirav Bhatt**

Department of Biotechnology

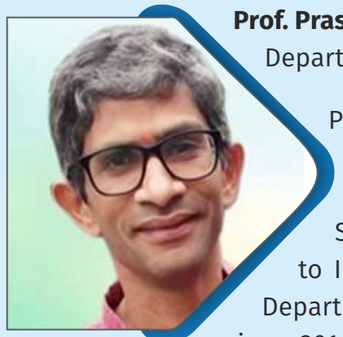
Prof. Nirav Bhatt earned his Bachelor in Chemical Engineering from the MS University of Baroda, Masters in Chemical Engineering from IIT Madras, and Docteur es Science (DSc) in Control Systems and Data Science from EPFL, Switzerland. Currently, he is an Assistant Professor at the Department of Biotechnology, Bhupat and Jyoti Mehta School of Biosciences.

He was an INSPIRE Faculty Fellow with the Department of Chemical Engineering, IIT Madras. He is a coordinator of Network Systems Learning, Control and Evolution Group, and a core faculty member at Robert Bosch Centre for Data Science and Artificial Intelligence and Initiative for Biological Systems Engineering, IIT Madras. His research interests include modelling and control of biological networks from multi-sensor and multi-scale data, safe learning and control of man-made networks, and AI/ML techniques for biochemical processes.

**Prof. Palaniappan Ramu**

Department of Engineering Design

Prof. Palaniappan Ramu holds a Bachelor of Engineering in Mechanical (Madurai Kamaraj University, Madurai) and a PhD in Aerospace Engineering (University of Florida, Gainesville). Prior to coming to the IIT Madras, he worked as a postdoctoral research associate at the University of Notre Dame and as an optimization engineer at the Caterpillar Champaign Simulation Center, Urbana-Champaign. He has been on the faculty of the department of Engineering Design at IIT Madras since December 2009. He heads the Advanced Design, Optimisation and Probabilistic Techniques Laboratory (ADOPT).



**Prof. Prasad Patnaik BSV**
Department of Applied Mechanics

Prof. Prasad Patnaik BSV received his PhD from IIT Madras in 1998. During 1998-99, he was a post-doc at UBC, Canada. He taught at the National University of Singapore (NUS) during 1999-2006, before moving back to IIT Madras in 2006. He is currently Professor in the Department of Applied Mechanics at IIT Madras, Chennai since 2014. He specializes in Computational Fluid Dynamics (CFD). His broad research interests include Fluid Structure Interaction (FSI), Nuclear Thermal Systems, Bio-Fluid Mechanics, etc.

**Prof. Preeti Aghalayam**
Department of Chemical Engineering

Prof. Preeti Aghalayam is a professor in the Chemical Engineering department at the Indian Institute of Technology, Madras. She was on the faculty at the Indian Institute of Technology, Mumbai, & a post-doctoral researcher at MIT, Cambridge, prior to this. She has vast experience in the area of Chemical Reaction Engineering and has worked on problems of automotive NOx reduction, underground coal gasification, carbon black production, and soot formation in flames.

She has several international papers & conference publications and has recently authored a book on Underground Coal Gasification. She was presented with the Indian National Academy of Engineering 'Young Engineer' award in 2007 and the Amar Dye Chem award in 2008.





**Prof. Rahul R. Marathe**
Department of Management Studies

Prof. Rahul R. Marathe is a faculty at IIT Madras in the Department of Management Studies. He obtained his PhD and MS from Iowa State University in Industrial Engineering and Statistics, and his B.E in Production Engineering from Mumbai University.

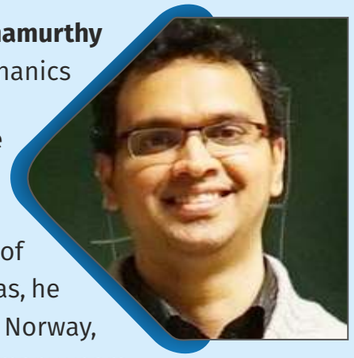
His research interests include decision-making under uncertainty and, Mathematical and Statistical modelling.

**Prof. S. Ramakrishnan**
Department of Applied Mechanics

Prof. S. Ramakrishnan is currently the Professor in Biomedical Engineering Group in the Department of Applied Mechanics, IIT Madras. His current areas of research include Biomedical Instrumentation, Biomedical Signal Processing applied to pregnancy monitoring and emotion detection, and Medical Device Regulations and Standards.

He has published more than 425 papers in Journals and Conferences. Currently, he is the Principal Investigator of the project on Centre of Excellence for Medical Device Regulations and Standards.

**Prof. Vagesh D. Narasimhamurthy**
Department of Applied Mechanics



Dr. Vagesh D. Narasimhamurthy is an Associate Professor and Head of the Computational Flow Turbulence and Combustion Laboratory at the Department of Applied Mechanics, Indian Institute of Technology Madras, Chennai, India. Prior to IIT Madras, he was a Senior Research Engineer at Gexcon AS, Norway, developing the commercial CFD software, FLACS, for many years. He holds a PhD degree in Fluids Engineering from Norwegian University of Science and Technology (NTNU), Trondheim, Norway and MS degree in Computational Turbulence from Chalmers University of Technology, Gothenburg, Sweden. His research interests include direct numerical simulation of transition and turbulent flows, multiphase flows and gas-explosion modelling.

**Prof. Varadhan SKM**
Department of Applied Mechanics

Prof. Varadhan SKM is a faculty at IIT Madras in the Department of Applied Mechanics. He obtained his PhD from The Pennsylvania State University, MS from IIT Madras and B. Tech from University of Madras

His research interests include Movement Neuroscience, Finger/Hand Biomechanics, Bimanual Coordination, Motor Behaviour and Motor Learning, Rehabilitation, Understanding Action and Perception.





## Researchers

### V.S. Thasnimol

Thasnimol VS working as a Junior Research Fellow for the BRNS project on “Cost effective eye-tracking approaches to analyse human machine interface in nuclear power plants” in the hardware section. She has completed her Masters in Advanced Electronics and Communication Engineering, specialised in VLSI from Govt. Engineering College, Kottayam, Kerala. Her research interests include Signals and system, FPGA and Cadence design & Integrated circuit and systems.

### Priscilla Grace George

Priscilla Grace George joined in the Chemical Engineering Department of IIT Madras as a Senior Project Associate for the project titled- “Evaluating and Enhancing the overall Reliability of a Submarine Sonar System using RBD, FMECA and Eye-tracking”. She is also doing a part-time research in the field of security risk assessment at Cochin University of Science and Technology, Kerala. Prior to this, she was working as an Assistant Professor in Muthoot Institute of Technology and Science, Kerala. She is a post-graduate in Electronics and Communication Engineering with specialization in Optoelectronics and Communication Systems.

## Haritha V.H

Haritha is a doctoral student at the Department of Management Studies, IIT Madras. She has completed M. Com in Finance from Central University of Karnataka and B. Com from MG University, Kerala. She has qualified Junior Research Fellowship in Commerce and was a University Rank Holder during her Post Graduation. Her research focuses on alternate approaches for valuing start-ups.

## Darpan Krishnakumar Shukla

Darpan Krishnakumar Shukla is a Post Doctoral Researcher (Selection) at Department of Chemical Engineering, Indian Institute of Technology Madras (IITM). He is working on “Evaluating and improving the overall reliability analysis of submarine sonar system using RBD, FMECA and Eye-tracking”. He has received his PhD with Department of Atomic Energy's Doctoral Fellowship (DDFS) from Homi Bhabha National Institute, Mumbai at Indira Gandhi Centre for Atomic Research, Kalpakkam on “Study of advanced methods for reliability analysis of digital I & C systems”. His research interests are applied probability, data analysis, hierarchical modeling, Monte Carlo simulation, electronic reliability and safety.





## Dr. G. Saravanan

Dr. G. Saravanan received his PhD from IIT Madras in 2021. Before joining PhD, he obtained Master's and Bachelor's degrees in Mathematics, from Anna University Chennai and Manonmanium Sundaranar University Tirunelveli respectively. His current research area includes Mathematical Models, Liquid Sloshing Dynamics, Wave-Structure Interaction and Computational Fluid Dynamics.

## Dr. Jayanand Sudhir

Dr. Jayanand Sudhir completed his MCh Neurosurgery and Post-doctoral fellowship in Cerebrovascular neurosurgery from Sree chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum. He is currently an Associate Professor in the Department of Neurosurgery at SCTIMST. His is subspecialized in vascular diseases of the brain including aneurysms, arteriovenous malformations, moya moya disease and stroke; and has research interests in computational simulation of aneurysms and other vascular pathologies.

## Staff

### Sudha Madhusudhanan

Sudha Madhusudhanan is a Post Graduate in Public Administration from University of Madras, having a vast experience in managing team and office.

She is now working as Lab Manager in DART Lab.





# Summary of Projects

| Title | PI Names | Collaborators | Starting Date | Ending Date |
|---|---|---|---|---|
| Improving active learning performance in the context of human heuristics and biases | Prof. Nandan Sudarsanam | | January 2020 | February 2022 |
| Human-in-the-loop Analytics for Operator Learning: Knowledge Assessment through Eye Tracking | Prof. Babji Srinivasan | | January 2020 | December 2021 |
| Upward voice decisions under felt uncertainty and psycho social risks. Role of emotion regulation | Prof. Lata Dyaram | - | September 2020 | August 2022 |
| Prediction of Preterm Risk using Uterine Contractions | Prof. S. Ramakrishnan | - | September 2020 | August 2022 |
| Visualizing Robust and Highly reliable designs using Interpretable Self Organizing Maps | Prof. Palaniappan Ramu | - | September 2020 | August 2022 |
| The role of aging in grasping objects that are challenging to grasp – study of behavior and neural correlates | Prof. Varadhan SKM | - | September 2020 | August 2022 |
| An online tool for analyzing human interactions with advanced process control architecture: Development and Benchmarking | Prof. Niket Kaisare | - | September 2020 | August 2022 |
| Effects of decision fatigue on the online checkout process | Prof. Rahul R. Marathe | | September 2020 | August 2022 |
| DART Behavioral Lab | Prof. Rajagopalan Srinivasan | | December 2020 | March 2025 |
| Development of a collision warning system using Explainable AI for Indian Urban Traffic | Prof. Arun K. Tangirala | | October 2021 | September 2022 |
| Indian Dataset for automatic facial emotion recognition | Prof. Babji Srinivasan | | October 2020 | December 2023 |
| Modeling hydrogen explosions for improving hydrogen safety | Prof. Vagesh D. Narasimhamurthy | - | January 2022 | December 2022 |
| Alternate Approaches for Valuing Start-Ups: Investigating The Effectiveness Of Risk Neutral And Cascade Neural Network Approaches | Prof. P. Krishna Prasanna | Prof. Thillai Rajan (DOMS) | January 2022 | December 2022 |
| Identifying the Risk Perception of Plant Operators during Accidents using Virtual Reality | Prof. Rajagopalan Srinivasan | Prof. Babji Srinivasan (AM) | January 2022 | December 2022 |
| Investigating the use of iSOM for time series analysis | Prof. Palaniappan Ramu | - | January 2022 | December 2022 |
| Rupture Risk prediction of intracranial aneurysms using big data | Prof. Prasad Patnaik | Dr. Jayanand Sudhir B | January 2022 | December 2022 |
| Experimentation on digital learning platforms to optimize learning outcomes | Prof. Nandan Sudarsanam | - | January 2022 | December 2022 |

# Related Projects

| Title | PI Names | Collaborators | Starting Date | Ending Date |
|---|---|---|---|---|
| Cost Effective Eye Tracking Approaches to Analyze Human-Machine-Interface in Nuclear Power Plants (The Board of Research in Nuclear Sciences (BRNS)) | Prof. Rajgopalan Srinivasan, Prof Babji Srinivasan | - | August 2020 | July 2022 |
| Evaluating and improving the overall reliability of submarine sonar system using Reliability Block Diagram (RBD), Failure Mode, Effects, and Criticality Analysis (FMECA) and Eye tracking (Naval Physical & Oceanographic Laboratory (NPOL)) | Prof. Rajgopalan Srinivasan, Prof Babji Srinivasan | - | November 2021 | November 2023 |
| Human-in-the-loop for Safe and Verifiable Reinforcement Learning. | Prof. Nirav Bhatt | - | January 2021 | January 2022 |
| Ethical and Explainable AI in Fintech applications | Prof. Arun Rajkumar | - | January 2021 | January 2022 |






# Ongoing Projects

## Rupture Risk prediction of intracranial aneurysms using big data

Principal Investigator: Prof. Prasad Patnaik

Intracranial aneurysm (ICA) is an abnormal dilation of the artery in the brain, which results in the gradual weakening of the arterial wall in the cerebral circulation (notice a typical MCA: middle cerebral artery aneurysm in the Figure-1). The risk of its rupture is life threatening and needs clinical intervention, which is neither too early nor too late. They are generally detected using imaging modalities such as, CT- Angio, MRI, DSA etc. Patient-specific assessment of risk using Computational Fluid Dynamics aided simulations can be beneficial to the clinician. Such as assessment can help clinicians and neurosurgeons to co-relate the significance of various morphological and hemodynamic parameters with the rupture-risk assessment.

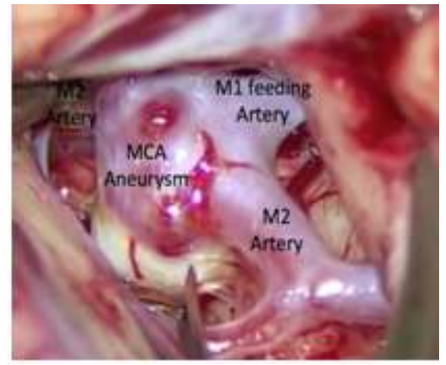



*Figure-1: Cerebral Aneurysm (middle cerebral artery (MCA))*

Typical sequence of the predictions using OpenFoam based CFD tools is shown below.

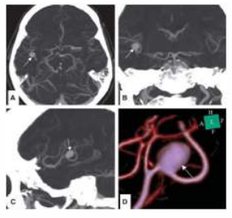
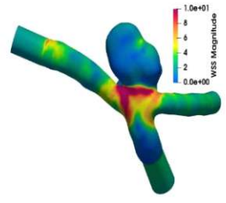
| CT-Angio DICOM DATA | 3D Extracted Model | CFD Simulation |
|---|---|---|
|  |  |  |



*Figure-2: Various stages of work flow*

Our research group in collaboration with SCTIMST, Thiruvananthapuram is further engaged in classifying this data of ruptured and un-rupture aneurysms to facilitate patient-specific predictions using machine learning algorithms and methodologies are in progress. The inputs for these models include population cohorts studies, morphological parameters as well as CFD based simulations.

# Time series analysis using Interpretable Self Organising Maps

Principal Investigator : Prof. Palaniappan Ramu

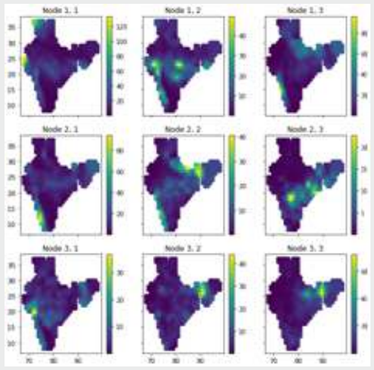
## Dataset

Daily rainfall over 428 geographical locations across India, from 1951 to 2008 (21885 days).

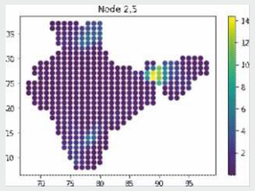
A SOM of 8X8 grid is setup for training. Each SOM node will have weights of dimensions equal to the number of geo-locations in the data set.

## Analysis of Time Series using Self-Organising Maps

SOM has been conventionally used in Time Series Analysis to capture recurring patterns. In our data set, the most frequent rainfall patterns over India are captured using SOM maps of different grid sizes. A sample 3x3 trained SOM map is shown in Figure-3.




It was seen that the node (2,5) was the most active as shown below.




The inference is that for the period 1951-2008, a pattern suggesting low rainfall over most of central India and moderate rainfall over some parts of north-east, southern and northern India was dominant.

*Figure-3: A 3x3 SOM grid capturing different rainfall patterns*

## Analysis of Time Series Data with iSOM:

The same data was studied with iSOM, iSOM was setup to study the variation of statistical properties of the time series data are captured geographically as well as in a temporal sense.

In Figures-4 (a) and 4 (b), the variation of mean and standard deviation of rainfall is captured by iSOM as a function of Latitude, Longitude, Altitude and year.

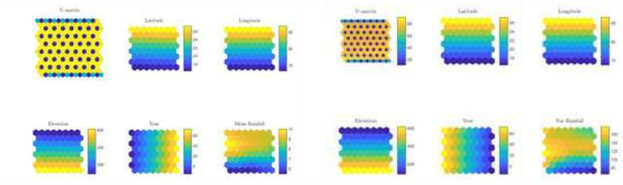


*Figure-4 (a): iSOM component plane strained with mean rainfall for a given node per year.*

*Figure-4 (b) : iSOM component planes trained with standard deviation of rainfall for a given node per year.*

It can be seen that, the variation in mean rain fall over the geo-locations have decreased in 2008 as compared to 1951. The standard deviation also shows a similar trend.

## Summary

We are studying the applicability of iSOM to capture the inherent trends in time series patterns and changes to compare them quickly and visually. Also, the study focuses on introducing additional covariates of a Time Series to study their relationships.





# Modeling hydrogen explosions for improving hydrogen safety

Principal Investigator : Prof. Vagesh D

Hydrogen as an energy carrier will be important to meet global energy demand. However, loss of containment of compressed or cryogenic hydrogen (due to human error or material degradation / embrittlement) is a serious safety concern. Hydrogen is highly reactive and easily ignitable, and accidental fires and explosions represent a serious hazard, especially in confined and congested fields. A computational fluid dynamic (CFD) and porosity/distributed resistance (PDR) based numerical modelling is being followed to assess such explosion hazards.

Before proceeding with the hydrogen explosion simulations, the sub-grid turbulence and combustion models in the open-source software PDRFOAM is first validated against Methane-air explosion experiments of British Gas. Following this, hydrogen combustion modelling in PDRFOAM is under progress, where the European Commission funded HySEA project 1 will be used for model validation and analysis.

# Upward voice decisions under felt uncertainty and psychosocial risks: Role of emotion regulation

Principal Investigator : Prof. Lata Dyaram

## Summary

Employee voice entails challenging the status quo and highlighting issues and concerns; hence, though it can benefit organizations, it may elicit negative repercussions for employees. Members tend to maintain equilibrium and resist change as voice can be inherently risky given associated perceived risks and uncertainty. We, thus, examined organizational uncertainty and risk to factor in the predicament posed by voice.

## Background of the project

As organizations face turbulent changes and disruptive business environment, there is a tremendous impetus in ensuring stability while enhancing adaptability by encouraging organizational members to contribute in the functioning of firms. Such contributions in the form of issue identifications, suggestions, and innovations are known to flow through employee voice. However, members tend to maintain homeostasis and resist change as voice can be an inherently risky decision given psychosocial risks and uncertainty at the work place. While contextual facets of positive and negative workplace climate have been examined, the role of uncertainty and risk at the work place are understudied in the context of voice. Further, given the perceived uncertainty and risk, it is unclear whether and to what extent does emotion regulation influence the decision to voice.

In our project, we propose to utilize skin conductance response (SCR), as the physiological indicator of emotional regulation, while the respondents make the decision to voice in simulated scenarios of political uncertainty and psychosocial risk. We propose two studies, one where study subjects will decide to voice in politically uncertain organizations and second where the decision to voice will be taken in the context of psychosocial risk at the workplace. We intend to examine the role of emotion regulation in both the studies in the link between perception of politics and psychosocial risk on the decision to voice.

## Objectives

- To analyze whether and how politically uncertain work environment and emotion regulation influence the decision to voice.
- To analyze whether and how psychosocial risk at work and emotion regulation influence the decision to voice.

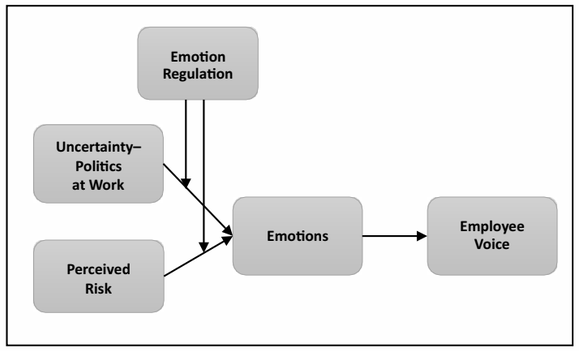



*Figure-5: Research frame work*





## Study Design

We conducted two studies, drawing on virtual reality simulation, first with perception of politics and the second with psychosocial risk as predictor variables for voice decision. We utilized external and non-intrusive electrodermal activity (EDA) and analysed skin conductance response (SCR) as indicator of emotion arousal through BIOPAC nomadix. The study design was between subjects, with each participant responding to one of the conditions for simulated perception of politics (high or low) and psychosocial risk (high or low) at work for voicing. Sample participants for the study were working professionals from varied service sector firms.

- The sample for the study was working adults in the age group of 24-53 years.
- The characteristics of the sample was a non-clinical sample.
- Executives from service sector firms with a functional knowledge of English were recruited for the study.
- To encourage participation, we donated Rs. 100 per participant to a charitable organization.
- Those who consented to participate in the study filled out a consent form. Post participant submission of informed consent, they were invited for the study and randomly assigned to a study condition.


*Figure-6: Study participant with (A) VR headgear and EDA setup (B) Palmar electrodes (C) Biopac nomadix wristband.*

## Method

- We sampled data from 240 working professionals at American Express Lab for DART.
- Participants were shown organizational scenarios in virtual reality.

## Key Findings

- Uncertainty in organizations such as that created by politics and perceived risk of voicing engenders negatives emotions.
- Negative emotions debilitate employee voice.

## Voice

- Emotion regulation in terms of expressive suppression/cognitive reappraisal and emotion arousal can mitigate the felt effects of uncertainty and perceived risks of voicing.

# Alternate Approaches for Valuing Start-Ups: Investigating the Effectiveness of Risk Neutral and Neural Network Approaches

Principal Investigator: Prof. P. Krishna Prasanna

## Purpose and Objective

The Startup firms are financed by business angels, venture capitalists and even by private equity firms in later stages. The empirical research on investment in start-ups is limited due to the private fragmented nature of the data. Generally due diligence, internal rate of return estimation and relative judgement based on personal instincts determine the investment decisions. This existing approach of determining a risk-adjusted rate relying on circumstances has proved to be futile and results in foggy estimation of growth rates. Incorporation of a model or a combination of models that estimates an appropriate risk-return profile of the firm is required in order to address this requirement. The challenge in the scientific valuation emerges from lack of information about their asset prices. The market value of their assets is available only at discrete time intervals as and when they proceed with the next stage of financing. Given this nature of data, the theoretical adherence of a discrete-time binomial model is widely recognized as suitable and calls for an empirical analysis of the same. Hence, this project intends to conduct an empirical analysis of the risk and return profile of start-ups in the Indian scenario using a risk-neutral model and support it with the findings of the neural network model. The study tries to make an effective comparison of alternate models to ensure that the most appropriate alternative is identified. The identified model can be used for effective risk analysis and managerial decision-making of investment proposals of startup firms.

## Work in Progress

- A list of 1002 start-up companies has been identified which matches the criteria of being incorporated after 2010 and has acquired minimum two rounds of financing.
- We have identified required variables and in the process of procuring the required data for the analysis.

The following data has been collected from YNOS data base

- Funding and Investor information for each round of financing
- Nature of funding entity at each stage – Business Angel /Venture Capital / Private Equity
- Number of Investors for each round of financing
- Shareholding Pattern (Control Rights)
- Funding Round – Series A/B/C

**We are in the process of sourcing the following data from a paid data base**

- Firm value at every stage of funding (either pre-money or post-money).
- Firm Value at the end of every financial year.
- Income Statement and Balance sheet for every Financial Year end (from inception till date).
- Exit events – details of investors who exit, date, amount and exit route (M&A, IPO).





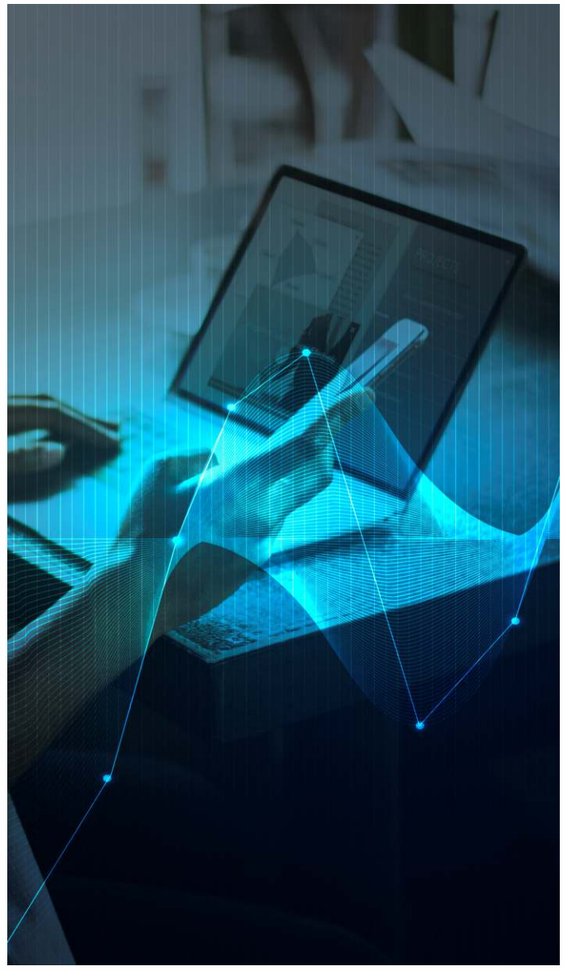
# An online tool for analyzing human interactions with advanced process control architecture: Development and Benchmarking

Principal Investigator: Prof. Niket Kaisare

## Summary

Model predictive control (MPC) is a leading advanced control technique in the process industry. MPC is a multivariate control technique, which uses future predictions of a model, rather than only the past behavior, to compute the control actions. Since MPC algorithm is often a black-box, its control actions are counter-intuitive. Hence, the plant operators often turn-off the MPC, especially during periods of large disturbances or faults. While this problem is acknowledged in the process industry, we intend to replicate this in a controlled environment for an academic study. To this end, this project focuses on developing a framework and corresponding methodology for analyzing the interactions between human operators and MPC-based control system.

During the first part of the project, a model for a multi-unit system, the hierarchical control layers, and a graphical user interface (GUI) was built using MATLAB. This was tested with a small number of individuals to get initial data. However, for a wider deployment, we recently completed the development of a web-based platform so that the analysis of human-machine interactions can be done remotely. In addition to the system, controller and GUI, we also incorporated a web-cam based eye tracking technology to capture additional information about the operator's behavior when interacting with the platform. The system performance, user actions and eye-gaze location data are all collected and the initial benchmarking exercise has been completed. We are currently generating data with multiple users, which will help in understanding the interactions between operators and GUI for advanced control. Furthermore, the proposed framework could also be extended to analyze GUI enhancements as well as aid the development of effective operator training programs.



# Development of a Collision Warning System using Explainable AI for Indian Urban Traffic

Principal Investigator : Arun K Tangirala

## Summary

This project aims to develop an explainable AI / ML - based methodology for driver and vehicle safety to provide safety alert to drivers in Indian urban traffic conditions. The 3D LIDAR (Light Detection and Ranging) measurements, that provides accurate representation of surrounding in the form of point cloud and onboard camera feeds are the primary sensors for data acquisition. In the paradigm under consideration, the AI / ML module can provide a warning and possible solution (on the steering direction and speed) to the human in the loop. This is in the spirit of explainable AI as against a fully automated decision-making system driven by AI that would take over the vehicle bypassing the driver. Moreover, the goal is to develop affordable technology that requires minimal instrumentation onboard and especially focus on Indian traffic conditions that are characterized by heterogeneity and lane indiscipline. The inputs to the algorithm are the LIDAR point cloud (as a function of time), onboard camera feeds, and optionally the On-Board Unit data (with GPS and/or accelerometer), while the outputs are the distance between the leading vehicle(s) and the vehicle of interest, potential conflict possibility, and the path to be taken by the vehicle. This will require processing of point cloud to detect the objects of interest (that can cause potential collision), accurate prediction of the path of the vehicle under consideration, model to derive conflict probability, safe vehicle following behaviour as possible solution, and estimating the traffic condition in the vicinity of the vehicle to explain the possible cause of the potential conflict. The above tasks will use widely varying solution techniques from ML and AI for point cloud, image processing, path prediction, microscopic traffic flow theory-based car following models, and estimation techniques.

## Progress

As part of the project a 16-channel LIDAR has been procured. The traffic data collection is conducted by using LIDAR and camera onboard a car. The processing of the point cloud data for segmenting unwanted regions like ground and clustering the objects of interest was carried out. The objects were classified by using the dimensions and point distribution features to an explainable classifier. Using multi object tracking framework the objects of interest are tracked, their velocity and future trajectory is predicted. Derivation of host vehicle trajectory, prediction of conflicts and suggestion of safety measures are the tasks planned for the remainder period.





# Indian Dataset for Automatic Facial Emotion Recognition

Principal Investigator : Prof. Babji Srinivasan

## Summary

Typically, Facial Emotion Recognition Systems (FERs) are developed using deep neural networks that process the facial images from video frames and provide various facial features (pertaining to face, eyes, head posture, etc.). These features are subsequently utilized to identify emotional state (using Facial Action Coding System and eye gaze data) of the person which include: attention, distraction, boredom, confusion, calmness, etc. However, these studies are typically not carried out in a dynamic work environment (such as industrial control rooms, air traffic control rooms, etc.). Further, most of the existing facial emotion recognition deep networks utilize Caucasian datasets and there are hardly few works that utilize Indian facial images to identify the emotional state of humans in their dynamic work environment. Therefore, this project seeks to: systematically utilize existing FER networks and associated algorithms to extract emotional state of Indians in their dynamic work environment. To achieve this objective, we plan to conduct experiments in which the participant will be performing a task using a display (such as computer screen), similar to a task performed by a Human operator in a process industry. The participants will be provided training (in the form of short video) before performing the task. During the task we will collect various facial features from the participant which will be subsequently utilized by various FER network and associated algorithms to identify the emotional state of the participants. The identified emotional state of the participant will be correlated with their task performance which will help validate the results obtained from the algorithms. If successful, results from this study can be then extended to identify the emotional state of humans in their work environments which can then be utilized to develop appropriate interventions to improve their performance.

## Objectives

1. **Systematic Evaluation of existing facial emotion recognition networks:** We plan to test the existing popular FER networks such as MIMAMO net on existing Indian dataset such as Indian Spontaneous Expression Database (comprising of 428 video frames).

2. **Development of an online platform to conduct experiments:** We plan to develop an online platform following standard ethical practices to collect data from various participants. Using this platform, we plan to collect approximately 500,000 video frames from around 200 participants.

3. **Design of Experiments:** For experiments, we will include only participants who are frequent computer users (for work and/or recreation). We plan to conduct experiments in which the participant will be performing a task, similar to a task performed by a human operator in a process industry. The task will not evoke various extreme emotions and we are only interested in observing states which include: attention, distraction, boredom, confusion and calmness.

4. **Development of Labelled dataset:** We plan to acquire feedback about the emotional state of the participant for each video watched by them. We will then use an online annotating tool and employ multiple annotators to annotate the frames in each video. This dataset will then be utilized to evaluate the existing FER networks based on various metrics such as F1 score, accuracy. etc. This labelled dataset will be a major outcome of this project which can be used to build facial emotion recognition networks for Indian population.

## Work Progress

1. **Experimental Studies:** We have obtained institute ethical clearance in April 2022 and have conducted experiments using various participants from IIT M. We have developed a platform to obtain video frames of participants during emotion recognition experiments. Facial emotion data was obtained from 45 participants using video clips that was designed to express six emotions (Sadness, Joy, Contempt, Disgust, Fear and Surprise). A total of 405 video clips were collected from the experiment.

2. **Evaluation using existing FER:** We have evaluated the collected experimental dataset using Affectiva©, a commercial software that provides information about human emotions using deep neural networks. Our preliminary studies using this software, indicate that the accuracy of the system (measured with regard to the one reported by the user and the video clip) varies between 55%– 60% and the system recognized joy and disgust better compared to other emotions.

3. **Studies using Micro expression recognition algorithms:** Currently, we are trying to integrate the results from commercial emotion recognition system with various micro expression recognition algorithms such as MIMAMO net to improve the accuracy of the FER.

4. **Development of Labelled data set:** We are planning to conduct new experiments using our developed platform in which the participant will be performing a task, similar to a task performed by a human operator in a process industry. The task will not evoke various extreme emotions and we are only interested in observing states which include: attention, distraction, boredom, confusion and calmness. We will then use this dataset with our FER to identify emotions. This dataset will also be labelled by the participants to evaluate the accuracy of FER systems.





# Events

In its second year, DART Lab conducted the 2nd Symposium on Data Analytics, Risk & Technology during 23-25 September 2021 in collaboration with Robert Bosch Centre for Data Science and AI at IIT Madras. A wide range of eminent speakers from industry and academia addressing themes which were spread across cognitive sciences, risk in operations & supply chain, and human-allied AI & decision-making. In addition to exciting talks, we also arranged break-out interaction sessions with the speakers, a tutorial session on the use of biosensors like eye tracking devices and student presentations of ongoing work at IIT Madras. The list of speakers are as follows.

**Dr. Madhav Durbha**
Coupa Software, USA

**Prof. Jhareswar Maiti**
Indian Institute of Technology Kharagpur

**Mr. Srikanth Mangalam**
Coupa Software, USA

**Prof. Sriraam Natarajan**
University of Texas, Dallas

**Prof. Rick Thomas**
Georgia Institute of Technology, Atlanta

**Dr. Di Xu**
American Express

**Dr. Shanqing Yin**
KK Women's & Children's Hospital, Singapore

**Prof. Denny Yu**
Purdue University, West Lafayette






# Research Facilities

Behavioural Science plays a crucial role across disciplines DART Lab is setting up a state-of-the-art facility for experimental studies of individual and team behaviors. This would enable us to collect primary data in a broad range of disciplines such as marketing, operations, biology, psychology, sociology, social neuroscience, and economics. The lab is equipped with a broad range of sensors for biometric (eye-trackers) and physiologic parameters such as electroencephalogram, Electrodermal activity, and Photoplethysmography.

## Eye Tracking

The DART Lab has procured Smart Eye Aurora which works with different screen sizes and variances in ambient lighting conditions. Smart Eye Aurora is compatible with glasses, contact lenses, and non-IR blocking sunglasses. Data output is available in real time or as a log file, and records eye position, gaze intersections, pupil diameter, saccades, fixations, blinks, eyelid opening, and more. It has a sampling rate of 30 Hz, 60 Hz, & 120 Hz with a headbox (freedom of head movement) of 50cm x 40cm at 50-80cm distance and Head Tracking Accuracy that is Rotation of 0.3 degrees. In addition to the Smart Eye Aurora. DART Lab is also developing its own in-house eye tracker. Most studies use hardware-based solutions that are expensive and obtrusive for the user. We propose to develop a framework for acquisition and analysis of multiple monitor-based eye tracking data. The images collected from this hardware setup are processed by a set of algorithms developed for face, eye and pupil detection. We have also developed application software to analyse the gaze position and pupil diameter to get insights into the cognitive behaviour of control room operators.

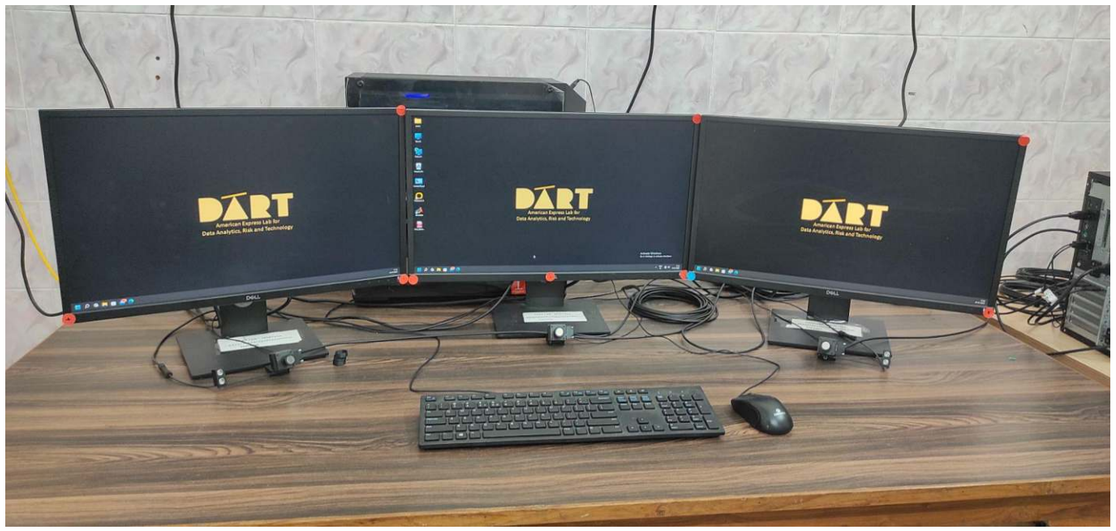



*Figure-7: Smart Eye Aurora integrated with a multiple monitor setup*

### Biopac Nomadix System

We have procured Biopac Nomadix which is a portable, wireless biosensor system that can be used to assess a person's emotional state by measuring physiological signals such as heart rate, skin conductance, and respiration. These signals can be used to infer emotional arousal and provide insights into a person's emotional state in real-time. The Nomadix system can be used in a variety of settings, including research studies, clinical assessments, and consumer applications. Additionally, the system is easy to use and can provide reliable and valid data, making it a valuable tool for assessing emotions.

### Virtual Reality Setup

The Oculus virtual reality device, procured by the DART Lab, is a headset that uses advanced technology to create immersive virtual reality experiences. The device's dual OLED displays and precise head-tracking capabilities provide users with a highly realistic and lifelike experience. The Oculus also features built-in speakers and a microphone, allowing for real-time communication with other users in a virtual environment. The device is compatible with a wide range of VR content, including games, educational experiences, and social media apps. Additionally, the Oculus platform allows for the creation and distribution of VR content, making it a powerful tool for research, education, and professional applications.

### Electroencephalography

Electroencephalography (EEG) involves the measurement of electrical activity of the brain using electrodes which are placed on the scalp. Electrical activity is the result of neural-oscillations occurring in the brain due to fluctuations in excitability of neurons in response to stimuli. Studies involving EEG aim to understand how different cognitive functions such as memory, perception, emotions, behaviour, monitoring and control are supported or implemented by the electrical activity from the neural populations of the brain. This electrical activity can be recorded from the scalp using EEG devices which contain electrodes that are placed on the scalp.

*Figure-8: A participant's galvanic skin resistance (GSR) and Photoplethysmography (PPG) acquisition being done using Biopac system while he is experiencing a virtual reality*

*Figure-9: A participant experience virtual reality*





# Education

A number of courses related to analytics and risk are currently being offered to educate students on topics directly relevant to the goals of DART Lab. The two illustrative examples are Introduction to Data Analytics & Process Safety. Details of the courses are as follows.

### Introduction to Data Analytics

The aim of the course is to make students better understand data, which will help students understand the world better and enable them to make better, data driven decisions. This course seeks to present students with a wide range of data analytic techniques and is structured around the broad contours of the different types of data analytics, namely, descriptive, inferential, predictive, and prescriptive analytics. The content of the course is as follows:

- Probability Distribution & Inferential Statistics
- Machine Learning
- Supervised Learning
- Associate Rule Mining & Big Data
- Clustering Analysis & Predictive Analytics

### Process Safety

The course focuses on understanding the important technical fundamentals of chemical process safety. The emphasis on the fundamentals will help the student to understand the concepts and apply them accordingly. The course focuses on assessing hazards in manufacturing plants as well as learning lessons from incidents and accidents. Major topics covered in the course are:

- Toxicological Studies
- Prevention of Fire and Explosion
- Source model and dispersion
- Hazard Identification, HAZOP analysis
- Risk Assessment 4 Reliability Engineering
- Economics of loss prevention

# Publications

## Journals

1. Banuvathy, Rajakumar, and S. K. M. Varadhan. ***"Distinct behavior of the little finger during the vertical translation of an unsteady thumb platform while grasping."*** Scientific reports 11, no. 1 (2021): 1-12.

2. Nagar, Deepak, Palaniappan Ramu, and Kalyanmoy Deb. ***"Interpretable Self-Organizing Maps (iSOM) for Visualization of Pareto Front in Multiple Objective Optimization."*** In International Conference on Evolutionary Multi-Criterion Optimization, pp. 645-655. Springer, Cham, 2021.

3. Shahab, Mohammed Aatif, Mohd Umair Iqbal, Babji Srinivasan, and Rajagopalan Srinivasan. ***"Metrics for objectively assessing operator training using eye gaze patterns."*** Process Safety and Environmental Protection 156 (2021): 508-520.

4. Bhakte, Abhijit, Venkatesh Pakkiriswamy, and Rajagopalan Srinivasan. ***"An explainable artificial intelligence based approach for interpretation of fault classification results from deep neural networks."*** Chemical Engineering Science 250 (2022): 117373.

5. Rajakumar, Banuvathy, and S. K. M. Varadhan. ***"Comparable Safety Margins of the Ulnar Fingers When the Thumb Remains on an Unsteady Slider."*** In Recent Advances in Applied Mechanics, pp. 261-274. Springer, Singapore, 2022.

6. Shahab, Mohammed Aatif, Mohd Umair Iqbal, Babji Srinivasan, and Rajagopalan Srinivasan. ***"HMM-based models of control room operator's cognition during process abnormalities. 1. Formalism and model identification."*** Journal of Loss Prevention in the Process Industries 76 (2022): 104748.

7. Shahab, Mohammed Aatif, Mohd Umair Iqbal, Babji Srinivasan, and Rajagopalan Srinivasan. ***"HMM-based models of control room operator's cognition during process abnormalities. 2. Application to operator training."*** Journal of Loss Prevention in the Process Industries 76 (2022): 104749.

8. Srinivasan, Babji, Mohd Umair Iqbal, Mohammed Aatif Shahab, and Rajagopalan Srinivasan. ***"Review of virtual reality (VR) applications to enhance chemical safety: from students to plant operators."*** ACS Chemical Health & Safety (2022).





# Publications

## Conference presentations and publications

1. Patil, Parag, Babji Srinivasan, and Rajagopalan Srinivasan. ***"Optimization of cleaning schedule of heat exchanger networks undergoing fouling considering maintenance constraints."*** In 2021 AIChE Annual Meeting, Boston, USA. American Institute of Chemical Engineers, 2021.

2. Shahab, Mohammed Aatif, Babji Srinivasan, and Rajagopalan Srinivasan. ***" Objective Assessment of Operator Training using Correspondence Analysis of Physiological and Behavioral Measures."*** In 2021 AIChE Annual Meeting, Boston, USA. American Institute of Chemical Engineers, 2021.

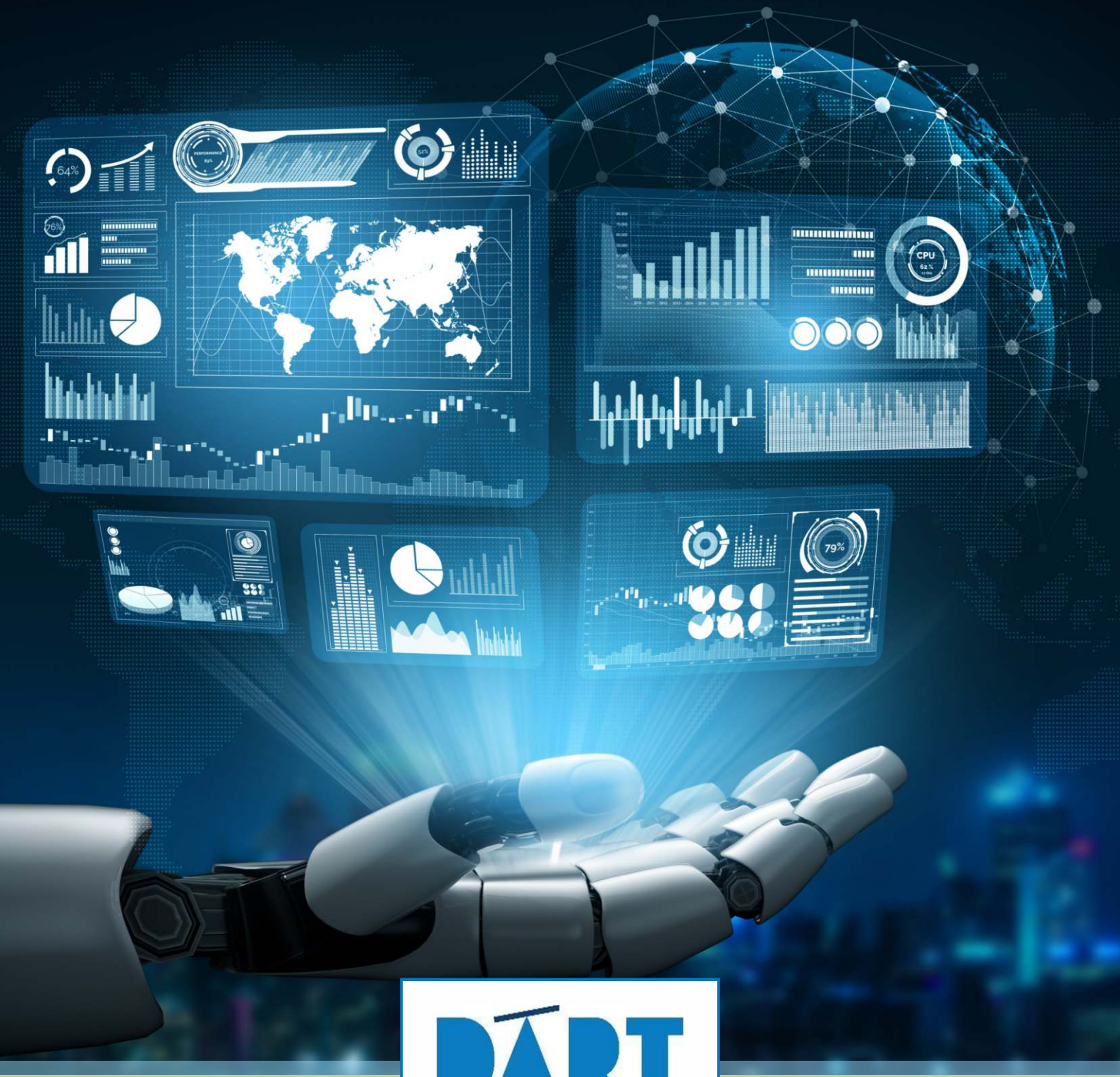
3. Shahab, Mohammed Aatif, Babji Srinivasan, and Rajagopalan Srinivasan. ***"Analysis of Control Room Operators' Competence using Cognitive Engineering Approaches to Improve Process Safety."*** In 2021 International Conference on Maintenance and Intelligent Asset Management (ICMIAM), pp. 1-6. IEEE, 2021.

## In Press and accepted for publications

1. Rajakumar, Banuvathy, and S. K. M. Varadhan. ***"Evidence to support the mechanical advantage hypothesis of grasping at low force levels."*** (Under review in Scientific Reports, 2022).

2. Rajakumar, Banuvathy, Swarnab Dutta, and S. K. M. Varadhan. ***"Validity of Mechanical advantage hypothesis of human grasping depends on the nature of task difficulty."*** (Under review in Scientific Reports, 2022).

3. Shahab, Mohammed Aatif, Babji Srinivasan, and Rajagopalan Srinivasan. ***"Self-Organizing Map Based Approach for Assessment of Control Room Operator Training."*** (Accepted for Publication in Computers Aided Chemical Engineering, 2022).




DART
AMERICAN EXPRESS LAB FOR
DATA ANALYTICS, RISK & TECHNOLOGY

**Data Analystics, Risk & Technology (DART)**
Indian Institute Of Technology Madras, Chennai-600036. Tamilnadu, INDIA.
https://dart.iitm.ac.in/

**Follow us on:**

IITM_Facebook IITM_Instagram IITM_Twitter IITM_Linkedin IITM_Youtube