MHRD Govt. of India

GIAN GLOBAL INITIATIVE OF ACADEMIC NETWORKS

A

Course

on

Physics-Aware Deep Learning

February 10-21, 2025

Organized in *offline* Mode at

PDPM IIITDM JABALPUR

PDPM Indian Institute of Information Technology, Design and Manufacturing, Jabalpur, India

Course Overview

Recent advancements in deep learning have enabled machines to identify patterns and generate text and images that resemble human creations. These developments extend beyond the realm of computer and data science, infiltrating various physical science disciplines such as mechanical, aerospace, industrial and manufacturing engineering, materials and chemical engineering, physics, chemistry, biology, and medical sciences. As a result, they facilitate activities like extensive data gathering, automated experiments, data-driven physics modelling, and more. However, a significant gap exists between advancements in deep learning and the physical world's fundamental principles. Neural network predictions often overlook physics laws and boundary conditions, leading to the emerging field of physics-aware deep learning, which aims to incorporate physics knowledge into neural network predictions.

This course covers a range of state-of-the-art techniques for integrating physics insights into the design, training, and inference of neural networks. The topics include deep neural network basics, Koopman operator theory and operator learning, reduced-order modelling, physics-informed neural networks, neural operators, physics-aware recurrent convolutions, and generative AI.

The course aims to develop an understanding of methods for infusing physics knowledge into deep neural networks, with a focus on current research. Through lectures supplemented by intensive reading and in-depth discussions, students will gain theoretical knowledge and practical skills in building physics-aware networks using Python libraries like PyTorch. A background in linear algebra, multivariate calculus, undergraduate-level statistics, probability, and programming is recommended.

The Course Instructor

Dr. Stephen Baek is an Associate Professor of Data Science at the University of Virginia, with an additional courtesy appointment in Mechanical and Aerospace Engineering. He received B.S. (2009) and Ph.D. (2013) in Mechanical and Aerospace Engineering from Seoul National University (SNU), with his award-winning study on the statistical space of human body shapes modeled in Riemannian manifolds. After postdoctoral research at the Institute of Advanced Machines and Design at SNU, he joined the University of Iowa in 2015 as an Assistant Professor of Industrial and Systems Engineering. He moved to the University of Virginia in 2021. His research interests include geometric data analysis, deep learning, and data-driven design, with significant publications in machine learning applications for materials design and cancer prognosis. Recipient of many honors and awards, Dr. Baek founded two startup companies specializing in computer vision and artificial Authentication (VGA). Currently, he is serving as a scientific advisor of Inseer and CTO of Mantis Grading.

Topics to be Covered

This course will cover the following topics:

Types of ML problems in physical sciences, Introduction to deep neural network building blocks and architectures.

Learning Nonlinear Dynamics and Manifold Learning: Dynamical systems, Koopman operator theory, proper orthogonal decomposition, Dynamic mode decomposition, Computing principal modes of flow in PyTorch, PyDMD package.

Neural Ordinary Differential Equations: Nonlinear dynamics identification – SINDy; Autoencoders – LaSDI, gLaSDI, GPLaSDI, SINDy and Autoencoders in PyTorch, Jacobian-vector products and the dynamics on latent space.

Physics-Informed Neural Networks: Modelling ODEs with neural networks, Neural ODEs - Autodiff and adjoint method, Modelling spring-mass-damper systems with neural networks, Neural ODEs in PyTorch.

Neural Operators: Discretization and finite difference, Solutions of PDE, Autodiff and PINN loss, Collocation points, Predicting heat diffusion with PINN, Adaptive Fourier neural operators, Deep-O Net, Physics-informed neural operators.

Physics-Aware Recurrent Convolutions (PARC): Darcy flow with Fourier neural operators, Principles of PARC and its generalization on different operating conditions (PARCel), Diffusion dominant PARC vs Advection/ reaction terms (PARCv2), Modelling extreme materials using PARC.

Deep Generative Models and Digital Twins: GAN, Conditional GAN, Diffusion models, Physics-inspired diffusion models, Material microstructure modelling using GAN.

Graph and Manifold CNNs: Graph spectra; Graph CNNs; Introduction to Manifolds; Manifold CNNs, Lung airflow modelling using graph PARC.

For more information, please contact

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Prof. Puneet Tandon
9425324240

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Who can Attend

Graduate and advanced undergraduate students in Mechanical Engineering, Design and Manufacturing, Materials Science and Engineering, Chemical Engineering, Civil and Construction Engineering, Physics, Chemistry, and other relevant disciplines.

Faculty members and researchers from reputed institutions, engineers and researchers from manufacturing organizations, corporate research centres, national laboratories, government agencies, and similar sectors.

Course Coordinators

Prof. Pritee Khanna is a Computer Science and Engineering professor at PDPM IIITDM Jabalpur, India, with over 24 years of experience in academia, research, and administration. Her research focuses on image processing and computer vision. She earned Ph.D. in Computer Science from Kurukshetra University and has research experience at Tokyo Institute of Technology through JSPS Fellowship. She serves as an Associate Editor for Engineering Applications of Artificial Intelligence, and Computers & Electrical Engineering journals. With over 130 publications, she has supervised eleven Ph.D. and twenty-seven MTech students. She has completed multiple government and industry-sponsored projects.

Prof. Puneet Tandon is a joint Professor of Mechanical Engineering and Design at PDPM IIITDM Jabalpur, India, with over 36 years of expertise in research, education, and academic administration. His research focuses on CAx technologies, innovative product design, and advanced manufacturing, including hybrid and additive methods. Prof. Tandon holds a Ph.D. in Mechanical Engineering from IIT Kanpur and has authored over 345 publications and 41 patents. He has supervised eighteen Ph.D. and eighty masters students. His research is highly recognized nationally and internationally. He has been awarded the DUO-India Fellowship and several industry awards. Prof. Tandon also serves as Topic Chair for ASME IMECE 2024, with an active role in multiple international committees and conferences.

Course Objectives

- To make the participants capable of designing deep neural network models for research and industrial applications.
- To understand techniques and paradigms to incorporate physical principles and constraints into DNN models.
- To make the participants capable of implementing core ideas of physics-aware deep learning from scratch using PyTorch.
- To familiarize participants with various methodologies to show applications of these processes from theory to practice.
- To demonstrate the adaptation of new theoretical algorithms to solve specific industrial problems.
- To furnish participants with detailed information concerning implementing new approaches in the industry.

How to Register

The participation fee (including GST@18%):

Industry/Research Organizations: INR 11,800 (INR 10,000 +GST)

Academic Institutions:

Faculty: INR 5,900 (INR 5,000+GST)

Research scholars: INR 4,720 (INR 4,000 + GST)

Students: INR 2,360 (INR 2,000 + GST)

Participants from abroad: US $250

- The above fee includes all instructional materials, assignments, tutorials, laboratory equipment usage, and internet facility.
- No TA/DA will be provided to the participants. Participants have to pay for accommodation and food as per actuals. Limited shared accommodation may be available (subject to availability) in the Institute Visitor Hostel on request.
- Last Date of Registration: Monday, February 3, 2025
- Targeted participants 50 only, first come first serve basis.
- The fee can be paid to the account number mentioned under bank details. After successful payment of the fee, the participants must register for the GIAN course by filling out the registration form: https://forms.gle/SVGbf8ZoTjoS922Q7

Account Name:	PROJECT ACCOUNT PDPM IIITDM JABALPUR
Account No.:	50210022387
Bank MICR Code:	482019014
Bank IFS Code:	IDIB000M694
Bank Name:	Indian Bank
Branch Name:	Mehgawan, IIITDM, Campus Branch, Jabalpur