Physics Aware Deep Learning @ Yonsei (Summer 2025)

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Course Overview

Artificial intelligence and machine learning (AI/ML) are playing an increasingly vital role in physics modeling and simulation. At the forefront of this progress is physics-aware deep learning (PADL), a class of algorithms that integrates physical laws and constraints directly into the learning process. Unlike conventional deep neural networks that primarily learn input-output mappings, PADL models can produce accurate predictions of physical phenomena while respecting underlying physical principles. PADL approaches have demonstrated strong performance across a wide range of problems, including fluid dynamics, heat transfer, structural deformation, and electromagnetics. In many of these problems, their predictive accuracy was shown to be comparable to that of traditional physics-based direct numerical simulations, while offering several orders of magnitude improvement in computational speed that enables applications that were previously unimaginable due to computational limitations.

The objective of this short course is to introduce PADL to advanced undergraduate and graduate students in mechanical engineering and relevant disciplines that concern with quantitative modeling and simulation of complex dynamic systems. The central goal of the course is to understand how physical systems can be represented in the language of neural networks. We will first introduce the essentials of neural networks and machine learning. We will then discuss how to incorporate physics principles and constraints in these neural networks via techniques such as physics-informed neural networks (PINN), neural operators, and physics-aware recurrent convolutions (PARC). Students will develop both a theoretical understanding of PADL methods and practical skills in building PADL models using open-source Python library PyTorch. Students are expected to possess a strong background in linear algebra, multi-variate calculus, statistics, probability, and computer programming.

Schedule

Day 1. Introduction to Neural Networks

Lecture 1: Onboarding & course logistics, introduction to PADL (1 hour)

Lecture 2: Introduction to neural networks (1 hour)

Lecture 3: Training neural networks: gradient descent, backpropagation, and more (1 hour)

Lab 1: Introduction to PyTorch—Build your first neural network (1 hour)

Day 2. Understanding Visual Patterns using Neural Networks

Lecture 4: Convolutional neural networks (1 hour)

Lecture 5: CNN architectures (1 hour)

Lecture 6 & Lab 2: How to train convolutional neural networks (2 hours)

Day 3. Physics Meets Deep Neural Networks

Lecture 7: Physics-informed neural networks (1 hour)

Lecture 8: Neural operators (1 hour)

Lecture 9: Physics-aware recurrent convolutions (1 hour)

Lab 3: Simulating simple physics using PADL (1 hour)

Required Technical Resources

To succeed in this course, you will need a laptop computer with either:

- Python and relevant development environment configured; OR
- Internet connection to access Google Colab (https://colab.research.google.com). Chrome web browser recommended.

Instructor Information

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