Physics-Informed Neural Networks

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Introduction

- The real world is governed by physical laws
- Most of them are described by complex Differential Equations (DEs)
  - Navier-Stokes
  - Diffusion
  - Poisson–Boltzmann
- Solving DEs is a challenging task and it is often impossible to find an analytical solution

Introduction

- Runge-Kutta methods
  - High computational cost
  - Mainly used for behavioural simulations
- Popularity growth of Deep Neural Networks (DNNs) to solve DEs [1]
  - Computational cost is moved to the training phase
  - Possibility to approximate nearly any kind of function
  - Downside of being only data-driven
- Neural Network with domain knowledge
  - **Physics informed neural networks (PINNs)**

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Background

- PINNs are a subset of the networks that exploits knowledge domain by modifying the loss function
- Loss of a normal neural network (i.e. Mean Squared Error):

$$loss = MSE = \frac{1}{n}\sum_{i}^{n}(prediction - ground\_truth)$$

- Loss a PINNs (i.e Mean Squared Error + Physics Loss):

$$loss = data\_driven\_weight \cdot \mathbf{MSE} + physics\_weight \cdot \mathbf{physics\_loss}$$

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Background

- INSERT THE GIF
- Harmonic Oscillator with a spring

$$m\frac{d^2x}{dt^2} + \mu\frac{dx}{dy} + kx = 0$$

  - m: mass of the oscillator
  - x: position of the oscillator
  - μ: coefficient of friction
  - k: spring constant

Background

- Show the image of the feed-forward NN
- Show the differentiation process
- Insert a bit of code to show the process of the actual physics loss
- insert the two gifs of normal NN and PINN
- Slide saying "Are you cheating? You have more points!"
- In this case yes, but think of a scenario where you are not able to generate the training point because there is not an exact solution to the problem
- Then talk to how we are applying this to batteries

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Bibliography

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