Wids midterm report

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0.1 Week 1: PINNs

PINNs stand for physics involved neural networks. This is applied when the available dataset is less in proportion and it is hard to train a model accurately on that dataset. In such cases a term related to physics is also considered while defining the loss function. This term is nothing but the differentiation equation for the given variable. Such consideration in loss function enables us to train a model with more precision on smaller proportion of data.

0.1.1 Exponential Decay

- For training exponential decay PINN, the equation is:

$$y(x) = e^{-x}.$$

- Taking the derivative with respect to x, we obtain:

$$\frac{d}{dx}\left(e^{-x}\right) = -e^{-x}.$$

- Substituting into the governing equation gives

$$\frac{d}{dx}\left(e^{-x}\right) + e^{-x} = 0.$$

- Thus, the problem reduces to the first-order ordinary differential equation

$$\frac{dy}{dx} + y = 0,$$

  with the initial condition

$$y(0) = 1.$$

- In the Physics-Informed Neural Network (PINN) framework, the physics residual is defined as

$$\mathcal{R}(x) = \frac{dy}{dx} + y.$$

- The model consisted of five fully connected (dense) layers with `tanh` activation functions, and was trained using the Adam optimizer with an adaptive learning rate.
- The network was trained for 200 epochs, during which all trainable parameters were optimized.

0.1.2 SHM

- The equation for SHM is:

$$a = -w^2 A sinwt$$

- This equation in differential form can be written as:

$$\frac{d^2y}{(dt)^2} = -w^2 y$$

- The boundary conditions were specified as:

$$(x, y) = (0, 0) \quad , \quad \left(\frac{\pi}{2}, 1\right) and \quad (\pi, 0)\,,$$

  with the angular frequency chosen as:

$$\omega = 1\ rad/s.$$

- In the Physics-Informed Neural Network (PINN) framework, the physics residual was defined as:

$$\mathcal{R}(x) = \frac{d^2y}{(dt)^2} + w^2 y$$

- Again for this task also Adam optimizer was used and trainable weights were optimized over 3000 epochs and physics loss and boundary condition loss both were considered.

Colab link for Week 1: `https://colab.research.google.com/drive/1zdMyQvXM7XhL_shmOThjGgHOHZ-qKHDX?usp=sharing`

0.2 Week 2: SoH(Pybamm)

State of Health (SoH) is a measure of the overall condition of a battery and indicates its ability to store and deliver energy relative to its original capacity. It reflects battery degradation due to aging, cycling, and operating conditions. The C-rate of a battery represents the rate at which it is charged or discharged and is inversely related to the time required for full discharge; for example, a 1C rate corresponds to a discharge time of one hour. In this work, the Single Particle Model (SPM) is employed to analyze battery behavior, as it provides a simplified yet effective electrochemical representation of lithium-ion batteries by modeling each electrode as a single spherical particle. The SPM enables efficient estimation of battery performance and health-related parameters while maintaining reasonable computational complexity.

0.2.1 Li-Concentration

- Used PyBaMM (Python Battery Mathematical Modelling) and implemented Single particle model on lithium ion
- Simulated the performance for as hour and plotted concentration of negative particle with repect to radius of cell
- Concentration is dependent on variables like time,radial distance and x-axis, so for a particular time mean with respect to x axis was taken and then plotted
- Timings considered in second were:

$$(0, 900, 1800, 2700, 3600)$$

0.2.2 OCV vs SOC

- The Single Particle Model (SPM) for a lithium-ion battery was employed and simulated using PyBaMM with its default parameter set.
- The battery behavior was simulated over the full state-of-charge (SOC) range from 0% to 100%, and the corresponding battery open-circuit voltage (OCV) in volts was obtained by solving the model.
- The OCV–SOC curve generated from the PyBaMM simulation was approximated using a fifth-degree polynomial by applying the `NumPy polyfit` function.

Colab Link for Week 2: `https://colab.research.google.com/drive/1NCOi2WyHIuYQ2f22gXSpqR7e4vNnyrWc?usp=sharing`