# $C_D$ estimation using SI-PINN with multi-frequency sampled data and comparison with Least-Squares

November 26, 2023

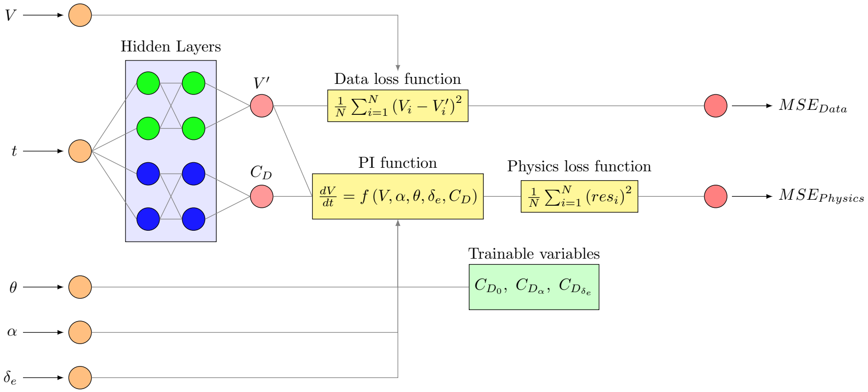
# Governing Equation

$$\frac{dV}{dt} = -\frac{\bar{q}S}{m}C_D + \frac{T}{m}cos(\alpha) + gsin(\alpha - \theta)$$

$$\frac{dV}{dt} = f\left(V, \alpha, \theta, C_D\right)$$

$$C_D = C_{D_0} + C_{D_\alpha}\alpha + C_{D_{\delta_e}}\delta_e$$

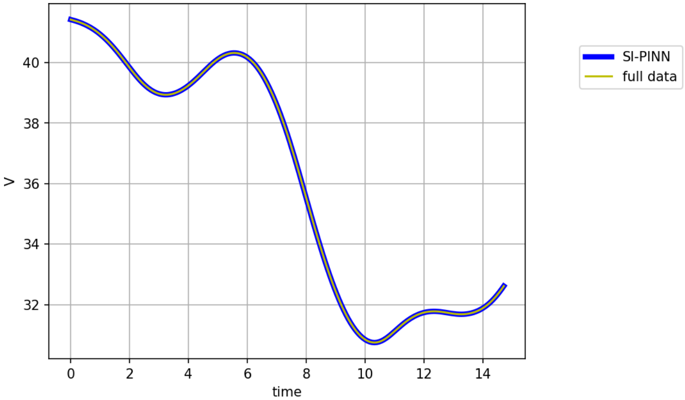
# Model Schematic



# Key Points

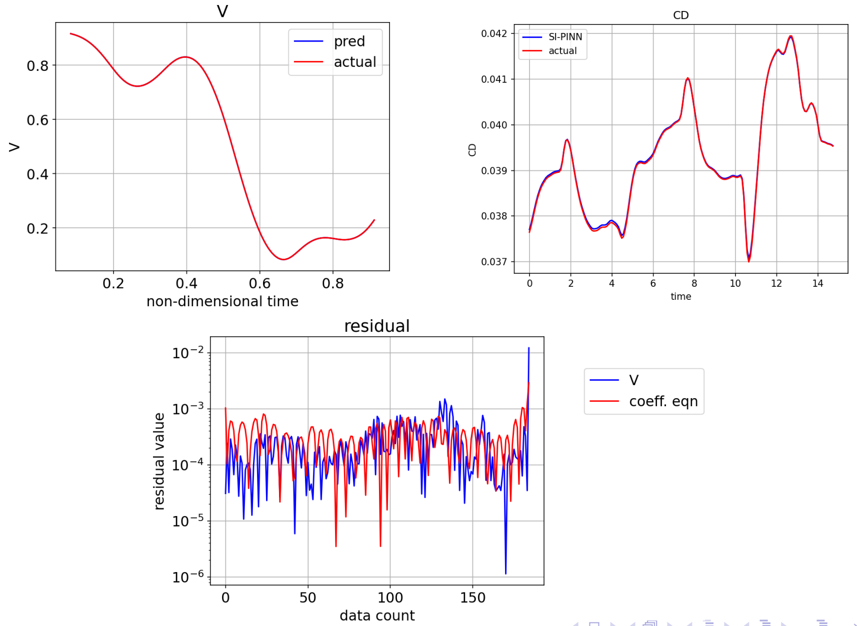
- MSE loss function is used.
- synthetic data is generated by using smoothed $\delta_e$
- V data is sampled at 6.3 Hz (93 points/14.78s) and other state variables at 12.5 Hz (185 points/14.78s)
- V-network is trained with down-sampled V data and CD network is trained with 185 points of other state variables
- The results are compared with Least-Squares estimate for same 6.3 Hz data

# Results: V prediction down-sampled data




V-network is trained with 93 data points and predicted for the 185 data points blue range. Yellow line is actual 185 data points curve.

# Results: prediction graphs



# Results: Estimation with down-sampled data points on V

Table: SI-PINN computed values

| coefficient | predicted value | actual value | error percentage |
|---|---|---|---|
| $CD_0$ | 0.0360884 | 0.036 | 0.245 |
| $CD_\alpha$ | 0.0401513 | 0.041 | 2.07 |
| $CD_{\delta_e}$ | 0.0250605 | 0.026 | 3.61 |

Table: Least-Squares computed values

| coefficient | predicted value | actual value | error percentage |
|---|---|---|---|
| $CD_0$ | 0.0370633 | 0.036 | 2.95 |
| $CD_\alpha$ | 0.0292532 | 0.041 | 28.65 |
| $CD_{\delta_e}$ | 0.0114898 | 0.026 | 55.80 |

# Observations

- SI-PINNs show better estimation with multi-frequency sampled data than least squares
- LS has to be evaluated at the least frequency of available points without pre-processing. But SI-PINN do not need that