**Supplementary Information**

**Towards accurate state of charge estimation for lithium-ion batteries using self-supervised transformer model: A deep learning approach**

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**Supplementary Table 1:** Specifications of the cylindrical LG18650 *LiNiMnCoO*2 cell.

**Supplementary Table 2:** Specifications of the cylindrical Panasonic *LiNiMnCoO*2 cell.

**Supplementary Table 3:** Train, validation, and test set drive cycles.

**Supplementary Table 4:** Architecture hyperparameter values for model.

**Supplementary Table 5:** Training hyperparameter of the proposed Transformer model.

**Supplementary Fig. 1:** (a) Optimal region (in green shade) of learning rate values that corresponds to the most rapid decline in the loss value and hence are better suited to be used in training. (b) Learning rate schedule during the training process. (c) Loss values on the training and validation set during training. (d) RMSE metric on the training and validation set during training.

**Supplementary Fig. 2: (**a) Relation between training modes and the RMSE metric. (b) Relation between training modes and training time.

**Supplementary Table 1.** Specifications of the cylindrical LG18650 *LiNiMnCoO*2 cell.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Type | Nominal  Capacity (Ah) | Nominal  Voltage (V) | Cut-off  Voltage (V) | Maximum  Current (A) | Specific  Energy (Wh/kg) |
| 18650 NMC | 3.0 | 3.6 | 2.5/4.2 | 20 | 240 |

**Supplementary Table 2.** Specifications of the cylindrical Panasonic *LiNiMnCoO*2 cell.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Type | Nominal  Capacity (Ah) | Nominal  Voltage (V) | Cut-off  Voltage (V) | Maximum  Current (A) | Specific  Energy (Wh/kg) |
| 18650 NMC | 2.9 | 3.6 | 2.5/4.2 | 10 | 206 |

**Supplementary Table 3.** Train, validation, and test set drive cycles.

|  |  |  |
| --- | --- | --- |
| Dataset | Dataset Drive Cycles | Total timesteps |
| Train | Mix1, Mix2, Mix3, Mix4, Mix5, Mix6, HPPC, HWFET | 318,072 |
| Validation | Mix7, Mix8 | 68,032 |
| Test | UDDS, LA92, US06 | 152,215 |

**Supplementary Table 4.** Architecture hyperparameter values for model.

|  |  |
| --- | --- |
| Hyperparameter | Value |
| Input dimension | 3 (voltage, current, temperature) |
| Number of layers in encoder | 3 |
| Sequence length | 400 |
| Number of features | 128 |
| Type of positional encoder | Zeros |
| Number multiheaded attention heads | 16 |
| Batch normalization | False |
| Dimension of feedforward layer | 256 |
| Activation function | Gaussian Error Linear Units (GELU) |
| Dropout in feedforward layer | 0.2 |
| Residual dropout in encoder | 0.1 |

**Supplementary Table 5.** Training hyperparameter of the proposed Transformer model.

|  |  |  |
| --- | --- | --- |
| Hyperparameter | Value | |
| Pretraining LR | 1e-3 |
| Retraining LR | 2e-4 |
| LR Schedule | Flat and cosine annealing |
| Optimizer | Ranger |
| Minibatch size | 128 |
| Training epochs | 25 |
| Loss function | Log-cosh |
| Error metric | RMSE & MAE |

**Supplementary Figures**

Supplementary Fig. 1 (a) shows the optimal region (in green shade) of learning rate values that corresponds to the most rapid decline in the loss value and hence are better suited to be used in training. Supplementary Fig. 1 (b) shows the learning rate schedule during the training process. In the beginning 75% of the training loop, the learning rate is held at a constant value and during the last 25% of the training, the learning rate value is decayed following the cosine function. Supplementary Fig. 1 (c) shows the loss values on the training and validation set during training. Supplementary Fig. 1 (d) shows the RMSE metric on the training and validation set during training.

|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
|  |  |
| (c) | (d) |

**Supplementary Fig. 1** (a) Optimal region (in green shade) of learning rate values that corresponds to the most rapid decline in the loss value and hence are better suited to be used in training. (b) Learning rate schedule during the training process. (c) Loss values on the training and validation set during training. (d) RMSE metric on the training and validation set during training.

Supplementary Fig. 2 (a) shows the relation between training modes and the RMSE metric and supplementary Fig. 2 (b) shows the relation between training modes and training time. Supplementary Fig. 2 (a) shows that PT+RT always results in lower RMSE compared to T and PT+FT. Supplementary Fig. 2 (b) shows that PT+RT takes almost the same amount of training time compared to training mode T. In both subfigures, it is evident that PT+RT mode contributes to the lowest RMSE and take approximately the same amount of time compared to models trained in training mode T.

|  |  |
| --- | --- |
|  | |
|  |  |
| (a) | (b) |

**Supplementary Fig. 2. (**a) Relation between training modes and the RMSE metric. (b) Relation between training modes and training time.