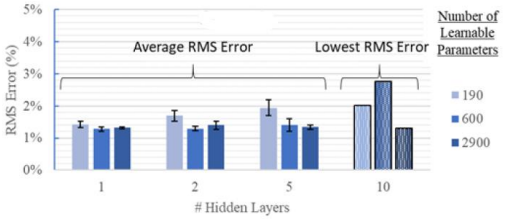
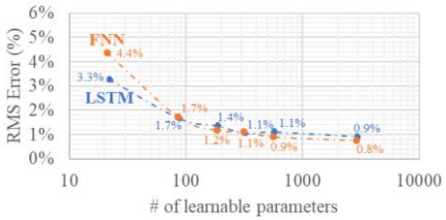
Configuration and Sizing of Machine Learning Algorithms for Battery SOC, SOH, and Temperature Estimation

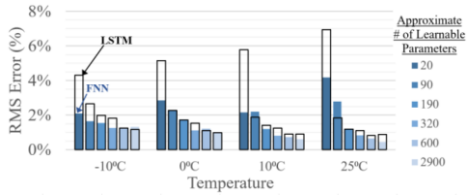
Supplemental Tables and Figures for Abstract



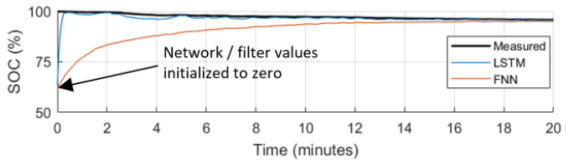
(a) Error versus number of FNN layers and learnable parameters



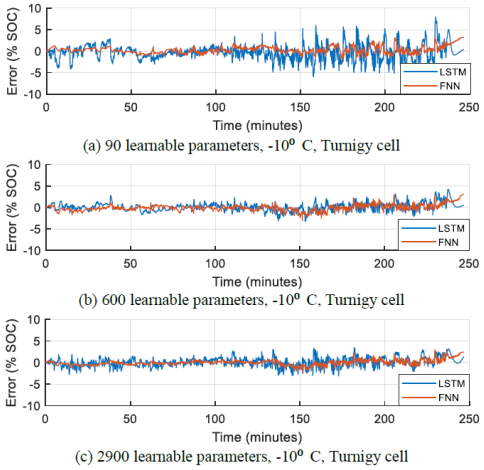
(b) Error versus number of learnable parameters



(c) Error versus temperature and number of learnable parameters



(d) Error for networks with memory blocks / filters initialized to zero

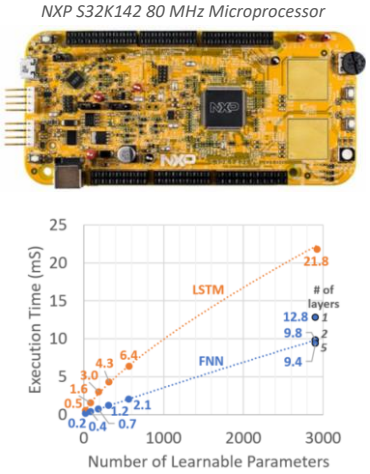


(a) 90 learnable parameters, -10⁰ C, Turnigy cell

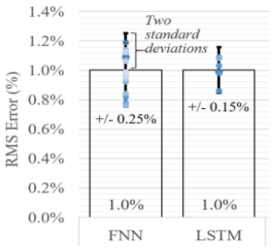
(b) 600 learnable parameters, -10⁰ C, Turnigy cell

(c) 2900 learnable parameters, -10⁰ C, Turnigy cell

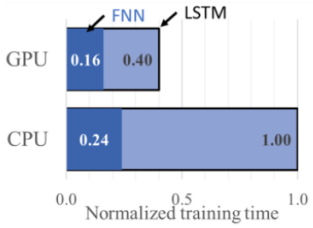
(e) Error versus number of learnable parameters



(f) Microprocessor execution time versus number of model parameters and FNN layers

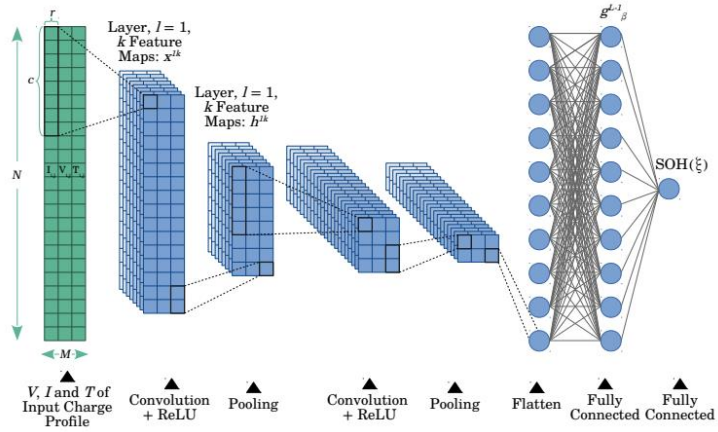


(g) Error versus training repetitions with unique initial parameters

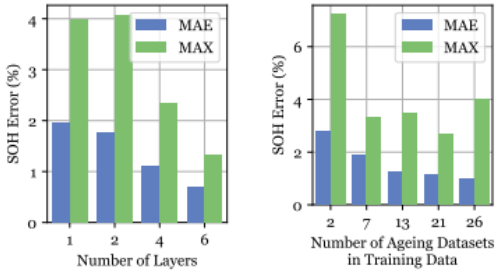


(h) Training time for 50,000 epochs on CPU and GPU

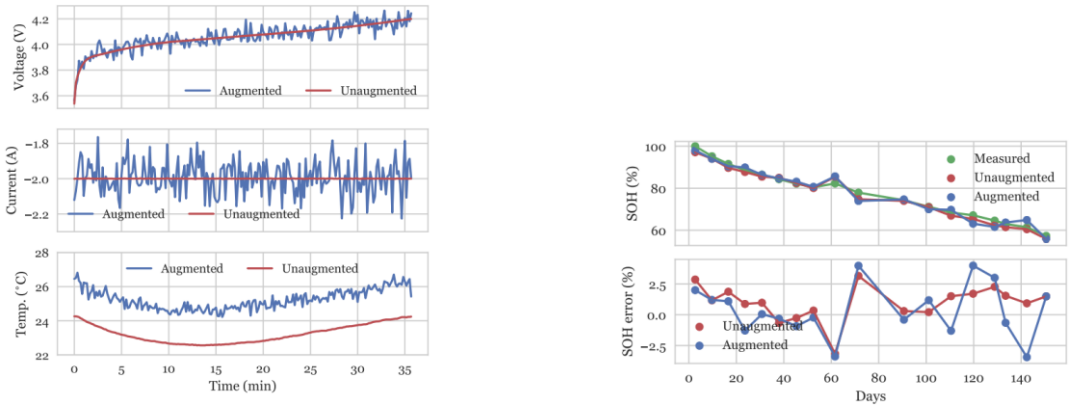
Figure 1 Comparative study of recurrent LSTM & non-recurrent FNN for SOC estimation



(a) Convolutional neural network SOH estimation algorithm structure



(b) Error versus number of layers and number of aging datasets in training



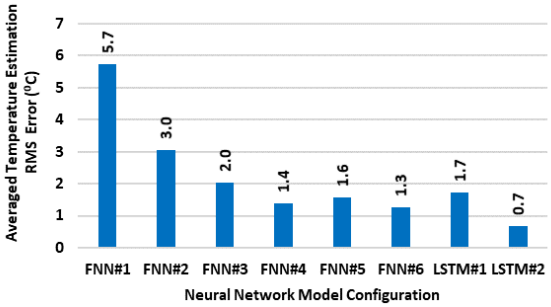
(c) Impact of augmentation of neural network training data with noise

Figure 2 Convolutional neural network configuration and approach for SOH estimation

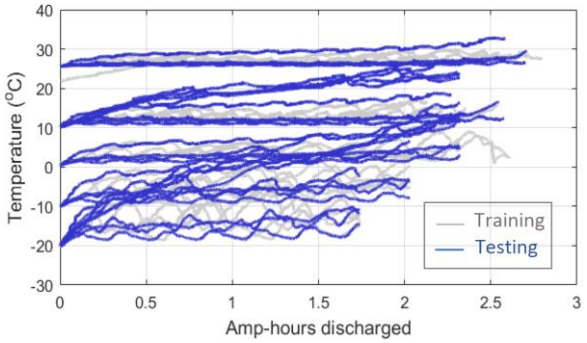
DIFFERENT INPUTS TO THE PROPOSED NN MODELS

Model	I	V	SOC	T_a	I_f (0.3 mHz)	V_f (0.3 mHz)	I_f (3 mHz)	V_f (3 mHz)
FNN#1	√	√	√					
FNN#2	√	√	√		√	√	√	√
FNN#3	√	√	√	√				
FNN#4	√	√	√	√	√	√		
FNN#5	√	√	√	√			√	√
FNN#6	√	√	√	√	√	√	√	√
LSTM#1	√	√	√					
LSTM#2	√	√	√	√				

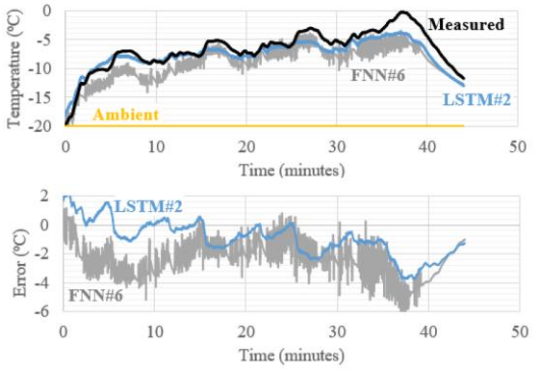
(a) Input feature combinations, T_a is ambient temperature, V_f and I_f are filtered voltage / current



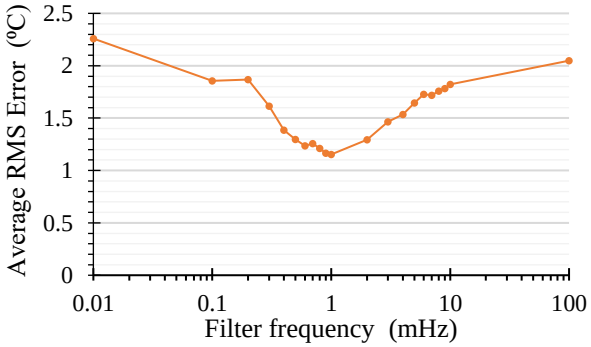
(b) Error for different input features and network types



(c) Measured cell temperature for training and testing data



(d) Estimated temperature for US06 drive cycle at -20°C



(e) Error versus FNN input filter frequency for one voltage and current filter

Figure 3 Feature selection and neural network type study for temperature estimation