Data-Driven Approach for SOC Estimation of Battery using Long-Short Term Memory Network

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Abstract: ***Lithium-ion batteries have a wide range of applications in many industries but mostly used in electronic devices and electrical vehicles as an energy storing equipment. A proper battery management is necessary for efficient energy storage and usage. As Electric vehicles need to run for longer durations, we need efficient battery management which can be achieved by state of charge estimation. State of charge (SOC) estimation is a key performance indicator for Battery Management system (BMS) hence, an accurate prediction of SOC is required. SOC estimation can help, and guide users to take necessary actions based on battery behaviors to increase its battery life. Non-linear nature and complex chemical reactions in batteries makes it not possible to directly predict or measure a battery's state of charge. This paper proposes a novel method for accurate prediction of SOC percentage of Li-ion battery using Long short term Memory network.***

Keywords: State of Charge Estimation (SOC), LSTM, Battery Management System (BMS)

1. Introduction

ELECTRIC vehicle industry has major demand because of their less maintenance cost and reduced carbon emissions. Now to satisfy user demands and make electric vehicle run for longer duration we need an energy source that can give high specific energy, long cycle's life, and low self-discharge rates with light weight. Lithium-ion batteries have these specifications and have long charging life. But there are few factors that can affect battery performance to degrade, few such factors are high ambient temperatures in batteries, overcharge and discharge rates. These factors can lead to misuse of battery state and in turn can reduce life span of battery. To improve battery performance we need a proper Battery Management system. State of charge estimation is a key performance indicator for battery management systems. State of charge estimation can help in improving battery performance and prevents battery from having over and under charge issues [10, 28] [own]. To make electrical vehicle run for long duration we connect large number of batteries in series or parallel and we must provide a scalable method of estimating SOC of a battery because Battery management systems can be affected by high computations. We build a model that can study the behavior of battery characteristics and can help in accurate SOC percentage prediction. State of charge is the amount of charge available in battery and this will be represented in percentages. Due to complex and nonlinear nature of chemical reaction in batteries it is not possible to directly measure battery SOC percentage. But information such as discharge current, discharge voltage, and ambient temperature can be used to measure the state of charge. There exists various proposed work and are classified into various groups based on their working and complexities. Direct methods find relationship between state of charge and batteries physical parameters. Model-based methods use filters and study the electrochemical properties of batteries to estimate SOC. Data-driven methods create algorithms that can take battery characteristics as input and output its state of charge in percentages. State of charge estimation provides reliable operation of electrical drive in electric vehicles for long driving ranges and provides a better battery balancing system. Incorrect estimation. The state of charge can lead to unstable performance of drive and also shortens the battery life. This paper analyzes and compares long short-term memory networks (LSTM) and Gated recurrent Unit (GRU) in accurate SOC percentage prediction.

2. Related Work

There are various methods proposed for state of charge estimation. Based on complexity they are grouped as direct, model and data-driven methods. In [1] Jong-Hyun Lee proposed state of health and state of charge estimation using Neural Networks and LSTMS. Where the SOH results are used for SOC estimation. Neural network is used for SOH and LSTM is used for SOC Estimation. Ephrem Chemali [2] proposed a LSTM based approach where the model is trained for fixed ambient temperature and tested on various test cases. [3] Zhengqi Liu proposed an Recurrent Neural Network for SOC estimation on li-ion batteries. The data is collected for different cyclic charges and discharge rates. Zhengqi Liu proposed an combined CNN-LSTM based model and used for SOC estimation and tested on BT2000 battery tester with cylindrical A123 18650 battery samples. [4] M. S. Hossain Lipu used deep recurrent neural networks and employed firefly algorithm for optimized number of parameters of recurrent network to overcome high complexity and used two batteries named lithium nickel manganese cobalt oxide and lithium nickel cobalt aluminum oxide for testing on developed model. One battery is tested at static discharge and other is with pulse discharge at room temperature. [5] Taimoor Zahid proposed a fuzzy clustering based neuro-fuzzy system compared to neural networks and the parameters that model takes is voltage, current, temperature, actual power loss, etc. And the proposed model is tested with different drive cycles of battery. And it showed remarkable advancements in estimating state of charge compared to many conventional methods.

3. Theoretical Base

In this section basic theory of long short-term memory Networks are introduced.

a) Long-short term Memory Networks

LSTM is a type of RNN that is trained using Back propagation through Time (BPTT) and this network can solve vanishing of gradient problem. The main difference between Multi Layered Neural Network and LSTM is that Neural networks use neurons whereas LSMTS use memory blocks which are connected in layers. Each block contains gates that manages the block state and also handles output. LSTMS has ability to add or remove information to cell state regulated by structure called gates. It totally has 3 gates to control and also protect cell state. Figure 1 shows the LSTM memory cell.

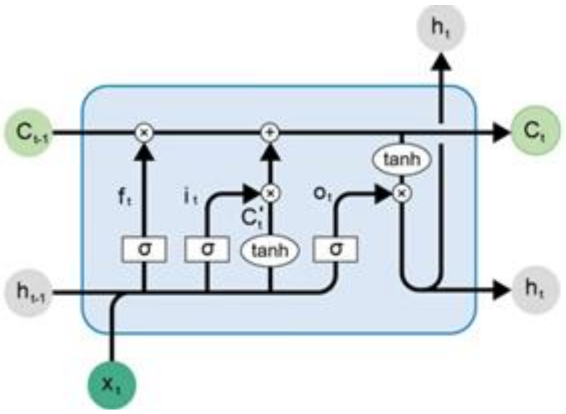


Figure 1: LSTM Architecture

$$it = \sigma\ (wi \cdot [ht-1, xt] + bi)\ (1)$$
$$ft = \sigma\ (wf \cdot [ht-1, xt] + bf)\ (2)$$
$$ot = \sigma\ (wo\ [ht-1, xt] + bo)\ (3)$$
$$c't = \tanh\ (wc \cdot [ht-1, xt] + bc)\ (4)$$
$$ct = ft * ct-1 + it * c't\ (5)$$
$$ht = ot * \tanh\ (ct)\ (6)$$

it, ft, ot from figure 2 represent three gates of LSTM memory cell. ft is forget gate and the input gate of memory cell. ot is the output gate. RNN fails to learn long-term dependencies, but LSTM has ct which represent the cell state in simple it is memory from the current cell where, ct-1 represents the memory from the previous cell and ht-1 is the output of previous cell.

4. Proposed Methodology

The proposed work includes data collection, data processing, data modeling and model selection. The work includes the entire life cycle of a basic machine learning project. The data used in this project is an open source dataset created by McMaster University but the dataset is further edited by including different temperatures and its corresponding voltage, current and SOC values. Figure 2 shows the proposed workflow of the entire methodology.

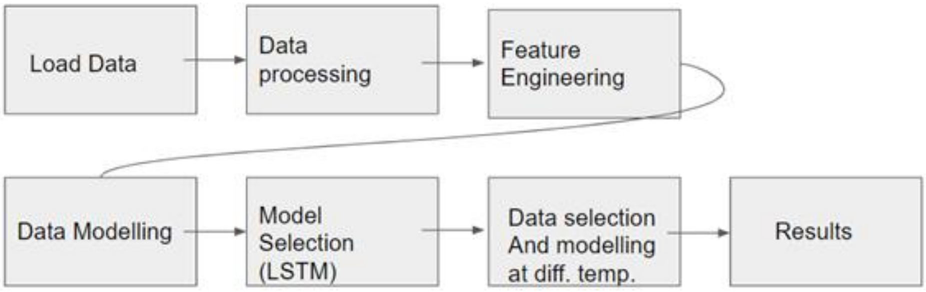
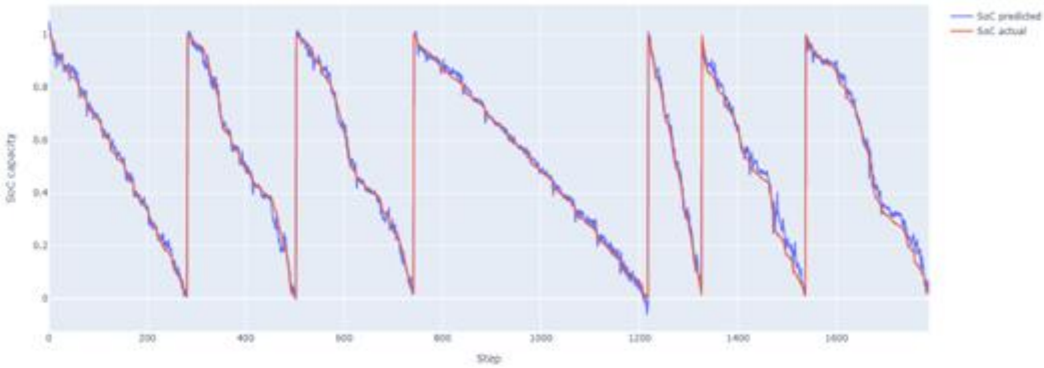


Figure 2: Proposed Methodology

5. Results

The results achieved by LSTM are presented in the figure 3. The best results are achieved after taking 300 cycles for each discharge and charging of battery. But the figure shows there are some values which are not predicted correctly but further model parameter tuning can help to achieve better results.



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Author Profile

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