# Comparative Analysis of GRU-RNN and LSTM Models for Battery Management System Visualization in Unreal Engine

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***Abstract*—This paper introduces a novel approach to visualizing battery management systems (BMS) using Unreal Engine for Digital Twin Technology. The proposed platform leverages advanced data visualization techniques to monitor and predict battery performance in real-time. We present a comparative study between two predictive models, GRU-RNN and LSTM, for State-of-Charge (SOC) estimation. The 3D visualization in Unreal Engine provides an immersive experience for analyzing battery behavior, with color-coded visual cues representing different SOC levels. The results showcase the potential of our approach in facilitating efficient decision-making for battery optimization.**

***Index Terms*—Digital Twin, 3D Model, Battery Management System, GRU-RNN, LSTM.**

## I. Introduction

The exploration of the digital twin concept and its various applications in the contemporary world is gaining momentum. A specific application that has attracted considerable research attention is the Battery Management System (BMS). The integration of a digital twin into BMS holds notable significance for several reasons. Firstly, it facilitates seamless integration into wireless networks, such as the cloud [1]. This connectivity significantly improves the precision of predicting critical parameters within the BMS. Moreover, it provides an accurate digital representation of the battery, facilitating comprehensive monitoring of its performance [2]. Emphasizing the significance of visualization in enhancing the effectiveness of the digital twin would add depth to the discussion [3].

As accurately predicting the parameters of a battery is pivotal for its optimal performance, addressing the state of charge is a key factor. The complexity arises from both implementing a digital Twin and determining the most accurate model to achieve optimal results [4]. Therefore, adopting a methodical and cautious step-by-step approach becomes crucial. Noteworthy is the possibility of utilizing AI within the metaverse, adding an important dimension to consider [5].

This paper incorporates the visualization required for constructing a digital twin and employs two distinct neural network models to predict the SOC. The objective is to identify the most effective model suitable for utilization within the Digital Twin framework.

## II. Methodology

This section delineates the suggested approach for formulating and merging the visualization platform of the Battery Management System (BMS) based on the Digital Twin in Unreal Engine. The sequential steps are depicted in Fig. 1.

### *A. Dataset Selection and Model Training*

The dataset utilized for training involves Panasonic 18650 data recorded at three temperatures: 0°C, 10°C, and 25°C [6]. The primary goal is to predict the battery's SOC. Two neural network models, GRU-RNN and LSTM, are chosen for this purpose, leveraging their respective strengths in handling sequential data. LSTM, known for its ability to capture long-term dependencies in sequences, proves advantageous in scenarios where intricate patterns and context preservation are crucial [7]. On the other hand, GRU-RNN, with a simpler architecture and fewer parameters, offers computational efficiency, making it suitable for applications where resource constraints are a consideration [8]. While both models share a common foundation for processing sequential data, their nuanced differences and distinctive advantages become apparent through comparative analysis, aiming to discern which one excels in achieving the highest accuracy in predicting SOC, considering their unique characteristics.

### *B. Integration with Unreal Engine*

Following the successful training of the AI model to ensure accuracy, the next crucial step involves its seamless integration into the Unreal Engine platform, renowned for its advanced capabilities in immersive visual experiences. The prediction results from the trained AI model serve as vital input for data visualization within Unreal Engine. Notably, extensive experimentation is conducted on both the model and Python codes to achieve effective importation into Unreal Engine, facilitating the visualization process.

TABLE I
Accuracy Results of GRU-RNN and LSTM Models

| **Metric** | **0°C** | **10°C** | **25°C** |
|---|---|---|---|
| RMSE (GRU-RNN) | 0.298 | 0.204 | 0.203 |
| MSE (GRU-RNN) | 0.088 | 0.041 | 0.041 |
| MAE (GRU-RNN) | 0.259 | 0.162 | 0.172 |
| RMSE (LSTM) | 0.149 | 0.157 | 0.137 |
| MSE (LSTM) | 0.022 | 0.024 | 0.018 |
| MAE (LSTM) | 0.128 | 0.130 | 0.119 |

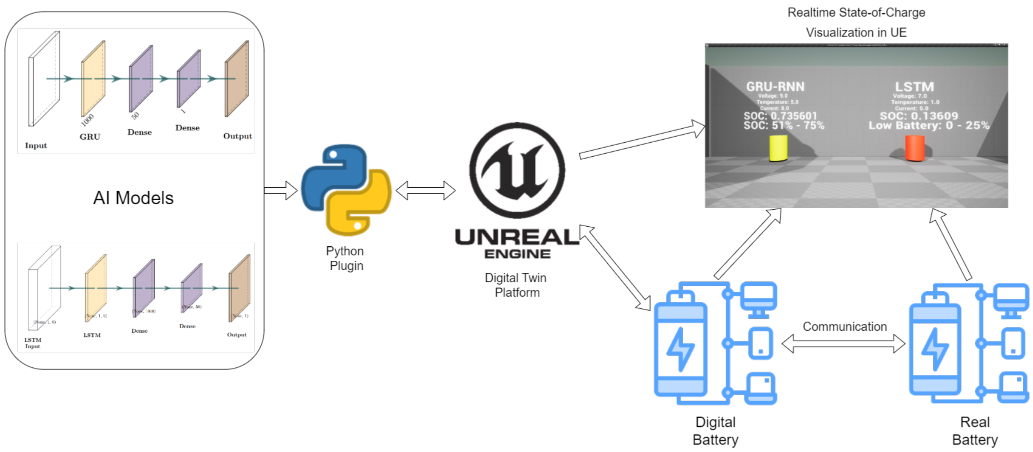


Fig. 1. Proposed Model

## III. Results and Discussion

### A. Accuracy Results of GRU-RNN and LSTM Models

The evaluation of accuracy involves metrics such as RMSE, MSE, and MAE, tested across datasets featuring three distinct temperature types for state of charge estimation. The comparative accuracy results are illustrated in Table I. Despite a marginal difference, the findings indicate that LSTM is more suitable for SoC prediction.

### B. Visualization Implementation

Fig. 2 showcases the visualization, featuring subtle design modifications and the inclusion of voltage, temperature, and current parameters to elevate the overall visual presentation. The alterations in the battery model are contingent on the predicted SoC using a specified threshold.

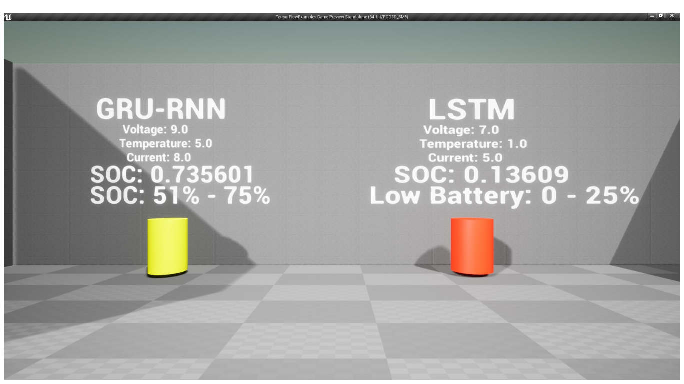


Fig. 2. Data Visualization of Battery in Unreal Engine

## IV. Conclusions

The successful accomplishment of the objective to compare the two distinct models is evident, along with their integration into the Unreal Engine, as illustrated alongside the GRU-RNN Battery Model. Despite successful outcomes, challenges persist, such as the static nature of input parameters within the Python file. There's a strategic plan to address this by transitioning control to the Unreal Engine. Additionally, hardware implementation is under consideration to attain real-time battery parameters. The incorporation of blockchain technology is being explored to enhance both data transparency and security.

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