

Battery Load Prediction under Real-World Conditions Using Big Data and Generative AI

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When lithium-ion batteries are used in electric vehicles, ensuring reliability against degradation and thermal runaway under real-world conditions is essential. To evaluate battery behavior under various operating conditions, one-dimensional vehicle system models are widely used. However, conventional analyses have primarily relied on standardized driving cycles, making it difficult to comprehensively represent the diverse usage patterns observed in the real-world. Therefore, we developed a method to generate driving scenarios that reflect real-world usage characteristics by applying generative adversarial networks (GAN) to real-world big data. The generated driving scenarios consist of time-series data of vehicle speed and road grade generated from statistical information representing driving characteristics.

In the proposed method (Fig.1), a GAN model is trained using real-world driving data and corresponding histograms of vehicle speed, acceleration, and road grade. After training, real-world-derived histogram data are provided as inputs to the generator, enabling the creation of driving scenarios that reproduce real-world usage characteristics. The target region was North America, and training data included urban and highway driving records with various driving durations and distances. Validation results confirmed that the generated scenarios successfully reproduced the characteristics of the original driving data, while reconstructed histograms showed errors of less than 10% for all validation datasets.

To evaluate battery load under real-world conditions, driving scenarios were generated from a North American real-world database containing 1406 samples. A representative subset of 100 samples was selected while maintaining the fuel-economy distribution of the original population. The generated driving scenarios were then analyzed using a one-dimensional vehicle system model for a battery electric vehicle (BEV).

Battery load was evaluated using accumulated absolute current and maximum voltage drop. The former is associated with battery degradation, while the latter reflects the degree of approach to the lower voltage limit and the risk of over-discharge. These indicators represent the long-term and instantaneous impacts of battery load, respectively.

The results (Fig.2) showed that accumulated absolute current was mainly distributed around the level of a conventional urban driving cycle. However, the value corresponding to the 2σ level exceeded that of a conventional highway driving cycle by approximately 4%. Similarly, the maximum voltage drop at the 2σ level exceeded the highway driving cycle by approximately 120%. These results indicate that real-world conditions, including sustained high-speed driving and road-grade-related driving events, can impose higher battery load than conventional test cycles.

By combining GAN-generated driving scenarios with a one-dimensional vehicle system model, the proposed method enables

estimation of battery load under real-world conditions and identification of high-load conditions that may occur in real-world environments. This approach provides a practical framework for incorporating real-world usage characteristics into battery evaluation.

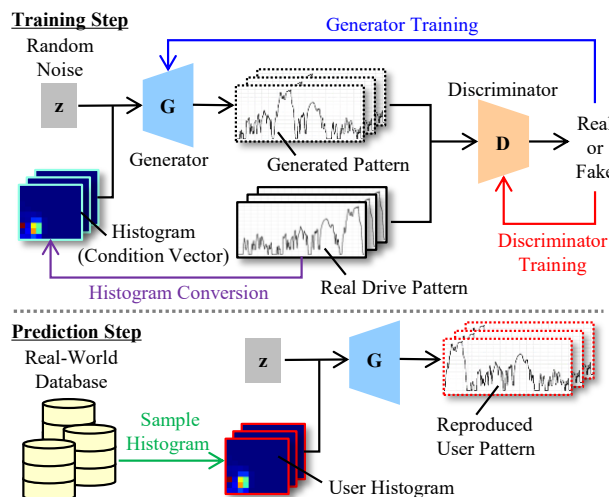
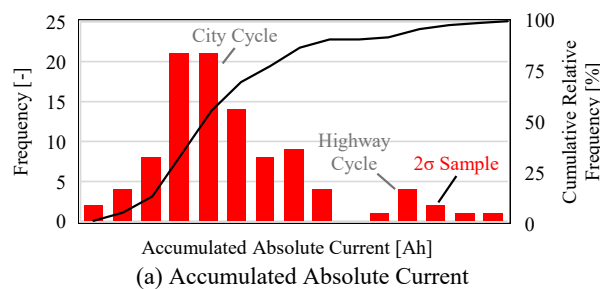
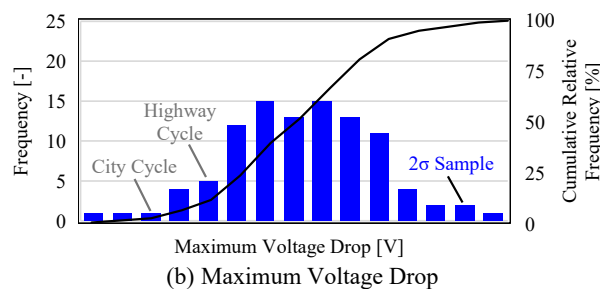


Fig.1 Driving Scenario Generation based on GAN



(a) Accumulated Absolute Current



(b) Maximum Voltage Drop

Fig.2 Battery Load Distribution in Generated Scenarios