

Battery Digital Twin: Machine Learning from Development to Vehicle In-use

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Machine learning (ML) is a powerful technique that can learn from data and generate predictions or decisions without explicit rules or formulas. ML has been widely applied to various domains, such as computer vision, natural language processing, recommender systems, and self-driving cars. In this paper, we focus on the application of ML to battery electric vehicles (BEVs), which rely on batteries as their main energy source, and the performance, safety, and lifetime of batteries are crucial for the success of BEVs. However, batteries are complex electrochemical systems that are influenced by many factors, such as temperature, current, voltage, state of charge, state of health, and degradation mechanisms. Moreover, batteries behave differently under different operating conditions, usage patterns, and environmental factors. Therefore, it is challenging to model, monitor, and optimize batteries with traditional methods that require physical equations or empirical formulas.

This paper presents the latest developments of ML applications for battery digital twin and explores the difficulties and possibilities. An ML toolbox of scalable battery digital twin components is presented. It consists of subcomponents for SoC/SoH estimation and prediction, load profile analysis and anomaly detection. The connections and influences are explained. Techniques like transfer learning and reduced-order models are also employed. The introduced concept offers an approach that can leverage the large amount of data collected from battery development, testing, and operation, and extract useful insights and patterns from the data. It can help to design better batteries, estimate their states and parameters, predict their future behavior and remaining useful life, and optimize their management and control strategies. The presented approach of ML based battery digital twin, which is a virtual representation of a physical battery that can mirror its real-time status and historical performance and provide feedback and recommendations for improvement.

A battery digital twin can be used throughout the battery lifecycle, from development to in-use to second life to recycling, and provide benefits for battery manufacturers, vehicle manufacturers, and end-users. Benefits for the OEM include reduced warranty costs, new features such as range prediction and customization, and predictive controls. For the owner, benefits include extended lifetime, reduced TCO, and new features.

