Analysis of Vehicle Battery Data for State of Health and Remaining Useful Life Prediction

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Abstract

The goal of the research is to create a model that estimates the state of health and predicts the remaining useful life (RUL) of a battery module used in a car. RUL prediction is important because if EV batteries have reached their End of Life, they are still usable for other applications. This report focuses on analyzing real-world datasets collected from different vehicles. It is important to determine which available battery data indicate battery degradation, since not all collected data correspond to battery aging. The data that indicates battery degradation can be used to train a model. The report starts with explaining the basics of a battery, then battery degradation is visualized during the real-world datasets analysis and recommendations are provided for further research. The main report contains the conclusions and further detailed information is provided in the appendix.

Keywords: Lithium-ion battery, State of Health (SoH), Remaining Useful Life (RUL), State of Charge (SoC), Battery degradation, Data driven approach

Contents

1. Introduction

We live in a demanding world where sustainability is one of the most important topics in the automotive industry (1). A vehicle battery consists of a lot of cells in a module, and every cell has a different battery life. Often, only a small number of cells in a module degrade faster than the others. If one cell is bad the total performance of the module is affected (2). If a module is then changed, it can affect the battery pack. If the pack is used and a new module is put into the pack that is different in State of Health (SoH), then the pack still won't work efficiently and the pack will age faster(3).

So it is important to know the SoH to predict the RUL. RUL prediction is important because if electric vehicle batteries have reached their End of Life (SoH < 80%), however the batteries are still usable for other applications (store renewable energy as an energy buffer) as shown in Figure 1 (4).

Therefore, this project focuses on analyzing and visualizing battery data from a mini truck and full electric vehicles. By determining the degradation of the battery module, a model can be created to predict the SoH of the battery, and the possibilities for a second life can be determined. So, with increasing demand for sustainable solutions, understanding and determining the battery health could be used to give the healthy cells a second life.

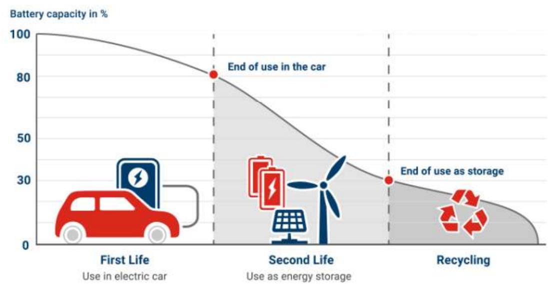

Figure 1: Battery life (4).

1.1. Research Objective

A method is needed to determine the SoH of the battery and predict the RUL. There is a lot of data of vehicle batteries available. So research is needed to find out what the available data contain, what does this data look like and how it can be related to battery degradation. After analyzing, the next step is to figure out how to select or create a data-driven method to process this data and turn it into a battery RUL prediction model.

1.2. Research Questions

The central research question guiding this project is:

- How can the RUL of battery cells be predicted using real-world vehicle data?

Additional sub-questions include:

- What does the available battery data contain, and how can it be analyzed?
- How can battery capacity be determined to estimate the SoH?
- How can the RUL of individual cells be accurately determined?
- How can the available data be related to battery aging patterns?
- How can a data-driven method be created to process the data and generate a battery RUL prediction?
- What are the differences between laboratory data and real-world data, and how do they affect prediction accuracy?

1.3. Scope and Structure of the Report

1.3.1. Scope

This report focuses on the analysis of real-world battery data from different vehicle datasets. The report contains the following topics: the basics of a battery are explained, the necessary steps to achieve the remaining useful life prediction, data analysis of different vehicles, the data is linked to the health indicators of battery degradation, a conclusion of the different data analyses, the further steps to achieve the remaining useful life prediction and a final conclusion. The appendix contains a detailed explanation of the topics discussed in the report.

1.3.2. Structure of the Report

The report is organized as follows:

1. **Chapter 1:** this chapter is the introduction, it provides background information, problem statement, research objectives, research questions, and scope.
2. **Chapter 2:** this chapter is about understanding batteries, it explains the battery topics to understand the further research.
3. **Chapter 3:** this chapter explains how to achieve remaining useful life predictions, it describes the steps and methods to achieve the remaining useful life prediction of a battery.
4. **Chapter 4:** this chapter explains the health indicators, it explains the health indicators used in different data analyses.
5. **Chapter 5:** this chapter analyzes the Carry dataset. The data is preprocessed, analyzed and linked to the health indicators.
6. **Chapter 6:** this chapter analyzes the Daf dataset. The data is preprocessed, analyzed and linked to the health indicators.
7. **Chapter 7:** this chapter analyzes the Hysteryale dataset. The data is preprocessed, analyzed and linked to the health indicators.
8. **Chapter 8:** this chapter draws a conclusion of the different data analyses. The conclusion is based on the health indicators.
9. **Chapter 9:** this chapter describes the potential data driven models for building a predictive model.
10. **Chapter 10:** this chapter describes the further steps. It contains an explanation of how to continue the research and provides recommendations for future research.
11. **Chapter 11:** this chapter is the conclusion. It contains a summary of findings during the research.