Prognosis of Lithium-ion Batteries Considering Cycle and Storage Conditions

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Student Poster

Research Objective

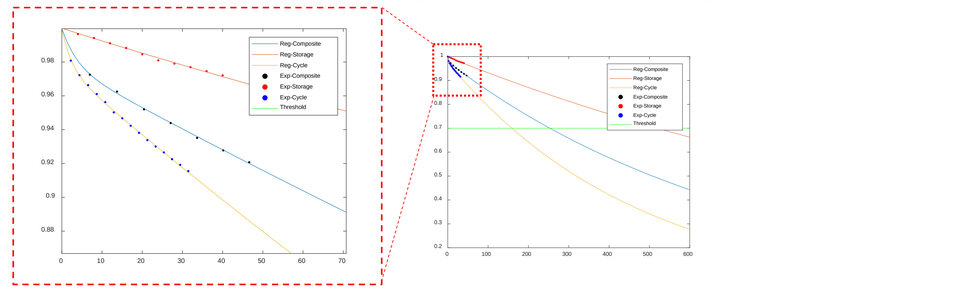
In order to accurately predict the li-ion battery lifetime of an electric vehicle, it is necessary to consider the usage conditions. However, combined condition (i.e., both cycle and storage conditions) tests take relatively longer than the tests for each conditions. The purpose of this study is **to predict the lifetime of a combined situation using the results of respective tests on cycle and storage conditions.**

Expected Contributions

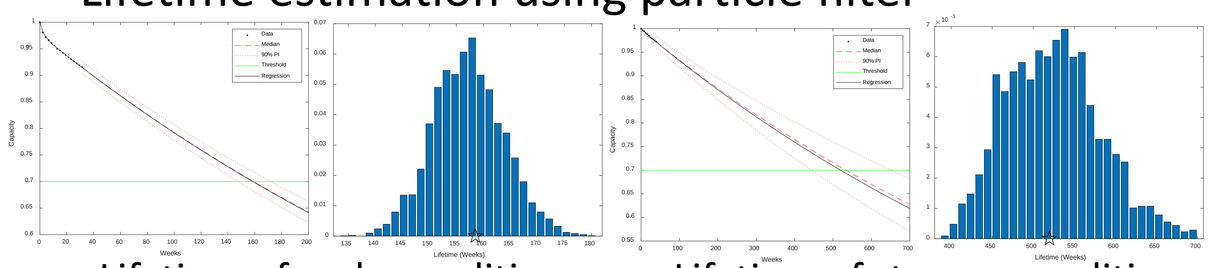
- It takes about 92 days for 100 cycles when conducting combined condition test, however, cycle test takes only 16 days for the same cycles.
- The storage test can be carried out at the same time as the cycle experiment, so it can be reduced by about 76 days.
- By controlling cycle-storage ratio, it is also possible to predict the combined condition lifetime for various usage conditions.

State of Research

- Li-ion battery degradation tests result
  - Degradation model: $y = a \cdot exp(-b \cdot t) + c \cdot exp(-d \cdot t)$



- Lifetime estimation using particle filter



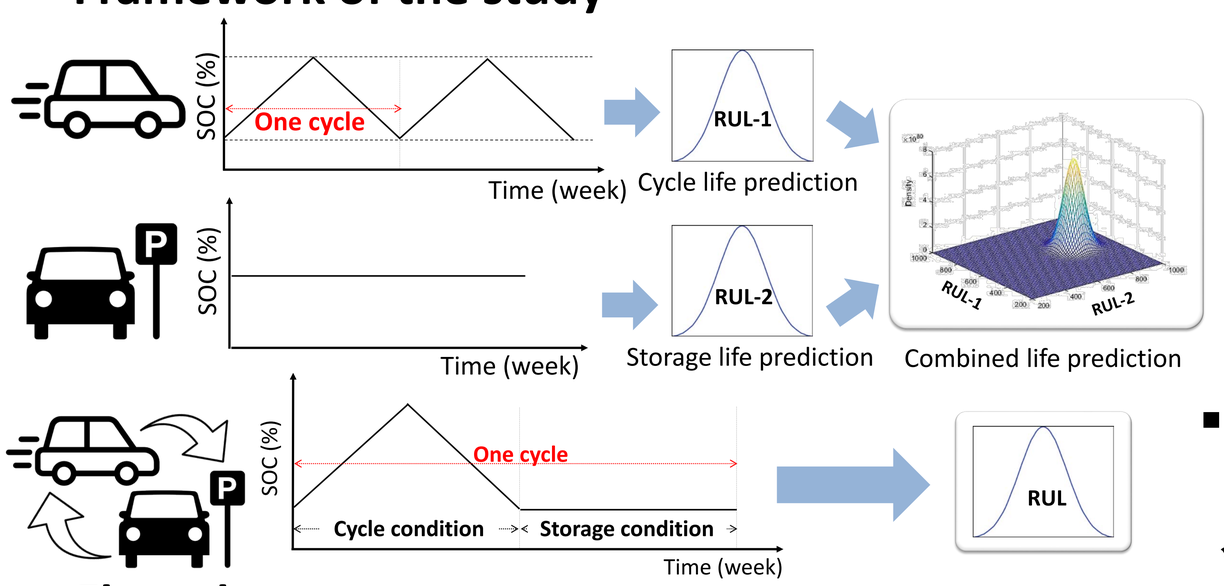
Lifetime of cycle condition | Lifetime of storage condition

Next Steps

- More accurate relationships between the combined and cycle-storage conditions are needed to reduce the errors.
- Further verification will be carried out through the test results conducted under various usage conditions.

Research Details

▪ Framework of the study

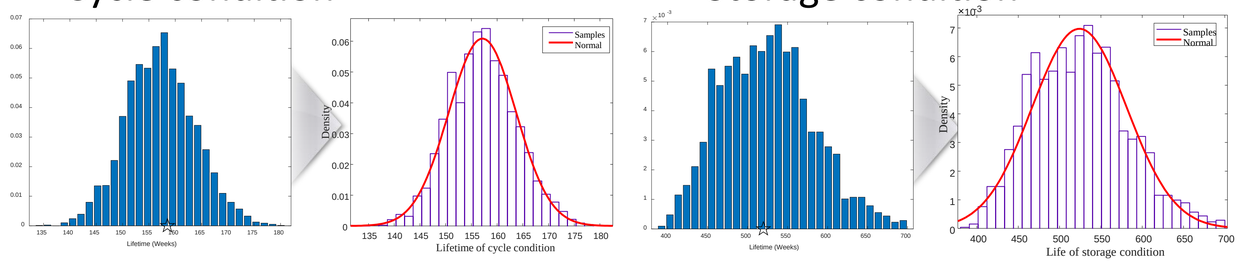


- Flow chart

Predicting lifetime using particle filter
↓
Estimating the distribution of probabilistic results
➔ Assume the normal distribution
↓
Predicting the combined condition lifetime using copula function and Miner's rule
↓
Comparing with the actual combined test results

▪ Distribution estimation

- Assume the Gaussian distribution
  - ✓ Cycle condition
  - ✓ Storage condition



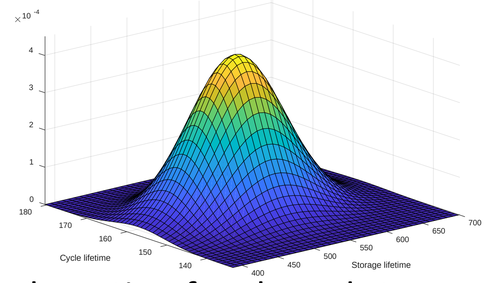
▪ Relationship of combined and cycle-storage condition

- Copula function

✓***Copula*** is the function that couples the multivariate distribution functions to their one-dimensional marginal distribution functions.

$$F_{X_1 \ldots X_n}(x_1, \ldots, x_n) = C(F_{X_1}(x_1), \ldots, F_{X_n}(x_n) | \theta)$$

$F_{X_1 \ldots X_n}$: multivariate joint CDF θ: correlation matrix
F_{X_n}: univariate marginal CDFs C: copula function



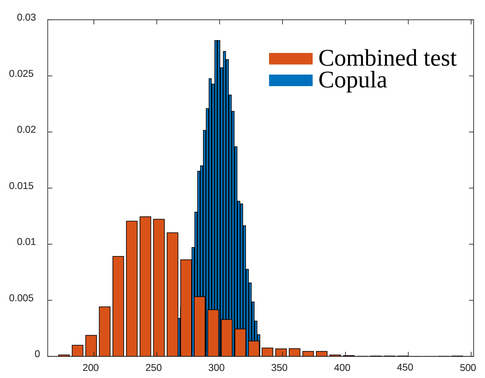
- The ratio of cycle and storage = 32/68
- Using Gaussian Copula function

- Miner's rule

$$\frac{n_1}{N_1} + \frac{n_2}{N_2} = \frac{1}{N} \quad (n_1 + n_2 = 1)$$

✓N_1: Lifetime considering only cycle
✓N_2: Lifetime considering only storage
✓n_1: Ratio of cycle
✓n_2: Ratio of storage

- Result



Lifetime of combined condition

Acknowledgement and References

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2. Takeno, Kazuhiko, et al. "Influence of cycle capacity deterioration and storage capacity deterioration on Li-ion batteries used in mobile phones." *Journal of power sources* 142.1-2 (2005): 298-305.