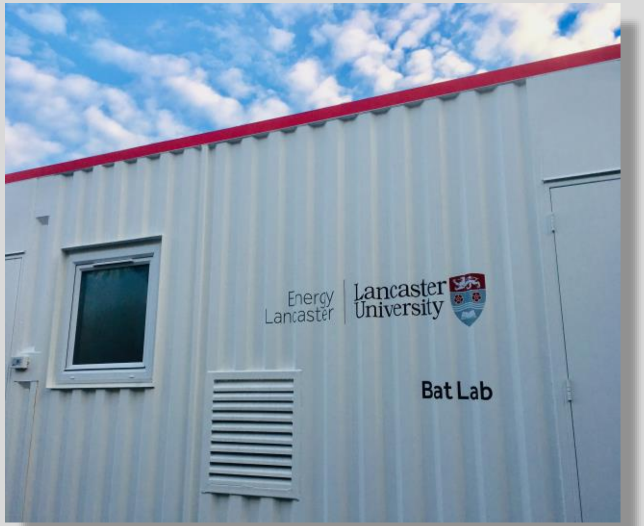
Random forest regression for lithium ion battery capacity estimation *

Yi Li

* Li, Y., Zou, C., Berecibar, M., Nanini-Maury, E., Chan, J.C.W., van den Bossche, P., Van Mierlo, J. and Omar, N., 2018. Random forest regression for online capacity estimation of lithium-ion batteries. *Applied energy*, *232*, pp.197-210.



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1. Background and motivation

Why do we need to know battery state of health (SOH)?

Battery Ageing

SOH = 100%

$$SOH = \frac{Q_t}{Q_0} \times 100\%$$

SOH = 80%

Battery Replacement

1. Background and motivation

Capacity Diagnosis

Off-line

- Capacity test: fully charge and then discharge

On-line

- Model Driven
- Data Driven
  - Empirical/Semi-empirical model
  - Machine learning
  - ….

2. Data & Model

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Machine Learning for SOH estimation

Step 1

Data collection	Data pre-processing	Predictive model development	Integrate analytics with systems
• Historical data base • Data collection from sensors (e.g. I, V, T)	• Reducing noise in data • Data reduction/ transformation • Feature extraction	• Model creation • Parameter tuning/ optimization • Model validation	• Embedded in BMS

2. Data & Model

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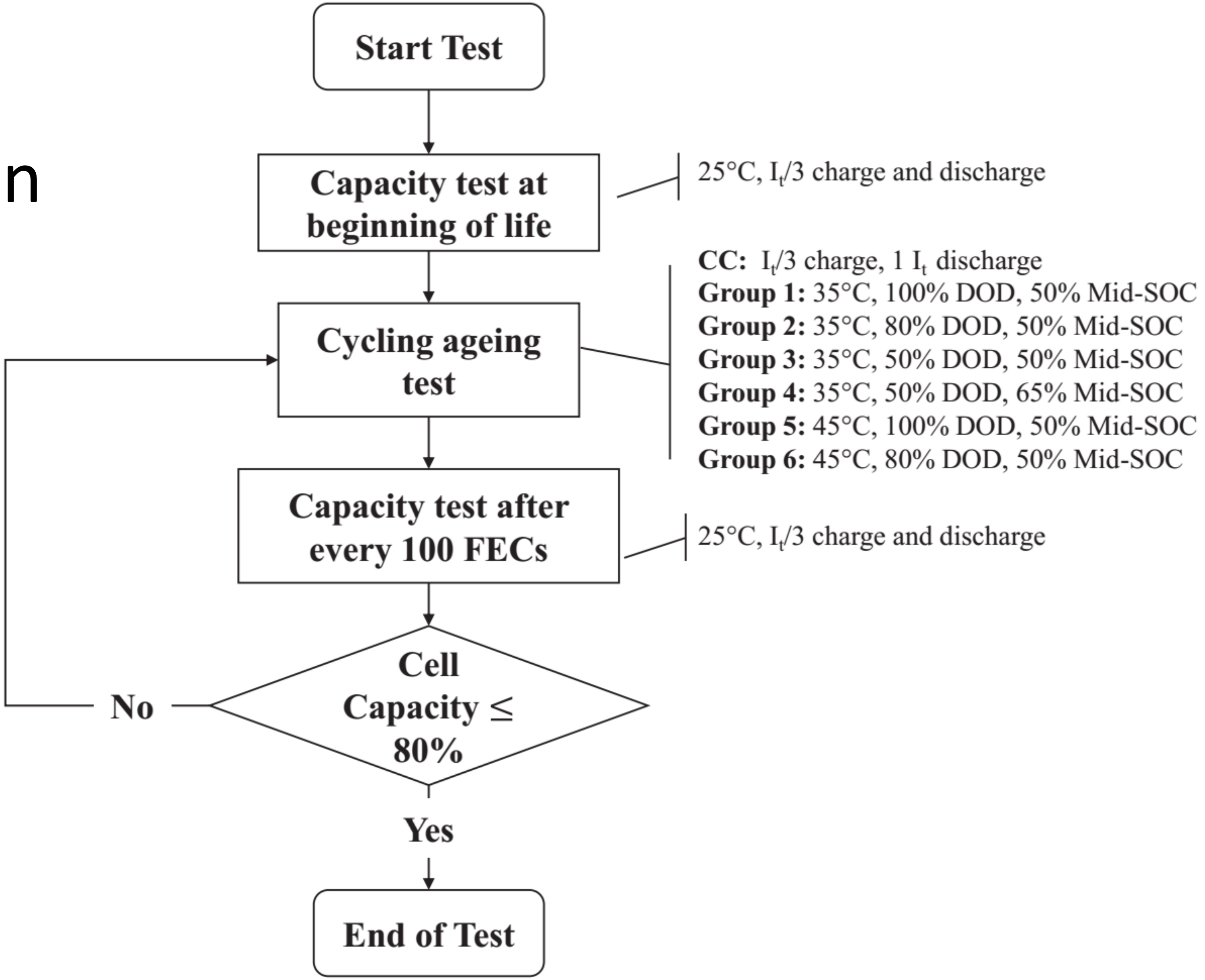
Step 1.

Data collection



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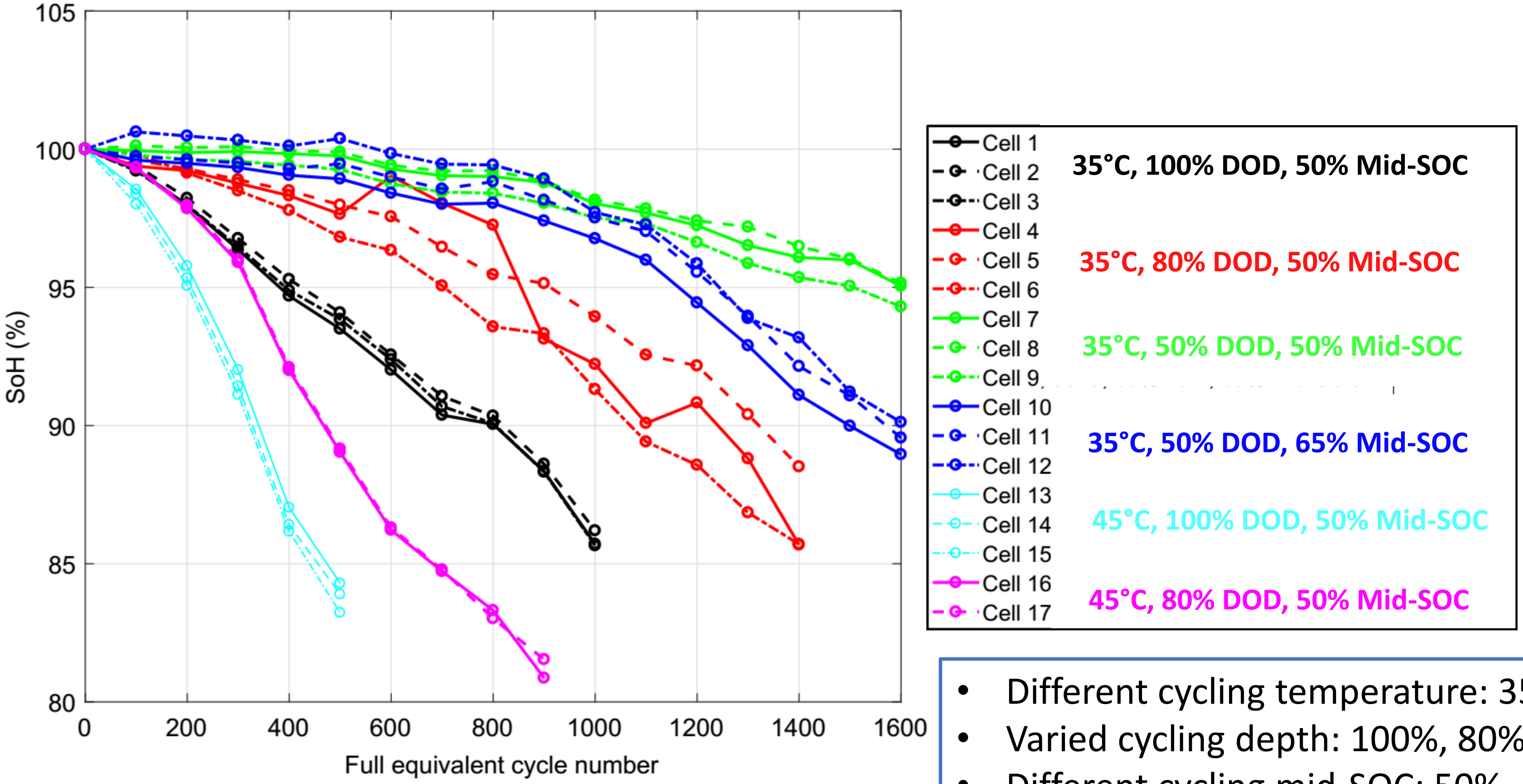
Capacity fade result :



- Different cycling temperature: 35, 45°C
- Varied cycling depth: 100%, 80%, 50%
- Different cycling mid-SOC: 50%, 65%

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Step 2

Access and explore data

- Historical data base
- Data collection from sensors (e.g. I, V, T)

Data pre-processing

- Reducing noise in data
- Data reduction/ transformation
- Feature extraction

Predictive model development

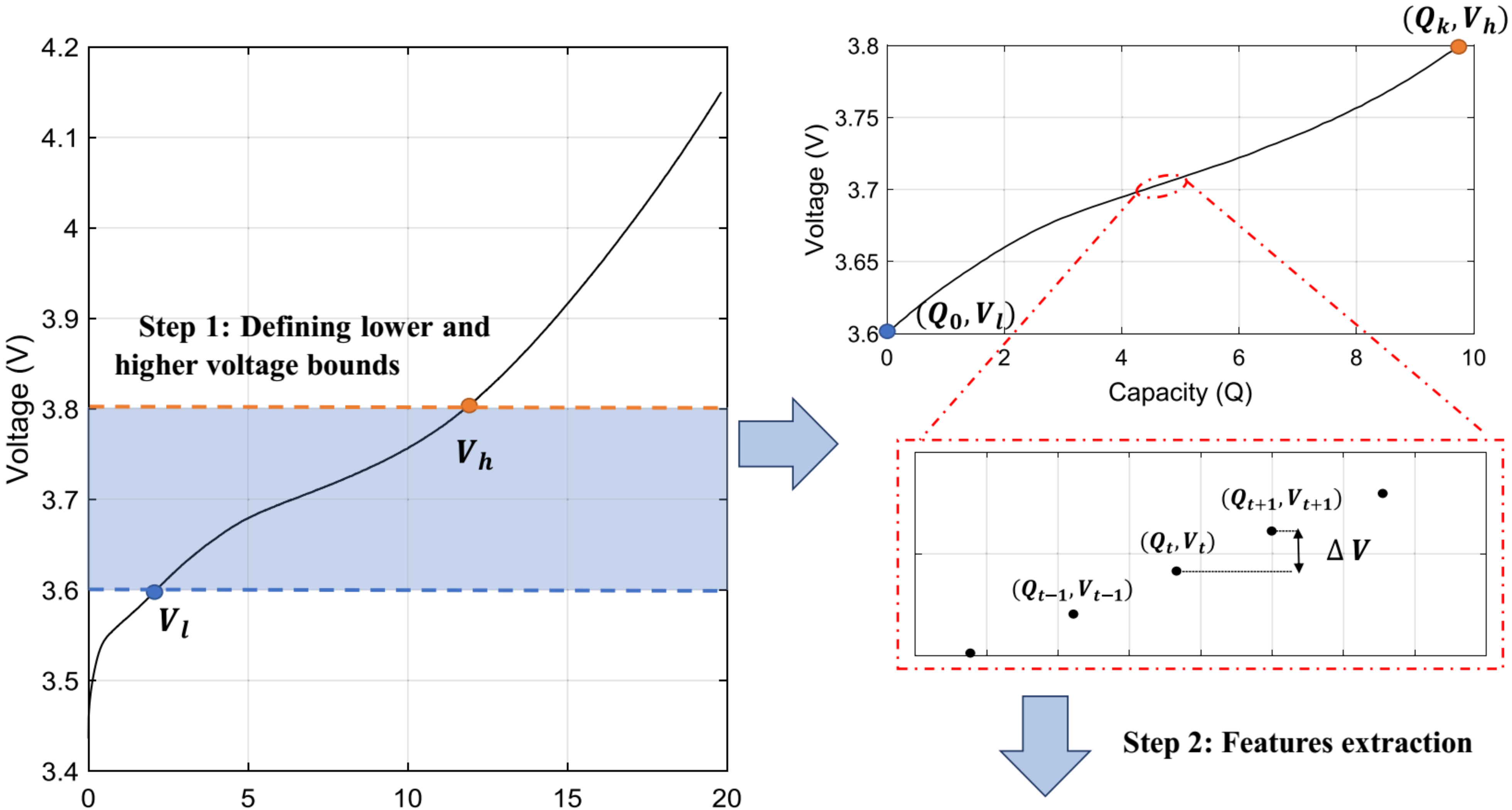
- Model creation
- Parameter tuning/ optimization
- Model validation

Integrate analytics with systems

- Embedded in BMS

2. Data & Model

Step 2. feature selection



$$\{X_i, Y_i\} = \{(x_0, x_1, \ldots, x_k), Y_i\} = \{(Q_0, Q_1, \ldots, Q_t, \ldots, Q_h), Y_i\}$$

2. Data & Model

Step 3

Access and explore data

- Historical data base
- Data collection from sensors (e.g. I, V, T)

Data pre-processing

- Reducing noise in data
- Data reduction/ transformation
- Feature extraction

Predictive model development

- Model creation
- Parameter tuning/ optimization
- Model validation

Integrate analytics with systems

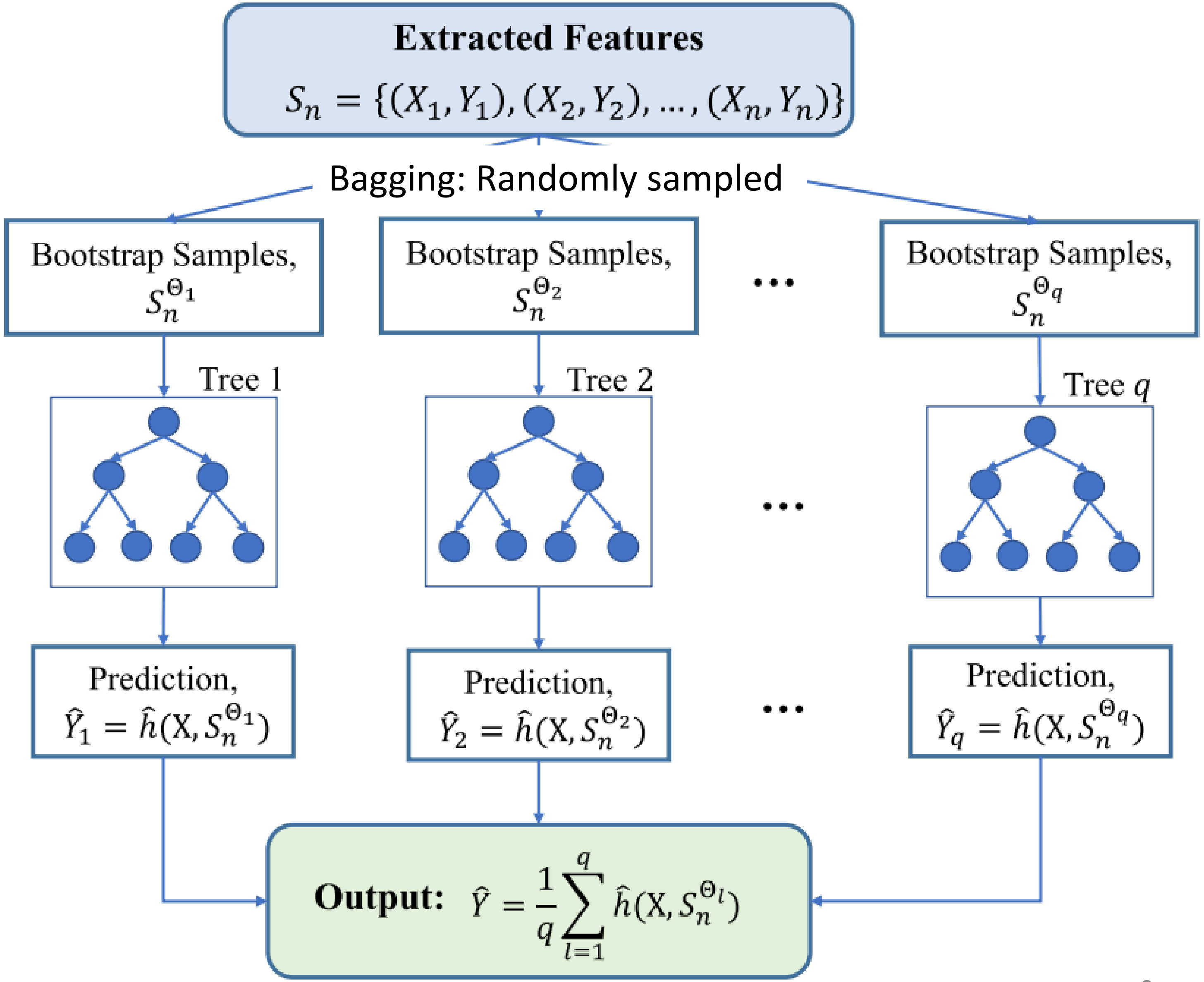
- Embedded in BMS

2. Data & Model

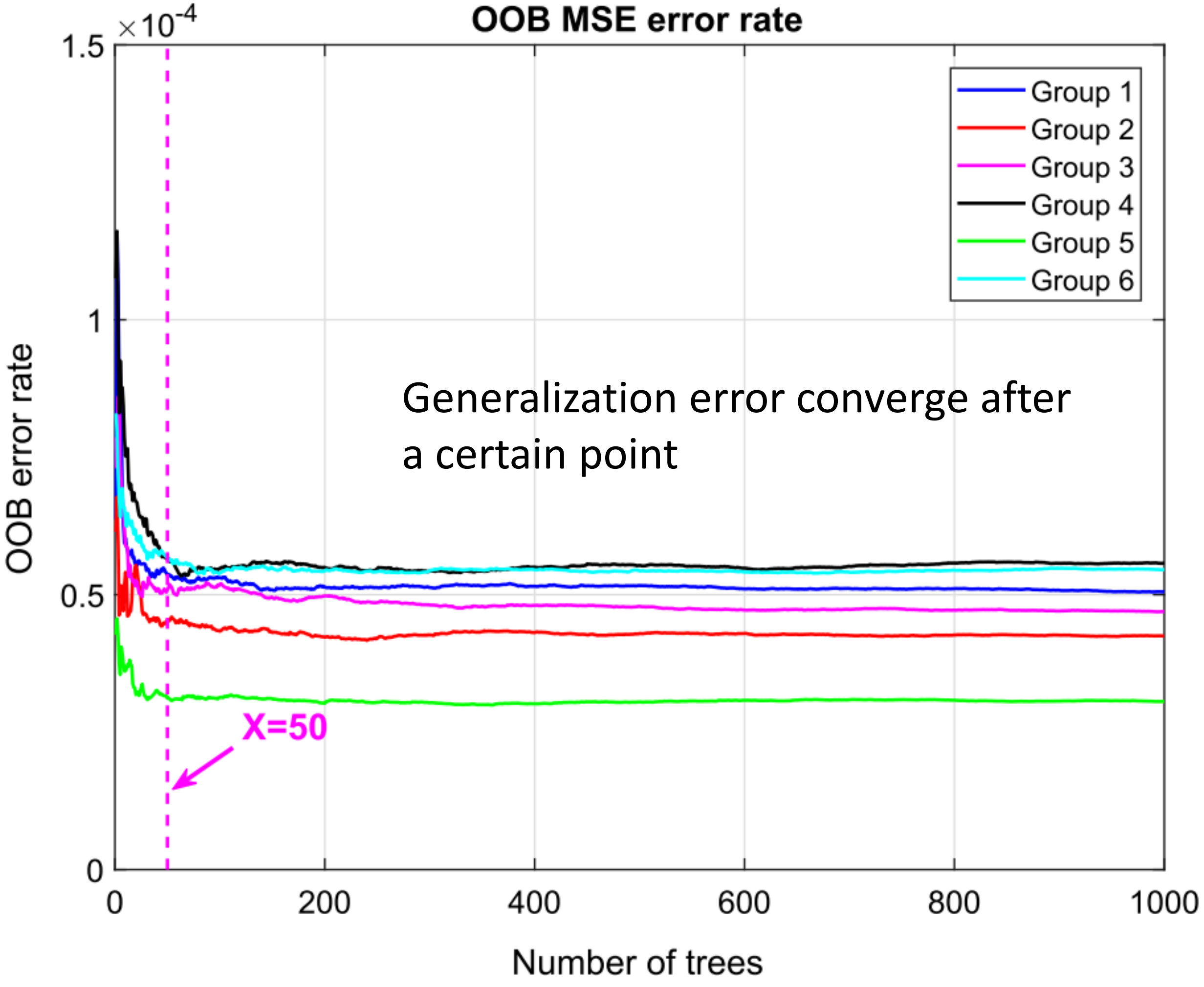
Step 3. Algorithm selection

Random Forest Regression:

An ensembled method



2. Data & Model



Offline parameter tuning

ntree: the number of trees
mtry: the number of random features for each split in the forest to build (default number)

$$Loss = MSE = \sum (y_i - y_i^p)^2$$

y_i: ith target value
y_i^p: ith prediction

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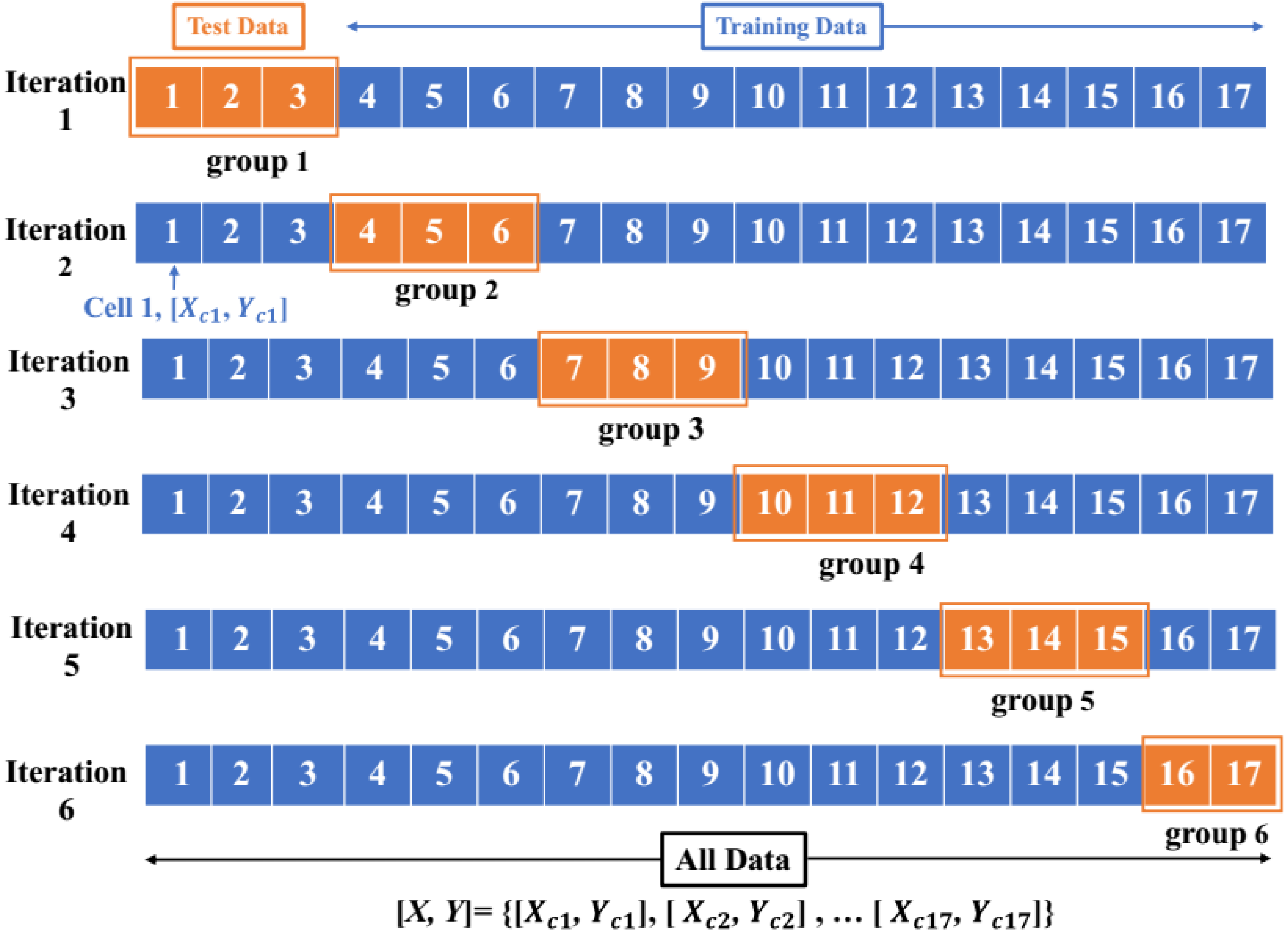
Leave n-out cross validation



2. Data & Model

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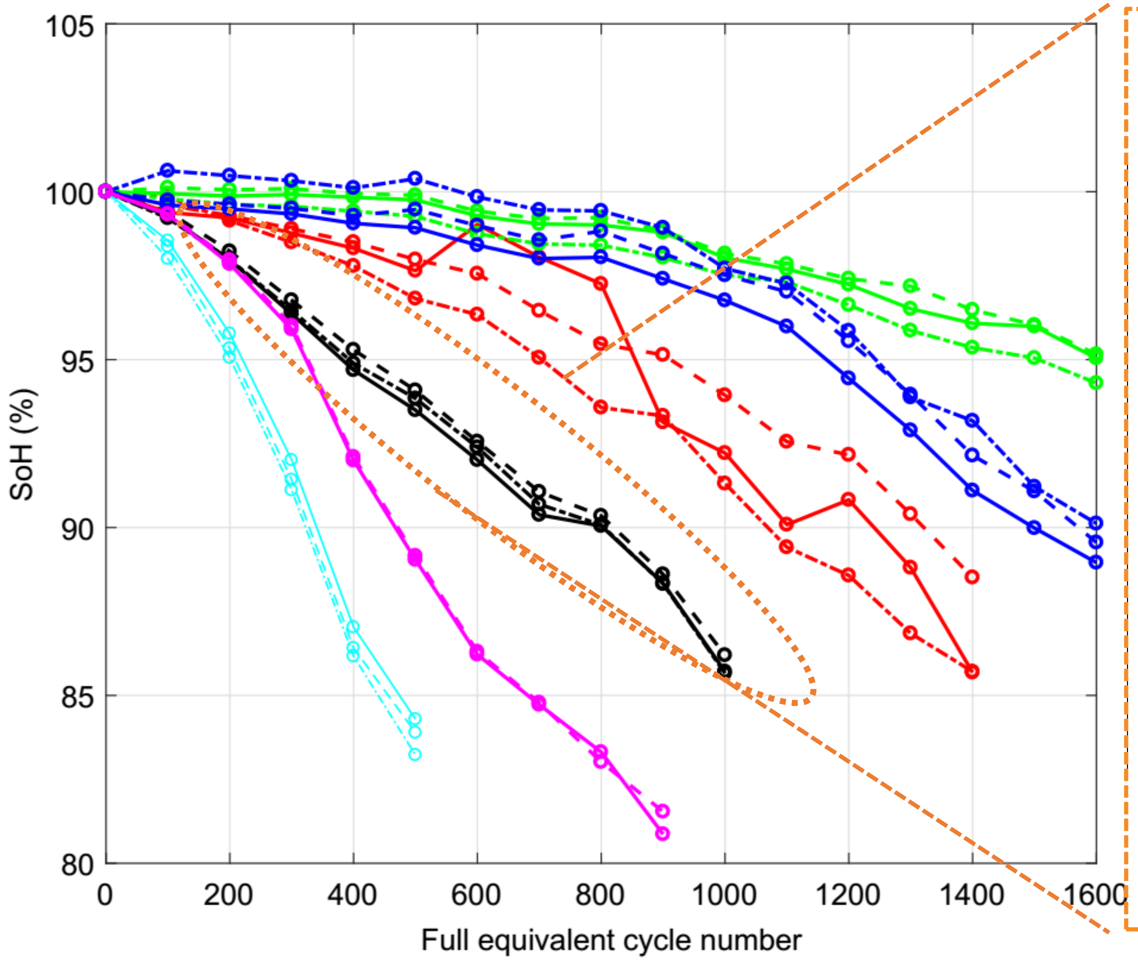
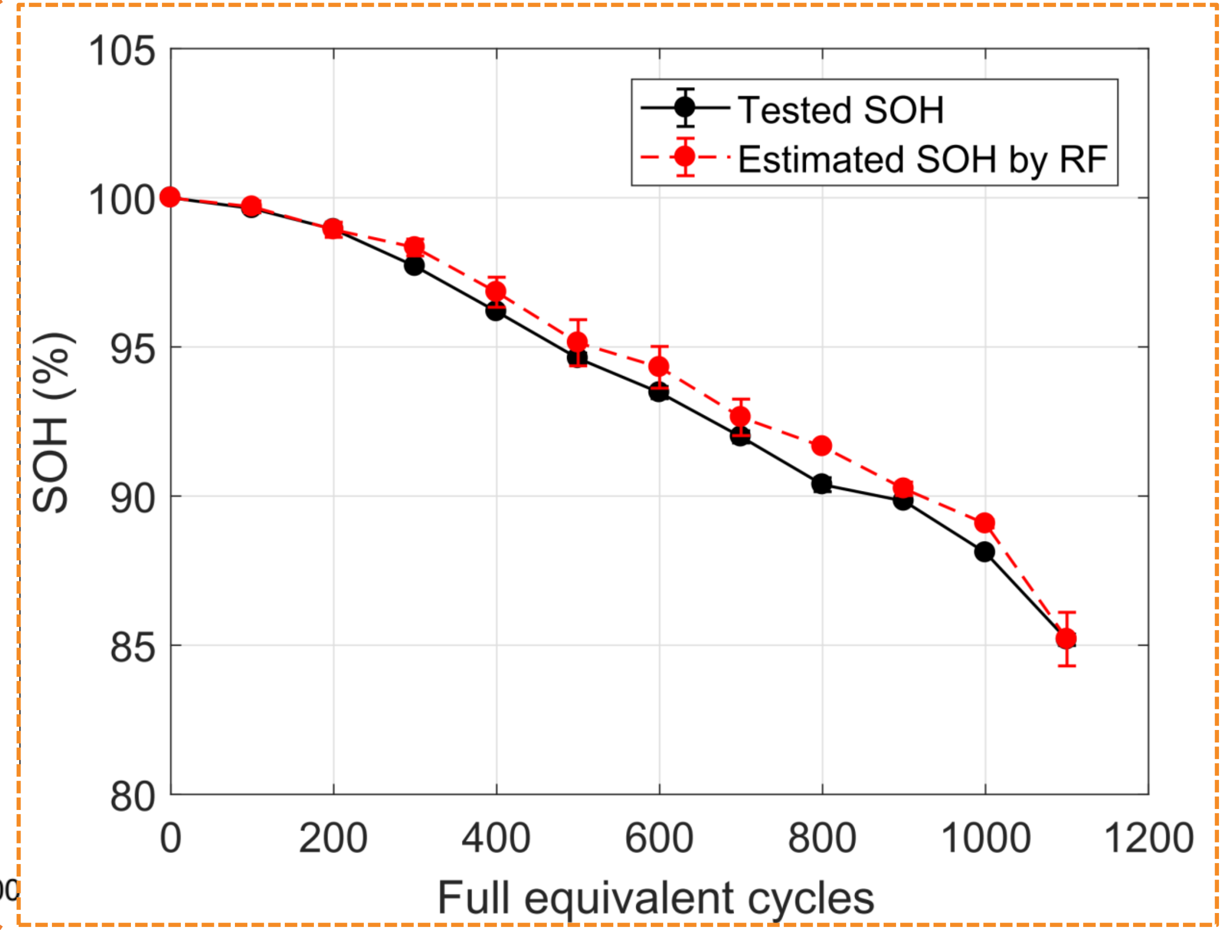
Experimental Results

Estimation Results





3. Results & Conclusion

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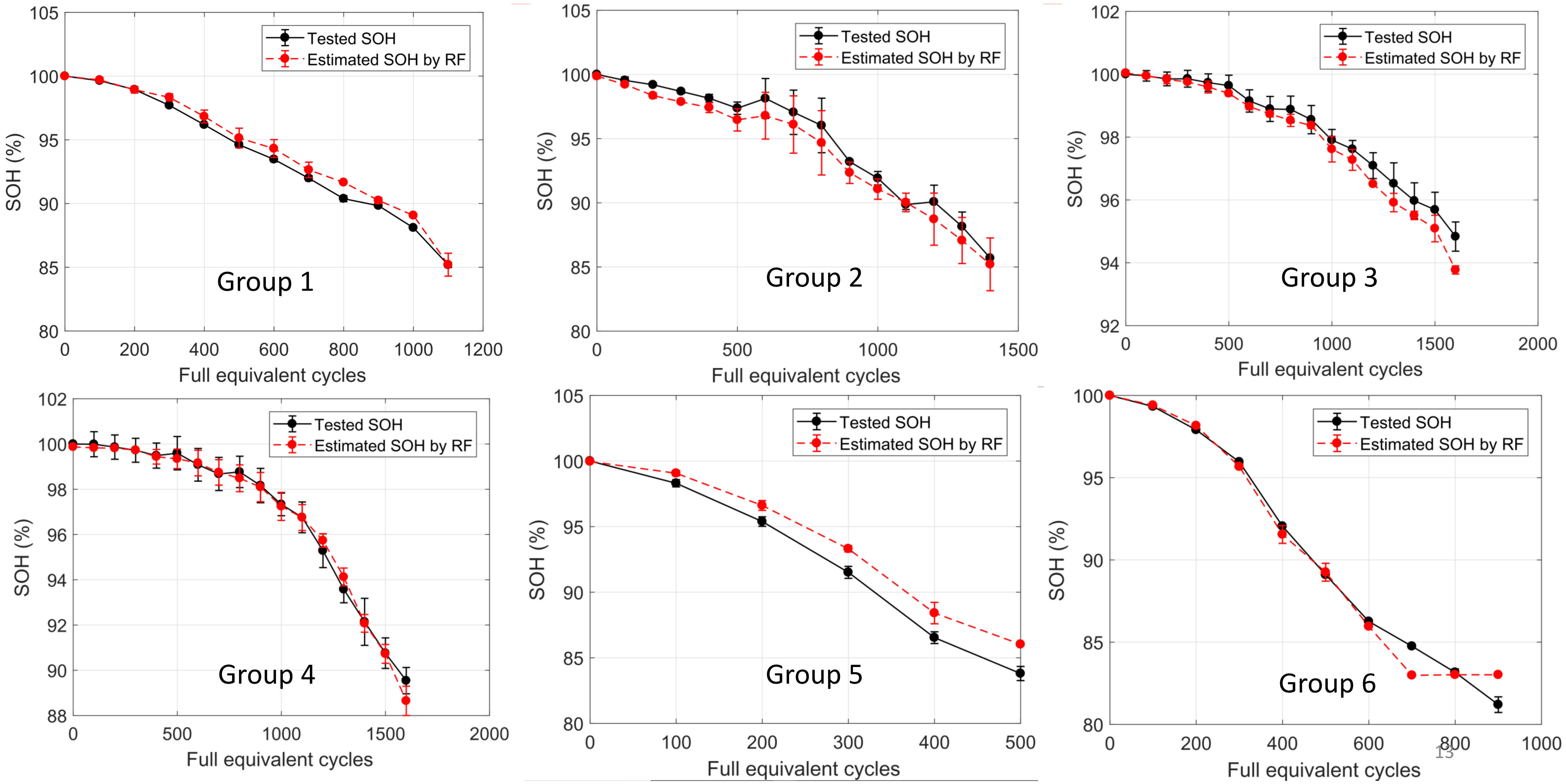
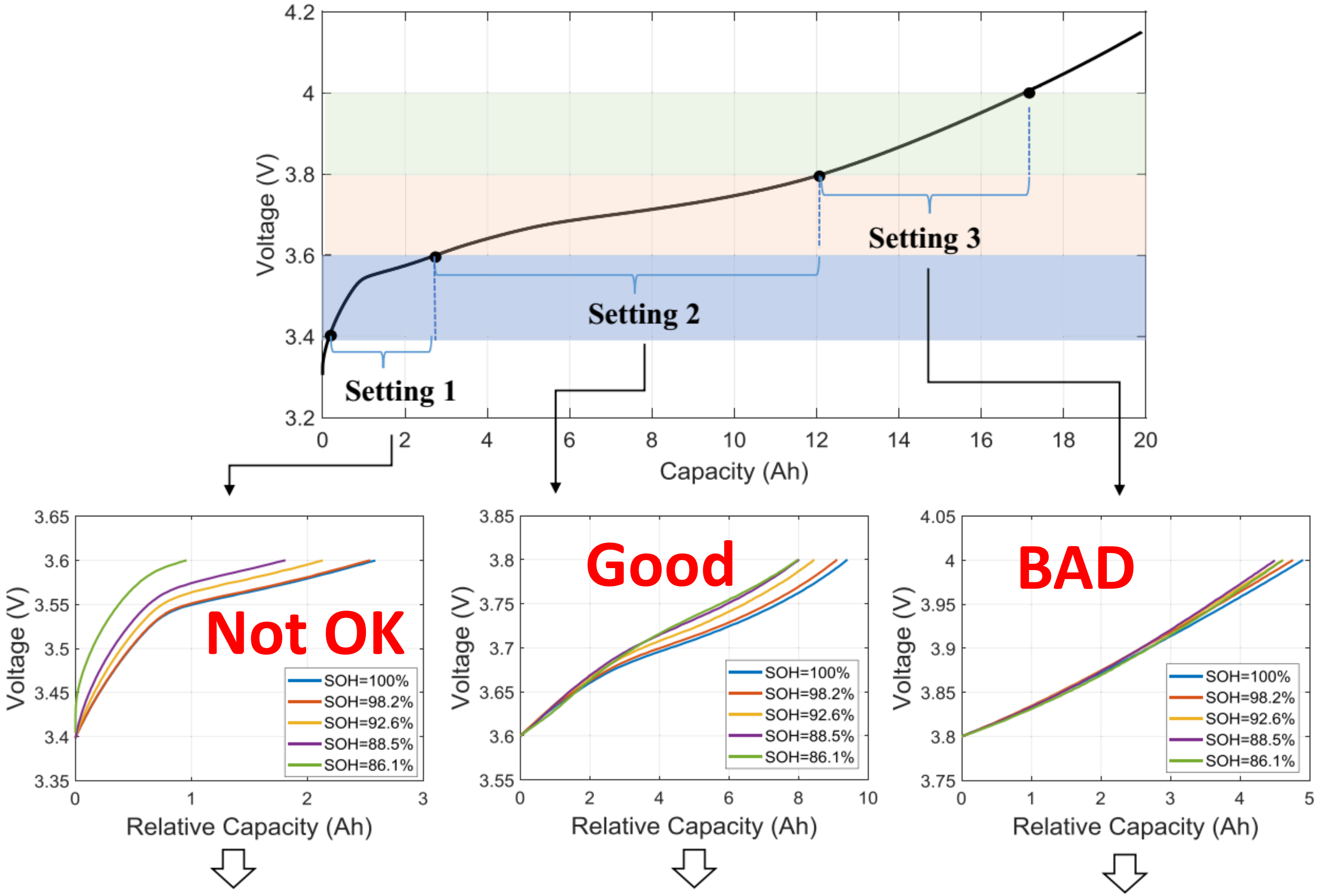
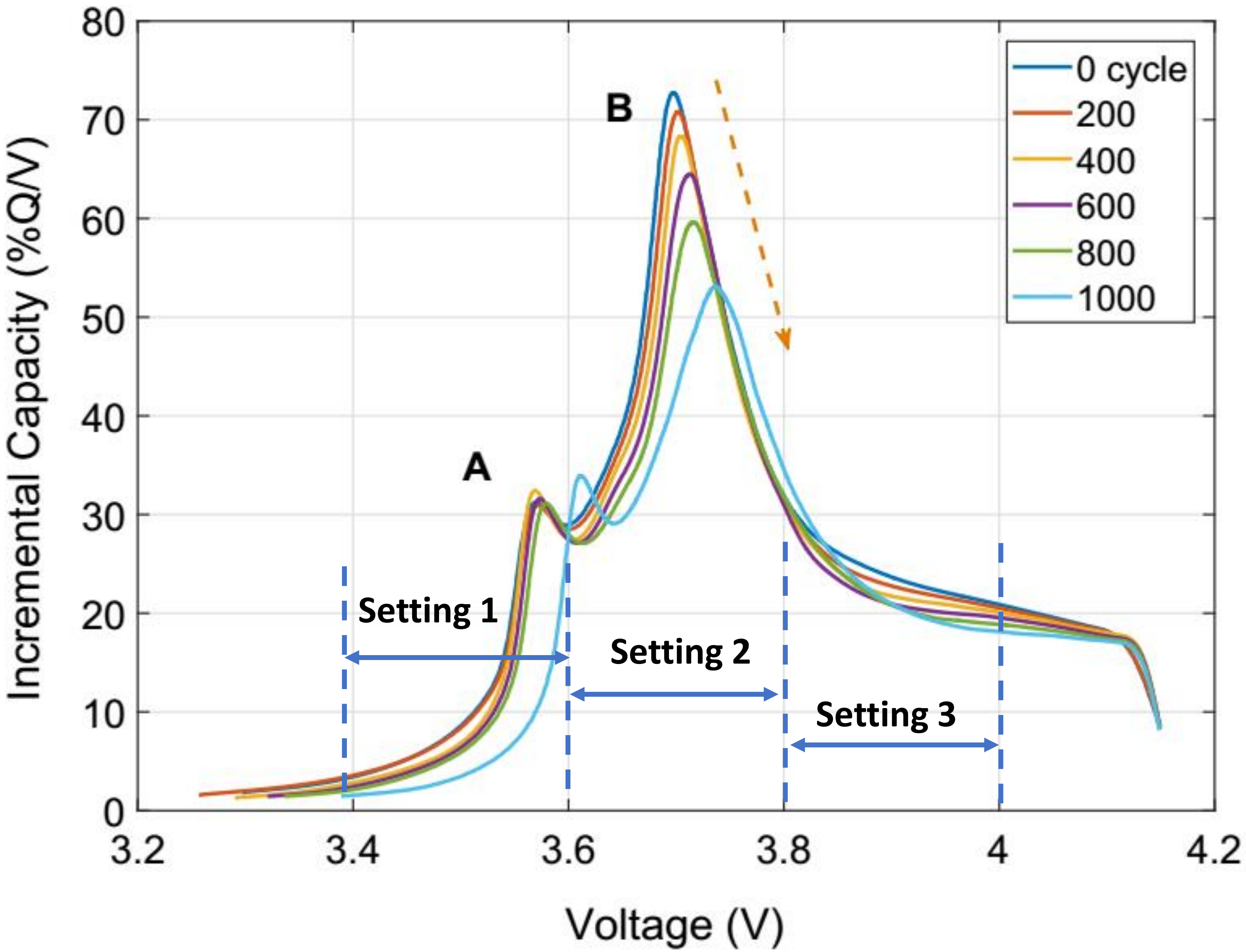


3. Results & Conclusion



$(X_1, Y_1), (X_2, Y_2)\ldots(X_M, Y_M)$ $(X_1, Y_1), (X_2, Y_2)\ldots(X_M, Y_M)$ $(X_1, Y_1), (X_2, Y_2)\ldots(X_M, Y_M)$

3. Results & Conclusion



Incremental Capacity analysis

$$\mathrm{IC} = \frac{dQ}{dV} \approx \frac{\Delta Q}{\Delta V} = \frac{Q_t - Q_{t-1}}{V_t - V_{t-1}}$$

3. Results & Conclusion

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Conclusion

- A online capacity estimation method with random forest regression was proposed
- Low effort for input feature collection
- IC analysis was used for input feature selection

Limits:

- Only charging voltage-capacity curves at 25°C are used for input feature selection
- Require constant current rate
- Low charging C-rate (C/3)

Outlook

- Dynamic using conditions
- Battery pack
- Health prediction

Thank you!

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Tuesday , 3rd

Shahin Nikman - Parallel Session 1b | 3 pm

Wed, 4th - Parallel Session 5a | 4pm

Michael Mercer

Beatrice Wolff

Robert Burrell

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