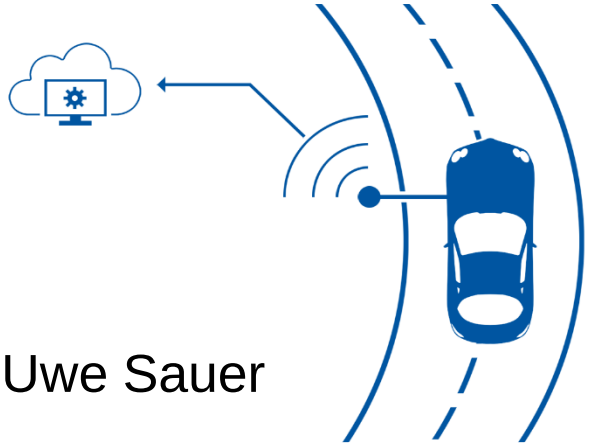
Battery Ageing • Battery Models • Battery Diagnostics • Battery Pack Design • Electromobility • Stationary Energy Storage • Energy System Analysis

Battery Cloud: Data-Powered Intelligent Battery Management for Mobile and Stationary Battery Systems

12th International Advanced Battery Power Conference
Münster, Germany

3/24/2020

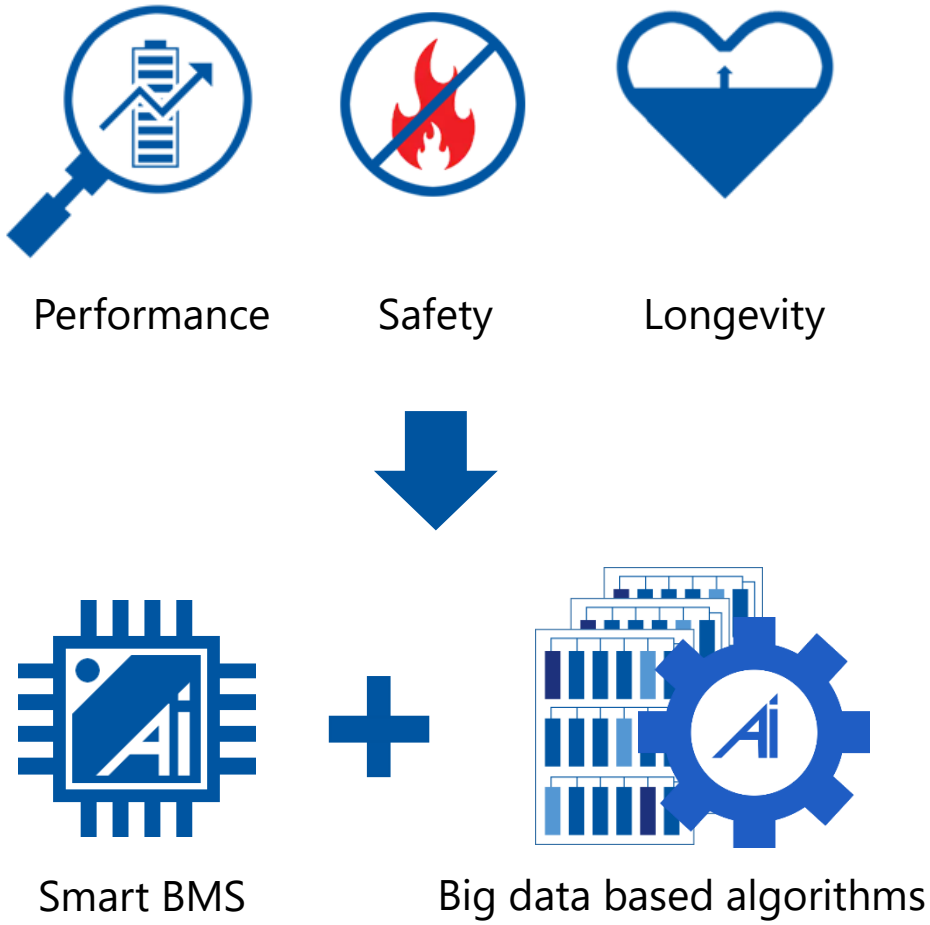
Weihan Li
Monika Rentemeister, Julia Badeda, Dominik Jöst, Dominik Schulte, Dirk Uwe Sauer



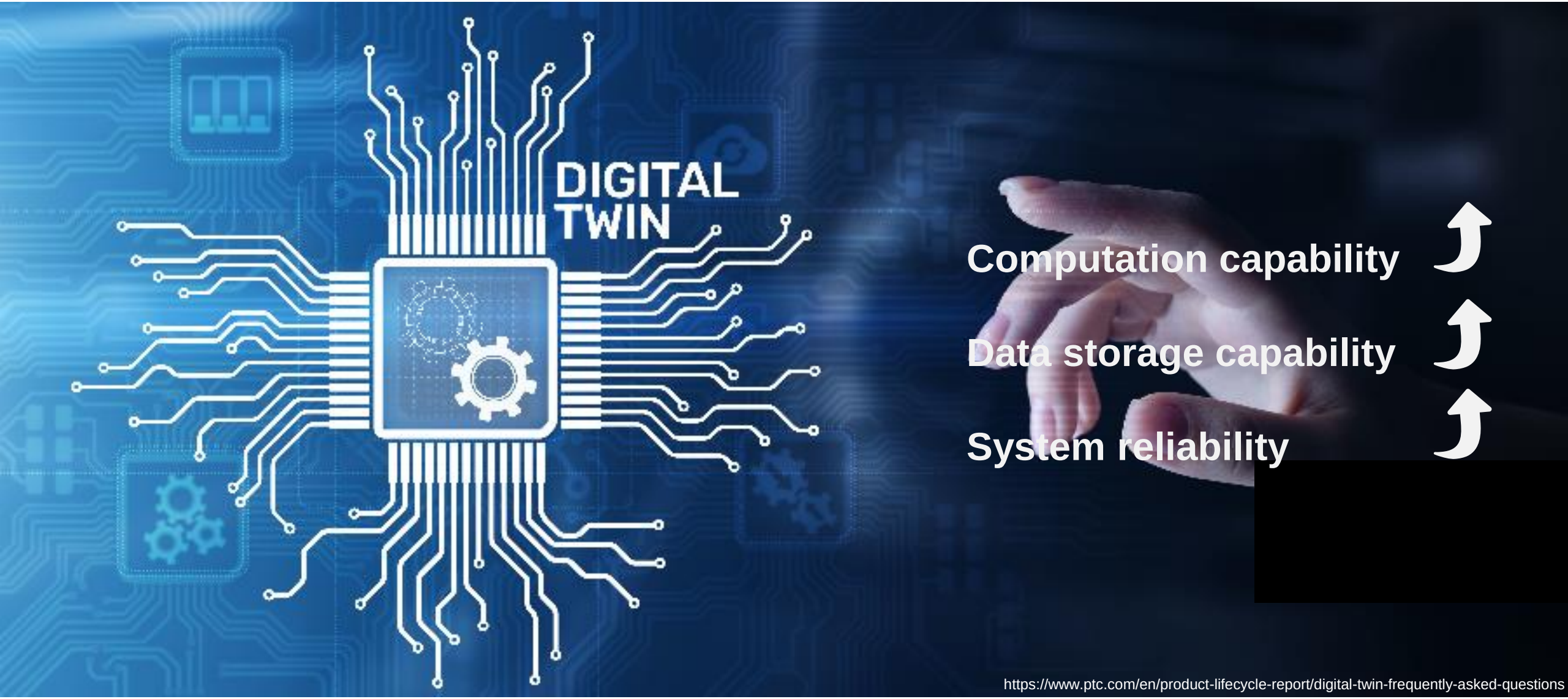
Chair for Electrochemical Energy Conversion and Storage Systems

iSEA Power Electronics and Electrical Drives | RWTH AACHEN UNIVERSITY

Motivation


Performance
Safety
Longevity
Smart BMS
Big data based algorithms

Digital Twin for Battery Systems



Computation capability

Data storage capability

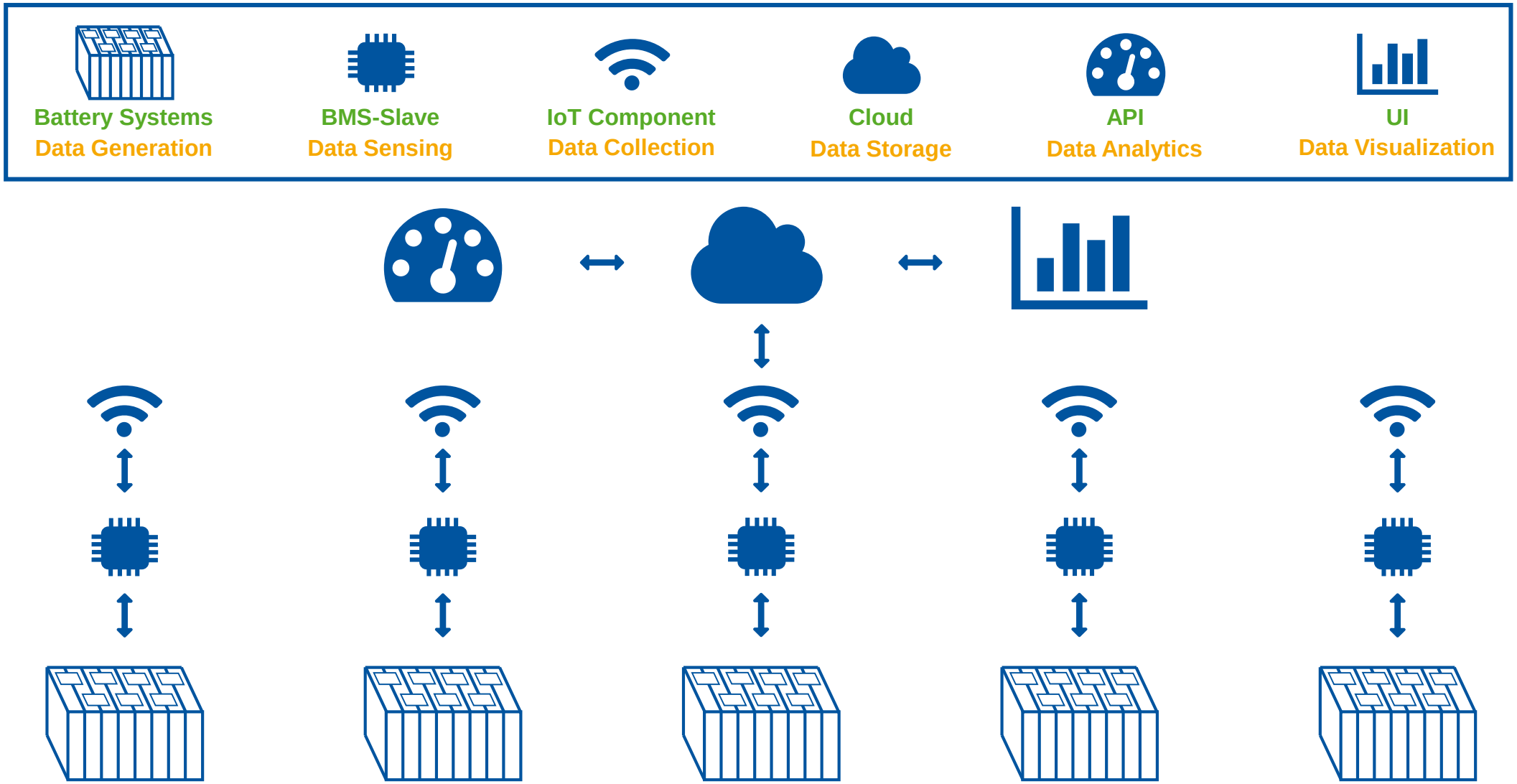
System reliability

https://www.ptc.com/en/product-lifecycle-report/digital-twin-frequently-asked-questions

Agenda

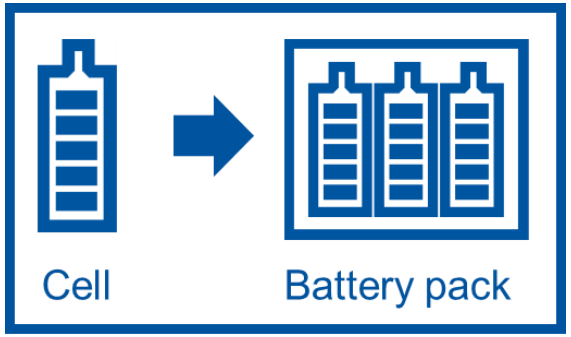
Agenda

Digital Twin: Cloud Battery Management System

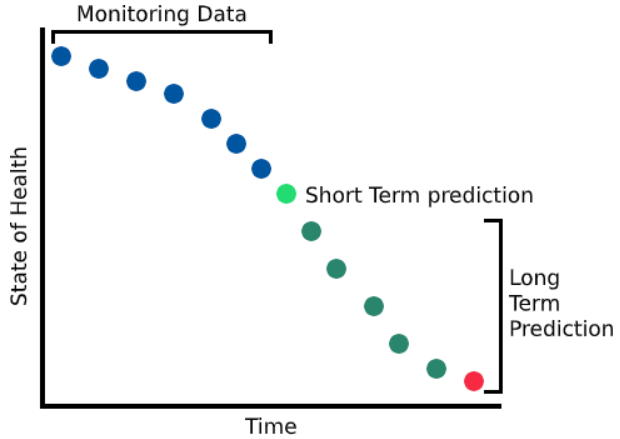


Digital Twin: Life cycle monitoring and optimization

Monitoring and Diagnostics

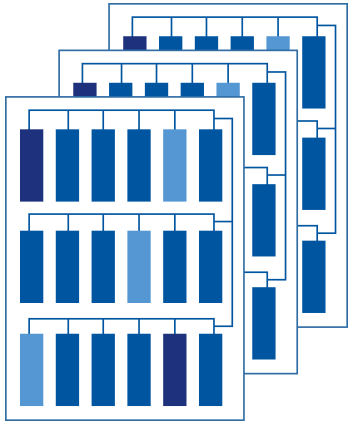


Lifetime Prediction

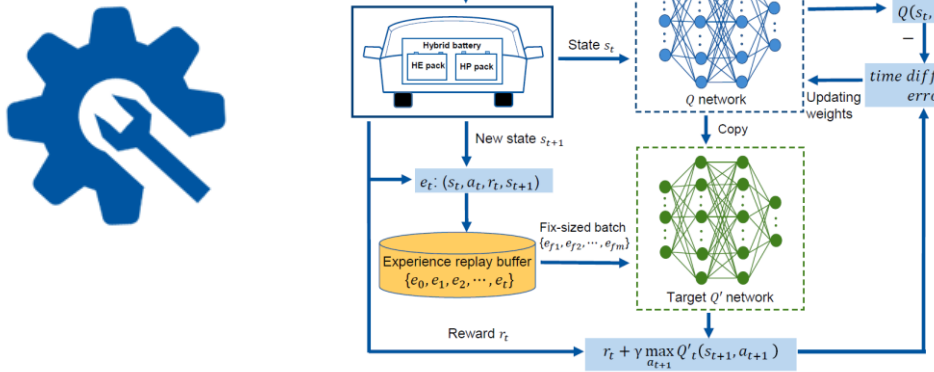


Digital Twin

Fault Diagnostic and Prediction



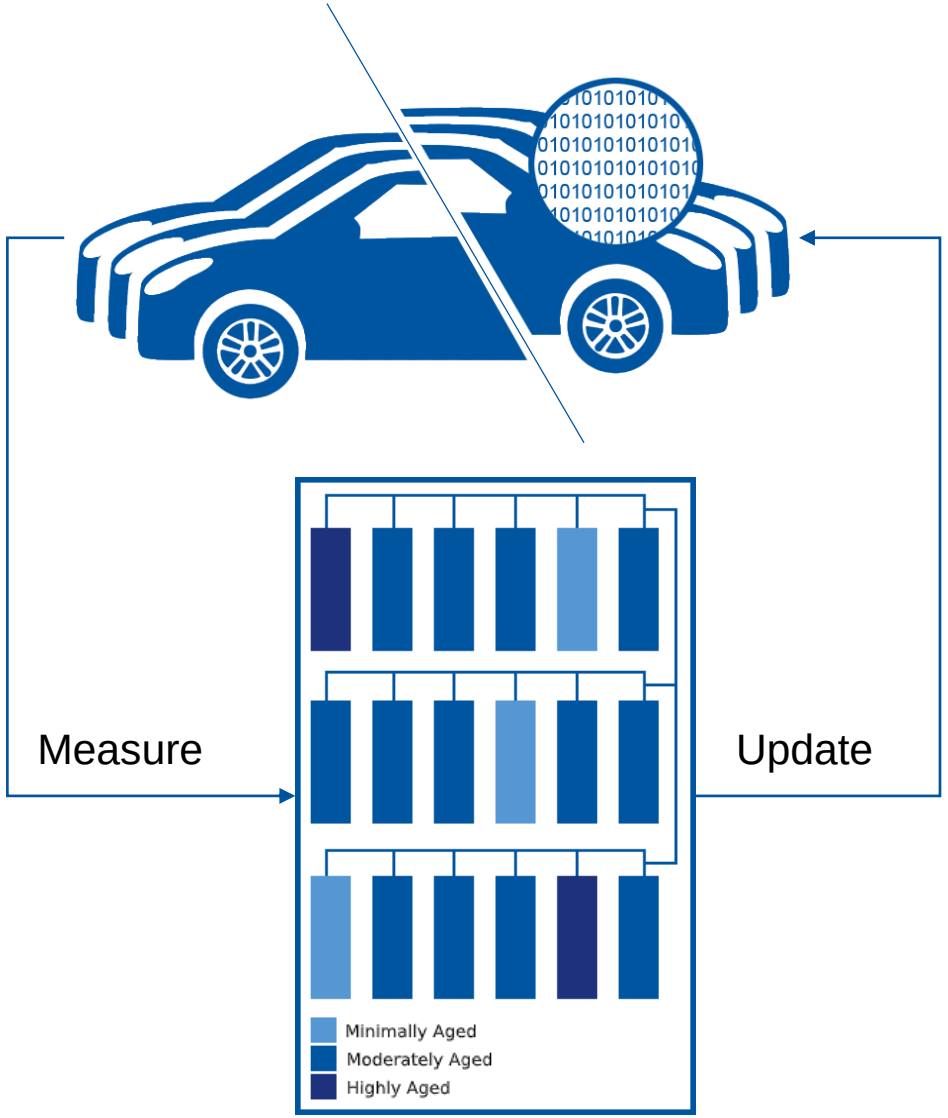
Evaluation and Optimization



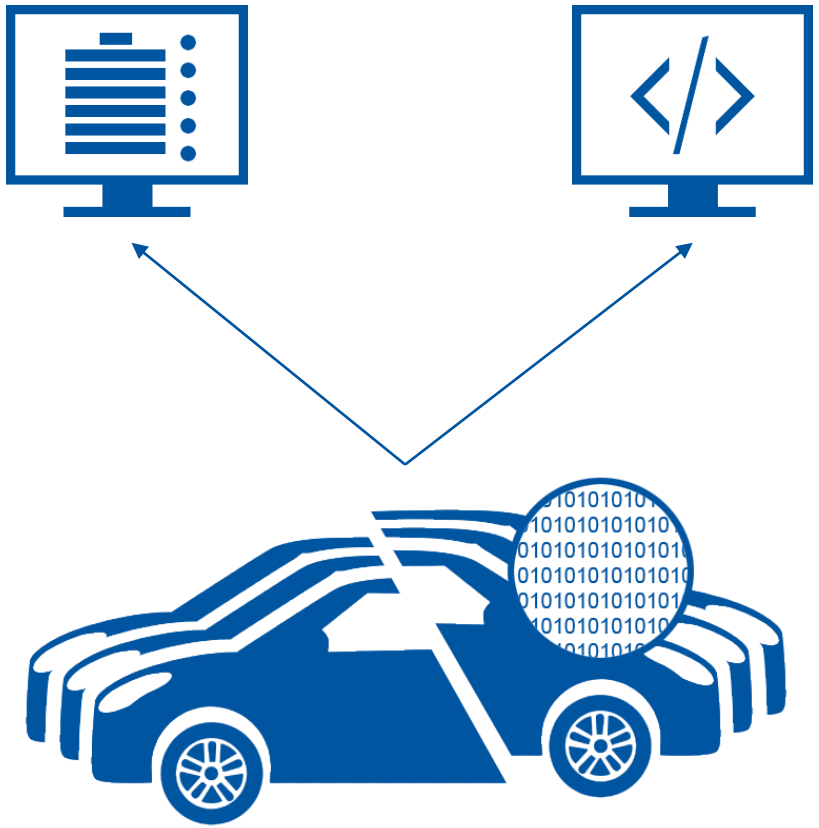
Agenda

Digital Twin: Monitoring and Diagnostic

- Seamlessly monitoring of the battery cells.
- By bridging the physical and the virtual world, data is transmitted seamlessly allowing the virtual entity to exist simultaneously with the battery systems.



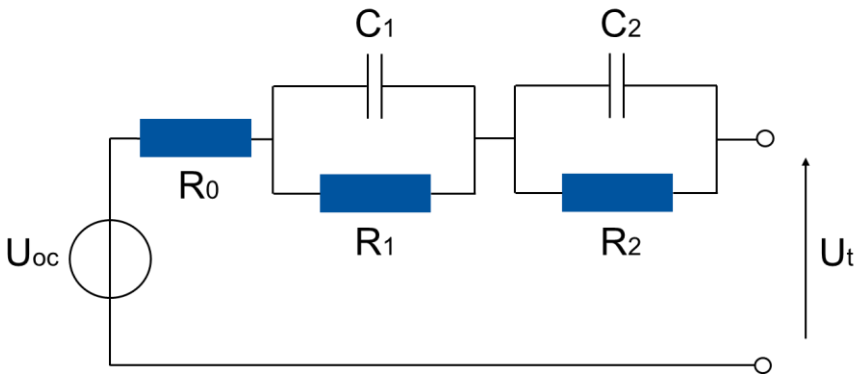
Digital Twin: Monitoring and Diagnostic

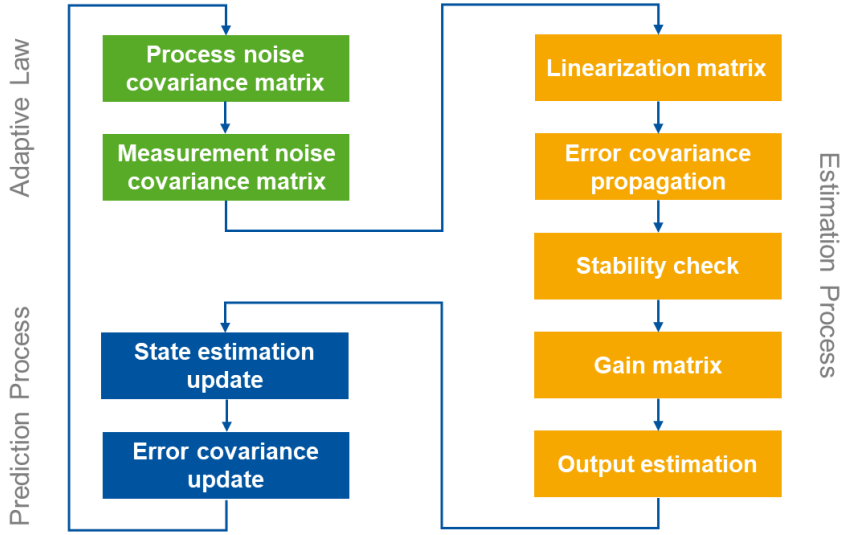


- Continuous updating of the cell parameters.
- Identification of various system parameters
  - Cell remaining capacity (SoC)
  - Cell impedance (SoH-R)
  - Cell capacity (SoH-C)
  - Pack impedance
  - Pack capacity
- Algorithms based on physical, electrochemical, and machine learning models

Model-Based State of Charge Estimation

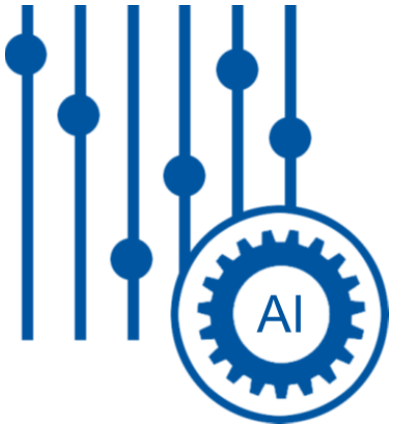
- Model-based state estimation
  - High robustness and accuracy
- Equivalent circuit model
  - Extended Thevenin model with two RC pairs
- State observer
  - Adaptive extended H-infinity filter
  - Covariance machine technique





Artificial Intelligence for State of Health Estimation

- Particle Swarm Optimization
  - Population-based and gradient-free global optimization method.
  - The optimal solution is searched by improving the candidate solutions based on the measure of quality.



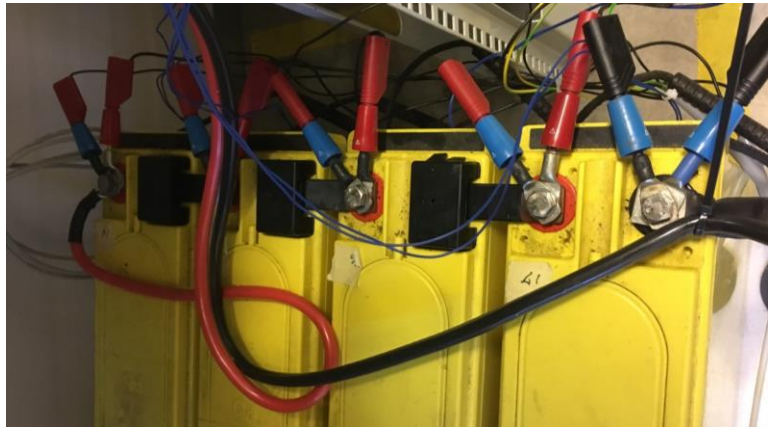
- Time-domain parameter identification
  - PSO algorithm tuning ECM parameters based on the real-world driving data.
  - Both SoH-R and SoH-C are estimated.

https://www.stratio.com/blog/swarm-intelligence-metaheuristics-part-2-particle-swarm-optimization/

Agenda

Field Validation of the Cloud BMS Functionalities

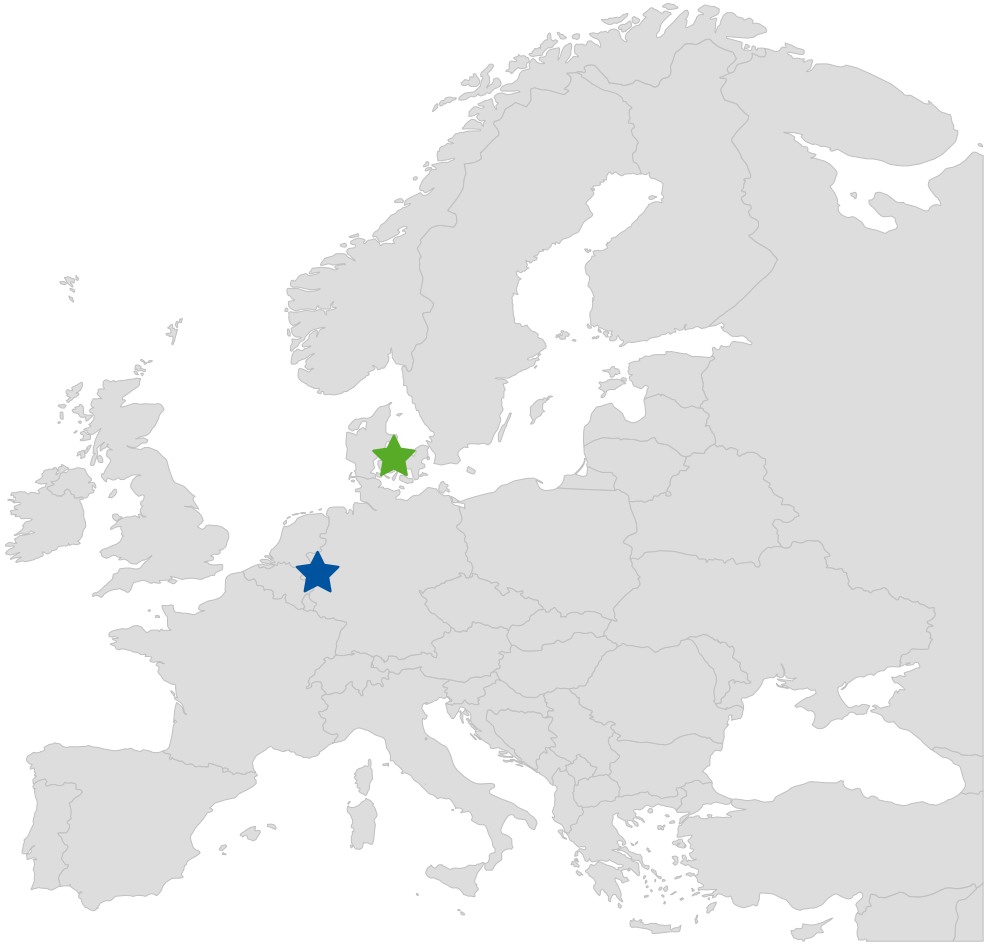
Voltage measurement



Temperature measurement

Current measurement

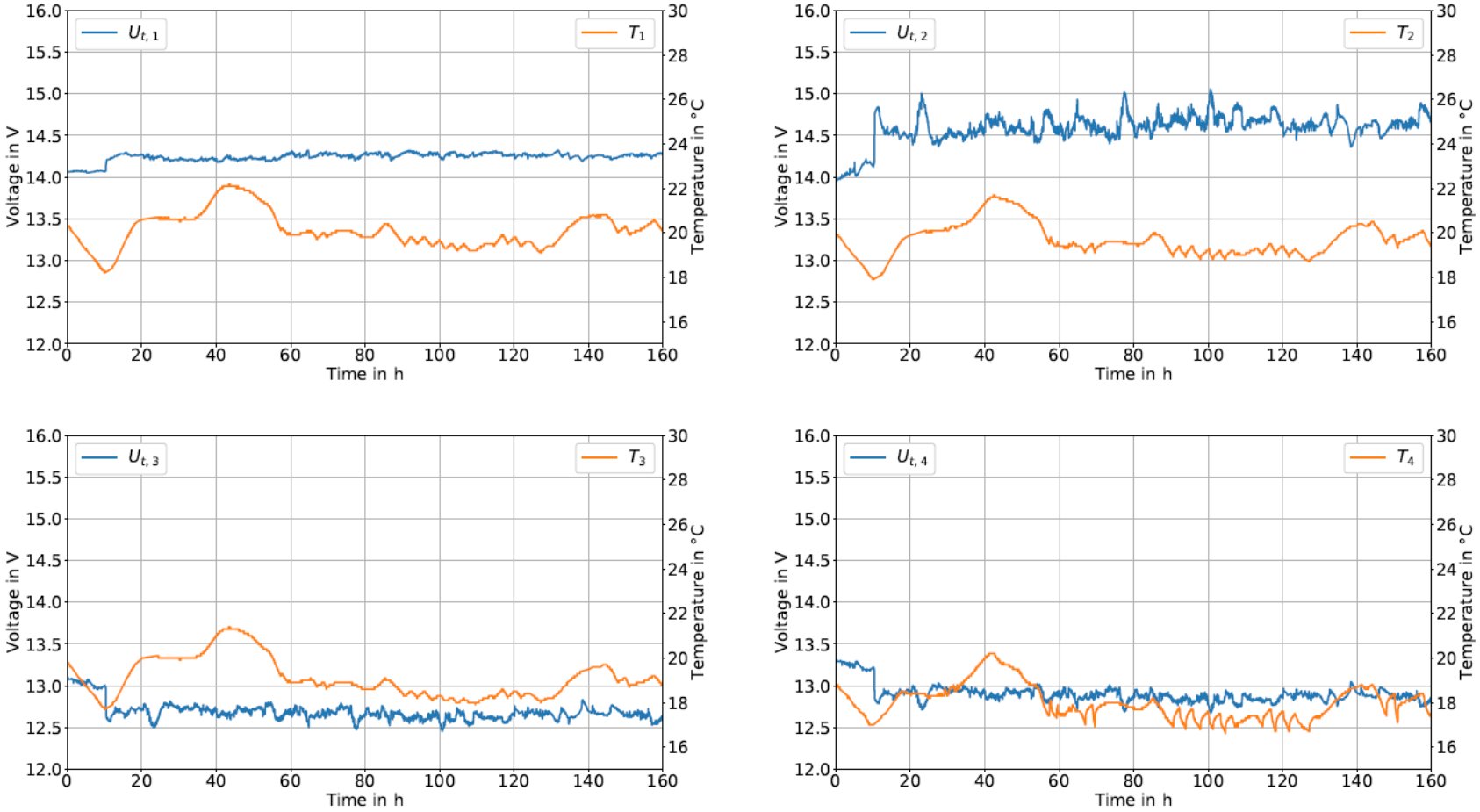
BMS-Slave



Field Validation of the Cloud BMS Functionalities

- Real-time remote monitoring
  - Voltage
  - Current
  - Temperature

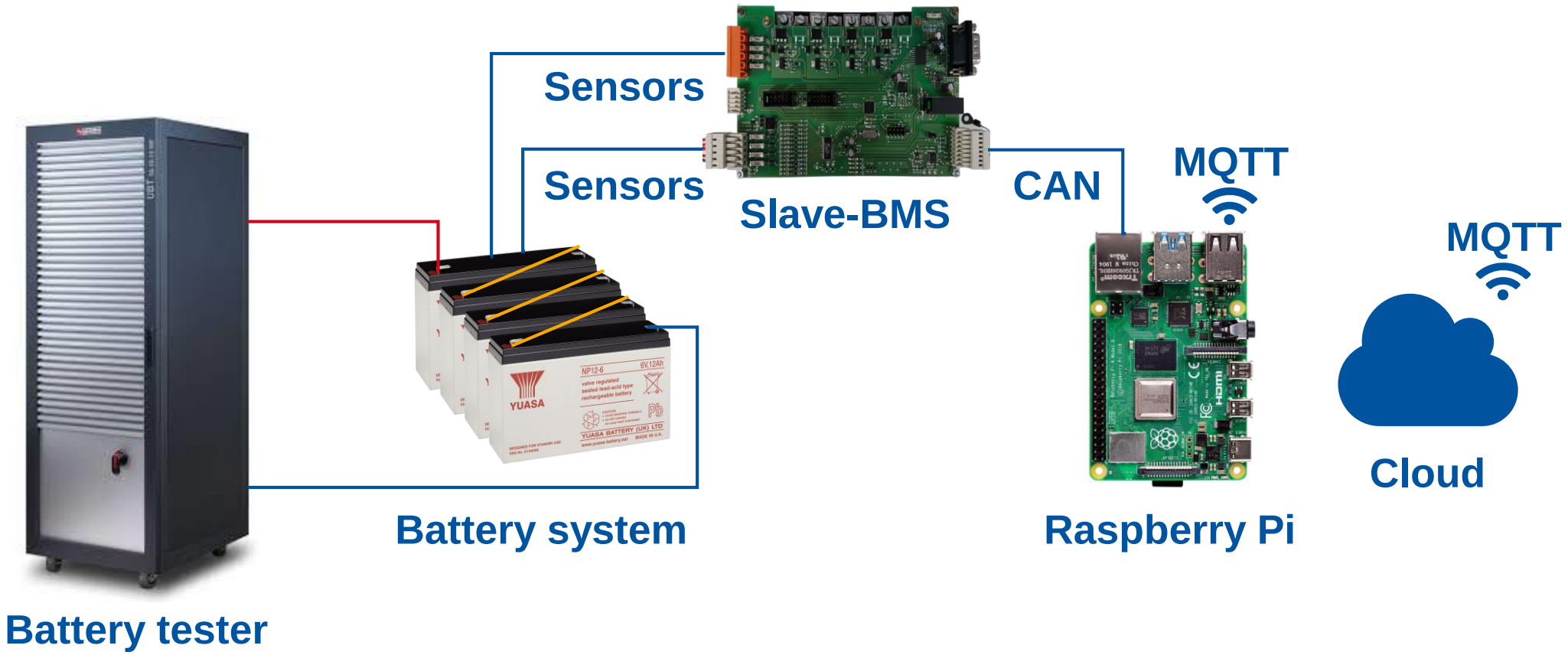
- Verification
  - Data sensing
  - Data collection
  - Data storage
  - Data visualization



Agenda

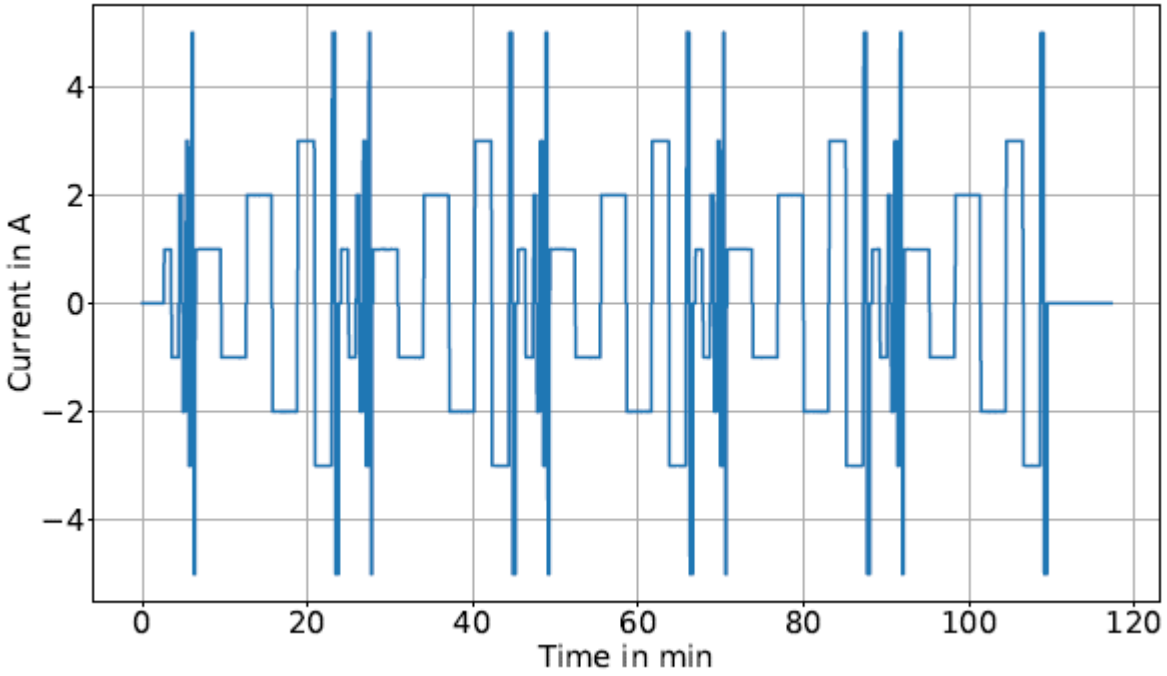
Agenda

Experimental Validation of the Diagnostic Algorithms

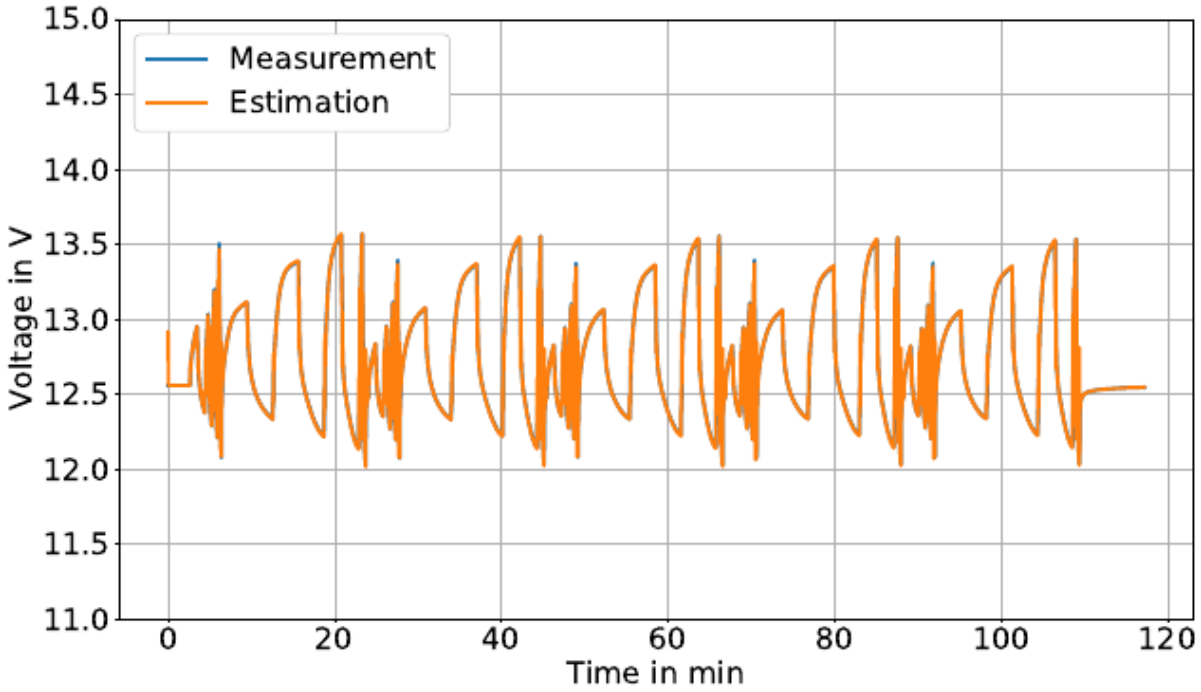


Experimental Validation of SoC Algorithm with Lead-acid Batteries

- A dynamic current profile with pulses
  - Multi-use stationary battery system

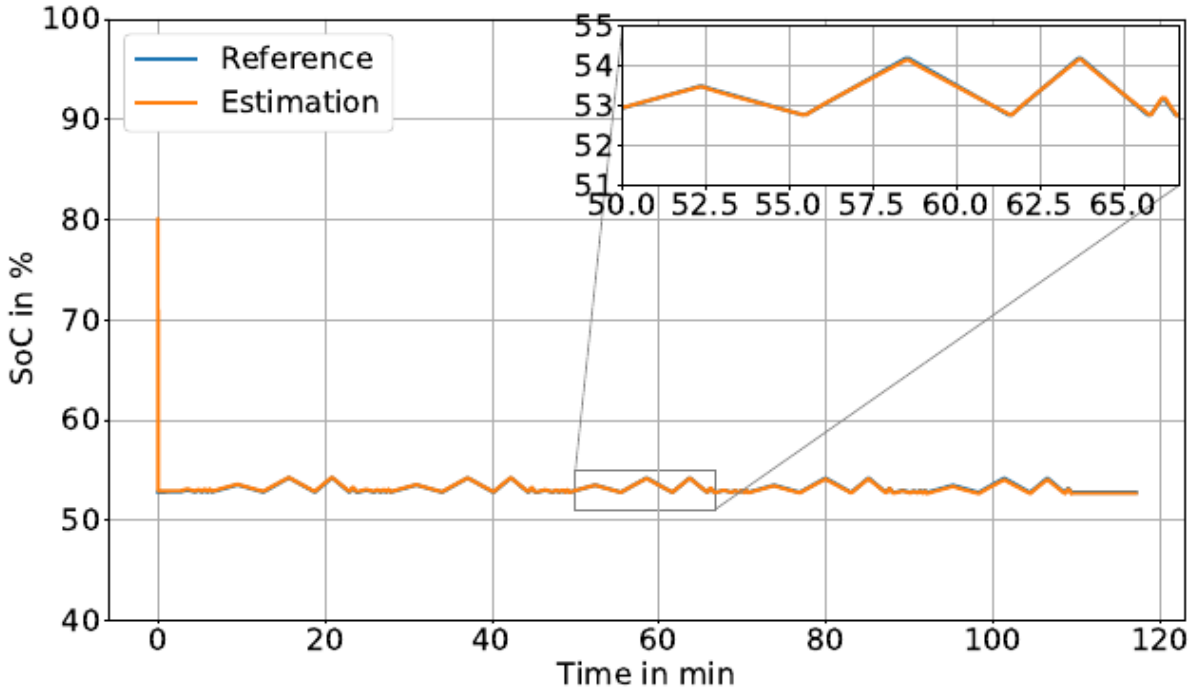


- Voltage estimation
  - Mean absolute error: 0.01 V

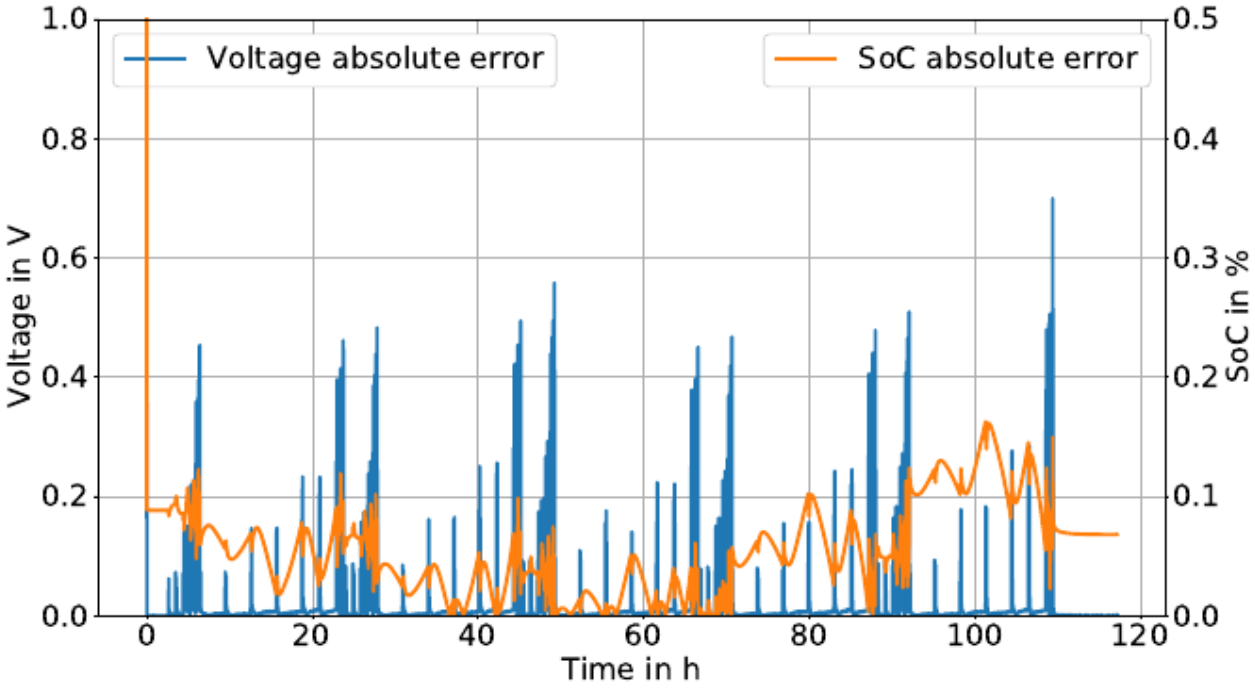


Experimental Validation of SoC Algorithm with Lead-acid Batteries

- SoC estimation
  - Mean absolute error: 0.06%.



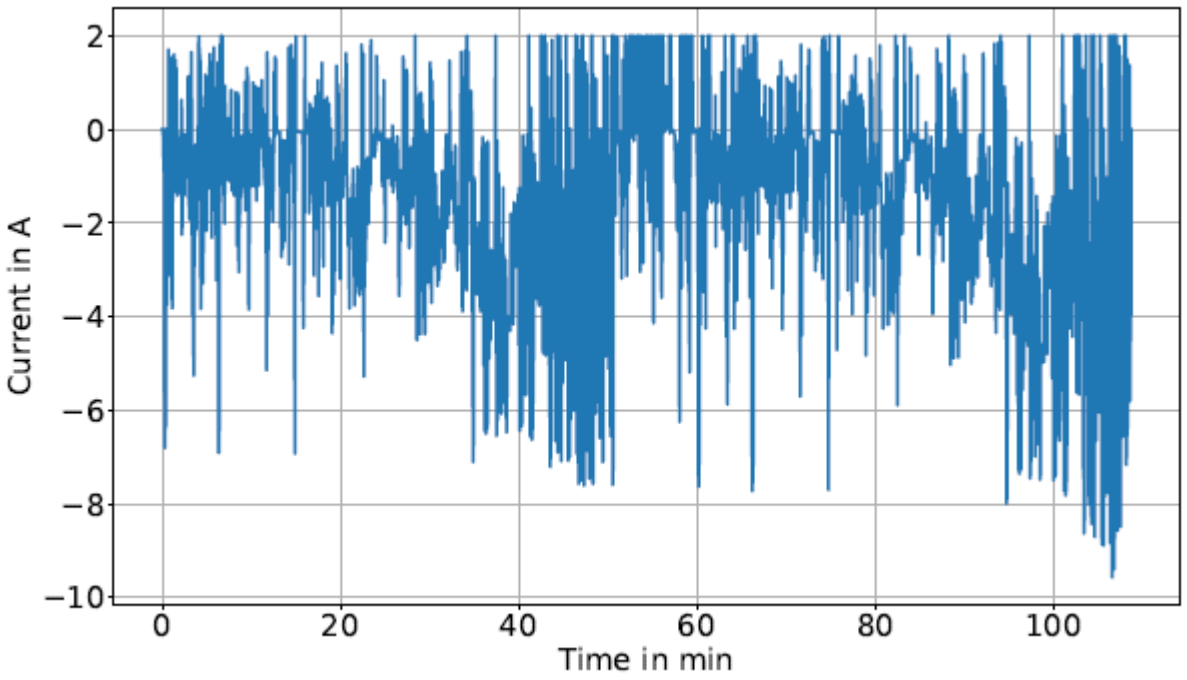
- Self-regulation ability
  - Both voltage and SoC converges fast to real values

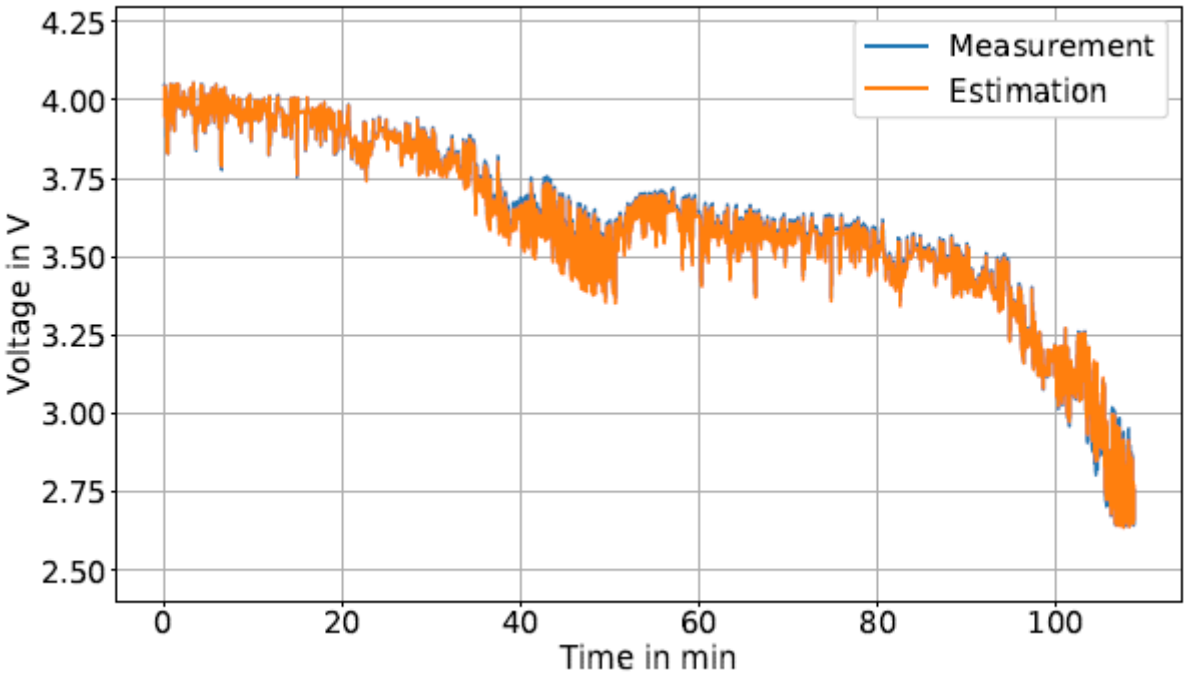


Agenda

Experimental Validation of SoC Algorithm with Lithium-ion Batteries

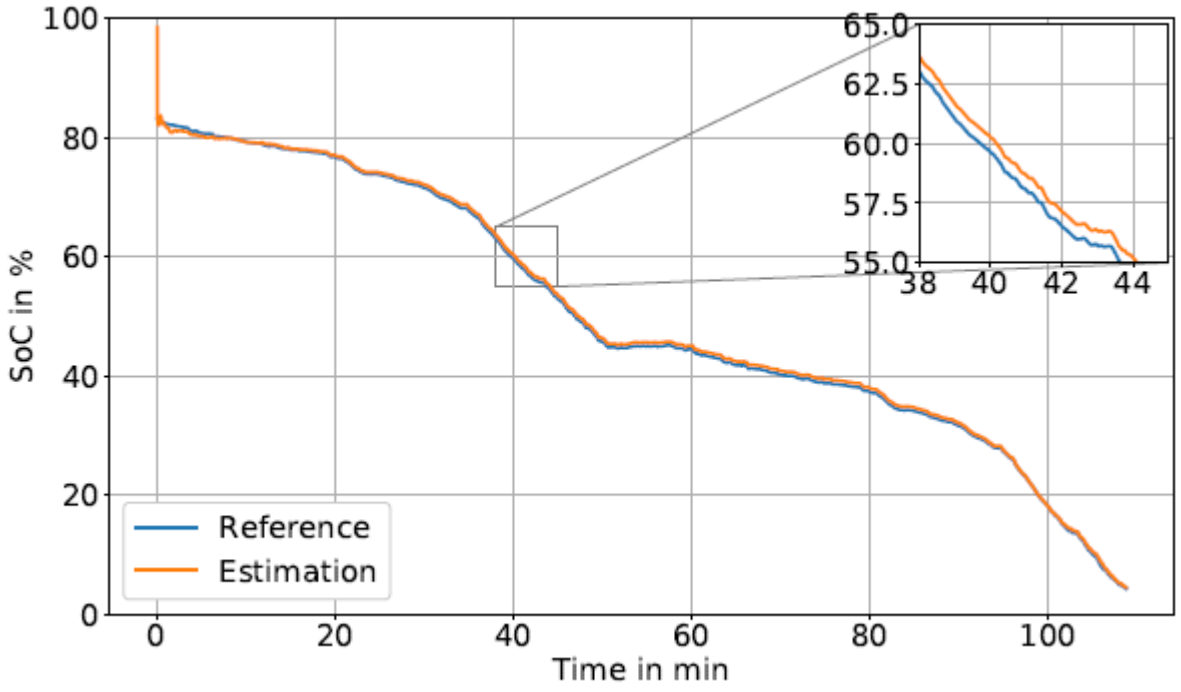
- High dynamic real-world driving data
  - Samsung 35e, NCA+Graphite/Si
- Voltage estimation
  - Mean absolute error: 0.01 V



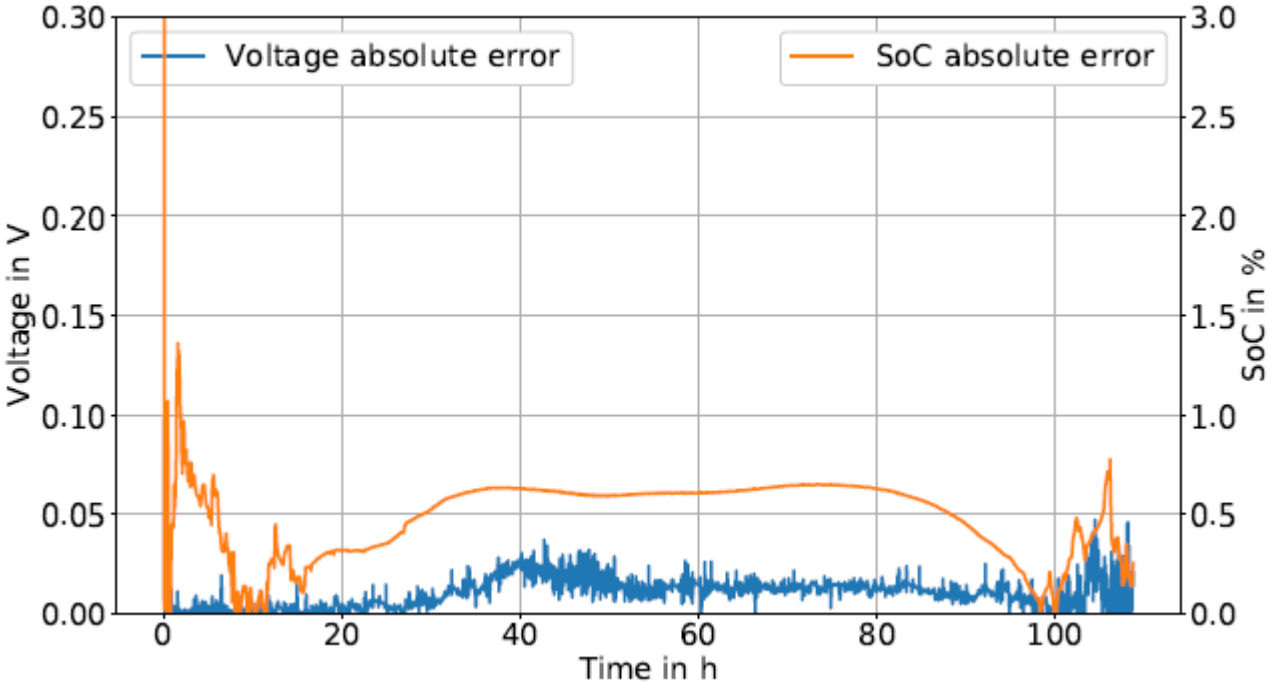


Experimental Validation of SoC Algorithm with Lithium-ion Batteries

- SoC estimation
  - Mean absolute error: 0.49%

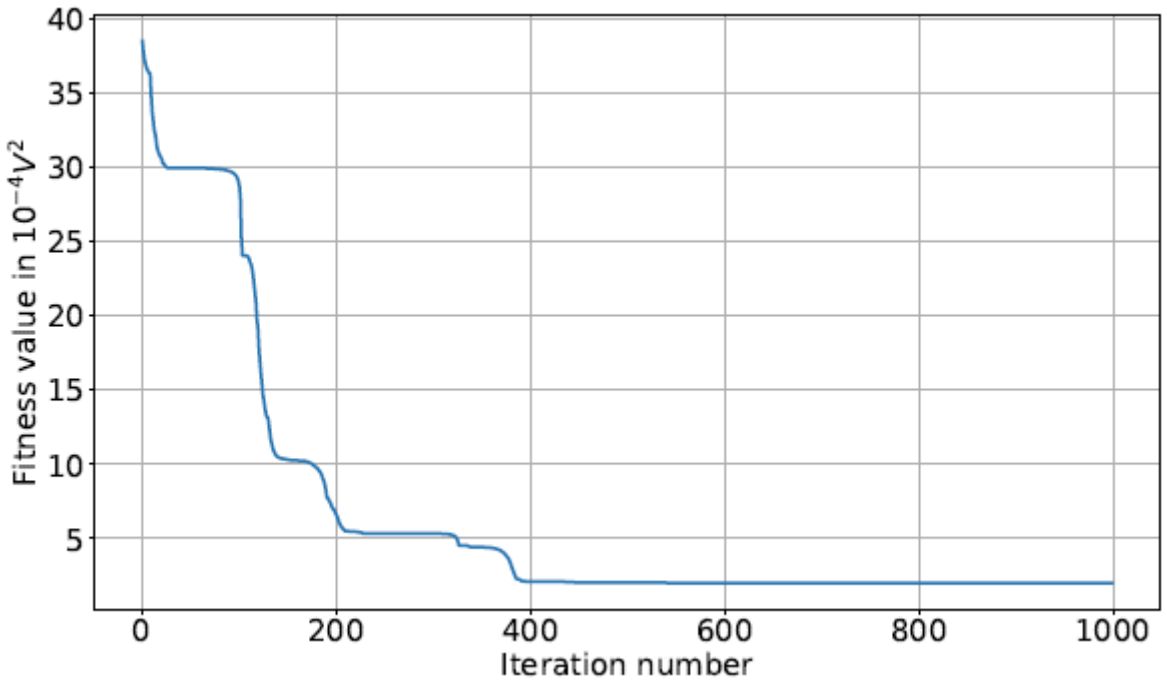


- Self-regulation ability
  - Both voltage and SoC converges fast to real values

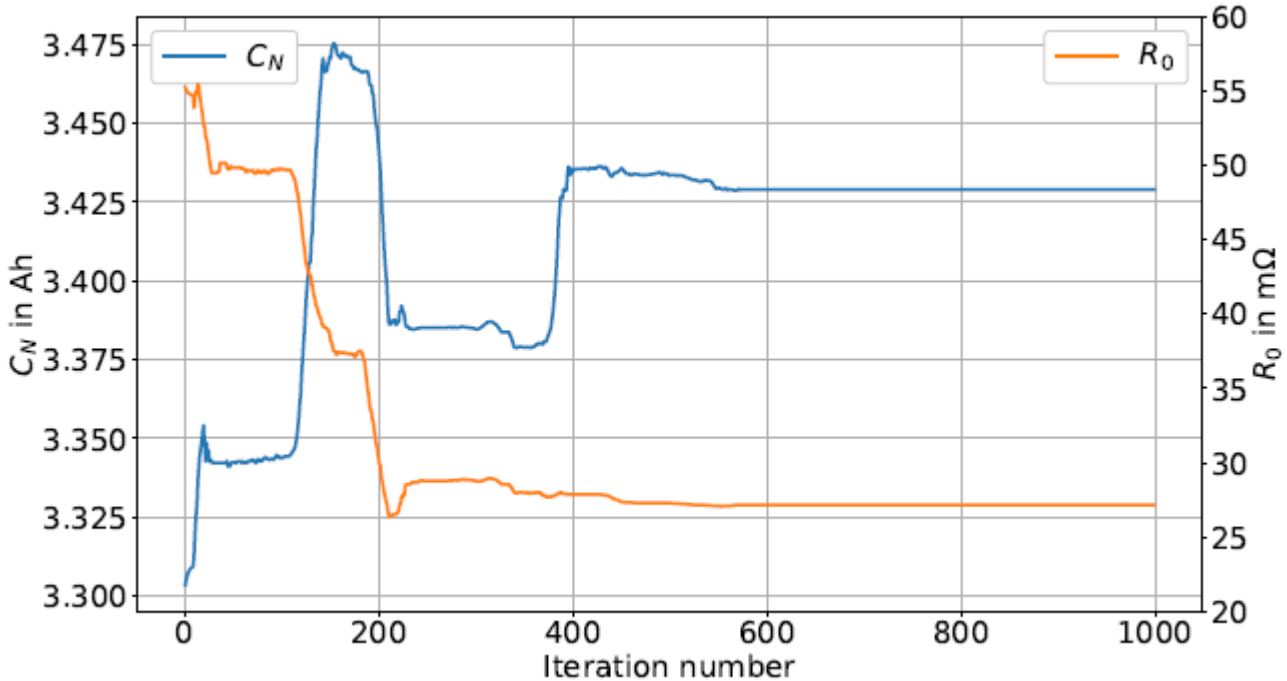


Experimental Validation of SoH Algorithm with Lithium-ion Batteries

- Convergence performance of the fitness value
  - Fitting error of the voltage data

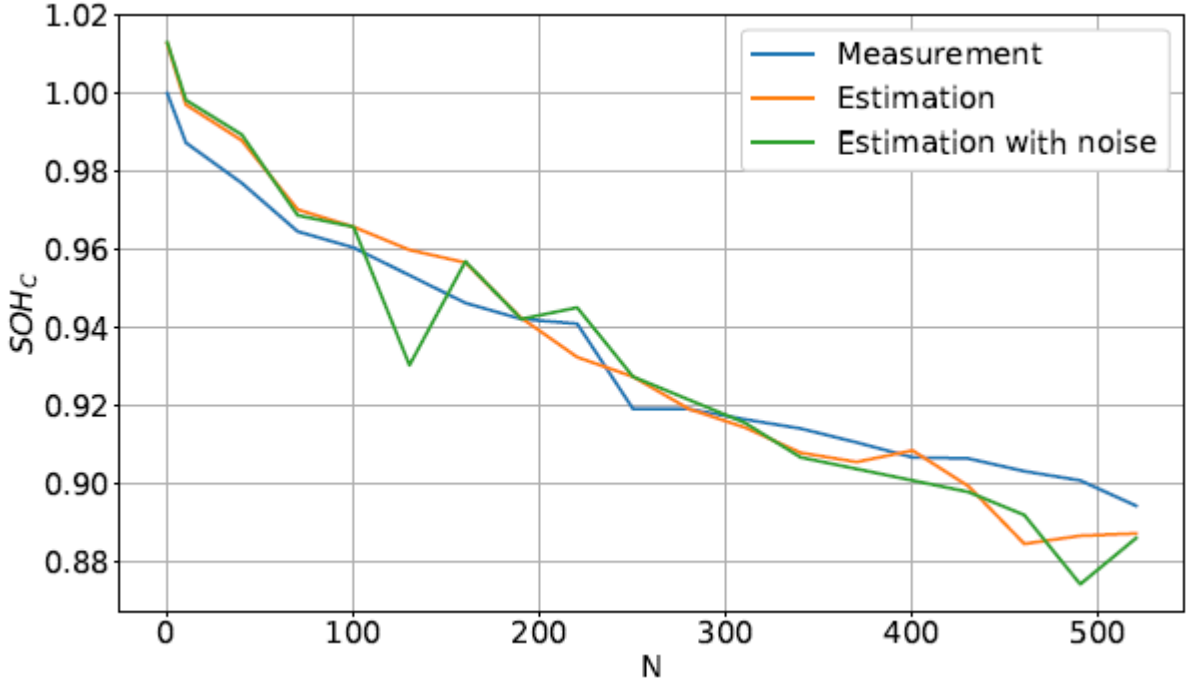


- Convergence performance of the cell parameters
  - Parameters converge after 600 iterations

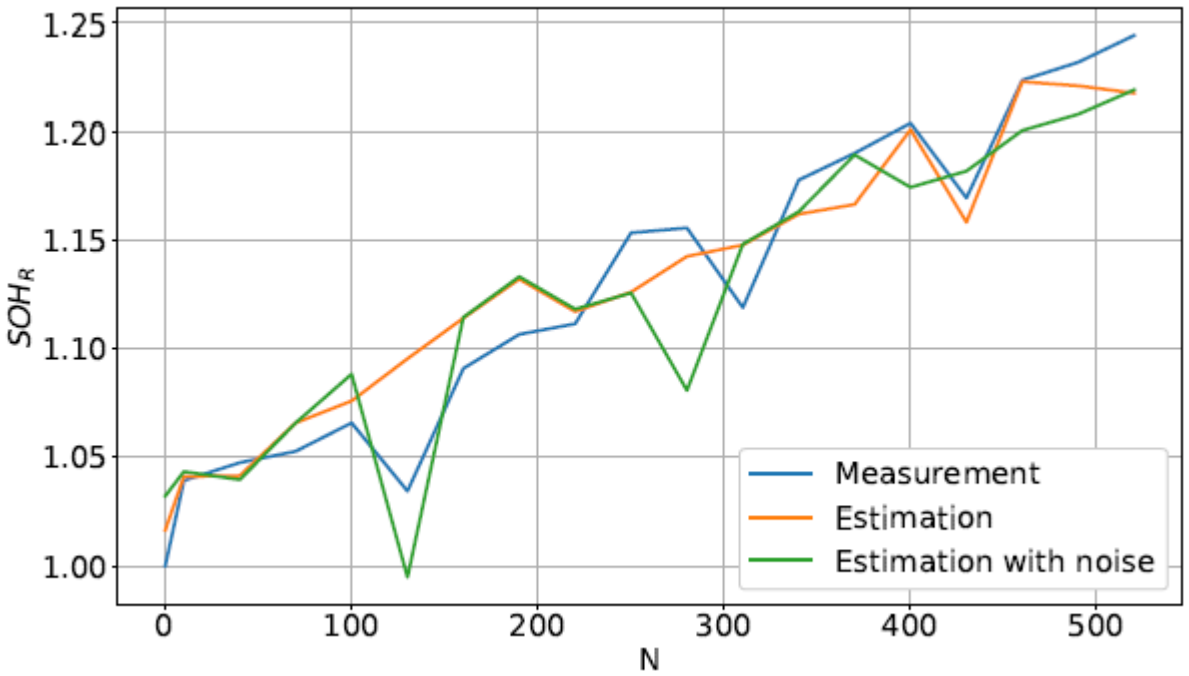


Experimental Validation of SoH Algorithm with Lithium-ion Batteries

- SoH-C estimation
  - Compared with capacity test with C/3
  - Mean absolute error is 0.74 %



- SoH-R estimation
  - Compared with Ohmic resistance @ 1C, 80%SoC
  - Mean absolute error is 1.70 %



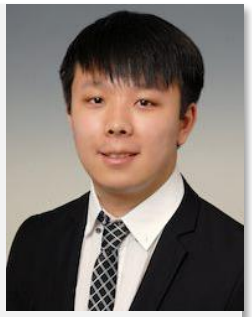
Agenda

Conclusion and Future Work

- Cloud BMS for digital twin of battery systems
- Model-based SoC estimation algorithm for both lead-acid and lithium-ion batteries
- Particle swarm optimization-based SoH estimation algorithm for both capacity fade and power fade
- Field and experimental validation of the monitoring and diagnostics for digital twin
- In the future work, other functionalities will be developed for cloud BMS
  - Lifetime prediction
  - Fault diagnostic
  - Evaluation and optimization
- For more information please refer to:
  - *W. Li, et al., Digital twin for battery systems: cloud battery management system with online state-of-charge and state-of-health estimation, Journal of Energy Storage, 2020, 101557.*

Thank you
for your attention

Contact



Weihan Li

Tel.: +49 241 80-49415
weihan.li@isea.rwth-aachen.de
batteries@isea.rwth-aachen.de

Chair for Electrochemical Energy Conversion
and Storage Systems
Univ.-Prof. Dr. rer. nat. Dirk Uwe Sauer
RWTH Aachen University

Jaegerstrasse 17/19
52066 Aachen
GERMANY

www.isea.rwth-aachen.de

We thank

BATTERIE INGENIEURE

EUROPEAN UNION
Investing in our Future
European Regional
Development Fund

EFRE.NRW
Investitionen in Wachstum
und Beschäftigung

Ministerium für Wirtschaft, Innovation,
Digitalisierung und Energie
des Landes Nordrhein-Westfalen

EVERLASTING

EVERLASTING-713771

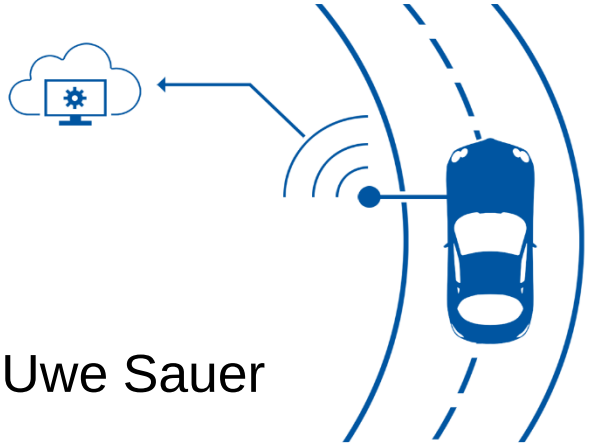
Battery Ageing • Battery Models • Battery Diagnostics • Battery Pack Design • Electromobility • Stationary Energy Storage • Energy System Analysis

Battery Cloud: Data-Powered Intelligent Battery Management for Mobile and Stationary Battery Systems

12th International Advanced Battery Power Conference
Münster, Germany

6/17/2020

Weihan Li
Monika Rentemeister, Julia Badeda, Dominik Jöst, Dominik Schulte, Dirk Uwe Sauer



Chair for Electrochemical Energy Conversion and Storage Systems

iSEA Power Electronics and Electrical Drives | RWTH AACHEN UNIVERSITY