TWAICE

MACHINE LEARNING ENABLING PREDICTIVE BATTERY ANALYTICS

YOUR PARTNER TO ACCELERATE THE TRANSITION TO E-MOBILITY

Manuel Wanisch, Senior Machine Learning Engineer

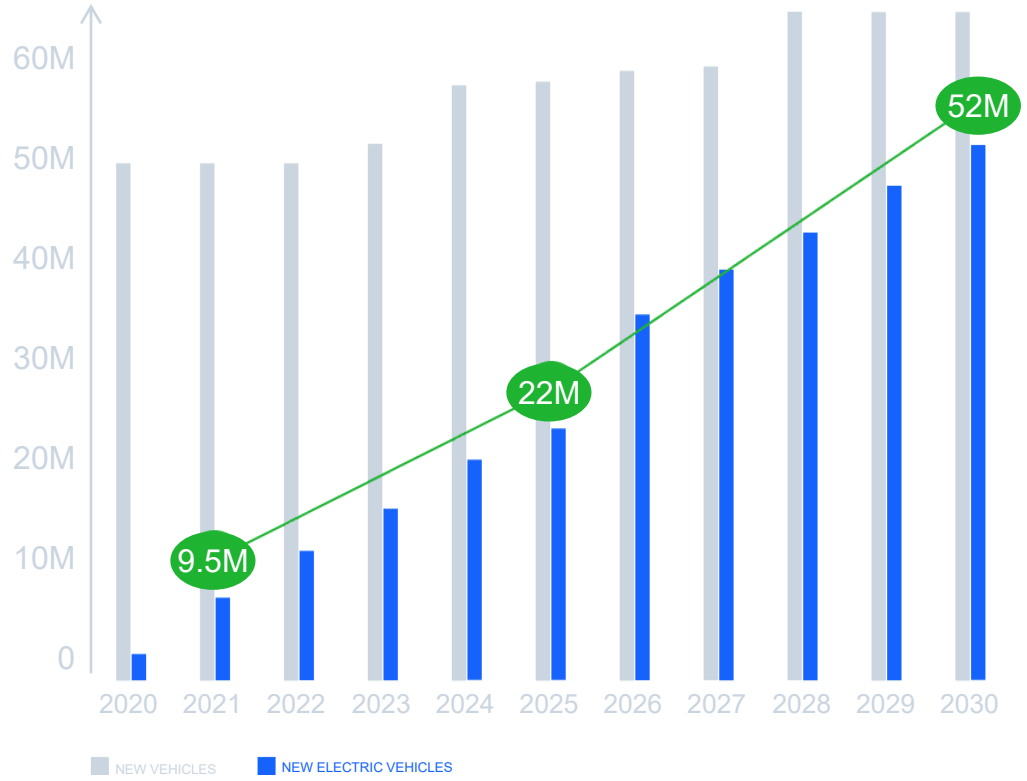
Munich, 5/12/2022

E-VEHICLES & GREEN ENERGY ARE ON THE RISE

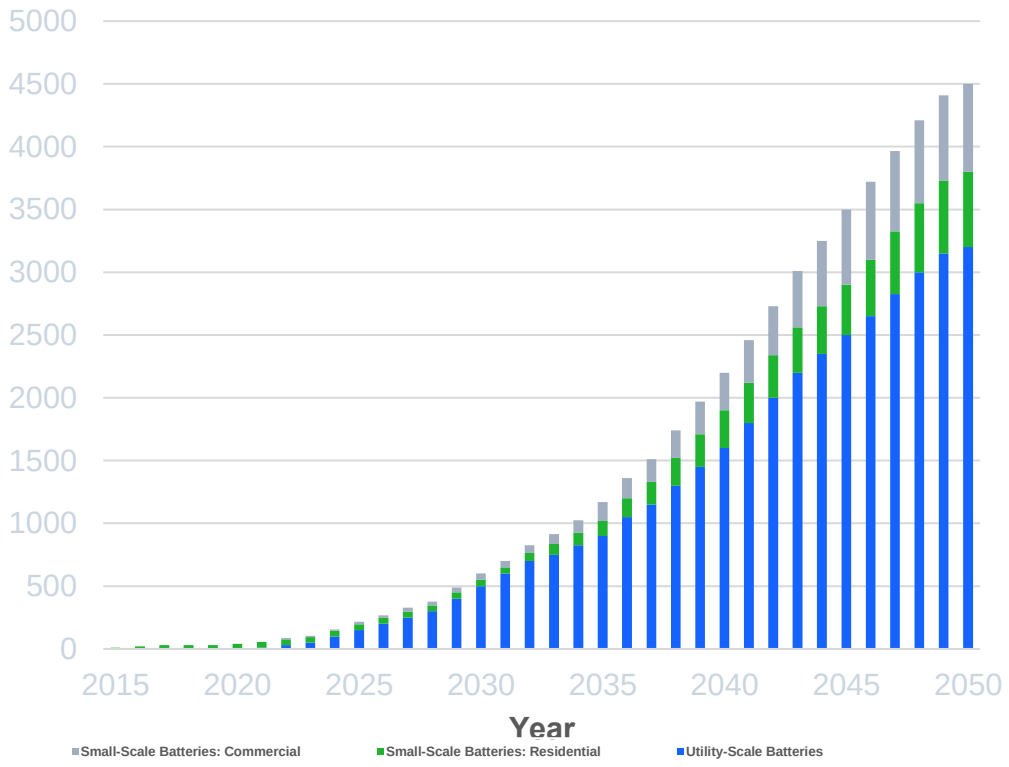
TWAICE

10 YEARS OF EXPONENTIAL GROWTH

Electric Vehicles Sales in Europe, North America & China



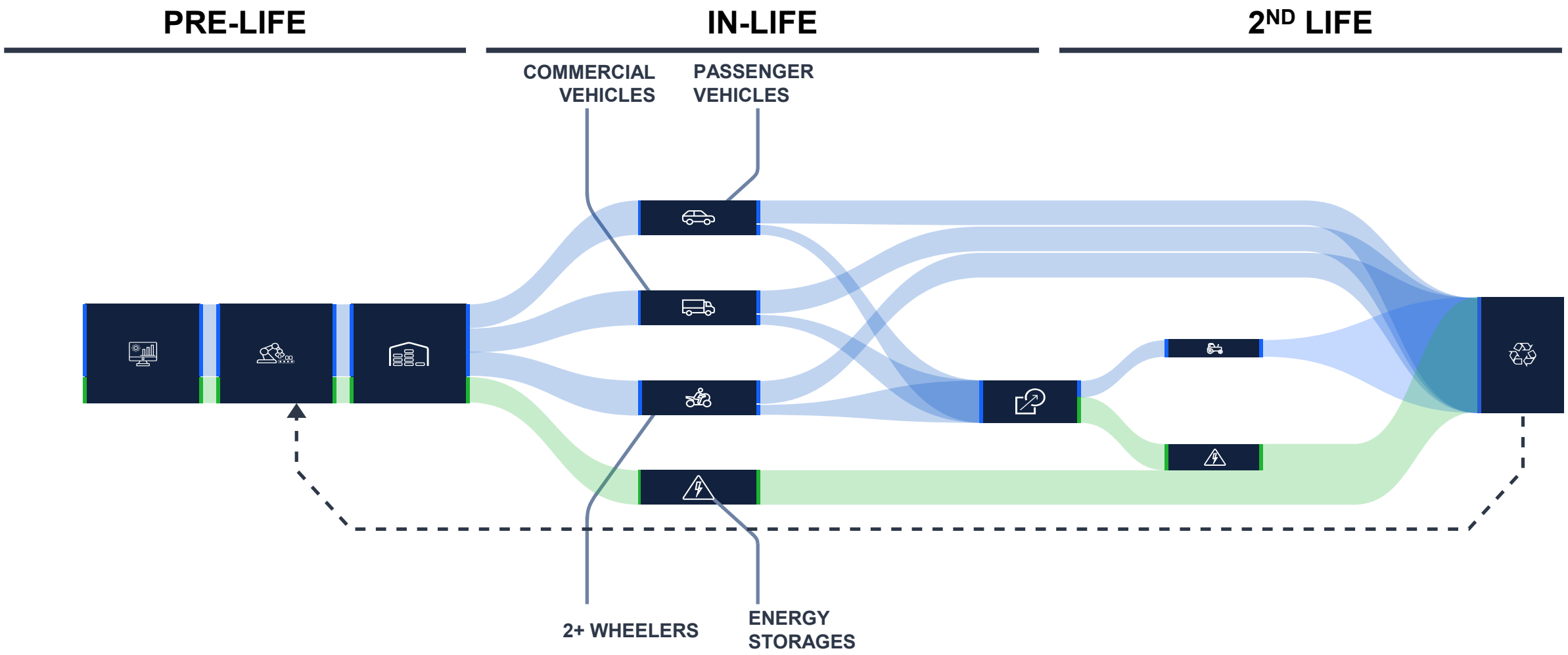
Global Cumulative Battery Storage Energy Capacity [GWh] (2020-2050)



BASED ON: ARK INVEST / BLOOMBERG NEF (1:1)

BATTERY LIFECYCLE

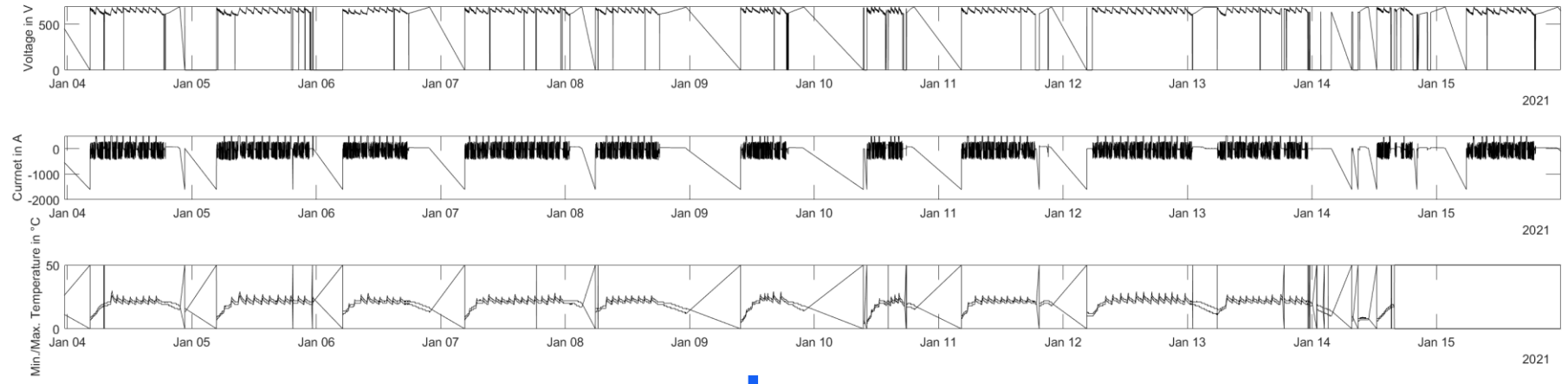
TWAICE ADDRESSES ALL STAGES OF THE BATTERY LIFECYCLE – ACROSS TRANSPORTATION & ENERGY



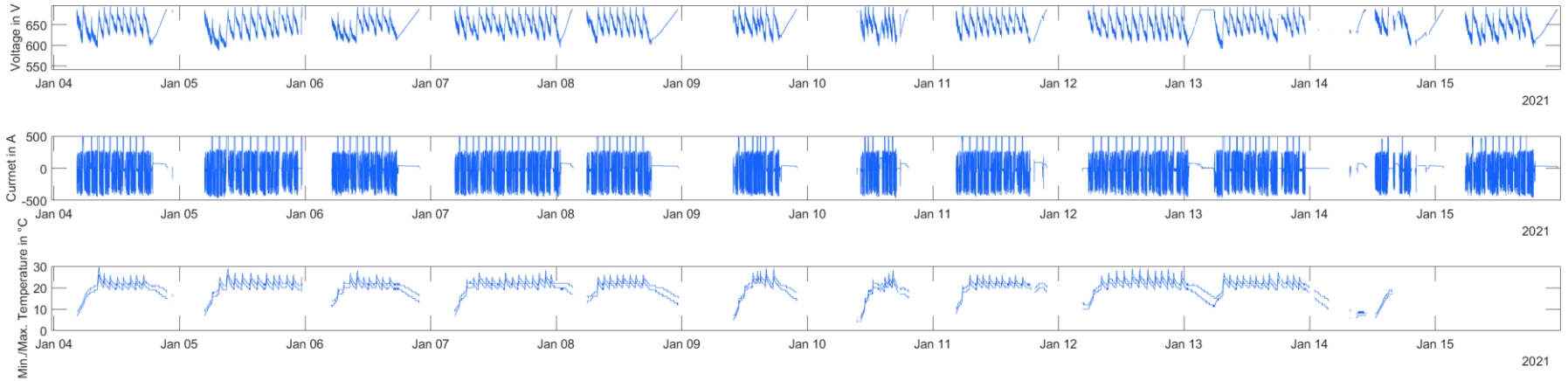
TWAICE

DATA PROCESSING

field data



TWAICE processed

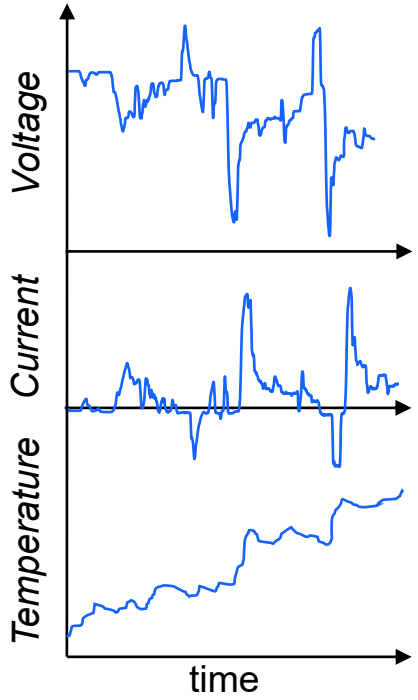


- Data ingest
- Data quality check
- Data filtering
- Outlier removal
- Parameter determination
- Feature calculation
- Label calculation
- …

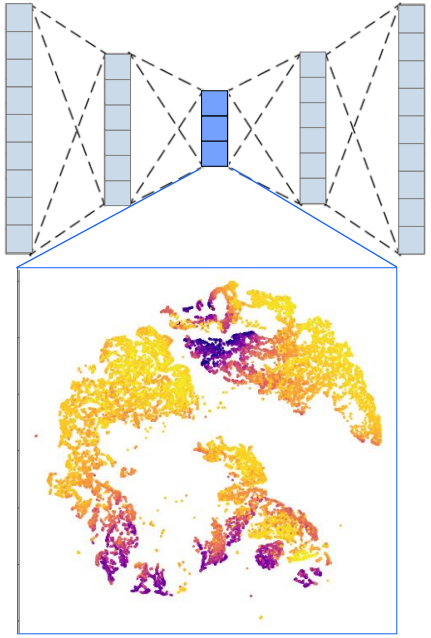
FEATURE CALCULATION

TWAICE

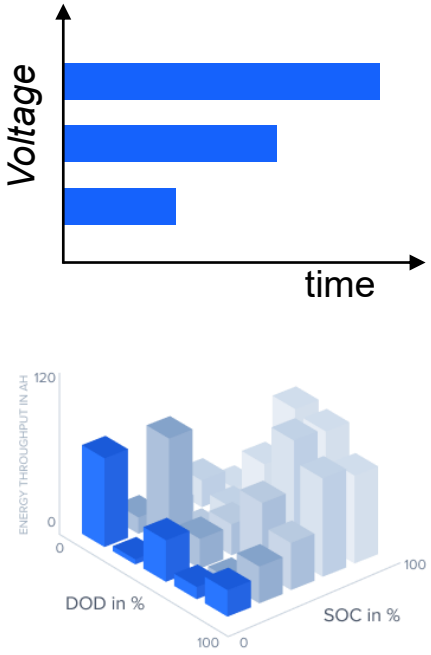
RAW DATA
Time Series Data



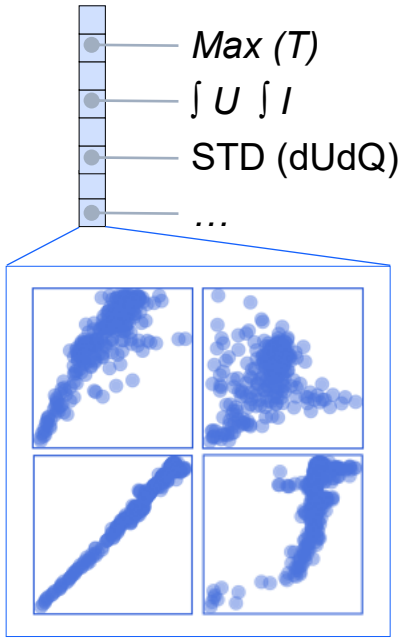
ML-CLUSTERING
Encoding Spaces



LOAD COLLECTIVES
Histograms / Clusters



SCALAR FEATURES
Feature-Vector



Amount of Data

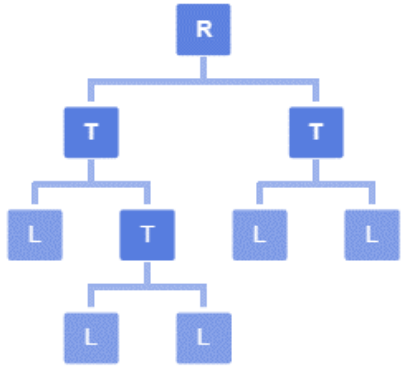
Domain-Knowledge

ML MODEL SELECTION

TWAICE

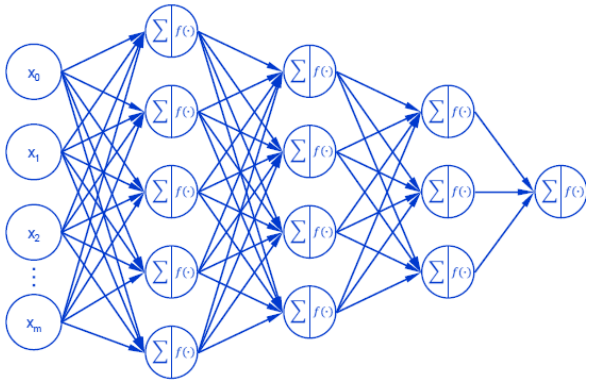
CLASSICAL MODELS

- Simple patterns like scalar features as input
- Understand correlations and influences of input space
- High interpretability



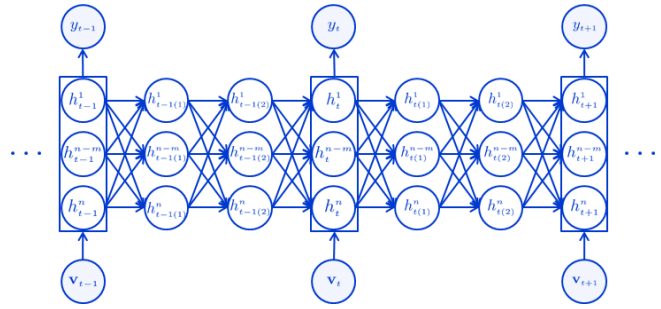
NEURAL NETWORKS

- Complex mapping of input to output
- High dimensional and complex patterns as input
- Improve accuracies from best classical model setting



RECURRENT NEURAL NETWORKS

- Temporal mapping of input sequences to output
- Learn correlations across timesteps
- Accuracies can be further improved



USE CASE BATTERY SWAPPING

TWAICE

CHALLENGE: IS THE BATTERY IN THE VEHICLE STILL GOOD FOR OPERATION?

STATUS QUO

- Regular or ad-hoc tests of selected buses to check Battery State of Health

Bus Roller Test Bench

PROBLEM WITH STATUS QUO

- Costly
- Not continuous
- Not scalable

Approach still scalable with

…100 e-buses in the field?

… 1.000 e-buses in the field?

… 10.000 e-buses in the field?

ML-EMPOWERED SOLUTION

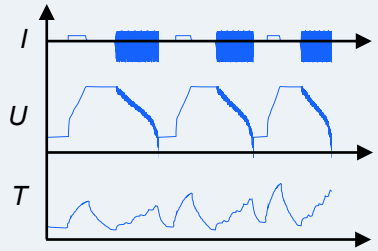
- No specific test procedures required
- Non-intrusive
- Robust regarding incomplete time series
- Continuous State of Health information

STATE OF HEALTH ESTIMATION

TWAICE

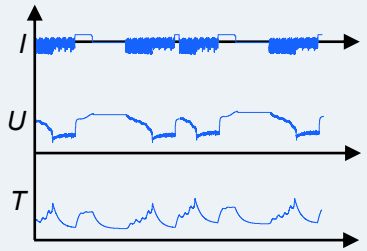
INPUT

Lab Data

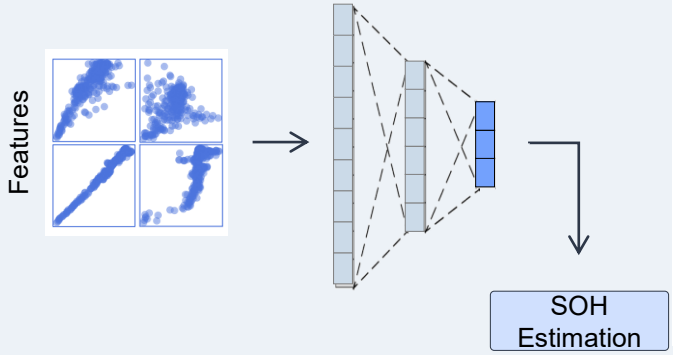


Application-Based Synthetic Profiles

Field Data

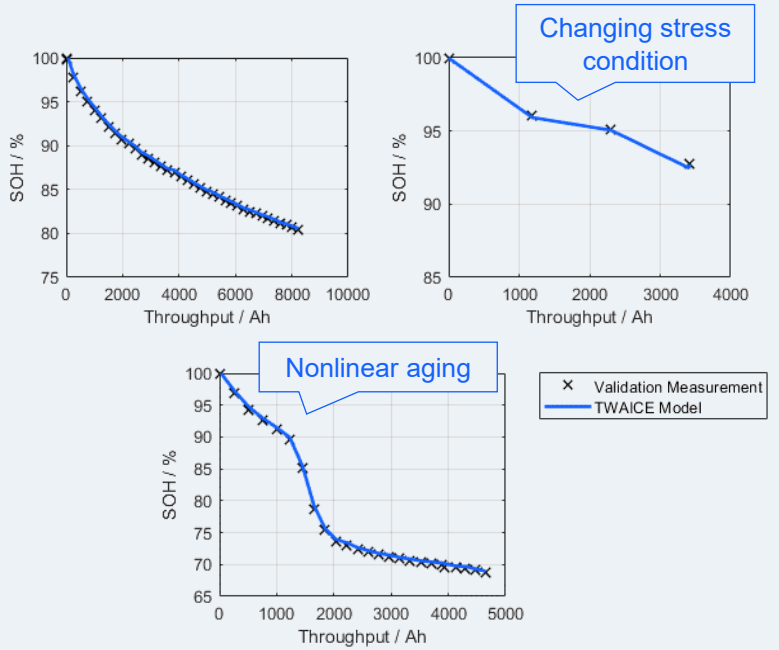


APPROACH



- Purely data-driven approach[1)] on dynamic real-world profiles
- TWAICE ML algorithms validated on laboratory measurements and real-world profiles

OUTCOME



- TWAICE machine learning algorithms consider changes in operating strategy and stress conditions as well as linear and nonlinear aging behavior
- High accuracy with absolute deviation of < 1%

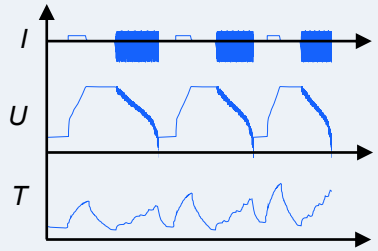
1) Patent in application

STATE OF HEALTH PREDICTION

TWAICE

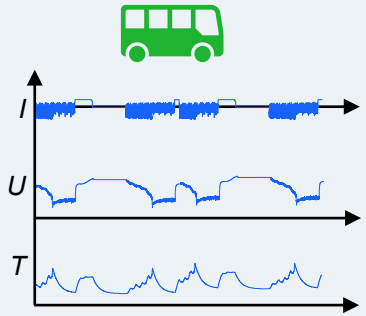
INPUT

Lab Data

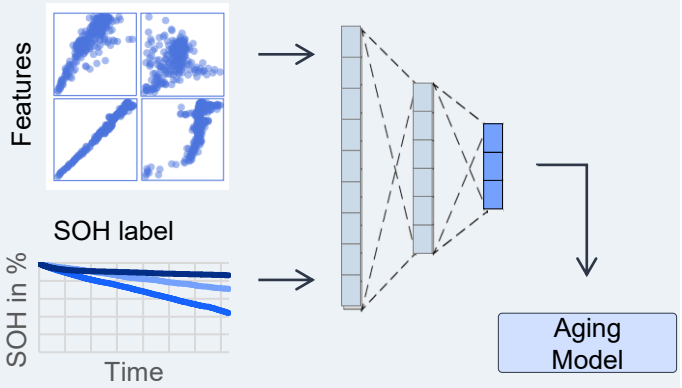


Application-Based Synthetic Profiles

Field Data

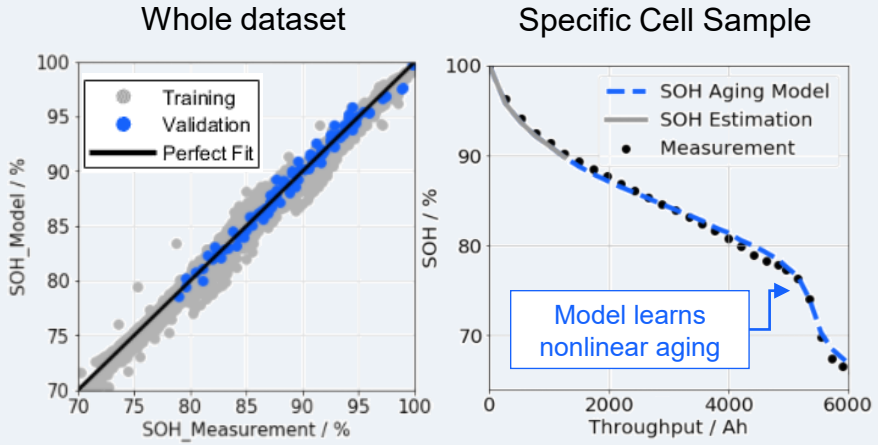


APPROACH



- Proprietary model architecture[1)] can learn aging behavior from dynamic operating data
- Feature calculation based on use case
- Model architecture allows transfer learning

OUTCOME

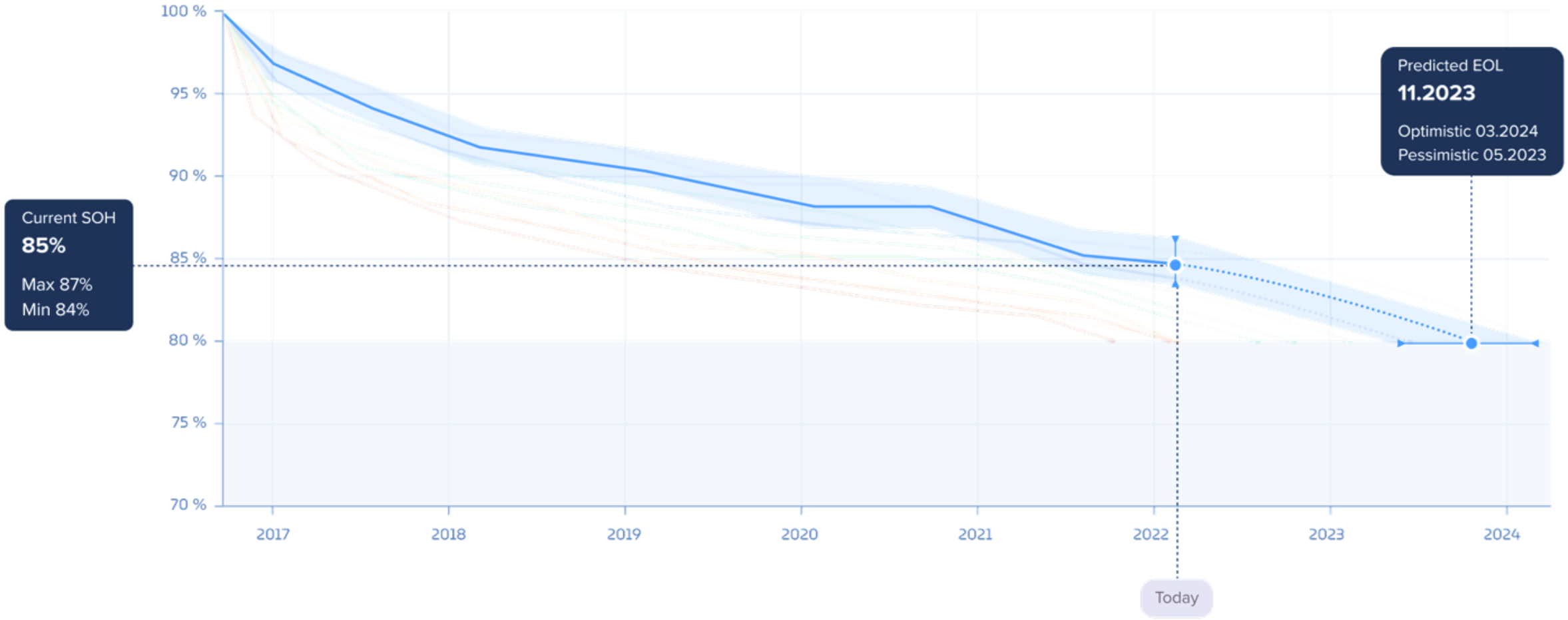


- TWAICE machine learning aging model considers dynamic and changing operating conditions as well as nonlinear aging
- High accuracy with mean deviation of < 1.5%

1) Patent in application

ML BASED SOH ESTIMATION AND PREDICTION

TWAICE



SUMMARY

TWAICE

- TWAICE combines battery, software and machine learning expertise
- Predictive battery analytics based on battery field data
  - Enables continuous state of health estimations and predictions
  - Safes manual testing efforts
- Modeling principles
  - Understand the problem
  - Start simple
  - Iterate fast