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AN AI APPROACH FOR BATTERY MONITORING SYSTEM

Sara Luciani

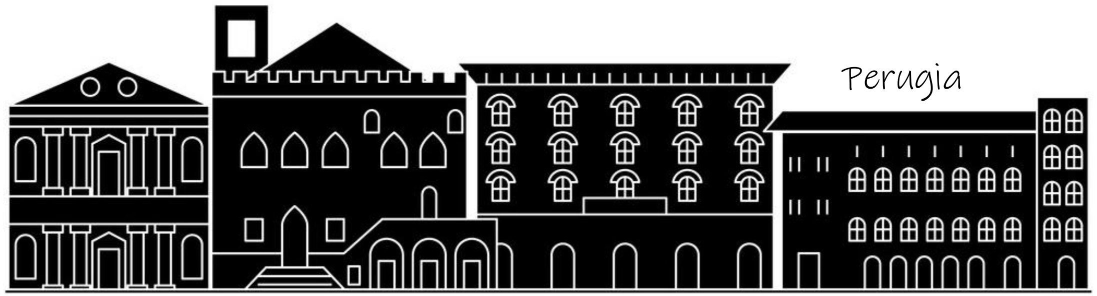
15th January 2021

WHO I AM

Sara Luciani, PhD candidate

WHAT I DID

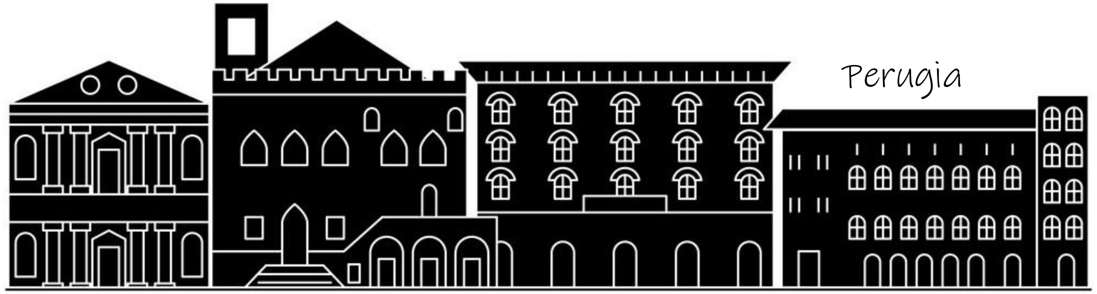
Mechanical Engineering @ Università degli Studi di Perugia
Mechatronic Engineering @ Politecnico di Torino

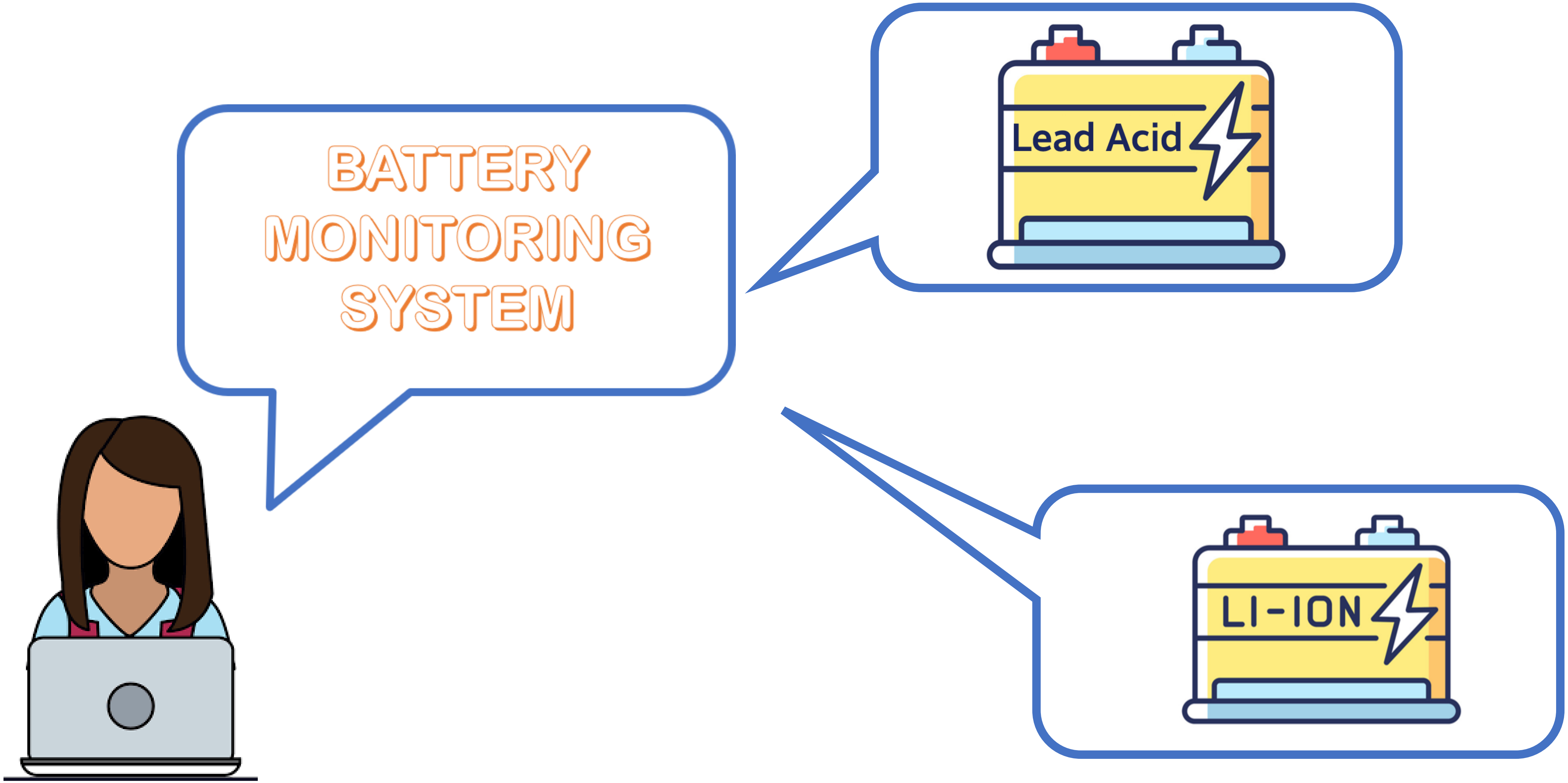


WHAT I AM DOING

PhD in Mechanical Engineering @ Politecnico di Torino

- *IVECO* – Design and implementation of State of Charge and State of Health estimation algorithm in heavy-duty vehicles.
- *PoC project* – Implementation of the State of Charge estimation algorithm in an open source environment and in real hardware.
- *Dayco* – Design and implementation of control and energy management strategies in Fuel Cell Electric Vehicles (FCEVs).
- *Rabotti* – Design and implementation of State of health estimation "tool" for a wide range of batteries type.

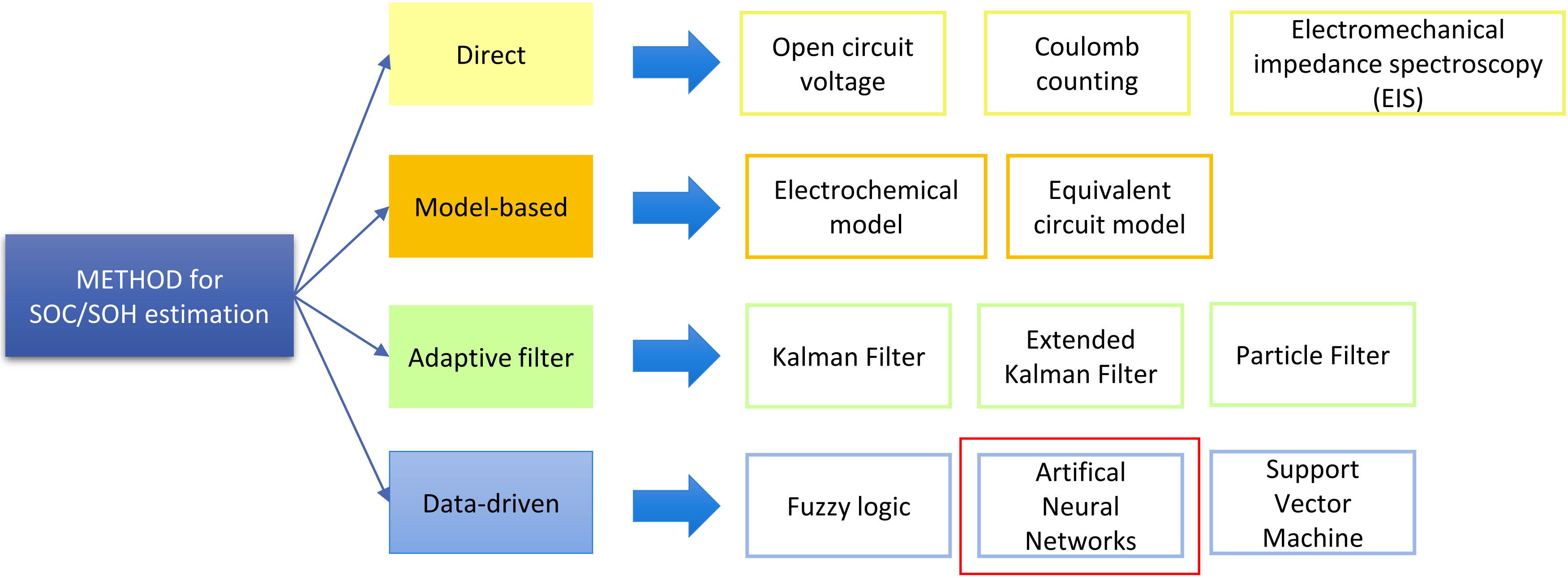



BATTERY MONITORING SYSTEM
Lead Acid
LI-ION

Why Artificial Neural Networks (ANNs) for the SOC and SOH estimation?

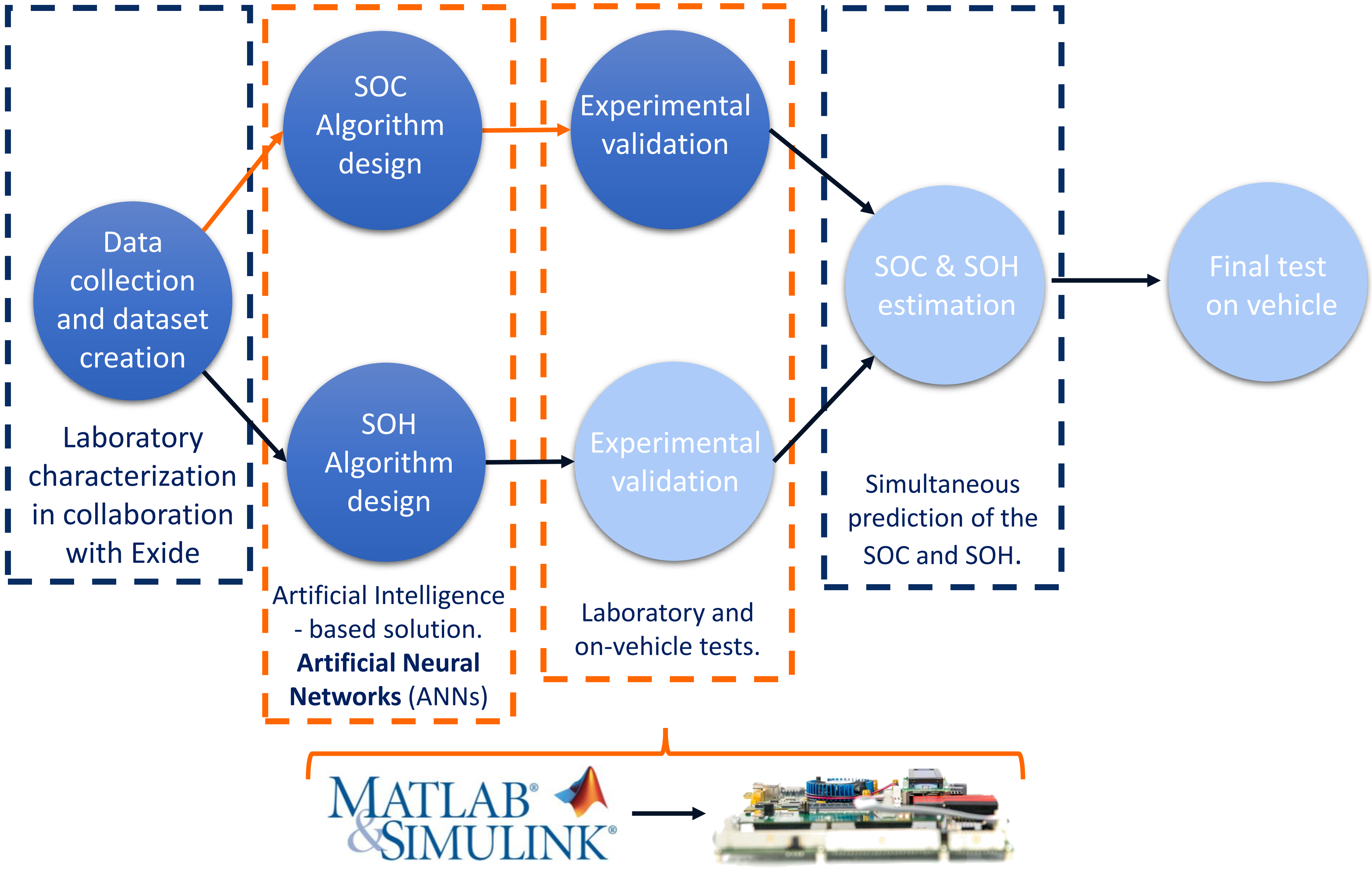
- **Why SOC and SOH estimation?**
  1. They are crucial parameters of the battery to ensure in predicting the energy and power availability.
  2. They cannot be directly measured.

- **SOC and SOH estimation should be:**
  - accurate
  - robust
  - indipendent of the battery chemistry
  - low computational cost for the implementation on Battery Management System (BMS) microcontrollers



- The battery provides the power necessary to:
  - start the vehicle,
  - the additional and permanent electrical consumers,
  - the cabin systems during the overnight stops.
- The monitoring of the state of the batteries
  - allows to supply the required power to the vehicle
  - avoids additional maintenance costs.

LEAD-ACID BATTERY MONITORING – Activity plan



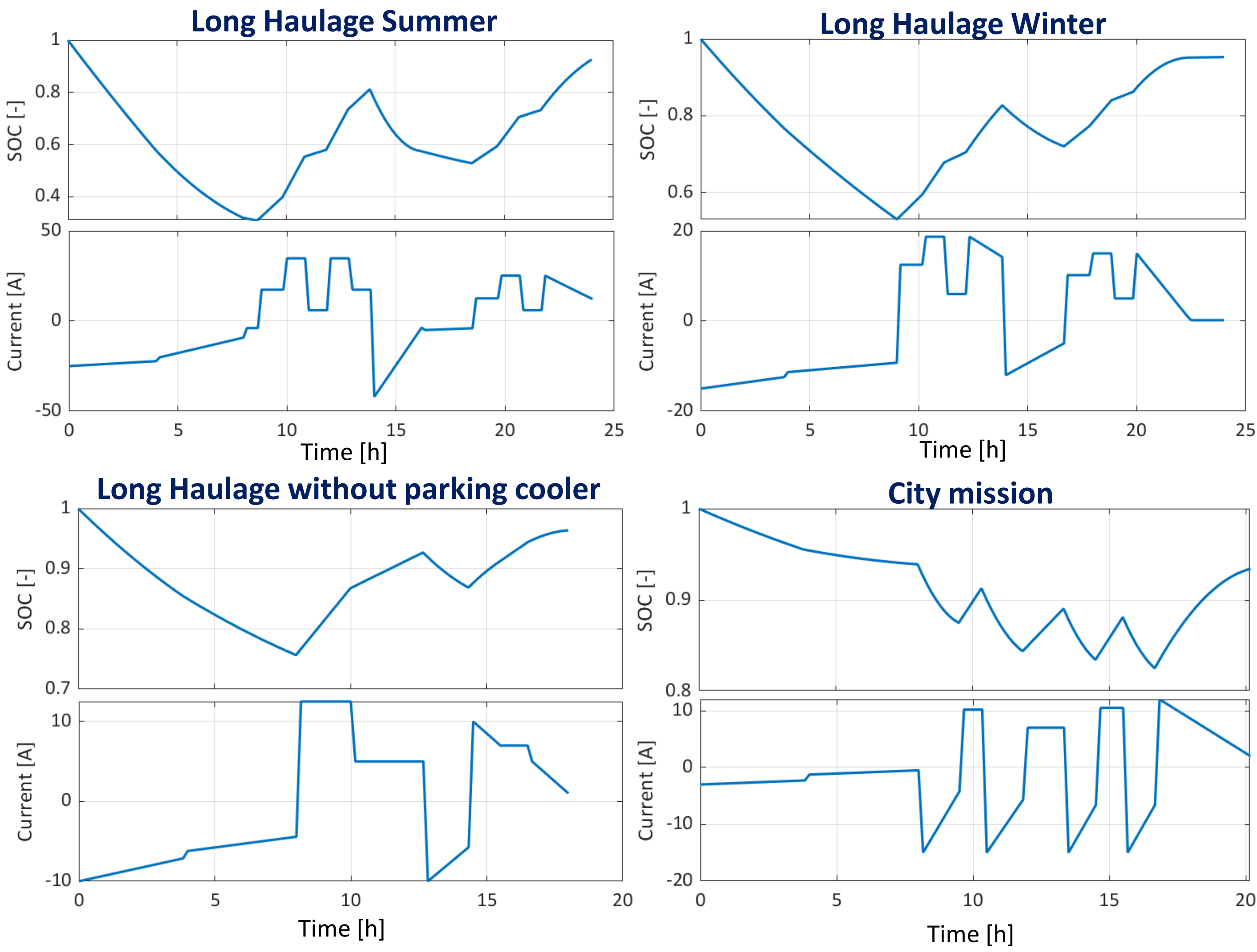
LEAD-ACID BATTERY MONITORING – Dataset collection and creation

- To train the algorithm it is needed to collect data that are representative of the "real" working condition.
- Four different SOC profiles, based on the energy balance model, were selected.
- From the SOC profile, the current profile was computed and shared with EXIDE to perform a test campaign.

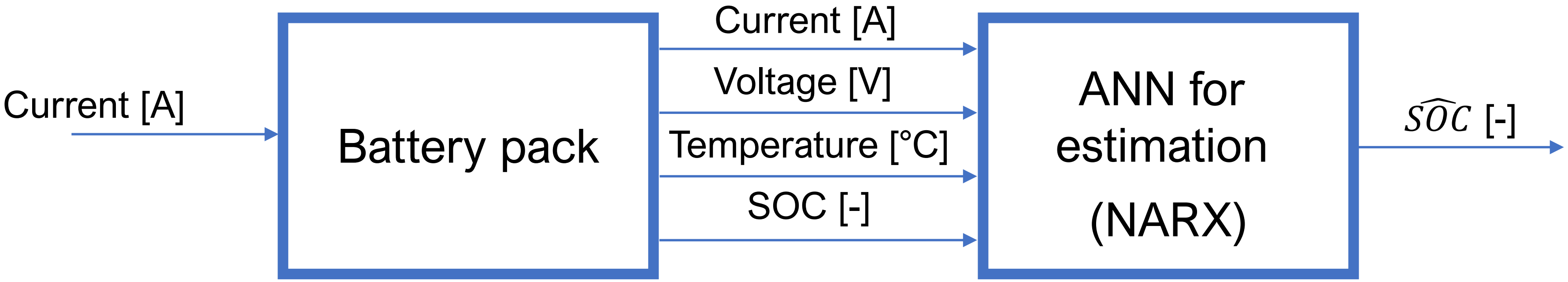
LABORATORY TEST CAMPAIGN EXIDE

- The current profiles is the input for the battery pack. The collected outputs are:
  - Voltage
  - Capacity
  - Current
  - Internal resistance
  - Temperature
- The tests are performed at different temperatures (-10,0,25,40°C) and different levels of SOH to explore as many working conditions as possible.

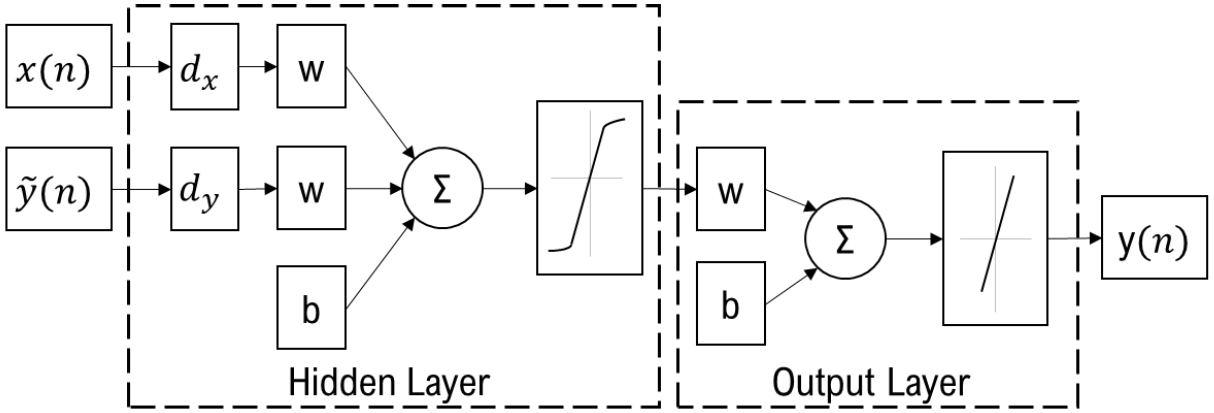
SELECETED MISSION PROFILES to train the ANN algorithm



LEAD-ACID BATTERY MONITORING – SOC estimation algorithm 1/4



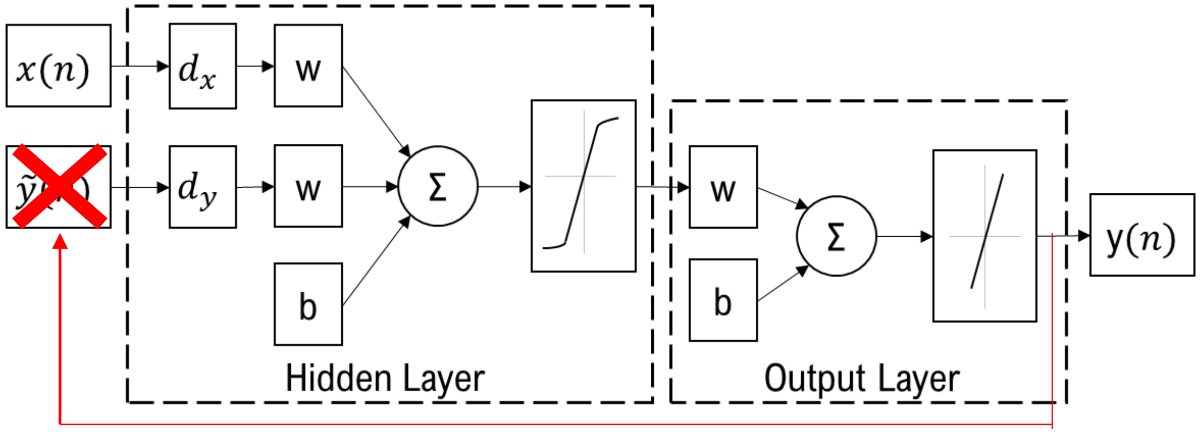
❑ Net configuration in the training process



INPUTs:
1. Current
2. Voltage
3. Temperature
4. SOC

OUTPUT:
1. Estimated SOC

❑ Net configuration in the real application

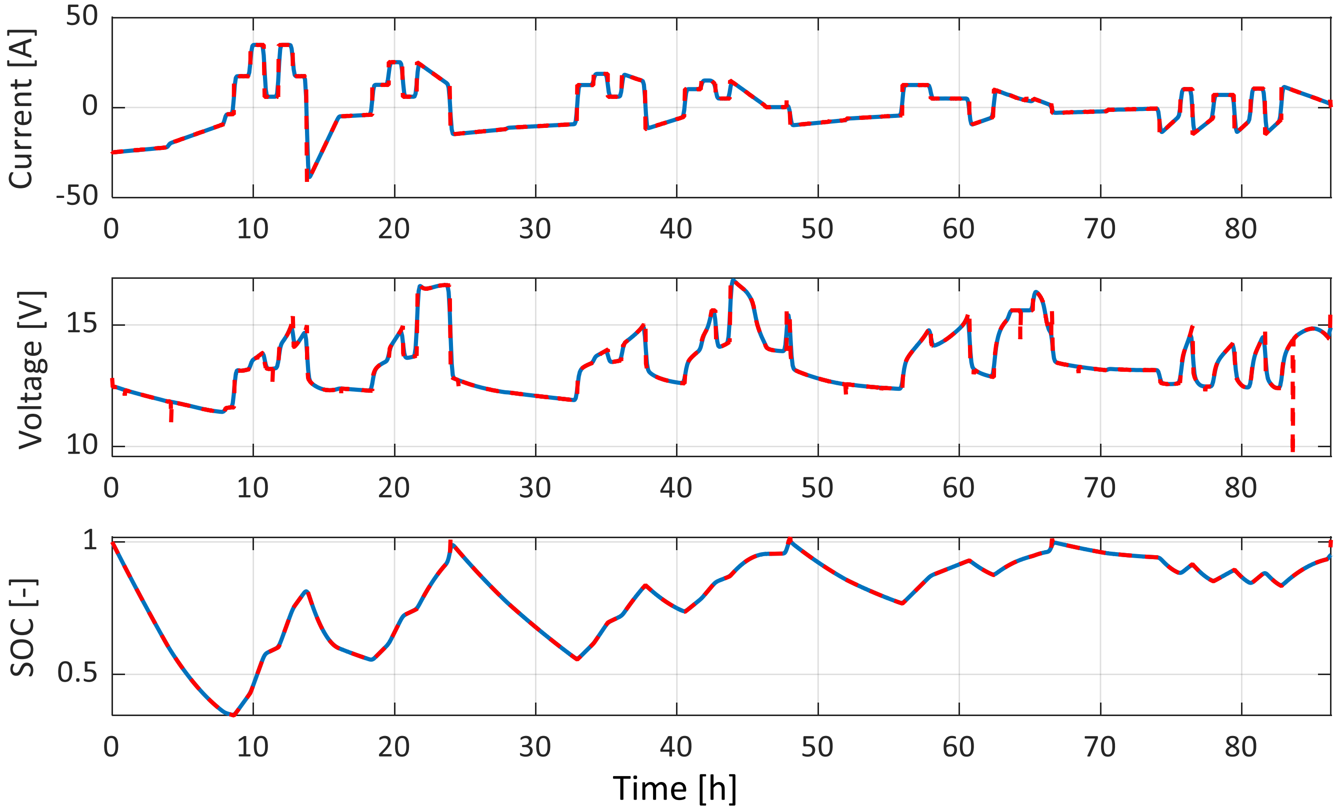


INPUTs:
Current
Voltage
Temperature

OUTPUT:
1. Estimated SOC

LEAD-ACID BATTERY MONITORING – SOC estimation algorithm 2/4

❑ Training dataset



❑ Neural network

Architecture: Recurrent NARX ANN

Training algorithm: Levenberg-Marquardt backpropagation

Hidden layer size: 5

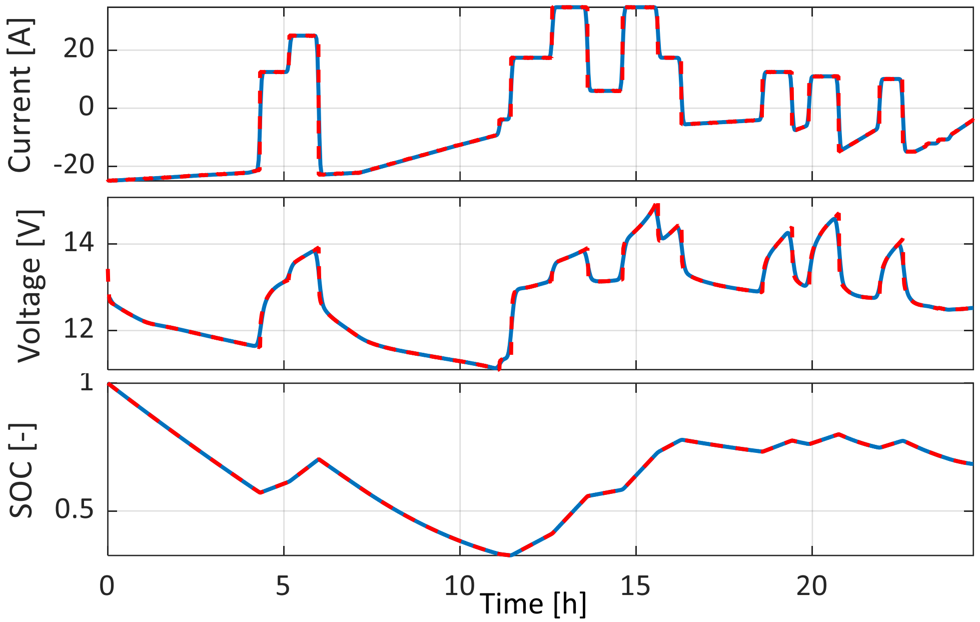
Delay: 2

Exide data

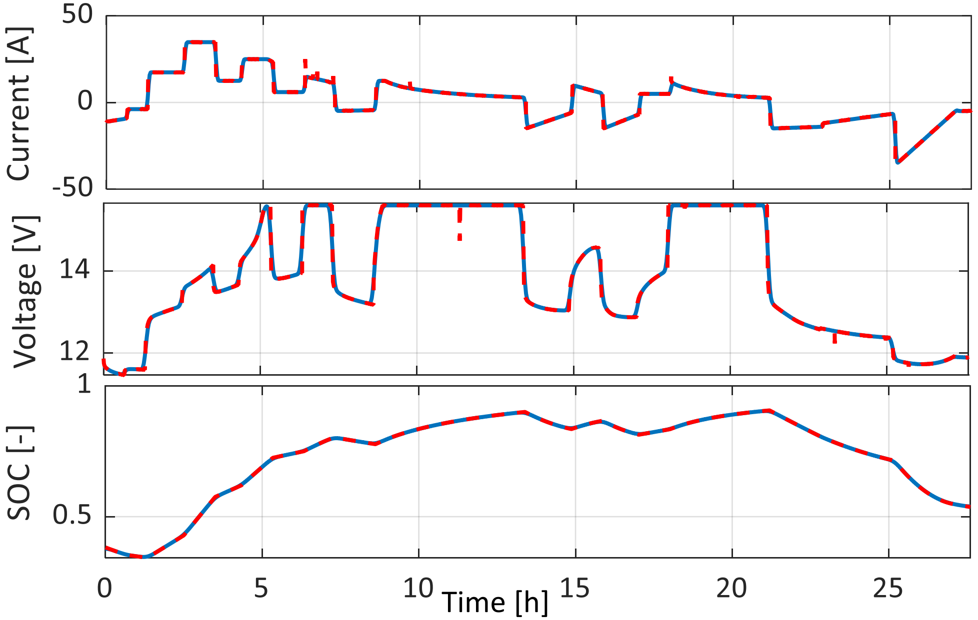
Processed data

❑ Validation datasets

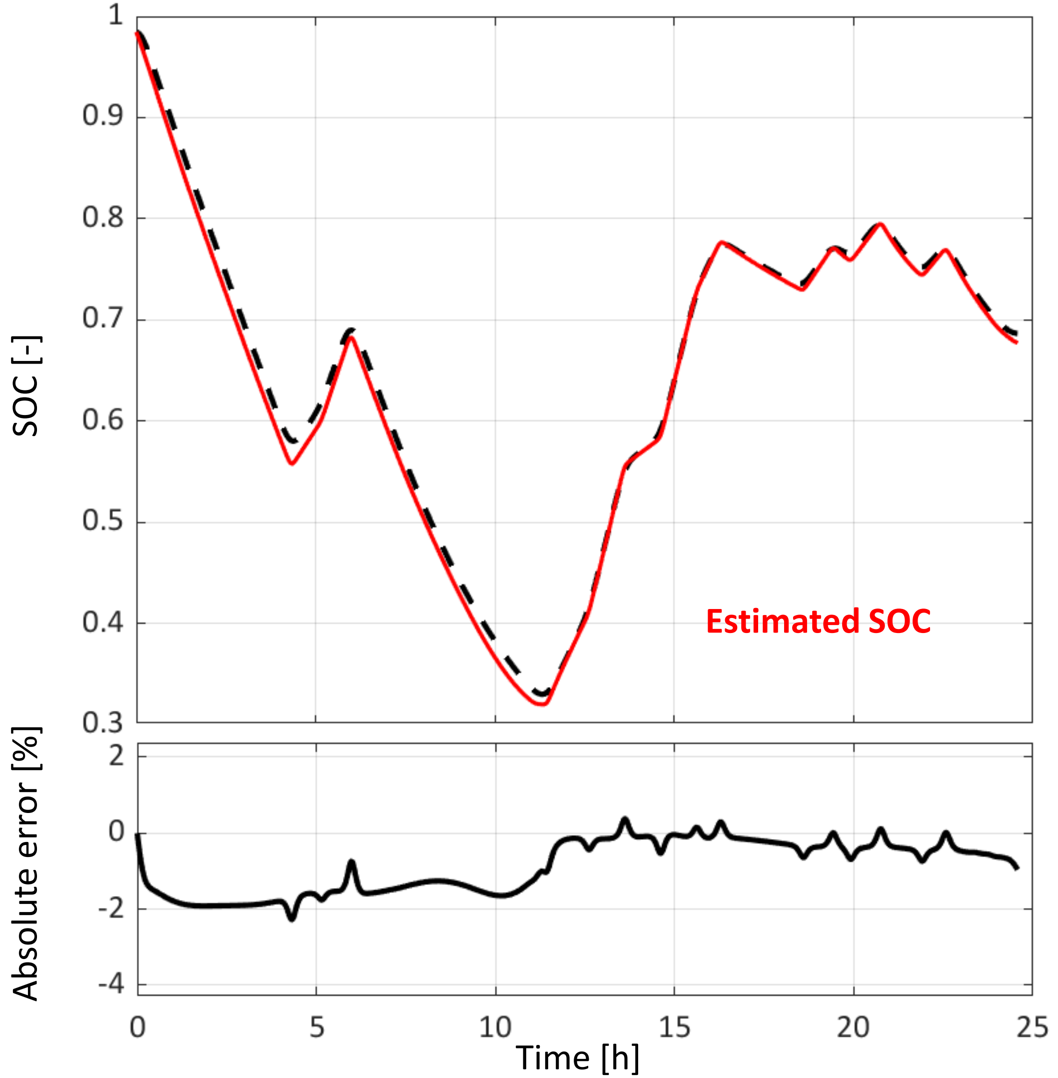
1.



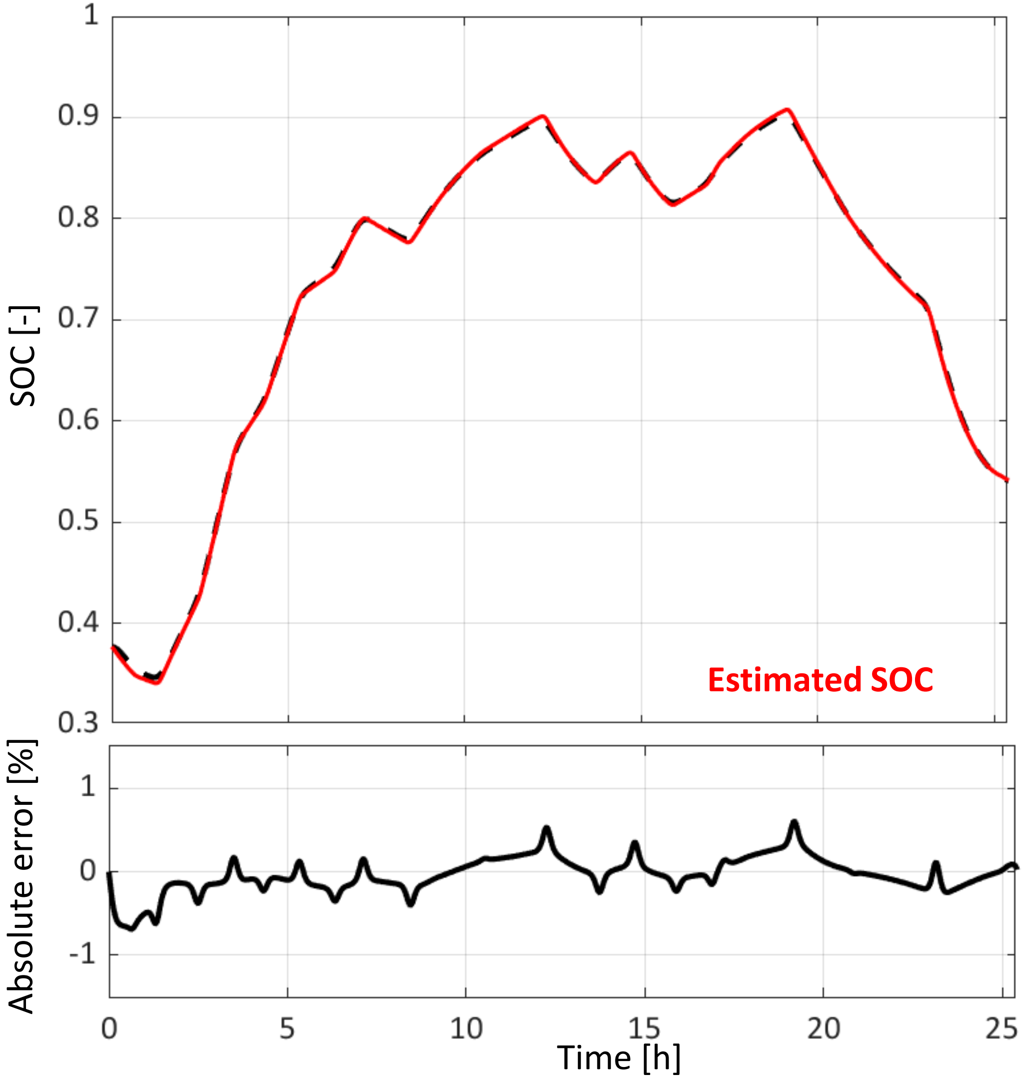
2.



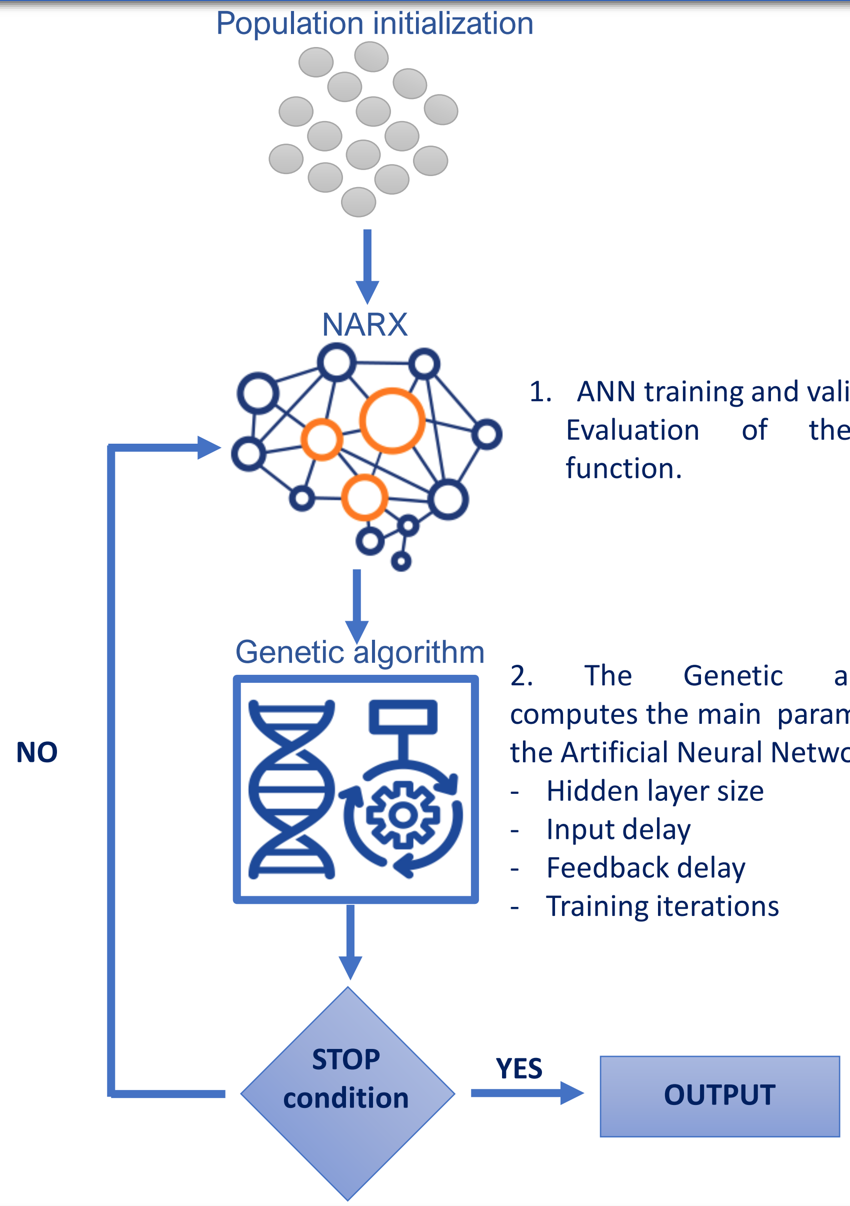
Validation profile 1



Validation profile 2

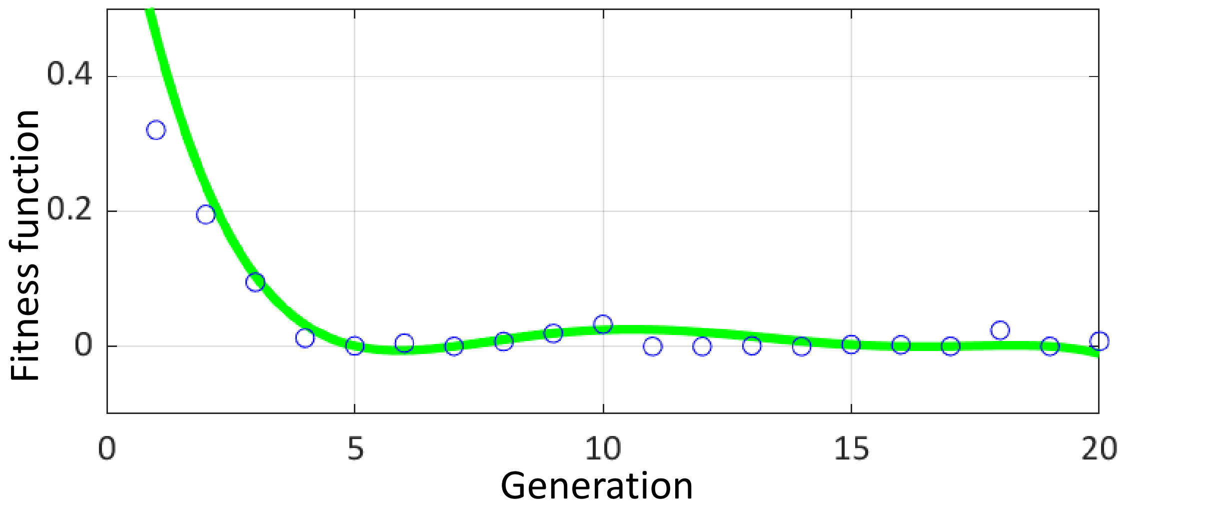


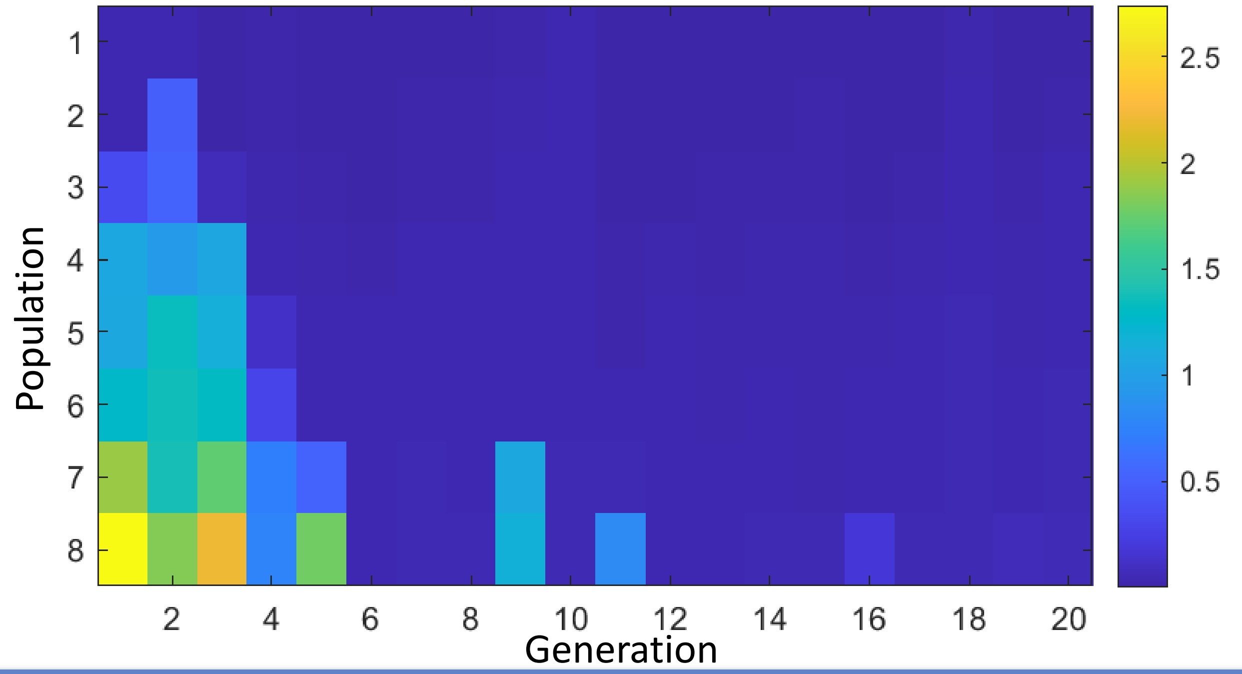
LEAD-ACID BATTERY MONITORING – SOC estimation algorithm 4/4



1. ANN training and validation. Evaluation of the fitness function.

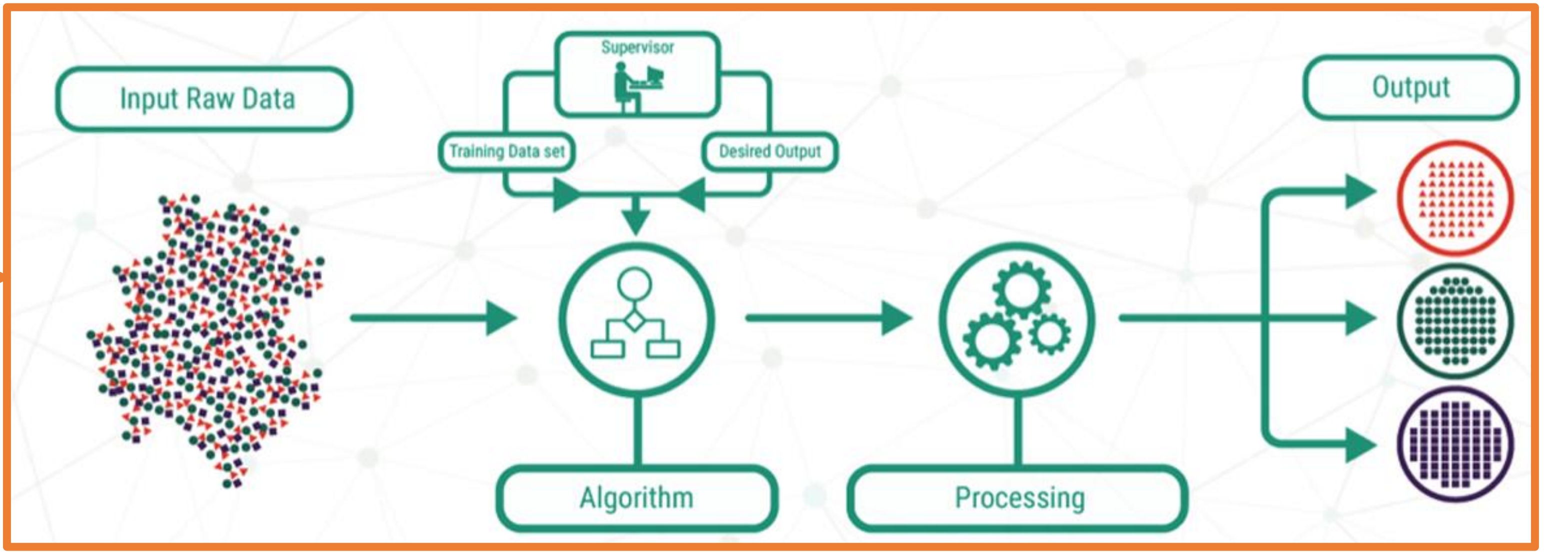
2. The Genetic algorithm computes the main parameters of the Artificial Neural Network:
   - Hidden layer size
   - Input delay
   - Feedback delay
   - Training iterations

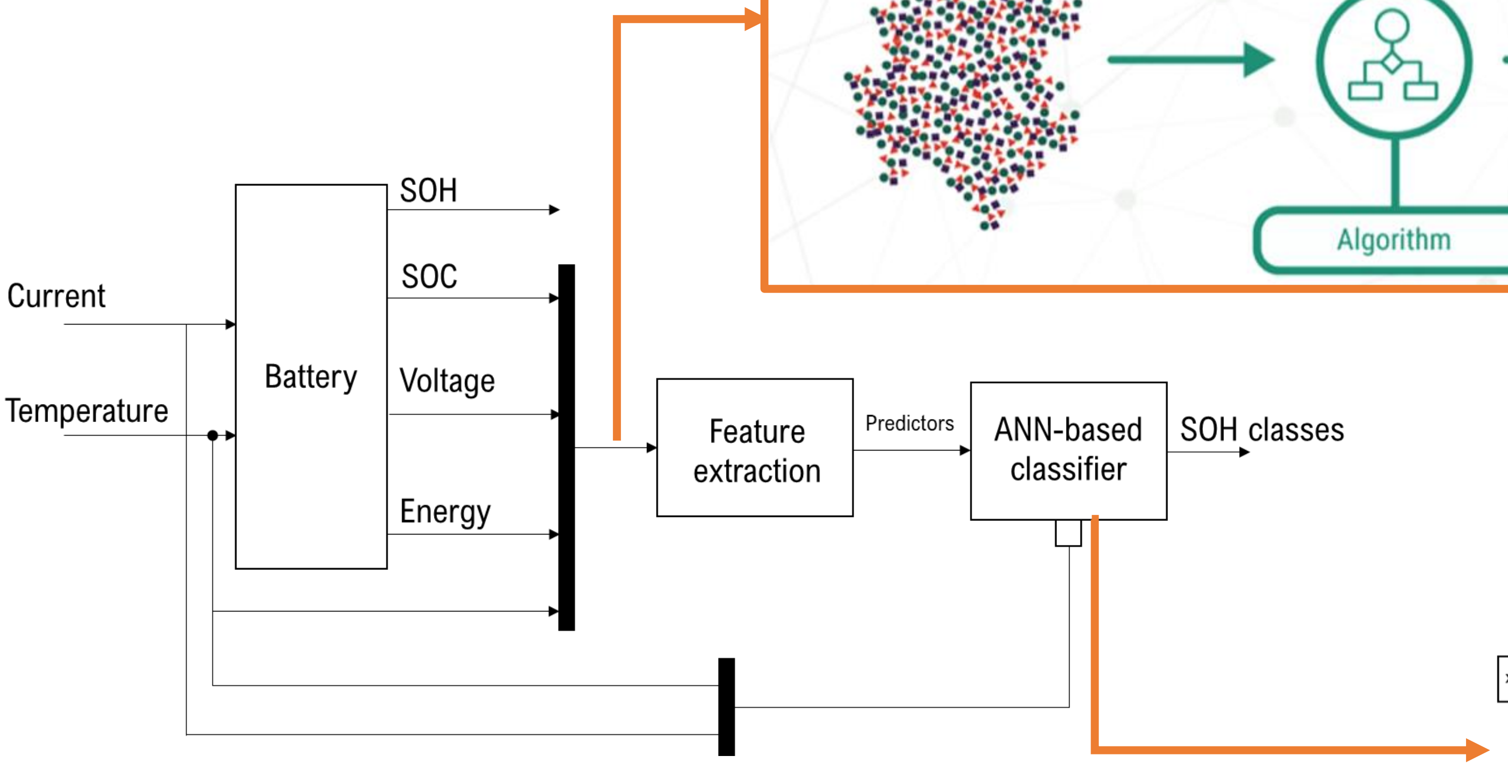




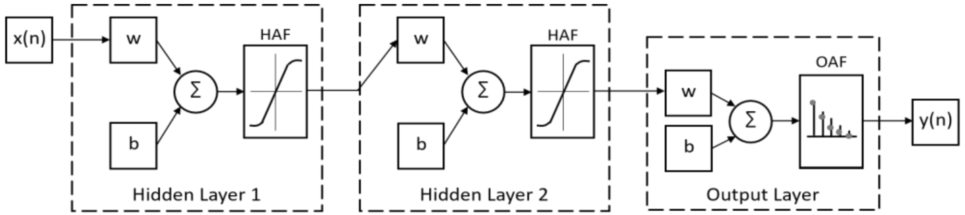
LEAD-ACID BATTERY MONITORING – SOH estimation algorithm

- A feed-forward pattern recognition classifier is used.
- Training datasets are collected at different temperatures and at the vehicle cranking condition.



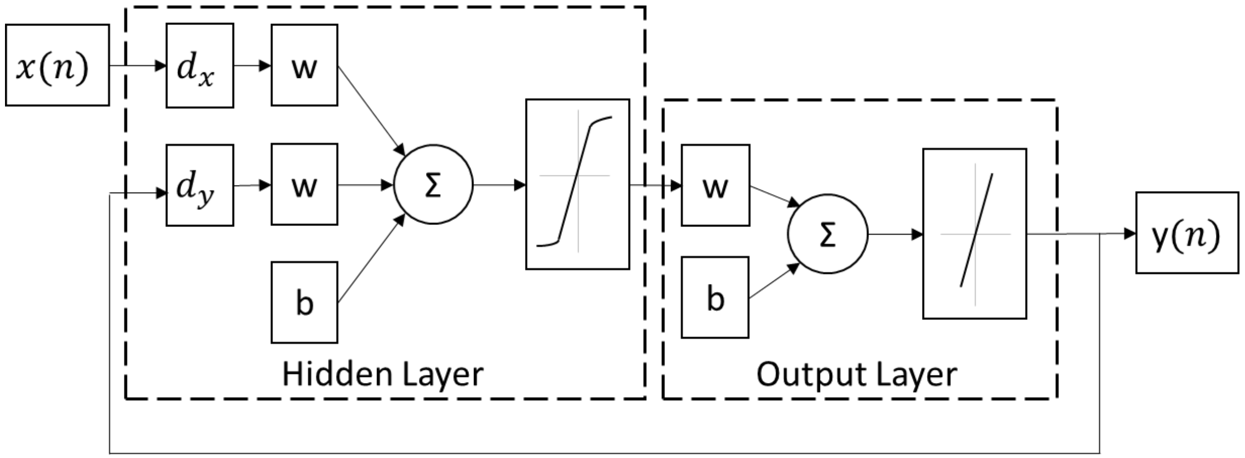


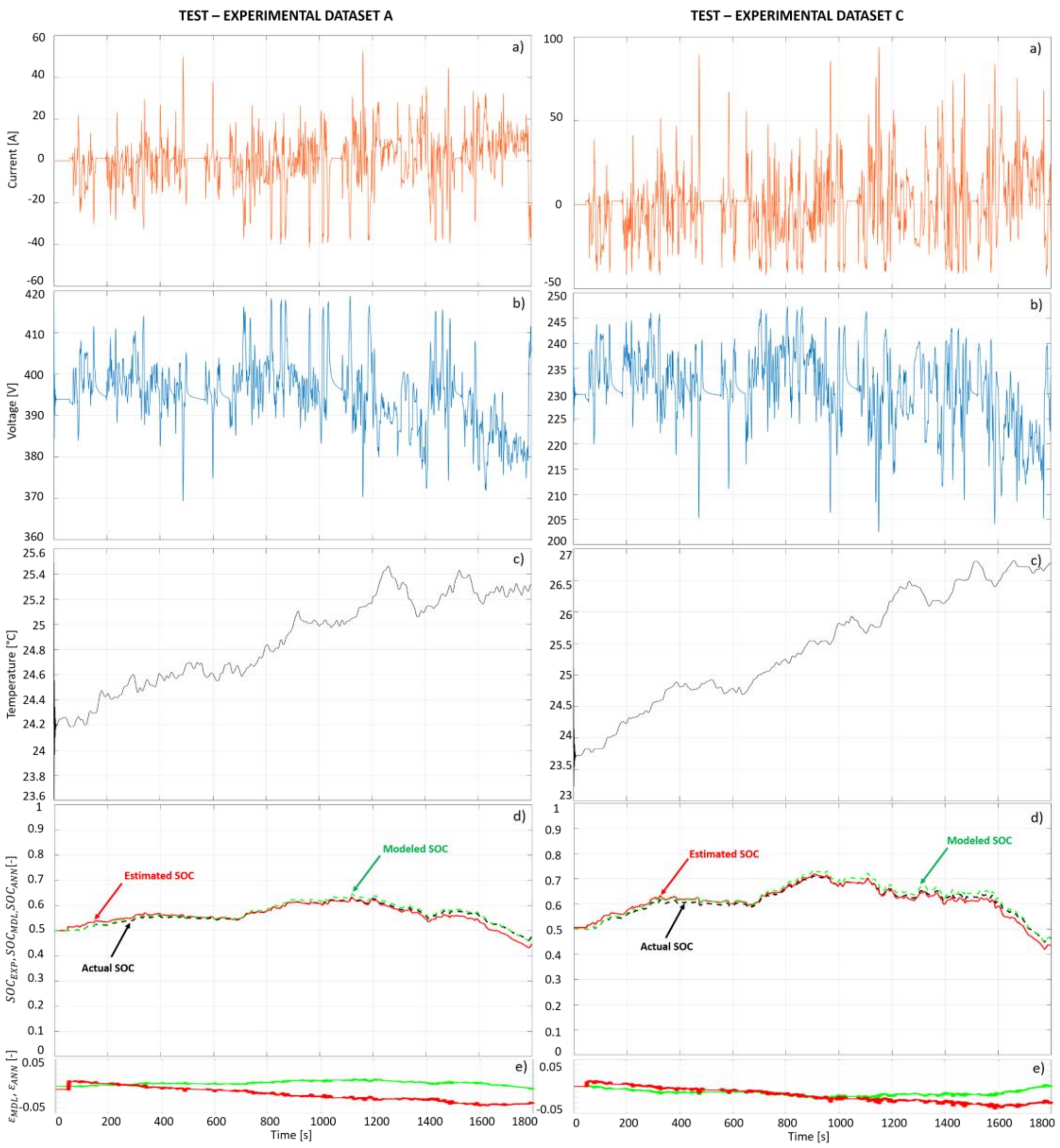
- Feed-forward pattern recognition classifier



In cooperation with PhD student Stefano Feraco

- The NARX neural network is here applied to estimate the State of Charge of two different battery packs for HEV.
- The training datasets are obtained from two charge/discharge profiles and they are collected at constant temperature equal to 25°C.
- The validation dataset represents a charge/discharge profiles of real driving missions during a WLTP cycle.

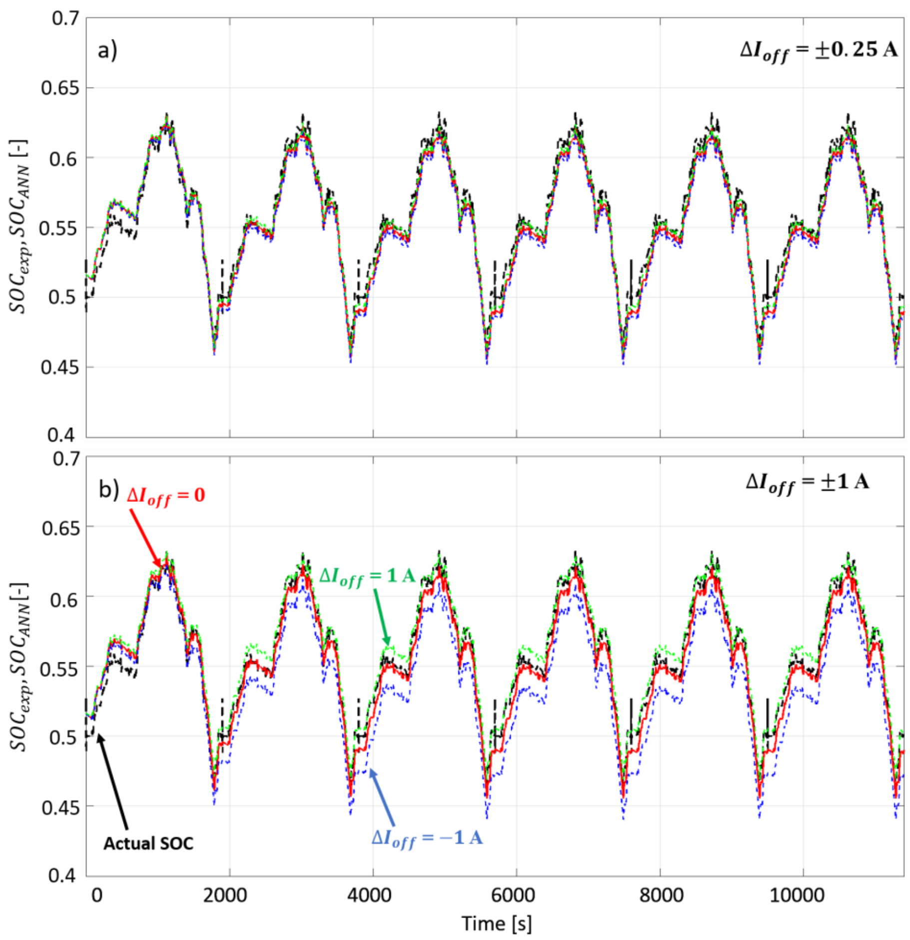


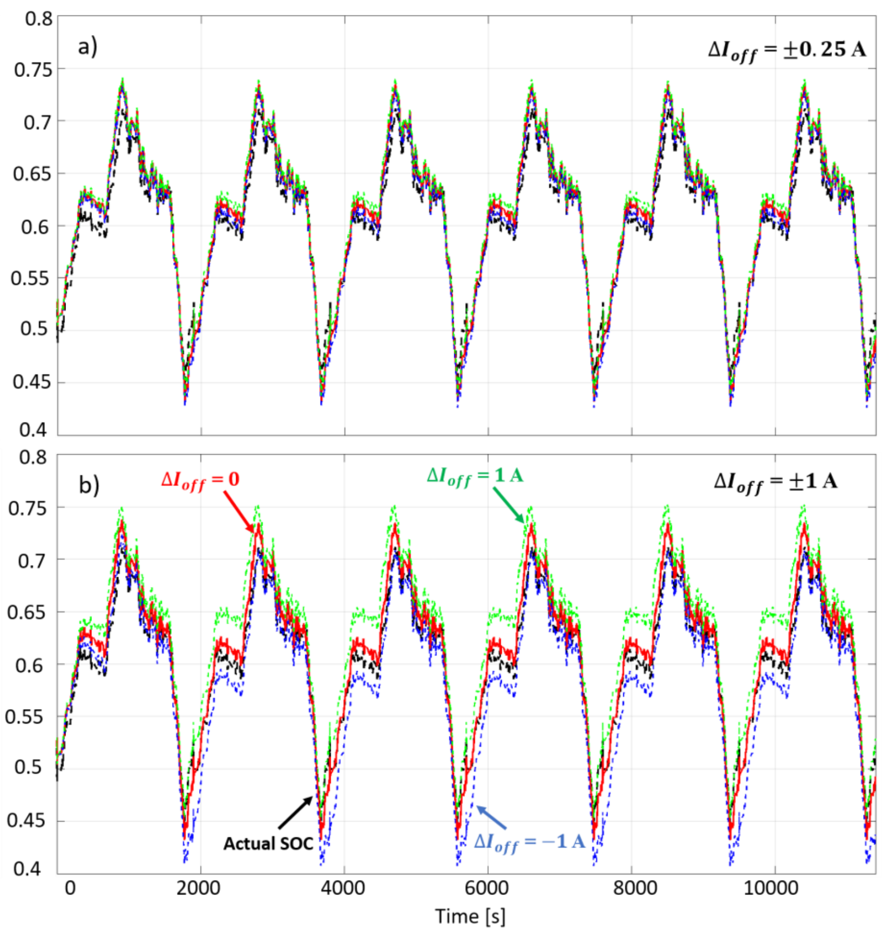


LI-ION BATTERY MONITORING – SOC estimation algorithm 2/2

In cooperation with PhD student Stefano Feraco

- A robustness analysis is performed to test the algorithm performance in the case of an offset error in the input current.
- Different offset current values ΔI_{off} are considered: ± 0.05 A, ± 0.25 A and ± 1 A.





CONCLUSION

- Scalability of the approach to different battery chemistries.
- No need for high-fidelity model of the battery.
- Validation of the method using real data.
- Systematic approach to define the main parameters of the Artificial Neural Network.

FUTURE WORK

- Validation of SOH estimation algorithm on real data in a simulation environment.
- Validation of SOC and SOH estimation algorithms on vehicle.
- Design of algorithm for the combined estimation of the State of Charge and the State of Health.
- Deployment of the resulting algorithm on a real Battery Monitoring System (BMS) of a commercial vehicle and test in real operating conditions.

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LIM – **L**aboratorio **I**nterdisciplinare di **M**eccatronica

Thank you!