

# Notes FYP

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November 6, 2025

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# 1 Constraining the research

Spent a fair amount of time learning about the basic machine learning techniques, then NN methods, then applying with pytorch. Managed to get a basic raw NN to work for fashion sets, then began looking at CNNs and LSTMS for learning data, in the hopes it could predict battery degradation over time. However, given the sheer data needed, as well as a very large possible set of outputs and too many inputs to consider, it did not look feasible to continue down this route. At least for a black box approach, to parameterise the current state of health, perhaps this could be used to live tune the current profile.

It was also found [1] that differences of only 2% can have large effects in the degradation states over time, meaning the ability for a NN to generalise well enough and capture these differences would be hard and more specifically, beyond the ability of the author of this paper.

Instead of a *black box battery* model, the goal is now to focus on the actual optimal charging method themselves, to reduce degradation. Specifically the constant current stage of the charging cycle, as this is where most of the heat is generated, research shows this to be a large factor of degradation alongside instantaneous applied voltages.

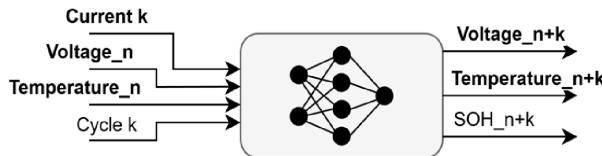


Figure 1: Original end objective: Black Box Battery to allow for discovery & testing of optimal charging profiles

## 2 Data Analysis on Dans Data

Gave a good insight to the degradation patterns on an array of lithium batteries, data was analysed and plotted on jupyter notebook. Despite not complete draining etc, resting points, internal resistance and *importantly* temperature were able to be extracted from the data too

## 3 Lithium Battery Modelling

Starting off, only knowing the basics of batteries, i.e the resistance increases over time, capacity drops etc. I'm continuing learning the various battery models, behaviours etc.

- For the most part, at least within the context of the problem, the dynamics of the battery can be modelled with an equivalent circuit model (ECM). Subject to vary between cycles
- Looking at dans data, parameters will be different between cells, as well as cycle degradation, but if the degradation can be modelled based off initial parameters, then an optimal charging method can be found for a given battery at a given time.
- Degradation causes:
  - SEI layer growth via pores  $\approx$  not really solvable, grows square root over time and cycle number
  - Lithium plating
    - Causes increased ageing and safety risks, its the deposition of metallic lithium on the anode surface, happens at high charging currents and low temperature. Since during charging, the lithium ions move, through the sei into the anode, if the ions cannot intercalate fast enough, they deposit and can become metallic lithium. Especially when charging is forced, local overpotential can cause the lithium plating, can cause dendrites **this is one of the main constraints for the charging profile**

- Active material loss (from parts mentiones above)
- SEI Brakeages
 

Charging too **high** of a temperatures causes mechanical stress on the sei layer, causing it to crack and reform, consuming more lithium ions in the process. Loose sei material can also float in the electrolyte, causing further issues.
- Electrolyte decomposition

Superlinear battery degredadion known as "Knee" is where degredation drops rappidly over later cycles.

Appears the multistage cc is advantagous for keeping charge time down, yet reducing degredation by ensuring most of the current is applied at lower states of charge, where the battery is less prone to lithium plating and high internal resistance heating.

## 4 Current work and Results

Looking at the paper on CLO, large question about the early predictor aoutcome, mentions its a linear mechanism, how are they confirming what the characteristics are after atleast the knee point?

## 5 Current plan

- Look at existing charging methods, including the complex ones and continous ones (explain complexity and non generalisability).
- Look at the different SOC estimation methods, since the cc high current section works good for 20-60 % soc [2] This could, and hopefully so, be a chance to use NN to predict soc quickly and something that can be implamented on hardware. Could also give chace to be compared against paings offline parameterisation solver
- If this is adaptive over the ageing, since R and C values change, need to look at maybe live cc tuning methods, maybe a form of MPC? , see the feasability of implamenting on actual hardware, explicit MPC could be a possibility, but not sure yet how recomputing QP (or probably nonlinear) with changing dynamics is done
- Run the experiment against standard cc-cv methods, look at temp, internal resistance and capacity over time.

Baselinse batterys with fixed cc cv (need to look at the cc used)

Idea: Use ICLOCS2, paings model to extract features and the ECM parameters Use this in a NN , possibly LSTM and NN to then allow for redicitoikn of furutre features

CC stages - follow roughly what Georges Paper utilised to minimise the constrains, maybe change the cost functions

Adapdtive, id like to be able to

## 6 Questions

- Deciding on the constraints, besides the total charge volume, does the charge time need to be minimised also? Or keeping that constant and purrley investigating the degredation effects compared to standard cc-cv method
- Enquire about dans temperature controll side, is the abient area controlled, can the temp be controlled?
- General guidance on the controll method, is this entire plan okay, any suggested reading? Some of the heavy matrices are a bit over my head. (Happy with the idea of matracies transforming vectors, some basic forms of matrices w properties ect)

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