GBatteries Project Proposal for

UofT Big Data Course: Fall 2020

Company Introduction

GBatteries is an advanced battery technology company, revolutionizing how batteries are charged. Operating at the intersection of artificial intelligence, electrochemistry, signal processing, and high-power electronics, we are pioneering an alternative way to charge lithium-ion (Li-ion) batteries. Our charging method uses adaptive pulses instead of the conventional charging protocol – CCCV – used as the standard Li-ion charging method. Our technology enables ultra-fast charge without compromising the health of the battery.

Our mission is to charge electric vehicles as fast as it takes to fill a tank of gas, to remove the “charge time” barrier. Our goal is to accelerate the adoption of electric vehicles, therefore reducing greenhouse gas emissions.

Background

The goal when developing a charging protocol is to:

1. Minimize degradation of the battery cell
2. Meet or exceed a charging speed
3. Comply with system constraints (maximum power delivered, maximum cell temperature, etc.)

Developing a charging protocol is an iterative process where a set of charging parameters (for example, charging current, duty cycle, frequency) are selected, then evaluated by seeing how many cycles the cell can cycle for before reaching end of life. A cycle consists of charging the cell, then discharging the cell and cycling is the process of running cycles until the battery reaches end of life (EOL). The problem is that a cell can cycle for months before reaching EOL which makes evaluating a protocol a lengthy process.

One strategy to combat this is to develop a model that predicts the cycle life (the number of cycles before the battery reaches EOL) as it is being tested. This can help rapidly speed up protocol development since the researcher can see what the expected cycle life of a battery may be. If it is poor, then they can end the test early and start another set of parameters.

EOL occurs when the retentive capacity of the battery is less than 80% of its nominal capacity. To measure the true retentive capacity while cycling a battery, we periodically conduct special tests called Reference Performance Tests (RPT). The first retentive capacity measurement is taken as the nominal capacity for each battery sample.

The plots below show the discharge capacity of the battery for every charge/discharge cycle.

1. Regular Cycles Selected: The regular cycles are cycles where our Active Battery Management System (ABMS) protocol is used to the charge the battery. The charge duration (red dots) show that the duration is around 15 minutes. During the regular cycles, the measured usable capacity lower than the retentive capacity of the battery.
2. RPT Cycles Selected: These are the specialized cycles we use to accurately measure the retentive capacity of the battery. An RPT is conducted by charging the battery slowly (>1 hour), then discharging the battery very slowly. You will notice that the RPTs typically occur in groups of two or three. The first RPTs are used to stabilise the battery, while the discharge capacity measured by the last RPT in the group will be taken as the retentive capacity.

Overall, the retentive discharge capacities from RPT cycles can be used to calculate the cycle life of the battery by finding the cycle number where the RPT discharge capacity crosses 80% of the nominal value of capacity. The regular cycles cannot be used to directly calculate the cycle life of the battery but provides some indication on the health of the battery.

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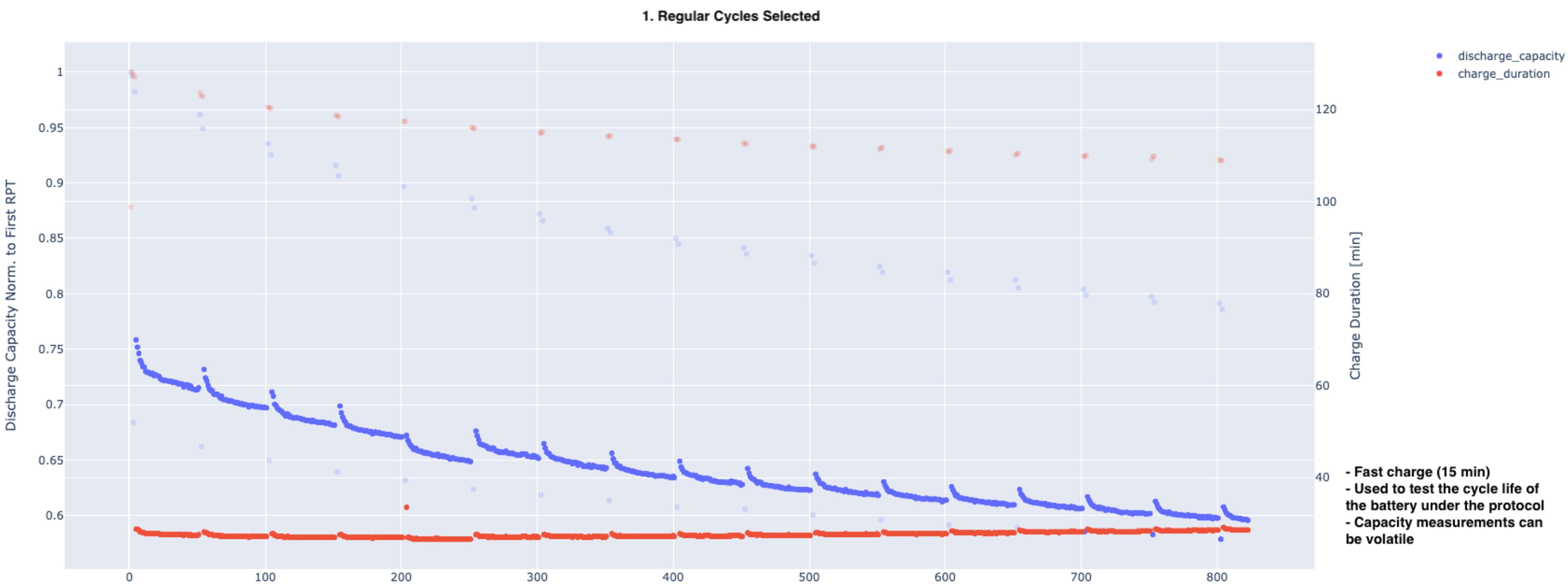
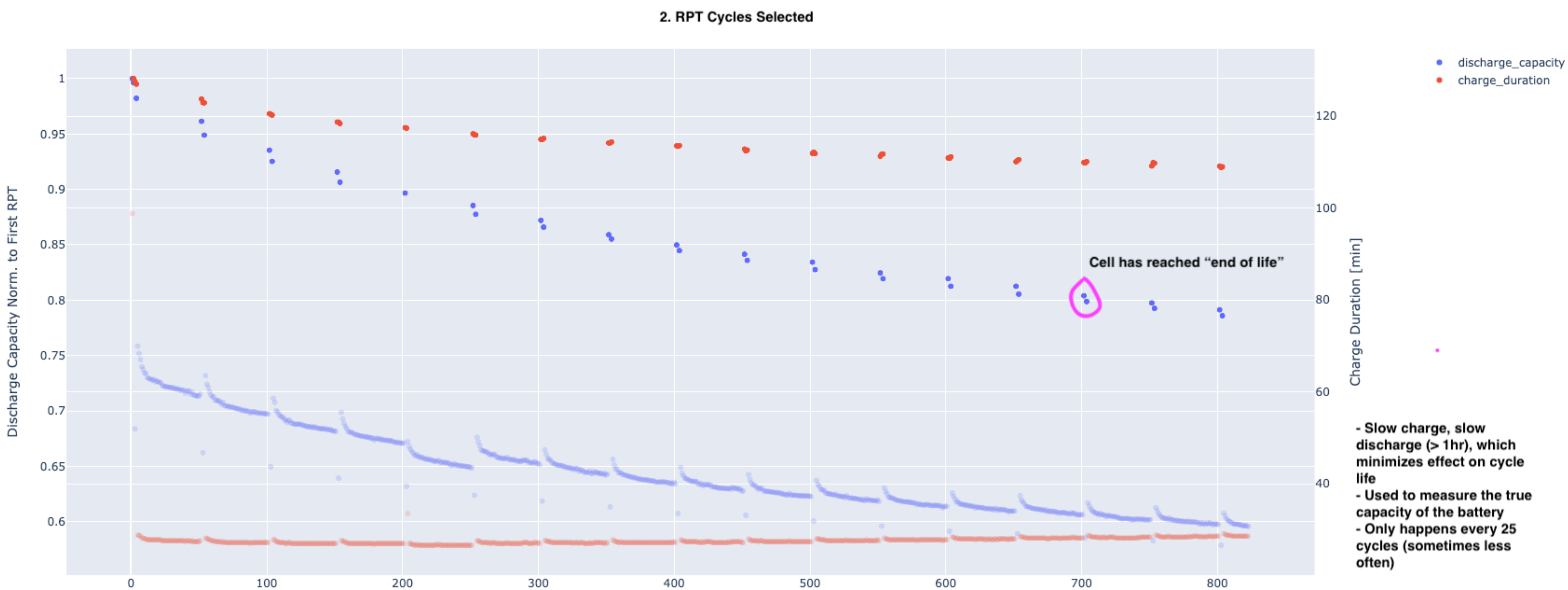


1. Regular Cycles Selected
Discharge Capacity Norm. to First RPT
Charge Duration [min]
discharge_capacity
charge_duration
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
120
100
80
60
40
0
100
200
300
400
500
600
700
800
- Fast charge (15 min)
- Used to test the cycle life of the battery under the protocol
- Capacity measurements can be volatile



- **Slow charge, slow discharge (> 1hr), which minimizes effect on cycle life**
- **Used to measure the true capacity of the battery**
- **Only happens every 25 cycles (sometimes less often)**

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Project Proposal

The goal for this project is to develop a model to predict the "RPT discharge capacity" at various steps into the future. The project groups will be provided with labeled data for thousands of cycles. Teams will be responsible for dividing the dataset into dev/test/train sets as they deem appropriate. The models developed will play a role in a monitoring solution that will be deployed in our battery testing facility.

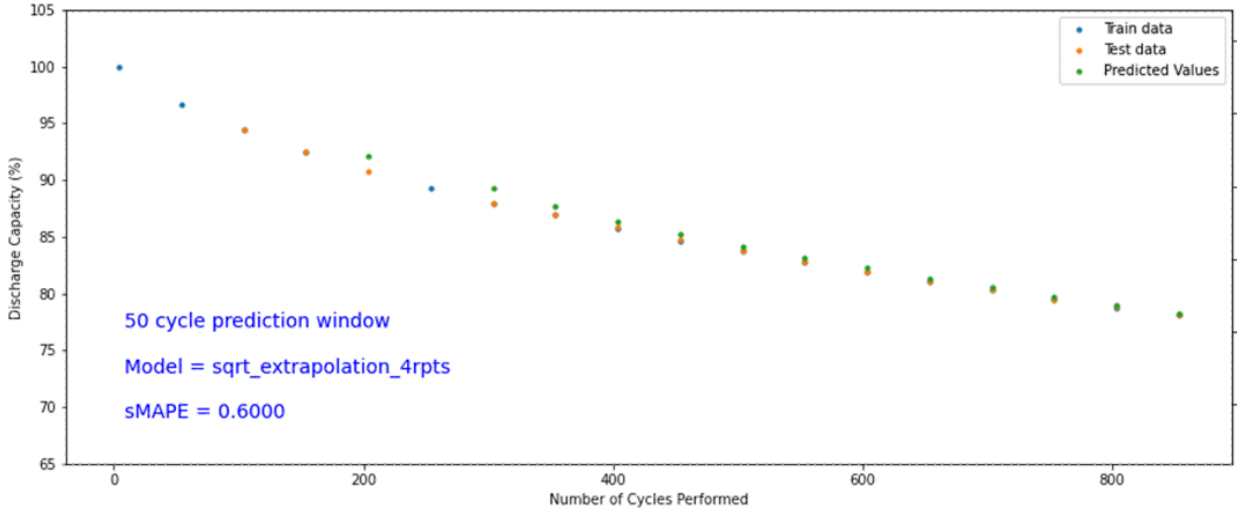
Targets

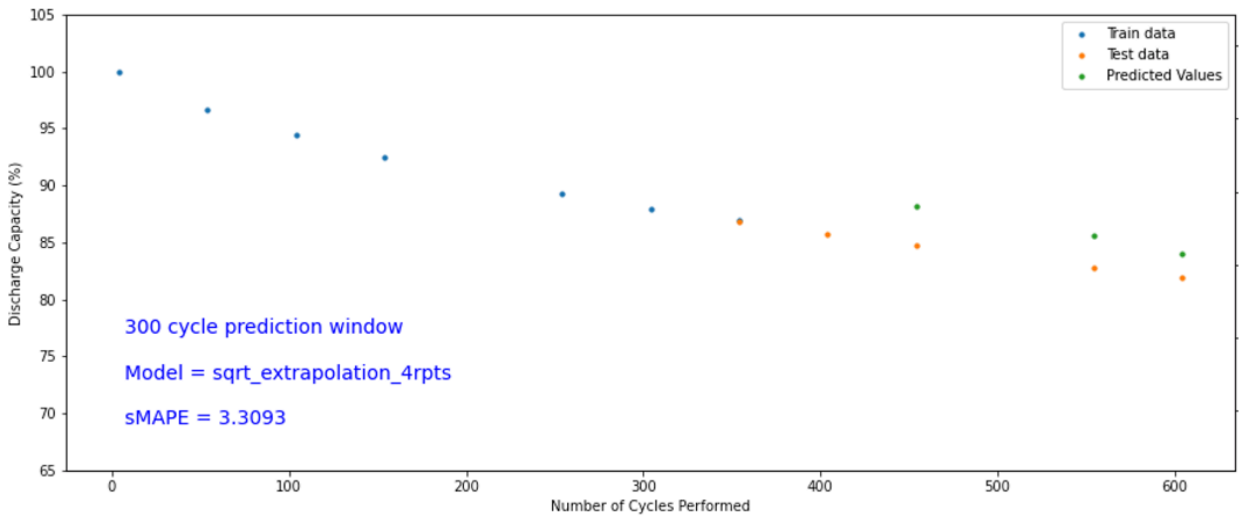
Internally, we are using sMAPE to evaluate the performance of different models. Below is an example of the sMAPEs we've achieved by fitting a square root function to the RPT discharge capacities and extrapolating the values.

Cell Model	**sMAPE 50_cycles**	**sMAPE 100_cycles**	**sMAPE 150_cycles**	**sMAPE 200_cycles**	**sMAPE 250_cycles**	**sMAPE 300_cycles**
A	0.7	0.8	1.0	1.3	2.0	2.3
B	1.6	1.5	2.1	1.9	1.2	1.7

For this application, an sMAPE less than 1.0 is considered "good" and can be used by our research team to make a decision on whether to continue cycling a cell or not. An sMAPE less than 3.0 is considered "acceptable" and can be used to get a general idea on the performance of a protocol, but not necessarily make a decision on the prediction.

Below are some plots of our square root model predicting RPT discharge capacities at 50 and 300 cycles into the future. The model is accurate enough for the team to make decisions 50 cycles into the future but extending the prediction window to 300 cycles significantly increases the error.





Description of Data

The dataset covers two different battery models and over 100 individual batteries. The features are defined at two different levels of granularity:

1. Features aggregated per cycle: Features that change from cycle to cycle. These include discharge capacity, the kind of cycle (RPT vs. Regular), and the charge duration.
2. Features aggregated within a cycle (per SoC region): An SoC (state of charge) region is a measure of what percentage the battery is charged to. We use this to divide a cycle further up. There are additional features that we can aggregate here which change from SoC region to SoC region and may also be correlated to the health of the battery.

The data is organized in .csv files where each battery cell has its own .csv. The below table summarizes the structure of each file:

Below are example contents for a .csv file for a single battery. Features that change per-cycle are highlighted in blue. Features that change within a cycle (per-SoC region) are highlighted in yellow.

Battery Model	Battery ID	Cycle Number	Cycle Type	Charge Duration	Discharge Capacity	SoC Region	feature_1	feature_2	feature_3	feature_4
A	1	1	RPT	3600	1	1	0.7885	0.3541	0.7895	0.6481
A	1	1	RPT	3600	1	2	0.7886	0.6481	0.7896	0.6481
A	1	1	RPT	3600	1	3	0.7887	0.6481	0.7897	0.6481
A	1	1	RPT	3600	1	4	0.7888	0.6481	0.7898	0.6481
A	1	1	RPT	3600	1	5	0.7889	0.6481	0.7899	0.6481
A	1	1	RPT	3600	1	6	0.789	0.6481	0.79	0.6481
A	1	1	RPT	3600	1	7	0.7891	0.6481	0.7901	0.6481
A	1	1	RPT	3600	1	8	0.7892	0.6481	0.7902	0.6481
A	1	1	RPT	3600	1	9	0.7893	0.6481	0.7903	0.6481
A	1	1	RPT	3600	1	10	0.7894	0.713433	0.7904	0.6481
A	1	2	Regular	900	0.82	1	0.7885	0.3541	0.7895	0.6481
A	1	2	Regular	900	0.82	2	0.7886	0.6481	0.7896	0.6481
A	1	2	Regular	900	0.82	3	0.7887	0.6481	0.7897	0.6481
A	1	2	Regular	900	0.82	4	0.7888	0.6481	0.7898	0.6481
A	1	2	Regular	900	0.82	5	0.7889	0.6481	0.7899	0.6481
A	1	2	Regular	900	0.82	6	0.789	0.6481	0.79	0.6481
A	1	2	Regular	900	0.82	7	0.7891	0.6481	0.7901	0.6481
A	1	2	Regular	900	0.82	8	0.7892	0.6481	0.7902	0.6481
A	1	2	Regular	900	0.82	9	0.7893	0.6481	0.7903	0.6481
A	1	2	Regular	900	0.82	10	0.7894	0.6481	0.7904	0.6481
A	1	3	Regular	901	0.81	1	0.7895	0.6481	0.7905	0.6481
A	1	3	Regular	901	0.81	2	0.7896	0.6481	0.7906	0.6481
A	1	3	Regular	901	0.81	3	0.7897	0.6481	0.7907	0.6481

A	1	3	Regular	901	0.81	4	0.7898	0.6481	0.7908	0.6481
A	1	3	Regular	901	0.81	5	0.7899	0.6481	0.7909	0.6481
A	1	3	Regular	901	0.81	6	0.79	0.6481	0.791	0.6481
A	1	3	Regular	901	0.81	7	0.7901	0.6481	0.7911	0.6481
A	1	3	Regular	901	0.81	8	0.7902	0.6481	0.7912	0.6481
A	1	3	Regular	901	0.81	9	0.7903	0.6481	0.7913	0.6481
A	1	3	Regular	901	0.81	10	0.7904	0.6481	0.7914	0.6481