MILESTONE 3: BACKGROUND RESEARCH

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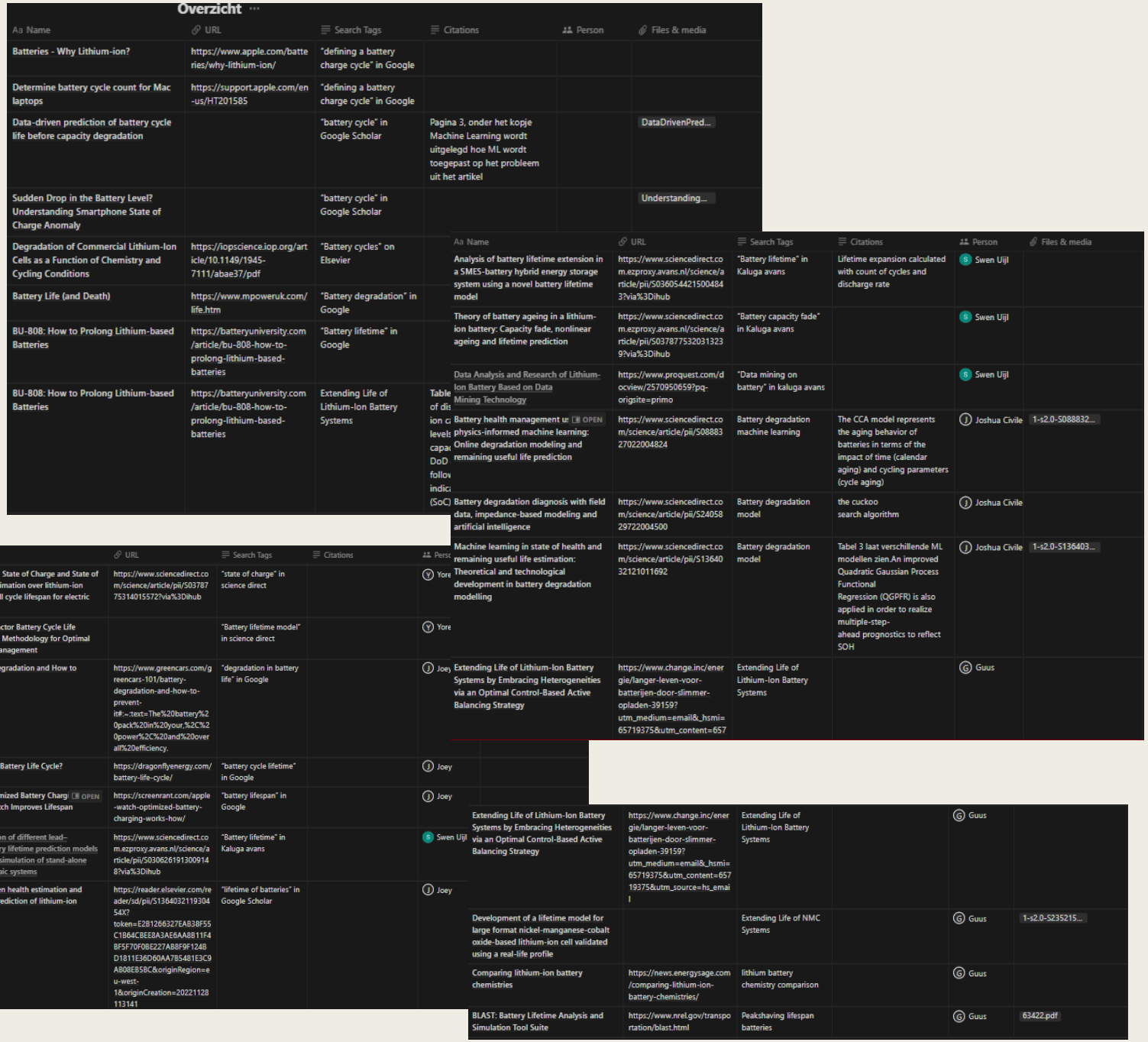
Research

- Definition of a battery cycle
- Different models and their characteristics
- 25 sources
  - 12 scientific articles
  - 13 websites



Overzicht

Name	URL	Search Tags	Citations	Person	Files & media
Batteries - Why Lithium-ion?	https://www.apple.com/batteries/why-lithium-ion/	"defining a battery charge cycle" in Google			
Determine battery cycle count for Mac laptops	https://support.apple.com/en-us/HT201585	"defining a battery charge cycle" in Google			
Data-driven prediction of battery cycle life before capacity degradation		"battery cycle" in Google Scholar	Pagina 3, onder het kopje Machine Learning wordt uitgelegd hoe ML wordt toegepast op het probleem uit het artikel		DataDrivenPred...
Sudden Drop in the Battery Level? Understanding Smartphone State of Charge Anomaly		"battery cycle" in Google Scholar			Understanding...
Degradation of Commercial Lithium-Ion Cells as a Function of Chemistry and Cycling Conditions	https://iopscience.iop.org/article/10.1149/1945-7111/abae37/pdf	"Battery cycles" on Elsevier			
Battery Life (and Death)	https://www.mpoweruk.com/life.htm	"Battery degradation" in Google			
BU-808: How to Prolong Lithium-based Batteries	https://batteryuniversity.com/article/bu-808-how-to-prolong-lithium-based-batteries	"Battery lifetime" in Google			
BU-808: How to Prolong Lithium-based Batteries	https://batteryuniversity.com/article/bu-808-how-to-prolong-lithium-based-batteries	Extending Life of Lithium-Ion Battery Systems	Table of dis ion c levels capa DoD follo indic (SoC)		

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Analysis of battery lifetime extension in a SMES-battery hybrid energy storage system using a novel battery lifetime model	https://www.sciencedirect.com.ezproxy.avans.nl/science/article/pii/S0360544215004843?via%3Dihub	"Battery lifetime" in Kaluga avans	Lifetime expansion calculated with count of cycles and discharge rate	Swen Uijl	
Theory of battery ageing in a lithium-ion battery: Capacity fade, nonlinear ageing and lifetime prediction	https://www.sciencedirect.com.ezproxy.avans.nl/science/article/pii/S0378775320313239?via%3Dihub	"Battery capacity fade" in Kaluga avans		Swen Uijl	
Data Analysis and Research of Lithium-Ion Battery Based on Data Mining Technology	https://www.proquest.com/docview/2570950659?pq-origsite=primo	"Data mining on battery" in kaluga avans		Swen Uijl	
Battery health management u: OPEN physics-informed machine learning: Online degradation modeling and remaining useful life prediction	https://www.sciencedirect.com/science/article/pii/S0888327022004824	Battery degradation machine learning	The CCA model represents the aging behavior of batteries in terms of the impact of time (calendar aging) and cycling parameters (cycle aging)	Joshua Civile	1-s2.0-S088832...
Battery degradation diagnosis with field data, impedance-based modeling and artificial intelligence	https://www.sciencedirect.com/science/article/pii/S2405829722004500	Battery degradation model	the cuckoo search algorithm	Joshua Civile	
Machine learning in state of health and remaining useful life estimation: Theoretical and technological development in battery degradation modelling	https://www.sciencedirect.com/science/article/pii/S1364032121011692	Battery degradation model	Tabel 3 laat verschillende ML modellen zien.An improved Quadratic Gaussian Process Functional Regression (QGPFR) is also applied in order to realize multiple-step-ahead prognostics to reflect SOH	Joshua Civile	1-s2.0-S136403...
Extending Life of Lithium-Ion Battery Systems by Embracing Heterogeneities via an Optimal Control-Based Active Balancing Strategy	https://www.change.inc/energie/langer-leven-voor-batterijen-door-slimmer-opladen-39159?utm_medium=email&_hsmi=65719375&utm_content=657	Extending Life of Lithium-Ion Battery Systems		Guus	

Name	URL	Search Tags	Citations	Person
Combined State of Charge and State of Health estimation over lithium-ion battery cell cycle lifespan for electric vehicles	https://www.sciencedirect.com/science/article/pii/S0378775314015572?via%3Dihub	"state of charge" in science direct		Yore
A Multi-Factor Battery Cycle Life Prediction Methodology for Optimal Battery Management		"Battery lifetime model" in science direct		Yore
Battery Degradation and How to Prevent It	https://www.greencars.com/greencars-101/battery-degradation-and-how-to-prevent-it#:~:text=The%20battery%20pack%20in%20your,%2C%20power%2C%20and%20overall%20efficiency.	"degradation in battery life" in Google		Joey
What Is A Battery Life Cycle?	https://dragonflyenergy.com/battery-life-cycle/	"battery cycle lifetime" in Google		Joey
How Optimized Battery Charg OPEN Apple Watch Improves Lifespan	https://screenrant.com/apple-watch-optimized-battery-charging-works-how/	"battery lifespan" in Google		Joey
Comparison of different lead–acid battery lifetime prediction models for use in simulation of stand-alone photovoltaic systems	https://www.sciencedirect.com.ezproxy.avans.nl/science/article/pii/S0306261913009148?via%3Dihub	"Battery lifetime" in Kaluga avans		Swen Uijl
Data-driven health estimation and lifetime prediction of lithium-ion batteries	https://reader.elsevier.com/reader/sd/pii/S136403211930454X?token=E2B1266327EA838F55C1B64CBEE8A3AE6AA8B11F48F5F70F08E227AB8F9F124BD1811E36D60AA785481E3C9AB08EB5BC&originRegion=eu-west-1&originCreation=20221128113141	"lifetime of batteries" in Google Scholar		Joey

Extending Life of Lithium-Ion Battery Systems by Embracing Heterogeneities via an Optimal Control-Based Active Balancing Strategy	https://www.change.inc/energie/langer-leven-voor-batterijen-door-slimmer-opladen-39159?utm_medium=email&_hsmi=65719375&utm_content=65719375&utm_source=hs_email	Extending Life of Lithium-Ion Battery Systems		Guus	
Development of a lifetime model for large format nickel-manganese-cobalt oxide-based lithium-ion cell validated using a real-life profile		Extending Life of NMC Systems		Guus	1-s2.0-S235215...
Comparing lithium-ion battery chemistries	https://news.energysage.com/comparing-lithium-ion-battery-chemistries/	lithium battery chemistry comparison		Guus	
BLAST: Battery Lifetime Analysis and Simulation Tool Suite	https://www.nrel.gov/transportation/blast.html	Peakshaving lifespan batteries		Guus	63422.pdf

Key findings

- Definition of a cycle according to Apple:
  - *A charge cycle happens when all of the battery's power is used, **BUT** this doesn't necessarily mean in a single charge*
  - *On one day, half of the battery can be depleted and then recharged to full. If the same thing happens the next day, that would count as one cycle*

- Which models are out there and their characteristics

Different models

Summary of different models.

- Supervised learning

- Model 1: Linear Regression
- Model 2: Logistic Regression
- Model 3: Support Vector Machine (SVM)

Model 1: Linear Regression

In short:

- Allows to summarize and study relationships between continuous variables
- The term "linear" refers to the fact that this method models data with a linear combination of the explanatory predictor variables

Why?

- Pro's
  - **Simple model**
  - **Computationally efficient**
  - **Interpretability of the Output**
- Con's
  - **Linearity Assumption**
  - **Overly-Simplistic**
  - **Inability to determine Feature importance**

How will we use it?

- *Train model with small part of data to get a quick result. Observe and continue from there*

Model 2: Logistical Regression

In short:

- Classification algorithm used to find the probability of event succes and failure
- Used when dependent variable is binary
- Introduces a non-linearity in the form of the Sigmoid function

Why?

- Pro's
  - **Very efficient to train**
  - **Good accuracy for many simple data sets and it performs well when the dataset is linearly separable**
  - **Logistic regression is less inclined to over-fitting**
- Con's
  - **The assumption of linearity between the dependent variable and the independent variables**
  - **It is tough to obtain complex relationships using logistic regression**

How will we use it?

- *Again train model with small part of data (because it can be done quick). Observe result and continue from there*

Model 3: Support Vector Machine (SVM)

In short:

- The SVM model represents different classes in a hyperplane in multidimensional space
- SVM aims to divide the datasets into classes to find a maximum marginal hyperplane

Why?

- Pro's
  - **SVM uses memory effectively.**
  - **Computationally efficient**
  - **Interpretability of the Output**
- Con's
  - **Linearity Assumption**
  - **Overly-Simplistic**
  - **Inability to determine Feature importance**

How will we use it?

- *We won't use it. This model is best used on small datasets. We have too much data for this model.*

Next steps

- Apply discovered definition of a battery cycle to our data

- Train chosen models with test data
- Test models on minimum of 5 batteries and observe squared error
- Cross validation

Questions?

Thank you for your attention