Battery Lifetime Prediction

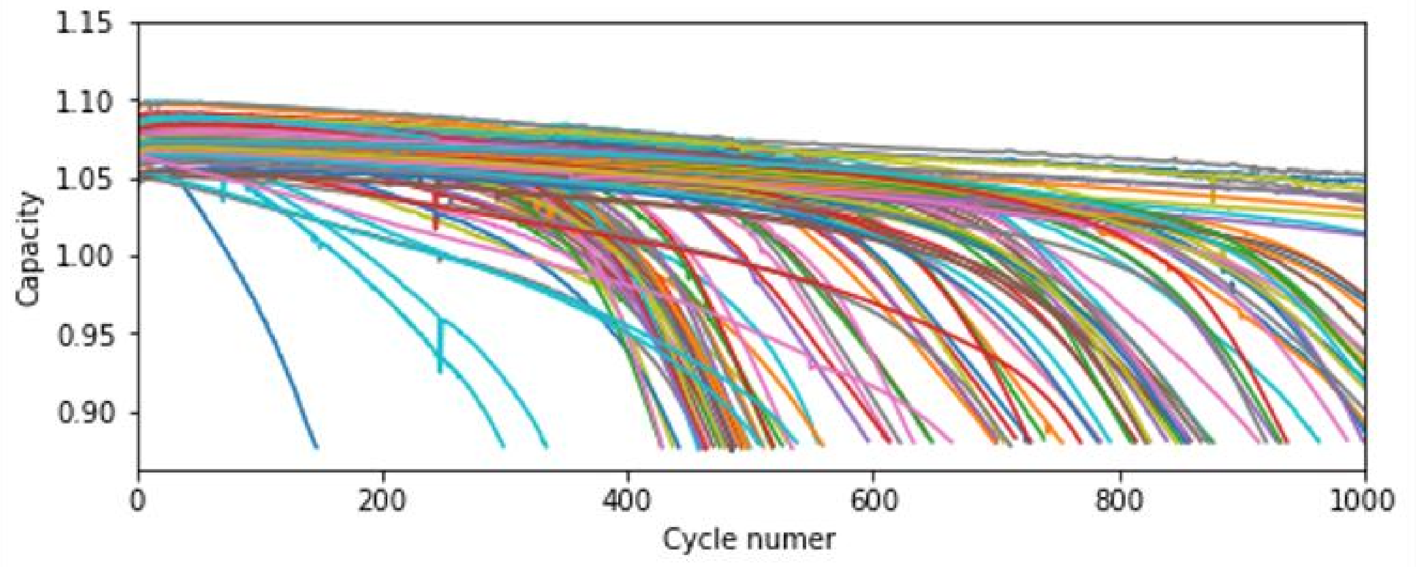
Given a few cycles

Jinpu Cao, Solomon Kim, Zewen Zhang

Battery Life Prediction Is Important

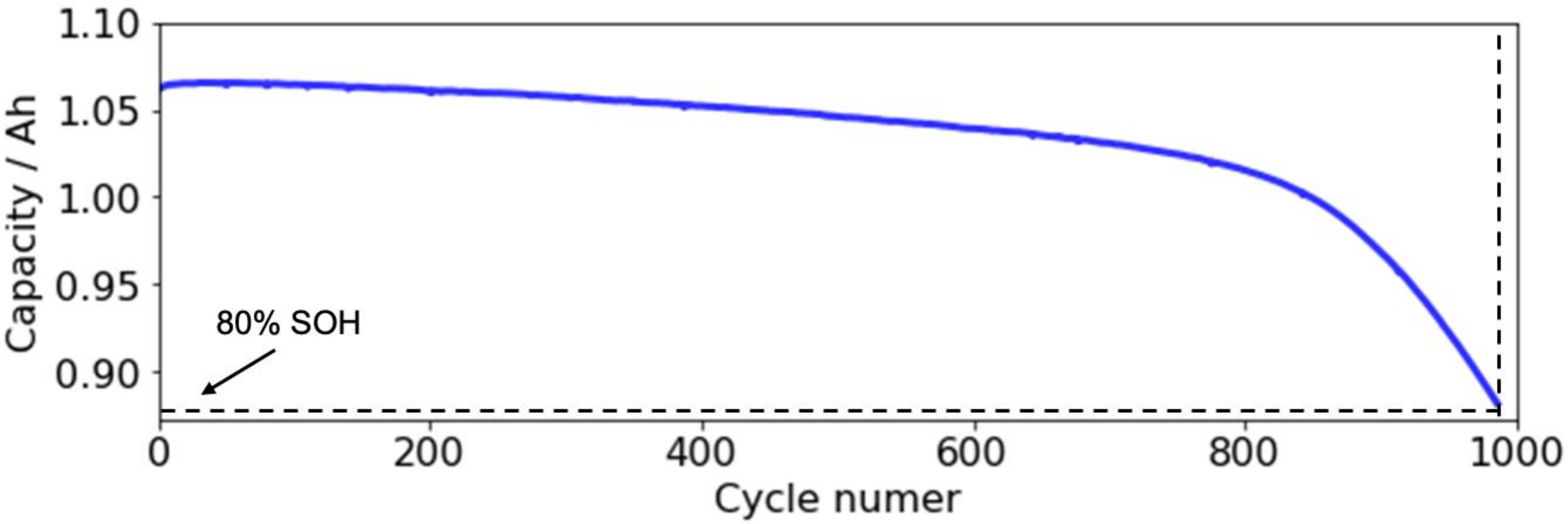
Battery life prediction

Non-linearity in Battery Degradation Modes

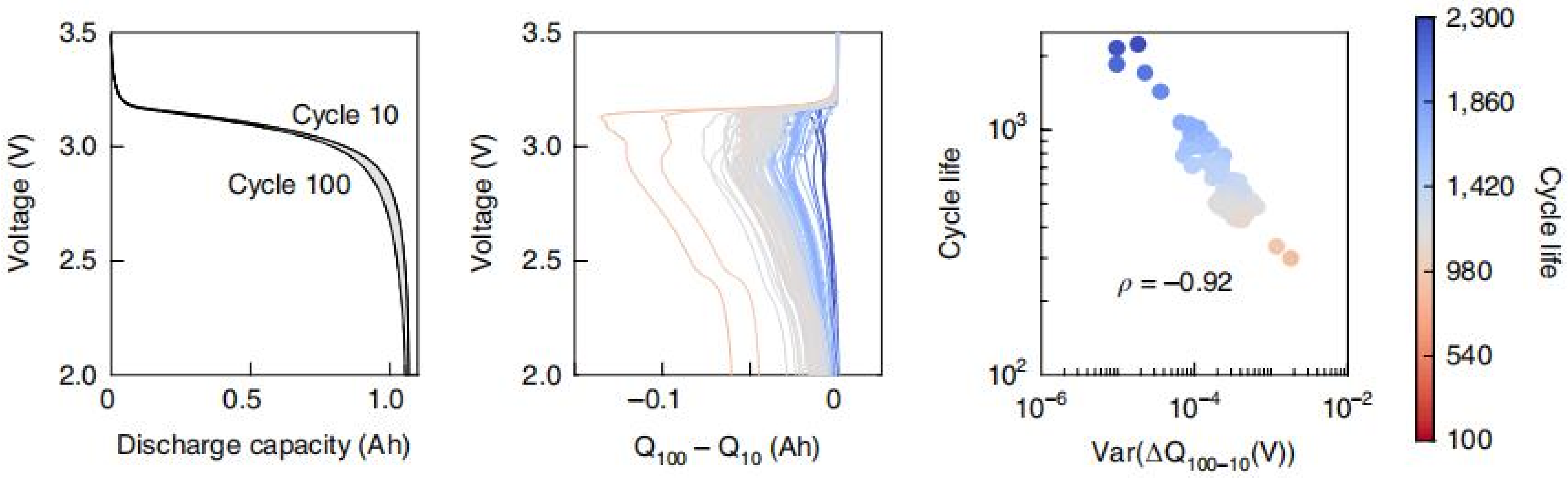


Mechanical / Chemical / Electrochemical **Heterogeneities**

Battery Lifetime Definition



Data-driven Methods For Battery Life Prediction

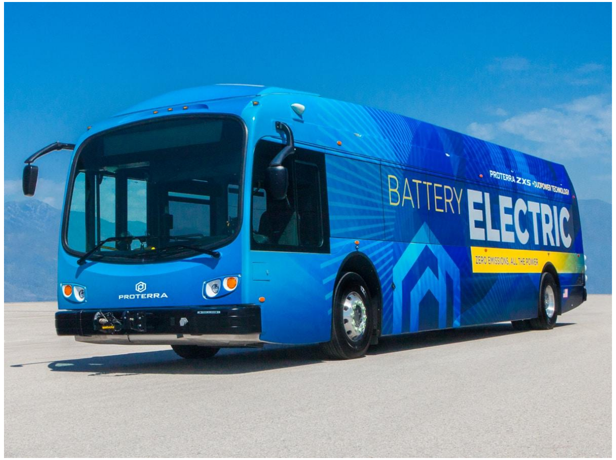


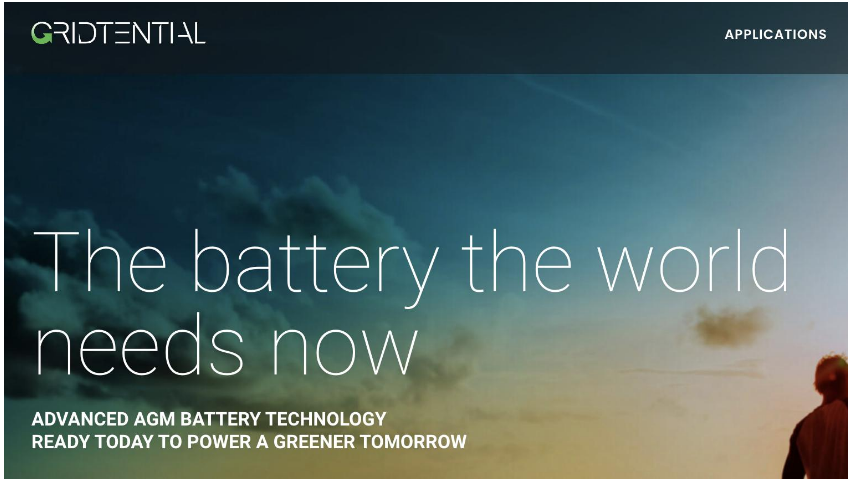
- Limited dataset size (124 cells)
- Feature extraction based on 100 cycles data

Severson, Kristen A., et al. *Nature Energy* 4.5 (2019): 383-391.

Target Area #1: Battery R&D Companies

- Interviewed many different Battery R&D Companies
  - Finding: Many don't use ML
- Respectfully, PhD's without strong CS/data science background
- Case Studies: Proterra, Gridtential





Target Area #2: EV Customers

- Create used EV car market
  - Customer's can determine lifetime on their batteries
- 3rd Party Certification Agency
- Accelerate EV adoption

Target Area #3: Second Use Battery Companies

- Partner with companies like B2U Storage Solutions
    - Interview Finding: No effective way to determine lifetime

What are potential competitors?

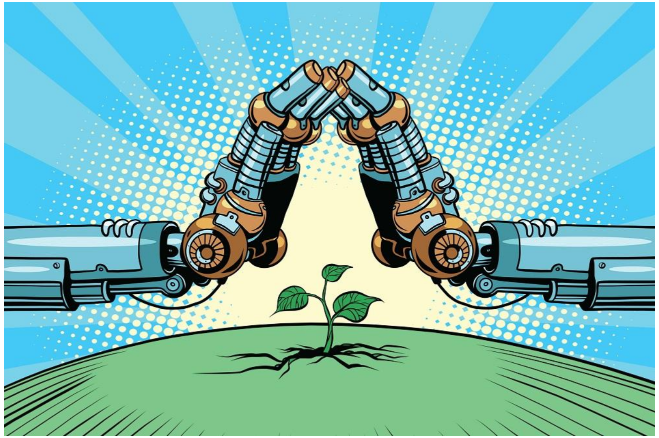
- Voltaiq is more focused on management not prediction
  - Called Sales Representative
  - Interviewed Yen T. Yeh
    - Battery Engineer

Long-term vision Part 1

- Scale AI for Climate
- Alternative to C3AI
  - Don’t work with oil companies
  - Focus on Climate Change

Long-term vision Part 2

- Work at intersection of AI and Climate Change
  - Agriculture
    - Crop detection
  - Green Buildings
    - Demand Response
  - Transportation
  - Smart Grids
  - Energy
    - Cloud Forecasting



Mentors

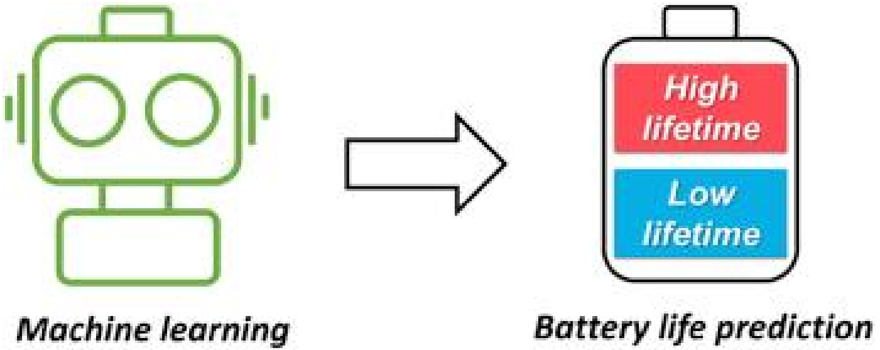
- Professor Simona Onori
  - Energy Resources Engineering Department
- Professor Adam Brandt
  - Energy Resources Engineering Department
- Brian Bartholomeusz
  - Executive Director of Innovation Transfer, TomKat Center for Sustainable Energy

Potential Challenges

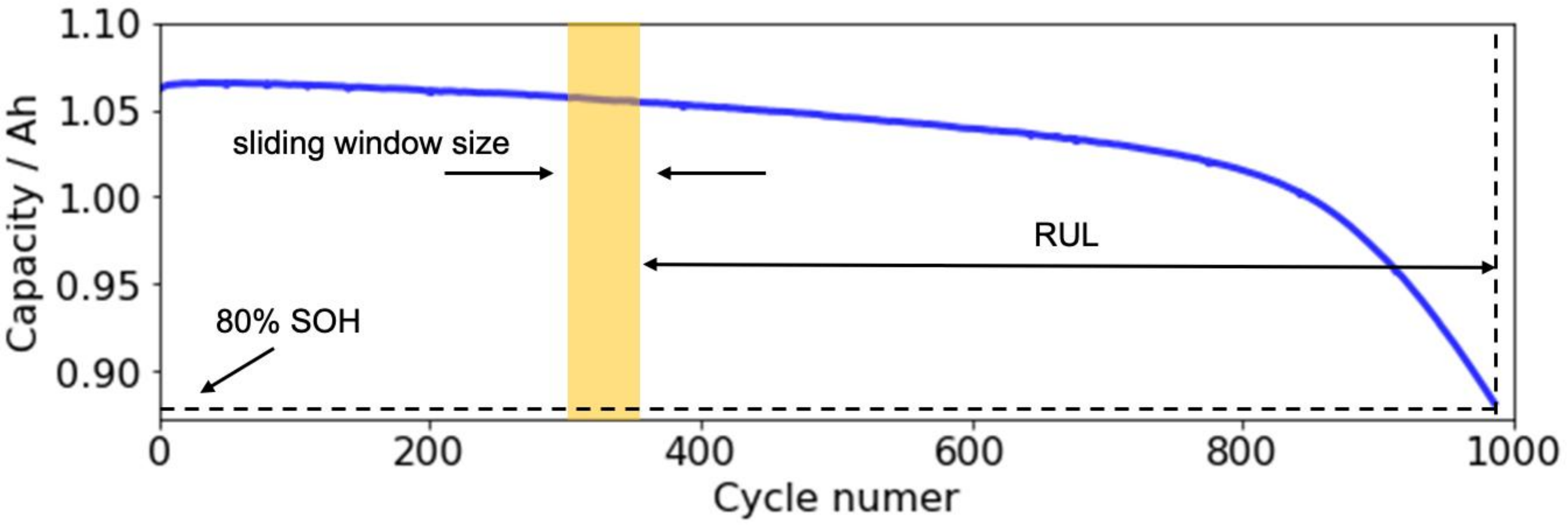
- Communicating the Effectiveness of AI
  - Use of Metaphors
  - Learn from Different Experts
- Learn from Alumni Community in Stanford Climate Ventures

What's going on under the hood?

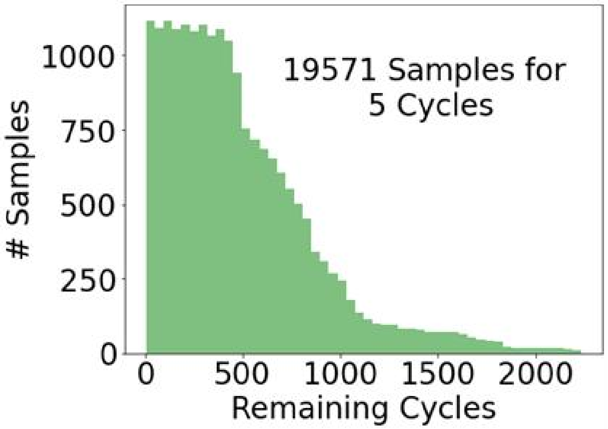
- Feel free to stop me/interrupt me :)
- Explaining the Machine Learning demonstrates uniqueness

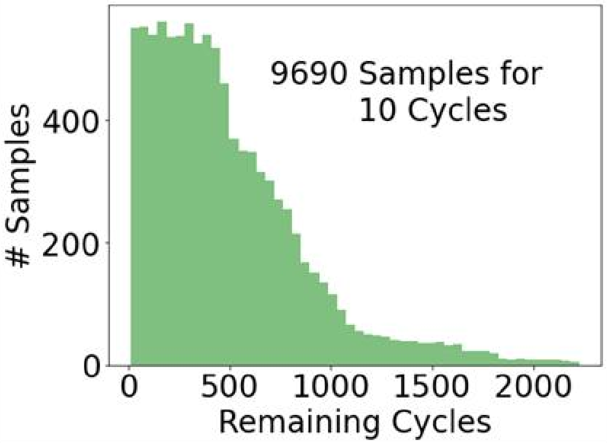


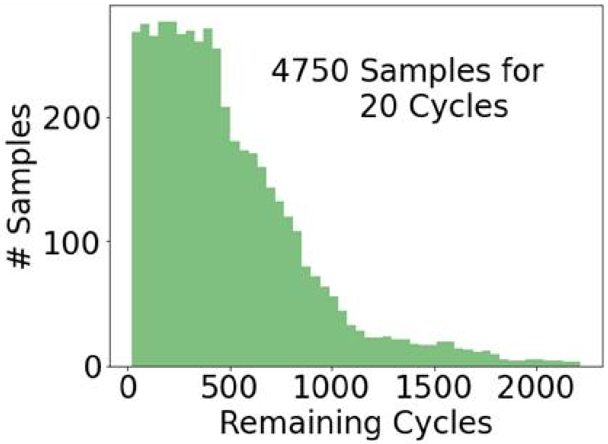
Sliding Window for Data Augmentation



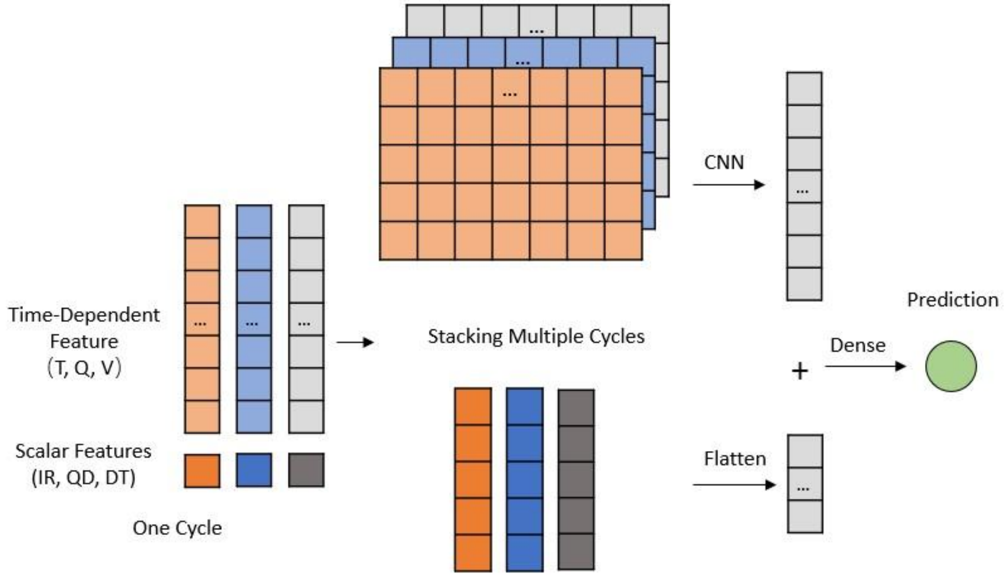
Augmented Dataset For Prediction

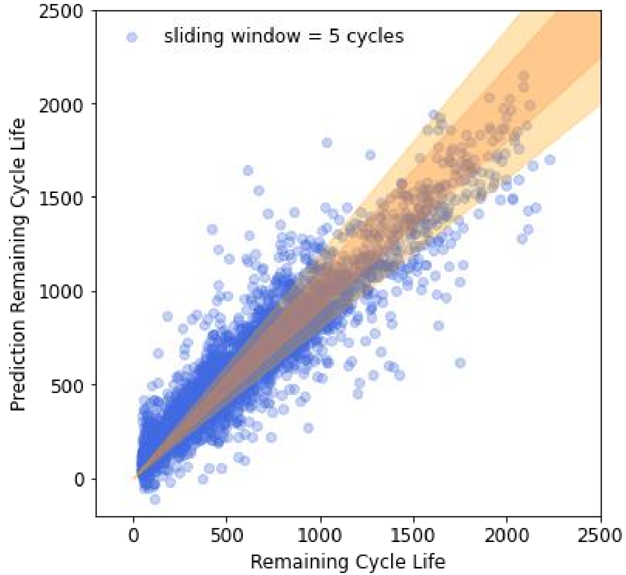




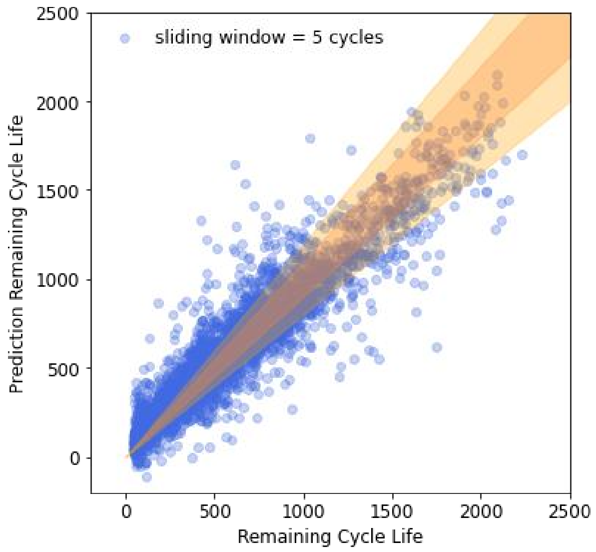


Convolutional Neural Network Based Models

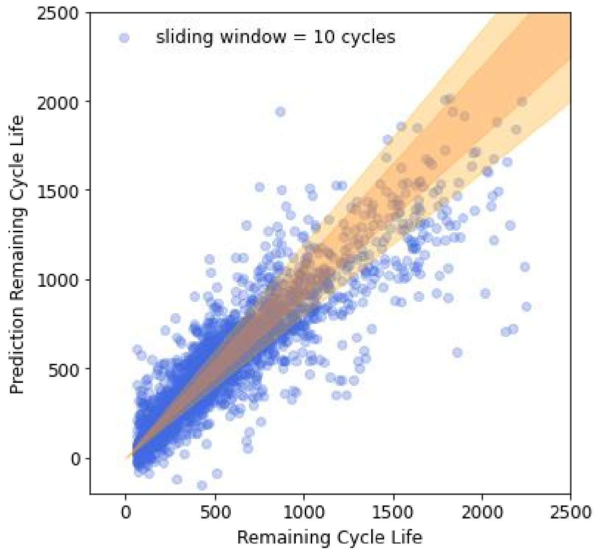




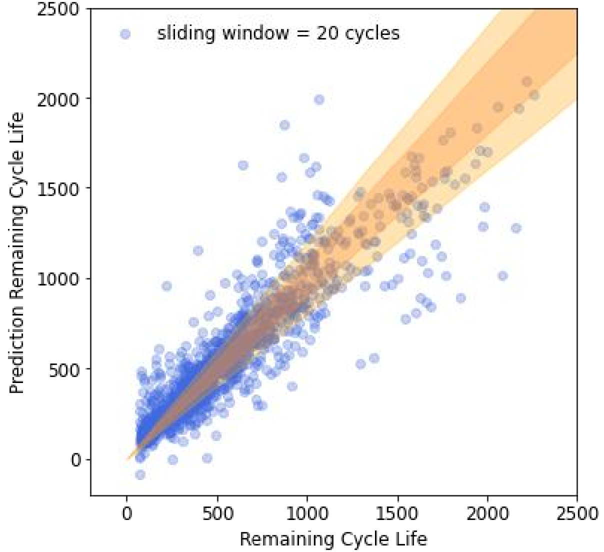
Results from CNN models



MAPE: 23.6%
10%-BAND: 38.2%
20%-BAND: 63.8%

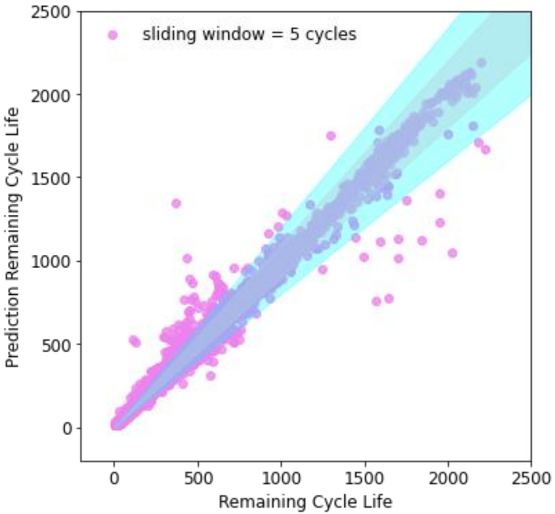


MAPE: 26.5%
10%-BAND: 32.6%
20%-BAND: 57.3%

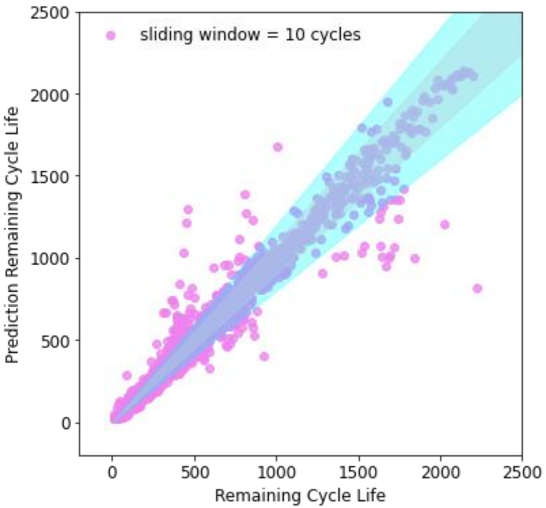


MAPE: 24.3%
10%-BAND: 38.2%
20%-BAND: 62.6%

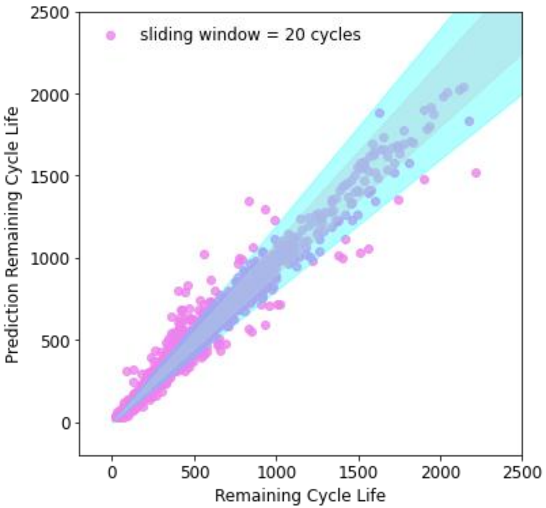
Results from RNN models



MAPE: 7.5%
10%-BAND: 81.5%
20%-BAND: 92.7%

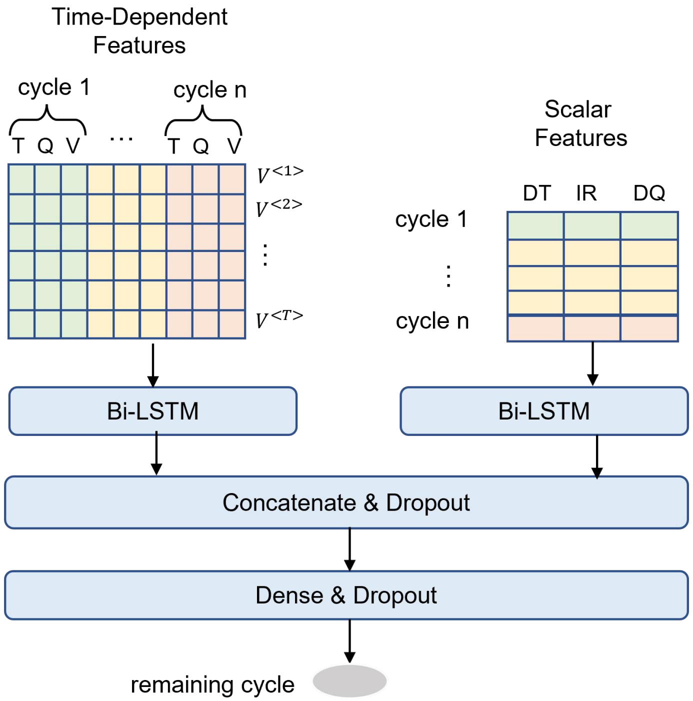


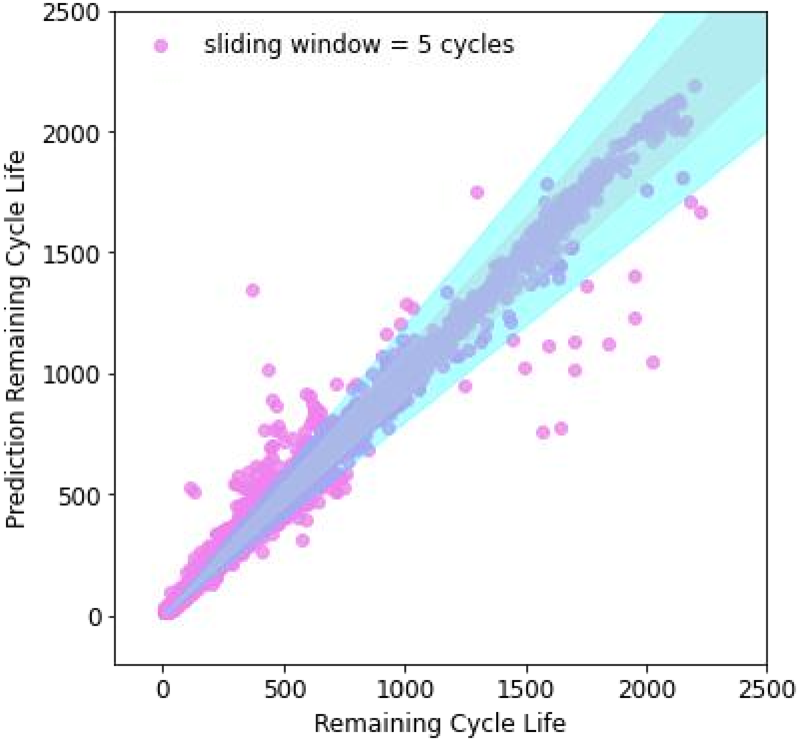
MAPE: 11.6%
10%-BAND: 61.8%
20%-BAND: 84,6%



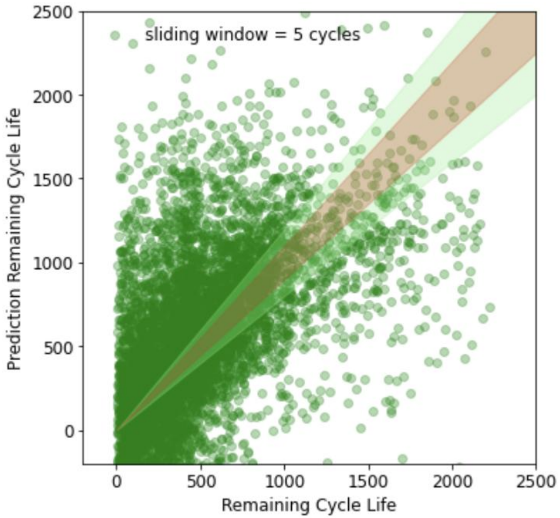
MAPE: 11.9%
10%-BAND: 59.1%
20%-BAND: 83.1%

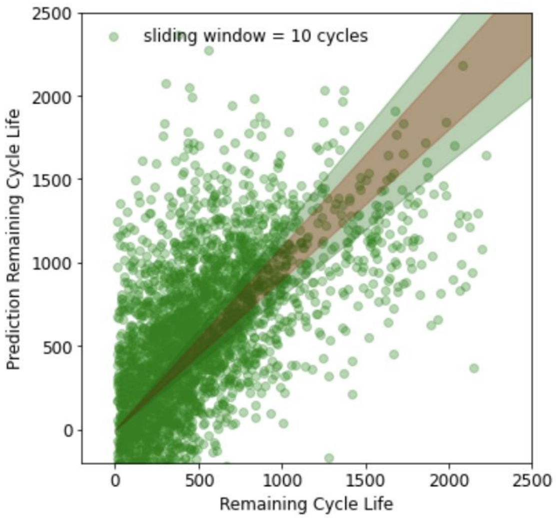
Recurrent Neural Network Based Models

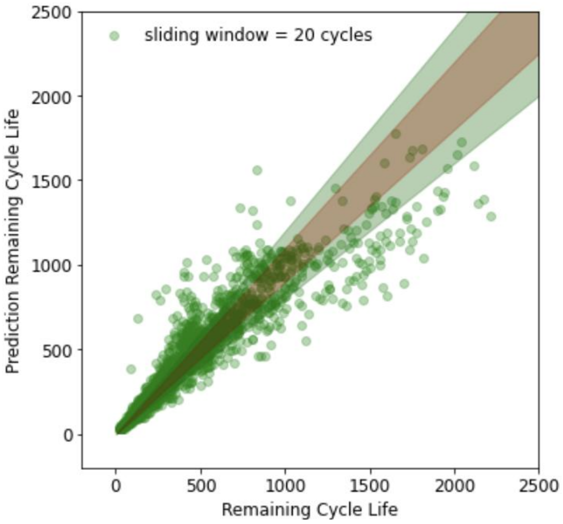




Results for Linear Regression





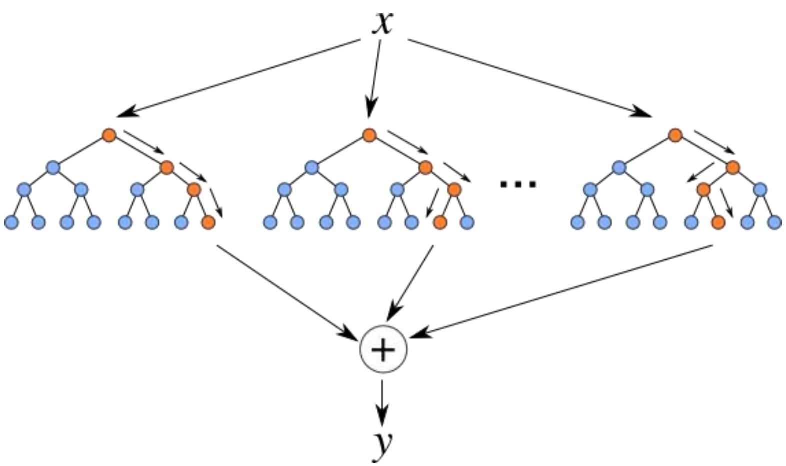


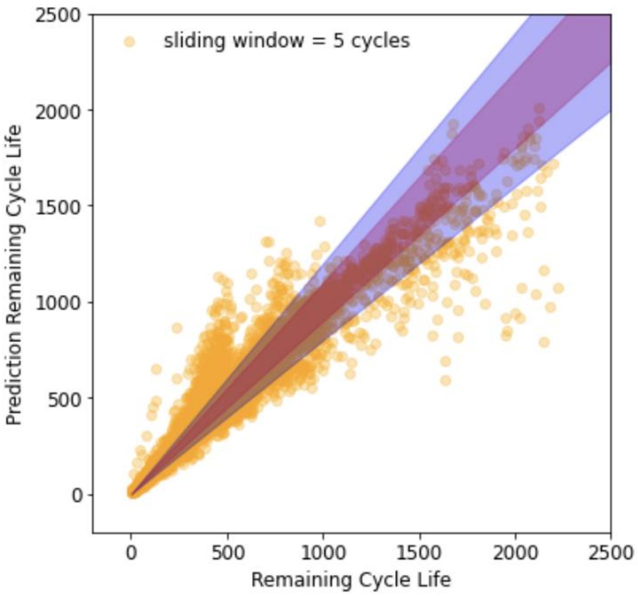
MAPE: 456%
10%-BAND: 10.5%
20%-BAND: 20.1%

MAPE: 254%
10%-BAND: 10.4%
20%-BAND: 21.0%

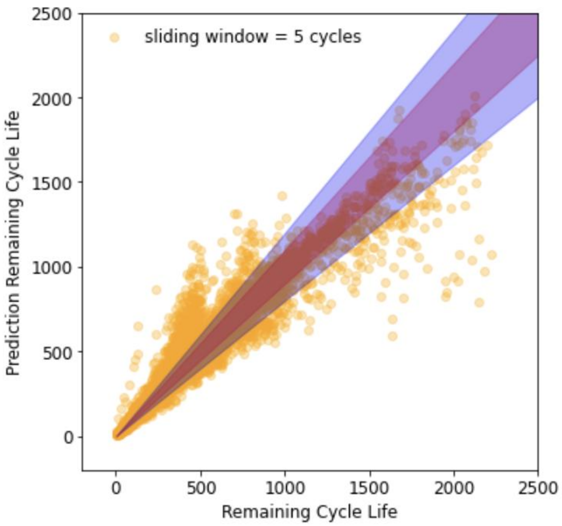
MAPE: 258%
10%-BAND: 10.5%
20%-BAND: 25.1%

Random Forest Regression Models

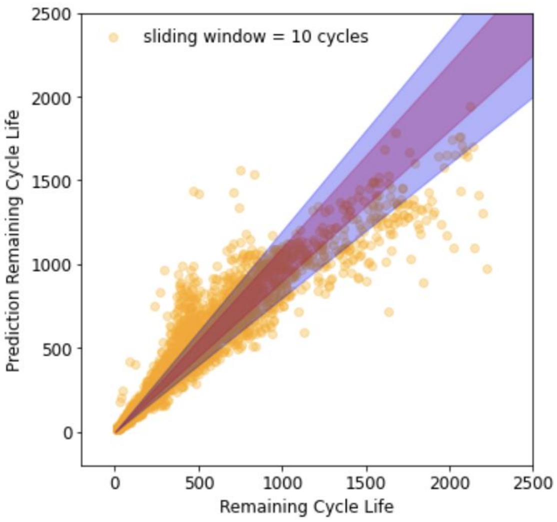




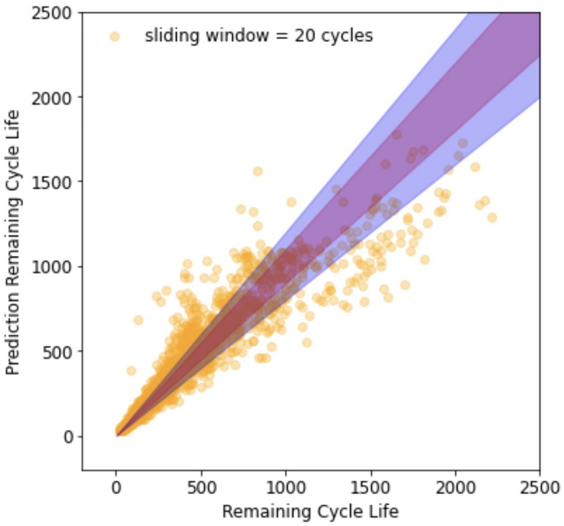
Results from Random Forest Regression



MAPE: 14.0%
10%-BAND: 50.4%
20%-BAND: 74.4%

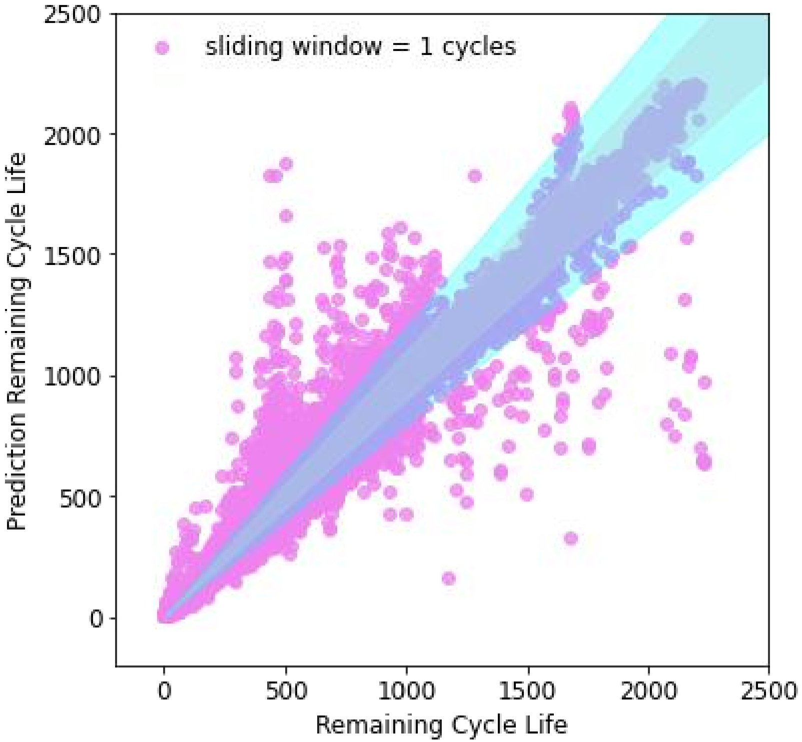


MAPE: 16.1%
10%-BAND: 40.0%
20%-BAND: 53.1%



MAPE: 17.9%
10%-BAND: 39.4%
20%-BAND: 52.6%

What about only 1 Cycle?



MAPE:12.1 % !

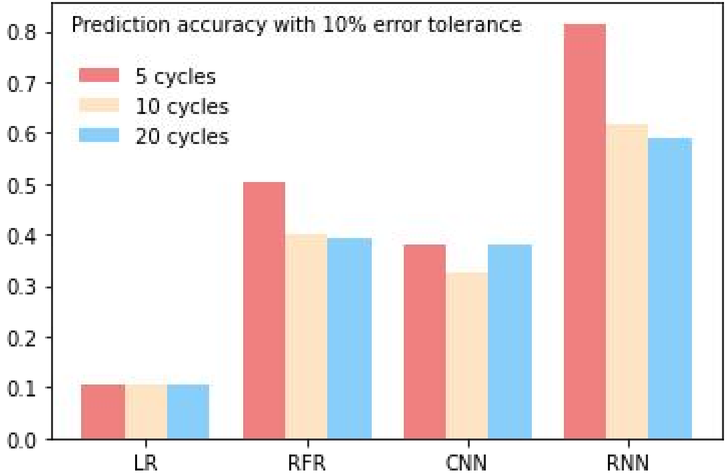
Challenges/Future Work

Summary

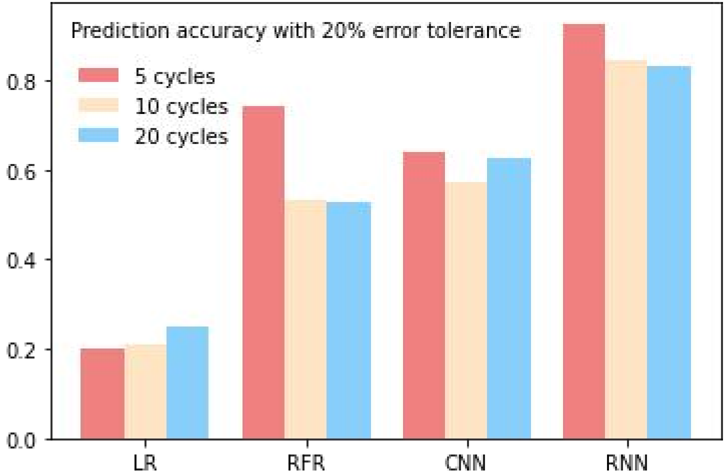
- Data augmentation
  - 124 batteries → ~13k samples
- Remaining cycles prediction model
  - Linear regression
  - Random Forest regression
  - Convolutional neural network (CNN)
  - Recurrent neural network (RNN)
- Discuss # cycles ~ prediction accuracy
- Develop confidence intervals for prediction

Thank you!

Prediction Accuracy with Given Acceptable Interval



#Cycles	Linear Regression	Random Forest	CNN	RNN
5	0.105	0.504	0.382	0.815
10	0.104	0.400	0.326	0.618
20	0.105	0.394	0.382	0.591



#Cycles	Linear Regression	Random Forest	CNN	RNN
5	0.201	0.744	0.638	0.927
10	0.210	0.531	0.573	0.846
20	0.251	0.526	0.626	0.831