DSCI 542 Lab 2

Creating a Blog Post for Your Audience

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Outline

Topic

- Battery Lifetime Prediction with Machine Learning Models

Why it Matters?

- Predicts how long your battery will last in your electric vehicle, medical device (example: pacemaker), energy storage system etc.
- Once a battery drops below 80% capacity relative to its initial capacity, it becomes much more dangerous in terms of susceptibility to failure and decrease in performance could cause the battery to die at an unexpected or dangerous time - we would like to know when this is happening and be able to predict when ahead of time in the battery's lifetime
- Renewable energy systems are becoming more and more important with the prevalence and urgency of climate change
- Show what happens when a battery fails to make the safety concerns apparent
- Electric Car reduced range could cause someone to be stranded
- A pacemaker battery dying before expected could have detrimental consequences to an individual
- You want to know when a battery will die and how its capacity will fade overtime

- Other lifetime considerations: battery will heat up more when degraded, battery will physically swell in size, battery voltage range will change, battery safe operation range area (SOA) will shirnk

Models and Techniques

- Time series techniques
- Data collection methods and techniques
- Importance of data quality and accuracy for prediction (matters how you take the physical measurements)
- Industry Standard machine learning models and solutions

Visualization of Time Series Data

- Drive Cycle Data Simulating Electric Car Acceleration and Braking Behaviour
- Safety limits or SOA plot
- Hysteresis plot for capacity ranges
- Machine Learning Battery Lifetime prediction curve

Difficult Aspects of the Problem and Ongoing Research

- Pitfalls of Time Series Analysis or misuse, time dependence issue for models
- Expensiveness of data collection and sample size issue
- Applicability of models to real world behaviour
- Scarcity of real world data
- Simulation models built on less data is an alternative
- Battery internal chemistry changes over time due to degradation and the mechanics are quite complex to model - ie. the problem is ripe for ML to learn complex hidden patterns and relationships with compute

Things to Avoid

- Battery and ML jargon, use key takeaways not technical details
- Failing to outline why advancement in this field matters
- Focusing too much on battery details and not relation or use in data science and ML/AI

Machine Learning for Battery Lifetime Prediction

One of the reasons machine learning and AI are such powerful tools in modern data analysis is their wide range of applicability to real-world problems across many different fields. One such field with extensive ongoing research for machine learning applications is battery design and technology. Batteries have become widely used in many industries including medical devices, automotive vehicles and energy storage systems. As part of a push for renewable energy solutions to combat climate change and the demand for better wearable and or implantable medical technologies, battery technology has accelerated in growth in recent years. Electric cars are more prevalent than ever, energy storage for renewable solar and wind energy is growing faster than ever and portable battery powered devices are sold by countless companies. The analysis of the data centered around these technologies has therefore become increasingly important in recent years as well. Machine learning and AI techniques for predicting of battery system behavior with laboratory or field data is at the frontier of development of these technologies.

You might wonder why does machine learning need to be applied to battery system data analysis? To make one of the major issues apparent in these technologies consider the example of a pacemaker and an electric car. If someone relied on a permanent pacemaker for their heart to function properly and safely, would you not like to know when the battery in the pacemaker is likely to begin functioning at a lower capacity after each charge and be in a more volatile state? You could replace the battery early to be cautious, but keep in mind that requires surgery and is expensive, you would therefore not want to replace. Furthermore, if you owned an electric vehicle for several years, would you not like to know when your car's range is not what it used to be and what it has decreased to now on a full charge? Electric car owners or prospective owners already have range anxiety with brand new electric cars, let alone ones with degraded batteries?

These examples point to a major issue with battery technologies, which is the decrease in charge capacity overtime due to use. Predicting in a quantitative way when this degradation will occur and by how much, turns out to be an extremely difficult problem with many variables influencing the so-called battery capacity lifetime (or commonly just referred to as battery lifetime). It turns out that with enough voltage, temperature and current data of a battery charging and discharging (simulated battery use in a laboratory), these predictions become tractable with physics modelling and machine learning. The state of the art of battery lifetime prediction models, almost always involves machine learning today. The models applied in this domain are time series in nature, and therefore the examples in the training and test data are causally linked through time dependence unlike models of other regression or classification applications. This comes with its own assumptions and challenges, however the battery lifetime prediction has become increasingly accurate and reliable consequently. The major problem in the field currently is the scarcity of high-quality data for training the models. This is due to proprietary company data not being widely available and the cost of collecting the data as it requires intensive labor, capital and physical space to execute testing, in comparison with data collection for other applications. If the scarcity of data problem can be solved in the future,

we will without a doubt see advances in machine learning for battery lifetime prediction.