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| Extended Kalman Filtering of State and Parametric Bias Estimation of a Li-Ion Battery Model |
| MAE 298 – Estimation Theory Final Project |
| Felipe Valdez  Jonathan Dorsey |

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| Abstract |
| *The increasing demand for electric vehicles (EVs) has led to technological advancements in the field of battery technology. State of charge (SOC) estimation is a vital function of the battery management system - the heart of electric vehicles, and Kalman filtering is a common method for SOC estimation. Due to the non-uniformities in tuning and testing scenarios, quantifying performance of SOC estimation algorithms is difficult. In this work, an SOC estimation algorithm is developed, Extended Kalman Filter (EKF), and tested for a variety of scenarios like adding sensor noise and bias to terminal voltage and current, and varying state and parameter initializations. A comparison between*  *a deterministic estimation technique using Youla paramertization and the well-established stochastic estimation technique, Extended Kalman filtering, is performed and analyzed for robust performance?* |

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# 1. Introduction & Literature Review

Introduce your project and briefly review the sources you used for this paper. This is expected to be 1-2 papers at most. Cite references in the text using IEEE style [1].

## Motivation

## Related Work

## Battery Modeling

## Estimation Algorithms

## Objectives

# 2. System Modeling & Analysis

## Overview of Li-Ion Battery

## State of Charge

## Open Circuit Voltage

## Electrical Equivalent Circuit Model

## Continuous Time Model

## Discrete Time Model

## Sensor Bias Modeling

## Current Sensor Bias

## Voltage Sensor Bias

## Observability Analysis

# 3. Algorithms & Implementation

## Linear Kalman Filter

## Extended Kalman Filter

## State & Parametric Estimation

## Dual Estimation

# 4. Results & Discussion

## The Setup

## Simulation Setup

## Performance Indices

## Simulation Results

## State KF vs EKF

## State EKF vs Dual EKF

## Sensor Bias

## State EKF vs Youla Estimation

NOTES:

**Model Validation**

**RMS Error**

**Parameter Estimation using Dual EKF**

**Covariance Agreement (Model vs Truth)**

**Biased Vs Unbiased Simulations**

**Robustness**

* Sensor noise
* Parameter Variation

**EKF vs KF Comparison**

## Figures

Figures should be centered on the page. Every figure should be numbered, have a caption, and be cited in the text. For example, see Figure 1. If you have many figures, you may find it useful to use Word’s Cross-Reference feature to keep track of figure, table, and equation numbering.

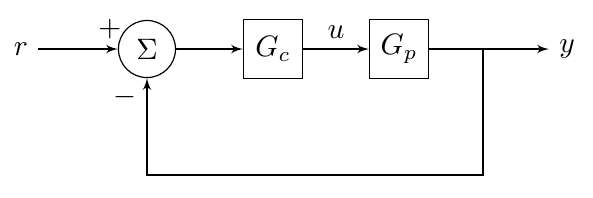


Figure 1 - A simple block diagram as an example of how to structure a figure.

## Tables

Tables of data should be treated like figures: centered, captioned, and cited in the text. For example, see Table 1.

Table 1 - This is a caption.

|  |  |  |
| --- | --- | --- |
| Column 1 Title | Column 2 Title | Column 3 Title |
| 1 | 5 | 9 |
| 2 | 6 | 10 |
| 3 | 7 | 11 |
| 4 | 8 | 12 |

## Equations

Equations should be on their own line and centered. Be sure to define all terms used in the equation. For example,

where is force, is mass, and is acceleration.

# Future Work

Briefly summarize your project and its findings. Discuss any open questions or potential avenues for further research.

UKF, PF, Adaptive EKF, Gain Scheduled EKF, MHE.

# References

Use IEEE format for your references. It is useful but not necessary to use Word’s built in features for references and bibliographies.

|  |  |
| --- | --- |
| [1] | IEEE Periodicals, "IEEE Reference Guide," IEEE, Piscataway, NJ, 2018. |

# Supplemental Material

Include all Matlab code (Matlab has a “publish” feature that will help format your code nicely for Word). If you have Simulink models, include pictures of the models and code for any user-defined functions. If applicable, include additional figures and any other important work that you did not include in the body.

## Matlab Code

### File 1

(code here)

### File 2

(code here)

## Simulink Models

### Model 1

(image here)

(code for user-defined functions here)

## Additional Figures

## Anything Else