STATE ESTIMATION MODEL DEVELOPMENT FOR LITHIUM-ION BATTERY PACKS

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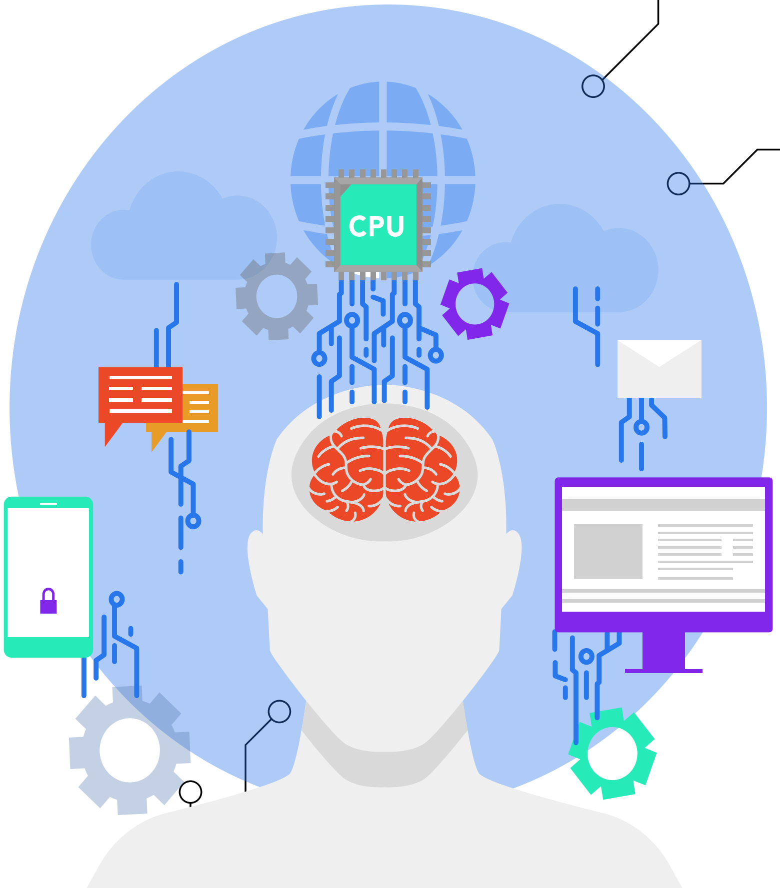


INTRODUCTION

PROBLEM STATEMENT

Transition from the **3IR** to the **4IR** has led to the widespread adoption of **AMRs** across various **Industrial Sectors.**

An effective and efficient **BMS** with accurate **SoC** estimation is crucial for **Discharging & Charging Cycles Schedule.**

CONVENTIONAL METHOD

- Linear Math-Based Models
- High Errors
- Low Accuracy
- Dynamic and Non-Linear System
- Tideous Parameters Optimizing

Vs

DATA-DRIVEN METHOD

- Dynamic Data-Based Models
- Low Errors
- High Accuracy
- Dynamic and Non-Linear System
- Straightforward Hyperparameters Optimizing

LITERATURE REVIEW

Coulomb Counting Method

- Based on CC Equation
- ***Process Experimental SoC***
- Predict (NO), Update (YES)

Model-B… …hod

- Based … Kalman …
- ***EKF, U… …tic…***
- Predict … (YES)

Neural N… …ethod

- Based … Black B… …odel
- ***BPNN, …M, G… …N***
- Predict … (NO)

AIM & OBJECTIVE

- Necessity & Importance for the Data-Driven Models
- Best-Performing Data Driven & Conventional Models
- Minimum MAE at 10, RSME at 15, and R2 at 0.8 for Reliable SoC Estimation Evaluation

Look-Up Table Method

- Bas… …hip **Cu… …f SoC & … …nal Pa… …er…**
- Pre… (YES), U… …e (NO)
- Open … …ge, Internal Resistance ...

Fuzzy L… …od

- Bas… …4 Layer Fuz… …Fu… …ule Base… …ence … …ne, Defuzz…

Support … Machi… Method

- Base… 2 Layers Kerne… Regress… …on

METHODOLOGY & WORKPLAN

Collect the Dataset

- Li-NMC, Li-Ion, Li-NCA, Li-PO, Li-FP
- Terminal Voltage, Load Current, Ambient Temperature
- Operating Temperature, Rate, States

Process the Dataset

Prepare SoC with Coulomb Counting Method, and Guidance of Experiment Notes

Develop the Model

- Develop the Models with the Open-Sourced Codes from GitHub and Pytorch Library.
- Optimize the Models based on the Parameters and Hyperparameters.

Evaluate the Model

Evaluate the Estimation Performance with MAE, RSME, R2 for each Model

Improve the Model

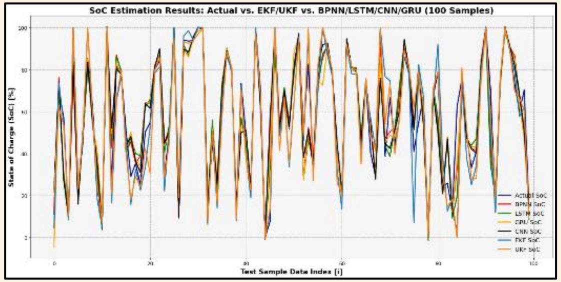
Fine-Tuning each Model to Exceed the Minimum MAE at 10, RSME at 15 and R2 at 0.8

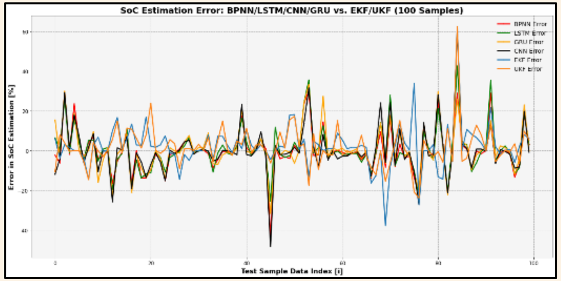
RESULT & DISCUSSION

Performance Metrics

	MAE	RSME	R2
BPNN	6.1325	10.1701	0.8806
EKF	6.3182	8.9174	0.8608
LSTM	6.4907	10.4336	0.8743
GRU	6.5692	10.8746	0.8634
CNN	6.8554	11.2293	0.8544
UKF	7.4654	10.0908	0.8279

SoC Estimation & Error





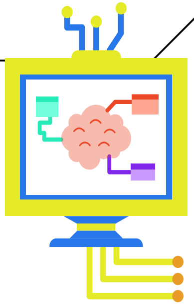
Key Points

BPNN MODEL

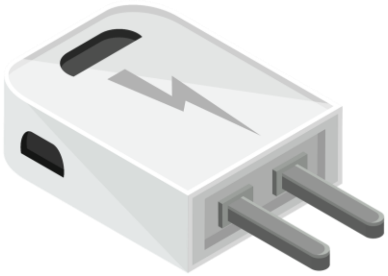
- Best: MAE & R2
- Hyperameter: 10
- APD: 26.98%
- Steady SoC Estimation & Error Values

EKF METHOD

- Best: RSME
- Parameter: 300
- APD: 28.32%
- High Fluctuation in SoC Estimation & Error Values



<u>CONCLUSIONS</u>

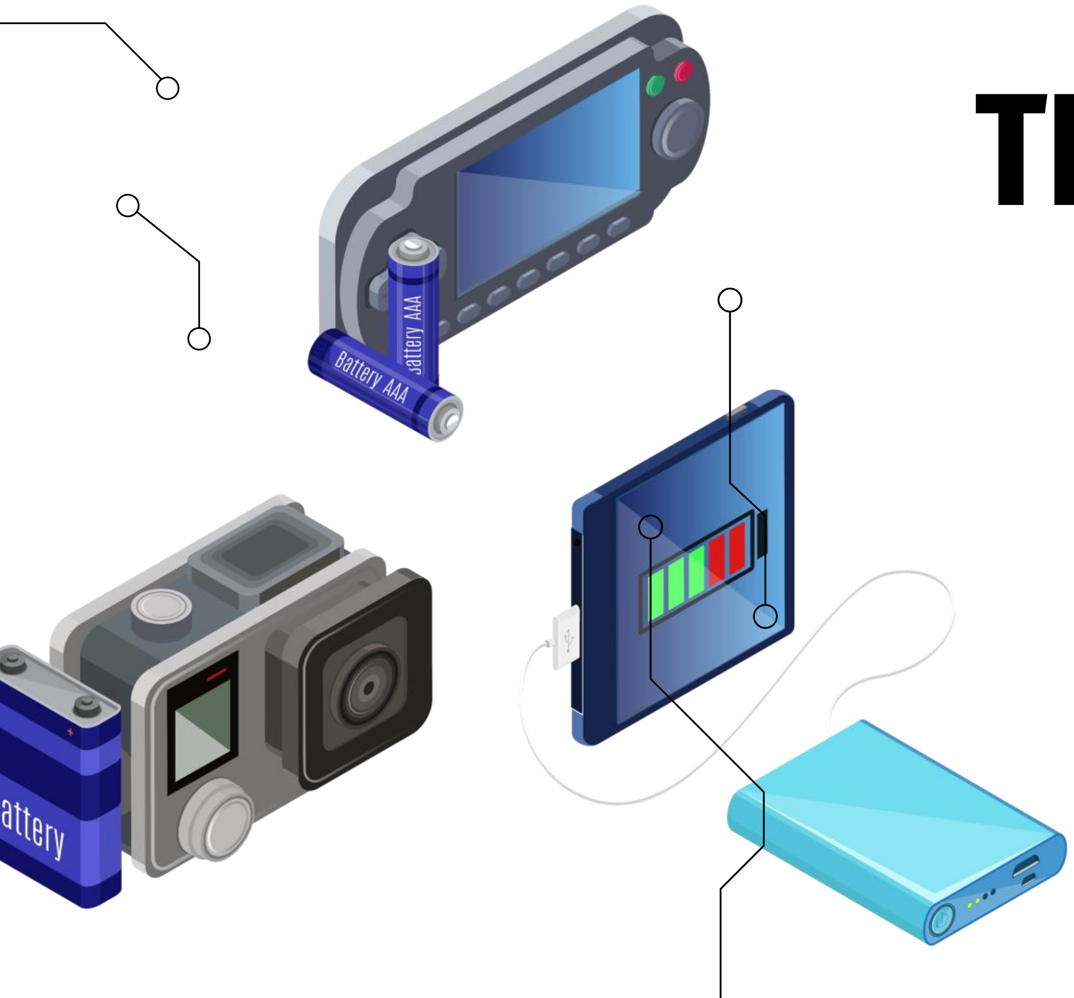


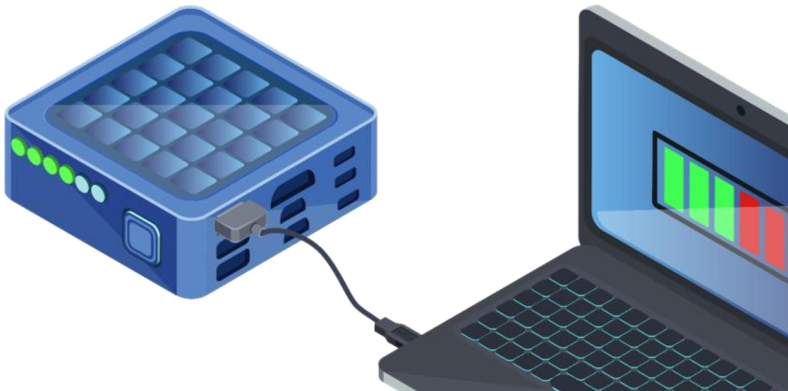
It is Necessary and Important to Implement the **Data-Driven Models** for **SoC Estimation** for the **LIB and LiBat Systems in AMR Sectors.**

- **Best-Performing Conventional Model –** EKF Method
- **Best Performing Data-Driven Model –** BPNN Model
- **Model Ranking –** BPNN, EKF, LSTM, GRU, CNN, UKF

THANKS FOR LISTENING!

Q & A SESSION
DO YOU HAVE ANY QUESTIONS?





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McNulty, D., Hennessy, A., Li, M., Armstrong, E. and Ryan, K.M., 2022. A review of Li-ion batteries for autonomous mobile robots: Perspectives and outlook for the future. Journal of Power Sources, 545, p.231943.
[INTRO – Problem Statement: Trend For Implementation of AMR in Industrial Sector]

Xiong, R., Cao, J., Yu, Q., He, H. and Sun, F. 2018, Critical Review on the Battery State of Charge Estimation Methods for Electric Vehicles. in IEEE Access, vol. 6, pp. 1832-1833.
[INTRO – Problem Statement: State Estimation Methods (Conventional vs. Date Driven)]
[LR – Conventional Methods (Look-Up Table/Coulomb Counting/Model-Based Methods)]
[LR – Model-Based Methods : Mathematical Models (ECM/EIM/EM Methods)]

Ali, M.U., Zafar, A., Nengroo, S.H., Hussain, S., Alvi, M.J. and Kim, H.J. 2019, Towards a Smarter Battery Management System for Electric Vehicle Applications: A Critical Review of Lithium-Ion Battery State of Charge Estimation. Energies, 12(3), pp. 446
[LR – Conventional Methods (Look-Up Table/Coulomb Counting/Model-Based Methods)]
[LR – Model-Based Methods : Adaptive Models]
[LR – Data-Driven Methods (ANN/FL/SVM Methods)]

Chang, W.Y. 2013, The State of Charge Estimating Methods for Battery: A Review. ISRN Applied Mathematics, pp. 1-7.
[LR – Conventional Methods (Look-Up Table/Coulomb Counting Methods)]
[LR – Data-Driven Methods (ANN/FL/SVM Methods)]

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Chang, W.Y. 2013, The State of Charge Estimating Methods for Battery: A Review. ISRN Applied Mathematics, pp. 1-7.
[LR – Conventional Methods (Look-Up Table/Coulomb Counting Methods)]
[LR – Data-Driven Methods (ANN/FL/SVM Methods)]

Moussalli, Z., Brahim Sedra, M. and Ait Laachir, A., 2018, State of Charge estimation algorithms in Lithium-ion battery-powered Electric Vehicles, 2018 International Conference on Electronics, Control, Optimization and Computer Science (ICECOCS), pp. 1-6.
[LR – Model-Based Methods : Adaptive Models - Filter-Based Methods (KF/EKF/UKF)]

Umair Ali, M., Hussain Nengroo, S., Adil Khan, M., Zeb, K., Ahmad Kamran, M. and Kim, H.-J., 2018, A Real-Time Simulink Interfaced Fast-Charging Methodology of Lithium-Ion Batteries under Temperature Feedback with Fuzzy Logic Control. Energies
[LR – Date Driven Methods : FL Method]

Patle. A. and Chouhan D. S., 2013, SVM kernel functions for classification, International Conference on Advances in Technology and Engineering (ICATE), 2013, pp. 1-9.
[LR – Date Driven Methods : SVM Method]

APPENDICES

Items	Website Link
Source Codes	**EKF Method:** https://github.com/larchuto/Battery-Kalman
	UKF Method: https://github.com/AlterWL/Battery_SOC_Estimation
	ANN Models: https://colab.research.google.com/drive/1KkYprjWm3QDoHpZ2NAOcj5Cyxoc53OcF
Battery Datasets	**LG 18650HG2 3000mAh 3.6V Li-NMC:** https://doi.org/10.17632/cp3473x7xv.3
	Samsung IN21700-30T 3000mAh 3.6V Li-Ion: https://doi.org/10.17632/9xyvy2njj3.1
	SB LiMotive 5200mAh 3.7V Li-NCA: https://doi.org/10.5683/SP3/LFPKAS
	Turnigy Graphene 5000mAh 3.7V Li-PO: https://doi.org/10.17632/4fx8cjprxm.1
	A123 1100mAh 3.2V Li-FP: https://data.mendeley.com/datasets/kxsbr4x3j2/2
	A123 2000mAh 3.2V Li-FP: https://doi.org/10.1016/j.apenergy.2013.07.008.
	A123 4400mAh 3.2V Li-FP: https://doi.org/10.57745/XIDTZH