ELECTRIC VEHICLE IMPROVISED STATE-OF-HEALTH (SOH) ESTIMATION

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DATASET

- Real-world EV dataset: ≈558 GB, 300+ vehicles, 10-second telemetry over multi-year usage
- Key signals: terminaltime, soc, totalvoltage, totalcurrent, min/max cell voltages, mintemp/maxtemp, batteryvoltage per cell.

MOTIVATION

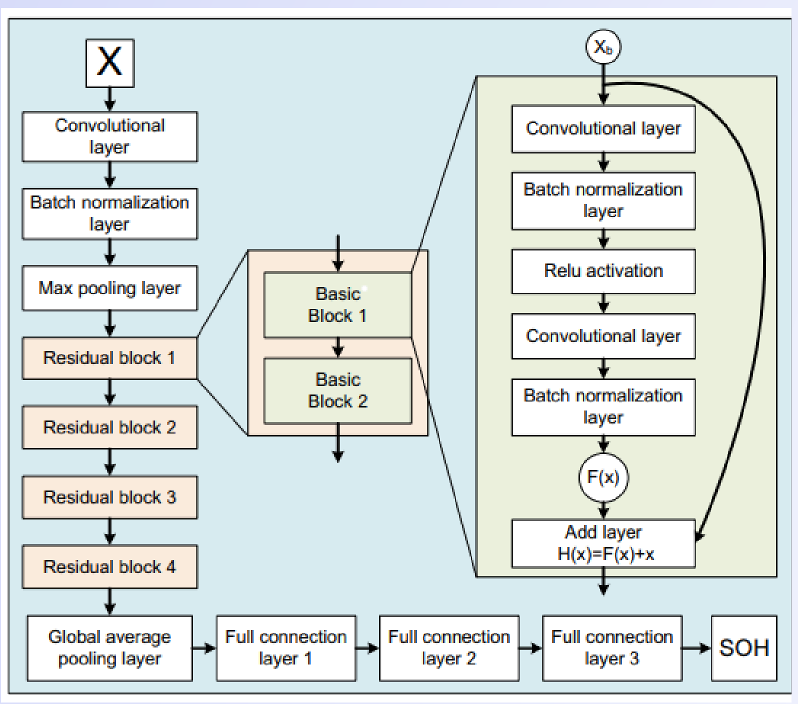
- SoH is critical for EV safety, warranty tracking, and fleet management.
- Real-world BMS telemetry is noisy — need robust, scalable models that fuse spatial and temporal signals.

ABSTRACT

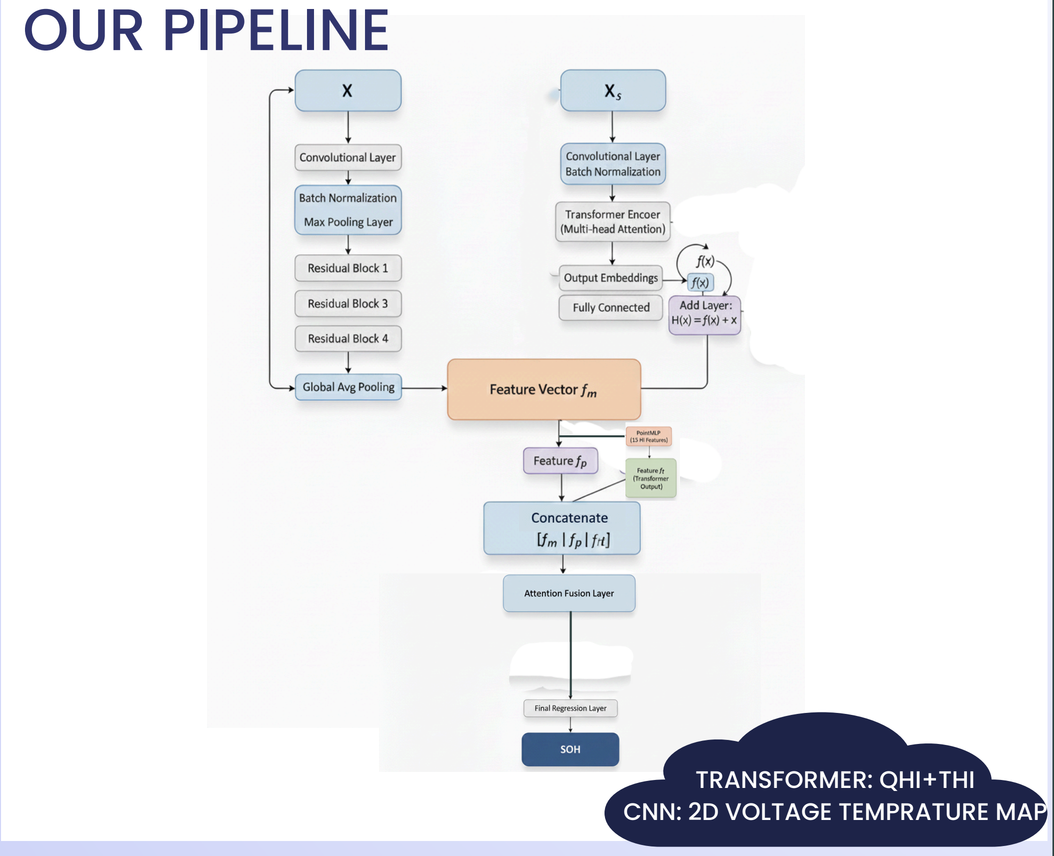
- Goal: accurate, scalable real-time SoH estimation for EV battery packs to improve BMS safety and maintenance.
- Approach: re-implementation and extension of Liu et al. (2025) multi-modal pipeline on a 558GB dataset

METHODOLOGY

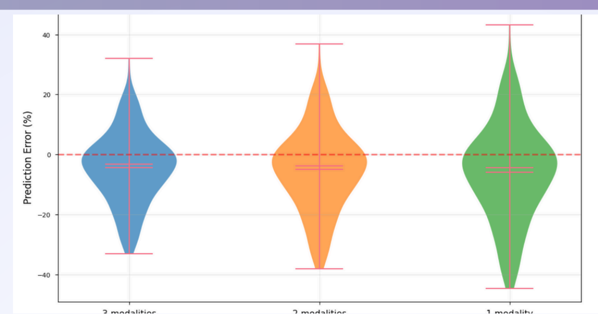
ORIGINAL PIPELINE



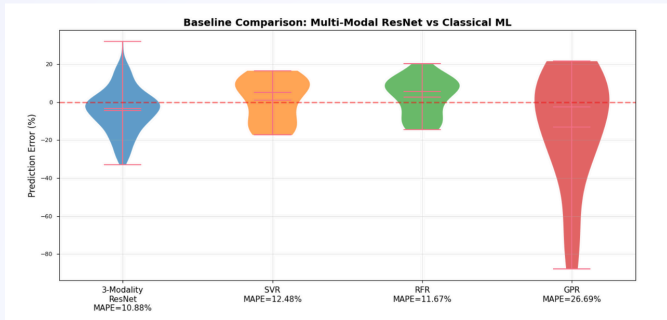
OUR PIPELINE



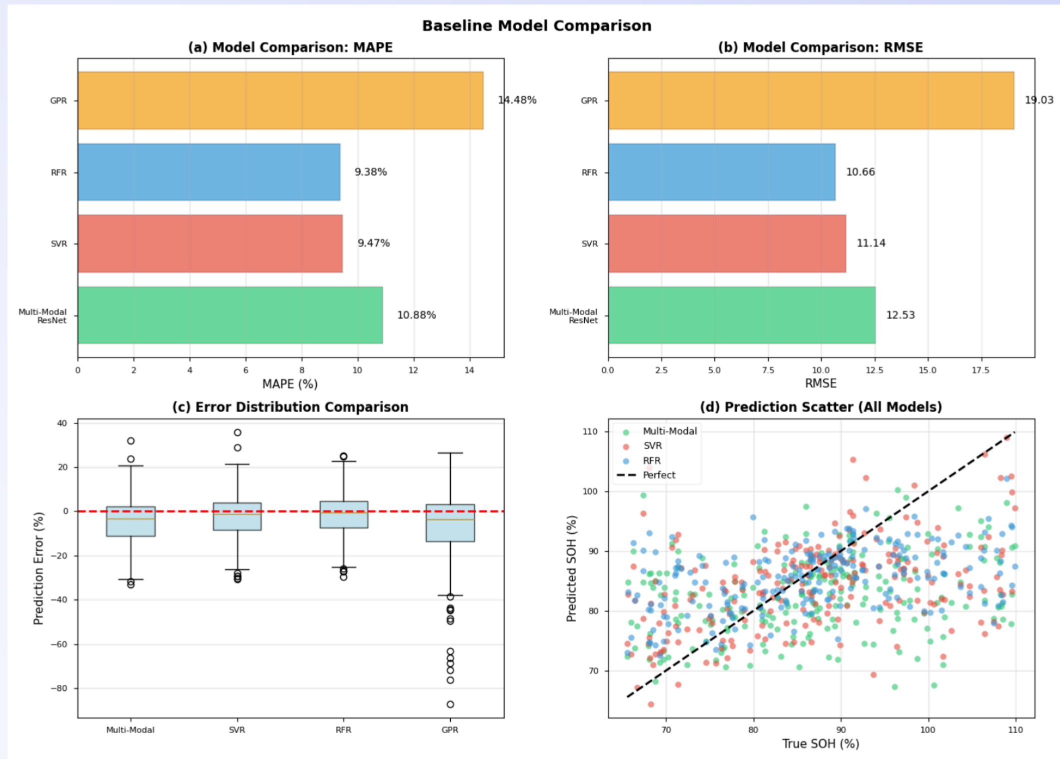
REPRODUCTION



EACH INPUT CONTRIBUTES SIGNIFICANTLY!



MULTI-MODAL SYSTEM HOLDS POTENTIAL!



SUCCESSFUL CONCEPTUAL REPRODUCTION

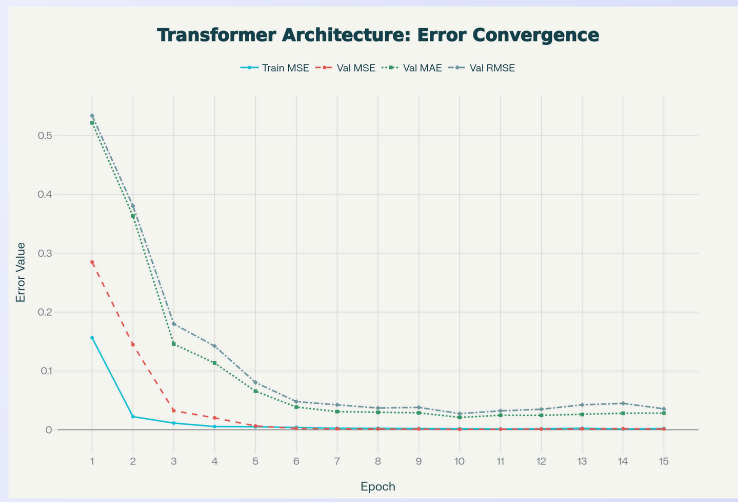
RESULTS

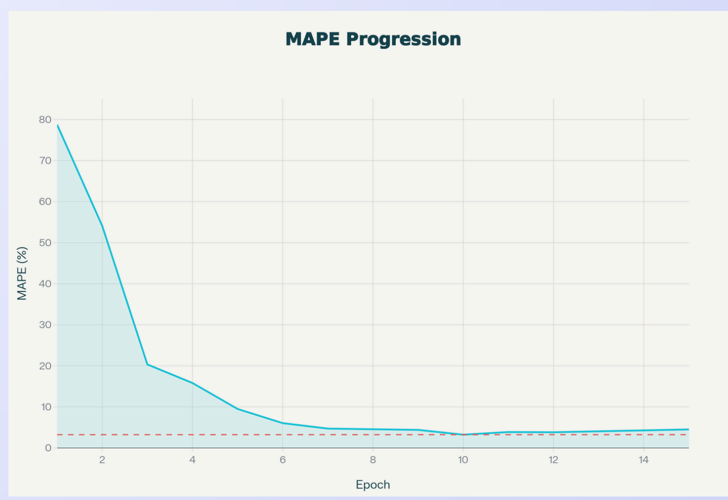
The architecture showcased rapid improvements over epochs:

- MSE: 0.2851 → 0.0008
- MAE: 0.5217 → 0.0211
- RMSE: 0.5339 → 0.0274
- MAPE: 78.74% → 3.23%

Average modality attention:
Voltage Map: 0.370
Sequence: 0.325
Point Features: 0.304

Test Set Scores	MSE	MAE	RMSE	MAPE
Original (ResNet)	0.080195	0.282946	0.283187	5.29%
Transformer (Final)	0.001419	0.029356	0.037667	4.62





IMPROVEMENTS

- Architectural Change: Transformer encoder + attention mechanisms and Integrated CNN, Transformer, and MLP modules to process MAP, QHI/THI sequences, and engineered features respectively
- Learned Modality Fusion: Applied trainable attention weights to dynamically fuse feature branches based on importance per sample.
- Out-of-Memory Fix: Implemented zero-copy data reading during training sequence to not overload our consumer GPU

TIMELINE

April 2025: Literature review and related papers found
May 2025: Literature review and related papers studied
June 2025: Data pre-processed
July 2025: Research on new pipelines and models
August 2025: Research on new pipelines and models
September 2025: Feature engineering, generation of 2D maps
October 2025: Architecture applied, trained and validated using standards metrics
November 2025: New architecture applied using same metrics (RMSE, MAPE)
December 2025: Comparative studies, Final analysis and wrap up

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CONCLUSION

Overall we achieved a good re-implementation of the original paper and was implement some improvements that overall contributed to a more accurate and efficient SoH estimation model. We were able to reduce the MAPE score from 5.29% to 4.62% which is close to 25% difference. Other metrics also showcased strong performance and we didn't run into OOM issues described in the paper during training thanks to zero-copy data loading

LIMITATIONS

- OOM issues during feature extraction on machine with 32GB of RAM. Could not fully utilize CPU resources due to insufficient memory for multi-threaded processing
- PyTorch support for XPU (Intel ARC B580) is immature compared to Nvidia's CUDA but usable in linux environment
- Paper defined methodology but didn't specify thus there was some issues during reproduction in regards to understanding the paper.

FUTURE WORK

- Extend the model to support real-time SOH prediction from live vehicle telemetry data streams rather than specifically during charging instances
- Adapt and validate the framework across multiple datasets and geographic regions.
- Add GPS, driving behavior, charging station metadata, and ambient temperature as additional modalities.