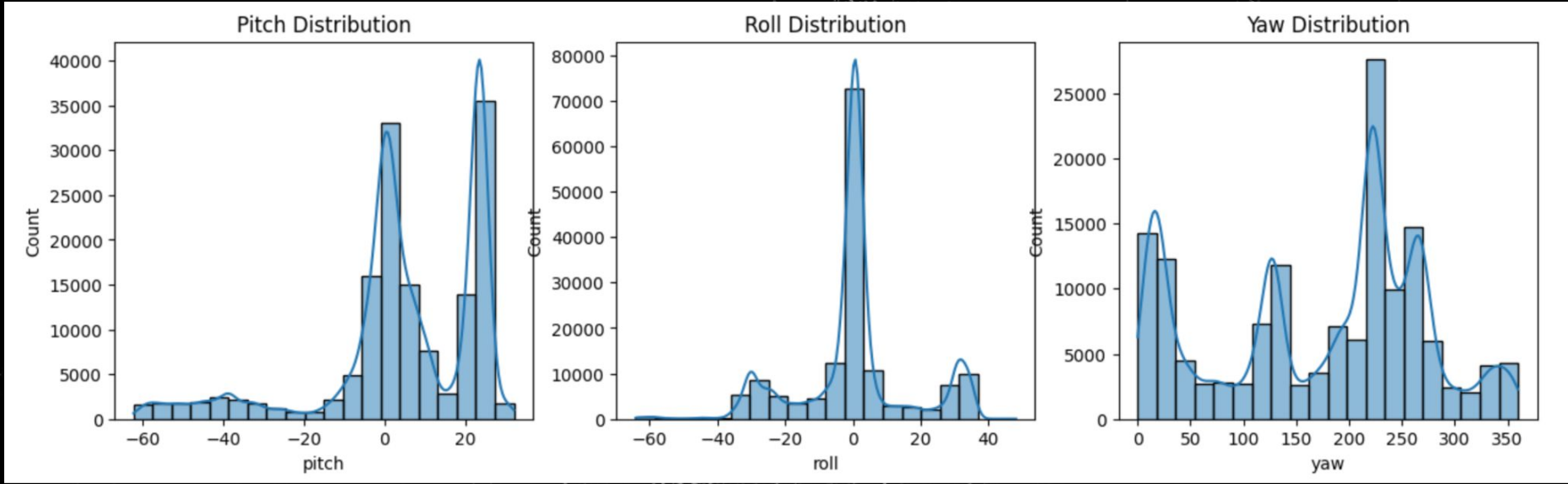
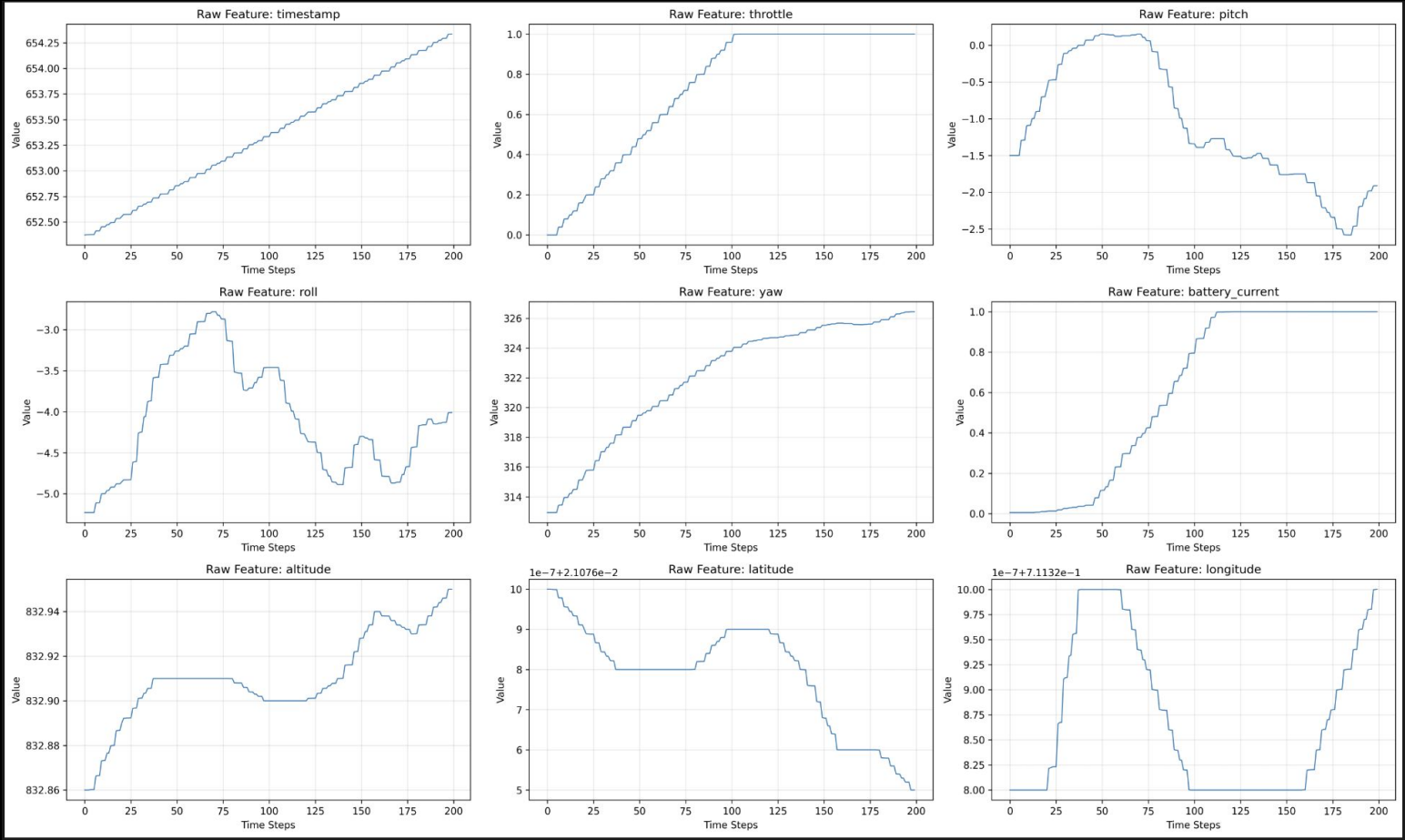
Machine Learning

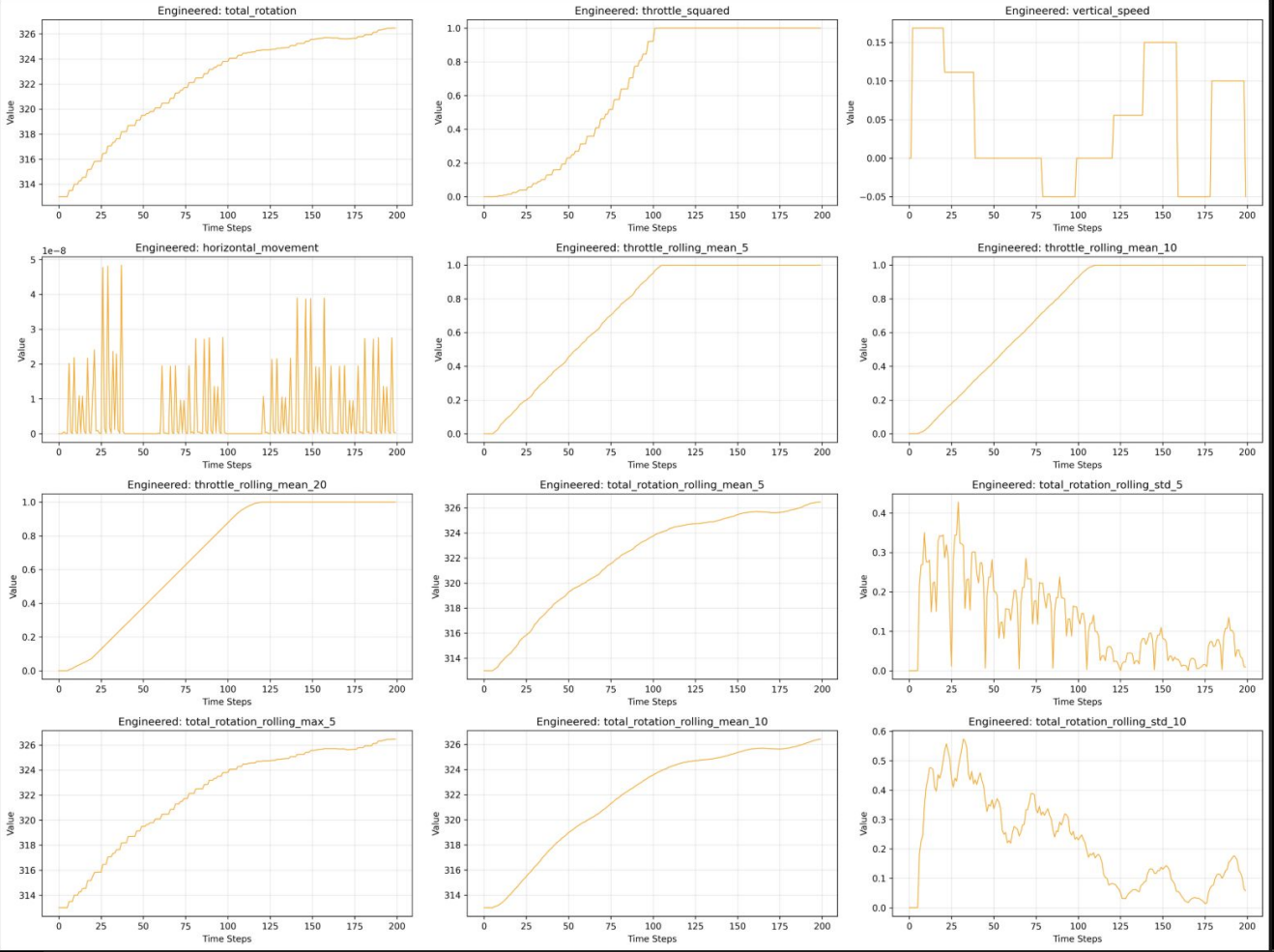
Battery Current Predictor

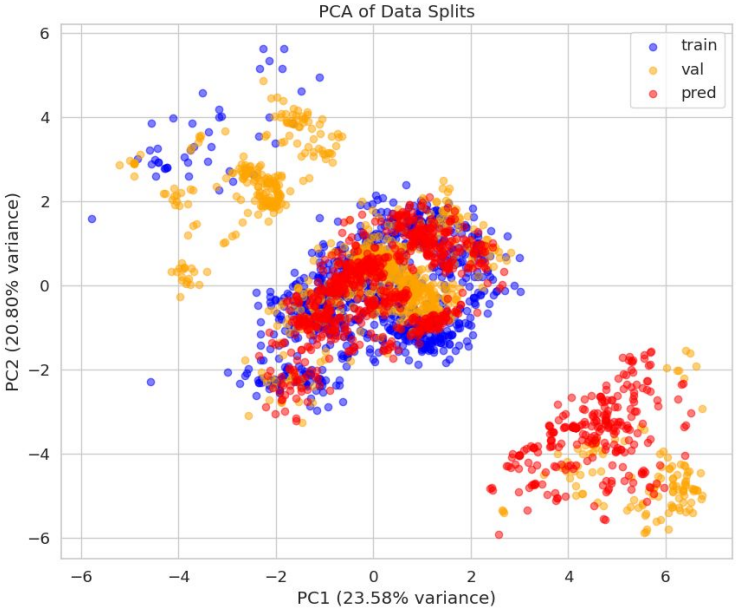
KRUNK

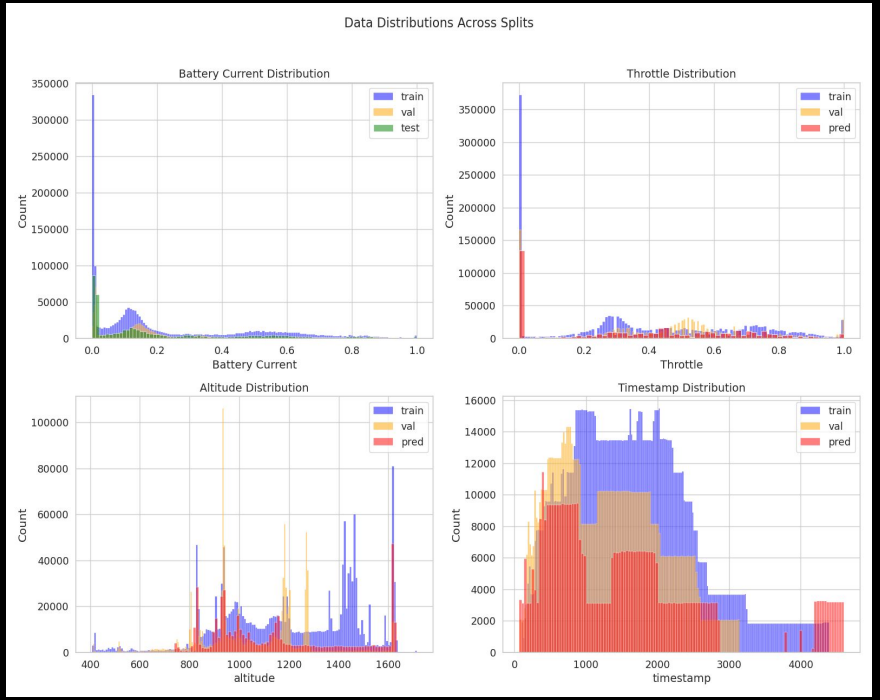
Directions' Angle

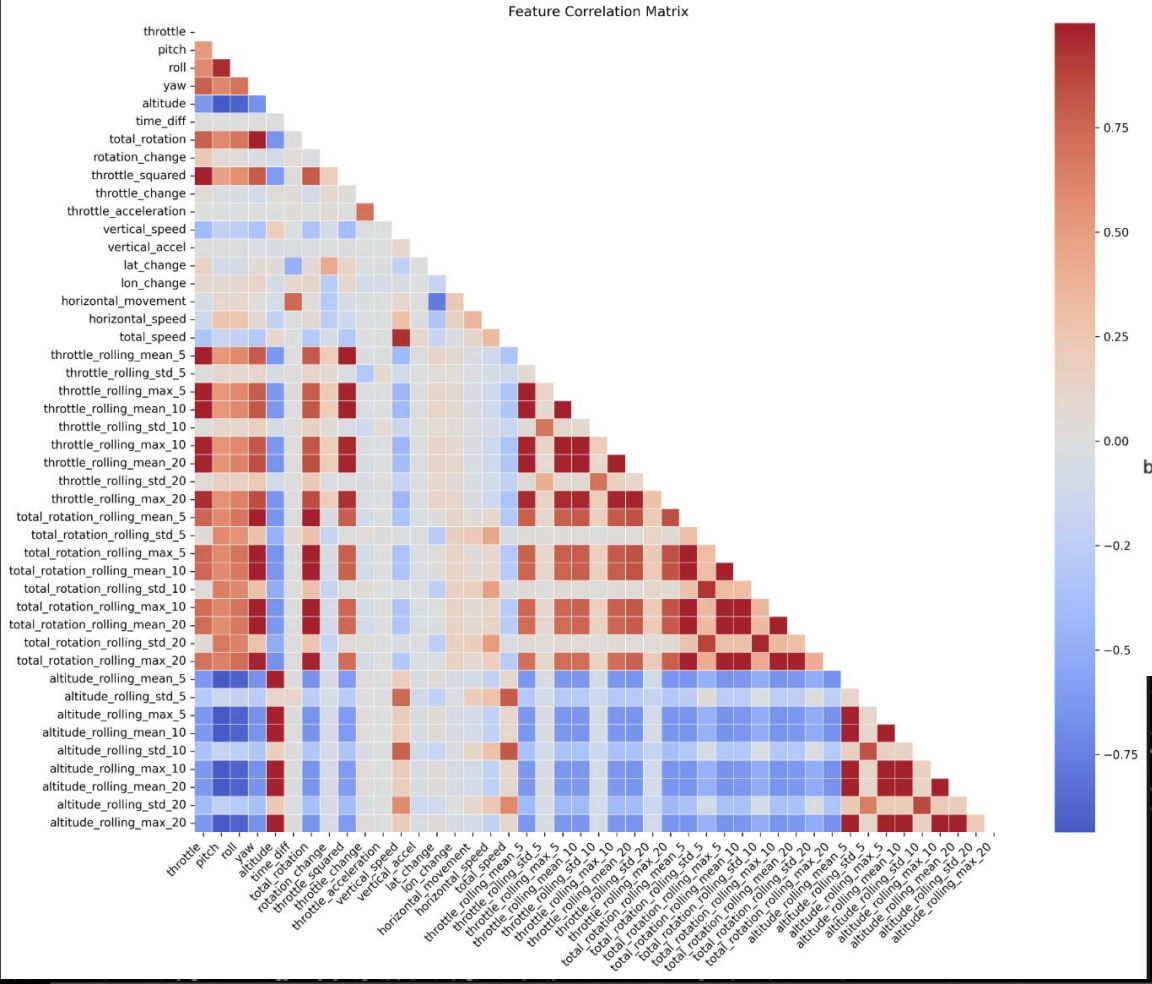


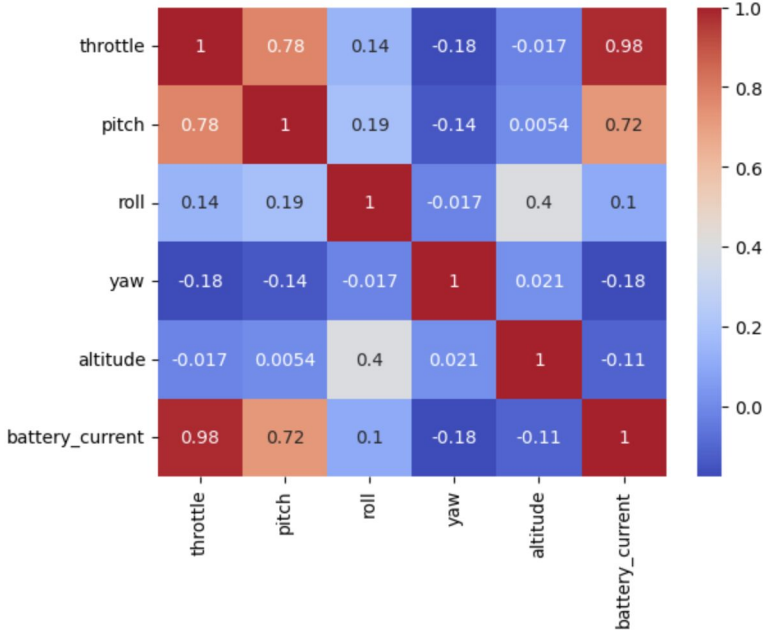

Raw Feature: timestamp
Raw Feature: throttle
Raw Feature: pitch
Raw Feature: roll
Raw Feature: yaw
Raw Feature: battery_current
Raw Feature: altitude
Raw Feature: latitude
1e−7+2.1076e−2
Raw Feature: longitude
1e−7+7.1132e−1
Value
Time Steps

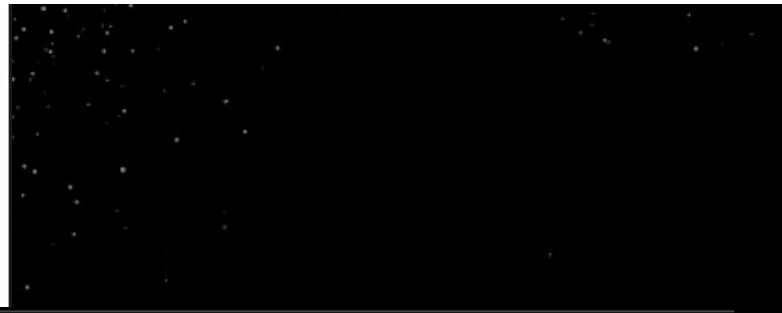

Engineered: total_rotation
Engineered: throttle_squared
Engineered: vertical_speed
Engineered: horizontal_movement
1e−8
Engineered: throttle_rolling_mean_5
Engineered: throttle_rolling_mean_10
Engineered: throttle_rolling_mean_20
Engineered: total_rotation_rolling_mean_5
Engineered: total_rotation_rolling_std_5
Engineered: total_rotation_rolling_max_5
Engineered: total_rotation_rolling_mean_10
Engineered: total_rotation_rolling_std_10
Value
Time Steps


PCA of Data Splits
train
val
pred
PC2 (20.80% variance)
PC1 (23.58% variance)
6
4
2
0
−2
−4
−6
−6
−4
−2
0
2
4
6

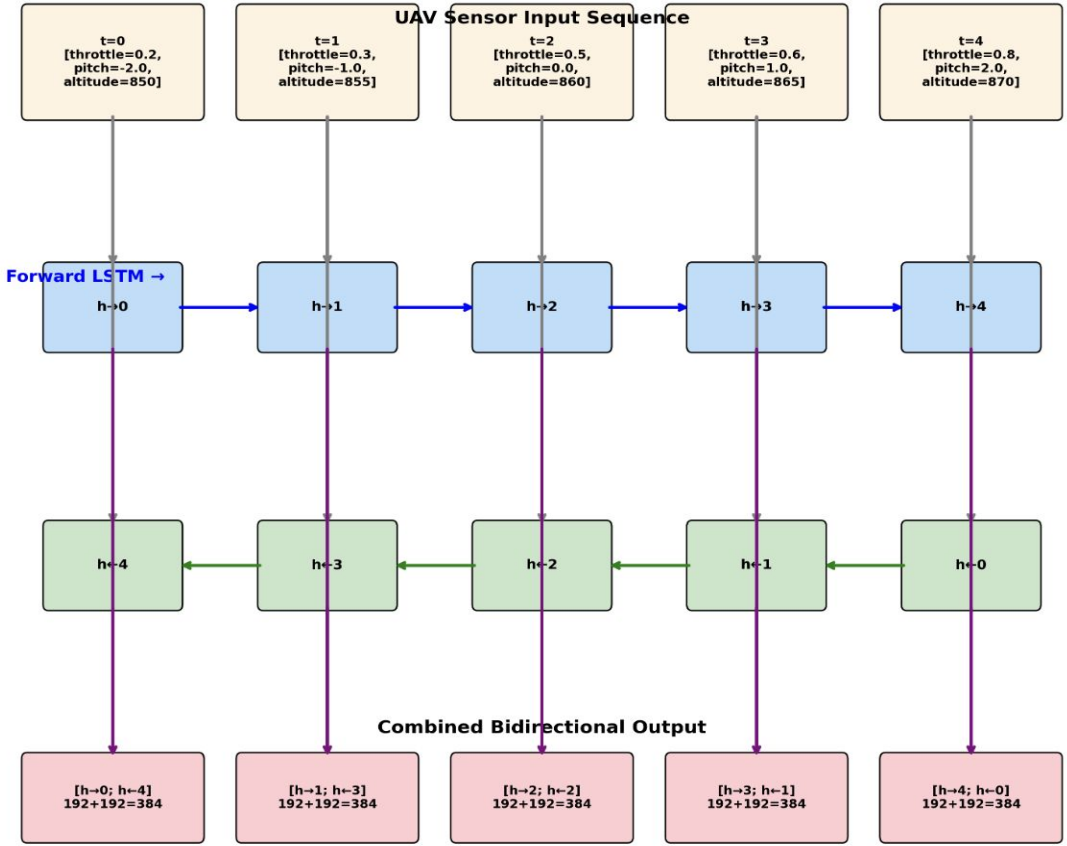

Data Distributions Across Splits
Battery Current Distribution
train
val
test
Count
Battery Current
Throttle Distribution
train
val
pred
Count
Throttle
Altitude Distribution
train
val
pred
Count
altitude
Timestamp Distribution
train
val
pred
Count
timestamp


Feature Correlation Matrix
throttle
pitch
roll
yaw
altitude
time_diff
total_rotation
rotation_change
throttle_squared
throttle_change
throttle_acceleration
vertical_speed
vertical_accel
lat_change
lon_change
horizontal_movement
horizontal_speed
total_speed
throttle_rolling_mean_5
throttle_rolling_std_5
throttle_rolling_max_5
throttle_rolling_mean_10
throttle_rolling_std_10
throttle_rolling_max_10
throttle_rolling_mean_20
throttle_rolling_std_20
throttle_rolling_max_20
total_rotation_rolling_mean_5
total_rotation_rolling_std_5
total_rotation_rolling_max_5
total_rotation_rolling_mean_10
total_rotation_rolling_std_10
total_rotation_rolling_max_10
total_rotation_rolling_mean_20
total_rotation_rolling_std_20
total_rotation_rolling_max_20
altitude_rolling_mean_5
altitude_rolling_std_5
altitude_rolling_max_5
altitude_rolling_mean_10
altitude_rolling_std_10
altitude_rolling_max_10
altitude_rolling_mean_20
altitude_rolling_std_20
altitude_rolling_max_20
0.75
0.50
0.25
0.00
−0.2
−0.5
−0.75

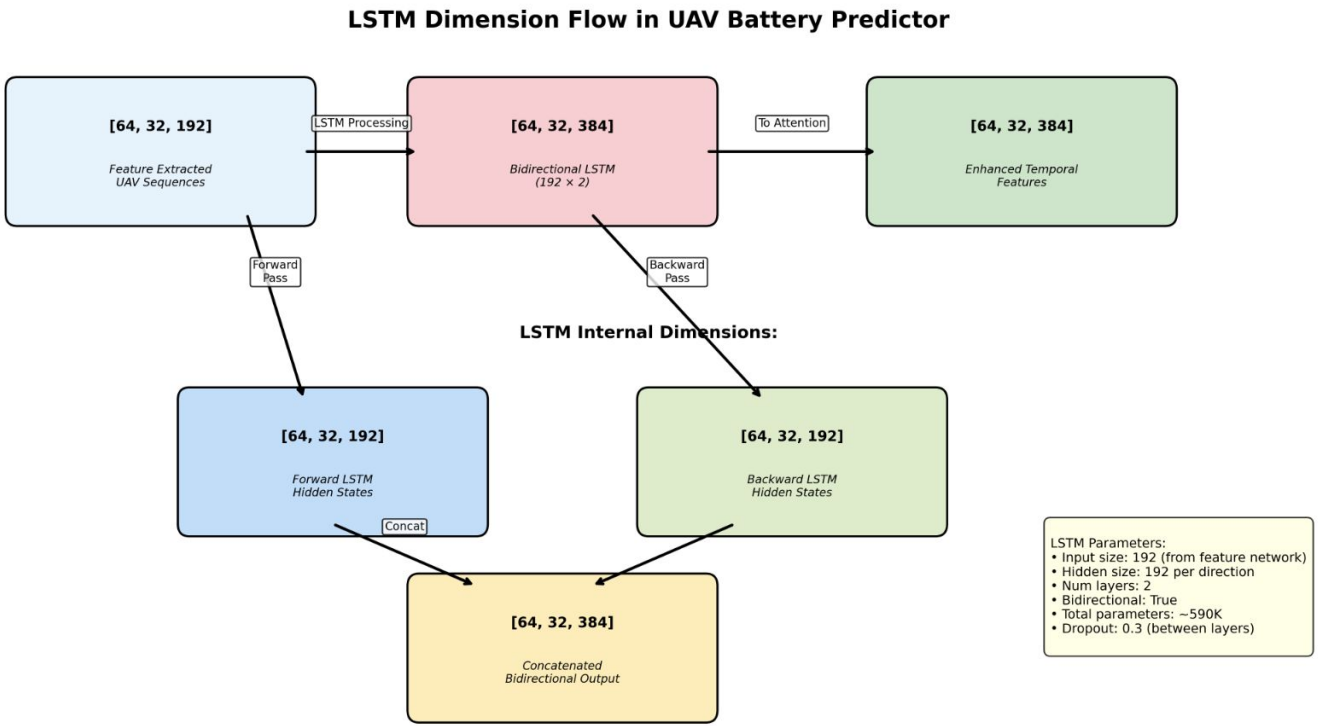

Correlation Matrix
throttle 1 0.78 0.14 -0.18 -0.017 0.98
pitch 0.78 1 0.19 -0.14 0.0054 0.72
roll 0.14 0.19 1 -0.017 0.4 0.1
yaw -0.18 -0.14 -0.017 1 0.021 -0.18
altitude -0.017 0.0054 0.4 0.021 1 -0.11
battery_current 0.98 0.72 0.1 -0.18 -0.11 1
throttle
pitch
roll
yaw
altitude
battery_current
1.0
0.8
0.6
0.4
0.2
0.0

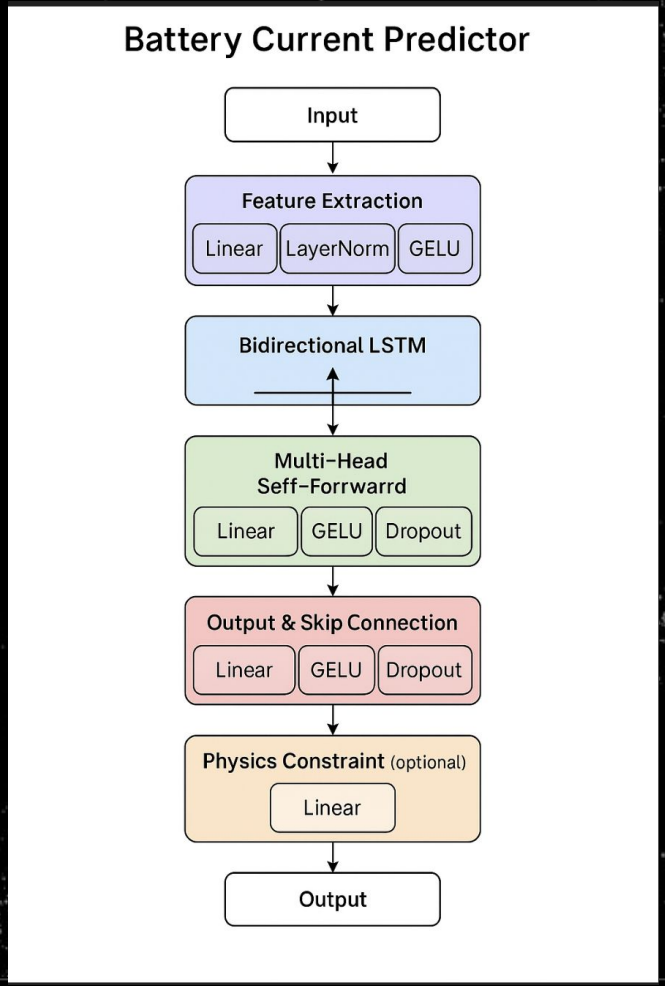


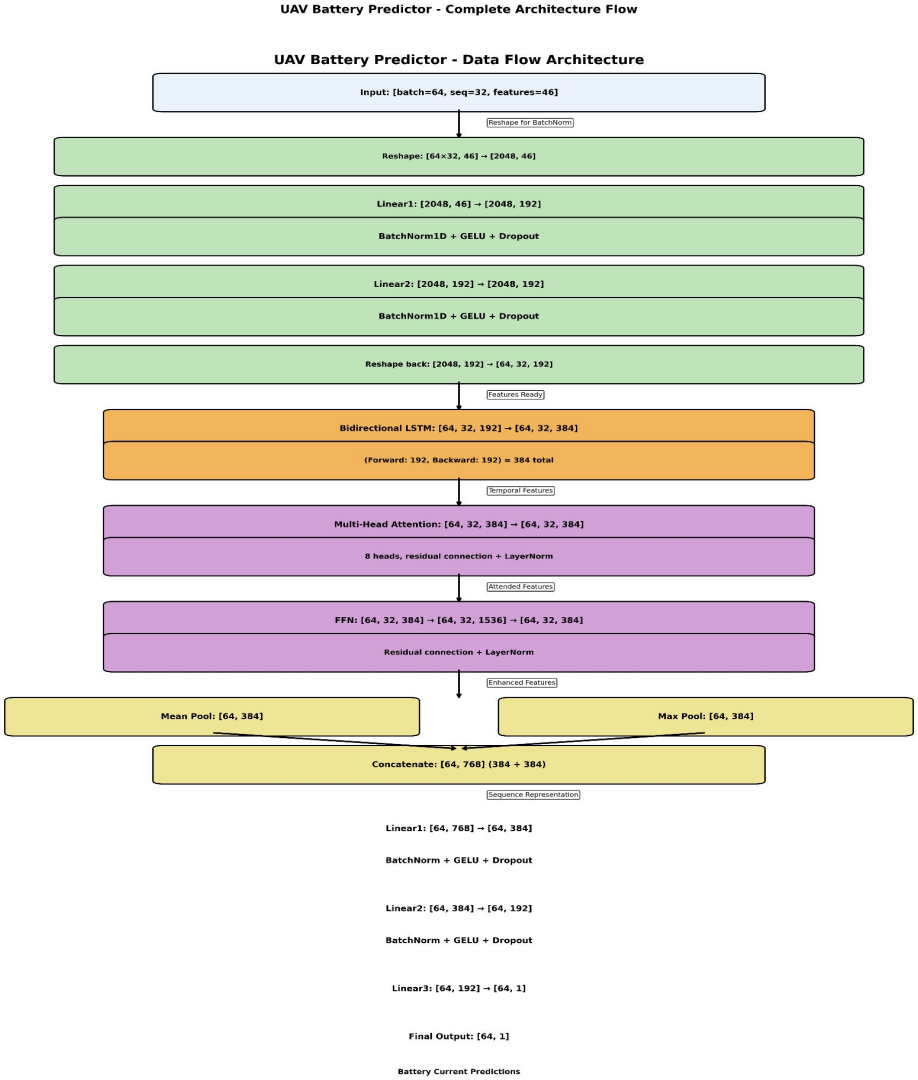
Bidirectional LSTM Processing UAV Sequence



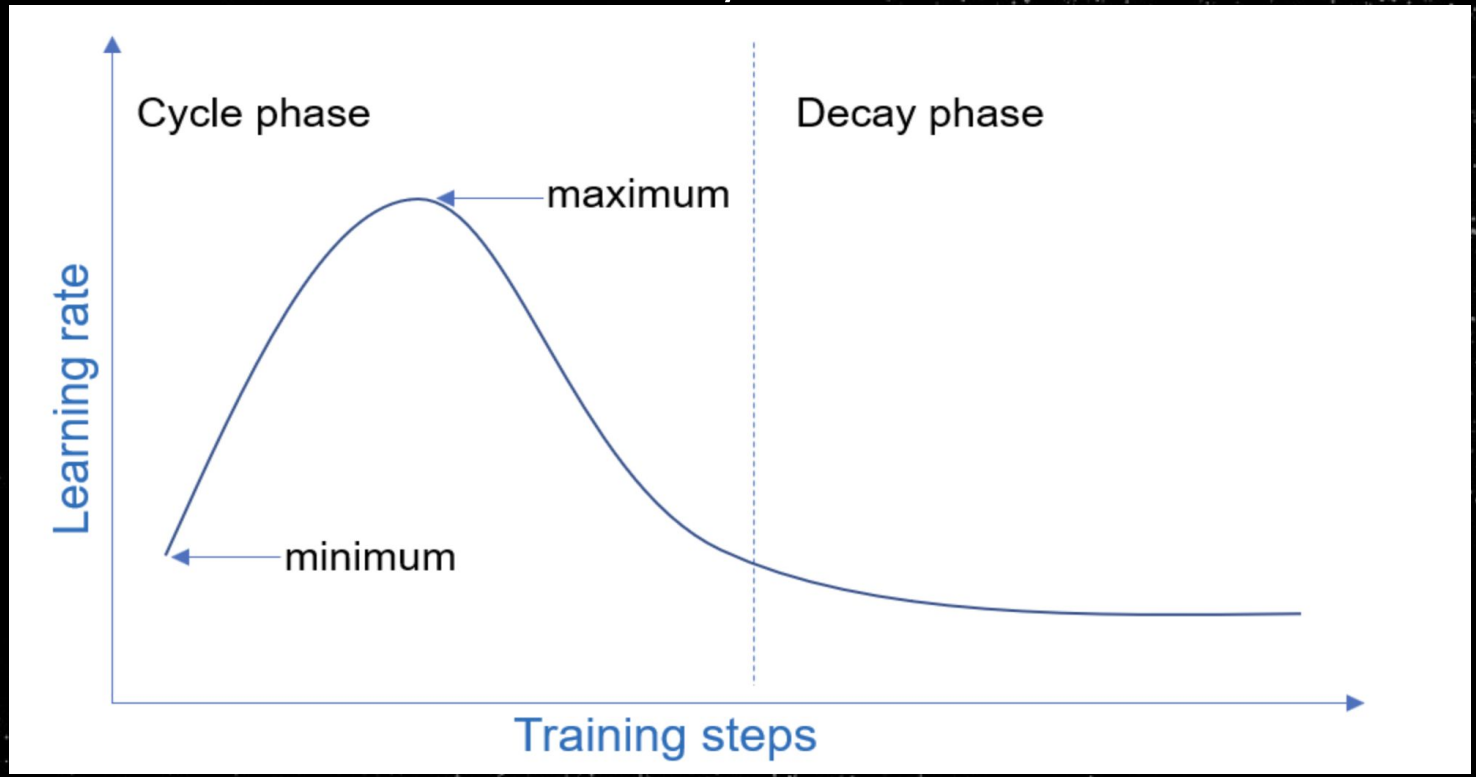
Bidirectional LSTM Benefits for UAV:
- Forward: Learns from past flight patterns
- Backward: Learns from future flight patterns
- Combined: Rich temporal understanding
- Example: At t=2, knows what happened at t=0,1 AND what will happen at t=3,4
- Better battery prediction with full context


LSTM Dimension Flow in UAV Battery Predictor
[64, 32, 192]
Feature Extracted UAV Sequences
LSTM Processing
[64, 32, 384]
Bidirectional LSTM (192 × 2)
To Attention
[64, 32, 384]
Enhanced Temporal Features
Forward Pass
Backward Pass
LSTM Internal Dimensions:
[64, 32, 192]
Forward LSTM Hidden States
[64, 32, 192]
Backward LSTM Hidden States
Concat
[64, 32, 384]
Concatenated Bidirectional Output
LSTM Parameters:
• Input size: 192 (from feature network)
• Hidden size: 192 per direction
• Num layers: 2
• Bidirectional: True
• Total parameters: ~590K
• Dropout: 0.3 (between layers)


Battery Current Predictor
Input
Feature Extraction
Linear
LayerNorm
GELU
Bidirectional LSTM
Multi-Head
Seff-Forrwarrd
Linear
GELU
Dropout
Output & Skip Connection
Linear
GELU
Dropout
Physics Constraint (optional)
Linear
Output


UAV Battery Predictor - Complete Architecture Flow
UAV Battery Predictor - Data Flow Architecture
Input: [batch=64, seq=32, features=46]
Reshape for BatchNorm
Reshape: [64×32, 46] → [2048, 46]
Linear1: [2048, 46] → [2048, 192]
BatchNorm1D + GELU + Dropout
Linear2: [2048, 192] → [2048, 192]
BatchNorm1D + GELU + Dropout
Reshape back: [2048, 192] → [64, 32, 192]
Features Ready
Bidirectional LSTM: [64, 32, 192] → [64, 32, 384]
(Forward: 192, Backward: 192) = 384 total
Temporal Features
Multi-Head Attention: [64, 32, 384] → [64, 32, 384]
8 heads, residual connection + LayerNorm
Attended Features
FFN: [64, 32, 384] → [64, 32, 1536] → [64, 32, 384]
Residual connection + LayerNorm
Enhanced Features
Mean Pool: [64, 384]
Max Pool: [64, 384]
Concatenate: [64, 768] (384 + 384)
Sequence Representation
Linear1: [64, 768] → [64, 384]
BatchNorm + GELU + Dropout
Linear2: [64, 384] → [64, 192]
BatchNorm + GELU + Dropout
Linear3: [64, 192] → [64, 1]
Final Output: [64, 1]
Battery Current Predictions

OneCycleLR


Cycle phase
Decay phase
maximum
minimum
Learning rate
Training steps

```
# Initial feature extraction
features = self.feature_net(x)

# LSTM processing
lstm_out, _ = self.lstm(features)

# Multi-head self-attention with residual connection
attn_out, attn_weights = self.attention(lstm_out, lstm_out, lstm_out)
lstm_out = self.norm1(lstm_out + attn_out)

# Position-wise FFN with residual connection
ffn_out = self.ffn(lstm_out)
combined = self.norm2(lstm_out + ffn_out)

# Get sequence representation
seq_repr = torch.cat([
    torch.mean(combined, dim=1),
    torch.max(combined, dim=1)[0]
], dim=-1)  # Results in [batch_size, hidden_size*4]

# Final prediction
output = self.output_net(seq_repr)
```

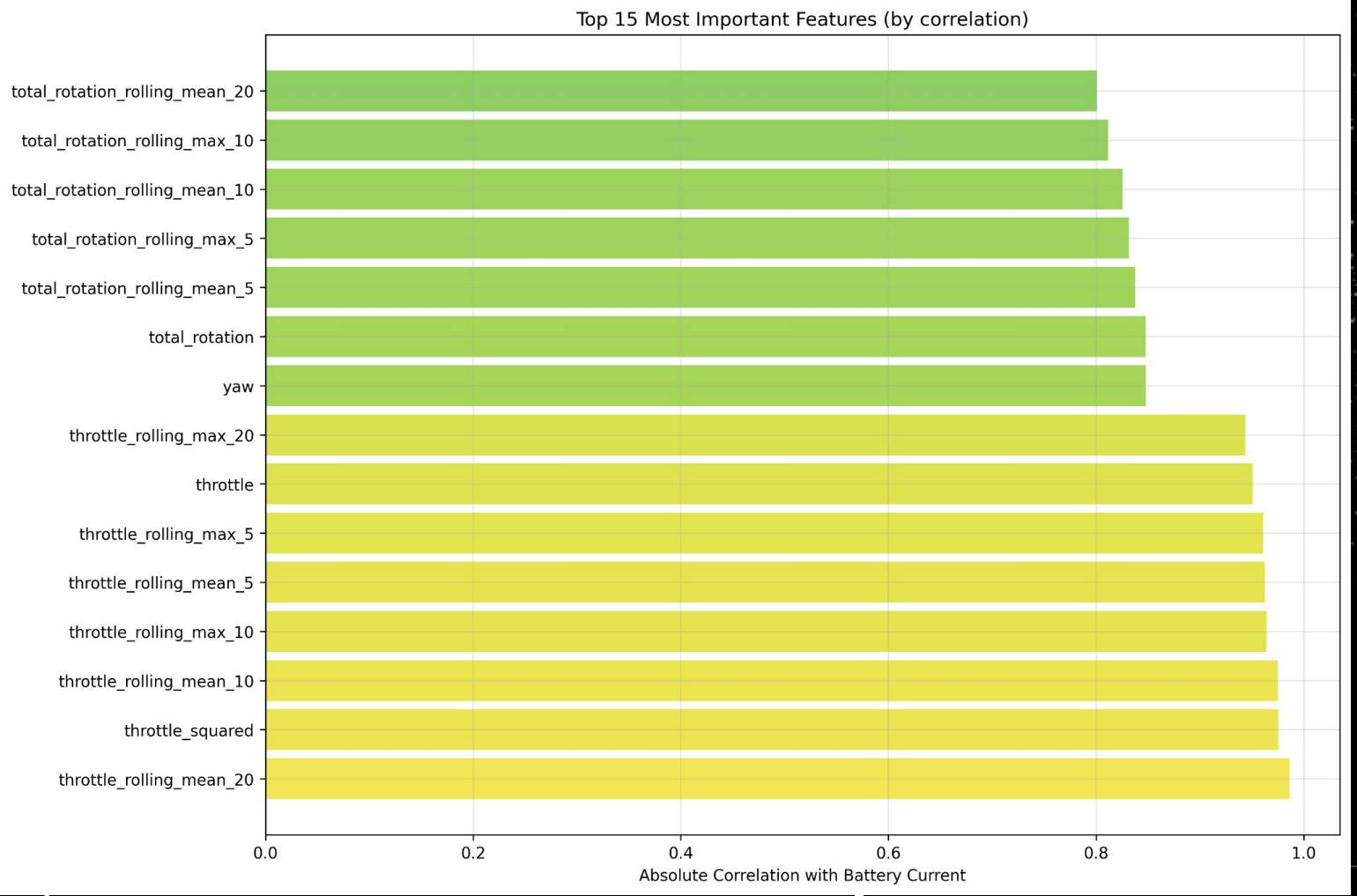
```
def compute_physics_loss(self, pred_current, throttle, voltage):
    # Optional: Add physics-based constraints
    predicted_power = pred_current * voltage
    expected_power = self.power_constraint(throttle)
    return nn.MSELoss()(predicted_power, expected_power)
```

Train and Val

```
2025-05-18 11:09:15,109 - INFO - Train Loss: 0.0021, RMSE: 0.0461, R²: 0.9661
Val Loss: 0.0011, RMSE: 0.0330, R²: 0.9777
Epoch time: 450.22s
2025-05-18 11:09:15,195 - INFO - Saved new best model with validation loss: 0.001089
2025-05-18 11:09:15,868 - INFO -
Epoch 2/50
Training: 100%|| 25928/25928 [06:22<00:00, 67.85it/s, avg_loss=0.0015, last_loss=0.0012, lr=0.00008
2025-05-18 11:16:48,681 - INFO - Train Loss: 0.0015, RMSE: 0.0385, R²: 0.9763
Val Loss: 0.0002, RMSE: 0.0124, R²: 0.9968
Epoch time: 452.81s
2025-05-18 11:16:48,762 - INFO - Saved new best model with validation loss: 0.000154
2025-05-18 11:16:49,437 - INFO -
Epoch 3/50
Training: 100%|| 25928/25928 [06:21<00:00, 67.94it/s, avg_loss=0.0015, last_loss=0.0008, lr=0.00013
2025-05-18 11:24:22,901 - INFO - Train Loss: 0.0015, RMSE: 0.0383, R²: 0.9766
Val Loss: 0.0005, RMSE: 0.0218, R²: 0.9903
Epoch time: 453.46s
2025-05-18 11:24:23,648 - INFO -
Epoch 4/50
Training: 100%|| 25928/25928 [06:22<00:00, 67.86it/s, avg_loss=0.0015, last_loss=0.0003, lr=0.00019
2025-05-18 11:31:56,326 - INFO - Train Loss: 0.0015, RMSE: 0.0388, R²: 0.9759
Val Loss: 0.0000, RMSE: 0.0066, R²: 0.9991
Epoch time: 452.68s
2025-05-18 11:31:56,412 - INFO - Saved new best model with validation loss: 0.000044
2025-05-18 11:31:57,112 - INFO -
Epoch 5/50
Training: 100%|| 25928/25928 [06:22<00:00, 67.71it/s, avg_loss=0.0015, last_loss=0.0021, lr=0.00028
2025-05-18 11:39:30,959 - INFO - Train Loss: 0.0015, RMSE: 0.0384, R²: 0.9764
Val Loss: 0.0002, RMSE: 0.0153, R²: 0.9952
Epoch time: 453.85s
2025-05-18 11:39:31,703 - INFO -
Epoch 6/50
Training: 100%|| 25928/25928 [06:22<00:00, 67.85it/s, avg_loss=0.0014, last_loss=0.0019, lr=0.00037
2025-05-18 11:47:04,360 - INFO - Train Loss: 0.0014, RMSE: 0.0377, R²: 0.9774
Val Loss: 0.0001, RMSE: 0.0110, R²: 0.9975
Epoch time: 452.66s
2025-05-18 11:47:05,068 - INFO -
Epoch 7/50
Training: 100%|| 25928/25928 [06:22<00:00, 67.83it/s, avg_loss=0.0013, last_loss=0.0004, lr=0.00047
2025-05-18 11:54:38,394 - INFO - Train Loss: 0.0013, RMSE: 0.0359, R²: 0.9795
Val Loss: 0.0002, RMSE: 0.0135, R²: 0.9962
```

Test

```
INFO:root:Using device: cuda
INFO:root:Model loaded successfully
INFO:root:Evaluating model...
INFO:root:
Test Set Results:
INFO:root:MSE: 0.0000
INFO:root:RMSE: 0.0061
INFO:root:R²: 0.9994
INFO:root:Generating plots...
INFO:root:Results saved to prediction_analysi
```


Top 15 Most Important Features (by correlation)
total_rotation_rolling_mean_20
total_rotation_rolling_max_10
total_rotation_rolling_mean_10
total_rotation_rolling_max_5
total_rotation_rolling_mean_5
total_rotation
yaw
throttle_rolling_max_20
throttle
throttle_rolling_max_5
throttle_rolling_mean_5
throttle_rolling_max_10
throttle_rolling_mean_10
throttle_squared
throttle_rolling_mean_20
0.0
0.2
0.4
0.6
0.8
1.0
Absolute Correlation with Battery Current

THANK YOU !