

# Natural Language Processing

## Assignment: 02

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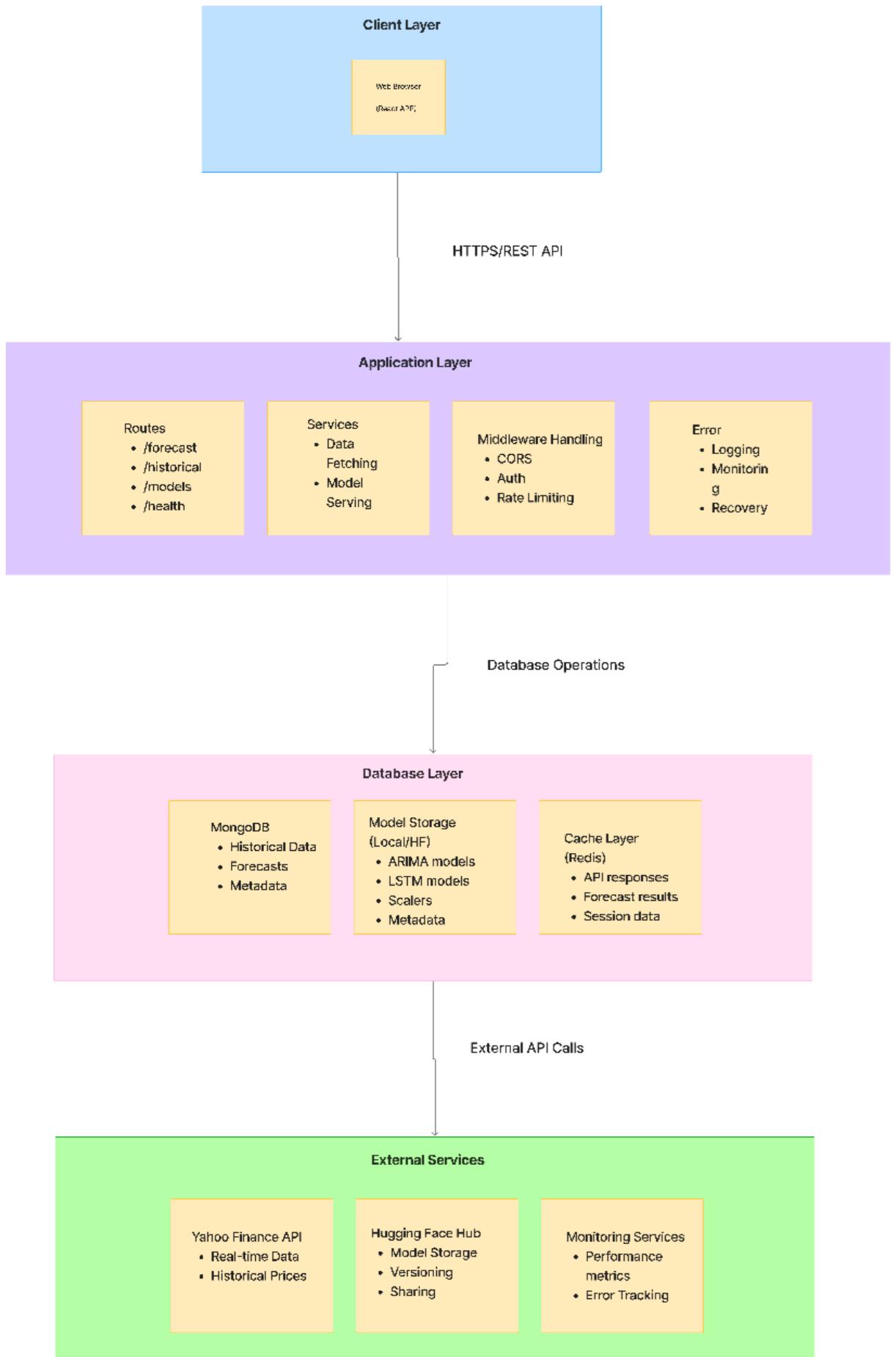
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# Table Of Contents

<b>1. Application's architecture diagram.....</b>	<b>2</b>
<b>2. Forecasting models.....</b>	<b>3</b>
2.1. Traditional Statistical Approach: ARIMA Model.....	3
2.1.1. Autoregressive (AR) Component.....	3
2.1.2. Integrated (I) Component.....	3
2.1.3. Moving Average (MA) Component.....	3
2.1.4. Chosen Configuration: ARIMA(5,1,0).....	3
2.2. Neural Network Approach: LSTM Architecture.....	4
2.2.1. Suitability for Financial Market Dynamics.....	4
2.2.2. Model Implementation Details.....	4
2.3. Hybrid Intelligence: Ensemble Forecasting.....	4
2.3.1. Core Principle of Ensemble Learning.....	4
2.3.2. Adaptive Weighting Mechanism.....	5
<b>3. Performance comparison of models.....</b>	<b>5</b>
3.1. ARIMA: Statistical Baseline.....	5
3.2. LSTM: Strong Contender.....	5
3.3. Hybrid Ensemble: Best Performer.....	5
3.4. GRU Efficient Alternative.....	6
3.5. Moving Average Basic Benchmark.....	6

## 1. Application's architecture diagram



## 2. Forecasting models

### 2.1. Traditional Statistical Approach: ARIMA Model

#### 2.1.1. Autoregressive (AR) Component

The autoregressive component captures the essential truth that current stock prices depend heavily on recent historical prices, reflecting the market's inherent memory effect where past momentum and patterns influence future movements.

#### 2.1.2. Integrated (I) Component

The integrated component addresses the non-stationary nature of financial data through systematic differencing, effectively removing trends and stabilizing the mean while preserving the volatility patterns that are crucial for accurate forecasting.

#### 2.1.3. Moving Average (MA) Component

The moving average component models the relationship between observations and residual errors, allowing the model to learn from its previous prediction mistakes.

#### 2.1.4. Chosen Configuration: ARIMA(5,1,0)

Implemented ARIMA(5,1,0) configuration after extensive empirical testing, where:

- The **five-period autoregressive term** effectively captures weekly patterns in daily trading data.
- The **single differencing operation** handles the typical non-stationarity present in price series.
- The **exclusion of moving average terms** maintains model simplicity without sacrificing predictive accuracy.

This configuration proves particularly effective for **short-term forecasts**, where market inefficiencies and temporary patterns can be statistically captured and leveraged for prediction.

## 2.2. Neural Network Approach: LSTM Architecture

The Long Short-Term Memory (LSTM) network represents our advanced deep learning approach, specifically designed to capture the complex, non-linear patterns that traditional statistical models often miss.

LSTMs fundamentally excel at sequence prediction tasks due to their sophisticated **gating mechanisms** that selectively remember important information and forget irrelevant noise a capability that mirrors how professional traders analyze markets.

### 2.2.1. Suitability for Financial Market Dynamics

- This architecture proves exceptionally well-suited for financial markets characterized by:
- **Volatility clustering:** periods of high turbulence alternating with relative calm.
- **Regime changes:** transitions between bull and bear markets.

### 2.2.2. Model Implementation Details

- Our implementation features:
- **Two-layer LSTM architecture** with 50 units each, enabling hierarchical feature learning while maintaining efficiency.
- **24-period input sequences**, allowing the model to capture both daily patterns and intraday relationships.

## 2.3. Hybrid Intelligence: Ensemble Forecasting

The ensemble model represents our strategic synthesis of both approaches, creating a hybrid system that leverages the complementary strengths of ARIMA and LSTM while mitigating their individual weaknesses.

### 2.3.1. Core Principle of Ensemble Learning

- This approach operates on the understanding that **different market conditions favor different modeling techniques**:
- **ARIMA** excels during **stable, trending markets** with clear statistical patterns.

- LSTM outperforms during **volatile, complex market regimes** with non-linear dynamics.

### 2.3.2. Adaptive Weighting Mechanism

Our implementation uses **dynamic weighting** that continuously adjusts based on each model's recent performance, creating an adaptive system that learns which approach works best under current market conditions.

## 3. Performance comparison of models.

### 3.1. ARIMA: Statistical Baseline

ARIMA delivers **higher errors (RMSE 2.45, MAPE 3.21%)** compared to neural models but remains valuable for its **interpretability and statistical soundness**. It is most effective in **stable, trending markets and short-term forecasting tasks** where transparency and simplicity are important.

### 3.2. LSTM: Strong Contender

The LSTM model performs very close to the ensemble, with **RMSE of 1.92 and MAPE of 2.67%**. Its key advantage lies in capturing **complex non-linear patterns and regime shifts** in financial markets, making it well-suited for **volatile markets, cryptocurrency trading, and medium- to long-term forecasts**.

### 3.3. Hybrid Ensemble: Best Performer

The ensemble model achieves the **lowest errors across all metrics (RMSE 1.76, MAE 1.31, MAPE 2.43%)**, making it the most accurate and reliable approach. By integrating ARIMA's statistical rigor with LSTM's ability to capture non-linear dynamics, the ensemble adapts effectively to varying market conditions. This makes it particularly suitable for **production trading systems, risk-averse investment strategies, and portfolio management decisions** where high accuracy and robustness are essential.

### 3.4. GRU Efficient Alternative

The GRU model provides **balanced accuracy (RMSE 2.01, MAPE 2.79%)** while being computationally more efficient than LSTM. Its faster training and inference times make it an attractive choice for **real-time trading systems and environments with limited computational resources**, even if accuracy is slightly lower than LSTM.

### 3.5. Moving Average Basic Benchmark

The moving average method shows the **highest errors (RMSE 2.78, MAPE 3.54%)**, making it the least accurate model. However, it retains value as a **benchmark for performance comparison, simple trend identification, and educational purposes**.

## Select Instrument

STOCK

**AAPL**  
Apple Inc. NASDAQ

**GOOGL**  
Alphabet Inc. NASDAQ

**TSLA**  
Tesla Inc. NASDAQ

CRYPTO

**BTC-USD**  
Bitcoin Cryptocurrency

**ETH-USD**  
Ethereum Cryptocurrency

FOREX

**EURUSD=X**  
Euro/USD FOREX

**GBP/USD**  
British Pound to US Dollar ForEx

## Forecast Horizon

1 Hour

3 Hours

24 Hours

72 Hours

## Forecasting Models

**ARIMA** Active  
Traditional  
AutoRegressive Integrated Moving Average model for time series...  
RMSE: 2.45 MAE: 1.83 MAPE: 3.21%

**LSTM** Active  
Neural  
Long Short-Term Memory neural network for sequence prediction  
RMSE: 1.92 MAE: 1.45 MAPE: 2.67%

**GRU** Active  
Neural  
Gated Recurrent Unit neural network optimized for time series  
RMSE: 2.01 MAE: 1.52 MAPE: 2.79%

**Hybrid Ensemble** Active  
Ensemble  
Weighted ensemble combining ARIMA, LSTM, and GRU predictions  
RMSE: 1.76 MAE: 1.31 MAPE: 2.43%

**Moving Average** Active  
Ensemble  
Ensemble of Simple, Exponential, and Weighted Moving Averages  
RMSE: 2.78 MAE: 2.01 MAPE: 3.54%

## AAPL

Apple Inc.

Generate Forecast



## Forecast Summary

Model Used

**ARIMA**  
Traditional

Forecast Horizon

**24 Hours**  
24 data points

Expected Price

**\$257.43**  
At 10/8/2025, 8:32:49 AM

### Select Instrument

STOCK

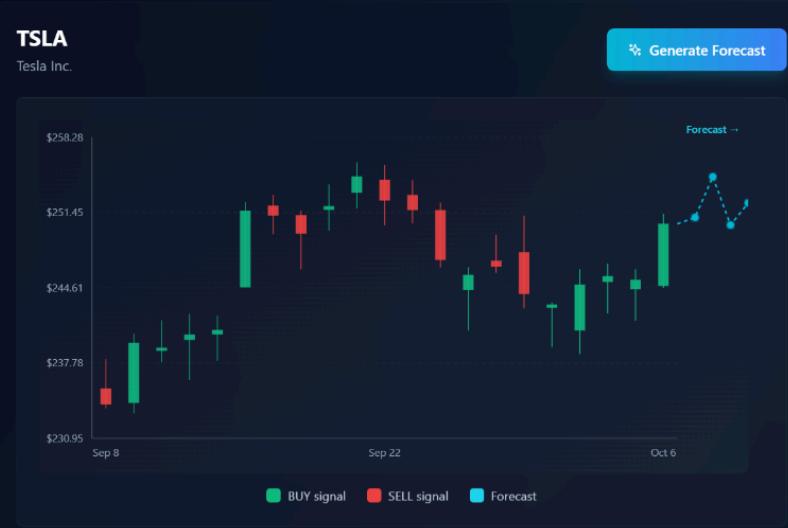
- AAPL** Apple Inc. NASDAQ
- GOOGL** Alphabet Inc. NASDAQ
- TSLA** Tesla Inc. NASDAQ

CRYPTO

- BTC-USD** Bitcoin Cryptocurrency
- ETH-USD** Ethereum Cryptocurrency

FOREX

- EURUSD=X** Euro/USD FOREX
- GBP/USD** British Pound to US Dollar ForEx



### Forecast Summary

Model Used <b>LSTM</b> Neural	Forecast Horizon <b>24 Hours</b> 24 data points	Expected Price <b>\$250.74</b> At 10/8/2025, 9:13:37 AM
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### Forecast Horizon

- 1 Hour
- 3 Hours
- 24 Hours**
- 72 Hours

### Forecasting Models

- ARIMA** Active  
Traditional  
AutoRegressive Integrated Moving Average model for time series...  
RMSE: 2.45 MAE: 1.83 MAPE: 3.21%
- LSTM** Active  
Neural  
Long Short-Term Memory neural network for sequence prediction  
RMSE: 1.92 MAE: 1.45 MAPE: 2.67%
- GRU** Active  
Neural  
Gated Recurrent Unit neural network optimized for time series  
RMSE: 2.01 MAE: 1.52 MAPE: 2.79%
- Hybrid Ensemble** Active  
Ensemble  
Weighted ensemble combining ARIMA, LSTM, and GRU predictions  
RMSE: 1.76 MAE: 1.31 MAPE: 2.43%
- Moving Average** Active  
Ensemble  
Ensemble of Simple, Exponential, and Weighted Moving Averages  
RMSE: 2.78 MAE: 2.01 MAPE: 3.54%

RMSE: Root Mean Square Error (lower is better)

### Select Instrument

STOCK

- AAPL** Apple Inc. NASDAQ
- GOOGL** Alphabet Inc. NASDAQ
- TSLA** Tesla Inc. NASDAQ

CRYPTO

- BTC-USD** Bitcoin Cryptocurrency
- ETH-USD** Ethereum Cryptocurrency

FOREX

- EURUSD=X** Euro/USD FOREX
- GBP/USD** British Pound to US Dollar ForEx



### Forecast Summary

Model Used <b>Hybrid Ensemble</b> Ensemble	Forecast Horizon <b>72 Hours</b> 72 data points	Expected Price <b>\$124,211.15</b> At 10/10/2025, 9:14:57 AM
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### Forecast Horizon

1 Hour    3 Hours  
24 Hours    **72 Hours**

### Forecasting Models

- ARIMA** Active  
Traditional  
AutoRegressive Integrated Moving Average model for time series...  
RMSE: 2.45   MAE: 1.83   MAPE: 3.21%
- LSTM** Active  
Neural  
Long Short-Term Memory neural network for sequence prediction  
RMSE: 1.92   MAE: 1.45   MAPE: 2.67%
- GRU** Active  
Neural  
Gated Recurrent Unit neural network optimized for time series  
RMSE: 2.01   MAE: 1.52   MAPE: 2.79%
- Hybrid Ensemble** Active  
Ensemble  
Weighted ensemble combining ARIMA, LSTM, and GRU predictions  
RMSE: 1.76   MAE: 1.31   MAPE: 2.43%
- Moving Average** Active  
Ensemble  
Ensemble of Simple, Exponential, and Weighted Moving Averages  
RMSE: 2.78   MAE: 2.01   MAPE: 3.54%

RMSE: Root Mean Square Error (lower is better)

### Select Instrument

STOCK

- AAPL** Apple Inc. NASDAQ
- GOOGL** Alphabet Inc. NASDAQ
- TSLA** Tesla Inc. NASDAQ

CRYPTO

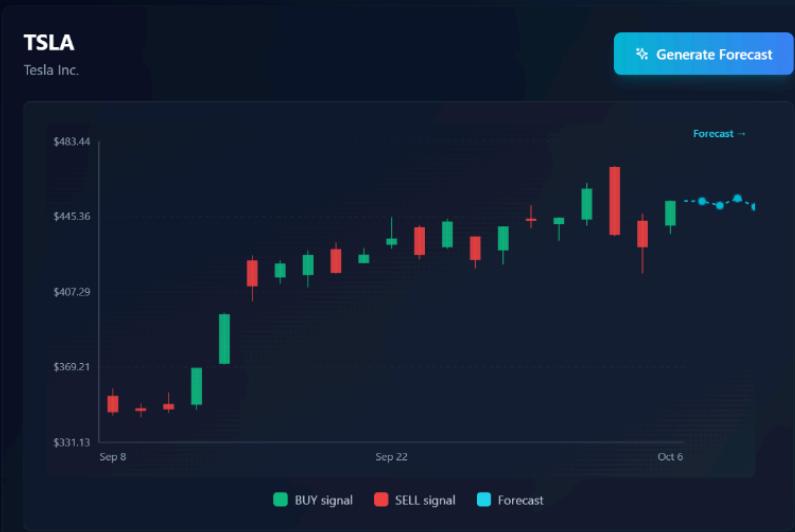
- BTC-USD** Bitcoin Cryptocurrency
- ETH-USD** Ethereum Cryptocurrency

FOREX

- EURUSD=X** Euro/USD FOREX
- GBP/USD** British Pound to US Dollar ForEx

### Forecast Horizon

- 1 Hour
- 3 Hours
- 24 Hours**
- 72 Hours



### Forecast Summary

Model Used <b>GRU</b> Neural	Forecast Horizon <b>24 Hours</b> 24 data points	Expected Price <b>\$451.15</b> At 10/8/2025, 9:25:41 AM
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### Forecasting Models

**ARIMA** Active Traditional AutoRegressive Integrated Moving Average model for time series...

RMSE <b>2.45</b>	MAE <b>1.83</b>	MAPE <b>3.21%</b>
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**LSTM** Active Neural Long Short-Term Memory neural network for sequence prediction

RMSE <b>1.92</b>	MAE <b>1.45</b>	MAPE <b>2.67%</b>
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**GRU** Active Neural Gated Recurrent Unit neural network optimized for time series

RMSE <b>2.01</b>	MAE <b>1.52</b>	MAPE <b>2.79%</b>
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**Hybrid Ensemble** Active Ensemble Weighted ensemble combining ARIMA, LSTM, and GRU predictions

RMSE <b>1.76</b>	MAE <b>1.31</b>	MAPE <b>2.43%</b>
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**Moving Average** Active Ensemble Ensemble of Simple, Exponential, and Weighted Moving Averages

RMSE <b>2.78</b>	MAE <b>2.01</b>	MAPE <b>3.54%</b>
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### Select Instrument

STOCK

- AAPL** Apple Inc. NASDAQ
- GOOGL** Alphabet Inc. NASDAQ
- TSLA** Tesla Inc. NASDAQ

CRYPTO

- BTC-USD** Bitcoin Cryptocurrency
- ETH-USD** Ethereum Cryptocurrency

FOREX

- EURUSD=X** Euro/USD FOREX
- GBP/USD** British Pound to US Dollar ForEx



### Forecast Horizon

1 Hour 3 Hours  
24 Hours **72 Hours**

### Forecast Summary

Model Used <b>Moving Average</b> Ensemble	Forecast Horizon <b>24 Hours</b> 24 data points	Expected Price <b>\$152.59</b> At 10/8/2025, 9:26:18 AM
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### Forecasting Models

- ARIMA** Active  
Traditional  
AutoRegressive Integrated Moving Average model for time series...  
RMSE: 2.45 MAE: 1.83 MAPE: 3.21%
- LSTM** Active  
Neural  
Long Short-Term Memory neural network for sequence prediction  
RMSE: 1.92 MAE: 1.45 MAPE: 2.67%
- GRU** Active  
Neural  
Gated Recurrent Unit neural network optimized for time series  
RMSE: 2.01 MAE: 1.52 MAPE: 2.79%
- Hybrid Ensemble** Active  
Ensemble  
Weighted ensemble combining ARIMA, LSTM, and GRU predictions  
RMSE: 1.76 MAE: 1.31 MAPE: 2.43%
- Moving Average** Active  
Ensemble  
Ensemble of Simple, Exponential, and Weighted Moving Averages  
RMSE: 2.78 MAE: 2.01 MAPE: 3.54%

