Pipeline Architecture & Documentation

Cryptocurrency Volatility Prediction System

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1. Introduction

This document describes the **end-to-end pipeline architecture** of the Cryptocurrency Volatility Prediction system. The pipeline defines how data flows from raw input to final volatility prediction, ensuring a structured, modular, and reproducible machine learning workflow.

The pipeline is designed to support accurate volatility forecasting, easy debugging, and smooth local deployment.

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2. Pipeline Overview

The system follows a **sequential machine learning pipeline**, where each stage processes the output of the previous stage.

High-Level Pipeline Stages

```
Data Ingestion
      ↓
Data Preprocessing
      ↓
Feature Engineering
      ↓
Exploratory Data Analysis (EDA)
      ↓
Model Training
      ↓
Model Evaluation
      ↓
Model Optimization
      ↓
Model Deployment
      ↓
Volatility Prediction Output
```

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3. Detailed Pipeline Stages

3.1 Data Ingestion

Description

- Loads historical cryptocurrency data from CSV files.
- Data contains OHLC prices, trading volume, and market capitalization.

Input

- Raw CSV dataset

Output

- Pandas DataFrame with raw records

Tools Used

- Pandas

3.2 Data Preprocessing

Description

- Handles missing values using forward fill
- Removes inconsistent or invalid records
- Sorts data by cryptocurrency symbol and date

Operations

- Missing value treatment
- Data type conversion
- Time-series ordering

Output

- Cleaned and preprocessed dataset

3.3 Feature Engineering

Description

Transforms raw market data into meaningful numerical features suitable for volatility prediction.

Engineered Features

Feature	Purpose
Log Returns	Capture price movement
Rolling Volatility (14-day)	Target variable
SMA (7, 14)	Trend identification
Price Range	Intraday volatility
Volume/Market Cap Ratio	Liquidity measure

Output

- Feature-enhanced dataset

3.4 Exploratory Data Analysis (EDA)

Description

- Analyzes statistical properties of the data
- Identifies trends, correlations, and anomalies

Activities

- Distribution analysis
- Correlation heatmaps
- Trend visualization

Output

- EDA Report with insights and visualizations

3.5 Model Training

Description

- Trains a machine learning model to learn relationships between features and volatility

Algorithm Used

- Random Forest Regressor

Training Strategy

- Time-series aware train-test split (80:20)
- No shuffling to preserve temporal order

Output

- Trained volatility prediction model

3.6 Model Evaluation

Description

- Evaluates model performance on unseen test data

Evaluation Metrics

- RMSE (Root Mean Squared Error)
- MAE (Mean Absolute Error)
- R^2 Score

Output

- Performance metrics and evaluation summary

3.7 Model Optimization

Description

- Improves model performance through hyperparameter tuning

Technique Used

- GridSearchCV

Tuned Parameters

- Number of trees
- Maximum tree depth

Output

- Optimized machine learning model

3.8 Model Deployment

Description

- Deploys the trained model locally using Streamlit
- Allows users to input market data and receive predictions

Workflow

1. User enters OHLC and market parameters
2. Input data is validated
3. Model predicts volatility level
4. Prediction is displayed to the user

Output

- Interactive volatility prediction interface

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4. Pipeline Characteristics

4.1 Modularity

- Each pipeline stage is implemented as a separate module
- Enables independent testing and maintenance

4.2 Scalability

- Pipeline supports multiple cryptocurrencies
- Can be extended to real-time data ingestion

4.3 Reproducibility

- Fixed random seeds
- Consistent data preprocessing steps

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5. Error Handling & Monitoring

- Input validation during deployment
- Exception handling during data loading
- Logging of model predictions and errors

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6. Benefits of the Pipeline Design

- Clear separation of concerns

• Easy debugging and enhancement
• Industry-aligned ML workflow
• Suitable for financial risk analysis

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7. Conclusion

The pipeline architecture provides a structured framework for cryptocurrency volatility prediction. By integrating data preprocessing, feature engineering, machine learning, and deployment into a unified flow, the system ensures accurate predictions, maintainability, and real-world applicability.

End of Pipeline Architecture & Documentation