Behavioral Bias Detection in Financial Markets

Overview

This project explores how **predictable human irrationalities** can be detected and modeled using data science. Instead of treating investors as perfectly rational agents, the system simulates realistic trading behavior influenced by well-known **behavioral finance biases** and applies interpretable machine learning models to identify them.

The goal is not just prediction accuracy, but **understanding *why* investors behave the way they do**.

Key Objectives

- Simulate realistic investor behavior using market data
- Model behavioral biases such as:
- **Herd Behavior**
- **Loss Aversion**
- **Overconfidence**
- Engineer behavior-driven features
- Detect biases using explainable ML models
- Evaluate robustness under noisy, imperfect data

Dataset

- **Source:** Yahoo Finance (historical stock price data)
- **Data Type:** Time-series market data (Open, High, Low, Close, Volume)
- **Preprocessing Highlights:**
- Conservative handling of missing values
- Return calculation and rolling statistics
- Avoidance of aggressive row drops to preserve signal

Behavioral Simulation

Investor actions (BUY / SELL / HOLD) are generated using probabilistic rules that reflect psychological biases:

Bias	Key Characteristics
Herd	Longer holding periods, trend-following

Bias	Key Characteristics
Loss Averse	Quick exits after losses
Overconfident	Frequent trades, short holding time

Noise is deliberately injected to mimic **human inconsistency** and prevent overly clean synthetic patterns.

Feature Engineering

Behavior-aware features include: - Holding duration - Trade frequency - Rolling returns and volatility - Profit & loss sensitivity - Action imbalance metrics

All features are engineered using **historical windows only** to prevent information leakage.

Modeling Approach

Two models were evaluated:

Logistic Regression (Primary Model)

- Chosen for interpretability
- Enables coefficient-based behavioral insights
- Robust under noisy conditions

Random Forest (Benchmark)

- Achieved perfect accuracy
- Used as a performance reference
- Not selected as final model due to overfitting risk

Evaluation

- Confusion Matrix
- Precision, Recall, F1-score (macro-averaged)
- ROC-AUC (multi-class)
- Noise stress testing to assess model stability

Performance degradation under noise validated **realistic generalization behavior**.

Key Insights

- Perfect accuracy can be a warning sign in behavioral modeling
- Noise improves realism and reveals true model robustness
- Interpretable models are essential for behavioral finance applications
- Investor irrationality is structured, not random

Project Structure

```
├── data/                # Raw and processed market data
├── eda/                 # Market & behavioral EDA
├── simulation/          # Investor behavior simulation logic
├── features/            # Feature engineering pipeline
├── models/              # ML models and evaluation
├── visualizations/      # Plots and interpretability outputs
└── README.md
```

Why This Project Matters

Traditional financial models assume rational actors. This project demonstrates how **behavioral signals can be quantified, modeled, and explained**, opening paths toward: - Better risk management - Behavioral-aware trading systems - Explainable financial AI

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Future Work

- Real investor transaction data
- Reinforcement learning agents
- Bias-aware portfolio optimization
- Market regime adaptation

> *“Markets are efficient — people are not.”*