Project Report: Early Panic Detection in Gold Markets Using News Sentiment and Price Volatility

1. Problem Statement

Background and Context

Gold is often considered a "safe haven" in times of political, economic, and financial turmoil. Black swan events—macroeconomic shocks or bearish investor sentiment—can cause an unanticipated spike in gold prices. Conventional financial indicators and statistical models tend to respond after the event (in hindsight), which is not helpful for early risk recognition and decision-making.

Problem Importance and Relevance

Early detection of panic-driven market behavior is critical for investors, risk managers, and policymakers. An intelligent system capable of identifying abnormal volatility patterns in conjunction with negative financial sentiment can provide timely warnings and improve situational awareness during crisis periods such as the 2008 Global Financial Crisis.

AI Task Definition

The goal of this work is a predictive and analytical AI problem that involves:

- Time-series volatility analysis
- Natural language sentiment classification
- Rule-based alert generation

It parses historical price and financial news data to identify publicly available indicators of potential panics in the gold market.

Objectives of the System

- To identify spikes of negative sentiment along with increases in volatile trading activity, to mark panic in gold markets

- To integrate quantitative price signals and qualitative sentiment signals to generate panic alerts
- To validate the system using historical crisis periods.

Objectives

Key Assumptions and Constraints

- The news data is posited to be related with the gold market variation on same day
- The study will exclude intraday signals(it's only for EOD)
- The system is a decision aid and not an automatic trading system
- The focus is on lawful, no financial advice or autonomous decision.

2. Approach

System Overview

1. The solution approach is in the spirit of the hybrid AI pipeline combining financial signal processing and deep learning-based sentiment analysis. There are four main stages in the workflow:
2. Data collection and preprocessing
3. Volatility extraction based on CEEMDAN and Hilbert–Huang Transform
4. Bi-LSTM Sentiment classification
5. Combining volatility and sentiment signals to create our panic alerts.

Data Strategy

- **Gold Price Data:** Daily gold futures prices were collected using the Yahoo Finance API (GC=F).
- **News Data:** Financial news headlines related to gold were provided in a CSV dataset.

Preprocessing Steps:

- Date alignment and merging of price and news data
- Text cleaning (lowercasing, punctuation removal)
- Tokenization and sequence padding for NLP input
- Handling class imbalance using weighted loss during training

AI / Model Design

Volatility Analysis

- Complete Ensemble Empirical Mode Decomposition with Adaptive Noise (CEEMDAN) was used to decompose gold price signals into intrinsic mode functions.
- The first IMF, representing high-frequency movements, was transformed using the Hilbert Transform to derive instantaneous volatility.

Sentiment Analysis

- A Bidirectional Long Short-Term Memory (Bi-LSTM) neural network was trained to classify news sentiment.
- The model captures contextual dependencies in both forward and backward directions, making it suitable for short financial headlines.

Inference and Fusion Strategy

- Panic alerts are generated when:
    - Volatility exceeds a statistically defined threshold, and
    - The probability of negative sentiment exceeds a predefined confidence level

Tools and Technologies

- **Programming Language:** Python
- **Libraries:** NumPy, Pandas, SciPy, PyEMD, TensorFlow/Keras, Scikit-learn
- **Visualization:** Matplotlib, Seaborn
- **Platform:** Google Colab

Design Decisions

- CEEMDAN was chosen for its robustness to non-stationary financial signals
- Bi-LSTM was selected over traditional classifiers to better capture contextual sentiment
- Early stopping and class weighting were used to improve generalization and handle data imbalance

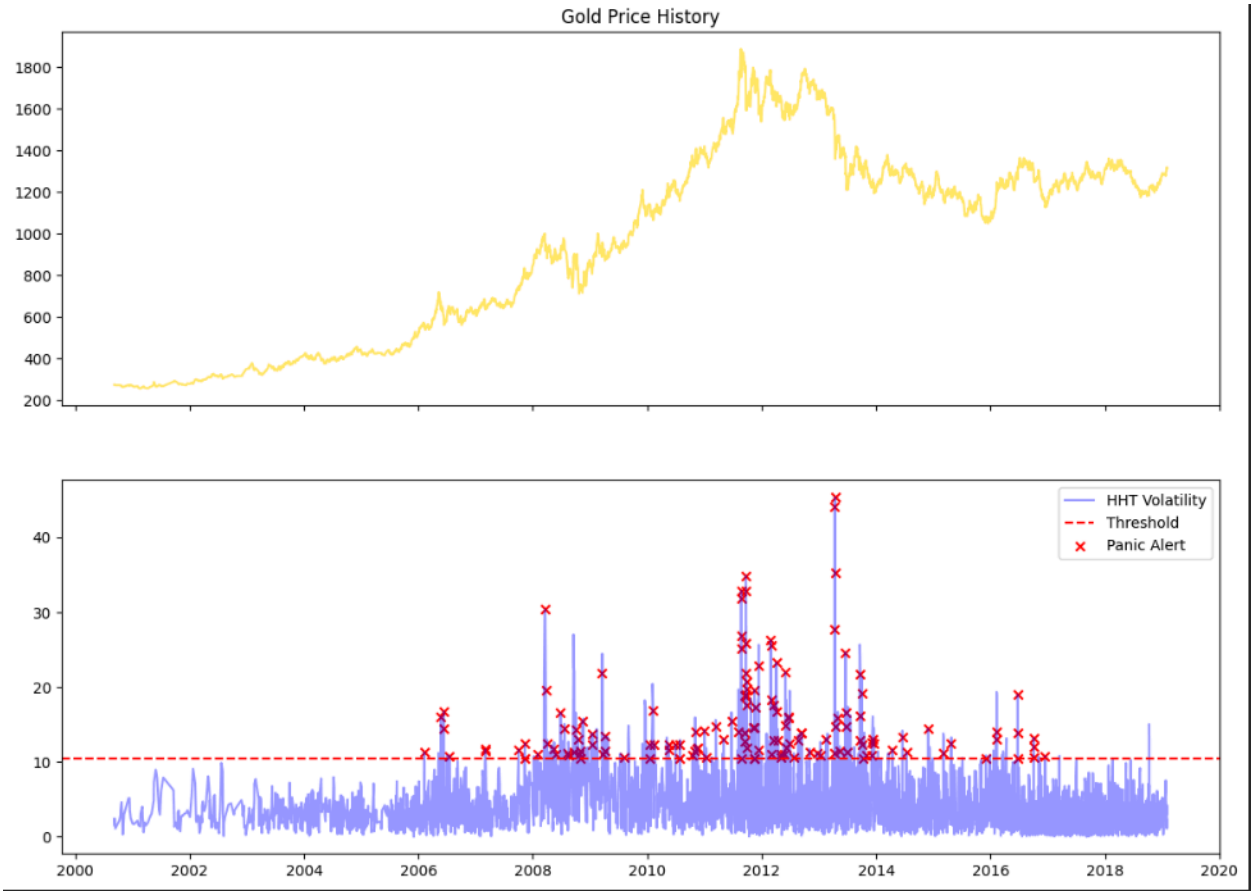
3. Key Results

Working Prototype

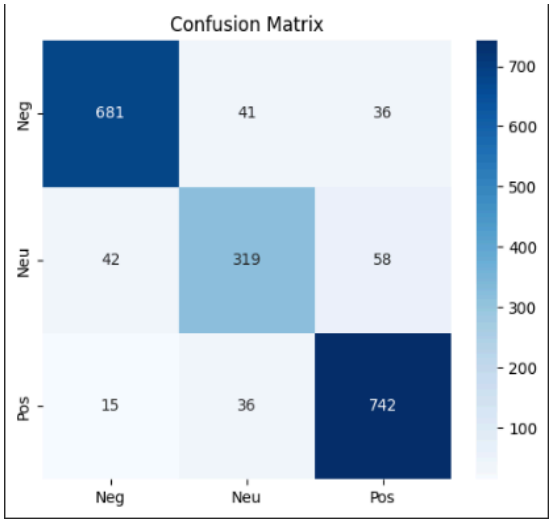
The system successfully processes historical gold prices and news headlines to generate panic alerts. A complete end-to-end pipeline was implemented, running without manual intervention from data ingestion to visualization.

Example Outputs

- Visual plots showing gold price movements and corresponding volatility spikes
- Highlighted panic alerts during known crisis periods (e.g., 2008–2009)



- Confusion matrix and classification report for sentiment predictions



Evaluation Methods and Metrics

- **Sentiment Model:** Accuracy, precision, recall, F1-score, and confusion matrix
- **Volatility Detection:** Visual and statistical validation against known market stress periods

Performance Insights

- An accuracy of 88%, which is competitive with state-of-the-art Bi-LSTM models used in financial news analysis, combined with high precision and recall for negative sentiment, indicates the model is reliable for risk monitoring and early-warning applications.
- Volatility spikes detected using CEEMDAN aligned well with historically turbulent periods
- The fusion approach reduced false alerts compared to using price or sentiment alone

Limitations

- Limited size and scope of the news dataset
- Daily frequency may miss intraday panic signals
- Threshold-based alerting may require recalibration for different market regimes

4. Learnings

Technical Learnings

- Practical fusion of multimodal inputs to gain deeper insights
- Implementation of Bi-LSTM models for sentiment classification
- Handling real-world issues such as class imbalance and library compatibility

System and Design Learnings

- Hybrid AI systems provide stronger insights than single-model approaches
- Combining quantitative and qualitative signals improves interpretability
- Environment and dependency management are critical for reproducible AI experiments

Challenges Faced

- Compatibility issues between scientific libraries in cloud environments
- Aligning noisy textual data with numerical price signals
- Balancing model complexity with computational efficiency

These challenges were addressed through controlled environment configuration, robust preprocessing, and careful model design.

Future Improvements

- Incorporating transformer-based models such as FinBERT for sentiment analysis
- Adding intraday price data and social media sentiment
- Adaptive thresholding using reinforcement learning
- Extending the framework to other commodities or financial assets

References & AI Usage Disclosure

Datasets

- Yahoo Finance Gold Futures Data (GC=F)
- Gold-related financial news dataset from Kaggle (CSV)

Tools and Frameworks

- Python, NumPy, Pandas, SciPy
- PyEMD, TensorFlow/Keras, Scikit-learn
- Google Colab

Citations

- Sinha, Ankur, and Tanmay Khandait. "Impact of News on the Commodity Market: Dataset and Results." Future of Information and Communication Conference, pp. 589–601. Springer, Cham, 2021. DOI/Publisher Link
    - The dataset and methodology inspired the news sentiment analysis in this project.
- Sinha, Ankur, and Tanmay Khandait. "Impact of News on the Commodity Market: Dataset and Results." arXiv preprint arXiv:2009.04202, 2020. arXiv Link
    - Used as a reference for constructing the gold news dataset and labeling strategy.
- Ozupek, O.; Yilmaz, R.; Ghasemkhani, B.; Birant, D.; Kut, R.A. "A Novel Hybrid Model (EMD-TI-LSTM) for Enhanced Financial Forecasting with Machine Learning." Mathematics, 2024, 12, 2794. DOI Link
    - Inspired the hybrid CEEMDAN + Bi-LSTM approach for time series and sentiment fusion.
- Wu, Z., & Huang, N.E.. "Ensemble Empirical Mode Decomposition: A Noise-Assisted Data Analysis Method." Mechanical Systems and Signal Processing, 2009, 24(4), 661–680. DOI Link

AI Usage Disclosure

AI tools were used for code assistance, debugging, and improving documentation clarity. All model design, implementation, experimentation, and analysis decisions were made by the project author.