Modeling Stock Price Dynamics With Student-t Random Walks: A Segment-Matching Approach for Improved Financial Analysis

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Financial models for stock prices play a crucial role in maintaining economic stability by enabling risk assessment, informed investing, and regulatory oversight. However, many conventional models rely on unrealistic assumptions and neglect tail risk, a dangerous oversight that has repeatedly contributed to financial crises. This project aims to construct and evaluate a random walk model capable of capturing tail risks and extreme market behavior, ultimately contributing to more resilient financial systems. Using historical Swiss stock exchange data, an extensive computational analysis was conducted to determine the parameters of the model. The step distribution found in the data exhibited heavy tails (kurtosis = 9.34), motivating the use of Student-t distributed increments (df=4.642). To evaluate the model, a novel segment-matching algorithm was developed: For each contiguous segment of a stock series, the trapezoidal area between the two paths is computed. This method computes the area between paths across all possible windows of an equi-length random walk with increments drawn from the Gaussian or Student-t distribution. The best-matched segment minimizes this metric. Evaluating the resulting areas using a Kolmogorov-Smirnov test showed that Student-t walks align more closely with real stock prices than Gaussian walks, better capturing extreme fluctuations. The heavy-tailed model improves the tail modeling by 70% compared to the Gaussian model. Using a Student-t distribution instead of a normal distribution significantly improves random walk models for stock price dynamics. The segment-matching method offers a novel approach to comparing financial time series to a model, contributing to improved market modeling and risk assessment strategies.

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