

TOPOLOGICAL DATA ANALYSIS OF FINANCIAL MARKET VOLATILITY: A STUDY OF PERSISTENCE DIAGRAMS

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Financial markets are known for their volatility, making it challenging to predict stock price movements using traditional methods. This study explores the application of Topological Data Analysis (TDA) to analyse financial time series data, focusing on identifying persistent topological features that correlate with periods of high volatility. To detect structural changes over time, each stock's closing price series was segmented into windows of 252 data points (equivalent to one trading year), and for each window, Takens' embedding method was applied to transform the time series into high-dimensional point clouds, which were then analysed using persistent homology to identify topological features. The most persistent features are structures as connected components (0-dimensional holes, detected via H_0) and loops (1-dimensional holes, detected via H_1), which persisted across a wide range of scales in the persistence diagram. From each diagram, the most persistent H_1 feature was extracted, and the overall maximum persistent point across all windows was identified along with its corresponding time series segment. The analysis was applied to major stock indices, including the S&P 500, the Dow Jones Industrial Average, Apple Inc., and Tesla. The emergence of persistent H_1 after high volatility indicates a return to structural regularity in the market, suggesting that after chaotic fluctuations, financial systems tend to reorganise into more stable configurations. Furthermore, computing market volatility using a rolling standard deviation supports this trend. This suggests that TDA can capture meaningful and stable market structures that arise after periods of instability, offering a novel perspective on market dynamics. Future research will focus on integrating machine learning models with TDA to enhance time series forecasting in financial markets.

Keywords: Financial markets, Financial time series, Market volatility, Persistence diagrams, Topological data analysis

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