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Characterization and Predictive Analysis of Volatile Financial Markets Using Detrended Fluctuation Analysis, Wavelet Decomposition, and Machine Learning

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ABSTRACT

This paper proposes a granular framework for examining the dynamics of stock indexes that exhibit nonparametric and highly volatile behavior, and subsequently carries out the predictive analytics task by integrating detrended fluctuation analysis (DFA), maximal overlap discrete wavelet transformation (MODWT), and machine learning algorithms. DFA test ascertains the key temporal characteristics of the daily closing prices. MODWT decomposes the time series into granular components. Four pattern recognition algorithms—adaptive neuro fuzzy inference system (ANFIS), dynamic evolving neural-fuzzy inference system (DENFIS), bagging and deep belief network (DBN)—are then used on the decomposed components to obtain granular level forecasts. The entire exercise is performed on daily closing prices of Dow Jones Industrial Average (DJIA), National Stock Exchange of India (NIFTY), Karachi Stock Exchange (KSE), Taiwan Stock Exchange (TWSE), Financial Times Stock Exchange (FTSE), and German Stock Exchange (DAX). MODWT-Bagging and MODWT-DBN appear as superior forecasting models.

KEYWORDS

Detrended Fluctuation Analysis, Forecasting, Granular, Machine Learning, Maximal Overlap Discrete Wavelet Transformation, Predictive Modeling, Stock Market

1. INTRODUCTION

Comprehending the key characteristics and conducting predictive analytics of financial markets are extremely arduous due to their nonparametric, nonlinear and chaotic nature of temporal movements (Zhang et al. 2015; Ghosh et al. 2017; Jammazi et al. 2017; Tiwari et al. 2018a, b; Jana et al. 2019). Researchers critically examine the behavioral aspects and develop forecasting frameworks for various practical implications (Cipollini et al. 2015, Sharif et al. 2017). Comprehending the properties of temporal evolutionary pattern beforehand is arduous for subsequent predictive modeling tasks (Ghosh et al. 2019, Ghosh et al. 2020) as the said exercise assists in identifying explanatory features.

Plenteous studies report the use of traditional econometric and statistical approaches for forecasting future movements of the financial time series (Granger 1992, Liu and Pan 2019). However, the shortcomings of these techniques become prominent when the time series demonstrates nonparametric, nonstationary and nonlinear patterns. Machine learning, deep learning and computational intelligence

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algorithms prevail and produce superior forecasts for such time series (Wang et al. 2011, Kao et al. 2013, Hsu et al. 2016, Zhao et al. 2017). One set of machine learning and related models work in a univariate framework using immediate past historical price information of stock markets as input features, while the other models work in a multivariate framework. The majority of the second category models either employ a set of technical indicators or conduct a fundamental analysis to estimate future movements (Zhang Dan et al. 2016, Ni Ping et al. 2011). Fundamental analysis considers several financial ratios estimated annually, biannually, and quarterly for assessing financial health of organizations and employ them to determine the share price at same time intervals. Fundamental analysis cannot be utilized for predicting daily stock prices directly. Technical indicators or univariate forecasting structures are applied for daily price forecasting.

Literature reports various predictive modelling frameworks for stock market prediction by utilizing a wide range of intelligent methods like artificial neural network (ANN), radial basis function neural network (RBFNN), particle swarm optimization (PSO), genetic algorithm (GA), support vector machine (SVM), ANFIS, DENFIS, Jordon neural network (JNN), and random forest (RF) (Dutta et al. 2006; Shen et al. 2011; Karazmodeh et al. 2013; Ghosh et al. 2017; Fan et al. 2019). Usage of these models have been found to be extremely efficient in other disciplines as well (Chakraborty et al. 2017, Chakraborty et al. 2019). Ghosh et al. (2019) developed maximal overlap discrete wavelet transformation (MODWT) driven time series decomposition driven forecasting framework incorporating seven advanced predictive modeling techniques namely, support vector regression (SVR), elastic net (EN), random forest, extreme randomized trees (ERT), boosting, deep neural network (DNN), long short-term memory network (LSTM) of machine and deep learning categories for predictive modeling of four emerging stock markets in Asia. DNN and boosting emerged to be the top two models in terms of quality of predictions. Long et al. (2020) proposed deep learning based paradigm for directional predictive modeling of Chinese stock market employing convolutional neural network (CNN) and bi-directional LSTM. Results demonstrate the efficacy of the framework. Work of Ghosh et al. (2020) designed an integrated decomposition based predictive model incorporating ensemble empirical model decomposition (EEMD) and singular spectrum analysis (SSA) in conjunction with bagging, random forest, and extreme learning machine for precise forecasting of commodity market. Zhou et al. (2020) developed a support vector machine (SVM) based framework for predictive modeling Chinese stock market at different time horizons using data from different information source. Predictive performance duly rationalized the framework. Extensive review work of Bustos and Quimbaya (2020) summarize the existing prominent work in the field of stock market forecasting. These frameworks primarily use ensemble mode decomposition (EMD), discrete wavelet transformation (DWT), and their variants as the time varying decomposition methods, and then use pattern mining techniques to discover the inherent patterns for estimating forecasts at the granular level (Wang et al. 2011; Zhang et al. 2015; Septiarini et al. 2016). Thus based on existing previous research, it can be concluded that the challenging task of stock market forecasting owing to high degree of volatility and external shocks has been well addressed by researchers through development advanced models either on multivariate framework or time series decomposition driven univariate frameworks. Technical indicators are predominantly used in multivariate frameworks. This research endeavors to contribute to the existing literature of stock market predictive analytics literature by combing technical indicators in time series decomposition driven multivariate frameworks for precise estimation of global stock markets. Moreover, a dedicated feature selection structure has been incorporated in this research to systematically identify the features with significant explanatory capability. Hall's (1998) correlation based feature evaluation architecture using dedicated searching algorithms has been considered in this paper as feature selection process.

Granular computing enables processing of a large number of complex datasets into smaller granules represented in classes, clusters, subsets, and intervals (Zadeh 1997). In granular computing paradigm, a collection of indistinguishable objects creates information granule based on similarity and functionality. It can effectively model high volatile time series by eliminating linear and nonlinear