Signal Processing for Financial Markets

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INTRODUCTION

The possibility to acquire on the Internet large amounts of financial data is today reshaping the processes of trading, investment research, and risk management. Due to the broad availability of this information, it is now possible to apply analysis techniques that are new to the financial industry, whereas traditional signal processing techniques (e.g. moving averages and regression approaches) have had limited success in predicting markets, due to the dynamic behavior of the markets. The financial industry is currently dominated by a handful of workhorses of a few historical models, such as the Capital Asset Pricing Model, CAPM, (see Agrawal et al., 2012) and the Black-Scholes option pricing model (and all related models).

Quantitative financial analysis is instead mainly based on econometrics methodology. Nonetheless, prediction of financial market trends has been an area of great interest both to those who wish to profit by trading stocks in the financial market and for researchers attempting to uncover the information hidden in the financial market data. This article aims at highlighting the huge possibility in exploiting signal processing methodologies in synergy with in synergy with financial markets. The design of such models faces many unique challenges, opportunities and risks that will be here reviewed.

BACKGROUND

In the last decades, there has been an explosive growth in the research area relating signal processing and financial trading (Gradojevic & Gencay, 2011; Bekiros, 2011), especially in the fields of business and banking researches and applications (Taskaya & Ahmad, 2003; Nuti et al., 2011; Zhang & Kedmey, 2011). Signal processing applications, which hold promising potential, remain relatively unexplored within finance but its applications for financial data would add a new perspective and could further enrich financial research. One example of signal processing used in finance is shown in (Benedetto et al., 2007, 2009), where the authors propose a business model founded on Bayes decision test for video-call billing based on the effective end-to-end quality of service (QoS). More recently, the *IEEE Journal of Selected Topics in Signal Processing* has promoted a Special Issue in "*Signal Processing Methods in Finance and Electronic Trading*" in August 2012 (Akansu et al., 2012), as well as the *IEEE Signal Processing Magazine* that has published a Special Issue in "*Signal Processing for Financial Applications*" in September 2011 (Pollak et al., 2011). However, empirical evidence shows that using traditional statistical and econometric models might lead to very poor prediction performances (Weigend & Gershenfeld, 1994). To this aim, the authors in (Abramson & Finizza, 1995) utilized a probabilistic model for predicting oil prices, while a semi-parametric statistical method is suggested in (Morana, 2001) for short-term oil price forecasting based on the GARCH properties of crude oil price. Similarly, a semi-parametric approach for oil price forecasting is introduced in (Barone-Adesi et al., 1998), while in (Yu et al., 2008) an empirical mode decomposition (EMD) based neural network ensemble learning paradigm is proposed for world crude oil spot price forecasting.

The EMD approach is also used by the authors in (Yuan & Xiao, 2011) presenting a new numeri-

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cal method for pricing binary options, showing with numerical examples that the proposed algorithm is conditional stable and convergent. In finance, a binary option is a type of option where the payoff is either some fixed amount of some asset or nothing at all. Binary options trading is based on algorithms of financial data processing, that usually run on remote proprietary broker platforms, providing the customer with the proper option to possibly trade a given stock. The binary options trading is becoming more and more popular because it provides easy indications to operate in a dynamic manner, and suited to occasional operators that usually trade by their remote Internet online platforms. Stock traders usually try to profit from short-term price volatility with trades lasting anywhere, from several seconds to several weeks, exploiting some analysis and prediction methods commonly employed in signal processing systems. Recently, a signal processing methodology applied to financial signals to evaluate the sign of the increment of the signal instead of the exact future value was introduced in (Tsakalozos et al., 2011), while the authors in (Giunta & Benedetto, 2012) proposed the application of a signal extrapolation algorithm in finance, showing a preliminary case study of binary options stock trading.

SIGNAL PROCESSING FOR FINANCIAL MARKETS

Related Works

Many data processing techniques have been used to analyze several financial stocks to extrapolate the hidden periodicities. They exploited cumbersome methods, such as the multiple signal classification MUSIC (Kay & Demeure, 1984), Pisarenko, and Prony algorithms (Kay & Marple, 1981), as well as simpler techniques such as statistical correlation / covariance analysis, and Fourier transform-based methods, periodogram, (Oppenheim & Schafer, 1975). Each of the above-mentioned techniques has been applied to different ensembles of financial stocks and the same trend has been observed: there is a positive correlation with a distance of 1 day and a negative correlation with a distance of 1 week from the maximum. Other correlations exist but they exhibit a random character and a more non-stationary behavior. In a recent development (Tsakalozoset et al., 2011), an interesting technique was proposed and applied on financial signals to capture the sign of the increment of the signal instead of the exact future value. Giunta and Benedetto (2012) move further using the phase of the predicted value, in order to buy/sell financial stocks, accordingly. In particular, the authors in (Giunta & Benedetto, 2012) have decided to focus on simpler extrapolation approaches (based on statistical autocovariance and discrete Fourier transform).

Data Processing Algorithm

In this Section, we review the data processing methodology applied in (Giunta & Benedetto, 2012) on financial signals, in order to highlight the huge possibility in exploiting signal processing in synergy with stock trading. The hidden market trends of stock prices are exploited for applying signal processing to stock trading. In particular, the case study consists of a preliminary example of trading stocks with a simple algorithm for binary options, which includes one buy/sell order of a fixed amount of cash (or exchange equivalent) to limit the maximum risk of the investment to that fixed amount. The advantage of using a simple trading model reflects in the fact that the performance evaluation is straightforwardly based on the return in terms of cash and stock portfolios at the end of the trading session. The method is well suited for an occasional trading (the observations of the stocks are taken once a day, the decisions are taken once a week).

In agreement with the authors in (Tsakalozos et al., 2011) that suggest exploiting a Fourier series-like expansion of the financial data, here we have decided to focus on simpler extrapolation approaches (i.e. autocorrelation and Fourier transform). In particular, given a random series $x(n)$ of N data, its auto-covariance is defined as follows (Oppenheim & Schafer, 1975):

$$Cov_x(i) = \frac{1}{N} \cdot \sum_{n=0}^{N-1} x(n) \cdot x^*(n-i) - |\mu|^2 \tag{1}$$

where $x^*(n)$ means complex conjugate, $i = 0, \pm 1, \pm 2, \ldots$, and the mean μ is expressed as:

$$\mu = \frac{1}{N} \cdot \sum_{n=0}^{N-1} x(n) \tag{2}$$