Analysis of financial time series using multiscale entropy based on skewness and kurtosis
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HIGHLIGHTS

- Multiscale entropy based on skewness and kurtosis is proposed to analyze financial time series.
- Results show that the modified method is more effective to the change of dynamics and has more valuable information.
- The method reflects the results of skewness and kurtosis discrimination is obvious and more stable.

ARTICLE INFO

Article history:
Received 10 April 2017
Received in revised form 18 June 2017
Available online 20 September 2017

Keywords:
Financial time series
Multiscale entropy (MSE)
Skewness
Kurtosis
Coarse-graining

ABSTRACT

There is a great interest in studying dynamic characteristics of the financial time series of the daily stock closing price in different regions. Multi-scale entropy (MSE) is effective, mainly in quantifying the complexity of time series on different time scales. This paper applies a new method for financial stability from the perspective of MSE based on skewness and kurtosis. To better understand the superior coarse-graining method for the different kinds of stock indexes, we take into account the developmental characteristics of the three continents of Asia, North America and European stock markets. We study the volatility of different financial time series in addition to analyze the similarities and differences of coarsening time series from the perspective of skewness and kurtosis. A kind of corresponding relationship between the entropy value of stock sequences and the degree of stability of financial markets, were observed. The three stocks which have particular characteristics in the eight piece of stock sequences were discussed, finding the fact that it matches the result of applying the MSE method to showing results on a graph. A comparative study is conducted to simulate over synthetic and real world data. Results show that the modified method is more effective to the change of dynamics and has more valuable information. The result is obtained at the same time, finding the results of skewness and kurtosis discrimination is obvious, but also more stable.

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1. Introduction

In recent years, some tools and methods have been introduced by using the complexity characteristics of financial time series generated by nonlinear dynamic systems [1–8]. With greater national economic development, stock markets present a popular scene. Meanwhile, it can be observed that the various nonlinear dynamic phenomena, such as formation chaos which are contained in the financial time series.

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http://dx.doi.org/10.1016/j.physa.2017.08.136
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There have already been some people who developed a universally econometric test for financial stability with quantile regression technique [9]. From a social interest standpoint, it is crucial to understand the stability and complexity of financial markets. There is also great interest in non-equilibrium statistical mechanics [10–12]. As a result, behavior and information in the financial time series system have generated considerable interest, and many researchers have succeeded in trying to analyze the different aspects of the stock market in recent decades.

Entropy is a thermodynamics concept with one of its parameters capable of characterizing the state of matter. Moreover, it is efficient in measuring system chaos. C.E.R [13] believed that the more stochastic time series, the more complex the system. Based on this idea he built the concept of Aromatic entropy on the basis of thermodynamics entropy. Consequently methodologies like Kolmogorov sample [14] Sinai sample [15]. Non-extensive entropy [16] were developed with the aim of analyzing systematic dynamic features. Pin [17,18] invented the algorithm of approximate entropy which is applicable in physiological and medical science. Approximate entropy is disadvantageous in that it dramatically depends on sample length and lacks relative uniformity. For this reason Richman and Mooraman [19] improved the sample entropy (SampEn) on the basis of approximate entropy, excluding the self-matching in the algorithm, leading to the fact that the speed of calculation accelerated approximately twice as quick as in the past [19–21]. On the other hand, entropy can also detect the uncertainty of system complexity in financial time series, and this has been widely used [22,23]. Costa [24–28] and others in the study of heart rate time series and coding and non coding DNA sequence and other biological system complexity, proposed the multiscale sample entropy (MSE) method. The specific method is to divide the time series into multiple scales, and to calculate the sample entropy of each scale.

The MSE curve has been recommended to be applied in the finance market because it provides available insights into stock index volatility over different scales. If the entropy value decreases monotonically on the scale, the self-similarity of the sequence on the scale and the complexity will have to be smaller in both cases. Especially, if the entropy values of one of this time series is higher than of another over most scales, the former has to be more complicated than the latter. We acknowledge that the entropy of the stock sequence has a corresponding relationship with the degree of financial market stability [27]. In this paper, four financial indices are compared and analyzed to explore their market stability characteristics. An interesting question is whether we will discard important information in using the mean value in deriving copies of the original signal in different time scales. In addition, the availability of using skewness and kurtosis in coarse-graining has remained invalidated, nor is there possibility to differentiate the stability of different markets. In our study, we compare the MSE results using multiscale entropy with generalization to skewness and kurtosis to coarse-grain the original time series. We verify the effectiveness and feasibility of the two coarse-grained methods for identifying time-series complexity: ARFIMA stochastic processes. After that, draw the function curve of entropy value on different time scales and observe the relationship between the different curves. Nonetheless more consideration is given to the analysis of the MSE curves so as to avoid assigning a single complexity value for every time series.

The remainder of this paper is as follows. We review the concept of SampEn and the procedure of MSE method algorithm and propose our modified method in Section 2. In Section 3, we test the effectiveness of the new algorithms with one type of artificial time series the ARFIMA process. Besides, we list several stocks in the European, Asian and American markets analyzed and we make use of them through data analysis. Section 4 includes the results of the real data are shown. In the last section, a conclusion is drawn.

2. Methods

Sample entropy (SampEn) provides an improved evaluation of time series regularity and should be a useful tool in studies of the dynamics of different systems [19]. It is a new method proposed by Richman to measure time series complexity Then, MSE is based on the application of SampEn, which is proposed by Costa et al. [24,26,27]. In this section, the theoretical backgrounds of SampEn algorithm is briefly described. At the same time, the concept of the MSE based on skewness and kurtosis algorithm is presented.

2.1. Sample entropy

The result of the algorithm is represented by SampEn(m, r, N).N is assumed that the original data length, r stands for the tolerance for the accepting matches, and m refers to embedding dimensions. Mathematically, the procedure goes as follows:

1. Let \((x_1, x_2, \ldots, x_N)\) represent a time series of length \(N\) and consider \(N - m + 1\) template vectors \(x_m(i) = (x_i, x_{i+1}, \ldots, x_{i+m-1})\), \(1 \leq i \leq N - m + 1\).
2. The distance by Eq. (1) between each pair of vectors is defined as the maximum difference between two vectors.

\[
d[\mathbf{x}_m(i), \mathbf{x}_m(j)] = \max(|x_{i+k} - x_{j+k}| < r; 0 \leq k \leq m - 1)
\]

(1)

3. Suppose \(n^m_i(r)\) is the number of pairs with their distances smaller than \(r\) between \(x_m(i)\) and \(x_m(j)\), where \(i\) is not equal to \(j\). The probability that \(x_m(i)\) is within \(r\) of \(x_m(j)\) is:

\[
C^m_i(r) = \frac{1}{N - m - 1} \sum_{i=1}^{N-m} n^m_i(r).
\]

(2)
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