Abstract

UNIVERSITY OF WARSAW

Faculty of Physics

Analysis of stochastic dynamic couplings by methods of statistical physics

Jarosław KLAMUT

One of the branches of statistical physics that has remarkably developed in recent years due to the inspiration of the natural and socio-economic sciences is the theory of stochastic processes. Currently, stochastic dynamics are widely used to describe processes and phenomena, both strictly physical and occurring in complex systems belonging to the broadly understood interdisciplinary physics. By the term 'stochastic dynamic couplings' I refer to couplings between random variables that involve time intervals. Examples of such random variables may be the interevent times themselves or these times together with the corresponding displacements.

In this dissertation I focus on the use of stochastic dynamics to study the activity of complex systems. I use here the times between individual events observed in the system as basic quantities. For example, in physical systems these can be times between charge carrier jumps located in the substrate potential minima in the photocurrent relaxation process, and in geophysics, time intervals between earthquakes. The description of process activity is complicated by the presence of a memory. Its consequence is the autocorrelation of a series of interevent times, which leads, among others, to the clustering of events. A prominent example that illustrates this type of clustering phenomena in a complex system are transactions concluded on financial markets resulting, among others, from the so-called 'herd effect'. That is why analyzes included in my doctoral dissertation are based on empirical data on stock market activity (widely available in large quantities).

In the first part of the dissertation, I present and describe in detail continuous-time random walk models. These are stochastic processes, in which both changes of the value of the process, as well as time intervals between these changes are random variables. Then, I introduce, solve and analyze the original variant of the continuous-time random walk model with correlated interevent times as the basis for dynamic couplings. I compare the stochastic properties of this variant with empirical financial data. These data make it possible to determine the exponent of the power laws characterizing both the decays of the step autocorrelation function of inter-trade time series, as well

as the non-linear temporal autocorrelation of absolute price change series. I compare the empirical relationships between these exponents with their equivalents introduced as theses of this dissertation. Thanks to this, the author's model served, among others, to show the fundamental role of correlated intertrade times in creating the volatility clustering effect.

In the second part of the dissertation, I focus on an in-depth interpretation of the relationships observed in stock market activity. For this purpose, I introduce a generalized multifractal detrended fluctuations analysis based on a series of mean times between events, i.e. based on a coarse-grained approach. This allows me to obtain the non-monotonic behavior of the Hölder exponent, previously only occasionally mentioned in the scientific literature. Then, by generalizing the standard approach, I obtain a wide, asymmetric, multi-branched multifractal spectrum, with well-defined stability of each branch of the spectrum.