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Algorithmic complexity of financial motions

Olivier Brandouy [a], Jean-Paul Delahaye [b], Lin Ma [c,*], Hector Zenil [d,e]

[a] Sorbonne Graduate Business School (IAE), Université de Paris 1, France
[b] Laboratoire d'Informatique Fondamentale de Lille, Université de Lille 1, France
[c] École Universitaire de Management, Université de Lille 1, France
[d] IHPST, Université de Paris 1 (Panthéon-Sorbonne), France
[e] Department of Computer Science, University of Sheffield, United Kingdom

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ABSTRACT

We survey the main applications of algorithmic (Kolmogorov) complexity to the problem of price dynamics in financial markets. We stress the differences between these works and put forward a general algorithmic framework in order to highlight its potential for financial data analysis. This framework is "general" in the sense that it is not constructed on the common assumption that price variations are predominantly stochastic in nature.
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1. Introduction

In driving the decisions made by investors, information fuels financial markets. But the market has proven to be very complex in its dynamics and therefore very hard to predict. Market price movements in themselves are unpredictable or barely predictable. Price movements can be seen as the outcome of interactions between investors following rules in their quest to reap a benefit. It has been suggested that the market alone is complex enough, even when isolated from external stimuli (see, e.g. Wolfram, 2002), yet external information can make it less or more predictable.

* Corresponding author.
E-mail addresses: brandouy.iae@univ-paris1.fr (O. Brandouy), delahaye@lifl.fr (J.-P. Delahaye), lin.ma@univ-lille1.fr (L. Ma), hectorz@wolfram.com (H. Zenil).

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These concepts are at the heart of one of the most famous hypotheses in finance: the Efficient Market Hypothesis (EMH), painstakingly reconstructed from the recently rediscovered works of Bachelier (1900) and subsequently refined. The concepts shaping this hypothesis, such as “information” or “randomness”, are undoubtedly of interest to computer scientists who have their own tradition of tackling these questions. Part of this tradition can be identified with the works of Shannon, and has provoked a burgeoning literature in finance. Another part of this tradition can clearly be linked with the works of Kolmogorov (1965) and Chaitin (1987). This paper attempts to assess the existing works in these fields, highlighting salient divergences and proposing a general algorithmic framework as an alternative to the mainstream probabilistic one used in financial analysis.

This article is organized as follows: after a theoretical introduction to algorithmic complexity in Section 1, we take a quick look at the relation between financial theories and the randomness of price variations in Section 2. As this relation is studied by some existing works applying the notion of algorithmic complexity, we provide a survey of these works in Section 3 and show why they failed to propose a general algorithmic framework for financial pattern tracking, which was not available until the publication of our work in Ma (2010) and Zenil and Delahaye (2011). The main contributions of these two works are then sketched in Sections 4 and 5, respectively.

2. Algorithmic information theory

At the core of algorithmic information theory (AIT) is the concept of algorithmic complexity,[1] a measure of the quantity of information contained in a string of digits (or more generally of symbols or integers). The algorithmic complexity of a string is defined as the length of the shortest algorithm that, when provided as input to a universal Turing machine (an idealized computer model), generates the said string. A string has maximal algorithmic complexity if the shortest computer program able to generate it is not significantly shorter than the string itself, perhaps allowing for a fixed additive constant. The difference in length between a string and the shortest algorithm able to generate it is the string’s degree of compressibility. A string of low complexity is therefore highly compressible, as the information that it contains can be encoded in an algorithm much shorter than the string itself. By contrast, a string of maximal complexity is incompressible. Such a string constitutes its own shortest description: there is no more economical way of communicating the information that it contains than by transmitting the string in its entirety. In algorithmic information theory a string is algorithmically random if it is incompressible.

Algorithmic complexity is inversely related to the degree of regularity of a string. Any pattern in a string constitutes redundancy: it enables one portion of the string to be recovered from another, allowing a more concise description. Therefore highly regular strings have low algorithmic complexity, whereas strings that exhibit little or no pattern have high complexity.

The algorithmic complexity $K_U(s)$ of a string s with respect to a universal Turing machine U is defined as the binary length of the shortest program p that produces as output the string s.

$$K_U(s) = \min\{|p|, U(p) = s\} \tag{1}$$

Algorithmic complexity conveys the intuition that a random string should be incompressible: no program shorter than the string can produce it.

Even though K is uncomputable as a function, meaning that there is no effective procedure (algorithm) for calculating it (for every string), one can use the theory of algorithmic probability to obtain exact evaluations of $K(s)$. This can be done for strings s short enough, thus for which the halting problem can be solved for a finite number of cases due to the size (and simplicity) of the Turing machines involved.

[1] Also known as program-size complexity, Kolmogorov complexity, or Kolmogorov–Chaitin complexity.

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