



# Cash Withdrawal from ATMS as Long Memory Time Series

Alexander Tsyganov

*National Research Nuclear University MEPhI, Moscow, Russia*  
*a2tsy-kaf22@yandex.ru*

## Abstract

Research objective - determination of long memory of a number of removals of cash. The model of determination of long memory of a time series relies on carrying out R/S and DFA of the analysis on Hurst's method. Calculation was carried out by means of Microsoft Excel and Microsoft Access. The executed calculations showed difference of a time series from random walks.

*Keywords:* Hurst exponent, ATM, time series, long memory, Microsoft Excel

## 1 Introduction

One of the most important tasks of analysis and forecasting of the movement of money in ATM systems is to forecast cash levels in the ATM network taking into account the cost of encashment and cost of cash.

Optimization of encashment allows to reduce transport costs, cost of cash, while meeting customer requests cash withdrawal.

Daily cash flow can be regarded as a time series. Time Series Prediction - urgent task in different areas: the study of natural phenomena, creation of technical systems, solving economic problems. In this time-series prediction is performed based on information contained in the historical data of a particular time series. Particular attention is paid to forecasting time series are far from simple Poisson flows. For such series it has proved useful to use prediction based on long-term memory.

Long-term memory is often associated with self-similar processes. Long-term memory has been detected in a variety of areas, such as modeling of Internet traffic, econometrics, hydrology, medicine.

Methods of testing the presence of long-term memory can be used without knowledge of the factors that operate in specific areas of concern, taking into account only the ranks of data. The results of these methods are the parameters of long-term memory, such as Hurst exponent  $H$ , or the fractional integration parameter  $d$ . The latter can be applied in modeling persistent processes using the process ARFIMA( $k, d, l$ ).

In work (Tsyganov, 2013)] the analysis of time series of cash withdrawals on 20 ATMs was carried out. In the real work data on 590 ATMs are analyzed

## 2 Database creation

To calculate the Hurst exponent was used the model constructed in Microsoft Excel.

Microsoft Excel allows you to build models that use very complex calculations, business graphics, database queries, and all of this can be controlled by a program written in Visual Basic.

Data on an hourly cash volume of ATMs have been presented in the form of text files. The total number of entries was more than 5.7 million records. Modern versions of Microsoft Excel allow you to enter on the worksheet about one million rows. Therefore, on the basis of hourly information on the status of ATMs was formed table in Microsoft Access. For each ATM indicates the time the report is generated, city, address, nominal values and balances all 4 cassettes and overall balance

The data for each ATM may be using Microsoft Query put a range on a Microsoft Excel worksheet. The hourly residues of cash received on each ATM were recalculated in hourly cash withdrawals, and then in daily cash withdrawals. The resulting time series was a series of accumulated sums, filmed from the ATM for 300 days. Prepared the time series is transferred to the sheets of Microsoft Excel workbook designed to calculate the Hurst exponent.

Some methods of an assessment are based on splitting the time series into blocks of length of  $m$  and study the power dependence between a certain statistical measure of the time series and the size of the block.

Within modeling on Microsoft Excel it is rather simple to construct model in which calculations will be performed for the entire range, it halves, quarters, etc. We will call such splitting - classical.

It is enough to take advantage of the presence in Microsoft Excel ability to build a calculated reference. Calculated reference can be built, for example, with use of the function INDEX or the function INDIRECT.

Splitting time series into blocks of length  $N/2^n$ , where  $N$  is the length of the entire series,  $n$  integer requires that the size of the original data was a power of two, which is not always possible in a real experiment. It is possible to use sliding window of length different from  $N/2^n$ , in this case the blocks can be placed tightly from the beginning of the data series, or selected with a random offset from the beginning of the data series. We will call such splitting's - close and random.

Creation of blocks of a length different from  $N/2^n$  has its own drawbacks. Splitting a vector of basic data into intervals which length isn't a divider of length of a concrete time series leads to emergence of residual data which should be rejected.

In addition, too short intervals ( $<10$ ) lead to an overestimation of values of coefficient of Hurst.

## 3 Analysis model in Microsoft Excel

Data for each ATM was located using Microsoft Query to a range on a worksheet in Microsoft Excel. For process control program was written in VBA for Application. To calculate the Hurst exponent was used R/S and DFA methods. (Sheng H., Chen Y., Qiu T., 2012).

R/S method uses R/S statistic - the rescaled range statistic. The R/S statistic is the range of partial sums of differences of a time-series values from its average, divided by its standard deviation. A log-log plot of dependence of the R/S statistic versus the aggregation block size has the inclination giving an estimation of Hurst exponent.

DFA method involves the following steps. Built partial sum of the series is normalized by the average. Obtained the integrated series is divided into blocks of equal length. In each block using the least squares method is polynomial time trend first order. Then calculate the standard deviation of the

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