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CONSTRUCTION OF INDICATORS PRECURSORS FOR BITCOIN TIME SERIES USING METHODS OF NONLINEAR DYNAMICS

Bitcoin (abbreviated as BTC) is an electronic payment system which is not regulated by any bank, department or any state entity, and relies only on the cryptographic protocols, and the distribution system of users involved in all transactions [1]. All members of the

new network are absolutely equal regardless of nationality or other characteristics.

The digital economy is impossible without currency (for today also without a cryptocurrency) and, therefore, the market of such currencies is formed over the past ten years. For objective and subjective reasons, it is under pressure from standard currencies that neither want to lose control over the financial market. According to objective reasons: because of the mining, illegal institutions for the support of terrorism. Therefore, monitoring and forecasting of fluctuations in this market is extremely relevant.

During the last two decades, a number of interesting methods have been proposed to investigate and detect changes in complex dynamical systems (like in Bitcoin). In the previous work [2], we have already used recurrence plots, recurrence quantification analysis and concept of permutation entropy. For this work, we concentrate our attention on investigating spectral and topological properties of our time series, and construct the network measures.

A complex network is a graph $G = \langle V, E \rangle$, where $V = \{v_1, \dots, v_n\}$ is the set of vertices, and $E = \{\{v_i, v_j\} : v_i, v_j \in V\}$ is the set of edges, where each edge is an unordered pair of vertices from the set V [3].

In the theory of graphs and combinatorics, there are many theorems in which the spectra of graphs are used, although they are not found in the formulation of theorems. The very important method which uses the spectra of graphs, is called spectral. The spectrum of the graph is the set of eigenvalues of the matrix corresponding to this graph. Several approaches to establishing a connection between graph G and its spectrum are known. For the case of regular graphs (which are the time series of stock indexes), we can show that the different types of spectra are equivalent, namely, they contain the same amount of information about the structure of the graph G . One way of representing a graph in the form of matrix is the adjacency matrix:

$$M_A[i, j] = \begin{cases} 1 & \text{if } \{v_i, v_j\} \in E, \\ 0 & \text{otherwise.} \end{cases}$$

The Laplacian matrix M_L is also one of the graph representations. It can be used to calculate the number of spanning trees for a graph. The Laplacian matrix of a network is defined as:

$$M_L[i, j] = \begin{cases} d_i & \text{if } (i = j), \\ -1 & \text{if } (i = j) \wedge \{v_i, v_j\} \in E, \\ 0 & \text{otherwise.} \end{cases}$$

From spectral measures we use:

- Spectral gap is the difference between the largest and the second largest eigenvalue which provides how fast the synchronous state is reached.

- Max Degree. Degree, historically, the first and conceptually simple measure of centrality which is defined as the number of the links having a node. Max degree is the maximum measure of centrality which is calculated as $C_{\max} = C_i + C_o$, where C_i and C_o are input degree and output degree.

From topological measures we use:

- Network clustering is defined as the average clustering value across all nodes $clust(G) = clust_{clust} = \langle clust(i) \rangle_i$, where $clust(i)$ is a host clustering which is a local characteristic of the network. It characterizes the degree of interconnection between the nearest neighbors of this node.

- Link Density. Computes the link density of a graph defined as number of edges divided by number of nodes ((number of nodes-1)/2), where the latter is the max possible number of edges.

In order to evaluate the efficiency of our indicators crisis phenomena, we choosed Bitcoin time series for the period (16.07.2010 –07.09.2018), and identified 7 serious crashes which happened in several days. Their historical corrections you can see on the Table 1.

For each Bitcoin's crash, network measures were constructed. Calculations were carried out within the framework of the algorithm of a moving window. Further, comparing corresponding measure and actual time series, we can judge characteristic changes in the Bitcoin time series. If our measure starts to increase in a definite way before crash, and start to decrease on the beginning of crash, then it can serve as an indicator-precursor of such a crisis state.

Table 1

List of Bitcoin 7 crashes

Bitcoin (BTC) Historical Corrections							
List of Bitcoin major crashes							
Name	Correction Start Date	Correction end Date	Days in Correction	Bitcoin High Price	Bitcoin Low Price	% Decline	\$ Decline
The first serious crash	07.06.2011	10.06.2011	4	29.60 \$	14.65 \$	-50 %	-15.05 \$
The Crash of August 2012	15.08.2012	18.08.2012	4	13.50 \$	8.00 \$	-40 %	-5.50 \$
The Meltdown of April 2013	08.04.2013	15.04.2013	8	230.00 \$	68.36 \$	-70 %	-161.64 \$
The Crash of April-May 2013	23.04.2013	02.05.2013	10	154.19\$	98.09 \$	-36 %	-56.01 \$
Pop Goes the 2013 Bubble	04.12.2013	18.12.2013	15	1237.66 \$	540.97 \$	-56 %	-696.69 \$
The Mt. Gox Calamity	05.02.2014	25.02.2014	21	904.52 \$	135.77 \$	-85 %	-768.75 \$
The Crash of December-January 2014-2015	02.12.2014	14.01.2015	44	380.64 \$	164.91 \$	-57 %	-215.73 \$

On the figure 1 you can see work of network measures only for several of them, where crashes are located on point 100:

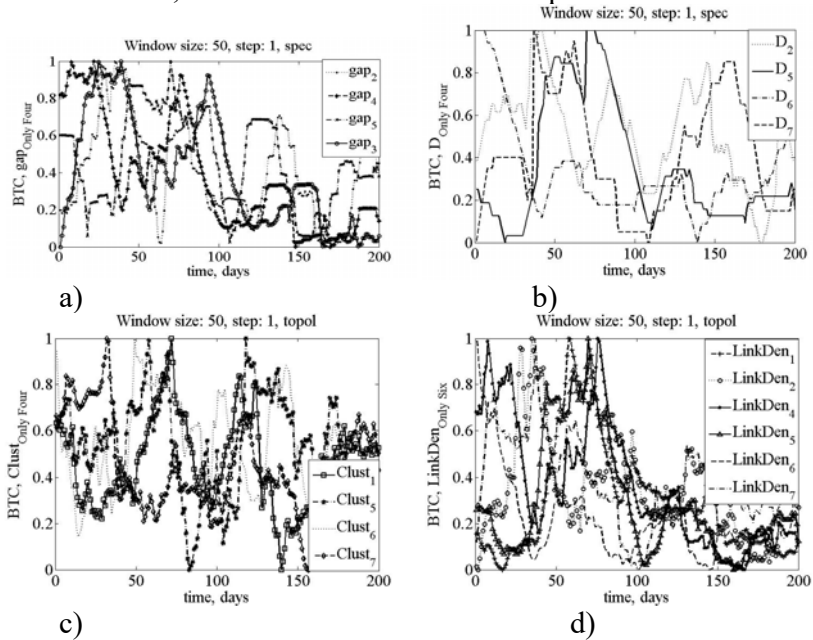


Fig. 1. Dynamics of spectral and topological measures: Spectral Gap (a), Max Degree (b), Clustering Coefficient (c) and Link Density (d)

As it has been shown by us, the theory of complex systems has a powerful toolkit of methods and models which give the possibility to predict possible crashes on Bitcoin market.

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INVESTIGATION OF THE PROCESS OF COMBATING BANK FRAUD BY THE METHOD OF SYSTEM DYNAMICS

One of the most common threats to the activities of banks, which can be internal and external, is banking fraud. Along with such type of bank fraud, as transactions with bank cards, hacker attacks on banking institutions are gaining in popularity in recent years. In [1] hacker attacks were described by modifying the «predator-prey» model.

Based on these assumptions, the investigation of the process of combating fraudulent attacks using methods of system dynamics is proposed. The structure of constructed model is presented in Table 1.

Table 1

Name of the variable of «predator-prey» model	Element of stock and flow diagram	Description
Fraudulent_Attacks	Stock	Displays the number of fraudulent attacks at the time t
Countermeasures	Stock	Displays the number of available tools to combat fraudulent attacks at the time t